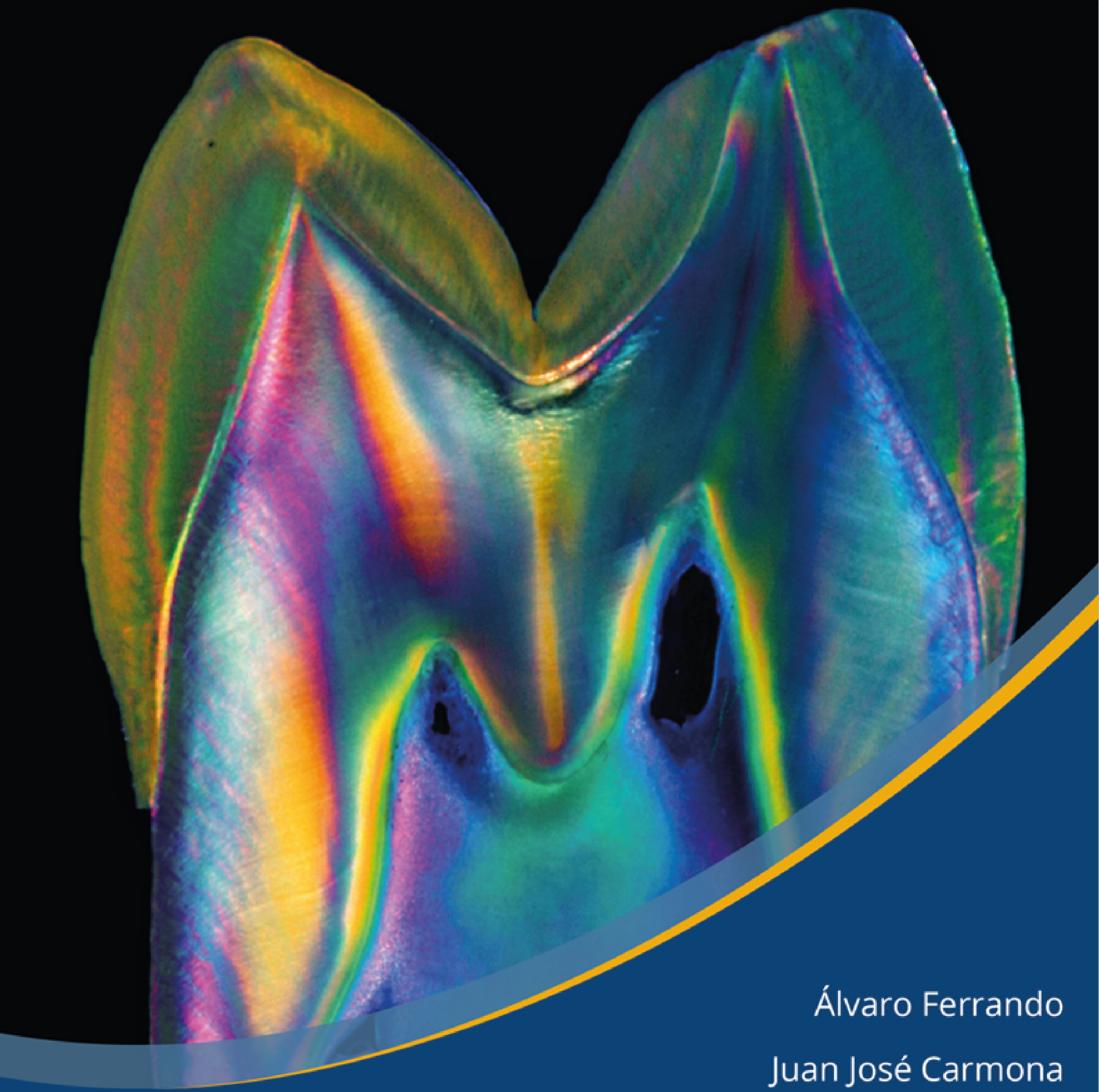
Aesthetic and Adhesive DENTISTRY



Álvaro Ferrando
Juan José Carmona
Emilio García · Marina Muñoz
Adrián Hurtado · José Manuel Granero

UCAM | Servicio de Publicaciones



UCAM

UNIVERSIDAD CATÓLICA
DE MURCIA

AESTHETIC AND ADHESIVE DENTISTRY

Second Edition

Prof. Dr. Álvaro Ferrando Cascales.
Prof. Juan José Carmona Serrano.
Prof. Emilio García Romero.
Prof. Marina Muñoz Piñera.
Prof. Adrián Hurtado Bermúdez.
Prof. Dr. José Manuel Granero Marín.

Aesthetic and Adhesive Dentistry

© Álvaro Ferrando Cascales, Juan José Carmona Serrano, Emilio García Romero, Marina Muñoz Piñera, Adrián Hurtado Bermúdez y José Manuel Granero Marín.

© Fundación Universitaria San Antonio

Murcia, 2025

I.S.B.N. Digital edition: 979-13-88027-99-4

All rights reserved.

Reproduction in whole or in part without the express written permission of the copyright holders is strictly forbidden.

Cover image: Dr. Fernando Rey Duro

Layout: Unidad de Contenidos Digitales Docentes – Vicerrectorado de Enseñanza Virtual

In memory of Prof Dr. Agustín Pascual Moscardó, a humanist who gave his all for the university and his students.

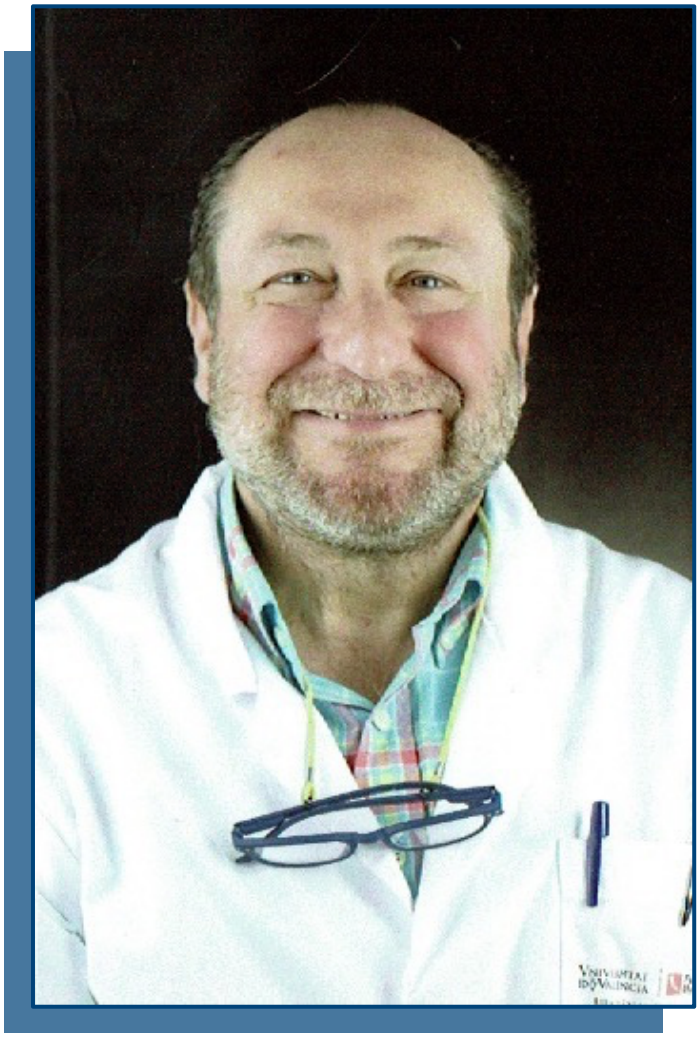


Table of Contents

Chapter 1. Introduction to Aesthetic Dentistry Biomimetic and Minimally Invasive Dentistry 36

1.1. Introduction. What is 'aesthetics'? 37

1.2. Evolution towards 'minimally invasive' dentistry 39

1.3. Aesthetic or purely cosmetic motivation of patients 40

1.4. Teamwork and Facially Generated Treatment Planning 40

1.5. Aesthetic and Adhesive Restorative Dentistry. Biomimetics 41

1.6. First visit in Aesthetic Dentistry 49

1.7. Legal aspects in aesthetic restorative dentistry 51

Chapter 2. Facial Aesthetics 56

2.1. Introduction: 57

2.2. Facial visual examination 57

2.3. Facial analysis 59

2.3.1. Frontal vision: 66

2.3.2. Lateral vision: 68

2.4. Core questions: 69

Chapter 3. Smile aesthetics 80

3.1. Dentolabial analysis 81

3.2. Exposure of the tooth when resting 83

3.3. Incisal edge. Incisal curve. 83

3.3.1. Incisal edge. Flat or inverted incisal curve 83

3.3.2. Incisal edge. Incisal profile. 84

3.4. Smile line. Frontal analysis 85

3.5. Smile width: 4-4,6-6,7-7 86

3.6. Labial corridor 86

3.7. Interincisal midline versus facial midline 86

3.8. Occlusal plane versus intercommissural line 88

Chapter 4. Smile aesthetics. Dental analysis 90

4.1. Dental analysis 91

4.2. Tooth colour 95

4.2.1. Dental colour. Considerations for aesthetic rehabilitation. Subjective methods of colour communication 97

4.2.2. Dental colour. Considerations for aesthetic rehabilitation. Objective methods of colour communication 100

4.3. Shape and contour of the maxillary teeth. Anatomy 1st. 101

4.3.1. Shape and contour of the maxillary teeth. 1st anatomy. Perception and optical illusion 103

4.4. Macro and microtexture of the maxillary teeth. 2nd and 3rd anatomy…… 104

4.5. Dimensions and proportions of the maxillary teeth 106

4.6. Incisal margin and profile.....107

4.6.1. Incisal margin 107

4.6.2. With regard to the incisal profile 107

4.7. Tooth composition of the maxillary teeth 109

Chapter 5. Aesthetic composite resins 128

5.1. Definition.....129

5.2. Basic composition of composite resins 129

5.2.1. Organic matrix 130

5.2.2. Inorganic particles 131

5.2.3. Bonding agent 131

5.3. Developments in composite resins.....132

5.4. Characteristics of composite resins 134

5.5. Use of composite resins.....135

5.5.1. Main failure factors in composite resin restorations 136

5.6. Large composite resin treatments in the anterior and posterior regions..... 136

Chapter 6. Composite resin stratification 155

6.1. Definition..... 156

6.2. Colour for stratification 157

6.3. Strata 161

6.4. Compendium of stratification techniques with composite resins.... 163

6.5. Simplified stratification technique..... 166

Chapter 7. Adhesion in aesthetic dentistry..... 171

7.1. Introduction to adhesion 172

7.2. Rationale for keeping up to date in adhesive management..... 173

7.3. Main adhesive substrates..... 174

7.3.1. Enamel 174

7.3.2. Dentin 174

7.4. Historical development of adhesive dentistry..... 180

7.5. Historical evolution of the chemical formulation of adhesives. Generations..... 182

7.6. Degradation of dentin adhesion 194

Chapter 8. Vital and non-vital whitening 201

8.1. Vital and non-vital whitening..... 202

8.2. Bleaching agents. Action mechanism. Activation systems..... 203

8.3. Whitening of vital teeth. At-home and in-office whitening 206

8.4. Tooth whitening. Endodontics. Dental preparation. Clinical techniques..... 211

8.5. Bleaching side effects and how to prevent them..... 214

8.5.1. ‘Over-the-counter’ bleaching products. 215

Chapter 9. The current state of dental porcelain..... 217

9.1. Ceramics in Dentistry. Concept 218

9.2. Classification of dental ceramics 220

9.3. Classification according to strength and abrasiveness. Low, moderate and high 222

9.3.1. The first group, feldspathic porcelain 223

9.3.2. The second group, the popular lithium disilicate 225

9.3.3. The third group 227

9.4. Veneers, crowns and partial restorations. Anterior and posterior sector 231

9.4.1. Feldspathic porcelain veneers 231

9.4.2. Lithium disilicate ceramic veneers 232

9.4.3. Crowns on anterior teeth 234

9.4.4. Onlays in premolars and molars 234

9.4.5. Crowns on premolars and molars 234

9.4.6. Bridges (anterior or posterior) 235

Chapter 10. Bonded partial posterior restorations 239

10.1. Bonded posterior partial restorations 240

10.1.1. Definition and indications 242

10.1.2. Materials 243

10.1.3. Treatment procedure 244

10.1.3.1. FIRST VISIT 244

10.1.3.2. SECOND VISIT 248

Chapter 11. Horizontal retentive and adhesive restorative dentistry 257

11.1. Introduction. General concepts of dental preparations for complete veneers 258

11.1.1. Principles of retention, strength and stability of anterior preparations. 258

11.2. Horizontal preparation of the anterior tooth for a crown 263

11.2.1. Horizontal preparation of anterior teeth –Shoulder and Chamfer–…….....264

11.3. Location of the margins of horizontal preparations[104] 266

11.3.1. Supragingival margin 267

11.3.2. Juxtagingival margin 267

11.3.3. Intrasulcular margin 268

11.3.4. Subgingival margin 270

11.4. Preparation of porcelain veneers or veneers 270

11.4.1. Vestibular preparation thicknesses on porcelain veneers 274

11.4.2. Step-by-step preparation phases[102-109] 274

11.5. Complete clinical case of porcelain veneers step by step of 1.2 - 2.2. Aesthetic diagnosis, preparation, impressions, feldspathic veneers, temporary restorations, cementation and finishing.....280

Chapter 12. Vertical retentive and adhesive restorative dentistry 301

12.1. Introduction to vertical preparations for full veneers.....302

12.2. Biomechanical advantages of vertical over horizontal preparations…….....304

12.3. Vertical preparation and BOPT technique. Are these the same?.....306

12.4. Differences between the Shoulderless and the BOPT technique.....317

12.5. Advantages of preparations with round-ended tapered diamond bur with a non-cutting end. 320

12.6. Vertical preparations for porcelain veneers 321

12.6.1. Vertical preparation technique for porcelain veneers (Imburgia M)[124] ……...321

Chapter 13. Aesthetic restorative dentistry and Periodontics.....325

13.1. Definition.....326

13.2. Oral aesthetics and Periodontics: 'gingival aesthetic criteria' 327

13.2.1. Periodontal parameters or criteria: 327

13.2.1.1. Gingival health.....327

13.2.1.2. Interdental papilla 328

13.2.1.3. Gingival contour zenith 329

13.2.1.4. Balance of the margins 330

13.3. Periodontal biological width 331

13.3.1. Factors determining the aggression to the biological width 331

13.3.1.1. Finishing line: 331

13.3.1.2. Impressions: 'gingival separation' 333

13.3.1.3. Temporary restorations: 335

13.3.1.4. Restoration design: 335

13.4. Periodontal phenotype 338

13.5. Clinical situations: Gingival smile and recessions 340

13.5.1. Gingival smile 340

13.5.2. Gingival recession 351

Chapter 14. Aesthetic restorative dentistry and Oral surgery 356

14.1. Exodontics vs Conservative dentistry 357

14.2. Situations in which a tooth must be extracted: 358

14.3. Conservative approach: 358

14.4. Analysis of extreme situations: 359

14.4.1. Root ratio 359

14.4.2. Ferrule effect 360

14.4.3. Clinical case 362

14.5. Implants in the aesthetic zone 369

14.5.1. Digital planning 370

14.5.2. Emergence profile 370

14.5.3. Design of the emergence profile for implants in healed bone 371

14.5.4. Design of the emergence profile in immediate implants 373

14.5.5. Clinical protocol.....375

14.5.6. Evaluation of the aesthetic result.....377

14.6. Laser in Dentistry.....379

REFERENCES..... 383

APPENDIXES..... 395

List of Figures

Figure 1. Equivalence of dental hard tissues and biomaterials. Here you can see the equivalence between dentin-enamel bonding and adhesive systems…….....42

Figure 2. Maximum strength of the restoration-tooth interface (MPa) as a function of the restorative possibilities. 43

Figure 3. Balance and relation between biology, mechanics, function and aesthetics. 44

Figure 4. Clinical indications for composites and porcelain veneers. ..45

Figure 5. Dental fragment in perfect condition for bonding and collage…….....45

Figure 6. Photographic composition showing the initial situation and below a sequence under absolute isolation depicting the approach of the tooth piece and the final newly bonded situation.....46

Figure 7. Photographic composition showing comparative smile and intraoral detail before/after one month check-up. 46

Figure 8. Clinical case showing a Class IV in 1.1 which is continuously breaking according to the patient. In 2.1 there is a 'collage' with a poorly adapted fragment. The preparations for bonded porcelain restorations (BPR) can be seen next to it. It is noteworthythat in the preparation of 2.1 the bonded fragment has been included, which, although poorly adapted, has never come off since being bonded, as opposed to 1.1, where the composite has been completely removed as it does not contribute any biomechanical value. 47

Figure 9. Photographic composition showing the intraoral detail of the final situation 10 years after the BPR. At the corners, you can see the shade of the initial situation and the preparations with a personalised guide of the fired feldspathic porcelain that was used to make the BPR.....47

Figure 10. Photographic composition of smiles showing the initial/final comparison 10 years later. The absolute integration of the BPR is noteworthy, and you can also observe that Class II malocclusion has increased.....48

Figure 11. Photographic composition showing the initial/final comparison of the face 10 years later. 48

Figure 12. First visit in aesthetic dentistry.....49

Figure 13. Porcelain veneer consent sample; risks. 51

Figure 14. Sample consent form for in-office whitening.....52

Figure 15. Liability insurance Cover page.....52

Figure 16. Risk coverage, including aesthetic treatments. 53

Figure 17. Update on the use of botulinum toxin by dentists. 54

Figure 18. Sensitivity and warranty sections of the informed consent for aesthetic dentistry. Made by Ferrando A and courtesy of Adolfi D. 55

Figure 19. Equal division of the face in thirds. 60

Figure 20. Division from Nasion (Na). 61

Figure 21. Powell angles to study the aesthetic masses of the face relating the nose to the face. 63

Figure 22. Classification of nose shape into three main groups. 64

Figure 23. Determination of upper lip (Sn-St) and lower lip (St-Me). 65

Figure 24. Main types of facial profiles.....68

Figure 25. Facial analysis summary. 72

Figure 26. Main objectives of facial analysis. 73

Figure 27. Reference lines. Bipupillary line.....73

Figure 28. Reference lines parallel to the bipupillary line.....74

Figure 29. Intersection of midline and bipupillary reference lines.....74

Figure 30. These reference lines determine a framework for assessing facial harmony.....75

Figure 31. Lines of reference, determining an organised frame that allows the identification of symmetry/asymmetry.....75

Figure 32. A digital image duplicating half of the face (left and right), with the normal face in the centre. This digital trick shows that the vast majority of faces have a certain degree of asymmetry.....76

Figure 33. First conclusion. Facial analysis. Symmetry and diversity. ...76

Figure 34. Second conclusion. Facial analysis. Symmetry and diversity…….....76

Figure 35. Example of a typical asymmetrical face, bipupillary line inclined to the left of the patient, as well as the chin, with one eye higher than the other……77

Figure 36. Facial analysis. ……77

Figure 37. Occlusal plane recording with Kois Dento-Facial Analyzer ...78

Figure 38. Facial analysis. ……78

Figure 39. Facial analysis. Main sign of vertical disharmony. ……79

Figure 41. Dynamic dentolabial analysis.……81

Figure 42. Natural head position. Dynamic facial and dentolabial analysis…… ……82

Figure 43. Before/after comparison of the incisal profile in a periodontal patient. Note the orthodontic correction of the inclination This situation should never be approached solely from a restorative point of view if the biomimetic philosophy is followed. ……84

Figure 44. Examples of smiles before and after interdisciplinary treatment. For example, a large correction of the gingival smile (very high) of the orthodontic patient is observed, which becomes high……85

Figure 45. Abstract of the article by Kokich V et al. ……87

Figure 46. Phonetic analysis……88

Figure 47. Prosthetic considerations for aesthetic rehabilitation. F/V/S sounds……89

Figure 48. Dental analysis.……91

Figure 49. Basic tooth morphology and surface features. ……92

Figure 50. Morphology of teeth and their relation to visagism. ……93

Figure 51. Morphology of teeth, type of occlusal plane and their relation to visagism……94

Figure 52. Equivalence between wavelengths and frequencies in the spectrum visible to the human eye. ……96

Figure 53. General colour of the natural dentition……97

Figure 54. Vita classical shade guide, sorted according to shade. ……98

Figure 55. Ascending gradation of saturation of shade A.……98

Figure 56. Vita Classical B/W shade guide, sorted according to value...99

Figure 57. Vita Classical shade guide, sorted according to value.....99

Figure 58. Objective and subjective methods of colour communication…….....101

Figure 59. Anatomy of the upper central incisor. 102

Figure 60. Anatomy of the upper lateral incisor and upper canine.....104

Figure 61. Natural front anterior teeth. Note the very pronounced 2nd anatomy, for instance in the upper left lateral incisor.....105

Figure 62. Composition of natural anterior teeth in profile, polarised photo and transillumination to observe incisal translucency. The 3rd anatomy or microtexture is very marked in the incisors in profile, as a 'rough' enamel surface is evident.....105

Figure 63. Dimensions and proportions of upper central incisors.....106

Figure 64. Incisal profile diagram, occlusal and sagittal view. From the right of the figure there is an incisal profile with normal convexity (compatible with a triangular shape), the one in the centre is straight (compatible with a square shape) and the one on th left is excessively convex (compatible with an oval shape). 107

Figure 65. Dental analysis summary. Considerations for aesthetic rehabilitation…….. 108

Figure 66. Explanation of the Fibonacci series and its relation to the divine proportion.....110

Figure 67. Continuation of the explanation of the Fibonacci series and its relation to the divine proportion.....110

Figure 68. Diagram of golden ratio in anterior teeth. 110

Figure 69. Different recurrent tooth proportions with constant central incisor size…….. 111

Figure 70. Composition of natural smiles by digitally modifying the recurrent tooth proportion, keeping the size of the central incisors constant. The 70% was the most liked in this study. 112

Figure 71. Natural front anterior teeth, interdental angles.....113

Figure 72. Before and after composition of a set of teeth 1.3-2-3. Clinical case showing the axial axis clearly distal to 1.2, and the giroversions of the

canines. They were corrected at the end with orthodontics and implants in 1.2 and 2.2. because they had resorbd roots. 114

Figure 73. Dental analysis: mandibular teeth. Prosthetic considerations for aesthetic rehabilitation. 115

Figure 74. Anterior teeth: functional aspects.....116

Figure 75. Functional adjustment composition of anterior teeth.....117

Figure 76. Tooth composition of the maxillary teeth. Symmetry of margins……. 118

Figure 77. Tooth composition of the maxillary teeth. Gingival margins and zeniths…….. 119

Figure 78. Papilla height of the anterior teeth.....120

Figure 79. Overview of dental analysis, ideal considerations for aesthetic prosthetic restorations. In the case of implant depth, 4mm from the implant head to the gingival margin is currently recommended. 120

Figure 80. 2D DSD composition. 121

Figure 81. Dispensing Bisacryl in a silicone key to perform the actual Mock-up…….....121

Figure 82. Immediate result of the actual Mock-up. 122

Figure 83. Facial comparison start-up/mock-up after analogue waxing based on a 2D DSD 122

Figure 84. Clinical case. Initial situation.....123

Figure 85. Clinical case. Virtual 2D mock-up situation. 123

Figure 86. Clinical case. Real mock-up situation.....124

Figure 87. Clinical case. Final restoration situation with porcelain facets, showing the closure of diastemas and the restoration of the occlusal plane, as well as a more harmonious smile.....124

Figure 88. Alignment of an .obj file (AFT Face Scanner) with a .stl file in a 3D digital design software (Exocad). 125

Figure 89. Initial situation. A 3D DSD (Nemotec Biotech France software) will be developed to prepare injected composites. 125

Figure 90. DSD 3D from 1.3 to 2.3 with Nemosmile design 3D software (Nemotec Biotech France).....125

Figure 91. Digitally printed 3D wax-up model and transparent silicone key (Exaclear GC Japan) 126

Figure 92. Immediate final result comparison of injected composites/printed model. 126

Figure 93. Comparison of right profile before/planning of 3D digital waxing/final result. 126

Figure 94. Comparison of left profile before/planning of 3D digital waxing/final result. 127

Figure 95. Immediate final result. Face and smile. 127

Figure 96. Final result after one year. Smile 127

Figure 97. Mosaic outlining the composition of the composite. The blue mantle resembles the organic matrix in which the inorganic particles are embedded, shown in purple and lined in the bonding agent (black line), silane……. 129

Figure 98. Acrylic resin and brush for composite handling. 132

Figure 99. Characteristics of macrofilled composites. 133

Figure 100. Characteristics of hybrid composites 133

Figure 101. Characteristics of nanoresins. 133

Figure 102. Characteristics of microfilled composites. 134

Figure 103. Characteristics of microhybrid composites. 134

Figure 104. Initial situation 137

Figure 105. Take pictures or videos. 137

Figure 106. Case study and diagnosis. A DSD is always necessary and has to be confirmed with a mock-up. Order a diagnostic wax-up and reference silicone keys from the laboratory. 138

Figure 107. Analysis of the characteristics of the teeth 138

Figure 108. Absolute isolation with rubber dam. 139

Figure 109. 45° bevel of incisal edges. 139

Figure 110. Sandblasting and acid etching. 140

Figure 111. Adhesive application. 140

Figure 112. Palatal walls and incisal edge using silicone keys. 141

Figure 113. Dentin layers. 141

Figure 114. Application of shades.....142

Figure 115. Enamel layers.....142

Figure 116. Shape analysis.....143

Figure 117. Analysis and creation of macrotexture.....143

Figure 118. Analysis and creation of microtexture.....144

Figure 119. Final polishing.....144

Figure 120. Post-treatment evaluation.....145

Figure 121. Post treatment evaluation 1 week later 145

Figure 122. Pre- and post-treatment comparison.....146

Figure 123. Protocol for direct posterior reconstructions.....146

Figure 124. Clinical analysis.....147

Figure 125. Radiographic analysis.....148

Figure 126. Absolute isolation with rubber dam.....148

Figure 127. Detect and remove carious tissue. 149

Figure 128. Analysis of cavity and remaining tooth structure. 149

Figure 129. Choosing the restorative technique according to the remaining tooth structure.....150

Figure 130. Use of matrix, wedge and ring to restore proximal wall in Class II cavities…….....150

Figure 131. Two-step adhesive application.....151

Figure 132. Proximal wall restoration. 151

Figure 133. Creation of dentin layers.....152

Figure 134. Characterisation by means of shades. 152

Figure 135. Applying enamel layers.....153

Figure 136. Occlusion adjustment using articulating paper.....153

Figure 137. Final polishing.....154

Figure 138. Pre- and post-treatment comparison.....154

Figure 139. Natural stratification.....156

Figure 140. Microanatomy.....156

Figure 141. Colour properties.....157

Figure 142. Colour properties.....157

Figure 143. Light penetration capacity in an object according to its translucency and opacity.....158

Figure 144. Opacity and translucency in natural teeth. 159

Figure 145. Opalescence in a natural tooth.....160

Figure 146. Layers for stratification of composite resins.....161

Figure 147. Colour properties to be transferred in the different stratification layers…….. 162

Figure 148. Single layer technique.....163

Figure 149. Simplified technique.....163

Figure 150. Radial technique. 164

Figure 151. Customised block technique.....164

Figure 152. Lorenzo Vanini's technique. 164

Figure 153. Mamelon characterisation technique.....165

Figure 154. Newton Fahl's Technique.....165

Figure 155. Single mass technique.....165

Figure 156. Reverse technique.....166

Figure 157. Representation of the simple stratification technique.....167

Figure 158. Initial situation of teeth 2.1 and 2.2. 168

Figure 159. Colour, isolation and removal of the old restoration. 168

Figure 160. Stratification with composite resins. 169

Figure 161. Stratification protocol for Class IV restoration.....169

Figure 162. Pre- and post-treatment comparison after 3 days. 170

Figure 163. CLSM reflection/fluorescence projection image exemplifying the interfacial characteristics after prolonged ageing under pulpal pressure for 1 year of the resin-dentine interface created using the Optibond FL. The presence of a gap/degradation (pointer) wthin a dentine that is affected by caries (d) still demineralised and infiltrated by the fluorescein [a1: single projection in fluorescence mode] can be seen in this image 173

Figure 164. SEM micrograph (Magnification 5000 x HV 10.0kV WD: 15.0mm), showing the dentin tubules in detail with possible resinous tags, but a large amount of inter- and intratubular collagenous fibrils completely denuded without resinous infiltration, susceptible to degradation with ageing…… 176

Figure 165. Microscopic image FVM-DIC x 1250. The surface dentin (DE) is visible. Enamel (ES). Note the small amount of dentin tubules and the increase of intertubular dentin near the dentinoenamel junction..... 177

Figure 166. Microscopic image FVM-DIC x 1250. Deep dentin (DE) next to the pulp (PL). A large number of dentin tubules and a smaller area of intertubular dentin are observed. 178

Figure 167. Microscopic image FVM-DIC x 1250. This is the dentin corresponding to a 55-year-old patient with sclerotic dentin generated by a slow abrasion process. 179

Figure 168. Diagram of the effect of total dentin etching with orthophosphoric acid. 184

Figure 169. AD-concept diagram. 187

Figure 170. Original chemical structure of MDP monomer developed by the Kuraray company in 1981. 188

Figure 171. On the right, a diagram of total etch adhesives 188

Figure 172. Timeline of 189

Figure 173. Most important properties of 10-MDP monomer. 189

Figure 174. Diagram of the adhesion-decalcification concept of 10-MDP…… 190

Figure 175. Overview of the direct adhesive protocols using universal adhesives (UA). 191

Figure 176. Overview of the direct adhesive protocols using conventional etch&rinse (E&R) and self-etch (SE) adhesives.....191

Figure 177. Diagram of the adhesive generations: What is the 8th generation adhesive? 192

Figure 178. Diagram of adhesive strategies according to clinical indications…….....193

Figure 179. Diagram representing the structure of a metalloproteinase.195

Figure 180. Classification of adhesives according to their clinical application and commercial names of the most prominent brands in each group. Some of them feature an additional bottle that makes them self-curing……. 196

Figure 181. Protocol for the use of self-etching adhesives, step by step……. 197

Figure 182. Protocol for the use of etch-and-rinse adhesives, step by step……. 198

Figure 183. Protocol for the use of universal adhesives, step by step. ..199

Figure 184. Initial situation.....209

Figure 185. Polarised photograph of the isolation for in-office bleaching, showing an intensification of the white spots due to dehydration. 209

Figure 186. Immediate result after 45 minutes of Zoom.....210

Figure 187. On the left of the document is the final colour determination after one month. 210

Figure 188. Example of periapical radiograph showing cervical external resorption……. 211

Figure 190. Photographic comparison of internal bleaching with twin flash, polarised and ring flash. Initial (bottom) and final situation (top).....212

Figure 191. Internal 213

Figure 192. SEM micrograph of Mullita.....219

Figure 193. General classification of ceramics.....220

Figure 195. SEM micrograph and physicochemical properties of leucite-reinforced feldspathic porcelain.....224

Figure 196. SEM micrograph of the IPSe.max Press lithium disilicate structure……. 225

Figure 197. Commercial presentation of lithium disilicate ingots. 225

Figure 198. IPS. e.max Press fluorescence. There is more in the bleach ingots than in the HT (High Translucency), which is why HTs tend to grey in the clinic…….....226

Figure 199. SEM micrograph of the IPSe.max CAD lithium disilicate structure…….....226

Figure 200. Commercial presentation of lithium disilicate blocks.....226

Figure 201. Crystalline phase transformation in zirconia.....228

Figure 202. Diagram depicting H2O leaching due to massive phase transformation leading to a change in overall density and thus an increase in brittleness…….. 229

Figure 203. Diagram depicting the transformation toughening. 229

Figure 204. Diagram depicting the transformation of the tetragonal phase to monoclinic as opposed to cubic which does not transform.....230

Figure 205. Outline of clinical indications and different materials. 236

Figure 206. Classification of ceramic materials.....237

Figure 207. Decision-making for single-tooth restorations based on the invasiveness of the procedure. 237

Figure 208. Types of indirect restorations. 240

Figure 209. Diagrams representing the remaining cuspid thickness and the decision-making process at the time of cutting and veneering. 245

Figure 210. Objectives of Build-up.....245

Figure 211. Comparison of cavity geometry without and with build-up..246

Figure 212. Deep margin elevation.....246

Figure 213. Diagram showing the isthmus between the boxes of an inlay, which must in turn have the corners of the base rounded.....247

Figure 214. Diagram showing the transition angles, which must follow the contour of the tooth and the contact points, which in turn must not be preserved…… 247

Figure 215. Diagram representing transition and cavosuperficial angles at 90º, with final preparation following occlusal anatomy. 248

Figure 216. The preparation for overlay/endo crown of an endodontic tooth. There is a large amount of exposed dentin and composite sandblasted with AO 50µm.……...250

Figure 217. Preparation of a vital tooth with exposed dentin. After sandblasting with bioactive glass, apply a 'universal' adhesive that will be blown to evaporate the solvent and will be left to polymerise (Prime & Bond Active Dentsply Sirona) to receive the restortion.....251

Figure 218. Surface treatment of lithium disilicate. The cleaning of the ceramic with orthophosphoric acid can be replaced or implemented by an ultrasonic bath with 95% alcohol for 4 minutes.....252

Figure 219. Cleaning of a ceramic veneer in an ultrasonic bath with 95% alcohol for 4 minutes and subsequent application of silane.....252

Figure 220. Surface treatment of CAD-CAM nano-ceramic resin. The phosphoric step could be avoided. In that case, simply wipe the surface with plenty of water to remove the aluminium oxide particles, but make sure that the surface is spotless and dry before silanising.....253

Figure 221. Excess composite flowing out of the margins of the restoration. An ultrasonic tip at the bottom left of the picture assists in the settling of the restoration.....256

Figure 222. Application of oblique force to occlusal surface results in potential rotation of crown (a) around a fulcrum (f). Rotation is resisted by the cement above the arc of rotation of the base of the crown being thrown into compression – represented by arrow. Rotation of the shorter crown (b) results in tensile forces fracturing the cement lute. It is therefore important that the radius of rotation intersects the opposing axial wall. On the left, the placement of axial grooves increases resistance by effectively reducing the radius of rotation…….....259

Figure 223. A comparative drawing shows (a) an under preparation where (a) there is an overcontour but the structure is preserved and (b) over preparation that compromises the tooth and pulp strength. The ideal result is the middle ground.....260

Figure 224. The contour of the preparation should be in harmony with the natural tooth, despite a deep shoulder or chamfer of approximately 1.3mm and a reduction of between 1.5 and 2mm. 260

Figure 225. The same rules apply to the lingual surface of the tooth as to the labial surface. The tooth has to be reduced in order to allow sufficient space for the crown and to restore normal occlusal and protrusion relations……. 261

Figure 226. When reducing the vestibular surface of the tooth, the exact contour of the tooth must be imitated to avoid removing too much tissue and to obtain a crown of regular thickness. The drills shall be applied in two directions. A) The first orientation to the 2/cervicals of the tooth. B) The second, to the incisal third.....261

Figure 227. Comparison of correct chamfer execution and creation of retention due to excessive horizontal and vertical cutter insertion. 262

Figure 228. Thickness diagram for a classic porcelain fused to metal crown preparation…….....262

Figure 229. Different types of shoulder finish lines. 264

Figure 230. Different types of chamfer finish lines.....265

Figure 231. Classic preparation of posterior teeth. 265

Figure 232. Contemporary posterior tooth preparation for monolithic zirconia and/or lithium disilicate. These thicknesses were only described for metal…….. 265

Figure 233. Classic preparation guidelines for anterior teeth for lithium disilicate and zirconium oxide (today the thicknesses can be reduced if the substrate is favourable).....266

Figure 234. Diagram of how to sequentially and clinically achieve an intrasulcular margin.....269

Figure 235. Brasseler TPS milling cutter for the preparation and finishing of porcelain veneers. 273

Figure 236. Diagram showing tooth preparation on mock-up compared to direct tooth preparation, clearly showing less preservation of structure in the preparation without mock-up.....273

Figure 237. Different types of preparations for veneers: a) Preparation that does not go beyond the incisal edge (contact lens style), b) Preparation that goes beyond the incisal edge (classic palatal chamfer style), c) Preparation that goes well beyond the incisal dge (three-quarter style).....275

Figure 238. Butt joint preparation. 275

Figure 239. Basic elements of anterior tooth preparation. These sketch views show that the preparation can only respect the natural shape of the tooth if a horizontal frontal path of insertion is used (right): the mesiodistal dimension is narrower at the cervical leel than at the incisal level (left). (b) Axial reduction can vary between 0.3 and 0.4mm at the cervical margins and up to 0.5 to 0.6mm at mid-height, but can exceed these values when discolourations have to be masked. The incisal clearance is approximately 1.0 to 1.5mm, but may extend to 5 to 7mm in the case of a fractured tooth. Note that the highest curvature (zenith) of the gingival margin is distal to the central incisors. When the gingival contour is too symmetrical (and lacks this distal displacement), the use of a retractor wire is recommended to extend the margin to the distogingival gingival sulcus and to obtain this effect with the contour of the restoration. It is extremely important to round all sharp edges (incisal view), which can be achieved with coarse-grained flexible discs. ..277

Figure 240. Envelope design in the presence of a pre-existing class 3 restoration. The white dotted arrow shows the level of the incisal preparation. The grey dotted arrows mark the interdental preparation level. An interdental extension ('right end of the picture) is recommended due to the limited aesthetics and potential thermal effects of the composite restoration favourable for both aesthetics and thermal stresses. The full envelope (centre left of the picture) can be a beneficial design, indicated when combined with a flat or slanted incisal margin. An extensive chamfer to the palatal fossa (left end and bottom of the picture) should be avoided due to functional stresses and because a sharp incisal edge is often generated. 278

Figure 241. The different options for finishing the ceramic against a pre-existing Class III in an occlusal section. 'Partial or full veneering of pre-existing composite restorations reduces the thermal stress at the ceramic/composite interface.' In large and mediuminterdental veneers, part of the composite mass is replaced by ceramic, reducing the influence of expansion and contraction of the underlying filling composite and thus preventing future fractures that may occur at the ceramic interface. 279

Figure 242. Close-up of a ceramic finish that does not encompass the pre-existing class III. Electron microscopy shows micro-fracture at the interface due to differences in the thermal coefficient of the materials. 279

Figure 243. Four key clinical questions to be asked when dealing with a porcelain veneer case. 280

Figure 244. Initial intraoral situation, periapical detailed x-ray of the 1.1 and smile, which is low. 280

Figure 245. Detail of initial situation with 1.2 fractured in incisal, 1.1 darkened, reconstructed and endodontic, 2.1 fractured in incisal and 2.2 palatalised and very disproportionate in size due to a very open distoincisal angle…….....281

Figure 246. Remove the metal post and seal the canal with new gutta-percha…….....281

Figure 247. Etch and rinse approach. Seal the gutta percha with opaque white flowable composite (XBW.GC). 282

Figure 248. Internal bleaching with Opalescence endo (Ultradent Inc)…282

Figure 249. Before/after comparison of internal bleaching in 1.1. Detail of upper front……. 282

Figure 250. Before/after comparison of internal bleaching in 1.1. In addition, at-home external bleaching was performed on the rest of the teeth. Intraoral detail. 283

Figure 251. Test of a fibreglass post in tooth 1.1. The system chosen for adhesive cementation is detailed on the left side of the picture.....283

Figure 252. Periapical x-ray showing the result of the final restoration with the post. In addition, the sequence of the adhesive procedure. Total etching with orthophosphoric acid (nowadays it would be done with self-etching strategy), rinsing and drying of the canl with paper points. Placement of 5th generation adhesive, Prime and Bond NT+ SCA activator and cementing of the post with dual core x. flow resin cement.....283

Figure 253. Semi-additive aesthetic wax-up of 1.2-2.2.....284

Figure 254. Aesthetic dental analysis of the wax-up; meets the requirements described in chapter 4. 284

Figure 255. Wax-up detail.....284

Figure 256. Wax-up detail.....285

Figure 257. Condensation silicone key test (Zetalaabor.Zhermack) for mock-up on the wax-up.....285

Figure 258. Detail of the condensation silicone key (Zetalaabor.Zhermack) for mock-up on the wax-up. 285

Figure 259. Detail of more silicone keys on the wax-up to control the preparations…….. 286

Figure 260. Colour impression with VITA guide prior to the mock-up. ...286

Figure 261. Detail of intraoral mock-up with bisacrylic resin. 286

Figure 262. Detail of mock-up smile with bisacrylic resin and correction with flowable composite in 2.2. 287

Figure 263. Detail of the anterior front of the mock-up with bisacrylic resin…….....287

Figure 264. Detail of the burs and soflex disc used. 287

Figure 265. Preparation on mock-up, horizontal grooves.[108] 288

Figure 266. Preparation on mock-up, finishing area. 288

Figure 267. Evolution of preparation on mock-up; it can be seen that it is being lost by areas.....288

Figure 268. Preparation on mock-up, elimination of interproximal contact……. 289

Figure 269. Preparation on mock-up, 2.1 can already be seen without it…….....289

Figure 270. Evolution of the preparation on mock-up, showing that there is still a reduction in 2.2. In 1.1 a 4/4 preparation was chosen to include the palatal resin…….....289

Figure 271. Finished preparations with the termination still to be defined……. 290

Figure 272. Preparations 1.2-2.2 with the retraction wire 00 in place and the cervical margin defined in the intrasulcular position.....290

Figure 273. Thickness control with silicone key, it was decided to give more thickness to the technician in 1.1 because the substrate is a little less favourable than in 2.1. (despite the bleaching). 290

Figure 274. Thickness control with occlusal/vestibular silicone key. Comparison of the final space that the technician will have for the ceramic restorations (above) versus the space that existed at the beginning, before the preparations (below), showing that the ke does not even fit.....291

Figure 275. Transmission of the final shade of the preparations to the technician…….....291

Figure 276. Two-step silicone impression. The margins are completely defined…….....291

Figure 277. Comparative views of the mock-up with the final dental preparations…… 292

Figure 278. Manufacture of feldspathic porcelain veneer facets on platinum foil…….....292

Figure 279. Checking the setting and adjustment of the porcelain veneer on the solid model. 292

Figure 280. Anatomical detail of the feldspathic veneers.....293

Figure 281. Detail of the porcelain veneers, ready to be tried in and cemented…….. 293

Figure 282. Detail of the intraoral situation of the bisacrylic temporaries (Integrity. Dentsply Sirona) after three weeks.....293

Figure 283. Detail of the veneers try-in, 'dry' on the 1.2 and 2.2 sides, and with two different value try-in pastes on 1.1 (Calibra veneer try-in bleach. Dentsply Sirona) and 2.1 (Calibra veneer try-in translucent. Dentsply Sirona)…….....294

Figure 284. Surface treatment of the feldspathic porcelain as described in chapter 10……. 294

Figure 285. Detail of the isolated preparations under rubber dam (Optidam anterior .Kerr) with dental floss ligatures. 294

Figure 286. Detail of preparation 1.1 isolated under rubber dam (Optidam anterior .Kerr) and modified clamp No. 212.....295

Figure 287. Detail of porcelain restoration 1.1 cemented under rubber dam (Optidam anterior.Kerr) and modified clamp nº 212. Excess cement has been removed at the bottom left.....295

Figure 288. Detail of the preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212 with dry seated porcelain restoration…….. 295

Figure 289. Detail of orthophosphoric acid conditioning of preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212.....296

Figure 290. Detail of orthophosphoric acid conditioning of preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212. Note the large amount of enamel available, as well as the dentin-enamel junction…….. 296

Figure 291. Detail of the restoration cemented in 1.2 isolated under rubber dam (Optidam anterior.Kerr) and clamp nº 212 modified. On the right, the glycerine gel for the elimination of the inhibited layer during the final polymerisation and, and on the left, the deail of the adjustment. 296

Figure 292. Detail of the restoration cemented in 1.2 isolated under rubber dam (Optidam anterior.Kerr) and clamp nº 212. modified. Note the detail of the cervical adjustment. 297

Figure 293. Detail of the cemented restorations in 1.2, 1.1 and 2.2 isolated under rubber dam (Optidam anterior.Kerr). The preparation of 2.2 can be seen without the floss bonded restoration.....297

Figure 294. Detail of the preparation in 2.2 isolated under rubber dam (Optidam anterior.Kerr) and modified clamp no. 212. On the left of the composition, the detail of the porcelain restoration. 297

Figure 295. Photographic arrangement of Initial situation/ Finished result. The background is the preparation 3/4 of 1.1 under rubber dam (Optidam anterior.Kerr) and clamp nº 212. modified. The cervical margin can be seen in detail…….. 298

Figure 296. Detail of the anterior front of the cemented restorations after one month. Note the gingival health. 298

Figure 297. Intraoral detail of the cemented restorations after one month. Note the gingival health and integration with the rest of the teeth. 298

Figure 298. Intraoral comparison of the initial situation/final result.....299

Figure 299. Photographic composition of the final result in the occlusal view where the aligned veneers can be seen in comparison with the plaster model of the initial situation, showing the gyroversions of 1.2-2.2. 299

Figure 300. Photographic composition of initial situation/final result after 6 months…….. 299

Figure 301. Smile photographic composition. Initial situation/ Final result after 6 months. 300

Figure 302. Final or Take-Home Message. 300

Figure 303. Preparations for full veneer crowns on an upper central incisor. Note the differences at the marginal level between a horizontal preparation with a chamfer (a) and a vertical preparation or one without a termination line (b)…… 303

Figure 305. Super imposition of different preparation designs: a vertical shoulderless preparation (less opacity) and two horizontal ones (chamfer of 0.4mm and 0.8mm). Clearly there is more structure in the vertical. 306

Figure 306. BOPT milling diagram. 308

Figure 307. Diagram showing the modification of the gingival margin position according to the cervical angulation of the prosthetic restoration. The most common angle is around 45º.....309

Figure 308. Initial situation of a clinical case of four misaligned porcelain-fused-to-metal crowns 1.2-2.2.....309

Figure 309. Vertical preparations, B.O.PT protocol, note the marks left by the temporary on the gingiva just after passing it.....310

Figure 310. Internal aspect of the provisional just passed, clearly identifying two lines: an internal one corresponding to the limit of the dental preparation and an external one corresponding to the future gingival margin…….....310

Figure 311. Filling the compensation area between the two lines to redefine the future prosthetic margin. 310

Figure 312. Adjustment, finishing and polishing of the overfilled temporary prosthesis…….....311

Figure 313. Photographic composition showing the comparison between the initial and final situation with the newly installed provisional prosthesis…….....311

Figure 314. Detail of the maturation of the temporary prosthesis after 16 weeks, just before cementation of the final restorations.....311

Figure 315. Comparison of smile before/after BOPT protocol with 1.2-2.2 zirconia-reinforced lithium disilicate crowns. 1.4,1.5,1.3,2.3,2.5 and 2.6 are veneers…….....312

Figure 316. Comparison of anterosuperior front detail before/after BOPT protocol with 1.2-2.2 zirconia reinforced lithium disilicate crowns. 1.4,1.5,1.3,2.3,2.5 and 2.6 are veneers.....312

Figure 318. Initial intraoral situation. Porcelain fused to metal crowns mismatched in 1.1 and 2.1. 314

Figure 319. Vertical preparation with the flame-shaped bur in the gingival sulcus…….. 314

Figure 320. Emergence profile after removing the interim prosthesis. ...315

Figure 321. Final result with definitive restorations 1.1 and 2.1 (zirconium oxide)……. 315

Figure 322. Diagram showing a subgingival 'step' accidentally made by tilting the active tip of the 862-864 'flame' bur too much towards the tooth (left part of the photo). 316

Figure 323. Comparison of the 'flame' drill and the inactive tip drill. 317

Figure 324. Photographic composition of the inactive tip drill 857 (Intensiv. Switzerland) over the premolar stump and into the sulcus to ensure vertical preparation without scaling. 318

Figure 325. Comparison of the vertical preparation in the BOPT protocol, also called 'edgeless' compared to 'shoulderless'. There is more structure in the second one, thanks to the overlapping, and also better tissue behaviour at the level of the interproximal papillae.....318

Figure 326. Differences between 'Shoulderless' and 'Edgeless' preparation designs……. 319

Figure 327. Vertical EDGELESS and SHOULDERLESS versus horizontal termination. Differences in the depth of preparation and the future margin of the restoration. 319

Figure 328. Initial situation of the anteroinferior sector worn and with recessions……. 322

Figure 329. Shoulderless preparations of 3.2-4.2. Note the high definition of the sulcus depth with an analogue condensation silicone impression…322

Figure 330. Detail of the preparation of the substrate for cementing the veneers (Table 5), the dentin-enamel junction can be seen in the 3.2 cervical…….. 323

Figure 331. Comparative photographic composition before/after treatment with lithium disilicate veneers on margin-free preparations in the lower arch. The periodontal health is remarkable, as well as the aesthetic result of the white part……. 323

Figure 332. Photographic composition of the vertical preparations and the veneers placed in harmony with the soft tissues. Note the anatomical emergence profile of the BPRs, in accordance with the periodontal phenotype, emulating a cementoenamel junction but ARTIFICAL. 324

Figure 333. Outline of free gingiva, attached gingiva and alveolar mucosa……..326

Figure 334. Aesthetic gingival parameters.....327

Figure 335. Parameters indicating gingival health. 328

Figure 336. Ideal position of interdental papillae.....329

Figure 337. Ideal position of gingival zeniths. 329

Figure 338. Parallelism and symmetry of gingival margins. 330

Figure 339. Biological width components.....331

Figure 340. Margins of tooth preparations respecting the biological width…….. 332

Figure 341. Combination of endodontic and restorative treatment.....333

Figure 342. Preparations with the retractor wire in place.....334

Figure 343. Silicone impressions of implants copying the emergence profile and tooth details. 334

Figure 344. Functions of the interim prosthesis.....335

Figure 345. Wheeler classification. 336

Figure 346. Schematic representation of the col.....337

Figure 347. Detail of anterior teeth profile.....338

Figure 348. Thick biotype vs thin phenotype.....338

Figure 349. Smile classification according to dental and gingival exposure……. 340

Figure 350. Frontal smile analysis. Patient with APE.....344

Figure 351. APE classification.....344

Figure 352. Treatment plan established in clinical case.....347

Figure 353. Frontal analysis and Digital Smile Design.....348

Figure 354. Placement of Mock Up and periodontal study.....348

Figure 355. Step by step gingivectomy, bone resection, carving and provisionalisation of the case.....349

Figure 356. Immediate situation after surgery. 349

Figure 357. Situation after monthly re-evaluation. 350

Figure 358. Final re-evaluation prior to prosthodontic rehabilitation.....350

Figure 359. Classification of gingival recessions described by Miller....351

Figure 360. 1.3 root coverage. 352

Figure 361. Step-by-step treatment of 2.4 gingival recession. 353

Figure 362. Graphical representation treatment types 1, 2 and 3. 354

Figure 363. Graphical representation treatment types 4 and 5. 355

Figure 364. Clinical crown 2.2 restoration with horizontal coronal fracture…… 357

Figure 365. Ideal vs. minimum root ratios. 359

Figure 366. Clinical image of subgingival fracture in 3.4. 363

Figure 367. Periodontal and radiographic analysis of remaining tooth structure…… 363

Figure 368. Full-thickness flap debonding surgery in order to perform bone resection and gain sufficient remaining tooth tissue to obtain ferrule and ensure the long-term prognosis of the final restoration. 364

Figure 369. Absolute isolation with a rubber dam to avoid fluid filtration that could interfere with the bonding process (1). Acid etching of the tooth surface (2). Adhesive application (3). Placement of fibreglass post (4). Core build-up with resin (5). 365

Figure 370. Tooth preparation with BOPT technique. 366

Figure 371. Provisionalisation considering the aesthetic, biological and functional aspects. 366

Figure 372. Measurements are taken using digital flow with an intraoral scanner and communicated to the laboratory. 367

Figure 373. Definitive cementation. 368

Figure 374. Pre- and post-treatment comparison. 368

Figure 375. Lateral view of the emergence angle of the deep zone. (1) Straight profile with an emergence angle of more than 15 degrees. (2) Straight profile with an emergence angle of 0 degrees. (3) Straight profile with an

emergence angle of -8 degrees. (4) The anged axis of the implant in relation to the axis of the prosthesis and to the bony ridge affects the emergence angle…….....371

Figure 376. Lateral view of cervical and transition zone design options for implants placed in healed bone. (1) Convex. (2) Straight. (3) Concave.....372

Figure 377. Proximal design of transitional and cervical zones in healed anterior sites, demonstrating the effect of critical proximal space on the final design. (1) Concave. (2) Straight. (3) Convex.....372

Figure 378. Lateral (a) and frontal (b) view of the design of the anatomical healing cap for immediate implants.....374

Figure 379. From left to right: CBCT, STL and photograph.....376

Figure 380. Planning the placement of an implant for the fabrication of a guided surgery splint.....376

Figure 381. Guide for the use of PES/WES based on the virtual presentation of an optimal single-tooth implant restoration.....378

List of Tables

Table 1. Physical properties of dental hard tissues and corresponding biomaterials ……42*

Table 2. Core questions.....72

Table 3. Zirconium generations 230

Table 4. Classification of lithium disilicate ingots according to translucency, processing technique and indications. 233

Table 5. Tooth treatment.....249

Table 6. Restoration treatment.....254

Table 7. Indications, advantages and disadvantages of the supra/juxtagingival location margin.....268

Table 8. Porcelain veneer grading system based on exposed dentin……. 272

Table 9. Porcelain veneer grading system based on the remaining enamel (opposite of the above). 272

Table 10. Differences between thin and thick phenotypes. 339

Table 11. Classification pf Passive Altered Eruption.....343

Table 12. Therapeutic options in cases of gummy smile.....346

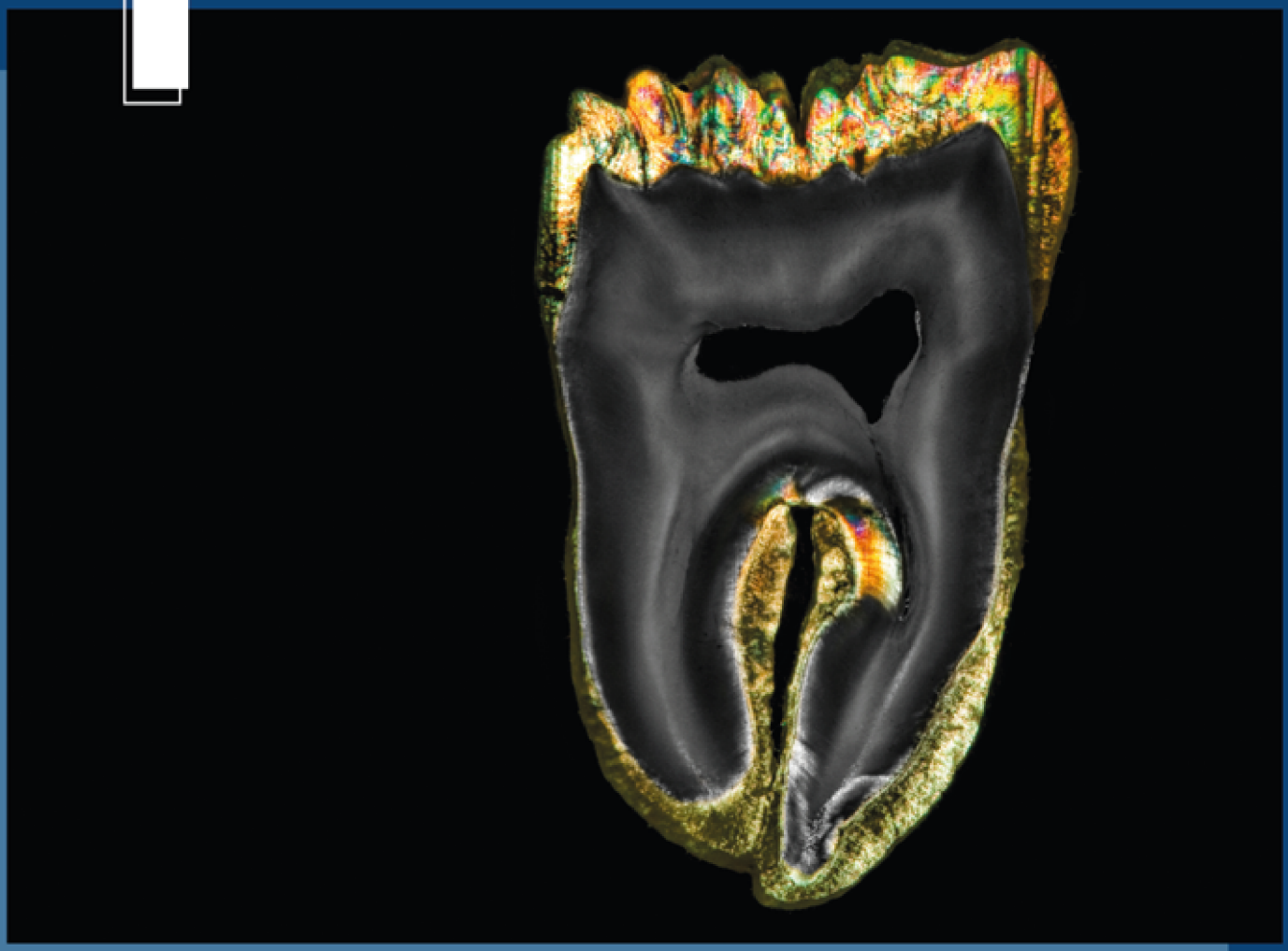
Table 13. Classification of gingival recessions.....351

Table 14. Classification of treatment options for gingival recessions associated with cervical abrasions proposed by Zucchelli.....354

Table 15. Types of lasers used in dentistry.....380

UCAM

Chapter 1



Introduction to Aesthetic Dentistry
Biomimetic and Minimally Invasive Dentistry

Legal aspects in aesthetic restorative dentistry

Photo by Dr. Fernando Rey Duro

1.1. Introduction. What is 'aesthetics'?

The term 'aesthetics' is borrowed from the Greek word 'aesthesia', which means sensation or sensibility. It can be defined as 'belonging to the appreciation of the beautiful'. 'Esthete', the noun form of the same word, may be used to describe a person who enjoys or perceives a pleasant sensation. Similarly, the meaning of the term in adjective form indicates ability to respond to beauty in art or nature. The relation of this term with dentistry **must be differentiated** from the word 'cosmetic', which is derived from the Greek word 'kosmos', or adornment, and **has no functional considerations**[1].

E.g.: Adhesive technology has given rise to innovative jewellery that can be attached to the teeth simply as an ornament (Skice. Ivoclar Vivadent. Liechtenstain).

In 1936, Pilkington E. L.[1] defined dental aesthetics as

> 'the science of copying or harmonizing our work with that of nature, making our art inconspicuous'.

Aesthetic dentistry enhances the natural beauty of the mouth and face, as a whole – the term implies an improved comprehensive-functional relationship rather than a solely superficial relationship.

Aesthetic dentistry has opened an entirely new world for most clinicians and changed the lives of hundreds of thousands of patients in a **positive** way. Likewise, the image of dentistry has evolved from one of pain relief and functional restorations, to a more sophisticated aesthetic perception. And, therefore, to the development of a profession that is more enjoyable today than ever before.

In the 21st century, and especially during the last few years, a large portion of the treatment protocol of dentists has entailed more and more aesthetic dentistry. It is estimated that as many as 50% of individuals seeking dental care are actually seeking aesthetic self-improvement. In an aesthetic-conscious society, where 'beautiful' tends to create the image of someone 'good' and 'successful', individuals are prepared to **invest in the improvement of their teeth** and, therefore, their

appearance. Not all of these patients require complex multidisciplinary treatment, and some may in fact suffice with routine procedures, such as bleaching, composites and veneers to achieve the desired effect.

However, all areas of dentistry, including orthodontics, oral surgery, periodontics and classical prosthodontics, can be involved in the goal of making dentistry **aesthetic**.

- The objective of any oral rehabilitation is to provide a restoration that fits harmoniously into the facial composition, while hoping to emulate the previously existing teeth, gingiva and other soft tissues, providing that these components previously existed in aesthetic harmony. In an optimal restoration, the observer should not be able to recognise the presence of a replacement. **The patient and the observer should perceive the restorative result as entirely natural[1].**

The continuing aesthetic evolution has fostered a growing need for materials and application techniques that increase the arsenal for aesthetic design. Despite any advances, the basic and universal principles of minimal invasiveness and structure preservation cannot be overturned.

Some patients may complain that their new restorations are not ‘aesthetically pleasing’ due to the fact that their friends or relatives failed to notice their new teeth from ‘miles away’ (i.e., the USA aesthetic concept). The reason for this is that by adhering to the natural morphological state, an aesthetic harmony has been successfully achieved. Some patients may go as far as to ask the dentist to ‘spoil’ this naturally pleasant smile. It is therefore essential to bear in mind that ‘aesthetic values’ vary not only from nation to nation, but also from individual to individual.

1.2. Evolution towards 'minimally invasive' dentistry

The entire concept of dentistry has changed dramatically over the last 30 years, and an entirely new era of restorative dentistry has begun. Practice has moved out of the classic era of dentistry, when the extraction of teeth was a common procedure, and has moved into the age of conservative restoration with **minimally invasive procedures**.

These procedures are becoming simpler and even more conservative with every passing day. It is now a moral obligation of the restorative dentist to respect the tissue that the patient brings in as much as possible[2].

In accordance with Dr Agustín Pascual Moscardó, who was Professor and Director of the Máster Propio en Odontología Estética Adhesiva y Mínimamente Invasiva (Master's Degree in Aesthetic, Adhesive and Minimally Invasive Aesthetic Dentistry) at the University of Valencia, the guidelines in regular dental practice ought to be:

1) PRESERVE BEFORE REMOVING
2) RESTORE RATHER THAN REPLACE
3) ADD RATHER THAN SUBTRACT

1.3. Aesthetic or purely cosmetic motivation of patients

It is not defining as long as minimally invasive principles are respected, and the biological cost does not outweigh the aesthetic benefit. As previously mentioned, a beautiful smile seems to reflect a certain 'lifestyle', and the improvement of facial beauty is one of the main goals of patients seeking elective dental care. The lower third of the face has a great impact on the perception of facial aesthetics, and thus the role of a beautiful smile is undeniable. Once the ideal relationship between the restoration and facial soft tissues is achieved, improvements in natural beauty are expected to follow.

With the increasing importance placed on appearance by the media, patients and society in general, there is an even greater emphasis on aesthetic dentistry as a discipline.

1.4. Teamwork and Facially Generated Treatment Planning

Surgeons, Orthodontists and Restorative Dentists now have a unique opportunity to address functional needs while creating an aesthetically pleasing smile.

The main aspiration of the restorative dentist is to fully rehabilitate the stomatognathic system in compliance with biofunctional and aesthetic principles.

Dental aesthetics has become a relevant topic in most dentistry areas and disciplines. In planning to alter or improve the appearance of the teeth of a patient, the practitioner must have a logical diagnostic approach to always generate a **facially generated** treatment plan[2,3,4]. In most patients, the prosthodontist cannot achieve these goals individually and interdisciplinary teamwork is required.

During diagnosis, it is important for the team to have an **aesthetically based approach**; the aim is to achieve a treatment plan that not only improves the appearance of the patient, but that is also done without sacrificing the structural, functional and biological aspects of the teeth.

1.5. Aesthetic and Adhesive Restorative Dentistry. Biomimetics

Biomimetics is the **philosophy followed in adhesive** restorative dentistry, popularised and described by Dr Pascal Magne at the beginning of the 20th century, which can be summarised as **recovering the original biomechanical integrity** of the tooth by means of adhesive materials. Therefore, the indication of composite or ceramic for example will depend mainly on this criterion, but firstly on the biological cost, making it a case-by-case dilemma.

The biomimetic dental approach really falls within the scope of minimally invasive dentistry, as it is absolutely compatible with the Hippocratic oath: **'Do no harm'**, and seeks to promote the following concepts, reprinted by Magne P and Belser U[5] in 2021:

1. Preserving more dental pulps.
2. Crack repairing or elimination.
3. Elimination of pathologies.
4. Preserving the maximum amount of tooth structure.
5. Tooth structure strengthening.
6. Delaying the retreatment cycle.

Having said that, and regardless of the artificial material chosen to replace dental tissues, the three general rules of Dr Pascal Magne related to biomimetic adhesive dentistry are:

1. Shape is more important than colour.
2. The operator is more important than the adhesive technique.
3. The adhesive technique is more important than the adhesive.

Table 1. Physical properties of dental hard tissues and corresponding biomaterials*

Dental hard tissue	Elastic modulus (GPa)	Thermal expansion coefficient (X 10^{-6}/ ºC)	Ultimate tensile strength (MPa)	Corresponding material	Elastic modulus	Thermal expansion coefficient	Ultimate tensile strength
Enamel	80[31]	17[32]	10[33]	Feldspathic porcelain	60-70[34]	13-16[35]	25-40[36]
Dentin	14[37]	11[32]	105[37]	Hybrid composite resins	10-20[38]	20-40[39]	40-60[30]

*All values are approximations.

Note. This table represents the physical analogies between enamel and feldspathic porcelain, and between dentin and hybrid composite resins. It is noted, for example, that the hybrid composite resin has an elastic modulus four times less than enamel and would therefore not be the best choice to replace enamel in these terms. From Magne P. and Belser U[5]

It is clear from Table 1[5] that composite is the closest material to replace dentin, and that feldspathic porcelain would be suitable to replace enamel. However, composite resin restorations can be used instead of porcelain veneers to cover tooth discolourations or malformations. However, composite durability is questionable as composites are susceptible to discolouration (they absorb water), marginal fractures and wear. Consequently, any aesthetic result requiring long-term durability is either compromised or subject to frequent **maintenance**; whereas porcelain veneers are superior in aesthetic quality and longevity. The biocompatibility and non-porous surface together with the optical and mechanical properties of bonded porcelain have increased its popularity and indications for overcoming aesthetic and functional challenges.

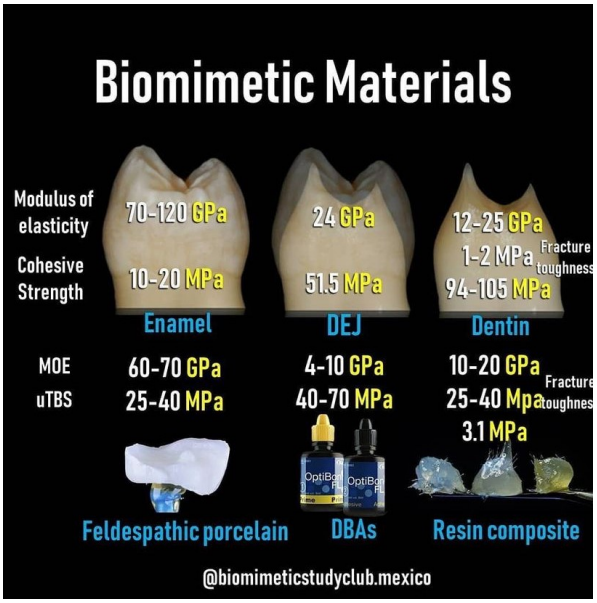


Figure 1. Equivalence of dental hard tissues and biomaterials. Here you can see the equivalence between dentin-enamel bonding and adhesive systems. Made by Biomimetic Study Club [6]

In this regard, it should be noted that porcelain bonded to anterior teeth is a 'restitutio ad integrum' of the original biomechanics of the anterior teeth. In 1991, *Andreasen FM*[6] already demonstrated that an anterior tooth with a veneer is even stronger and more resistant than the intact tooth itself. This is due to the fact that the intrinsic resistance of the material becomes adhesive, multiplied by the fact that the adhesive procedure is conceived as a **load transmission** process, so that tooth + restoration act as a single body under stress. This does not happen with composites; the tooth is not reinforced, and they do not behave as a whole, with only the intrinsic resistance of the resinous material predominating independently of the tooth. Therefore, under repeated impacts, a Class IV composite will tend to fracture more than the same tooth restored with a porcelain veneer.

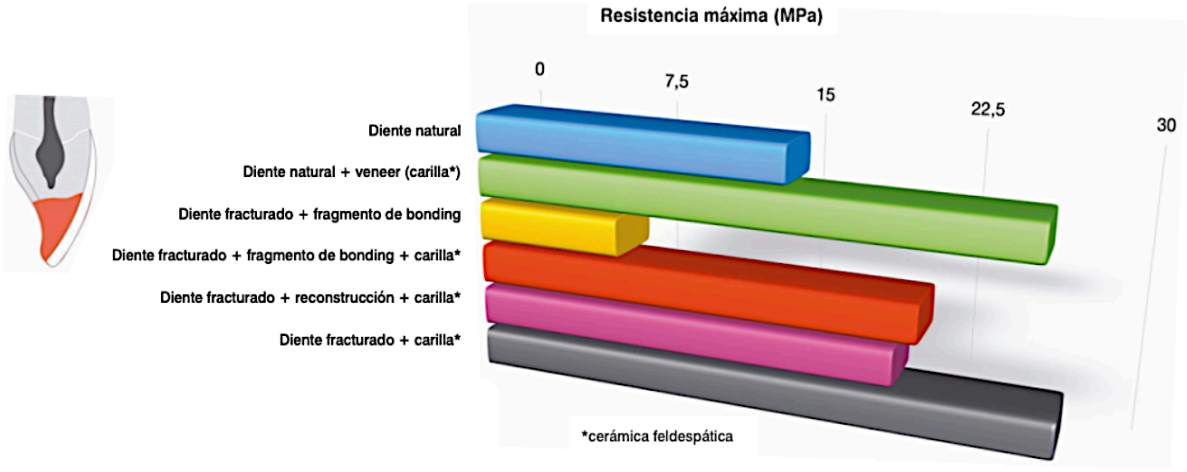


Figure 2. Maximum strength of the restoration-tooth interface (MPa) as a function of the restorative possibilities. Made by Andreasen FM y cols.[7]

The elastic modulus is a measure of stiffness. Higher values indicate stiffer materials, with less deformation under load. However, in restorative dentistry, biomechanical compatibility does not depend solely on stiffness, but also on other factors such as tensile strength, adhesion, and the ability to dissipate stresses

The tooth balances **four concepts**: **BIOLOGY, MECHANICS, FUNCTION AND AESTHETICS**[5]**.**

Therefore, the therapeutic approach must always take these aspects into account in order to be biomimetic, since the restoration chosen will be the one that most closely resembles the tissue to be replaced, i.e., the one with similar optical and mechanical properties, with the lowest biological cost and the one that best performs biomechanically during function. Bonded Porcelain Restorations (BPR) would be

the best indication in a case of diastema closure from this point of view, if there is no biological cost (if no grinding is required). However, if the vestibular enamel had to be removed to create a pathway for the insertion of porcelain restorations (BPR), direct composites would be the choice as they would have zero biological cost.

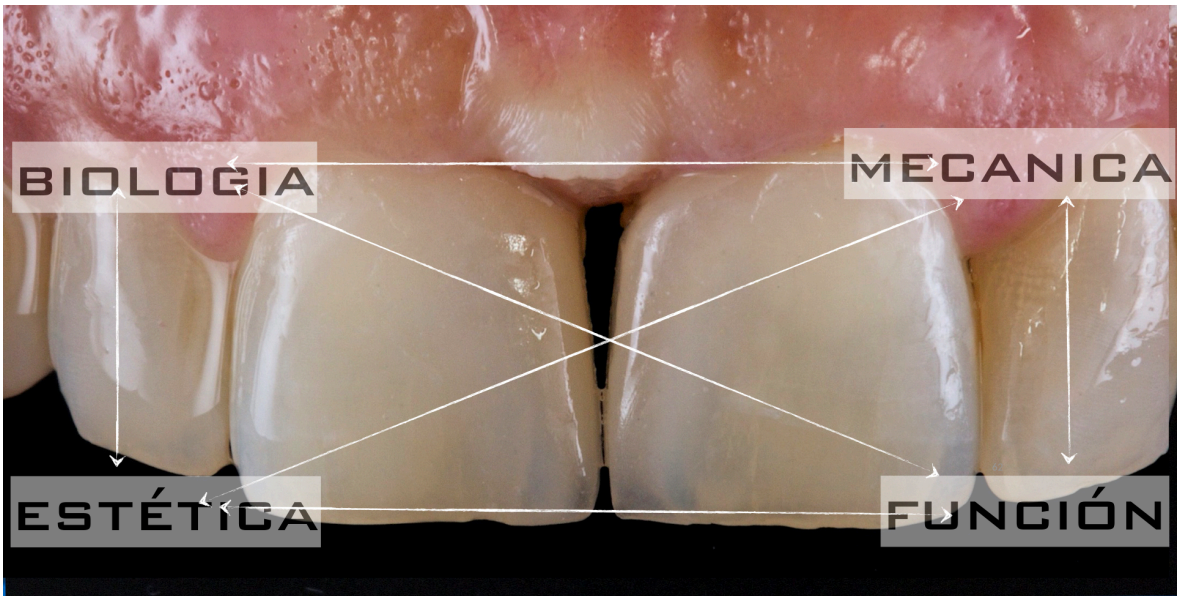


Figure 3. Balance and relation between biology, mechanics, function and aesthetics. Developed by Ferrando A and inspired by Magne P.[5]

Nevertheless, the acceleration in the development of dental materials, porcelains and adhesives has made tooth-preserving preparation and restorative procedures that were never before imaginable possible. These new techniques allow the dental clinician to achieve aesthetically pleasing results without any indications for **EXCLUDING** materials!

PRACTICAL INDICATIONS FOR COMPOSITES AND PORCELAIN VENEERS.



Figure 4. Clinical indications for composites and porcelain veneers. Made by Ferrando A.



Figure 5. Dental fragment in perfect condition for bonding and *collage*. Made by Ferrando A.

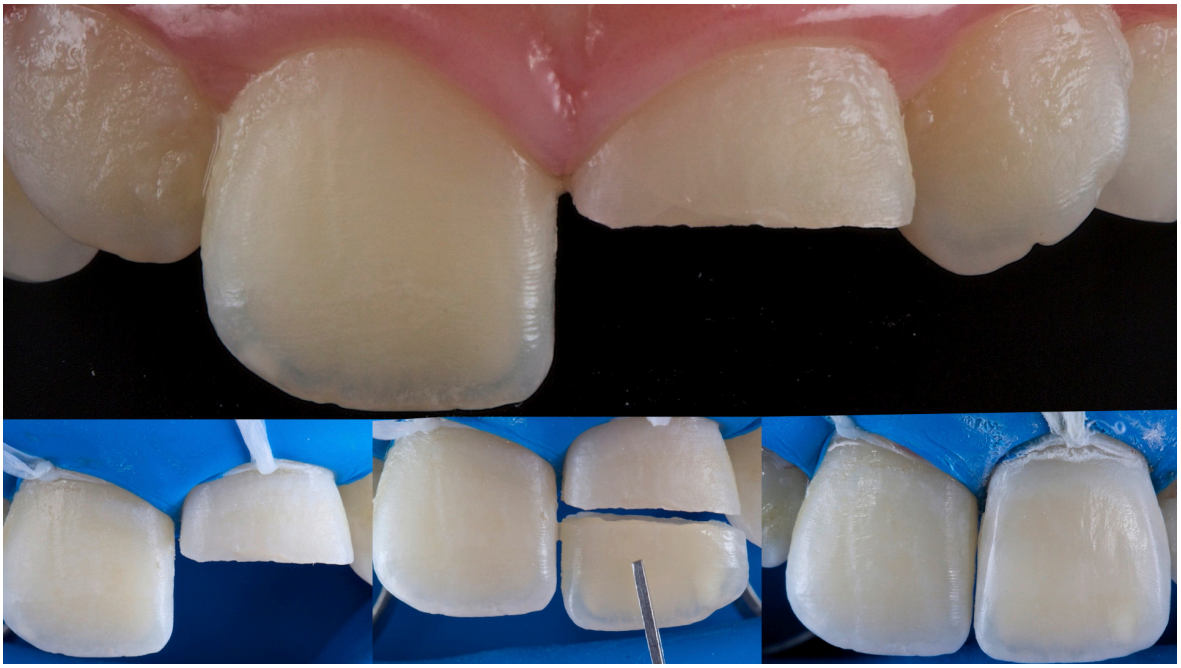


Figure 6. Photographic composition showing the initial situation and below a sequence under absolute isolation depicting the approach of the tooth piece and the final newly bonded situation. Made by Ferrando A.[8]



Figure 7. Photographic composition showing comparative smile and intraoral detail before/after one month check-up. Made by Ferrando A.

While noting that the composite/ceramic indications are not strict, but a logical orientation when dealing with different clinical situations, it should be borne in mind that the restoration of vestibular enamel thickness is an attempt to combine biomechanics and aesthetics, as its loss over the years directly affects the rigidity of the crown[5], even more than Class III cavities.

CLINICAL CASE



Figure 8. Clinical case showing a Class IV in 1.1 which is continuously breaking according to the patient. In 2.1 there is a 'collage' with a poorly adapted fragment. The preparations for bonded porcelain restorations (BPR) can be seen next to it. It is noteworthy that in the preparation of 2.1 the bonded fragment has been included, which, although poorly adapted, has never come off since being bonded, as opposed to 1.1, where the composite has been completely removed as it does not contribute any biomechanical value. Made by Ferrando A y Ballester J.



Figure 9. Photographic composition showing the intraoral detail of the final situation 10 years after the BPR. At the corners, you can see the shade of the initial situation and the preparations with a personalised guide of the fired feldspathic porcelain that was used to make the BPR. Made by Ferrando A y Ballester J.

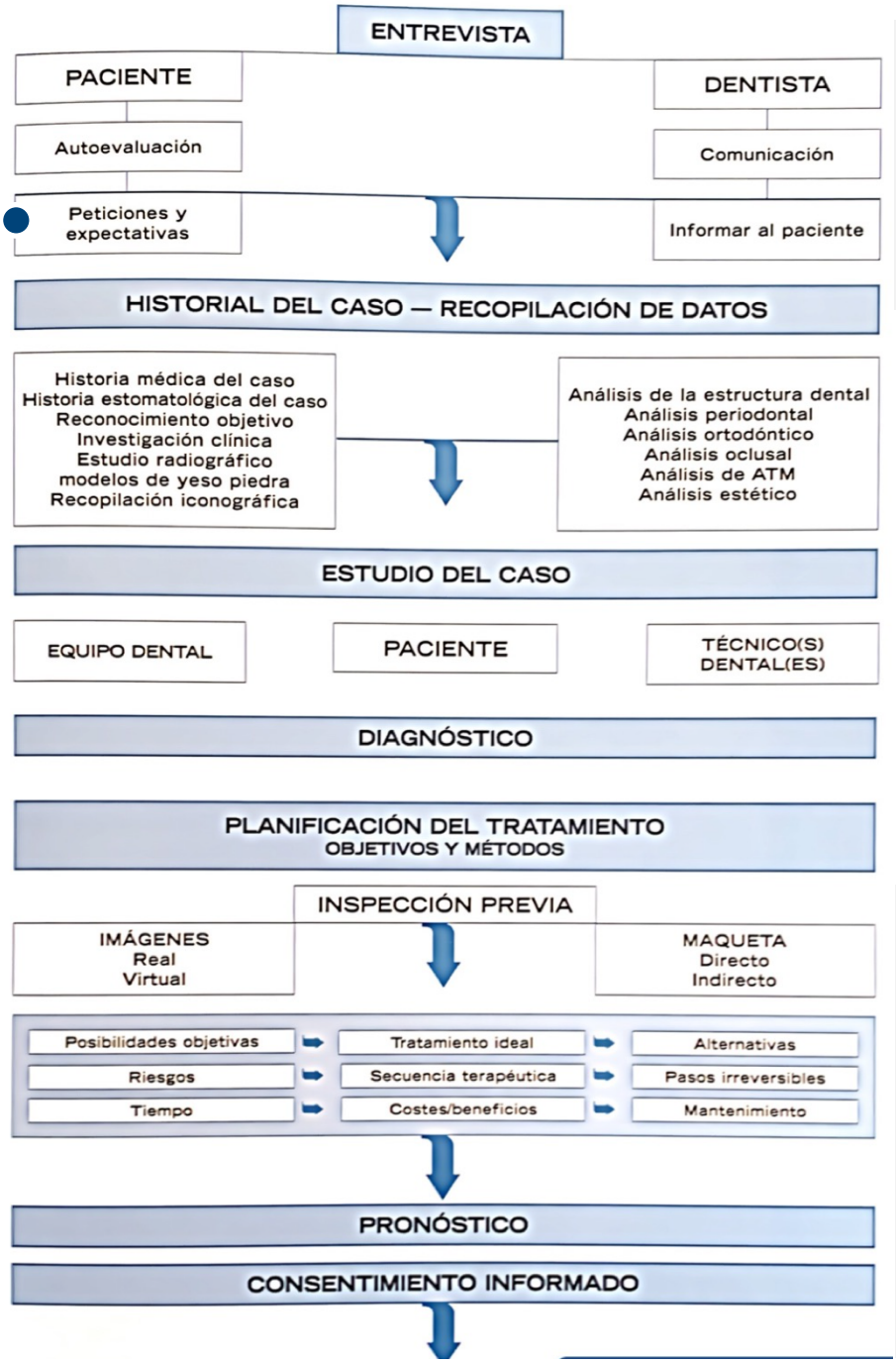


Figure 10. Photographic composition of smiles showing the initial/final comparison 10 years later. The absolute integration of the BPR is noteworthy, and you can also observe that Class II malocclusion has increased. Made by Ferrando A y Ballester J.



Figure 11. Photographic composition showing the initial/final comparison of the face 10 years later. Made by Ferrando A y Ballester J.

1.6. First visit in Aesthetic Dentistry



First 'casual' visit. How can I help you?

Introduce similar cases for the patient to identify themselves.

Visit of records - photos, models, videos.

Digital Smile Design 2D and 3D. TO COMPLETE THE CLINICAL DIAGNOSIS AND PRIORITIZE THE TREATMENT PLAN.

A good long-term PROGNOSIS is guaranteed by respecting biological and functional principles, together with the correct choice of materials and techniques, especially in extensive rehabilitations.

Figure 12. First visit in aesthetic dentistry. Made by Fradeani M.[9]

- The expectations of the patient and their understanding of the possible therapeutic solutions are essential before embarking on any type of treatment in aesthetic dentistry.[7]

  Therefore, the first visit-interview is key, where you should foster a **relaxed environment**, as the patient will be seeking help to solve a usually complex problem. You need to assess their general state, behaviour, spontaneous smile, facial expressions and, above all, ensure that they express their demands calmly.

  Only then can a discussion about possible solutions begin, without forgetting the risks involved in any intervention, which is why an informed consent form for aesthetic dentistry must be provided and you must know how to respond to any questions adequately and in a language that is understandable to the patient.

  Some patients arrive with photos of their celebrity as an aesthetic model. While it is easy to laugh it off or take it lightly, this attitude is counter-productive since the patients are opening up and revealing their aspirations with regard to the image they want to convey. They need to be taken seriously, but do not forget to communicate that the solutions are often complex. Treatment is usually **interdisciplinary**, and it is the job of the professional to convey the complexity, number of sessions and duration so that the financial outlay is not underestimated. If the expectations are impossible to achieve, this must be made clear.

As for deciding the ideal aesthetics for each case, this can only be achieved with true and sincere communication between PATIENT-DENTIST-TECHNICIAN.

Finally, it should be noted that some patients are not **involved**, and it is your responsibility to instil in them that they must overcome the hygienic phase and must be fully involved throughout the entire treatment.

In summary, the general philosophy we follow in the course of Aesthetic and Adhesive Dentistry is based, whenever possible, on minimally invasive intervention combined with a biomimetic approach that achieves a natural appearance. Thus, even if the treatment involves significant changes to the dental composition, the result should not be evident as an artificial modification, but rather perceived by the observer as a noticeable improvement in the smile and overall facial appearance.

1.7. Legal aspects in aesthetic restorative dentistry

Informed consents are mandatory for each procedure and should be individualised according to the specific circumstances of the patient.

LEGAL ASPECTS INFORMED CONSENT FOR VENEERS

Risks of veneers

The risks of veneers, among others, are as follows:

- ✓ I understand that preparing a tooth for a veneer involves removing a minimal thickness of enamel from the surface of the tooth involved. This preparation may irritate the nerve tissue (pulp) in the centre of the tooth, leaving it sensitive to heat, cold or pressure, which usually disappears within a few days due to the minimal preparation.
- ✓ I understand that keeping my mouth open during treatment may cause my jaw to feel temporarily tense and sore and it may be difficult for me to open my mouth wide for a few days.

  This may occasionally be an indication of an additional problem. I should inform the dentist if I have this or any other concern or question.
- ✓ I understand that, although unlikely, veneers can come loose and fall out. To minimise the risk of this happening, I must not bite my nails, pens, ice or other hard objects and I must not put pressure on my teeth. Grinding my teeth can also cause the veneer to become dislodged or fractured.
- ✓ I understand that the veneer will be close to my gum line, which is an area prone to irritation. Infection and/or deterioration. Proper brushing, flossing, a healthy diet and professional dental cleaning are some of the essential preventative measures to help control these problems.
- ✓ I understand that I may be given a local anaesthetic and/or other medication. In rare cases the patient may have a reaction to the anaesthesia.

The Patient _____

who is _____ years old, resides in _____,

And with ID number _____ .

I declare

that Dr Álvaro Ferrando Cascales, professional identification number 880, has explained to me that he is going to subject me to an aesthetic-prosthetic treatment that aims to improve my chewing function and dental aesthetics, which he will perform by means of _____.

The doctor and his team have informed me of all the possible treatment alternatives and their

Figure 13. Porcelain veneer consent sample; risks. Made by Ferrando A and courtesy of Peláez J.

LEGAL ASPECTS INFORMED CONSENT FOR ZOOM!® TEETH WHITENING

Tooth sensitivity/pain – During the first 24 hours after Zoom! treatment, some patients may experience some tooth sensitivity or pain. This is normal and is usually mild, but it can be more intense in susceptible individuals.

I understand that Zoom! treatments are not intended to whiten artificial teeth, caps, crowns, bridges, veneers or porcelain, composite or other restorative materials, and that people with dark yellow or yellow-brown teeth often achieve better results than people with grey or blue-grey teeth. I understand that teeth with multiple discolourations, bands, spots or discolourations due to tetracycline or fluorosis may not whiten equally well, they may require several treatments or may not even whiten at all. I understand that teeth with many fillings or cavities may not whiten and would be better treated with non-whitening alternatives. I understand that temporary or provisional restorations made of acrylic may discolour after exposure to Zoom treatment!

I understand that the results of my Zoom treatment can NOT be guaranteed!

Regression – The teeth will naturally darken a little after the Zoom! treatment. This is normal and usually very mild but may be accelerated if the teeth are exposed to different colouring agents. Treatment is usually done with wearable splints or by repeating the Zoom! treatment. I understand that the results of Zoom! treatment are not permanent, and that after a period of time a retreatment or at-home treatment with splints will be necessary to maintain the colour I desire for my teeth.

Figure 14. Sample consent form for in-office whitening. Prepared by Zoom.



Figure 15. Liability insurance Cover page. Drafted by AMA (insurance company) for Ferrando A.

1.1. Risks Coverage

The insurance coverage includes the Professional Civil Liability of the Insured against third parties, stemming from damages caused in the exercise of their profession, as governed by the regulations in force, and especially for damages arising from:

* Errors, excesses or deviations in treatment.

* Errors in the performance of surgical interventions.

* For the acts of personnel in the service of the Insured, for damages caused by them in the performance of their assigned duties, when the claim is directed against the Insured. Similarly covered is any liability directly demanded of non-qualified personnel.

* Civil Liability of the Insured Party arising from claims for professional acts of non-qualified assistants.

* Errors in the information given to patients or third parties regarding the complications or consequences of a specific treatment or illness.

* Application or delivery of pharmaceutical products approved by the competent bodies or recognised by medical science, if their approval is not required.

* Liability of the Insured derived from claims and/or damages originating from the extraction, transfusion and/or conservation of blood or blood plasma or which are a consequence of the acquisition, transmission or contagion of Acquired Immune Deficiency Syndrome (AIDS).

* First aid in the event of an accident or illness.

* Use of equipment and installations recognised by medical science as well as their use for exploratory purposes.

* In the case of claims arising from the preparation of expert reports, third party damages are covered, even if there has been no personal loss.

* Claims made against the Insured in the course of their teaching activity, performed in Faculties, Schools and Centres officially recognised for this purpose. This also applies to work experience outsourced from officially recognised centres carried out in the Clinics of the Insured.

* The refund of the acquisition cost, which can be documented, of medical products that are individually identifiable and non-recoverable is covered, **provided that said refund has been declared in favour of the Injured party in court, as an integral part of the compensation for the damages covered by the policy**.

* Claims derived from purely aesthetic damages due to not having achieved the intended purpose in dental interventions are covered, as well as for aesthetic treatments carried out on the lower third of the face with resorbable materials, which do not imply the need to make cuts or sutures in the skin and which are authorised by the Spanish Medication Agency for dental use (lip microfillers), **as long as the professional has not expressly undertaken to obtain a specific result**.

* The reimbursement of the professional fees of the insured dentist is covered, **up to a limit of 3,000 Euros per claim**.

Figure 16. Risk coverage, including aesthetic treatments. Drafted by AMA (insurance company) for Ferrando A.

Update on the use of botulinum toxin by dentists

On 8 February 2023, the Spanish General Councils of Dentists and Doctors signed an agreement to promote matters of interest to both groups. By virtue of this agreement, and in view of the increasing number of intrusive practices in the field of aesthetic treatments (particularly facial treatments), the Councils of Dentists and Doctors signed a declaration on the matter.

This states that **doctors and dentists are the only professionals with the competence and authority** to carry out certain aesthetic or therapeutic treatments using microfillers (hyaluronic acid) or botulinum toxin within their respective fields of activity.

At present, in the case of dentists, botulinum toxin drugs can only be used, as a general rule, **for the treatment of chronic hypersalivation in adults and children**. This is due to the fact that, at present, **there are no botulinum toxin medicinal products with indications in their data sheet within the field of action of the dentist**, except for the indicated case. Therefore, for other therapeutic or aesthetic indications of botulinum toxin, **the only professional with the capacity to use it is a doctor**.

Nowadays, new therapeutic applications of botulinum toxin are being explored for temporomandibular joint disorders, bruxism and grinding, orofacial pain or gummy smiles. The usefulness of this substance for treating these clinical cases has been proven and **in some countries such as the United States, its use by health professionals is permitted**. In Spain, however, **there is currently no medication with botulinum toxin authorised for these cases**.

On the other hand, **hyaluronic acid can be applied by dentists within its field of action**, such as the lips or cheeks, as anatomical parts of the mouth, which respectively constitute its anterior and lateral walls. However, for all possible uses beyond what is commonly referred to as the 'lower third of the face', **only medical practitioners have the capacity and authority to use hyaluronic acid medications**.

The Spanish General Council of Dentists would like to remind patients interested in these treatments that they **should verify the qualifications of the professional who is going to apply these medications**, to ensure that they are in the hands of professionals who have the appropriate competences and legal powers for this purpose.

Figure 17. Update on the use of botulinum toxin by dentists. From htttp://consejodentistas.es/dentistas-y-medicos-son-los-unicos-profesionales-con-atribuciones-para-realizar-tratamientos-con-microfillers-y-toxinas-botulinica/.

LEGAL ASPECTS INFORMED CONSENT FOR AESTHETIC DENTISTRY

3,5 – Sensibility

Postoperative sensitivity may possibly follow restorative procedures, periodontal surgery or whitening treatments. This is a temporary sensitivity that should be immediately reported to the practitioner so that appropriate measures can be taken to reduce or completely eliminate it. Should the sensitivity persist irreversibly, a careful evaluation should be made for a possible indication for endodontic treatment - point 2.8.

3.6-Repairs - Warranty

Composite resin procedures, especially in anterior restorations, are subject to fractures, cracks or chips, due to chewing or harmful habits such as tooth clenching or bruxism. These require only 30 minutes for an emergency consultation by a professional dentist, who will then assess the need for another change. These repairs are mainly done with composite resins and have a lower cost than the original restoration if they take place within the first year of completion.

Fractures, or cracks, can rarely occur in porcelain restorations, as it is a harder material compared to composite, but no restorative material has all the functional and mechanical characteristics found in natural teeth. Porcelain repairs are often not possible in the clinic, and the piece must be remade in the laboratory. The warranty covers 100% during two years (the patient should request the warranty when the treatment is fully paid for and the definitive prosthesis is delivered), and only the cost of the laboratory values will be charged, without the fees of the professional dentist between the 2nd-5th year from the delivery of the prosthesis. Between 5-10 years each individual situation would need to be reassessed.

Figure 18. Sensitivity and warranty sections of the informed consent for aesthetic dentistry. Made by Ferrando A and courtesy of Adolfi D.

UCAM

Chapter 2



Facial Aesthetics

Guest author: Dr. Raúl Ferrando Cascales

Photo by Dr. Fernando Rey Duro

2.1. Introduction:

Dentists are used to working in a very small field where 1 millimetre is of vital importance. They are able to distinguish the smallest detail, however small it may be. This so-called obsession, or all the importance given to small details, prevents them from seeing the balance or harmony of the whole clearly.

Beauty is the sum of aesthetics and harmony. As already mentioned, the word ‘aesthetics’ comes from the Greek word ‘aesthesia’, which refers to that which is perceived through sensations, that is, a set of perceptions generated by the contemplation of an object and the gratifying reaction it produces in the observer. The word ‘harmony’ comes from ‘harmonia’ which is the convenient proportion and correspondence of some things with others.

Facial proportions and, consequently, dental proportions must match in order to achieve a natural, harmonious and beautiful appearance. Facial analysis is fundamental in the diagnosis and treatment planning of patients.

There are universal aesthetic qualities that are valued depending on time, culture and race, but the subjective factors of the patient and his or her environment must not be forgotten, nor the objective factor of the professional.

The cult of image explains the growing demand for aesthetic consultations, and dentists are therefore faced with the need to achieve aesthetic harmony based on dento-skeletal alterations, for which knowledge, experience and artistic skills are necessary.

Patients who have a mental disorder due to a distorted self-image (body dysmorphic disorder) should be treated by an interdisciplinary team.

2.2. Facial visual examination

Before considering drawing plans and measuring, a visual impression of the face of the patient must be taken. You must assess the impression that a face makes on you. Is it long or short? Is it asymmetrical? Prognathic or retrognathic?

On the other hand, you have to assess the functionalism and symmetry of the expressions of the patient. The patient may make a certain gesture to cover up a defect or may discover a defect when speaking that is not seen at rest.

In facial analysis, you must keep in mind five factors that influence the interpretation and success of the results achieved in a treatment. While there are many elements that can affect this, the following are worth considering: age, race, sex, body habits and the personality of the individual.

Age

Ageing is a natural process that causes inevitable and irreversible changes in an organism with the passing of time.

In humans, these changes include: a reduction in tissue flexibility, loss of fat in the subcutaneous tissue, loss of collagen, etc., so that the skin begins to sag, resulting in creases and wrinkles that lead to a shift in facial proportions in favour of the upper sections with baldness and receding hairline, drooping of the nasal tip, loss of teeth and subcutaneous lipodystrophy, which accentuate the facial skeleton.

Generally, signs of facial ageing appear from the age of 30 onwards, prompting most patients to seek treatment.

Race

Race is how human beings are classified according to their physical and genetic characteristics and is mainly identified by skin colour, but appearance and facial features are very important when analysing facial proportions.

Sex

There are differences in facial appearance between men and women. The nose is an example of these different proportions, as will be discussed in more detail below.

Men have a more prominent supraorbital arch, smaller eyes and larger cephalic size than women.

Female faces tend to be rounder, with curved lines, while males have stronger, more angular complexions.

Body conditions

There is a correspondence between facial appearance and body habits, brevilineal individuals tend to have broad, round faces with small, broad noses, while longuineal individuals tend to have long, thin faces with large, narrow noses.

Personality

The facial expression gives you a good impression of the individual, you can judge the personality through the facial signs. Communication is not only through oral language, but also through mimicry: humans can express feelings, desires, tendencies, express joy, sorrow, anger, disgust, surprise or fear.

2.3. Facial analysis

For a correct assessment and an individualised diagnosis, it is necessary to perform quality complementary tests.

These are essential:

1. Orthopantomography.
2. Lateral teleradiography.
3. CBCT.
4. Extraoral photographs.
5. Intraoral photographs.
6. Study models or intraoral scans.
7. Extra: periapical X-rays, extraoral and intraoral videos.

Definition of some key points in facial analysis [10]:

- **The horizontal Frankfort plane** is a line drawn from the upper side of the external auditory canal to the lowest point of the suborbital rim while the patient's eyes are parallel to the ground.
- **The Trichion (Tr)** is the point in the medio-agittal plane where the hairline begins.
- **The Glabella (Gl´)** is the most prominent area of the forehead in the medio-agittal plane.
- **The Nasion (N)** marks the deep depression where the skin of the forehead meets the root of the nose.
- **The Subnasal Point (Sn)** is where the columella (base) ends, and the upper lip begins.
- **The Stomion Point (St)** is where the upper lip ends, and the lower lip begins.
- **The Mentolabial Sulcus (Si)** is the most posterior area between the lower lip and the chin.
- **The Pogonion (Pg)** is the most prominent point of the soft tissue of the chin.
- **The Mentum (Me´)** is the lowest point of the soft tissue of the chin.

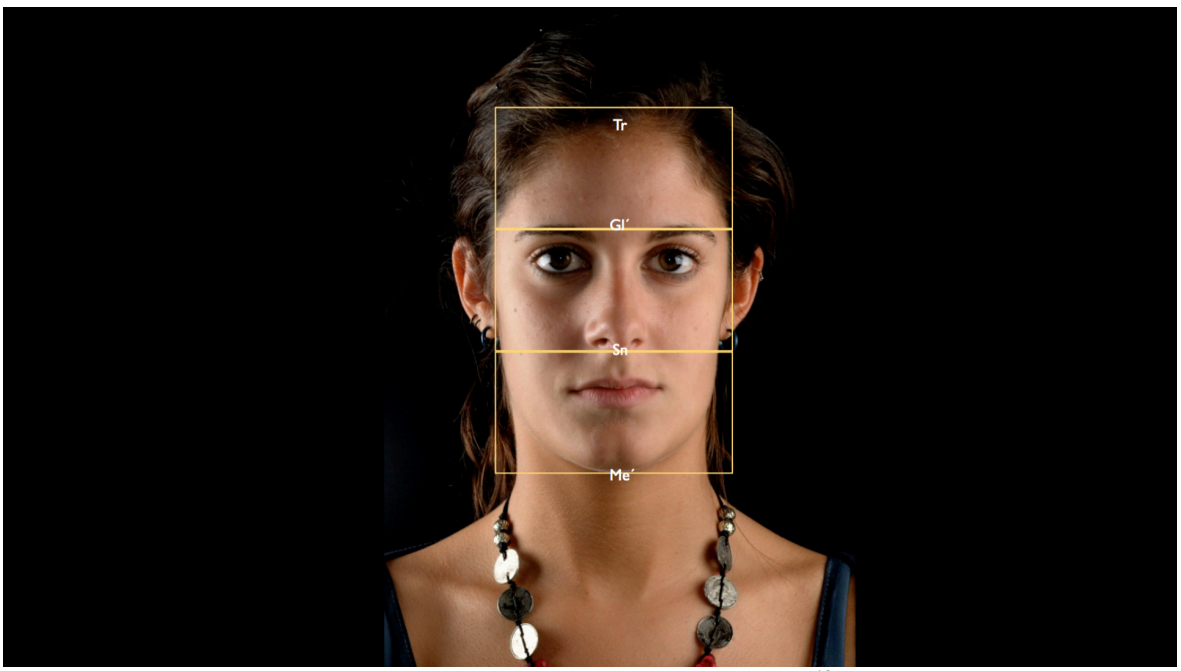


Figure 19. Equal division of the face in thirds. Courtesy of Martins E.[10]

Facial height is divided into three equal parts: the first third goes from the trichion (Tr) to the glabella (Gl‘, the apostrophe here indicates that it is measured in soft tissue), the middle third from the Gl’ to the subnasal point (Sn’) and from this point to the chin (Me'), corresponds to the lower third of the face.

Given the variation in forehead height with the secondary changes that come with age, such as alopecia that raises the hairline, many dentists often exclude the upper third of the face and take the measurements from the N' (abbreviated as Na' in Fig. 20) to the (Sn’) point representing nasal height (43%), and from the Sn’ to the chin (Me’) representing the lower half of the face (57%).

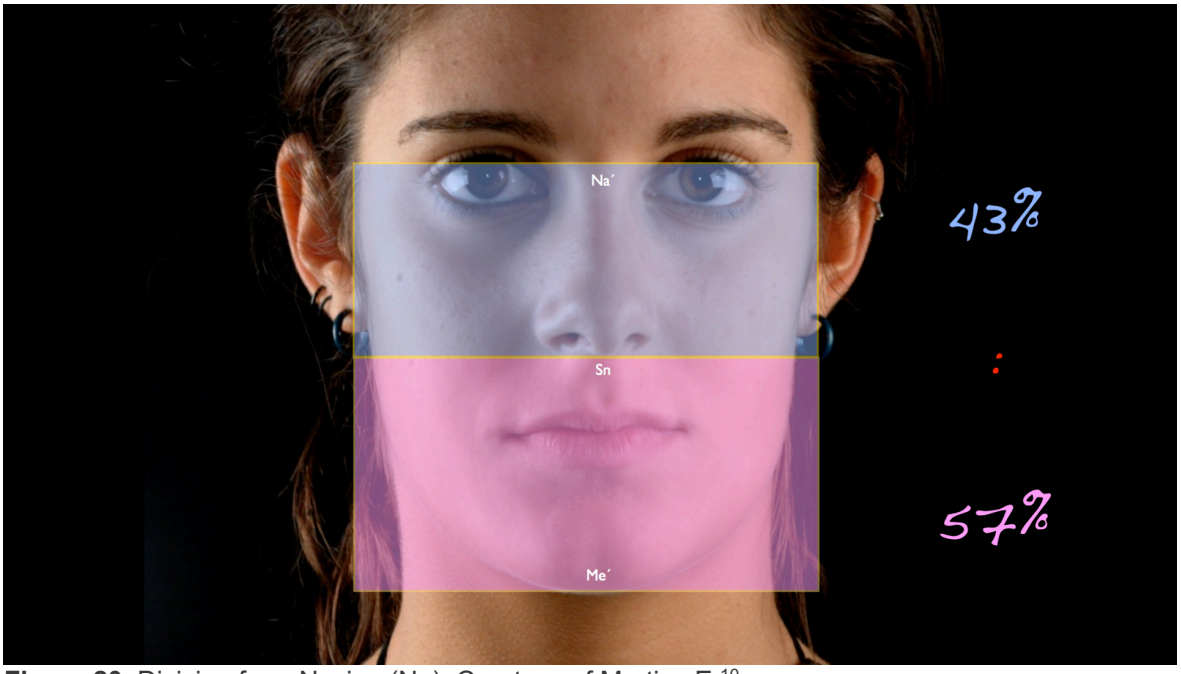


Figure 20. Division from Nasion (Na). Courtesy of Martins E.[10]

In most people there is no perfect degree of facial symmetry. People have variations in facial features on the two sides of the face that do not allow for perfect symmetry.

The forehead:

The forehead is the upper third of the face, from the eyebrows to the hairline. From the side, it produces a slight convexity, although it may vary and be flat, protruding, etc.

The eyebrows:

These form a hair-covered curvilinear arch over the socket of both eyes, which is slightly above the supraorbital rim in women and is on it in men. If you draw a line ascending from the facial-alar sulcus to the medial canthus of the eye and arriving perpendicularly to a line running parallel to the palpebral sulcus, you have the beginning of the eyebrows, and they end in a line drawn from the facial-alar sulcus to the lateral canthus of the eye. The beginning and the end of the eyebrows should be in a horizontal plane. The highest point of the arch of the eyebrows is on the line drawn tangentially to the lateral limbus.

The eyes:

Eyes are smaller in men than in women. The width of the eyes is equal to one fifth of the face, so the distance between the two eyes is equal to their width, if this distance is greater, there is a telecanthus. The lateral canthus of the eyes is slightly higher than the middle canthus. The crease of the upper eyelid is 7 to 15 mm from the lash line. In a neutral gaze the upper eyelid covers an area of the iris without reaching the pupil and the lower eyelid is 1 to 2mm from the iris.

The nose:

The nose constitutes a facial aesthetic unit which is further divided into subunits.

- Nasal subunits:
  - Nasal dorsum, lateral walls, alar lobules, nasal tip, soft triangles and columella.

Based on Powell's studies, the main aesthetic masses of the face can be analysed in a simple way using lines and angles interrelated to each other. These studies formulated relationships between the nose and the face.

The Nasofacial relationship includes four angles:

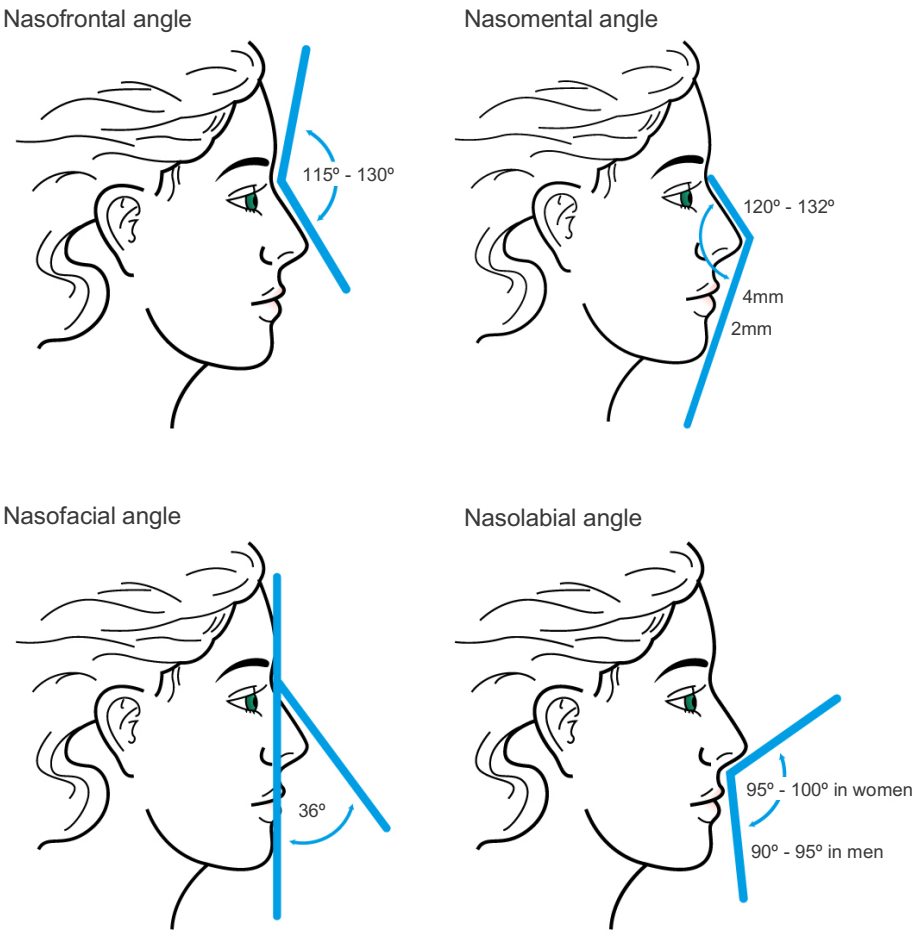


Figure 21. Powell angles to study the aesthetic masses of the face relating the nose to the face. Made by Ruiz Gaitán F.[11]

1) Nasofrontal angle: the transition from the nose to the forehead. The angle is formed by the tangent line to the glabella through the nasion which intersects with a tangent line from the nasion to the nasal dorsum. This angle fluctuates in value between 115º and 130º, and is conditioned by the prominence of the glabella, which changes from one individual to another, so many authors consider it to be perhaps the least important angle.

2) Nasolabial angle: this is formed by the intersection of a line tangent to the upper lip at the subnasal point (Sn) and from this (Sn) a tangent to the most anterior point of the columella. This angle measures 95º to 100º in women and 90º to 95º in men.

3) Nasofacial angle: this is the inclination of the nasal dorsum in relation to the facial plane. First, find the Facial Plane, which is determined by a line that joins the glabella with the pogonion. Then draw the tangent to the nasal dorsum, which is found by drawing a line that starts at the tip of the dorsum of the nose and goes to the nasion. With this angle you evaluate the balance of the nasal projection with the profile of the patient. The nasofacial angle ranges from 30º to 40º. For women, values close to 30º are considered aesthetically more acceptable, and vice versa.

4) Nasomental angle: this describes the angle between the tangent line from the N' to the nasal tip and the intersection of the line from the tip to the Po'. This angle is considered the most important of the Powell aesthetic triangle. This angle ranges from 120° to 132° and relates two masses: the nose and the chin.

   There are multiple nose shapes and different classifications according to their type, but three main groups can be considered on the basis of ethnic parameters:

   - Leptorrhine (Caucasian nose.A), Mesorrhine (Asian nose.B) and Platyrrhine (African nose.C). The width of the nose is approximately the width of one eye.

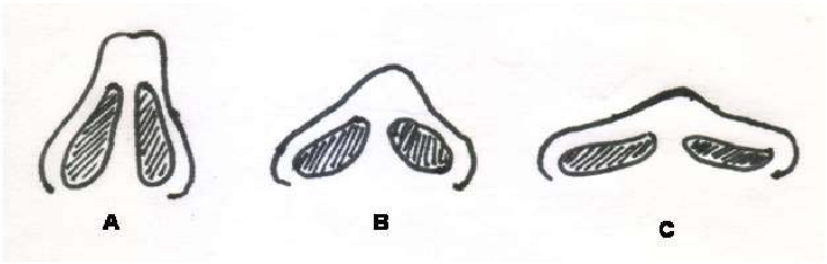


Figure 22. Classification of nose shape into three main groups. Taken from Estébanez Gastón B.[12]

The lips

The ideal lower third is further divided into thirds. The upper lip occupies the first third and the lower lip and chin the other two.

The length of the upper lip and its thickness need to be analysed. The length is measured from the subnasal line to the St of the upper lip. Arnett establishes a range between 19-22mm. Older individuals and males are at the higher end of the range. With the lips relaxed and teeth in contact there is usually a gap (interlabial cleft) of between 1-5mm measured between the lower point of the upper lip and the upper

point of the lower lip. Females show a larger gap within the normal range. The smaller cleft in males is related to longer lips.

The other two thirds are measured from the St of the lower lip to the chin. This distance should be 51±3mm in males and 48±3mm in females (A). Arnett reduces this range to 42-48mm. This measurement increases with age due to fat accumulation in the chin.

Arnett also establishes values for the length of the vermilion. The upper range is 6-9mm and the lower 8-12mm.

If the lower third is increased, then the cause should be determined. This may be due to an excessively long chin or excessive vertical growth of the maxilla causing mandibular protraction, which results in an enlarged lower third.

The position and shape of the lips is determined by: a true vertical line through Sn, where the lips should be: Upper lip between 2 and 4mm forward, lower lip at 0 and chin between 0 and -4mm.

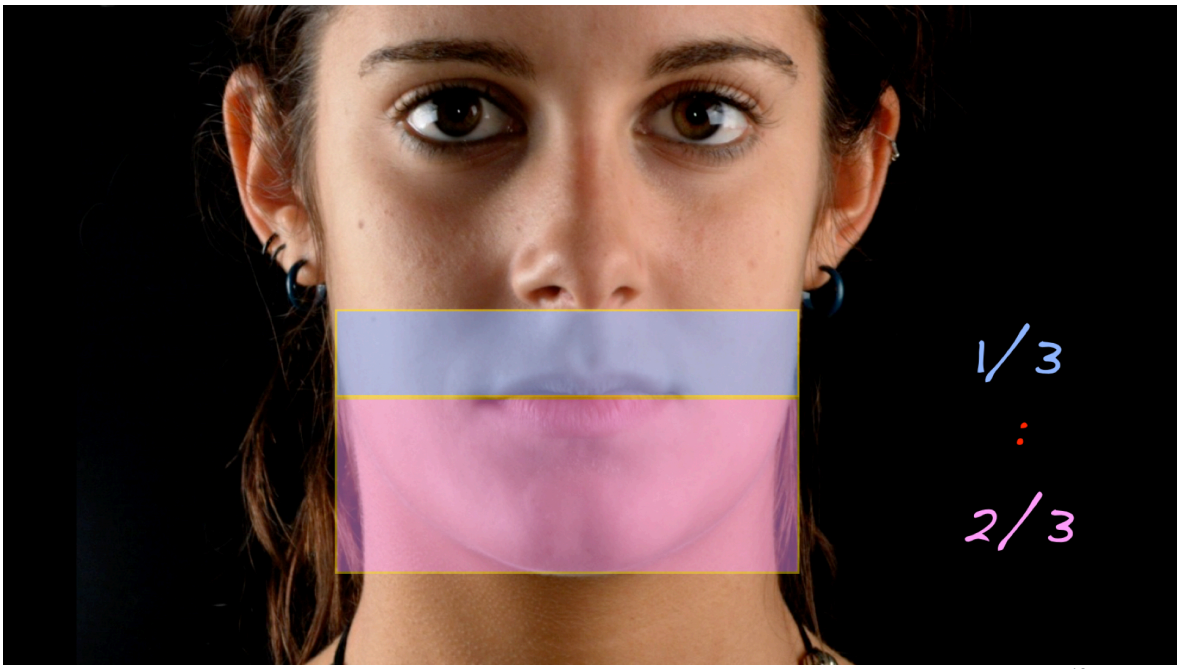


Figure 23. Determination of upper lip (Sn-St) and lower lip (St-Me). Courtesy of Martíns E.[10]

The chin

The ideal position of the chin is in a line from the nasion lying perpendicular to the horizontal Frankfort plane. In women the chin should be posterior to this line.

2.3.1.Frontal vision:

When analysing patients from a frontal view, draw horizontal and vertical lines to serve as a reference for a correct and protocolised diagnosis, for all patients. From this same frontal view, you can easily measure the facial thirds [9].

Horizontal reference lines:

Interpupillary line and commissural line. Draw a line joining the pupils and another line joining the commissures. These lines, when parallel to the horizon, represent the ideal reference plane. The occlusal plane and the gingival contour should be parallel to the interpupillary and commissural line to create a pleasing harmony.

Vertical reference line:

The line perpendicular to the horizontal reference lines that divides the face into two halves passing through the glabella (Gl') and the subnasal point (Sn) is called the **midline**.

The intersection of the midline with the horizontal planes creates a framework for detecting facial asymmetry.

To be noticeable to the observer, an asymmetry must be more than 3%. However, this does not mean that it is perceived negatively.

Horizontal bipupillary or commissural lines may be slightly offset from the rest of the horizontal references without compromising a pleasing effect of the facial features as a whole. Alignment is always preferable, but small differences or small irregularities can even provide a pleasing natural appearance.

***Horizontal disharmony:**

Sometimes the interpupillary line, commissural line and horizon are not parallel at all. In such a case, the horizon will be taken as the ideal reference without taking into account the commissures or the pupils, and it will be up to the dentist to decide where to correctly position the occlusal plane and the midline [9].

***Vertical disharmony:**

As previously mentioned, the glabella, the subnasal point and the chin are reference points for locating the midline in the lower half of the face of the patient, but sometimes these points do not provide a reliable reference as they often differ from the main axis of the face. For these cases, the centre of the upper lip can be used as an ideal reference to position the facial midline of the patient [9].

From a prosthetic point of view, a small asymmetry in the midline position of the patient would not be of vital importance; however, a dissonance in the verticality of the interincisal midline would be decisive in obtaining pleasing and harmonious results.

Face proportions:

An ideal, harmonious face is divided into the three facial thirds already mentioned:

- Upper third: from Tr' to Gl'.
- Middle third: from Gl' to Sn'.
- Lower third: from Sn' to Me'.

These three thirds must be of equal size for facial harmony. The focus will be on the lower third, which could be larger or smaller than the rest of the thirds. Understanding the harmony of the facial thirds of the patient helps you make a diagnosis and an appropriate treatment plan to minimise errors and achieve better results.

2.3.2.Lateral vision:

From a lateral view you can see the side profile of the patient. There are three types of profile. The profile is assessed by following 3 of the 4 points used to measure the facial thirds: glabella, subnasal and mentum or chin.

1. **Straight profile**: when the lines joining these three points form an angle of 170º.
2. **Convex profile**: when the lines form an angle of less than 170º. This usually occurs when the jaw or chin is receding.
3. **Concave profile**: when the lines form an angle greater than 180°. This is found in patients with a protruding jaw or a more anterior position of the chin.

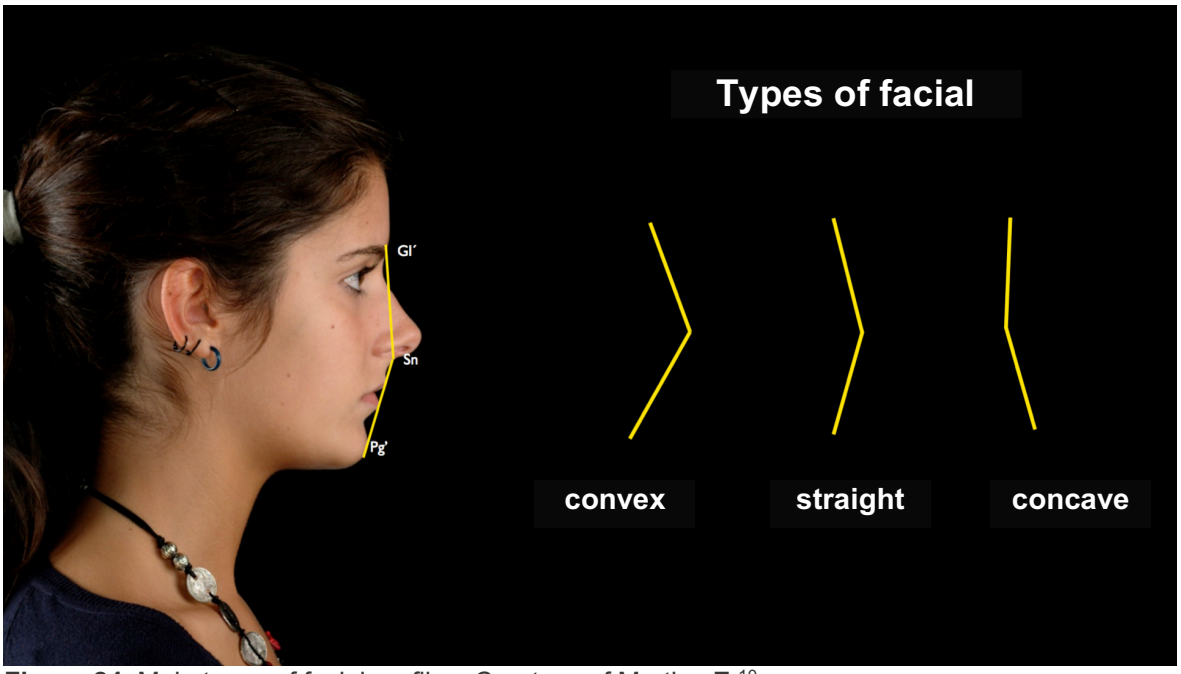


Figure 24. Main types of facial profiles. Courtesy of Martins E.[10]

In the same perspective, it is possible to analyse the **nasolabial angle**, which is the angle formed by the intersection of two lines in the subnasal area. These lines start from the subnasal point. One is tangent to the base of the nose and the other to the outer edge of the upper lip. Their normal values are 90-95º for men and up to 100º is acceptable in women.

The shape of the lips can also be appreciated correctly from this side view. The lips are classified according to their shape and size as thin, medium or thick. The height of the upper lip is usually half the height of the lower lip. The upper lip can also be

measured in relation to the lower third of the face; in this case the upper lip measures 1/3 of the lower third of the face and the remaining 2/3 corresponds to the lower lip.

The shape and size of the lips is at times related to psychological traits. Thick lips are associated with extroverted, subjective and sometimes materialistic personalities, while thin lips indicate introversion, objectivity and self-control.

2.4. Core questions:

When diagnosing and making a treatment plan for a patient, there are often hesitations if you cannot identify what aesthetic problem the patient has.

Making the right decision about the vertical dimension of the patient, coronal lengthening or not - why does the patient have a gummy smile? It is not easy to determine which decision will be the right one or which is the best treatment plan for the patient.

In many cases, it is important not only to develop an appropriate treatment plan, but to be aware of the limitations of the treatment and to be able to explain to the patients their situation, possible solutions as well as to lower the expectations of the patients in order to adjust them to a more realistic and predictable situation.

In their book 'Global Diagnosis', Dr. J. William Robbins and Dr. Jeffrey S. Rouse[13] simplify the identification process of the aesthetic problem of the patients and its possible solutions in 6 key questions or points.

They call these 6 key points core questions:

1. Face height

The face is commonly divided into 3 facial thirds and these 3 thirds are of equal size. The first point to evaluate is whether the lower third is the same size as the rest of the facial thirds.

The lower third may be smaller than the rest of the facial thirds. This may be due to the loss of teeth or prolonged dental wear over time. In these cases of loss of vertical dimension, dentists can increase or restore this vertical dimension by means of prosthetic rehabilitation, restoring the worn teeth or replacing the missing teeth.

In another situation with regard to facial height, the lower third is larger or longer than the rest of the facial thirds. The ideal treatment for this case would

be orthognathic surgery, and dentists can help with orthodontics in coordination with a maxillofacial surgeon.

2. Upper lip length

The second core question is the length of the upper lip which can lead to 3 situations:

a. The lip is of normal size and the exposure of the central incisor when resting is adequate.

b. The lip is narrow, and the central incisor is too prominent when resting, then the gums are too exposed when smiling, causing a gummy smile. Solution: hyaluronic acid or Botox so that when smiling the gums do not show so much. However, this will greatly limit the mobility of the lip.

c. The upper lip is too large and covers the lower incisors when resting and the teeth are barely visible when smiling. Solution: cosmetic surgery to reduce the size of the lip.

The average length of the upper lip size in men is 22-24 mm and 20-22 mm in women.

3. Upper lip mobility

The cause of a gummy smile is difficult to diagnose. Sometimes patients are diagnosed with photos or in a static way and not dynamically with gestures and lips in movement.

That is why it is so important to include videos in your protocol of complementary tests for a correct diagnosis.

To measure upper lip mobility first measure the upper lip at rest and then measure the upper lip at maximum smile. By subtracting the measurement of the upper lip at rest and the upper lip at maximum smile, you can determine the upper lip mobility. The average mobility is 6-8mm.

In patients with less mobility, you cannot perform any treatment, but in patients who have a lot of mobility, Botox works very well as you manage to reduce the movement and, therefore, the patient camouflages their gingival smile and goes on to present a normal gingival exposure.

4. Straight gingival line

An irregular or deviated gingival architecture can also become an aesthetic problem. To assess this situation, simply draw a line along the gingival margins of the upper incisors and interpret it.

In case of irregularity there are two options to level the gingival architecture: coronal lengthening, gingivectomies (subtractive) or connective grafts (additive).

5. Length of the maxillary central incisor

The clinical crown exposure of a central incisor measures on average 10mm. When analysing the central incisors, if this measurement is lower, it may be due to wear, microdontia or altered passive eruption.

In such cases the vertical dimension can be increased but first consider the exposure of the central incisors when resting, as when the size of the incisors is increased, the exposure when resting and/or smiling may not be adequate. Another option is coronal lengthening or orthodontic treatment.

6. Probing CEJ

Finally, in order to correctly diagnose altered passive eruption, you must probe very well for the cementoenamel junction (CEJ). If you are able to detect the CEJ, the patient does not have altered passive eruption, except in type 1a and 2a cases. However, if you are unable to feel the CEJ, the patient may have an altered passive eruption, and a coronary lengthening would be indicated.

CBCTs can also help to measure and correctly diagnose altered passive eruption.

To speed up and protocolise the diagnosis, this table summarising the 6 fundamental values is of great help and can be easily incorporated into the routine.

Table 2. Core questions.

	Core Questions	Case values	Irregular
Face height?	1:1		
Lip length?	20-22 mm female 22-24 mm male		
Lip mobility?	6-8 mm		
Gingival line?	Level with horizon		
Tooth length?	10mm		
Feel CEJ?	Yes		
Notes:			

Note. Questions and clinical parameters to be noted and analysed in the clinical history of each case in order to carry out an adequate aesthetic assessment. Made by García E.[13]

Facial Analysis

The frontal and lateral examination of the patient, including the analysis of the position of the eyes, nose, chin and lips, enables the identification of the **reference points and lines** that are essential for aesthetic rehabilitation.

Esthetic Rehabilitation in Fixed Prosthodontics - Esthetic Analysis - Vol. 1. - Fradeani

Figure 25. Facial analysis summary. Made by Ferrando A.[9]

Facial Analysis

Objectives

- Restore proper **PARALLELISM** between the occlusal plane and the horizontal reference lines.
- **ALIGN LMD (dental midline) WITH LMF (facial midline).**
- Restore the **IDEAL HEIGHT** of the lower third of the face.
- Reconstruct an appropriate predominance/**DOMINANCE** of the front teeth in harmony with the patient's profile and lips.

Figure 26. Main objectives of facial analysis. Made by Ferrando A.[9]

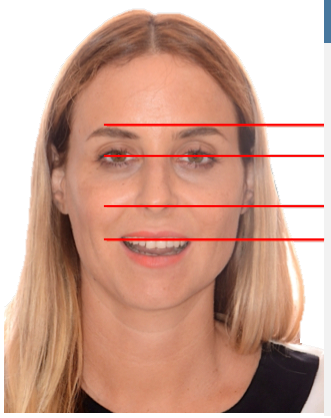
Facial Analysis – Frontal Vision

Reference Lines

The **interpupillary** line is determined by the straight line passing through the centre of the eyes and represents, if parallel to the horizontal plane, the most suitable reference for a correct facial analysis. IF ONE EYE IS HIGHER THAN THE OTHER, TAKE THE AVERAGE. PNC predominates (head natural position)



Figure 27. Reference lines. Bipupillary line. Made by Ferrando A and courtesy of Coachman C[9].



Facial Analysis – Frontal Vision

Reference Lines

Horizontal lines:

- Ophriac (through the eyebrows)
- Intercomissural (through the corners of the mouth)
- Interalar (along the base of the nose alar lobules)

These are the most commonly used references to align the incisal plane, the occlusal plane and the gingival contour.

Figure 28. Reference lines parallel to the bipupillary line. Made by Ferrando A and courtesy of Coachman C[9].

Facial Analysis – Frontal Vision

Reference Lines

The midline is drawn by tracing a hypothetical vertical line through the glabella, subnasal, and mentum points. This is generally perpendicular to the interpupillary line, creating a T-shape. The more centred and perpendicular these two lines are, the greater the feeling of total harmony on the face.

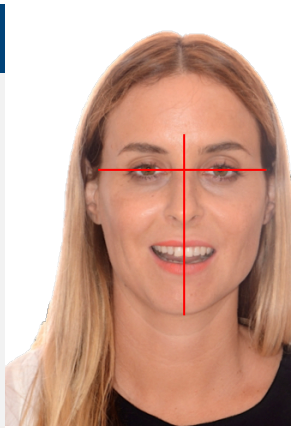


Figure 29. Intersection of midline and bipupillary reference lines. Made by Ferrando A and courtesy of Coachman C[9].

Facial Analysis – Frontal Vision

Reference Lines

In a harmonious face there are certain lines which together create a somewhat regular geometry.

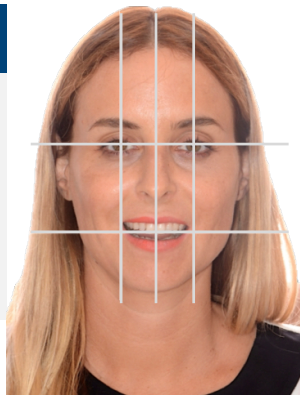


Figure 30. These reference lines determine a framework for assessing facial harmony. Made by Ferrando A and courtesy of Coachman C.[9]

Facial Analysis – Frontal Vision

Symmetry and Diversity

The intersection of the midline with the aforementioned horizontal planes creates a kind of ORGANISED FRAME by which the presence or absence of **symmetry** between the left and right side of the face can be identified.

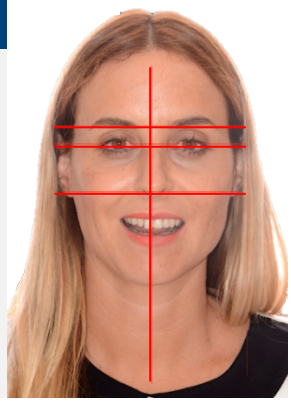


Figure 31. Lines of reference, determining an organised frame that allows the identification of symmetry/asymmetry. Made by Ferrando A and courtesy of Coachman C.[9]



Figure 32. A digital image duplicating half of the face (left and right), with the normal face in the centre. This digital trick shows that the vast majority of faces have a certain degree of asymmetry. Courtesy of Martins E.

Facial Analysis

Symmetry and Diversity

In most cases where asymmetry is found, the **dimensional difference** between the right and left side of the face is less than 3%, and this is therefore considered to be the limit beyond which a facial irregularity becomes evident to the eye of the observer.

Figure 33. First conclusion. Facial analysis. Symmetry and diversity. Made by Ferrando A and courtesy of Coachman C.[9]

Facial Analysis

Symmetry and Diversity

A general sense of alignment is, of course, desirable. However, the presence of **moderate differences or slight irregularities** does not compromise the final aesthetic result but may even provide a naturally pleasing appearance to the features as a whole.

Figure 34. Second conclusion. Facial analysis. Symmetry and diversity. Made by Ferrando A and courtesy of Coachman C.[9]



Figure 35. Example of a typical asymmetrical face, bipupillary line inclined to the left of the patient, as well as the chin, with one eye higher than the other. Made by Ferrando A.

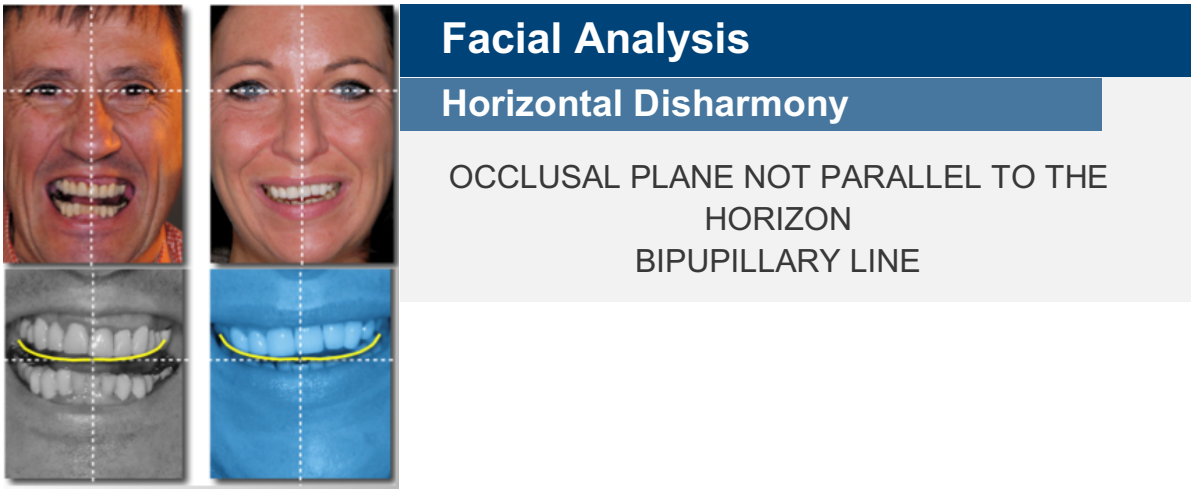


Figure 36. Facial analysis. Horizontal disharmony definition. Courtesy of Coachman C.[14]



Figure 37. Occlusal plane recording with Kois Dento-Facial Analyzer[15]. Made by Ferrando A.

Facial Analysis

Vertical Disharmony

From a prosthetic point of view, there is little importance attached to any possible asymmetry of the midline that may exist. Therefore, reconstructions can be integrated within the overall context of the face without taking into account this dissonance but giving priority to the **verticality of the interincisal and TRUE VERTICAL line unless it is very asymmetrical**.

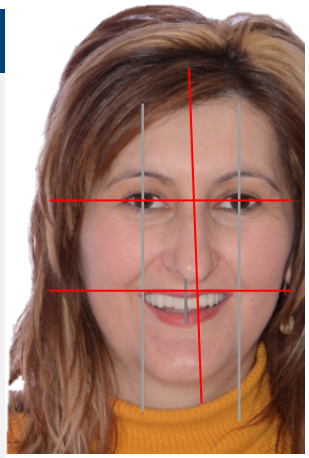
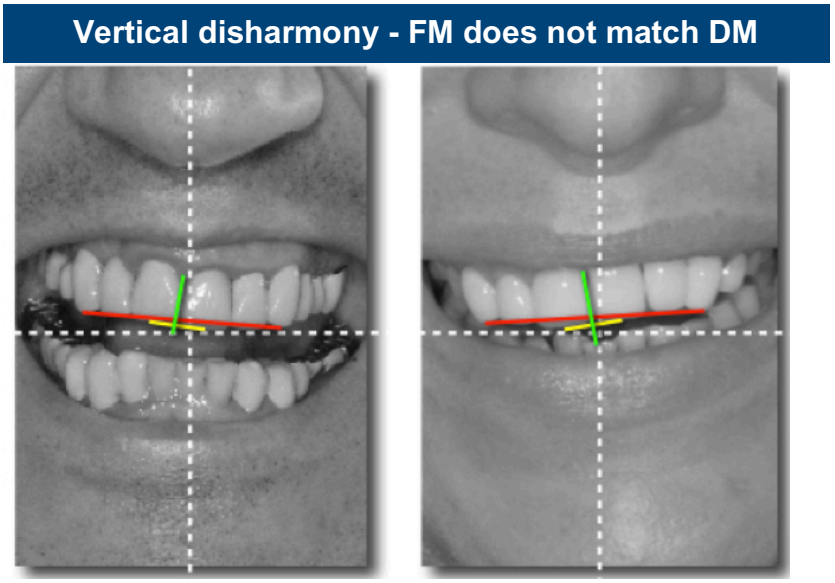


Figure 38. Facial analysis. Vertical disharmony introduction. Made by Ferrando A and courtesy of Coachman C.[9]



IN VERY DISHARMONIC FACES THE DENTAL MIDLINE SHOULD FOLLOW THE OSSEOUS ASYMMETRY WHERE THE JAW DEVIATES WHEN SMILING

Figure 39. Facial analysis. Main sign of vertical disharmony. Made by Ferrando A and courtesy of Coachman C.[9]

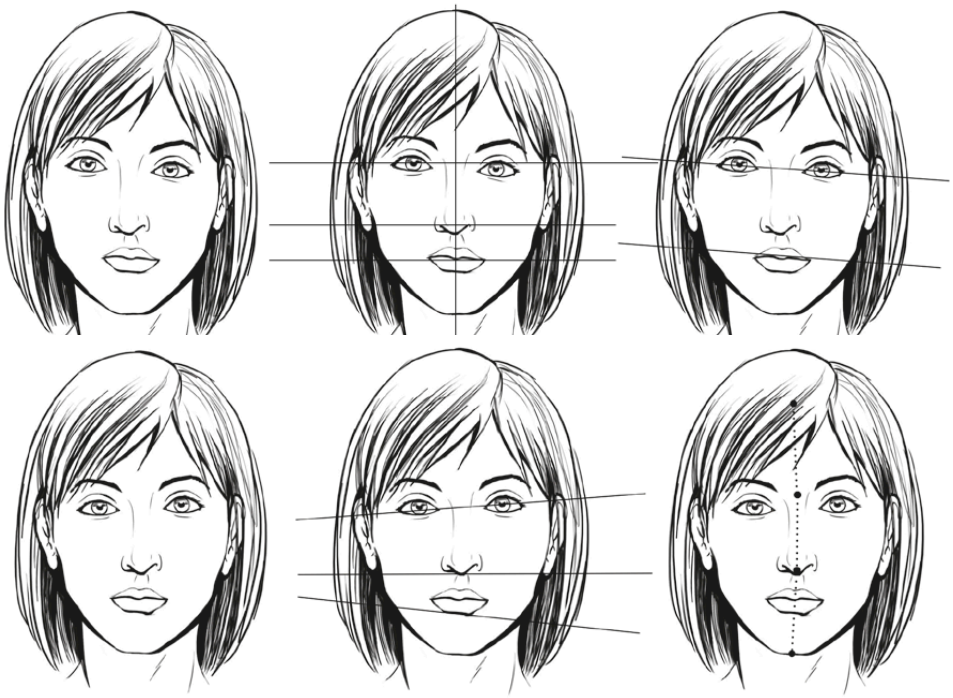


Figure 40. A composition of six faces. The top three represent NEGATIVE harmonic facial asymmetry and the bottom three POSITIVE harmonic facial asymmetry. Courtesy of García Adámez R et al. His attached articles on the midline are highly recommended.[17,18].

UCAM

Chapter 3



Smile Aesthetics

Anterior teeth. Dentolabial analysis

Photo by Dr. Fernando Rey Duro

3.1.Dentolabial analysis

Dentolabial analysis. The combination of the face and lips is a dynamic framework[19-22] that is constantly changing while speaking and smiling, resulting in different dental exposures. Accurate parameters need to be evaluated to achieve a complete dentolabial analysis and thus a correct aesthetic integration of the rehabilitation.

Dynamic dentolabial analysis. Made by Ferrando A.[22]



Figure 41. Dynamic dentolabial analysis. Made by Ferrando A.[22]

The **Natural Head Position (NHP)**[10,19] is a determining factor in the final and total evaluation of the face. This is essential in the dentolabial analysis to correctly evaluate the proportion between the teeth and the lips in the different phases of the smile and speech. It is essential to determine the NHP in the first interview (relaxed environment), the lips must always move in the horizontal plane, they must be parallel to the interpupillary line which usually represents the first facial reference

plane. However, it is not uncommon to find lip ptosis due to asymmetries and neurological problems, which affect the lip tone and will lead to the exclusion of this parameter[9].

Natural head position.
Dynamic facial and dentolabial analysis[22].



Figure 42. Natural head position. Dynamic facial and dentolabial analysis. Made by Ferrando A.[22]

- Important points to assess:
    1. **Exposure of the tooth when resting.**
    2. **Incisal edge. Incisal curve.**
    3. **Smile line.**
    4. **Smile width.**
    5. **Labial corridor.**
    6. **Interincisal midline versus facial midline.**

3.2. Exposure of the tooth when resting

It will be 1-5 mm depending on age; on average women expose more than men (3.40mm vs. 1.91), young people (under 30 years) more than older people (50-60), due to accumulated wear and tear and decreased peribuccal muscle tone, leading to greater exposure of the lower incisors[9,20].

3.3. Incisal edge. Incisal curve.

The identification of the position of the 3D incisal edge, both apical coronally (incisal curve) and anteroposteriorly (incisal profile) represents the starting point of the correct dentofacial aesthetic diagnosis and will condition all subsequent treatment by the restorative team.

In general, the incisal plane, when viewed from the front, forms a convex curve that follows a parallelism to the natural concavity of the lower lip while smiling. This is found in 85% of cases and is very evident in class I patients, it flattens out in class III and in class II cases there is a more abrupt incisal curve with a marked difference between the centrals and laterals due to the differences in apicocoronal height between them.

The convexity of the incisal curve is fundamental to radiate symmetry; adding ideal proportions will always result in a pleasant smile.

If there is a separation of the incisors from the lip, it will be a 'non-contact' curve, and if they are touching the lower lip, it will be a 'contact' curve. Both are pleasing.[9,20]

3.3.1.Incisal edge. Flat or inverted incisal curve

Abrasion of the incisal edges leads to flat incisal curvature generating an unpleasant effect. The incisal angles are lost and therefore the discrepancy between the curvature of the lower lip and the incisal plane increases, creating a **NEGATIVE SPACE**. At the same time, there is horizontal symmetry, and this causes a loss of cohesive strength in the dentofacial composition, generating an objective anti-aesthetic and ageing effect[9,19].

The flat or inverted incisal curve also causes a functional compromise, as the anterior guide disappears[9].

Highlights:

1. More frequent in people over 60 years of age.

2. The original incisal contour is lost.
3. The primary anatomy or macrotexture[23] is lost (angled lines and planes are softened).
4. Secondary and tertiary anatomy or microtexture[23] is lost (teeth are smoothed, with mamelons and perikyma/ta disappearing).

3.3.2.Incisal edge. Incisal profile.

Indicates the position of the incisal edge in the anterior-posterior direction and should generally be contained within the inner border of the lower lip. This allows proper closure of the lips without dental interference. Excessive alteration by progression of the incisal profile is more likely to occur in severely or terminally affected periodontal patients.[9,20]



Figure 43. Before/after comparison of the incisal profile in a periodontal patient. Note the orthodontic correction of the inclination This situation should never be approached solely from a restorative point of view if the biomimetic philosophy is followed. Made by Ferrando A.

3.4.Smile line. Frontal analysis

A pleasing or aesthetic smile is one that fully exposes the maxillary teeth and 1 to 3 mm of gingiva, beyond which it can be considered unsightly or unattractive. Smiles can be classified into three types:[20,22]

LOW:	MEDIUM:	HIGH:
Upper labial mobility exposes up to 75% of the anterior teeth.	Upper labial mobility exposes 75-100% of the anterior teeth, including the interproximal papillae.	Upper labial mobility exposes all anterior teeth, and a gingival band of variable height.

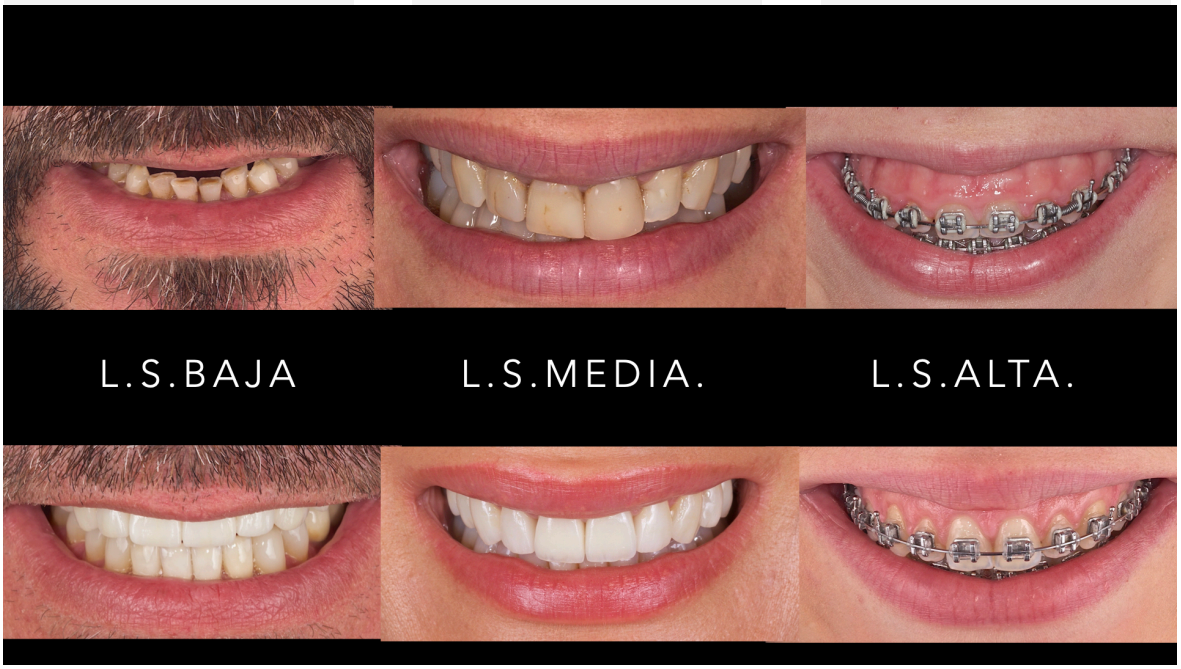


Figure 44. Examples of smiles before and after interdisciplinary treatment. For example, a large correction of the gingival smile (very high) of the orthodontic patient is observed, which becomes high. Made by Ferrando A.

3.5.Smile width: 4-4,6-6,7-7

This is a crucial parameter in aesthetic rehabilitation, as lip movement can expose up to premolars (80%) or even molars (20%), and if this is not taken into account it can lead to 'short smiles' when only considering the aesthetic range from canine to canine. When making 3-3 veneers, it is common to oversize the canine, 'covering' the premolars, giving the impression that the posterior sector is absent[20].

3.6.Labial corridor

The labial corridor is the BLACK space seen on either side of the mouth during smiling, between the buccal walls of the maxillary teeth and the corners of the mouth. This gap is always visible in harmonious smiles and is the culmination of the natural progression of the smile. This is the end in the perspective of the observer's eye, who sees a progressive decrease in the height of the clinical crowns and their reflection from the anterior to the posterior teeth, generating a sensation of depth. Eliminating or not considering this lip corridor in the design of aesthetic restorations is a common mistake and will generate 'flat' smiles due to an excess of teeth (insufficient lip corridor) or 'narrow' smiles due to a lack of teeth (very broad lip corridor).

3.7.Interincisal midline versus facial midline

If the best way to identify the facial midline is to look at the philtrum, in the case of the dental midline it would be the interincisive line of the upper central incisors. However, any mediolateral inclination is immediately perceived as an unsightly effect and invalidates it, so in these cases the papilla between the central incisors would be more reliable.

There is often a mismatch between the facial and dental midline in nature, and the greater the mismatch, the more asymmetry is perceived.

The study by Kokich V[24] in 1999 is very relevant, where he concludes that variations of up to 4mm between the facial midline and the dental midline were not detectable, when it comes to axial displacement, evaluating the general population - even general dentists or orthodontists also needed to reach 4mm to qualify the

displacement as less aesthetic. In contrast, mediolateral inclinations of 2mm were already noticeable by all groups.

Comparing the Perception of Dentists and Lay People to Altered Dental Esthetics

VINCENT O. KOKICH Jr DMD, MSD, H. ASUMAN KIYAK MA, PHD, PETER A. SHAPIRO DDS, MSD

First published: 01 July 2007 | https://doi.org/10.1111/j.1708-8240.1999.tb00414.x | Citations: 372

PDF TOOLS SHARE

Abstract

Abstract: *Purpose:* This study was designed to determine the perceptions of lay people and dental professionals with respect to minor variations in anterior tooth size and alignment and their relation to the surrounding soft tissues.

Materials and Methods: Smiling photographs were intentionally altered with one of eight common anterior esthetic discrepancies in varying degrees of deviation, including variations in crown length, crown width, incisor crown angulation, midline, open gingival embrasure, gingival margin, incisal plane, and gingiva-to-lip distance. Forty images were randomized in a questionnaire and rated according to attractiveness by three groups: orthodontists, general dentists, and lay people; 300 questionnaires were distributed.

Results: The response rate was 88.2% for orthodontists, 51.8% for general dentists, and 60.6% for lay people. The results demonstrated threshold levels of noticeable difference between the varying levels of discrepancy. A maxillary midline deviation of 4 mm was necessary before orthodontists rated it significantly less esthetic than the others. However, general dentists and lay people were unable to detect even a 4-mm midline deviation. All three groups were able to distinguish a 2-mm discrepancy in incisor crown angulation. An incisal plane cant of 1 mm as well as a 3-mm narrowing in maxillary lateral incisor crown width were required by orthodontists and general dentists to be rated significantly less esthetic. Lay people were unable to detect an incisal plane asymmetry until it was 3 mm, or a lateral incisor narrowing until it reached 4 mm. Threshold levels for open gingival embrasure and gingiva-to-lip distance were both at 2 mm for the orthodontic group. Open gingival embrasure became detectable by the general dentists and lay people at 3 mm, whereas gingiva-to-lip distance was classified by these groups as noticeably unattractive at 4 mm.

Figure 45. Abstract of the article by Kokich V et al. Taken by Ferrando A, from the Wiley Online Library.[24]

3.8. Occlusal plane versus intercommissural line

The occlusal plane is determined by drawing a line from the incisal edges, passing through the canines and ending at the mesio-vestibular cusp of the first molars. It is essential that this plane is parallel to the ground or horizon in the frontal view, as well as being in harmony with the bipupillary and commissural line, in the lateral aspect almost parallel to Camper (Porion-ENA). Any inclination is immediately detected and is a very frequent error in total aesthetic rehabilitation if it is not recorded and diagnosed[9,20].

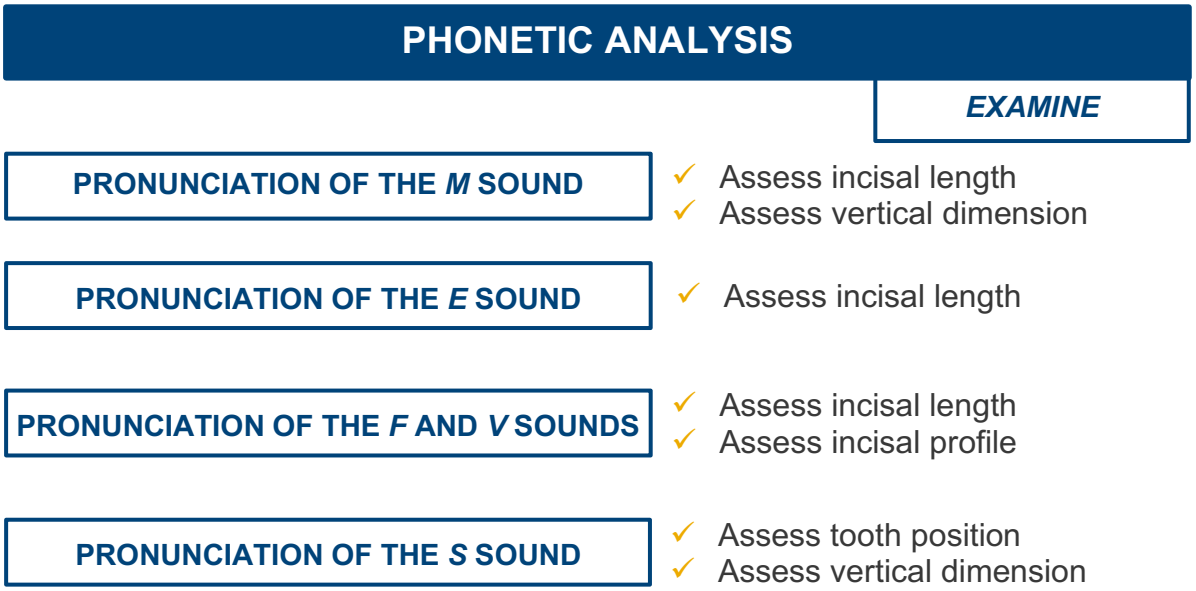
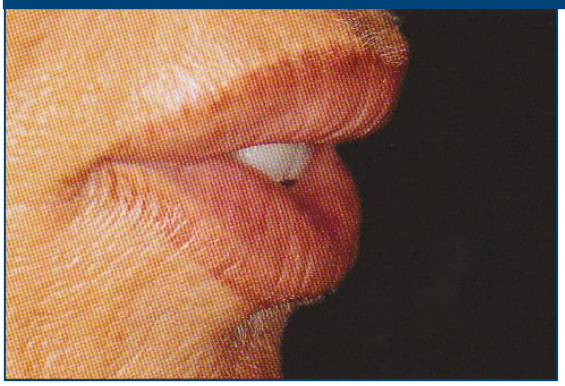


Figure 46. Phonetic analysis. Made by Fradeani M.[9]

F/V SOUND





Prosthetic considerations for aesthetic rehabilitation

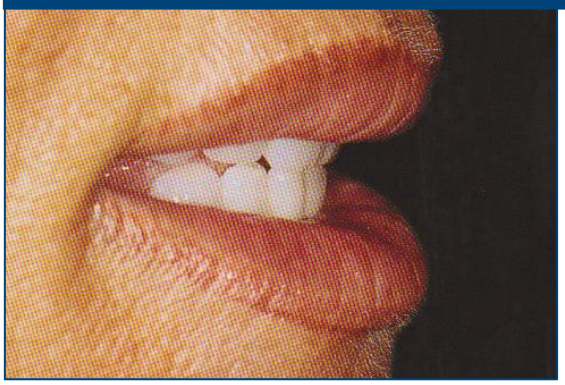
- LENGTH OF THE INCISORS

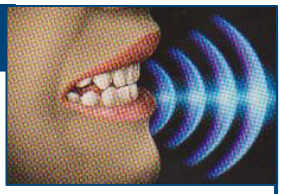
While pronouncing these two sounds, the maxillary incisal edge and the lower lip should touch slightly.

- PROFILE OF THE INCISORS

The vermilion border of the lower lip is the maximum limit within which the incisal margins of the restorations should be positioned.

SOUND S





Prosthetic considerations for aesthetic rehabilitation

- TOOTH POSITION

Assess mandibular movement (vertical or horizontal) if it is deemed necessary to move the anterior teeth in the oral-lingual plane.

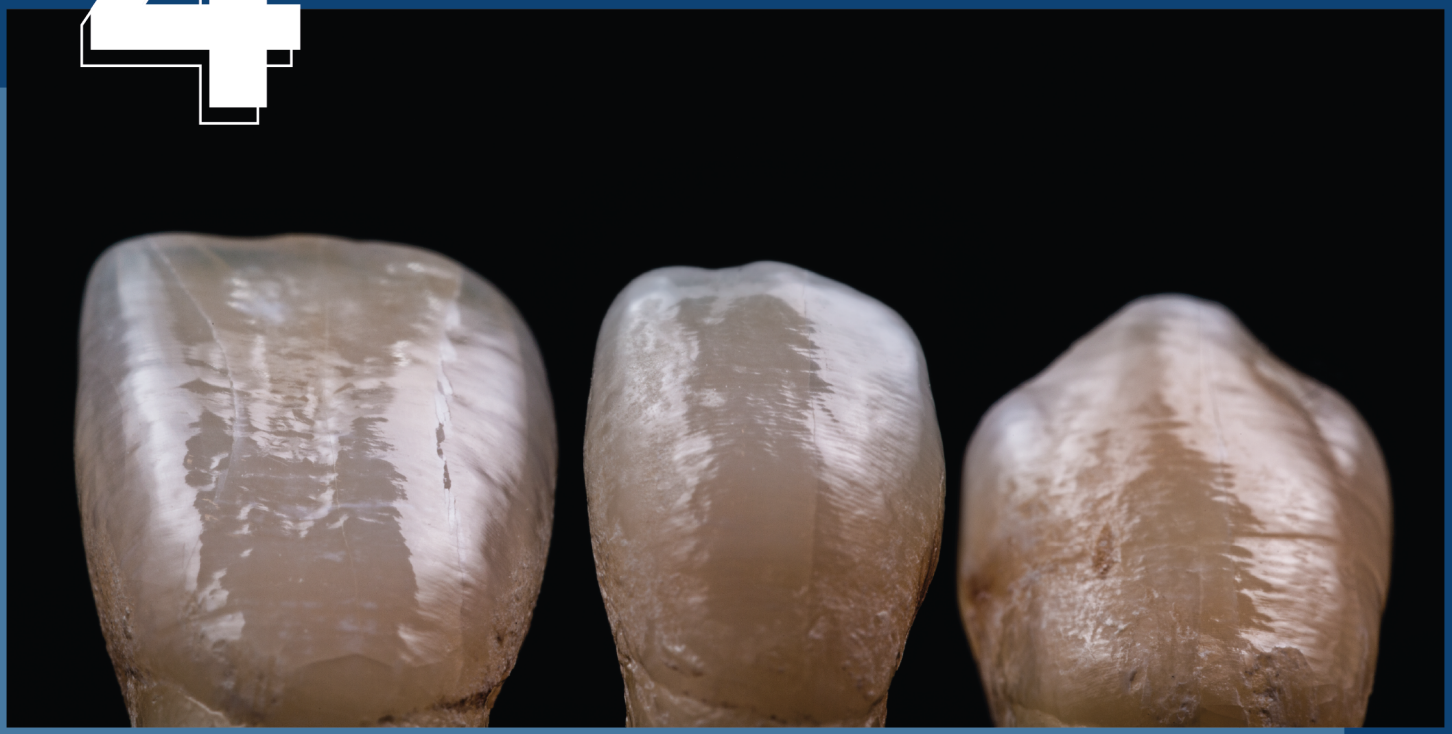
- **VERTICAL DIMENSION**[21]

The teeth should never touch while pronouncing this sound.

Figure 47. Prosthetic considerations for aesthetic rehabilitation. F/V/S sounds. Made by Fradeani M.[9]

UCAM

Chapter 4



Smile aesthetics. Dental analysis

Individual dental analysis. Tooth composition and gingival factors (shape, colour, axes, dominance, dimensions and proportions, DSD, virtual and real mock-up).

Photo by Dr. Fernando Rey Duro

4.1.Dental analysis

In the DENTAL ANALYSIS there are 6 important points to assess:

1. **Type of tooth.**
2. **Tooth colour.**
3. **Shape and contour of the maxillary teeth. 1st anatomy.**
4. **Macro and microtexture of the maxillary teeth. 2nd and 3rd anatomy.**
5. **Dimensions and proportions of the maxillary teeth.**
6. **Incisal margin and profile.**



Figure 48. Dental analysis. Made by Ferrando A.

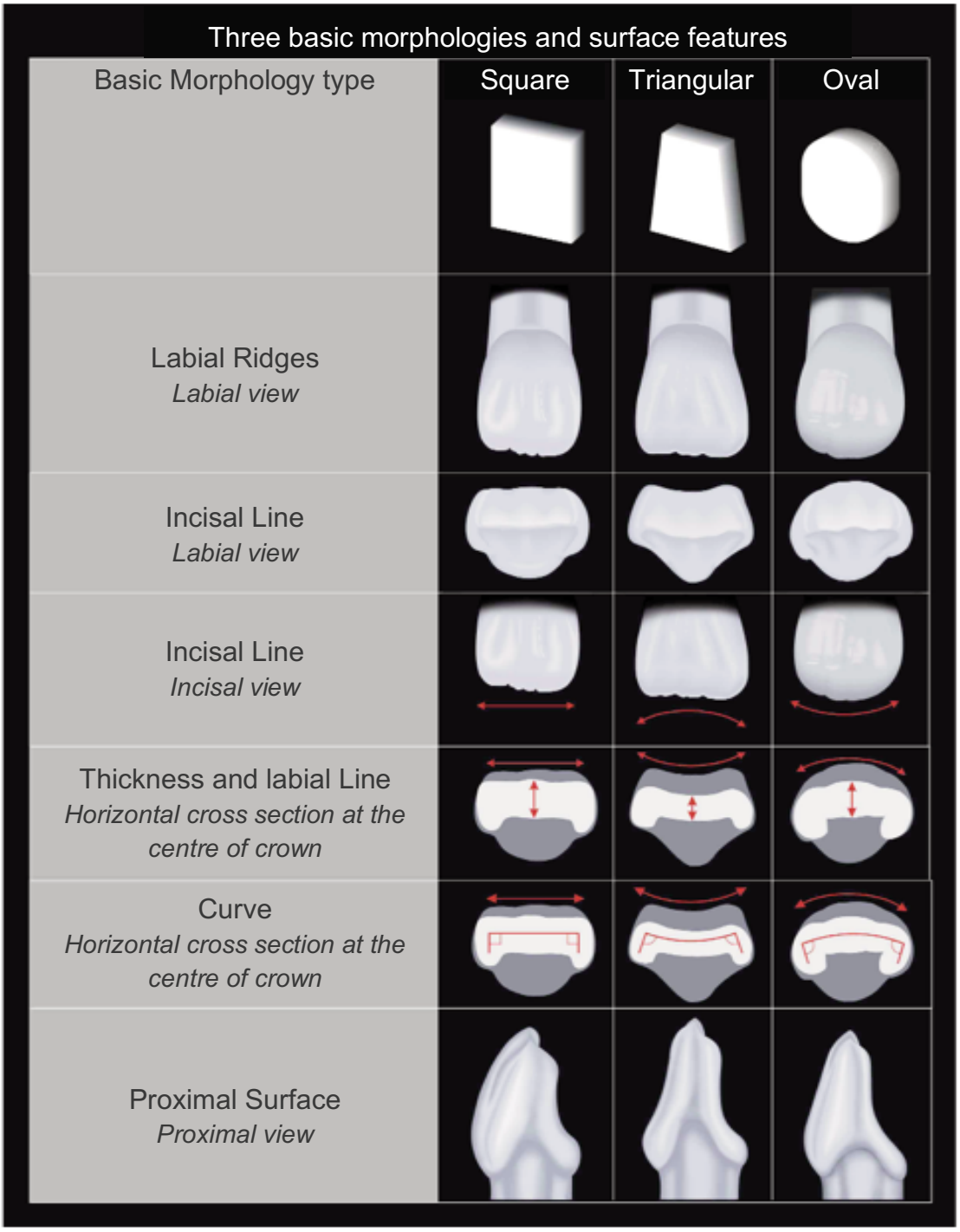


Figure 49. Basic tooth morphology and surface features. Made by Fradeani M.[9]

The shape of the set will depend on VISAGISM[25,26], which basically consists of highlighting the most important aspects of the personality that are to be expressed with the smile, and which can be related to the shape of the teeth and their composition. In this sense, the 3D DOMINANCE of the central incisors in the canine to canine composition should be emphasised. The search for symmetry, correct proportion and re-establishing dominance in the three planes of space should be an essential objective of any aesthetic rehabilitation. By modifying just these two teeth, it is possible to convey any aspect of personality.

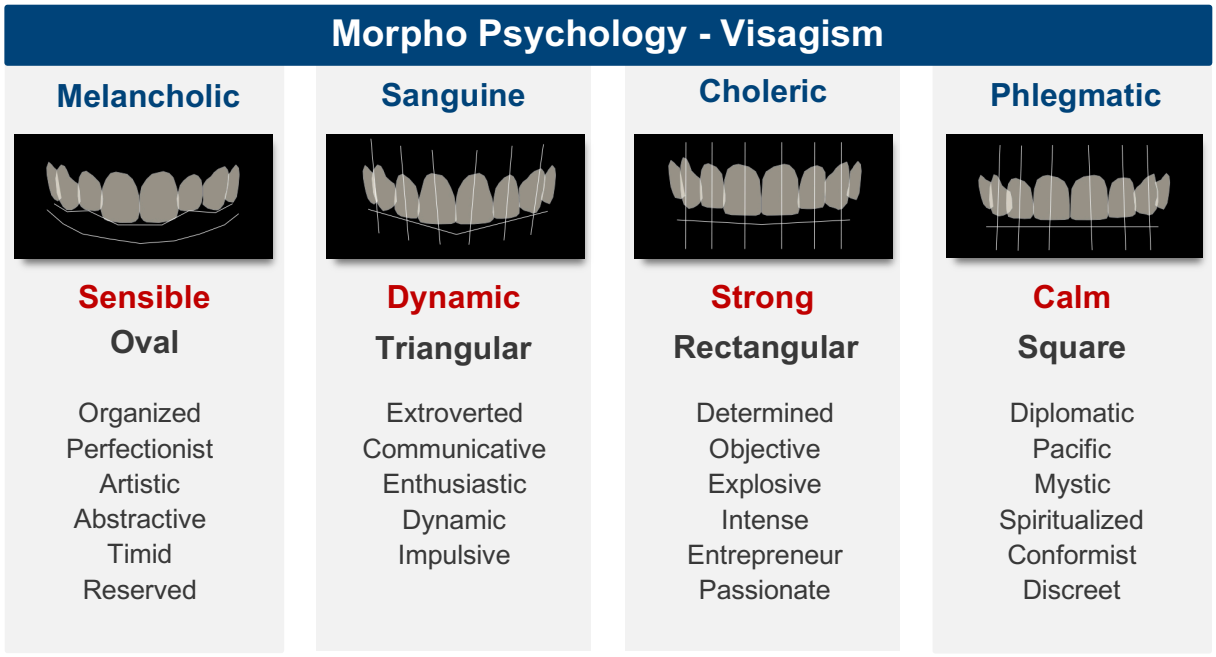


Figure 50. Morphology of teeth and their relation to visagism. Made by Paolucci B.[25]

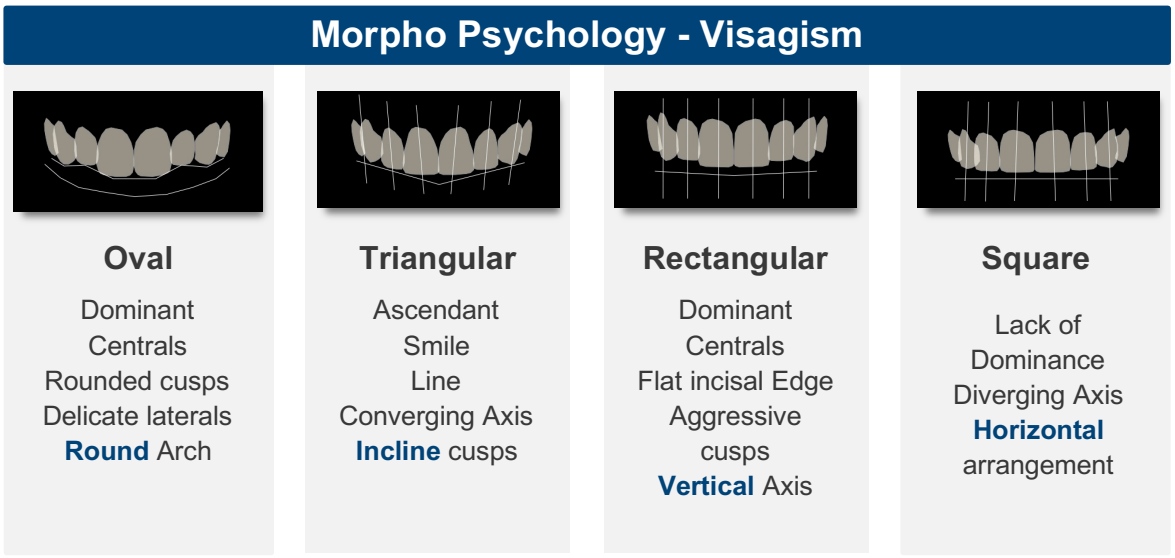


Figure 51. Morphology of teeth, type of occlusal plane and their relation to visagism. Made by Paolucci B.[25]

'The excessive value placed on image is one of the most important characteristics of the contemporary world. People recognise its importance and power as they seek personal well-being, professional success and social acceptance through it. And they increasingly undergo procedures in all areas of medicine and aesthetics to improve their appearance. In this regard, there has been a great demand from patients for dental treatments that restore the beauty of the smile. Such procedures have great power in the perception of personal image, directly influencing the sense of identity, self-esteem and quality of life.

Developed by visual artist Philip Hallawell, Visagism is the art of personal image personalisation. The aim is to find solutions that visually express the positive characteristics of a personality. This is done by making conscious use of the artistic elements of visual language, such as lines, shapes and colours. These techniques can be accessed through consultations aimed at providing the practitioner with a better understanding of the patient, with his or her particularities, desires and personal needs, and only then propose a corrective solution.

Therefore, there is a new approach to dentistry, seeking personalised solutions for your patients through a smile design that visually translates their main qualities. This concept leads us to a truly à la carte dentistry.' Braulio Paolucci"[27].

· Case Report Estetica ·

Il visagismo, l'arte de comporre i denti[27]

· Visagism ·

The Art of Dental Composition[27]

4.2. Tooth colour

In 1670, Isaac Newton demonstrated that white light breaks down into all the colours of the spectrum when it passes through a prism. Therefore, light will be the source of colour when it strikes natural teeth, and it will also influence the outcome of prosthetic restorations.

Two processes that occur when a light ray hits a surface are of particular interest: *reflection and refraction*. When an electromagnetic wave or beam of light strikes a surface, part of the wave is refracted and is deflected in a different direction as it passes through the surface. The rest of the electromagnetic wave changes direction when it hits the same surface and returns to the medium from which it came (reflection.) This is the light on which all efforts must be focused because it is the light that affects us when carrying out aesthetic restorations, as it is the light that reaches us.

The spectrum of visible light for the human eye ranges from 400nm-700nm, the light of each of these wavelengths is perceived by the human brain as a colour, below this is ultraviolet light and above this is infrared light.

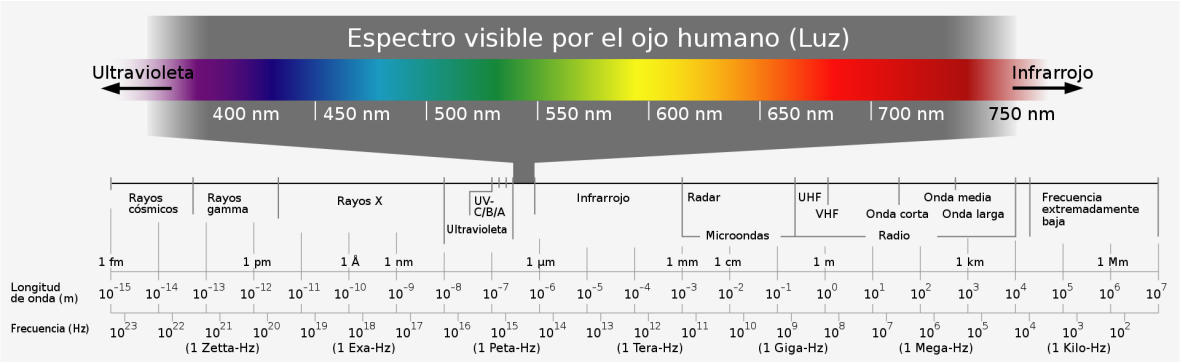


Figure 52. Equivalence between wavelengths and frequencies in the spectrum visible to the human eye. Taken from https://es.wikipedia.org/wiki/File:Electromagnetic_spectrum-es.svg[28].

Pure tooth colour is the end result of refraction and reflection phenomena on the surface of the tooth, which gives it its final colour depending on the thickness and saturation level of the dentine. The balance between how much light is absorbed and reflected by the tooth.

How do humans perceive colour?

Strictly speaking, it is a product of the sight organ. The human eye has *rods and cones*. With the rods humans perceive the value, the brightness-darkness, while the cones are in charge of perceiving the hue or pure tone (red, orange, yellow...). Humans have more rods than cones, which is why sensitivity to value is greater. Moreover, women tend to have more cones than men, which is why they distinguish more colour nuances (e.g., light pink)[29].

In the natural dentition the teeth are not all the same colour, the central incisors are the lightest and brightest, they DOMINATE the dental set and composition. The lateral incisors seem to have the same shade and brightness, but their colour is less intense. The maxillary and mandibular canines have a very intense colour, appearing darker than the rest of the teeth, and in the premolars and molars the brightness and tone is usually recovered at the level of the laterals. Age produces an increase in the intensity of colour and a loss of brightness due to a decrease in the thickness of the enamel.



Figure 53. General colour of the natural dentition. Taken from Ferrando A.

4.2.1. Dental colour. Considerations for aesthetic rehabilitation. Subjective methods of colour communication

A. ***Shade guides***: colour guides, such as the Vita classical shade guide, are one of the most commonly used methods in dentistry for colour transfer.

Following Munsell's colour system, colour can be divided into three fundamental aspects:

1. **Hue**: tint or tone, refers to the pigment, thus the guides include the different dental shades that are not pure colors as such, but rather a mixture of orange with reddish-brown (A), bluish-yellow (B), greyish (C) and pinkish-brown (D).

In summary.

A. Orange-reddish-brown

B. Orange-yellow-blue.

C. Orange-yellow-gray.

D. Orange-pinkish-brown



Figure 54. Vita classical shade guide, sorted according to **shade**. Made by Ferrando A and courtesy of Gómez Cogolludo P.

2. **Chroma or saturation**: refers to the intensity of colour. A1, A2, A3, A3.5.



Figure 55. Ascending gradation of **saturation of shade** A. Made by Ferrando A and courtesy of Gómez Cogolludo P.

3. **Value or lightness.** This is the dimension of the colour that allows you to measure the amount of grey it contains. This is why you should arrange the

classic Vita shade guide according to value instead of shade. However, there are other guides such as the Vita 3D MASTER, with 5 groups based on value. The problem is that each guide is slightly different. The technician's guide may have other shades, so the ideal situation would always be to know the technician's ceramics and take the colour with a customised guide from the commercial house or made by the same technician.



Figure 56. Vita Classical B/W shade guide, sorted according to **value**. Made by Ferrando A and courtesy of Gómez Cogolludo P.



Figure 57. Vita Classical shade guide, sorted according to **value**. Made by Ferrando A and courtesy of Gómez Cogolludo P.

An important aspect to take into account in aesthetic rehabilitation is to use shade guides such as the Ivoclar Vivadent Natural Die, which is important for material selection. Mobile applications such as SNA can also be used to help determine the value/hue and intensity of the ceramic material to be selected, as they combine thicknesses and clinical indications.

That said, according to the literature and as a method of communication, there are many factors that affect colour selection, such as age, room lighting (ideally 12:00 noon daylight) and the experience of the operator (Chen et al 2012[30]). For all these reasons, the accuracy is low and therefore it is recommended to rely on quantitative and instrumental methods (Miyajiwala et al. 2016[31]).

4.2.2. Dental colour. Considerations for aesthetic rehabilitation. Objective methods of colour communication

A. ***Colourimeters.*** These methods fell into disuse because they were designed for flat surfaces, had problems with the value and were quite irregular. Today we have more advanced colorimeters with spectrophotometric technology, such as OptiShade®, see the final appendix for more information on equipment and parameters in dental photography.

B. ***Spectrophotometers.*** These are the evolution of colourimeters, where there is no dependence on external light, giving you a chromatic map of the tooth which you can also modify using the software. The bad thing is that they have a considerable learning curve, they require exhaustive prior calibration, which must be repeated periodically, and they are sometimes uncomfortable for the patient.

C. ***Intraoral scanner.*** Nowadays, with the explosion of digital technology in the dental world, there is an impression register that also measures colour, although it needs to be scanned in HD (e.g., Real Color.Trios-3Shape).

D. ***Photography.*** This is an indispensable tool that has also been refined. Today there are colour communication protocols that use polarising filters and standardised grey cards, as well as software to quantitatively measure colour parameters (e.g., **eLABor-aid system)**[32].

Reviewing the literature, the spectrophotometer would be the most reliable method to communicate colour, followed by the HD scanner, classic colourimeter, photography and lastly the visual method[30].

Conclusions

1. There are objective and subjective methods which help convey colour.
2. You must give your technician as much information as possible.
3. You must know the characteristics of the teeth and be able to convey them.
4. You must be familiar with and calibrate the specific digital instruments.
5. Any misused instrument can be your enemy.

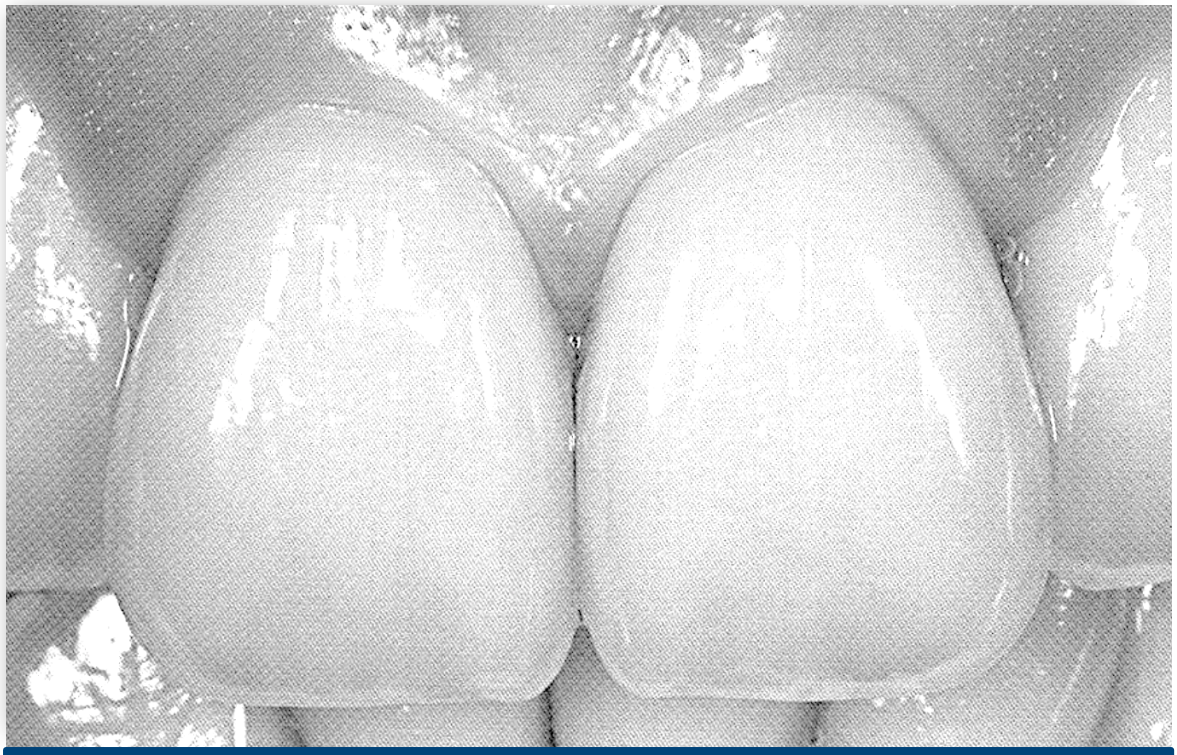
Figure 58. Objective and subjective methods of colour communication. Courtesy of Gómez Cogolludo P.

4.3. Shape and contour of the maxillary teeth. Anatomy 1st.

- **TRIANGULAR**: the outer limits of the vestibular face contour are incisally divergent and have a marked cervical convergence. This creates a narrow cervical area.

- **OVAL**: the outer boundaries tend to be curved or rounded, both incisally and cervically, along with a gradual reduction of the cervical area and the incisal edge.

- **SQUARE**: the outer edges are more or less straight and parallel, creating a wide cervical area with an equally large ridge.



Maxillary central incisor

- Vestibular surface with three ridges (lobes) and two concavities.
- Cervical area basically triangular, with its upper vertex (zenith) distal to the central axis of the tooth.
- Masial profile basically straight or slightly convex, with wide interproximal contact in the incisal third.
- Convex distal profile, with a little more apical contact compared to the buccal contact.
- Incisal edge slightly convex in adolescents and straight with vestibulo-lingual inclination in adults.
- Mesioincisal angle basically straight or slightly rounded.
- Rounded distoincisal angle.

Figure 59. Anatomy of the upper central incisor. Made by Fradeani M.[9]

4.3.1.Shape and contour of the maxillary teeth. 1st anatomy. Perception and optical illusion

HOW WOULD YOU MAKE A TEETH LOOK SHORTER AND WIDER?

- **SHAPING VESTIBULAR PLANES** (accentuated fragmentation of the three planes of the vestibular face) **AND TAKING THE ANGLE LINES TO THE OUTER PART**[9].

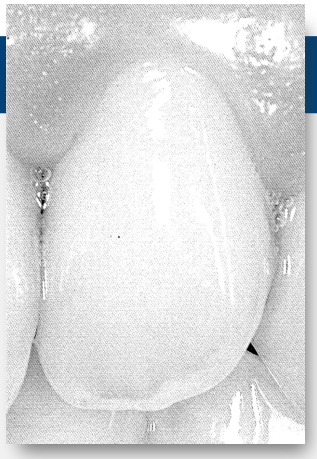
HOW WOULD YOU MAKE A TEETH LOOK LONGER AND NARROWER?

- **SHAPING THE VESTIBULAR FACE TO BE FLATTER** (minimal fragmentation/ defragmentation of the cervical and incisal planes) **AND MOVING THE ANGLE LINES CLOSER TO THE CENTRE**[9].

4.4. Macro and microtexture of the maxillary teeth. 2nd and 3rd anatomy

Maxillary lateral incisor

- Often with variations.
- Profile similar to that of the central incisor, but smaller.
- Distal contact area more apical than mesial.
- More marked convexity and roundness compared to central incisor.
- Distal incisal margin distinctly rounded.



Maxillary canine

- Marked prominence of the vestibular central lobe.
- Cervical area slightly concave, mesially and distally.
- Marked convexity in the distoincisal angle.
- Possible axial asymmetry.
- Possible asymmetry of the gingival levels of the two canines due to different vestibulo-lingual inclination.
- Frequently worn cusp tip.

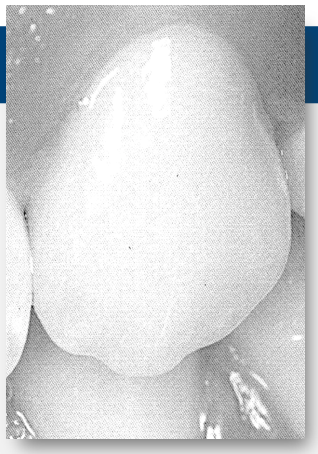


Figure 60. Anatomy of the upper lateral incisor and upper canine. Made by Fradeani M.[9]

In the natural dentition there are morphological surface characterisations known as macro- and microtextures. Macrotexture (2nd ANATOMY) refers to the lobes which, as a rule, divide the vestibular side of the tooth into distinguishable convexities and concavities. This is also distinguishable in young teeth but disappears with age due to erosion / abrasion / attrition phenomena.

Microtexture (3rd ANATOMY) refers to the horizontal lines (perikyma/ta), a product of the apposition of enamel in dental development, and very recognisable in young dentition. At 40-50 years of age, these are not usually visible[9].



Figure 61. Natural front anterior teeth. Note the very pronounced 2nd anatomy, for instance in the upper left lateral incisor. Made by Ferrando A.



Figure 62. Composition of natural anterior teeth in profile, polarised photo and transillumination to observe incisal translucency. The 3rd anatomy or microtexture is very marked in the incisors in profile, as a 'rough' enamel surface is evident. Made by Ferrando A.

4.5. Dimensions and proportions of the maxillary teeth

- (75-85% - ideally 80%. Chiche G[33]).

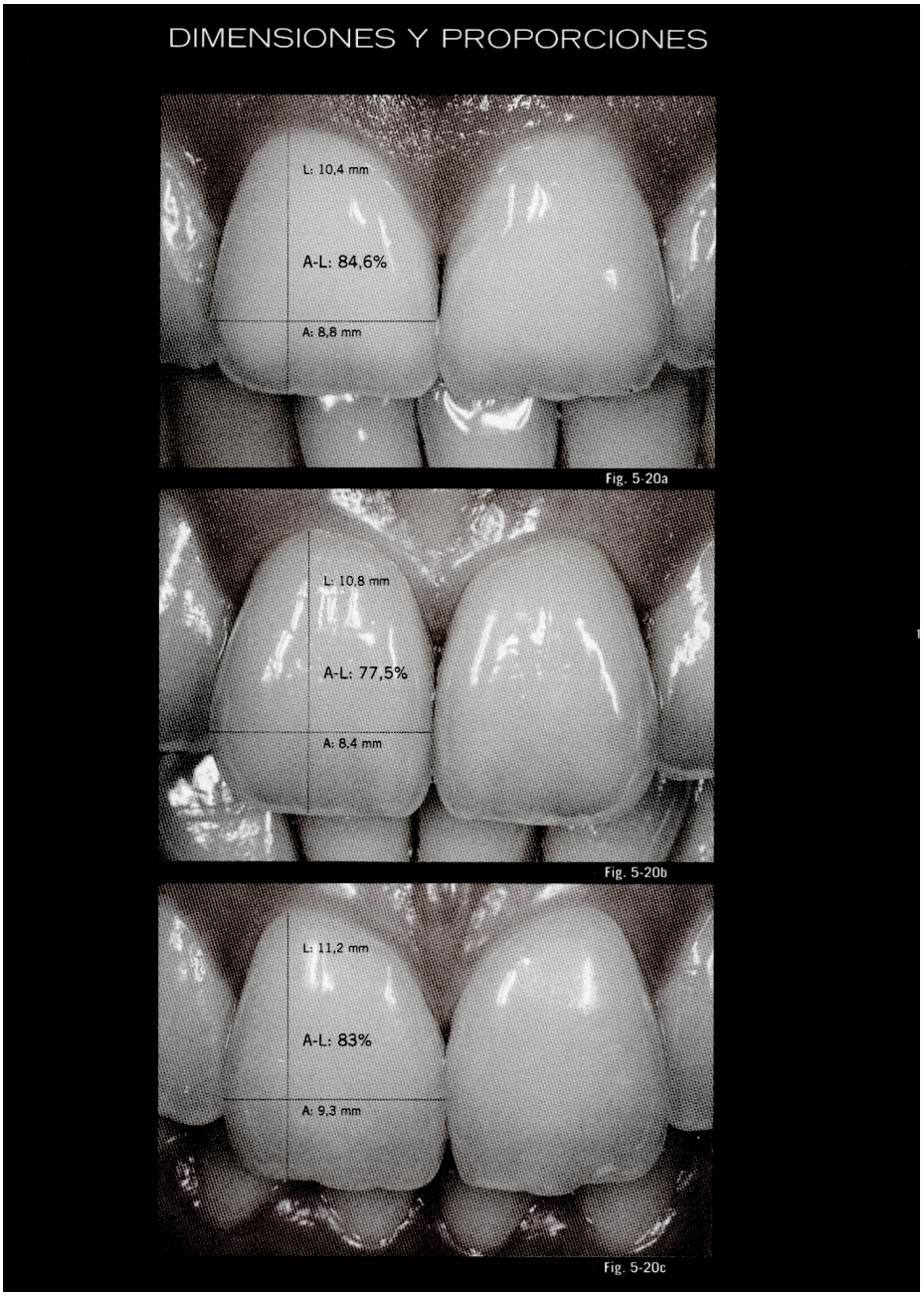


Figure 63. Dimensions and proportions of upper central incisors. Made by Fradeani M.[9]

4.6. Incisal margin and profile

4.6.1.Incisal margin

The **incisal margin** in adolescents, seen from the front, shows mamelons that tend to disappear early. The particular morphology of the incisal margin, which is inclined in the vestibulo-lingual direction, matches the phenomenon of total light reflection, forming what is known as an incisal halo (thin opaque band). The apical location of the palatal edge in relation to the vestibular edge must also be reproduced in the restorations to avoid creating an artificial appearance.

4.6.2.With regard to the incisal profile

With regard to the incisal profile, the vestibular side of the central teeth can be divided into three segments called thirds: cervical, middle and incisal. These will determine the degree of convexity of the total surface. The edge should not extend beyond the wet lip line or inner vermilion border of the lower lip.

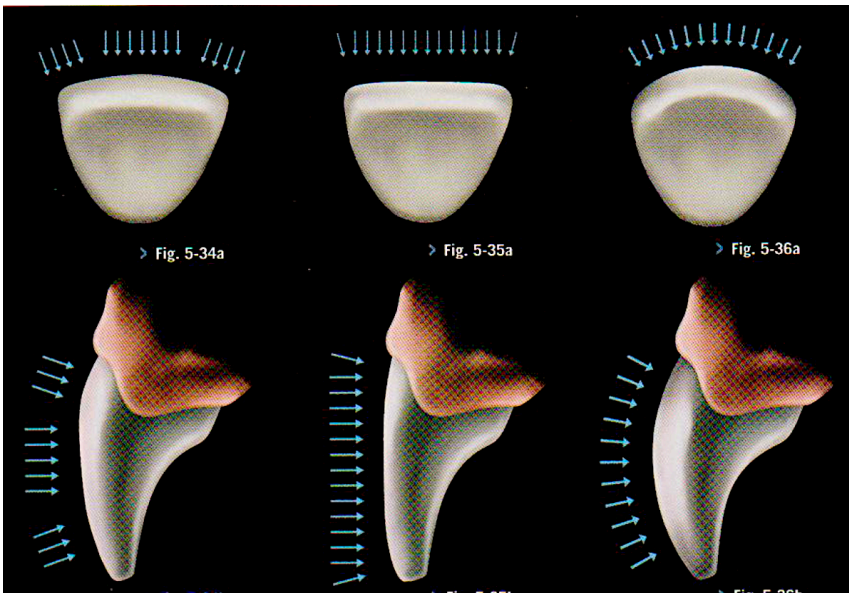


Figure 64. Incisal profile diagram, occlusal and sagittal view. From the right of the figure there is an incisal profile with normal convexity (compatible with a triangular shape), the one in the centre is straight (compatible with a square shape) and the one on the left is excessively convex (compatible with an oval shape). Made by Fradeani M.[9]

DENTAL ANALYSIS: MAXILLARY TEETH

PROSTHETIC CONSIDERATIONS FOR AESTHETIC REHABILITATION

➢ **TYPE**	• Identify the type of tooth based on:	› Adjacent teeth › Old photos and/or plaster models › Gingival architecture
➢ **COLOUR**	• Choose tooth shade based on: adjacent teeth, age, the patient's request. • Reproduce the chromatic programming from the central incisor to the canine. • Perception of optical illusion: Variations in hue, intensity, brightness, translucency/opacity and surface characterisations to create the optical illusion of modified dimension.	
➢ **TEXTURE**	• Finish the surface of the restoration with macro and microtextures based on:	› Adjacent teeth › Age of the patient
➢ **SHAPE AND CONTOUR**	• Restore shape and contour based on the morphological characterisation of each individual tooth. • Illusory perception: varying the angles of the transition line, contour, horizontal and vertical ridges and lines to create an optical illusion of modified size.	
➢ **DIMENSION**	• Reproduce dimensions similar to those found in nature.	› Central incisors: Width: from 8.3 to 9.3mm Length: from 10.4 to 11.2mm
➢ **PROPORTION**	• Restore natural proportions, especially in the central incisors.	› Width – Length: 75% to 80%
➢ **INCISAL MARGIN**	• Restore the correct buccolingual inclination of the incisal margin.	› Inner edge of the restoration in more apical position.
➢ **INCISAL PROFILE**	• Recreate a correct incisal profile.	› The maxillary incisal profile should be at the edge of the vermilion of the lower lip.

Figure 65. Dental analysis summary. Considerations for aesthetic rehabilitation. Made by Fradeani M.[9]

4.7. Tooth composition of the maxillary teeth

There are 4 points to evaluate:

1. **Tooth to tooth ratio.**
2. **Interdental contact areas and interincisal angles.**
3. **Axial inclination.**
4. **Tooth position and alignment.**

1. Tooth to tooth ratio

The evaluation of each individual tooth must be completed with the analysis of the anteromaxillary sextant as a whole. Therefore, the proportions between one tooth and another are analysed. The most important element has already been mentioned, and that is the **3D dominance** of the central teeth, both in terms of size and position in the dental composition.

Having said that, looking at the anterior teeth from the front you can follow the golden ratio, which says that the ratio between the width of the lateral incisor and the width of the central incisor should be 1:1.618, while the optimal ratio between the width of the lateral and the canine is 1:0.618. According to these rules, the central incisor should therefore appear 62% wider than the lateral incisor, and the lateral incisor, conversely, should be approximately 62% larger than the part of the canine that is visible from the front.

The Golden Ratios are also known as **divine** proportions. In 1982, Rickets RM[34], wrote an article entitled 'The biologic significance of the divine proportion and Fibonacci series'.

In this article[34] he states that aesthetics can be achieved on a scientific basis, rather than resorting to subjective perceptions, by simply applying basic mathematical and geometrical principles. Rickets[34] stated that in 1202, Filius Bonacci (Fibonacci) published a work in which he demonstrated the divine proportions based on a simple mathematical series made up of a progressive sum where the result obtained is added to the immediately previous number and so on. When level 89 is reached, each new addition is precisely 1.618 times the previous number, and this ratio of addition continues on to infinity.

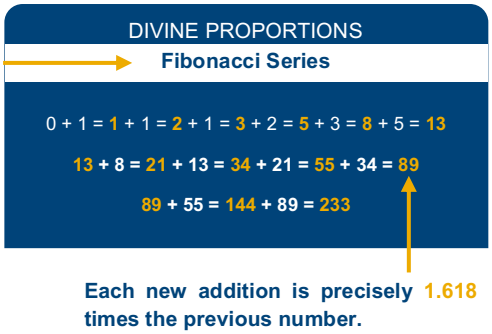


Figure 66. Explanation of the Fibonacci series and its relation to the divine proportion. Made by Rickets[34].

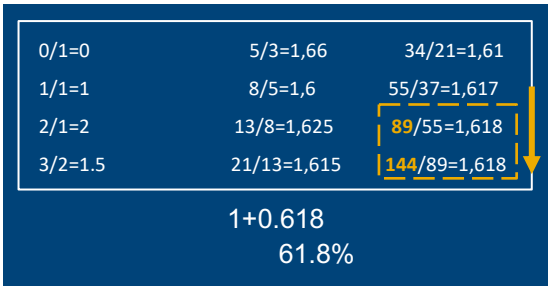


Figure 67. Continuation of the explanation of the Fibonacci series and its relation to the divine proportion. Made by Rickets[34].

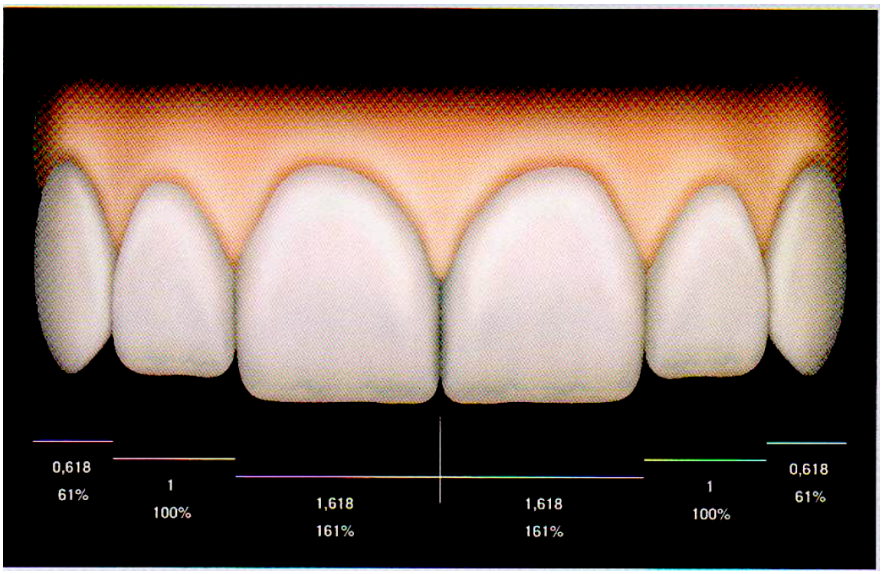


Figure 68. Diagram of golden ratio in anterior teeth. Made by Fradeani M.[9]

Recurring Esthetic Dental Proportion (RED proportion)

Following the golden ratio, the lateral incisor can appear too narrow at times, and the canine can lose too much dominance and become insignificant in the set. Therefore, using the RED proportion to design a set of teeth offers more flexibility. In the following figure there are three sets of teeth where the central incisors are always equally wide. In set A, the lateral is 80% wider than the central and the canine is 80% wider than the lateral. Note that the canine is particularly wide and gives a somewhat flat appearance to the set. In contrast, in B, the recurrent tooth proportion used is 70%, which is closer to observations of natural dentitions, where the proportions are usually between 66%-78%. This option is preferable in most cases, but must be adjusted to the skeletal pattern, face type and visagism of the patient. In an ectomorph (tall and thin) or mesomorph, you would move towards 65-70%, while in an endomorph (shorter and wider) it would be more 80%. Set C corresponds to the golden ratio, and it is clearly noticeable how the lateral is very narrow and the canine fades into the set[35].

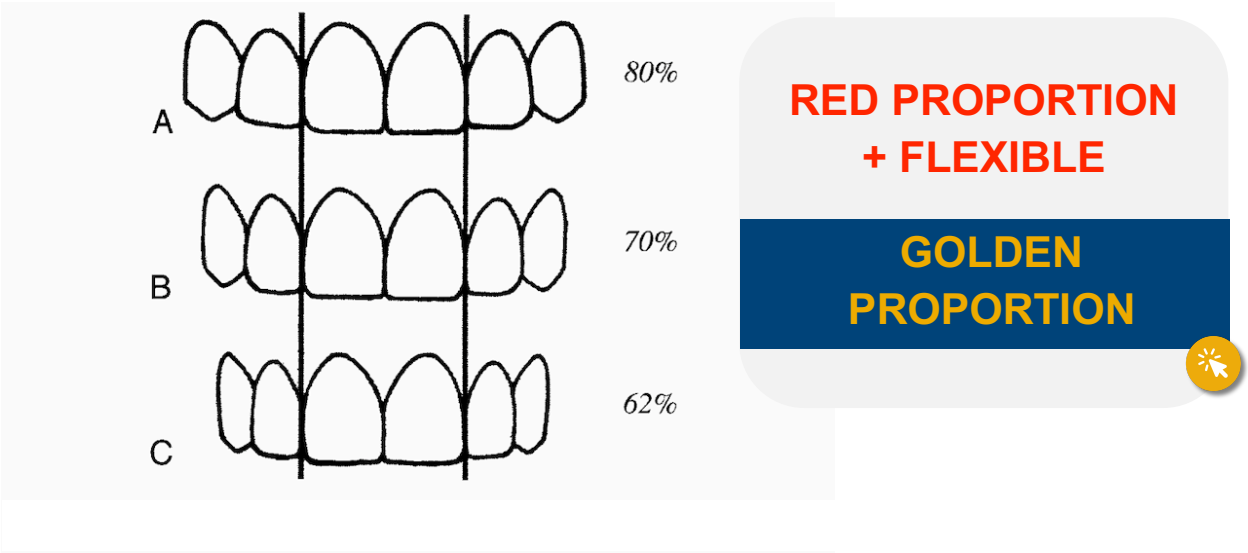


Figure 69. Different recurrent tooth proportions with constant central incisor size. Made by Ferrando A, from Ward DH.[35]

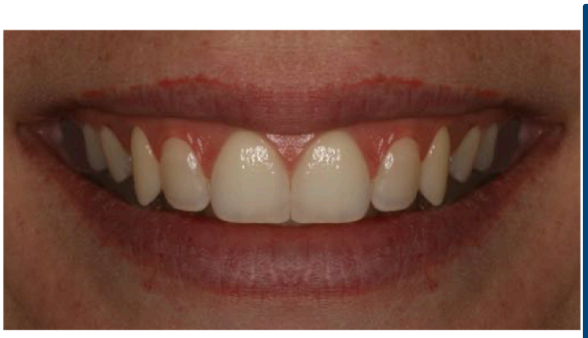


Fig. 9. RED proportion = 62%

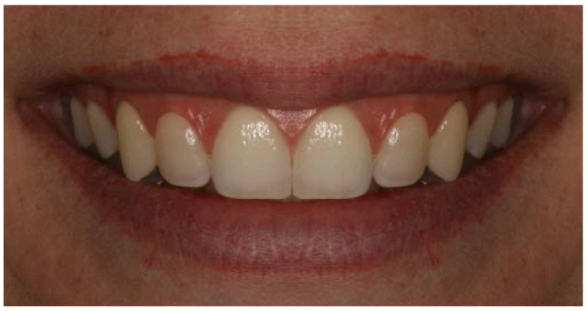


Fig. 10. RED proportion = 70%



Fig. 11. RED proportion = 75%



Fig. 12. RED proportion = 78,5%



Fig. 13. RED proportion = 80%

Figure 70. Composition of natural smiles by digitally modifying the recurrent tooth proportion, keeping the size of the central incisors constant. The 70% was the most liked in this study. Made by Manzano A.[36]

· Thesis. Dr Alberto Manzano ·

The conclusions are noteworthy.

2. Interdental contact areas and interincisal angles

Interincisal angles are openings found between one tooth and the adjacent tooth at the interincisal edge of the anterior teeth. Their width is determined by the position of the interdental contact area, the contact areas between the two central incisors, extending almost up to the cervical margin, they are particularly wide and draw a narrow interincisal angle. In an ideal dental composition, moving from the centrals to the canines, the interdental contact areas are gradually located more apically, thus producing a wider interincisal opening from mesial to distal[37].

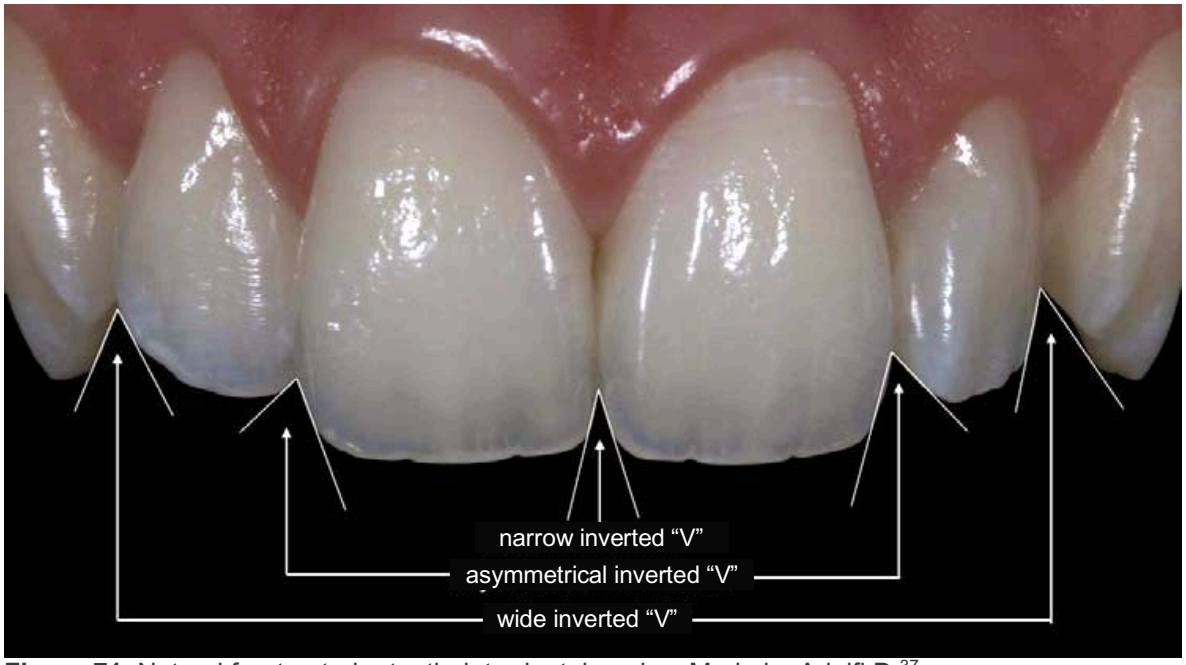


Figure 71. Natural front anterior teeth, interdental angles. Made by Adolfi D.[37]

3. Axial inclination

Compared to the midline, the tooth axes have an incisal mesioinclination and an apical distoinclination. This condition of coronal convergence and apical divergence is gradually accentuated from the central incisors, where it is minimal, to the canines. The axial inclinations of the IC, IL and C should ideally be symmetrical (mirror image). However, a certain degree of asymmetry is permissible; the lateral incisors may have a different shape and inclination, while the canines should be equal in shape, but not in inclination, where vestibulopalatine variations are acceptable.



Figure 72. Before and after composition of a set of teeth 1.3-2-3. Clinical case showing the axial axis clearly distal to 1.2, and the giroversions of the canines. They were corrected at the end with orthodontics and implants in 1.2 and 2.2. because they had resorbed roots. Made by Ferrando A.

4. Tooth position and alignment

Starting from the assumption that it is very difficult to find perfect alignment in nature, in an ideal composition, the lateral incisors should rest on two hypothetical lines that meet the central incisors with the canines, both cervically and incisally. A lateral incisor that is located more vestibularly would have a more apical gingival margin than the central incisor, and a shorter incisal margin. Conversely, a lateral that is located in a more lingual position, being normally subjacent to the central, may appear more shaded and have a more coronal gingival margin. The alignment of the teeth is closely related to the clear space in the dental arch. There are three types: 1. Square, 2. Oval, 3. Cone. The latter case is the one in which malpositions occur, as there is no space for correct 3D alignment.

Only prosthetic considerations for aesthetic restorations will be taken into account in the DENTAL COMPOSITION OF MANDIBULAR TEETH.

DENTAL ANALYSIS: MANDIBULAR TEETH	
	PROSTHETIC CONSIDERATIONS FOR AESTHETIC REHABILITATION
➢ **CONTOUR AND PROPORTION**	• Restore the distal profile of the lateral incisors, including making it more convex than the central incisor. • Restore the width of the lateral incisor, e.g., approximately 10% larger than the central incisor.
➢ **PLACEMENT**	• Restore the alignment of the four incisors without sacrificing space and contour. • Slight rotation and overlapping to give the tooth composition a dynamic and natural appearance.
➢ **INCISAL EDGE**	• Restore the inclination of the incisal edge in an anterior-posterior direction. • Restore the lingual contour higher than the vestibular contour.

Figure 73. Dental analysis: mandibular teeth. Prosthetic considerations for aesthetic rehabilitation. Fradeani M.[9]

ANTERIOR TEETH: FUNCTIONAL ASPECT

PROSTHETIC CONSIDERATIONS FOR AESTHETIC REHABILITATION

➢ MAXIMUM INTERCUSPATION POSITION

- The first choice of occlusion with a limited number of restorations.

➢ CENTRIC RELATION AND OCCLUSION

- Choose procedure in most cases or in cases of prosthetic rehabilitation.

When the dental relationships or the vertical dimension has been lost.

➢ INCISAL GUIDE

- Disocclusion of the posterior teeth during excursive movements.

➢ CANINE GUIDE

Bilateral simultaneous path contact in closure.

➢ OVERJET

40-micron paper passing through

- Excessive overjet: recreate contact between maxillary and mandibular teeth for correct guidance.
- Reduced overjet: orthodontic treatment is recommended to increase the level of overjet and to prevent fractures in the restoration.

➢ OVERBITE

2 – 4mm

- Deep overbite: reduce the depth to prevent the guide from being too steep and difficult during excursive movements.
- Reduced overbite: increase the level to avoid possible interference with the posterior teeth during excursive movements.

Figure 74. Anterior teeth: functional aspects. Prosthetic considerations for aesthetic rehabilitation. Fradeani M[9].

DENTAL COMPOSITION: MAXILLARY TEETH. FINAL FUNCTIONAL AND AESTHETIC CONSIDERATIONS

Protrusive and lateroprotrusive movements

The individualisation of each tooth will provide **harmony without symmetry** and must be influenced by the position of the antagonist teeth and jaw movements. FAILURE to develop these individual characteristics in an attempt to make the teeth look symmetrical will interfere with the supporting structure of the arch and may lead to fracture of the restorations. Interferences are identified with 40-µm articulating paper (Figs 1 and 2). These interferences must be carefully adjusted so as not to lose the incisal morphology created by protrusive and lateroprotrusive mandibular movements (Figs 3 and 4)[37].

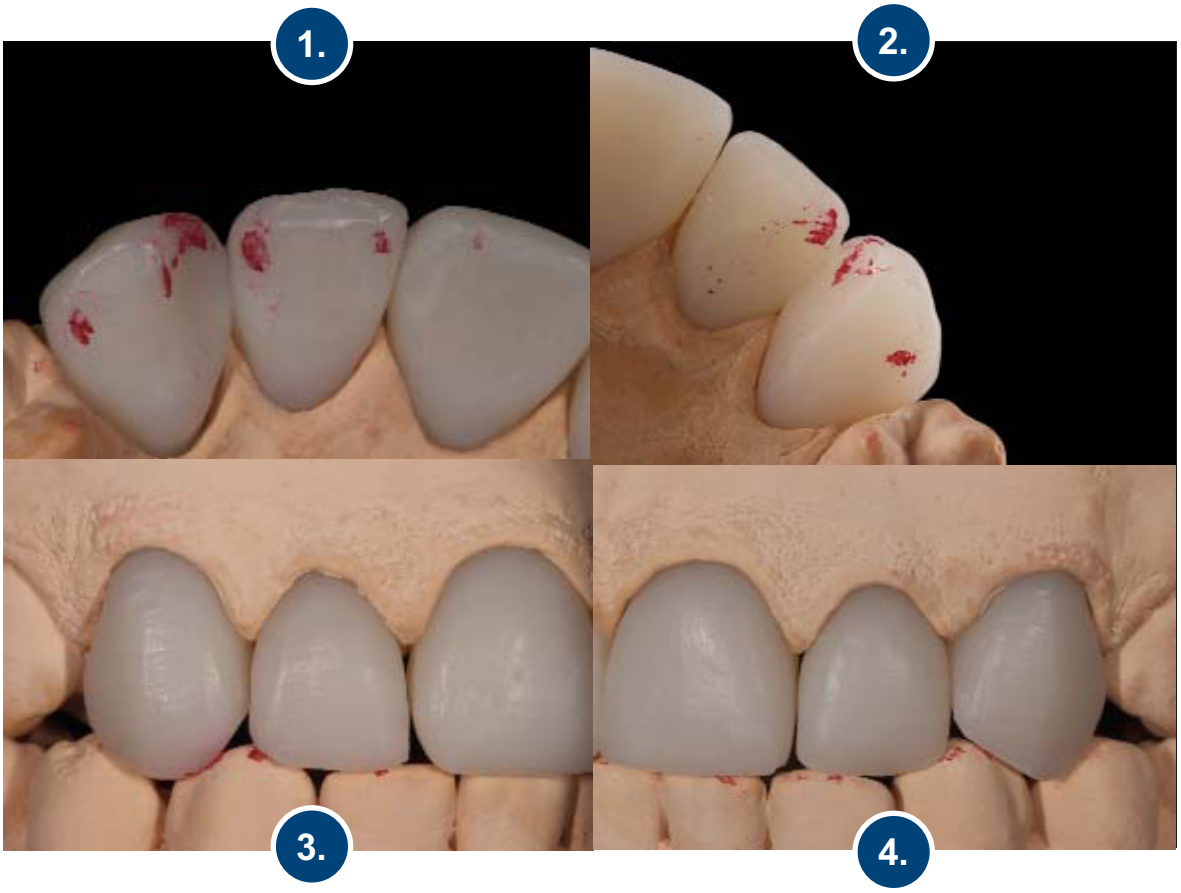


Figure 75. Functional adjustment composition of anterior teeth. Courtesy of Adolfi D.[37]

TOOTH COMPOSITION of the MAXILLARY TEETH. GINGIVAL MARGINS factors

There are 4 main aspects to be highlighted:

1. **Parallelism.**
2. **Symmetry.**
3. **Gingival zenith.**
4. **Interdental papilla.**

1. Parallelism

Ideally, the contour of the gingival margin is marked by the cervical level of canines and centrals and the margins have to be parallel or in line with the incisal edge and curvature of the lower lip. All gingival levels have to be parallel to the occlusal plane which in turn is related to the horizontal, bipupillary and intercommissural reference lines. The absence of parallelism detracts from the composition and has a negative aesthetic impact.

2. Symmetry

The margins of the centrals and canines must be symmetrical and in a more apical position than the laterals. A certain asymmetry can be allowed without compromising the aesthetic result, with the margin of the laterals being more apical to the centrals, but never more than the canines, which would break the natural progression towards the distal.

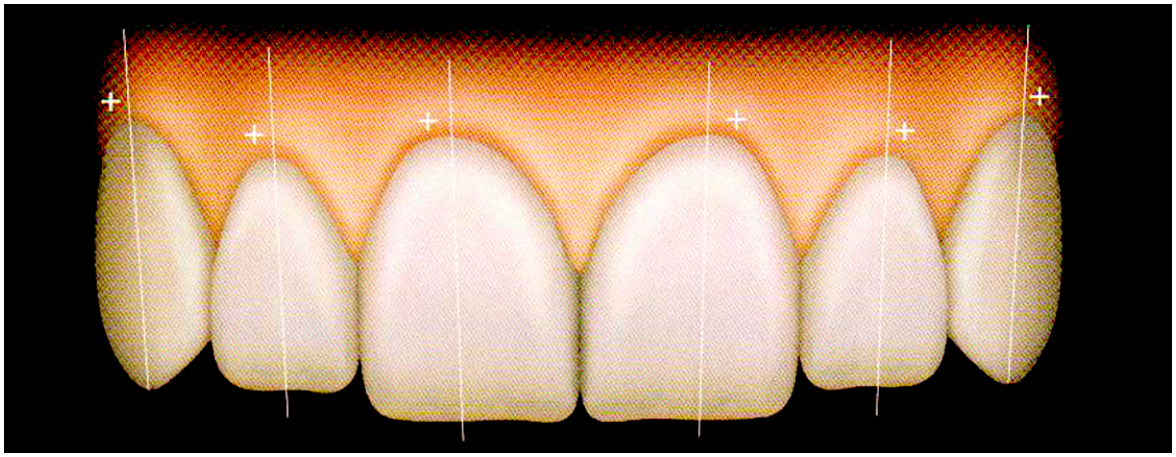


Figure 76. Tooth composition of the maxillary teeth. Symmetry of margins. Made by Fradeani M.[9]

3. Gingival zenith

This is the most apical point of the gingival contour and is located **distal** to the tooth axis. This aspect is important for dental preparation for porcelain restorations, for example, where it is important to emphasise this aspect and facilitate the work of the technician.

In conclusion, increased intrasulcular extension during tooth preparation, together with appropriate emergence of the restoration profile, can adequately support the gingival margins, redefining their contour and improving the position of the gingival zenith.



Figure 77. Tooth composition of the maxillary teeth. Gingival margins and zeniths. Made by Fradeani M.[9]

4. Interdental papilla

The typical gingival scallop architecture, parallel to the bony ridge and underlying cementoenamel junction, is characterised by the presence of papillae filling the interdental spaces. The papilla between the centrals is the longest. The papilla should be respected during tooth preparation to avoid inflammatory problems and always follow the gingival scallop.

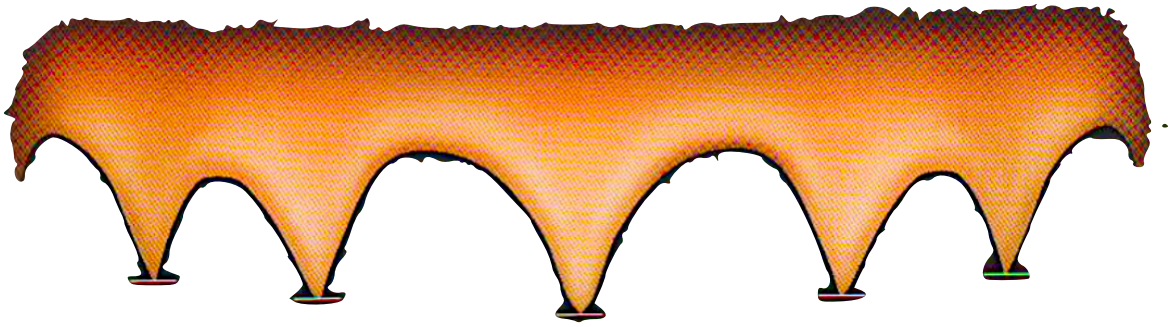


Figure 78. Papilla height of the anterior teeth. Made by Fradeani M.[9]

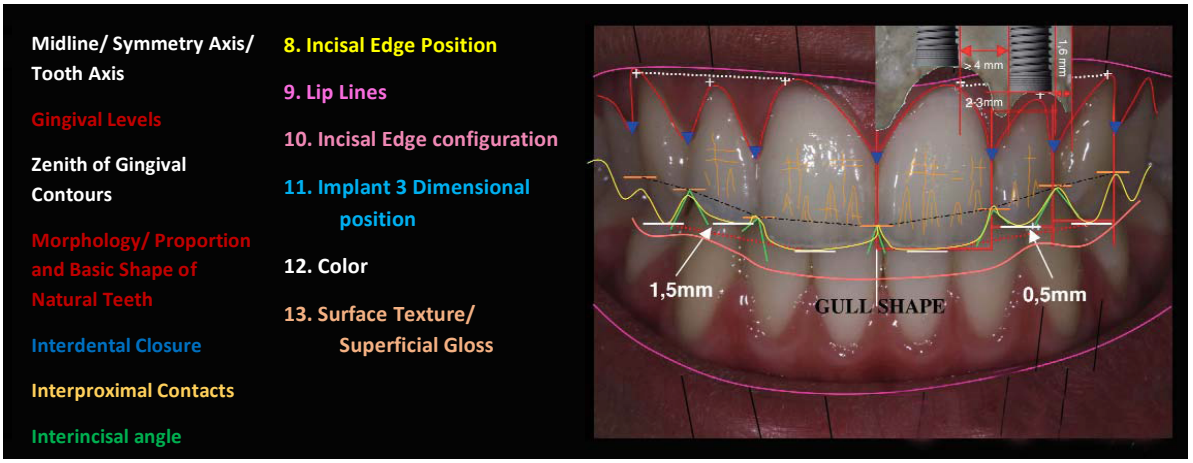


Figure 79. Overview of dental analysis, ideal considerations for aesthetic prosthetic restorations. In the case of implant depth, 4mm from the implant head to the gingival margin is currently recommended. Made by Adolfi A.[37]

DSD (Digital Smile Design) VIRTUAL AND REAL MOCK-UP

2D CONCEPT

‘The drawing and placement of lines on the photo of the patient, which after a specific sequence improves the evaluation of the aesthetic relationship between the teeth, gingiva, smile and face.’ ‘DSD involves the patient and the technician in decision making and helps to establish a hierarchy in problem solving’ [38].



Figure 80. 2D DSD composition. Made by Ferrando A.



Figure 81. Dispensing Bisacryl in a silicone key to perform the actual Mock-up. Made by Ferrando A.



Figure 82. Immediate result of the actual Mock-up. Made by Ferrando A.



Figure 83. Facial comparison start-up/mock-up after analogue waxing based on a 2D DSD. Made by Ferrando A.

This allows the result to be previewed digitally (virtual mock-up) and nowadays it is possible to print the project as a model to actually test it using a silicone key and bisacrylic resins (real mock-up).



Figure 84. Clinical case. Initial situation. Made by Ferrando A.



Figure 85. Clinical case. Virtual 2D mock-up situation. Made by Ferrando A.



Figure 86. Clinical case. Real mock-up situation. Made by Ferrando A.



Figure 87. Clinical case. Final restoration situation with porcelain facets, showing the closure of diastemas and the restoration of the occlusal plane, as well as a more harmonious smile. Made by Ferrando A.

3D CONCEPT

Due to the current boom in facial and intraoral scanners, as well as planning software based on libraries of natural teeth supported by 3D printers, it is now possible to perform a complete diagnosis on the virtual patient; from surgery, through orthodontics to definitive aesthetic rehabilitation mounted on a virtual articulator, made from the segmentation of the jaw in the CBCT and locating real condylar points. The most important aspect being that everything is facially generated, starting from aesthetics as the first premise. It is therefore a very

powerful tool, which will become indispensable when it comes to establishing the diagnosis and treatment plan with the clinical team and communicating with the patient[39].



Figure 88. Alignment of an .obj file (AFT Face Scanner) with a .stl file in a 3D digital design software (Exocad). Made by Ferrando A.[39]



Figure 89. Initial situation. A 3D DSD (Nemotec Biotech France software) will be developed to prepare injected composites. Made by Ferrando A.

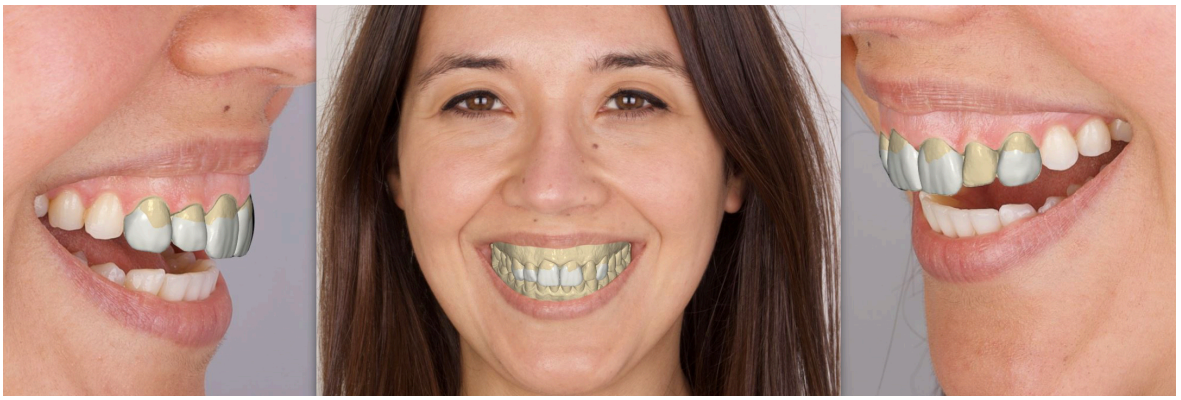


Figure 90. DSD 3D from 1.3 to 2.3 with Nemosmile design 3D software (Nemotec Biotech France). Made by Martínez Ballester MJ.

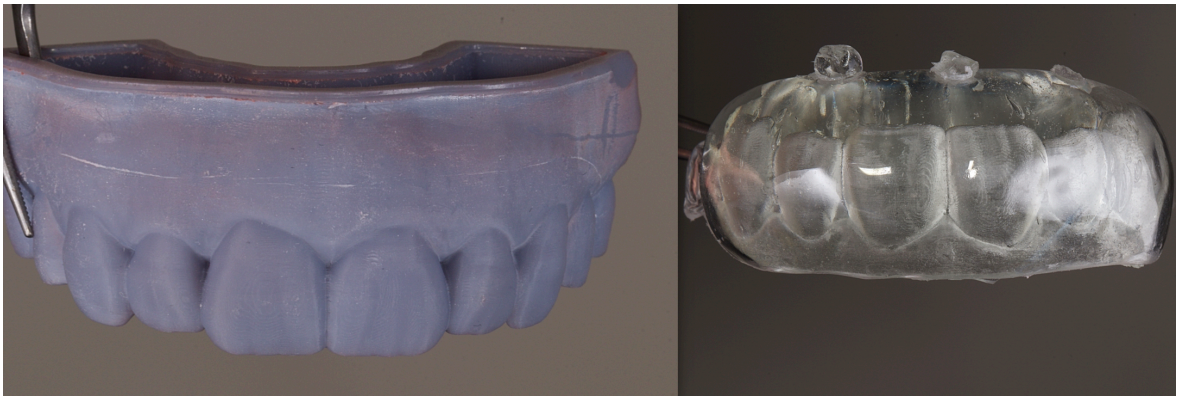


Figure 91. Digitally printed 3D wax-up model and transparent silicone key (Exaclear GC Japan) Made by Martínez Ballester MJ.



Figure 92. Immediate final result comparison of injected composites/printed model. Made by Martínez Ballester MJ and Ferrando A.



Figure 93. Comparison of right profile before/planning of 3D digital waxing/final result. Made by Martínez Ballester MJ and Ferrando A.



Figure 94. Comparison of left profile before/planning of 3D digital waxing/final result. Made by Martínez Ballester MJ and Ferrando A.



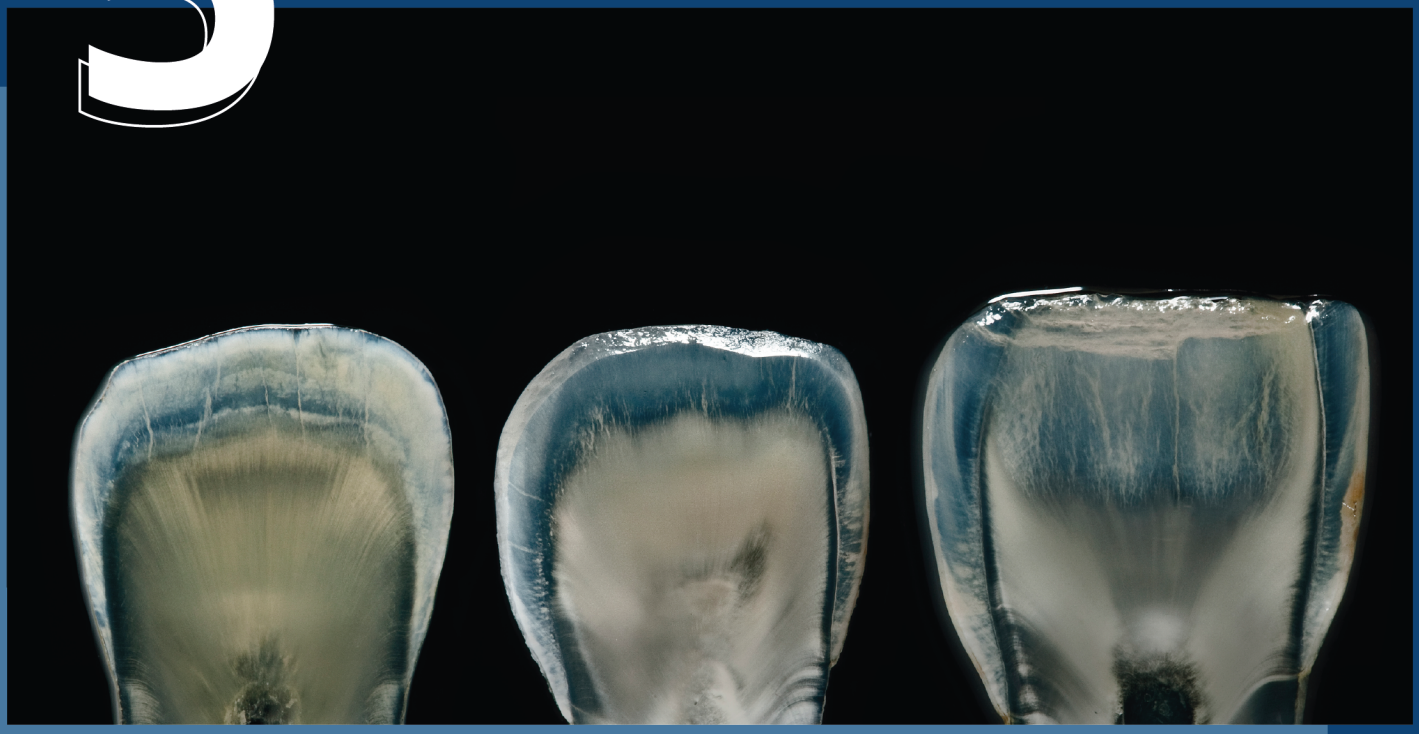
Figure 95. Immediate final result. Face and smile.



Figure 96. Final result after one year. Smile.

UCAM

Chapter 5



Aesthetic composite resins

Photo by Dr. Fernando Rey Duro

5.1. Definition

Composite resin is one of countless varieties of synthetic resins applied in dentistry, to which inert filler particles are added for the purpose of increasing strength and reducing the adverse effects of polymerisation shrinkage. The resins serve as an organic matrix for the insertion of the filler particles that increase the strength of the whole[40].

5.2. Basic composition of composite resins

The main components of composite resins are *organic matrix, inorganic particles and bonding agent*[41].

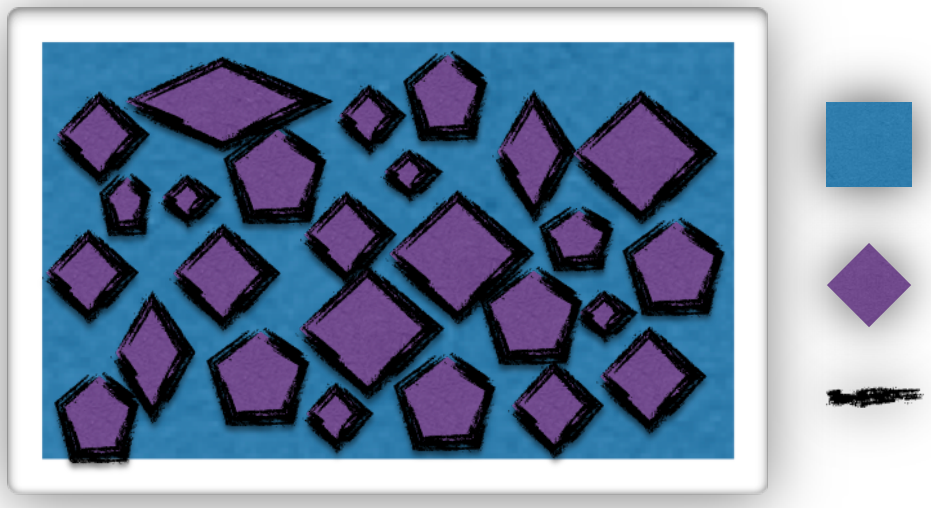


Figure 97. Mosaic outlining the composition of the composite. The blue mantle resembles the organic matrix in which the inorganic particles are embedded, shown in purple and lined in the bonding agent (black line), silane. Made by Carmona JJ.

5.2.1.Organic matrix

A set of monomers and molecules that constitute the base of resins. It consists of[40]:

1. High molecular weight monomers: bis-GMA, bis-EMA, UDMA.

   These are the base monomers in most composite resins. They reduce the undesirable effects of polymerisation shrinkage, preserving the bonding interface with the substrate. They have a high viscosity hindering the clinical handling of resins.

2. Diluents: MMA, EDMA, TEGDMA

   These are low molecular weight, low viscosity monomers. They are used to alleviate the problem of poor handling caused by the high viscosity of high molecular weight monomers.

3. Activators and Initiators:

   These are the triggers for the polymerisation of the composite resin. The molecules that make up these systems are specific and vary according to the type of polymerisation reaction, which can be chemically or by visible light.

4. Inhibitors: Hydroquinone

   Prevents spontaneous polymerisation of the resin when it has brief exposure to light, which prolongs its life and working time.

5. Radiopacifiers:

   These are heavy materials that generate a white image on the radiograph of the restoration for control.

5.2.2.Inorganic particles

To improve the properties of composite resins, different types of filler particles have been incorporated into their composition. The most commonly used particles are colloidal silica, zirconium-silica particles or glasses and ceramics containing heavy materials such as barium, strontium or zirconium. Depending on the category of composite resin, the particles have characteristic dimensions and distribution and are essential in determining its properties.

Generally speaking, the inclusion of inorganic content in composite resins reduces polymerisation shrinkage and thermal expansion coefficient, increases hardness and improves mechanical properties. Clinically, the handling and working consistency are also improved[40].

5.2.3.Bonding agent

The integrity of composite resins depends primarily on effective bonding of the organic matrix to the inorganic portion. This bonding is done by treating the surface of the inorganic particles with a bonding agent, commonly **silane**. This is a bifunctional molecule capable of forming, at one end, covalent bonds with the silica present in the particles, while the other end is available for copolymerisation with the organic matrix. The deficiency in this interaction implies an uneven distribution of the forces applied on the material during masticatory activity. This imperfection allows water to penetrate the resin-load interface, which compromises the clinical performance of the restoration[40].

A rare but very interesting exception in restorative dentistry is the group of **ormocers**, which act as hybrids between inorganic ceramics and organic polymers, such as Admira Fusion (VOCO), which does not have a classic Bis-GMA, UDMA, or TEGDMA resin matrix. Instead, it uses a resin matrix based on ORMOCER (“organically modified ceramic”) technology, developed in collaboration with the Fraunhofer Institute in Germany. This is a siloxane-organic hybrid matrix: the base resin is formed by **silicon** (Si-O-Si) networks modified with functional organic chains capable of polymerizing.

Clinical advantages of the ORMOCER matrix

• No classic monomers (Bis-GMA, TEGDMA, UDMA): reduces the risk of sensitization and release of potentially toxic substances.

• High chemical stability: means less water absorption and less degradation.

• Low polymerization shrinkage: improves marginal adaptation and longevity of the restoration.

• High biocompatibility: excellent option in areas close to the gums or in patients with allergies, although the **disadvantage** is that more work is required for finishing and polishing, and it does not hold up as well over time.

5.3. Developments in composite resins

In recent years, there has been an intense transformation of the characteristics of the inorganic portion of composite resins as a consequence of the emergence of filler particle product technology, new grinding techniques and the sol-gel process of chemical precipitation. This made it possible to develop new categories of composite resins with specific properties that improved clinical performance and durability.

To group the different composite resins, a classification system was developed based on their average particle size and size distribution[40].

The division into classes also serves to show the evolution of resins over the years, including some models used in the past that are no longer marketed today.

- **Acrylic resins**

  Contains only organic matrix, no filler particles.



Example: Composite Primer

Figure 98. Acrylic resin and brush for composite handling. Made by Carmona JJ.

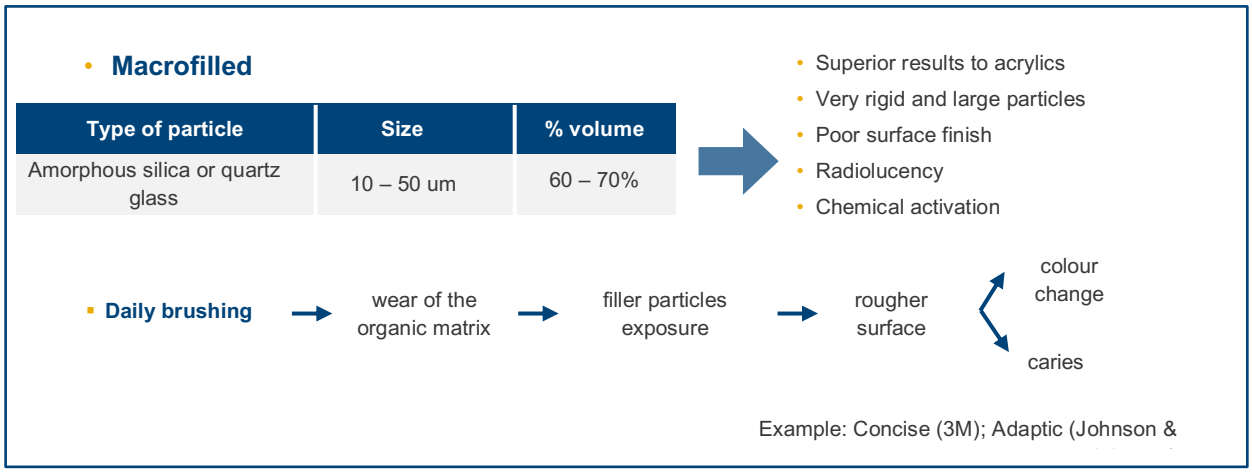


Figure 99. Characteristics of macrofilled composites. Made by Carmona JJ.

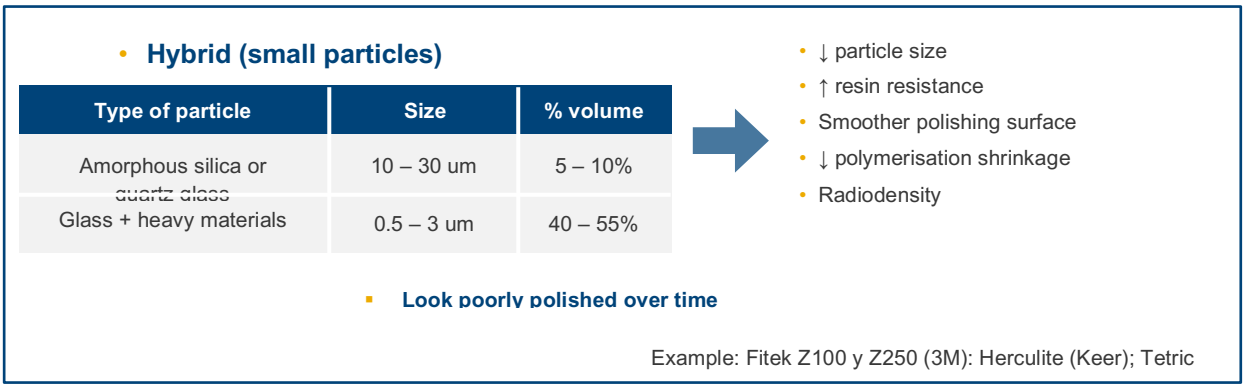


Figure 100. Characteristics of hybrid composites. Made by Carmona JJ.

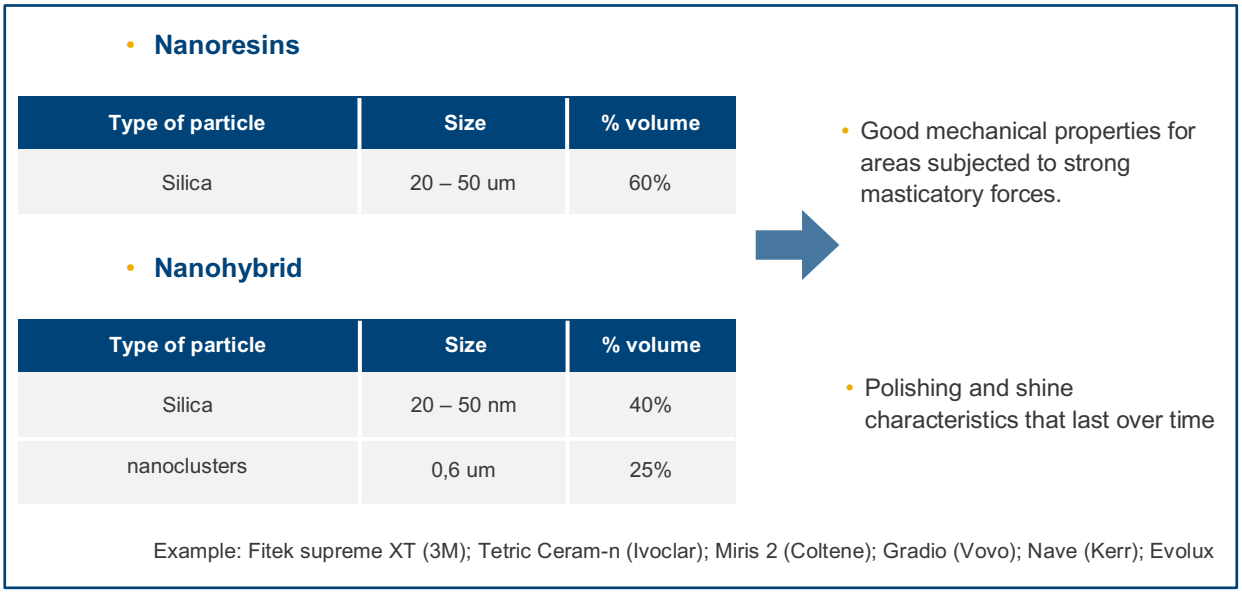


Figure 101. Characteristics of nanoresins. Made by Carmona JJ.

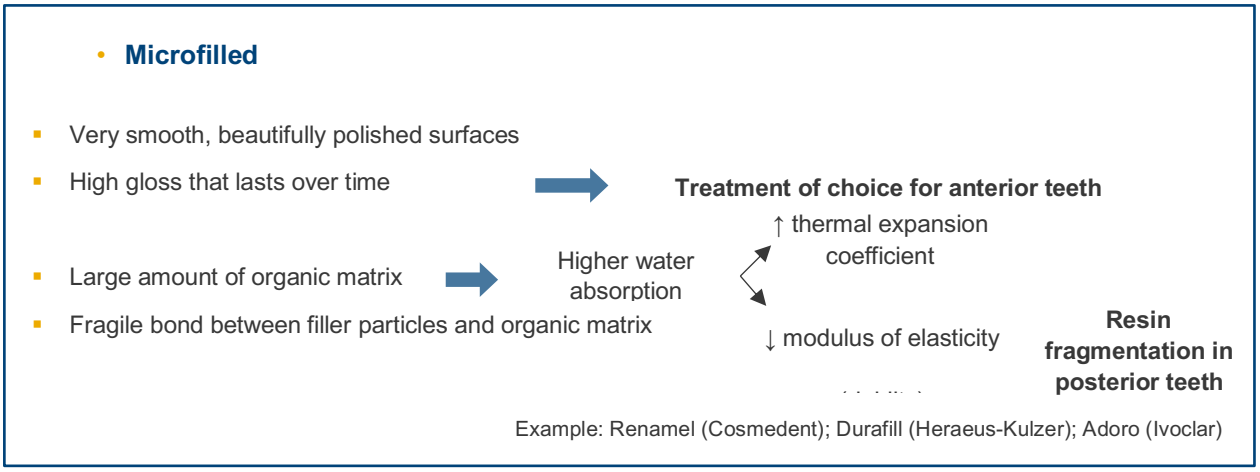


Figure 102. Characteristics of microfilled composites. Made by Carmona JJ.

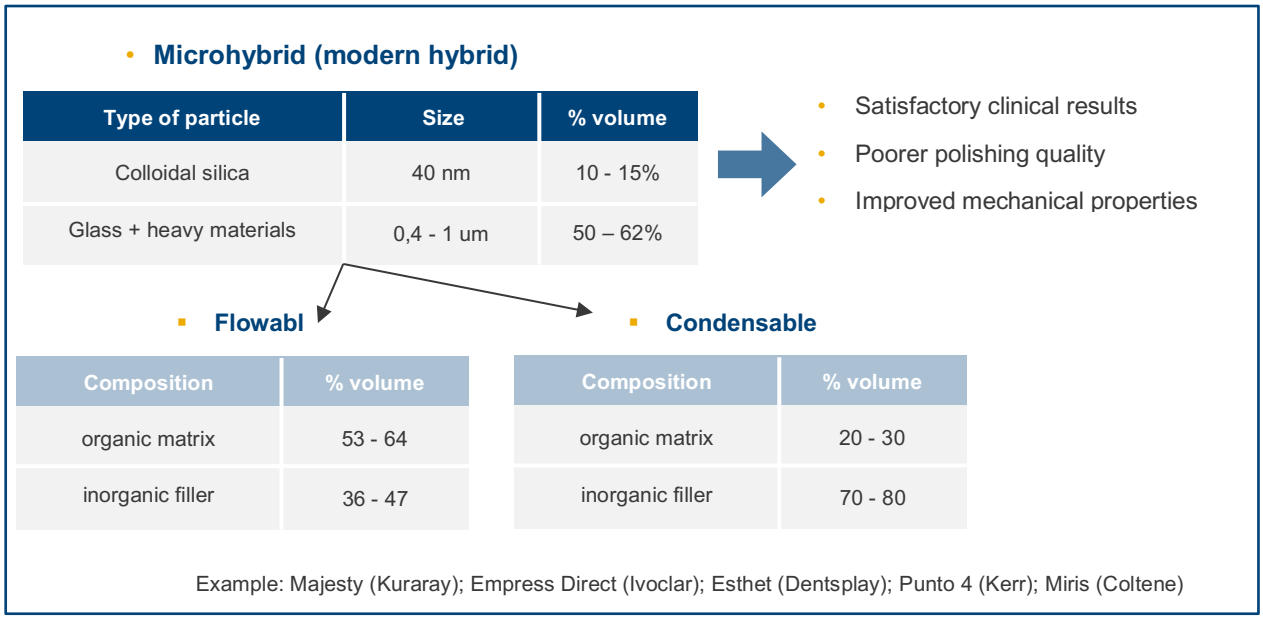


Figure 103. Characteristics of microhybrid composites. Made by Carmona JJ.

5.4. Characteristics of composite resins

Modern restorative dentistry is centred on concepts that aim to preserve tooth structure, and the choice of restorative materials and techniques capable of producing a behaviour similar to that of natural teeth. Composite resin exhibits mechanical properties similar to those of dentin, including modulus of elasticity, stiffness and resilience. These properties mean that the material behaves in a way that is similar to lost tooth tissue in terms of deformation and absorption of masticatory forces. In addition, it is able to effectively bond to dental tissues by means of adhesive systems and hybrid layer formation in a manner comparable

to that which occurs naturally at the dentinoenamel junction. Therefore, it is possible to achieve a biomechanical performance of the restored tooth similar to that of the intact tooth during masticatory function.

Another characteristic of this material is the diversity of colours, which makes it possible to reproduce dental polychromatism, conferring characteristics of excellence in the aesthetics of the restorations. These are the main characteristics that explain the clinical success of this restorative treatment model, which is able to combine biological and aesthetic aspects[40].

5.5. Use of composite resins

A. In anterior teeth:

1. Minor space closures.
2. Isolated problems.
3. Aesthetic restorations.
4. Minor alterations of shape.
5. Minor colour alterations.
6. Orthodontic completion in young patients.

B. In posterior teeth:

1. Cavities with reduced proximal boxes.
2. Cervical terminations visible and easily accessible.
3. Cavities without loss of cusps.

5.5.1. Main failure factors in composite resin restorations

A. Most frequent causes:

1. Retention failure (mainly in Class V cavities) or fracture of a part of the restoration (mainly in Class IV and in proximal boxes of posterior teeth).
2. Marginal pigmentation associated or not with maladaptation.
3. Caries adjacent to the restoration (CAR) and around the restoration edge.

B. Less frequent causes:

1. Body shade changes.
2. Loss of colour combination.

5.6. Large composite resin treatments in the anterior and posterior regions

These treatments described below are only suitable for dentists with highly developed skills and experience in the use of composite resins in the field of conservative dentistry in the area of dental aesthetics.

A. Protocol for the treatment of composite veneers using the direct technique:



Figure 104. Initial situation. Meet with the patient to discuss his or her aesthetic demand. Made by Carmona JJ.

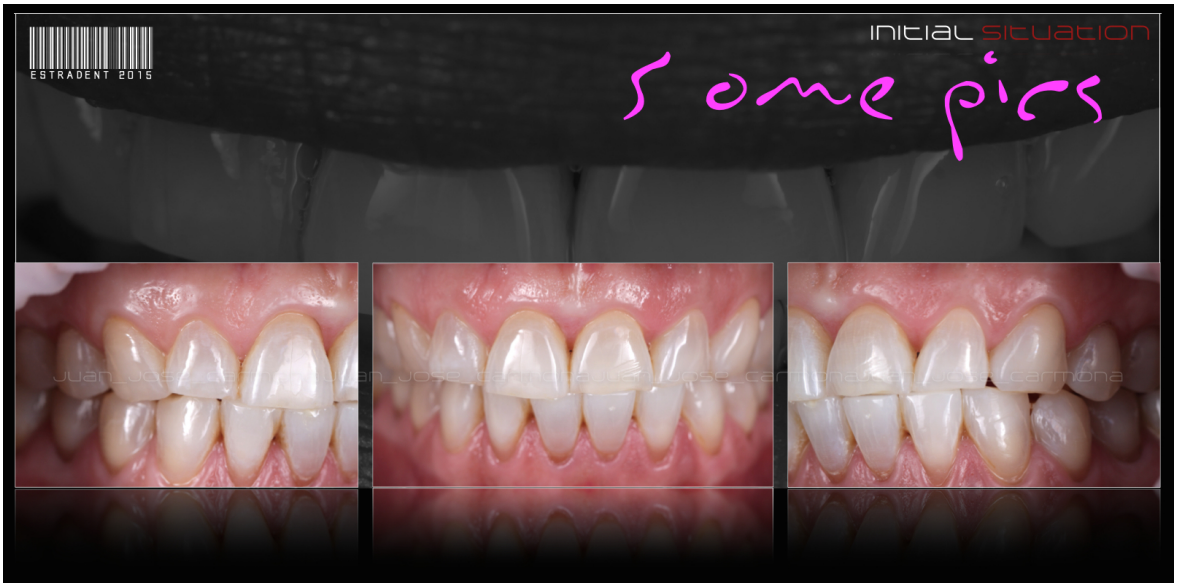


Figure 105. Take pictures or videos. Apply what you learned in Seminar 1. Made by Carmona JJ.

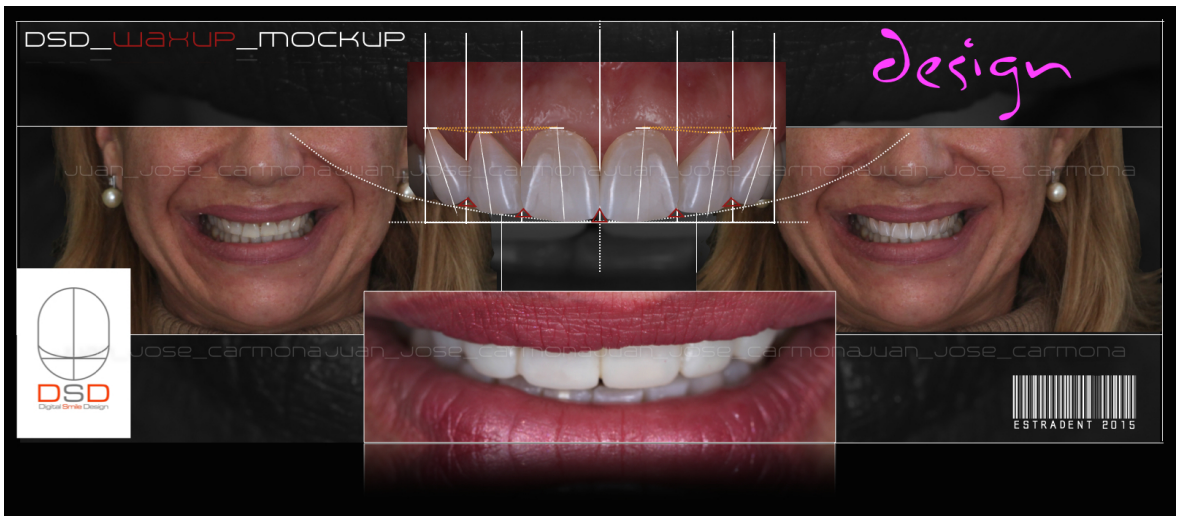


Figure 106. Case study and diagnosis. A DSD is always necessary and has to be confirmed with a mock-up. Order a diagnostic wax-up and reference silicone keys from the laboratory. Made by Carmona JJ.

DECIDE THE TREATMENT PLAN TO BE FOLLOWED

The patient must sign the informed consent form for treatment.

1. Analyse the characteristics of the teeth to be restored and choose the composite resins to be used. Apply what you learned in Seminar 1.

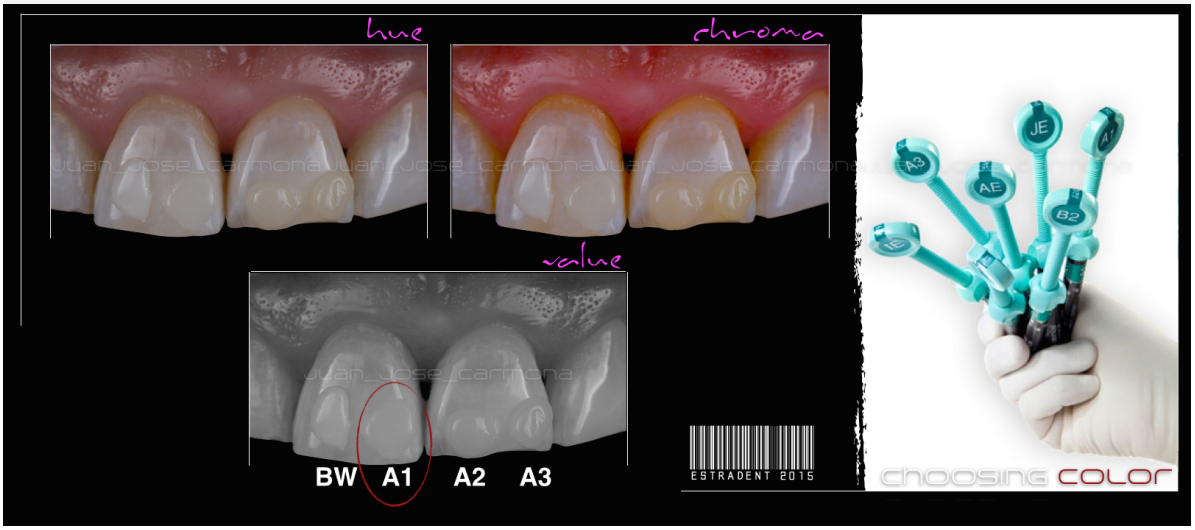


Figure 107. Analysis of the characteristics of the teeth. Made by Carmona JJ.

2. All restorative treatment with composite resins involves the placement of a rubber dam for absolute isolation.



Figure 108. Absolute isolation with rubber dam. Made by Carmona JJ.

3. To prepare the veneers, it is advisable to bevel the edges.



Figure 109. 45° bevel of incisal edges. Made by Carmona JJ.

4. Sandblasting with aluminium oxide and acid etching with total technique to prepare enamel and dentin for the adhesive.



Figure 110. Sandblasting and acid etching. Made by Carmona JJ.

5. Adhesive application:

   Two coats of primer are recommended followed by two coats of bond, removing all solvent.

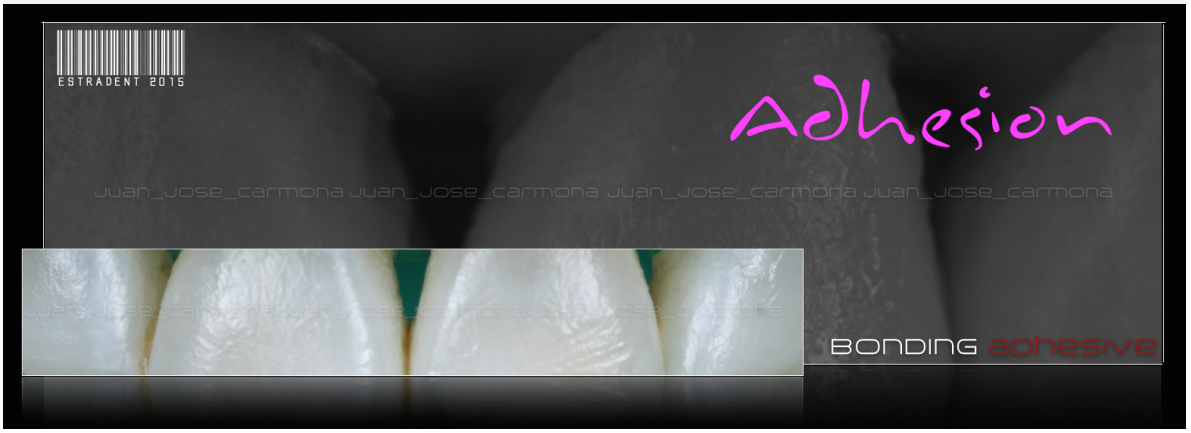


Figure 111. Adhesive application. Made by Carmona JJ.

6. Create palatal walls:

   Base and starting point of the restoration. Use silicone keys.



Figure 112. Palatal walls and incisal edge using silicone keys. Made by Carmona JJ.

7. Make the dentin layers: IN, internal stratum.



Figure 113. Dentin layers. Made by Carmona JJ.

8. Create characterisations using shades: MID, intermediate layer.



Figure 114. Application of shades. Made by Carmona JJ.

9. Make the enamel layers: OUT, external layer.



Figure 115. Enamel layers. Made by Carmona JJ.

10. Analyse the line angles and give the desired shape to the restoration: Square, triangular or oval teeth.

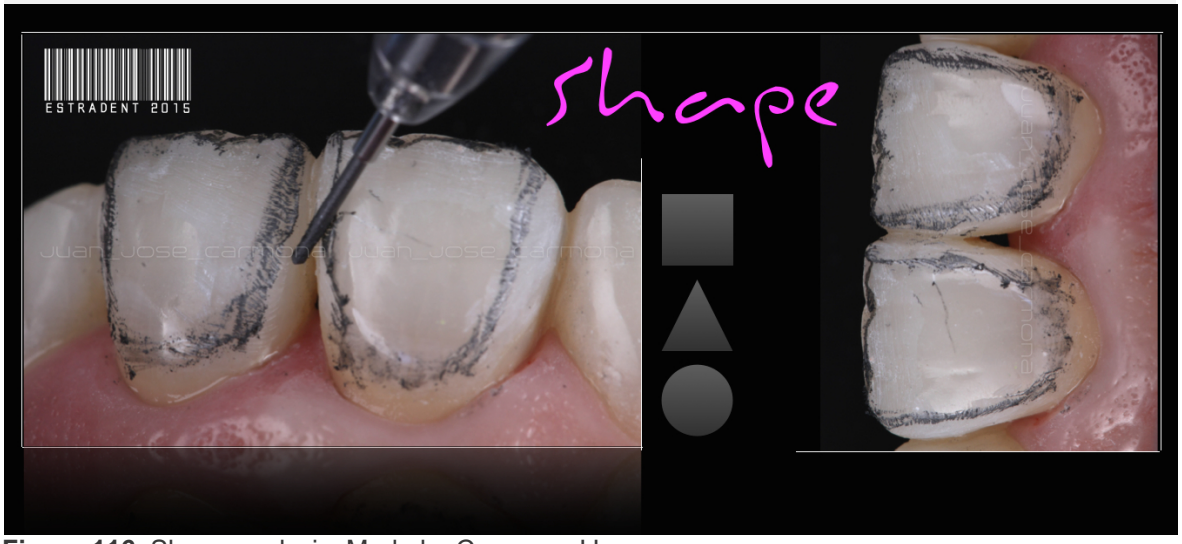


Figure 116. Shape analysis. Made by Carmona JJ.



Figure 117. Analysis and creation of macrotexture. Made by Carmona JJ.

11. Generate microtexture.



Figure 118. Analysis and creation of microtexture. Made by Carmona JJ.

12. Apply final polishing protocol.



Figure 119. Final polishing. Made by Carmona JJ.

13. Post treatment evaluation. Wait for the rehydration effect.



Figure 120. Post-treatment evaluation. Made by Carmona JJ.

14. Schedule a follow-up appointment one week later to evaluate the restorations after the rehydration effect.



Figure 121. Post treatment evaluation 1 week later. Check: incisal edge, tooth-restorative interface, shape, texture and colour. Made by Carmona JJ.



Figure 122. Pre- and post-treatment comparison. Made by Carmona JJ.

Once the restoration treatment with composite veneers has been completed, the patient is given a sheet with the pertinent recommendations and a series of appointments for the proper maintenance of the treatment.

B. Action protocol for the treatment of large reconstructions in the posterior area by direct technique:

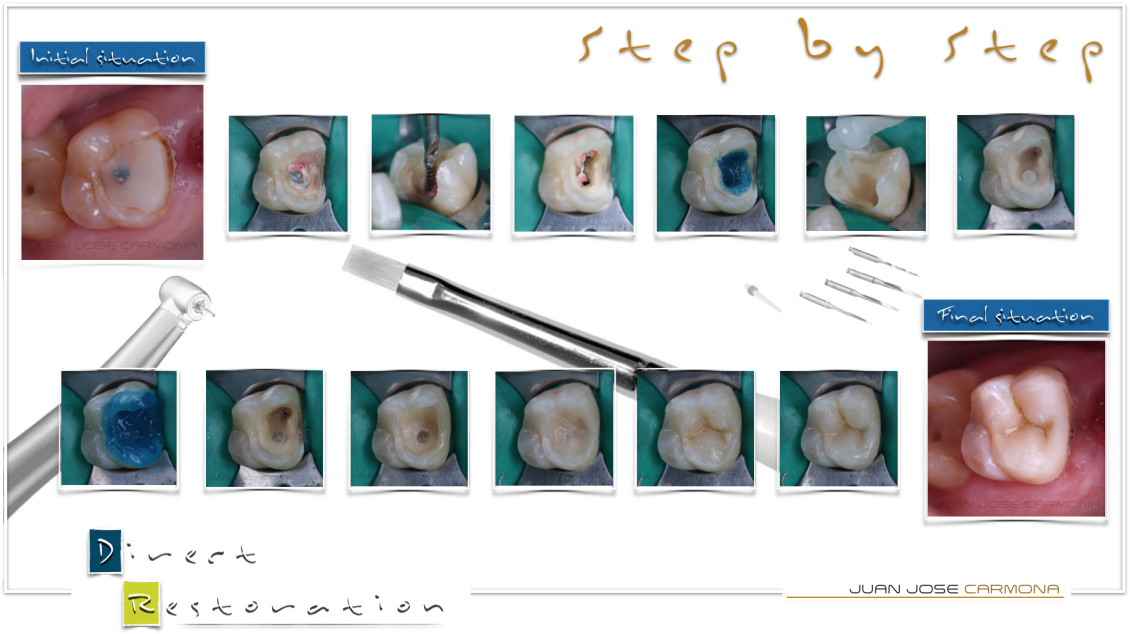


Figure 123. Protocol for direct posterior reconstructions. Made by Carmona JJ.

The great advance in adhesive dentistry, together with composites, is the use of direct resins in posterior restorations. In order for this practice to be safe and durable, it must be correctly prescribed and judiciously followed in all its steps, as the technique is very sensitive and any oversight in the details may result in future failures[36,37].

Direct restorations in posterior teeth are rather indicated when there are not very extensive occlusal and proximoocclusal boxes, without cusp loss and without very low walls. Situations where there is a major loss of structure involving cuspids, extensive proximal cases and very cervical endings with difficult access are best treated with semi-direct clinical or indirect laboratory restorations[41,42].

Clinical case:

The patient comes to the clinic to have two old restorations redone:

1. Radiographic and clinical visual analysis of the piece to be restored. Provide the informed consent for a restoration with composite resins for the posterior sector.



Figure 124. Clinical analysis. Made by Carmona JJ.

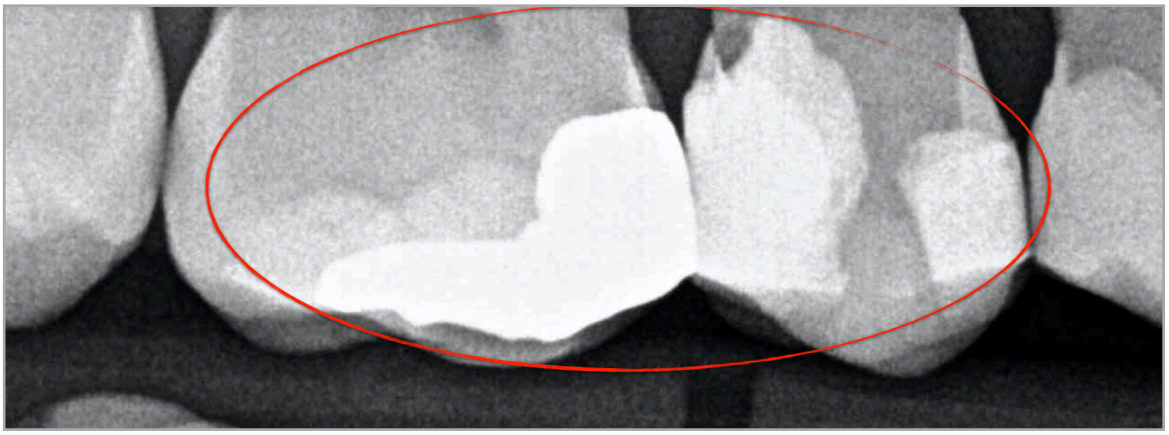


Figure 125. Radiographic analysis. Made by Carmona JJ.

2. Absolute isolation with rubber dam for a safe treatment.

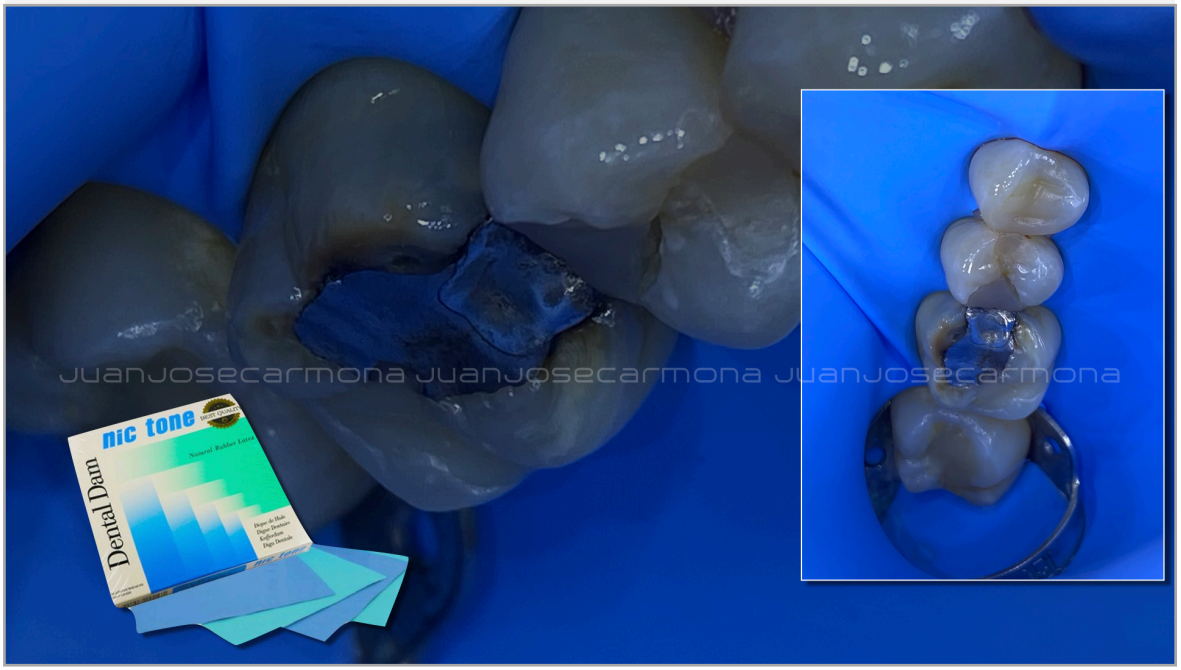


Figure 126. Absolute isolation with rubber dam. Made by Carmona JJ.

3. Removal of carious tissue, old leaking or fractured restoration. When this is due to fracture, evaluate the cause of the fracture very well.

4. Verify the absence of carious tissue with caries detector.

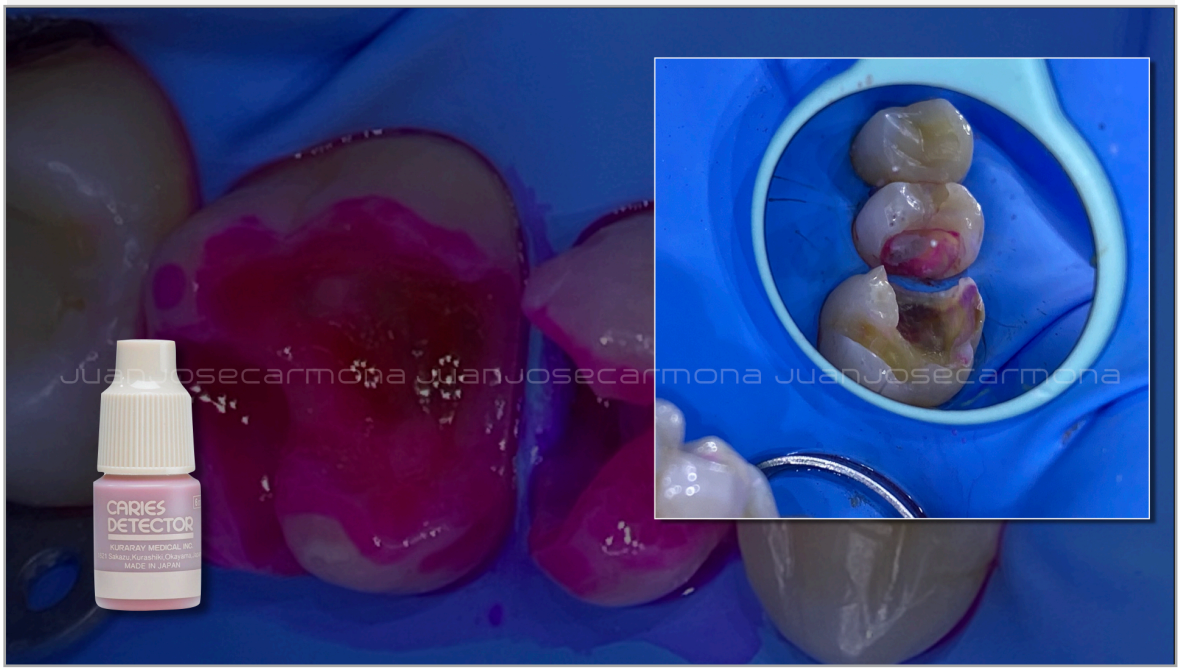


Figure 127. Detect and remove carious tissue. Made by Carmona JJ.

5. Analyse the cavity to be restored: cusp involvement, size of proximal boxes and very cervical endings.



Figure 128. Analysis of cavity and remaining tooth structure. Made by Carmona JJ.

DECIDING ON THE TECHNIQUE TO BE USED FOR THE RESTORATION:

DIRECT / SEMI-DIRECT / INDIRECT



Figure 129. Choosing the restorative technique according to the remaining tooth structure. Made by Carmona JJ.

6. In class II cavities it is necessary to place a wedge, matrix and ring to reconstruct the proximal side.
7. Sandblasting with aluminium oxide and acid etching with selective technique to prepare enamel for the adhesive.

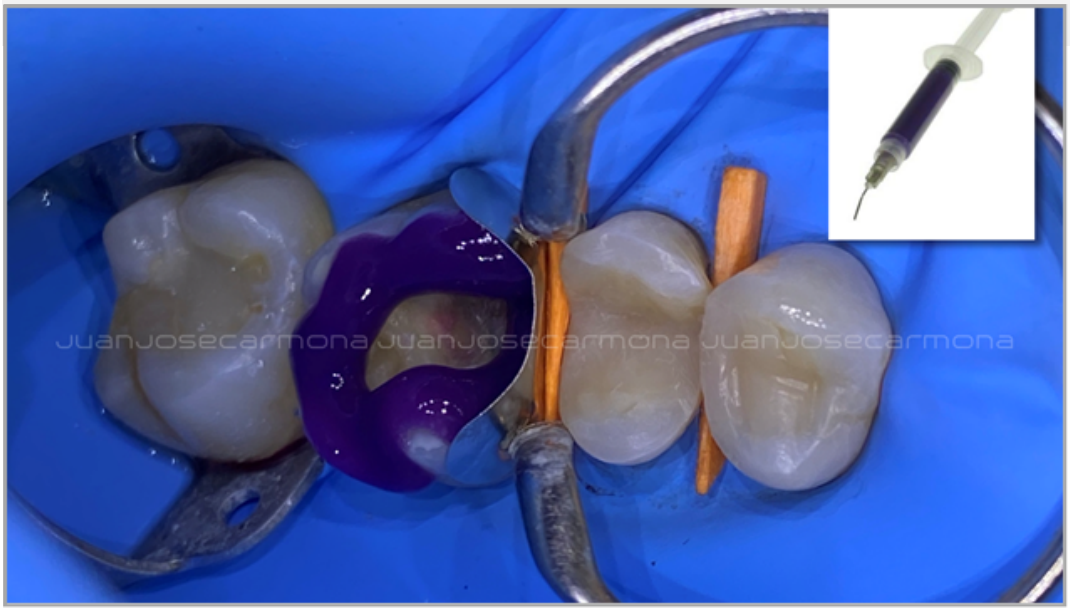


Figure 130. Use of matrix, wedge and ring to restore proximal wall in Class II cavities. Made by Carmona JJ.

8. Adhesive application: one coat of primer is recommended followed by two coats of bond, removing any excess with air.



Figure 131. Two-step adhesive application. Made by Carmona JJ.

9. Initial restoration of the proximal wall using flowable resin in the first layer and then condensable resin for finishing.

10. Remove matrix and ring, leaving the wedge in the proximal.

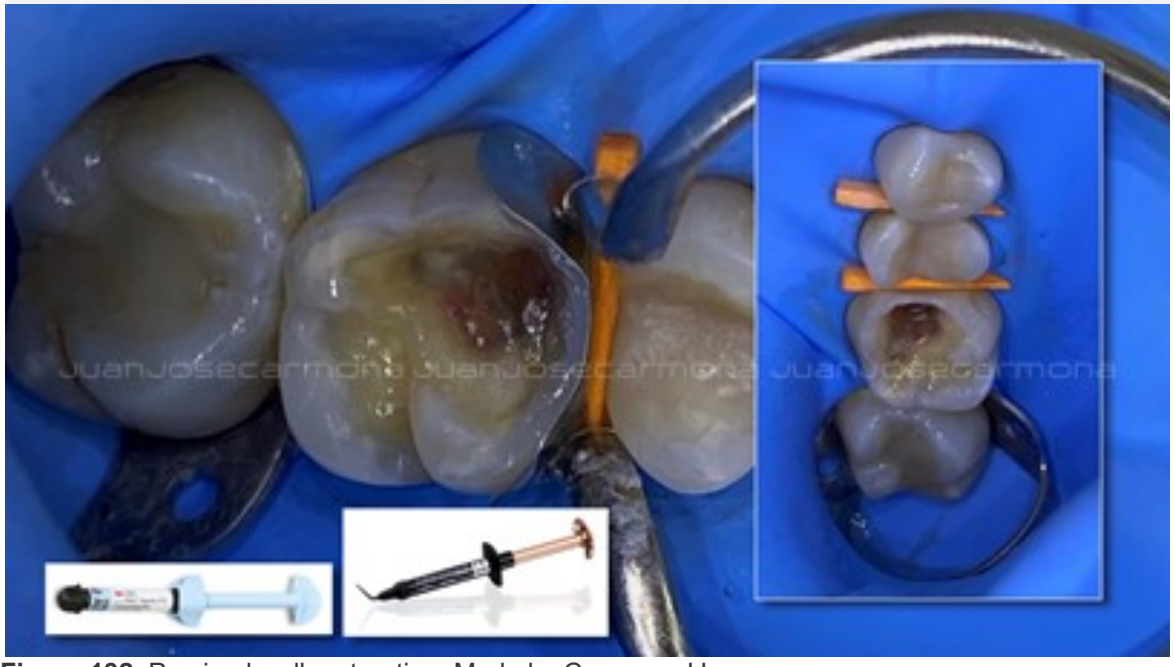


Figure 132. Proximal wall restoration. Made by Carmona JJ.

11. Make the dentin layers: IN, internal stratum.



Figure 133. Creation of dentin layers. Made by Carmona JJ.

12. Create characterisations using shades: MID, intermediate layer.



Figure 134. Characterisation by means of shades. Made by Carmona JJ.

13. Make the enamel layers: OUT, external layer.



Figure 135. Applying enamel layers. Made by Carmona JJ.

14. Adjust occlusion.



Figure 136. Occlusion adjustment using articulating paper. Made by Carmona JJ.

15. Apply final polishing protocol.



Figure 137. Final polishing. Made by Carmona JJ.



Figure 138. Pre- and post-treatment comparison. Made by Carmona JJ.

UCAM

Chapter 6



Composite resin stratification

Photo by Dr. Carlos Oteo Morilla

6.1.Definition



Figure 139. Natural stratification. Image taken from *Google Images*.

- **Stratum**: a single thickness of material that forms a more complex structure.
- **Stratification**: the action of creating a complex structure from the union of different strata or layers.

The best example of divinely designed structures is the tooth, as it combines completely different substrates: the dentin (D), the dentinoenamel junction (DEJ) and the enamel (E), resulting in a perfect combination of their respective properties that eliminates the individual weaknesses of each stratum. Enamel is brittle, but at the same time rigid and resistant to wear; dentin is the exact opposite; the dentinoenamel junction is the perfect adhesive between them. Without a doubt, this 'dental trinity' (E-DEJ-D) is one of the best examples of "union" to be emulated by today's society in order to function with greater harmony and cohesion [41].



Figure 140. Microanatomy. Made by Carmona JJ.

6.2. Colour for stratification

In an aesthetic restoration, stratification does not only depend on the colour itself, i.e., on the correct choice of **hue** (shade family), **saturation** (amount of shade or pigment concentration) or **value** (degree of brightness of the shade, which varies between light and dark, depending on the amount of black and white)[41,43].

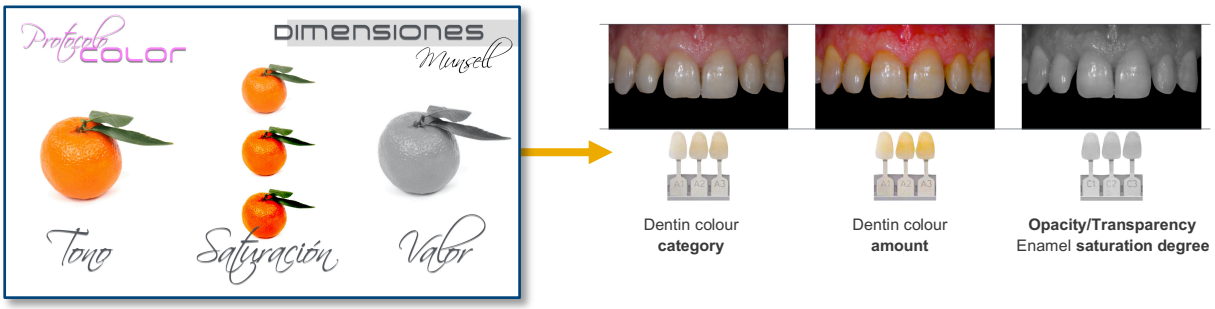


Figure 141. Colour properties. Made by Carmona JJ.



Figure 142. Colour properties. Made by Carmona JJ.

Light dynamics is also an important phenomenon, as it influences the faithful reproduction of the features of the natural dentition. Inadequate analysis of the optical behaviour of light on the tooth element can lead to unsuccessful restorative procedures[40,44].

Based on the concept of light transmission, which is the ability of a body to allow light to pass through it, the best transmitter, related to the incident light, can be classified as **opaque**, **transparent** or **translucent**. In other words, bodies and materials may or may not let light pass through them. If light passes through (refraction), they are referred to as transparent or translucent; if not (reflection), they are referred to as opaque. The optical behaviour of each medium is determined by the degree of scattering, refraction or absorption of the light beam inside[41,44-46].

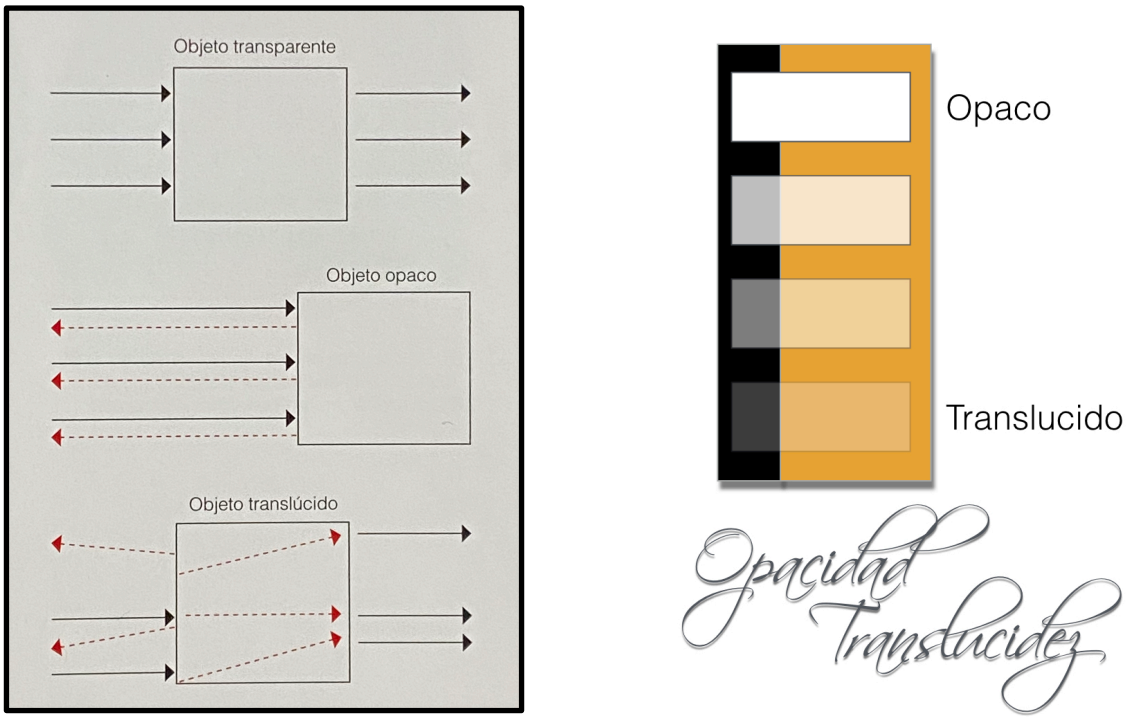


Figure 143. Light penetration capacity in an object according to its translucency and opacity. Taken from Manauta J[41].

There are three important factors to consider in a translucent body: the presence or absence of colour, the thickness of the material and the translucency degree. With regard to colour, there are both achromatic and chromatic translucent bodies:

The body is achromatic translucent →	no universal pigments in its base
The body is chromatic translucent →	it has universal pigments in its composition

Enamel resins are available with different pigments or no pigments at all and represent chromatic and achromatic translucency, respectively. Therefore, the colour perception of the dentin resin will be influenced by the enamel resin of choice.[1]

With regard to the thickness of the material, this factor is directly related to the variation of the refractive index of light in a translucent body. Therefore, as light is scattered inside it, the material becomes diffuse. Thanks to this characteristic, the translucency of a body can vary and leave a body with greater or lesser translucency; that is, for a material with two different thicknesses (0.5 and 2mm), the one with the lesser thickness will be more translucent. In the natural dentition, the thickness of the enamel is very variable, greater in the incisal area and gradually decreasing in the cervical direction. Consequently, the translucency of the cervical area will be higher compared to the incisal region, which provides a better perception of the dentin[41,45,46].



Figure 144. Opacity and translucency in natural teeth. Taken from Manauta J.[1]

The translucency of a body is inherent to the material and is its inherent characteristic. Light does not always pass through a material with the same direction of incidence, but a significant part is deflected by the action of particles or irregularities in the material it passes through. This concept is called scattering.

In dentistry, to imitate enamel, two phenomena are combined: translucency and value. Increasing the value of the resins increases the amount of white, altering their translucency. As a general rule, an increase in value results in an increase in opacity[41,46].

The use of high translucency materials will result in depth of shade and the appearance of a natural, vital tooth. If the outer layer has low translucency, it will hide the colour of the underlying dentin, its effects and characterisations. If the composite enamel is excessively translucent, there will be a violent absorption of light and little reflection, which means a loss of value and brightness and, consequently, a grey restoration.

Translucency is directly related to scattering, and these two concepts depend on the refractive index of the material. This paradox of a material having high translucency and high scattering and luminosity at the same time is called **OPALESCENCE**. To appreciate the opalescence of a material, it must be observed under different angles of light. Opalescent masses alter the passage of light; they appear blue under incident light and show amber and orange characteristics when backlit[41,44,46].

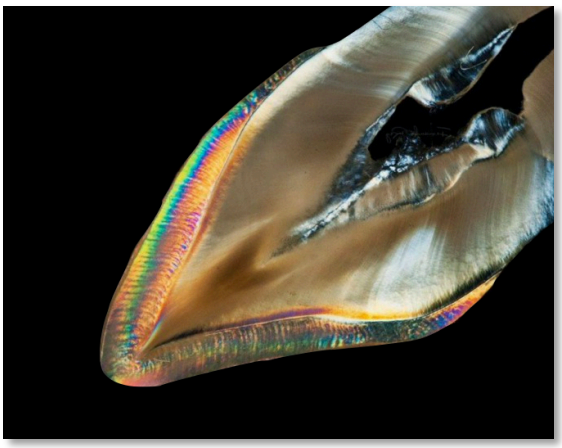


Figure 145. Opalescence in a natural tooth. Taken from Manauta J[41].

6.3. Strata

Just as the natural tooth is made up of different strata or layers, different layers are also used when restoring teeth. During the stratification of aesthetic materials there are three layers: the inner layer (In), the outer layer (Out) and the middle layer (Mid)[41].

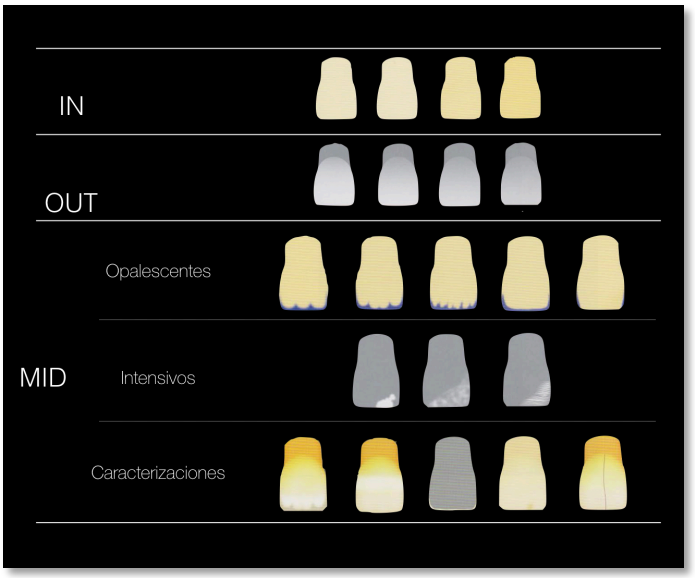


Figure 146. Layers for stratification of composite resins. Taken from Manauta J.[41]

- **In:** the inner layer consists exclusively of dentin.
- **Out:** the outer layer consists of enamel.
- **Mid:** the intermediate layer is used to reproduce special effects that occur spontaneously in natural enamel.

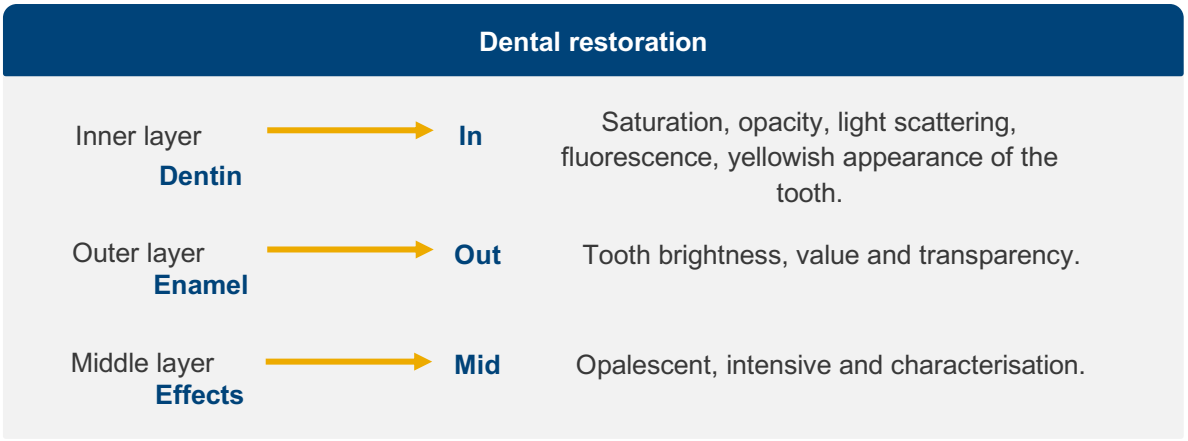


Figure 147. Colour properties to be transferred in the different stratification layers. Made by Carmona JJ.

Resin layers for stratification:

The success of anterior restorations is directly related to a good selection of resins with **favourable optical characteristics** and to their use with **adequate thicknesses** in the different regions of the tooth.

The actual stratification and method for working with composite resins is as follows: resins for body (dentin/opaque), resins for chromatic enamel (enamel or translucent) and resins for achromatic enamel (incisal, transparent or value resins). These resins each represent their own degree of translucency, which allows them to play a specific role within the stratification of the restoration[41,46].

1. Resin for the first layer. **IN**

   Usually called *opaque* or *dentin*, these are marked with a letter in addition to the colour 'O' or 'D'.

2. Resin for the second layer. **OUT**

   These are called chromatic or translucent enamel resins. They often have no special designation: when the resin does not indicate the layer for which it is intended, it is chromatic enamel. They are applied as a final layer or, depending on the stratification technique used, as a second to last layer.

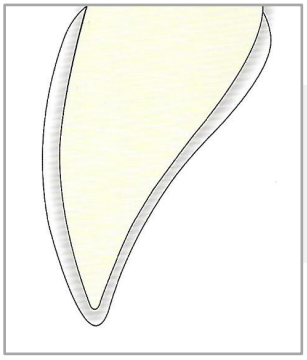
3. Resin for the third coat. **OUT**

   The correct name would be achromatic glaze, but each manufacturer creates a specific one. They can be used as a final layer in some dental regions and in some clinical situations, but their use is not mandatory and is not included in the protocol for all resins.

4. Resins for effects. **MID**

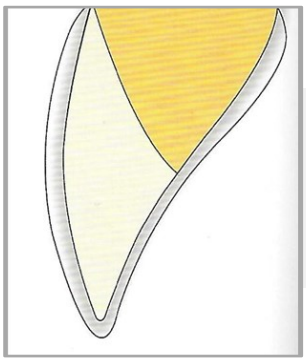
   These are resins used to reproduce effects in specific areas such as incisal and proximal, or even to reproduce regions with different characterisations or hypoplastic stains.

6.4. Compendium of stratification techniques with composite resins



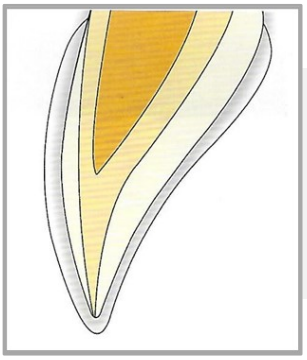
1. Single layer of enamel and dentin. Easy to use, this technique is useful for first-time users, as you can develop most of the shades.

Figure 148. Single layer technique. Taken from Manauta J.[41]



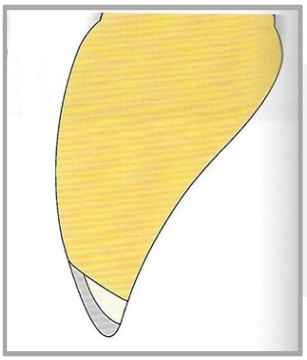
2. Simplified technique. Two layers of dentin and one layer of enamel. This technique is suitable in the vast majority of cases and when colours need to be developed.

Figure 149. Simplified technique. Taken from Manauta J.[41]



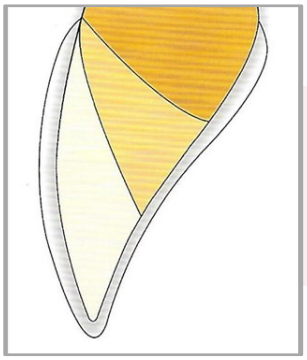
3. Radial technique. Two or more dentin and one enamel. The colour emerges from the centre and desaturates towards the surface. Used in the freehand modelling technique.

Figure 150. Radial technique. Taken from Manauta J.[41]



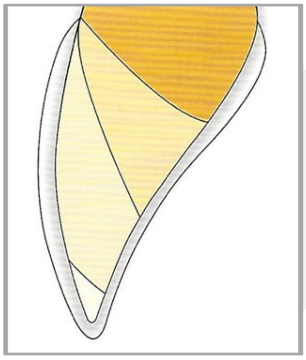
4. Customised block. Suitable for very translucent (body) or very opaque (dentin) teeth, the use of this technique is based on the use of a single mass for the whole tooth and the incisal edge is characterised to improve integration.

Figure 151. Customised block technique. Taken from Manauta J.[41]



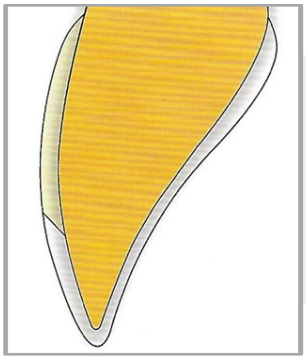
5. Lorenzo Vanini's technique. Stratification of three dentin shades. The use of advanced effects in the intermediate layer is suggested to achieve more natural teeth.

Figure 152. Lorenzo Vanini's technique. Taken from Manauta J.[41]



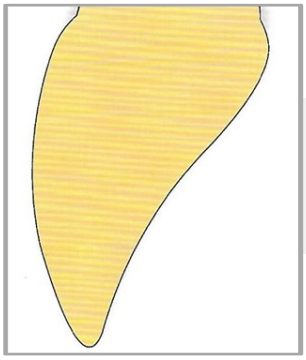
6. Characterisation of mamelons. With more opaque and less chromatic materials, the visibility of these structures is increased, regardless of the number of dentin layers used.

Figure 153. Mamelon characterisation technique. Taken from Manauta J.[41]



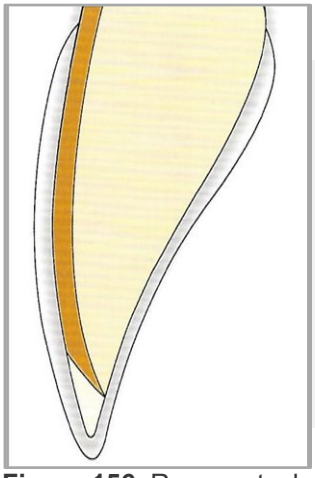
7. Newton Fahl's Technique. This polychromatic technique consists of using a chromatic enamel or body composite on the margin zone, and an achromatic enamel composite on the incisal portion of the restoration. Few dentin composites are required.

Figure 154. Newton Fahl's Technique. Taken from Manauta J.[41]



8. Single mass technique. This is recommended for temporary restorations and posterior restorations, also in cases where aesthetics are not essential.

Figure 155. Single mass technique. Taken from Manauta J.[41]



9. Reverse technique. Whiter opaque dentin composites are placed in the innermost portion for masking, followed by layering of chromatic dentin or body composites, near the surface in order to increase the chromaticity. The mamelons can be personalized as well. This technique is used to pacify undesirable dark features of teeth.

Figure 156. Reverse technique. Taken from Manauta J.[41]

6.5. Simplified stratification technique

You can develop less chromatically complex teeth with the use of fewer materials, while maintaining a high-quality aesthetic result.

This task is generally achieved with the use of two dentin masses and one enamel, depending on the size of the cavity.

The use of two dentins allows intermediate shades to be obtained. Despite not achieving full depth as in the advanced technique, the accuracy is very close to what is desired.

This technique simplifies stratification and saves time, especially in the lateroposterior sectors.

This technique should be used as an introductory technique and once mastered, more shades of dentin and intermediate layers can be inserted[41, 45, 46].

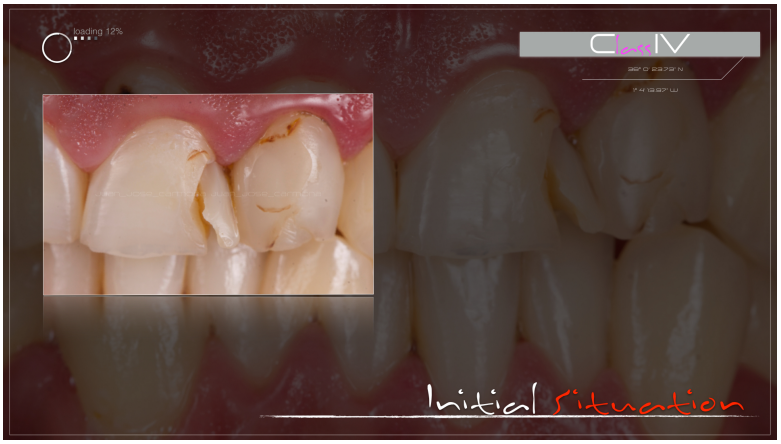
Procedure protocol:



Figure 157. Representation of the simple stratification technique. Made by Tapia J for GC.

1. The first step is to create an enamel base with appropriate corrections. Layer of 0.5mm.
2. A high chroma dentin is placed obliquely, occupying 60% of the volume.
3. Base dentin is placed to complete the remaining 40% of the total dentin dimension. The shape and contour of the mamelons are defined in this layer.
4. The final layer is the enamel. This technique requires the use of an optically efficient enamel to obtain opalescent effects and a high value without the need for effects. This layer has a thickness of 0.5mm.
5. Finishing and polishing is carried out until a high gloss is obtained.

Clinical case:



Patient comes to the clinic with the idea of changing his old restorations in 2.1 and 2.2. The caries filtration of both pieces and the fracture of the restoration in 2.1 can be observed.

Figure 158. Initial situation of teeth 2.1 and 2.2. Made by Carmona JJ.



The colour is taken with the tooth hydrated, subsequent isolation with rubber dam and, finally, removal of the old restoration and shaping of the new cavity.

Figure 159. Colour, isolation and removal of the old restoration. Made by Carmona JJ.



Using a simplified stratification technique, the palatal and proximal wall is first shaped with enamel. Then the dentin is placed. Finally, the vestibular enamel is placed.

Figure 160. Stratification with composite resins. Made by Carmona JJ.



Figure 161. Stratification protocol for Class IV restoration. Made by Carmona JJ, modified from Tapia J.

At a later appointment and after the rehydration process, the final state of the restoration was evaluated.

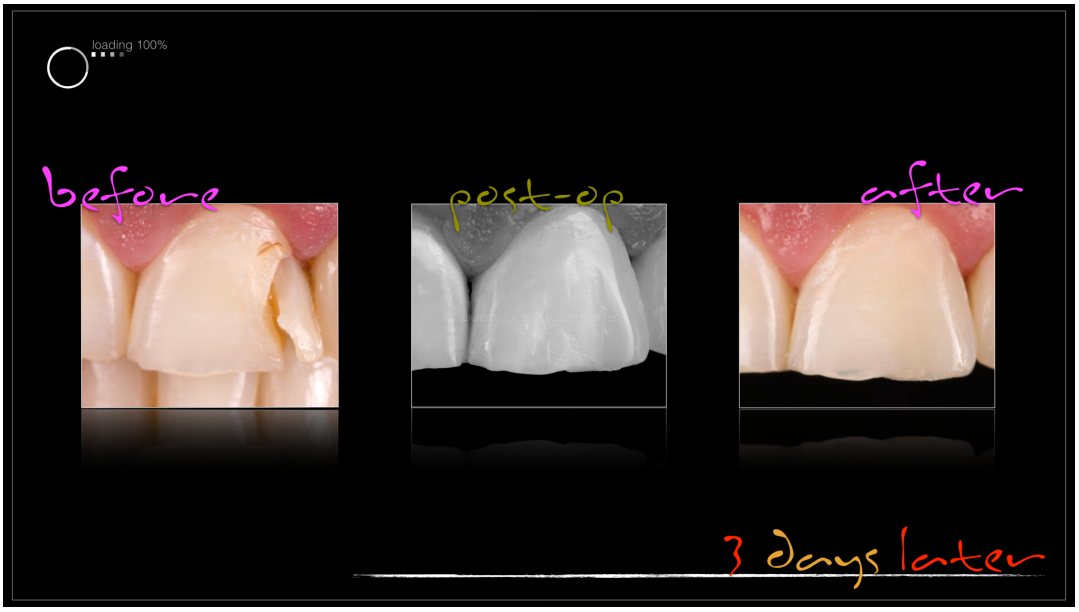


Figure 162. Pre- and post-treatment comparison after 3 days. Made by Carmona JJ.

UCAM

Chapter 7



Adhesion in aesthetic dentistry

History, development and perspectives. Biomimetic method

Photo by Dr. Fernando Rey Duro

7.1. Introduction to adhesion

Adhesion or bonding is nothing more than the joining of two things in such a way that it is difficult to separate them. Adhesion needs some **basic requirements** that are familiar to any dentist who has ever restored a tooth in any way, or to anyone who has ever repaired a household appliance.

1º **Preparing the substrate or adhesive 1**, the receptor. Whether metal, ceramic, resin, enamel or dentin, this is done to increase its surface energy so that the adhesive can 'wet' it. This always involves cleaning and roughening; depending on the substrate, a primer may be required to increase wettability.

2º **Applying the adhesive**. This will be in a plastic state and will always have such a low viscosity that it can be applied and the spaces created in the first step can be filled.

3º **Applying adhesive 2.** If this second adhesive is a previously fabricated rigid restoration (ceramic veneer, metal coping crown, ceramic crown or bracket), it must have been prepared in the same way as in the first step for adhesive 1. However, if this second bonding agent is a plastic (composite) restoration, this will not be necessary.

4º **Change of state of the adhesive.** From plastic to solid state, either by allowing it to set or by activating the setting (light curing)[48].

7.2. Rationale for keeping up to date in adhesive management

Bonding is the most important innovation in the history of dentistry, especially in recent decades. It has changed a whole generation of materials whose retention in the tooth was basically given by the cavity (macro-retention), for which a greater amount of tissue was worn away in order to increase the effectiveness of the material to be used. In addition, a large number of restorations failed due to marginal infiltration in the absence of a tooth-material interrelationship. Once composite resin appeared, bonding took a central role in dentistry, improving biocompatibility and also making dentistry less invasive and more conservative[49].

The evolution of restorative materials in dentistry today, demands impeccable management of the adhesive systems that will hold them in place. Dentists must apply the adhesive correctly, selecting not only a good adhesive but also knowing its properties, characteristics and handling, thus avoiding the frequent consequences of a failed procedure, such as postoperative sensitivity, gaps or marginal fractures, early hydrolytic degradation of the hybrid layer[50], recurrence of caries, etc.

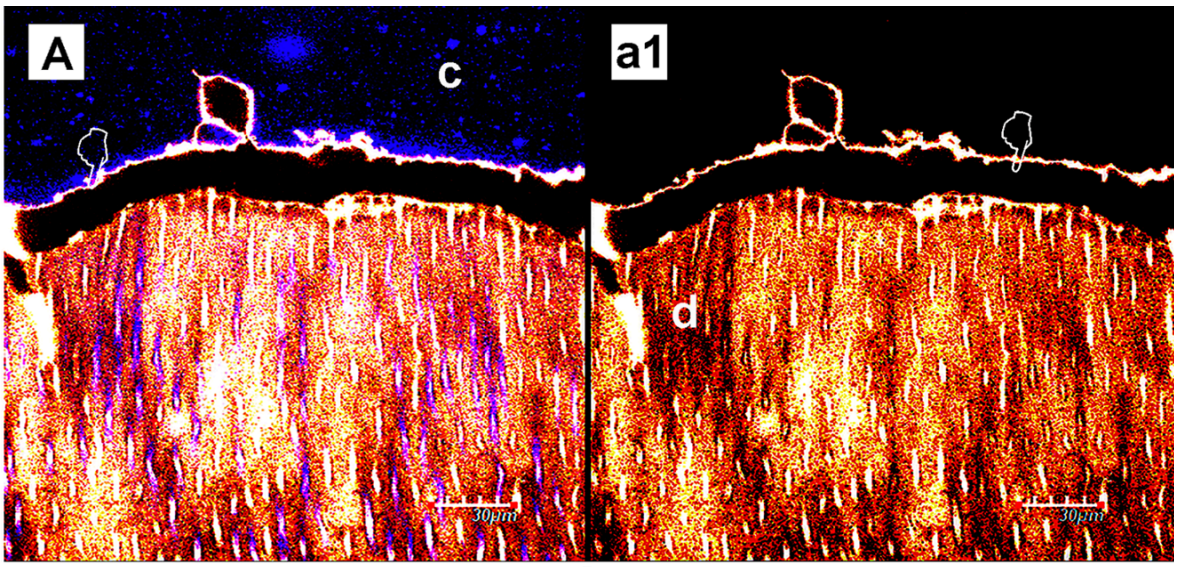


Figure 163. CLSM reflection/fluorescence projection image exemplifying the interfacial characteristics after prolonged ageing under pulpal pressure for 1 year of the resin-dentine interface created using the Optibond FL. The presence of a gap/degradation (pointer) within a dentine that is affected by caries (d) still demineralised and infiltrated by the fluorescein [a1: single projection in fluorescence mode] can be seen in this image[50].

7.3. Main adhesive substrates

7.3.1. Enamel

A hypermineralised ectoderm-derived tissue that covers and protects the dentin-pulp complex.

Mature enamel is composed of 96% hydroxyapatite crystals by weight, 3% water and 1% organic matrix. By volume, the percentages would be 85%, 12%, and 3%, respectively.

According to Shimada et al.[51] it is a microcrystalline, microporous and anisotropic tissue (different optical characteristics depending on the direction considered), acellular, avascular, aneuronal, highly mineralised and extremely hard but also brittle. Its fundamental characteristic is its unique and particular way of reacting to anything physical, chemical and biological, which is with a loss of substance, the magnitude of which is directly related to the intensity of the causal agent.

Enamel cannot regenerate and is affected by demineralisation, which can be acidic (caries, erosion and acid conditioning), by occlusal trauma (non-carious cervical lesion); as well as by abrasive substances or instruments (abrasion) and by trauma (fractures). **The defence mechanism it possesses is remineralisation but never regeneration**[52].

7.3.2. Dentin

This tissue is derived from the ectoderm, a product of the secretion of odontoblasts and their processes. One of its functions is to protect the dental pulp, and it is also a shock absorber for external forces as it is an elastic structure that can withstand a certain degree of deformation.

It is composed of hydroxyapatite crystals, accounting for 70% by weight, , with an organic component of 18% by weight formed by a cross-linked network of collagen fibres, glycosaminoglycans, proteoglycans and the prolongations of odontoblasts, and the remaining 12% is made up of water. In terms of volume, the percentages would be 50% hydroxyapatite, 25% organic matter, and 25% water.

Morphologically it consists of dentin tubules, peritubular dentin and intertubular dentin[52].

1. Dentin tubules

They extend from the dentinoenamel junction to the pulp. They contain odontoblasts and dentinal fluid, which will vary depending on the depth of examination.

2. Peritubular dentin

This is found surrounding the dentin tubules, with an abundance of hydroxyapatite crystals and a lack of collagen fibres.

This structure undergoes variations with age, because it increases in thickness, decreasing the diameter of the dentin tubules.

According to Avery and cols. (1994)[53] and Costa and cols. (1997)[54], this dentin is called *physiologic sclerotic dentin*, to differentiate it from *reactive sclerotic dentin*, which is produced in response to external stimuli of low intensity[55].

3. Intertubular dentin

Formed by collagen fibres, glycosaminoglycans, proteoglycans, growth factors and dentinogenic proteins, which support the hydroxyapatite crystals.

According to Avery and cols. (1994)[53], proteins are actively involved in adhesion mechanisms: collagen opposing the compression forces developed, and glycosaminoglycans and proteoglycans opposing stress-strain forces[55].

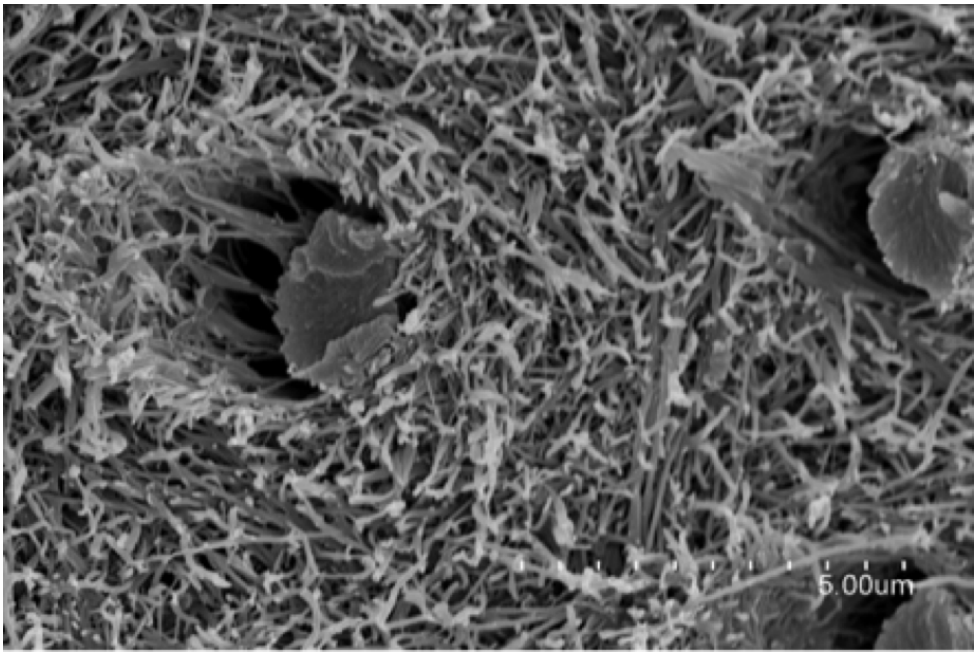


Figure 164. SEM micrograph (Magnification 5000 x HV 10.0kV WD: 15.0mm), showing the dentin tubules in detail with possible resinous tags, but a large amount of inter- and intratubular collagenous fibrils completely denuded without resinous infiltration, susceptible to degradation with ageing. Made by Ferrando A. y Sauro S.[52]

4. Types of dentin

Dentins can be differentiated according to their structure, development, location and the modifications they will undergo over the years in response to different stimuli.

a) Superficial dentin

According to Avery et al. in 1994[53], this is primary dentin that forms before and during active eruption, characterised by the presence of tubules without odontoblastic process in an amount of 18,000 tubules/mm2, with a diameter of 0.9 µm. This makes this dentin **the most efficient adhesive substrate, since intertubular dentin presents the maximum amount of collagen fibres and hydroxyapatite, with a minimum proportion of water**[55].

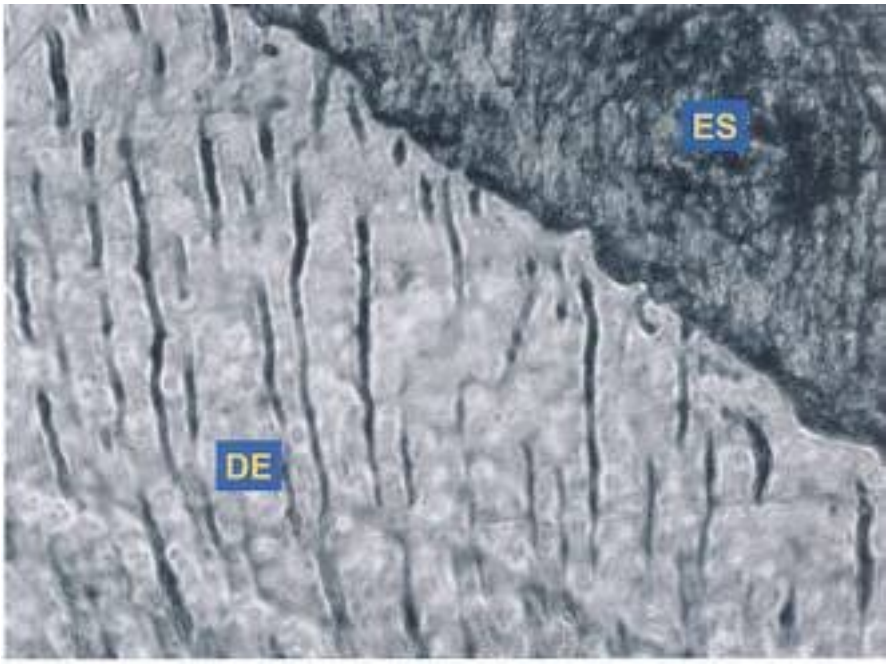


Figure 165. Microscopic image FVM-DIC x 1250. The surface dentin (DE) is visible. Enamel (ES). Note the small amount of dentin tubules and the increase of intertubular dentin near the dentinoenamel junction. Made by Henostroza G.[55]

b) Intermediate dentin

This is also primary dentin, with the characteristic of having more dentin tubules with or without odontoblast extensions, with an amount of 25.000 tubules/mm^2, and a diameter of 1.5 to 1.8 µm. This is an **effective adhesive substrate**, the intertubular dentin has collagen fibres, hydroxyapatite and water, in a considerable amount between the superficial and deep dentin.

c) Deep dentin

This can be primary or secondary dentin depending on age. Together with the predentin it protects the pulp. At this level, within the dentin tubules are the prolongations of the odontoblasts, with a diameter of 3.2 to 4.6 and a quantity of 66,000 to 90,000 tubules/mm^2. This is **the most deficient substrate** because of the diameter and number of tubules, decreasing the intertubular dentin surface, increasing the amount of water and decreasing collagen and hydroxyapatite[55].

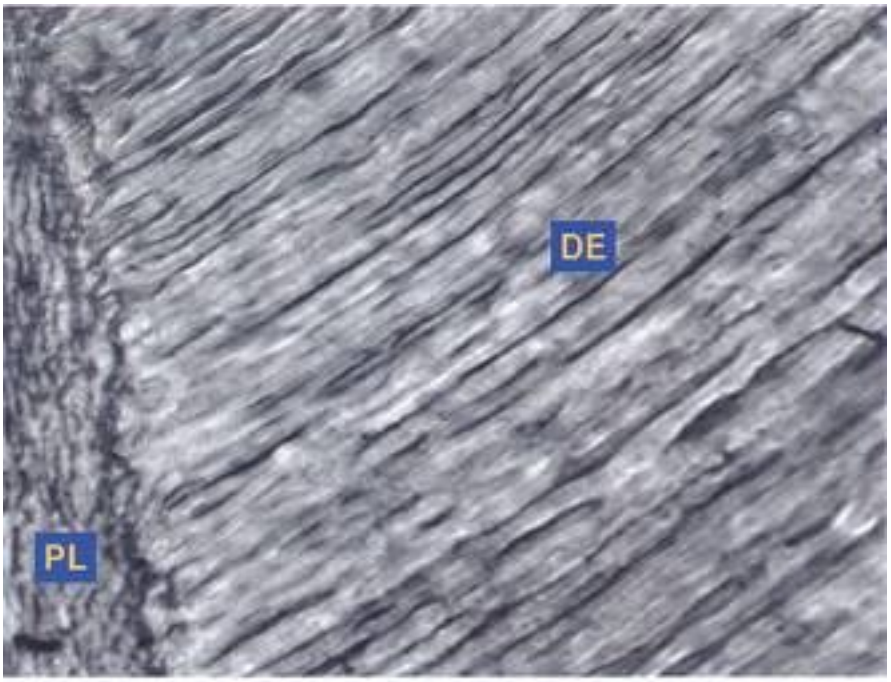


Figure 166. Microscopic image FVM-DIC x 1250. Deep dentin (DE) next to the pulp (PL). A large number of dentin tubules and a smaller area of intertubular dentin are observed. Made by Henostroza G.[55]

d) Sclerotic dentin

This is hypermineralised dentin formed in response to mild external aggression such as slow progressing caries, abrasions or attrition.

Avery and cols. in 1994[53] reported that, when dentin is exposed, plasma proteins and metabolites are transported by the dentin fluid into the hypermineralised intertubular dentin zone of the dentin tubule, increasing its thickness and reducing its lumen through high-calcium crystals. This hypermineralised dentin is suitable for bonding as long as it is properly conditioned by doubling the acid etching time or sandblasting with alumina oxide 29-50 µm[56].

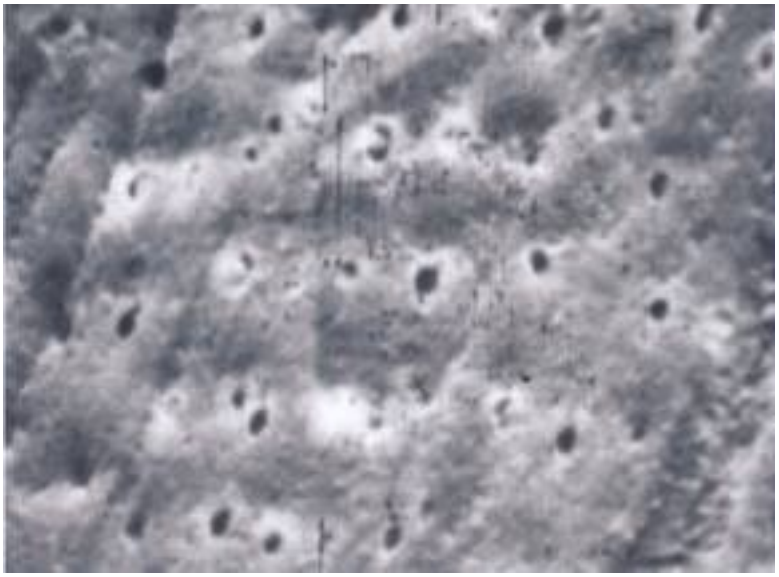


Figure 167. Microscopic image FVM-DIC x 1250. This is the dentin corresponding to a 55-year-old patient with sclerotic dentin generated by a slow abrasion process. Made by Henostroza G.[55]

e) Reactionary tertiary dentin

This is formed in response to moderate external aggressions which do not destroy the odontoblastic barrier, such as slowly advancing caries, abrasions, etc. Formation is rapid and disorderly, deforming the pulp chamber; **this is a weak substrate for adhesion[52]**.

f) Reparative tertiary dentin

According to Avery et al. in 1994[53], this is formed by severe external pathological aggressions, such as caries, fractures, abfractions (non-carious cervical lesions) or heat generated by the rotating instrument, which determine the destruction of the odontoblastic barrier.

Undifferentiated mesenchymal cells are in charge of replacing the lost odontoblasts that do not show cell mitosis phenomena, with odontoblastoid cells that heal the wound through a dentine bridge that deforms the pulp chamber. The neodentine formed is irregular in structure with minimal tubules. **This disorganised and anarchic dentin is an unreliable adhesive substrate**[55].

7.4. Historical development of adhesive dentistry

There is no doubt that adhesive bonding, together with dental implants, completely revolutionised dentistry in the second half of the 20th century. With regard to bonding, thanks to the pioneering concepts proposed by Buonocore in 1955, from the introduction of acid etching to enamel, in combination with Bowen's studies in 1965, the adhesive technique truly emerged. With the development of adhesive techniques on enamel and later on dentin, the need for macromechanical retention to retain an artificial restoration in a tooth cavity or on a tooth surface was completely eliminated, both in the case of direct and indirect restorations. This revolution altered and definitively changed the concepts of cavity preparation decades ago, enabling greater preservation of the remaining healthy tooth structure. In addition, aesthetic concepts were introduced into standard dental practice, due to the use of tooth-coloured materials

What is dental adhesion?

Adhesion is essentially a process that consists in the removal of minerals (calcium and phosphates) and infiltration of resin monomers in situ, favouring the micromechanical bond between the adhesive and the tooth structure, sealing the dentin tubules in the dentin, protecting and maintaining the homeostasis of the dentin/pulp complex[55].

Enamel and dentin adhesion

The **enamel** bonding technique helped improve and secure the marginal sealing of composite and porcelain restorations by altering the surface chemically, creating a new surface to which current materials can adhere. The key to success lies in the histology of the enamel itself, 96% of which is an inorganic prismatic/crystalline structure, susceptible to treatment with phosphoric acid, which induces a dissolution of the enamel, generating retentive surface etching patterns where the resin can infiltrate[52].

The final result is an increased bonding capacity of the resin due to several factors that were already described by Buonocore, which can be summarised as follows: (a) a tremendous increase in **surface area** due to the action of the acid attack, which improves the wettability of adhesives; (b) partial exposure of the enamel **prisms** depending on their orientation (ideally, the dissolution pattern of the prismatic core, perpendicular to the axis of the prisms, as this generates greater micromechanical retention), forming a network around which the acrylic can adhere or infiltrate; (c) the **removal of the old, inert enamel surface**, exposing a new, reactive surface more favourable for adhesion; and (d) the presence on the enamel surface of a **saturated layer of highly polar phosphate groups**, derived from the acid used (85% phosphoric acid at 85% at the beginning of his studies, which has currently evolved to solutions of 32-40% with similar effectiveness) and which favour the subsequent chemical process with the adhesive[52].

Furthermore, there is **dentin** where, to this day, there is '**adhesive uncertainty**', since, in short, it is a substrate that is not very favourable for long-term adhesion. The underlying reason for this is, unsurprisingly, its aforementioned histology (high water and organic matter content). Dentin is basically a dynamic substrate and therefore the adhesive technique is very sensitive and has to be applied carefully according to the substrate in question (dentin affected by caries is not the same as sclerotic).

To achieve the bonding process, the mineral component of the surface and subsurface is completely removed by etching with orthophosphoric acid. These are the classic etch and rinse (ER) adhesives, or partially with acidic primers, which are part of the more contemporary self-etch (SE) adhesives. In the latter case, the exposed collagen matrix is infiltrated with solvated adhesive resin monomers, ideally encapsulating the entire matrix with resin and forming a so-called 'hybrid layer' (CH), which after polymerisation of the monomer firmly anchors the adhesive and the overlying restoration to the dentine[52].

7.5. Historical evolution of the chemical formulation of adhesives. Generations

The water content of dentin was one of the main drawbacks for the development of new adhesive techniques, as most adhesives that existed in the beginning had a hydrophobic character that worked very well on enamel.

The first dentin bonding material was developed by the Swiss chemist **Oskar Hagger** in 1949, when he introduced a bonding product called *Sevriton Cavity Seal*, which showed good infiltration of the dentin surface by containing **GPDM** (glycerol phosphate-dimethacrylate), which today is part of the famous Optbond FL adhesive system (Kerr). **Kramer and Mc Lean**, on the other hand, also observed as early as 1952 that the product of the pioneer Hagger had a strong tendency to penetrate the dentin surface and form an intermediate zone between the dentin and the restoration.

The search for greater penetration into the dentine substrate in an attempt to take advantage of the water presence led to the development over time of hydrophilic resins and, with them, the description of the famous 'hybrid layer' in 1982 by Dr Nobuo Nakabayashi[57] as will be explained later[55].

- **Types of adhesives by generations**

1st and 2nd Generation (1970-1985): The first generation of adhesives in the late 1970s was not special. Although their bond strength to enamel was high (*generally, all generations of adhesives bond well to the microcrystalline structure of enamel; however, the biggest problem faced by dentists was the bond strength to semi-organic dentin*), the bond strength on dentin was 2-7 MPa. They were divided into oxalates and phosphates that acted as chelators. Oxalates emerged in 1982, and they were not very successful. They were 8-step systems in which conditioning was done with aluminium oxalate (e.g., Tenure System). Methacrylates and cyanoacrylates were used.

Phosphates, on the other hand, appeared in 1984 and tried to solve the lack of adhesion of the 1st generation. They maintained the smear in dentin and tried to combine it with hydrophobic and hydrophilic resins, although without much success, as they were not stable chemical formulations. Clearfil NewBond and Clearfil Fotobond (Kuraray), which was a new phosphate containing a long hydrophobic group (Mdp - Methacryloyloxyethyldihydrogen phosphate) and a hydrophilic group with higher wettability (HEMA, Hydroxy-Ethyl-Methacrylate), were marketed at that time. The clinical results were no better if the dentin was not etched/conditioned with

phosphoric acid. Scotchbond (3M ESPE) first appeared in 1983, very hydrophobic - 57% Bis-Gma and 43% TEGDMA. They achieved a bond strength of 12 Mpa[56].

3rd Generation (1986-1988): These achieved bond strengths of 9-18 MPa with improved dentin conditioning; EDTA, HEMA, ferric oxalate and 2.5% nitric acid were used. In short, weak acids to partially remove smear and infiltrate with hydrophilic resins.

Third generation adhesives were the first generation to bond not only to tooth structure, but also to metals and dental porcelains. The disadvantage with this type of bonding was its longevity. The only remaining product today is **GLUMA**[58] (Heraus kulzer) based on 5% glutaraldehyde and 35% HEMA, which is marketed as a desensitiser and also acts as a disinfectant. Its mechanism of action is summarised as coagulating the intratubular dentin proteins, reducing the flow of tubular fluid and thus reducing the occurrence of postoperative sensitivity[56].

4th Generation 1990-1995: Thanks to Professor Takao Fusayama and his group, who had been suggesting the use of orthophosphoric acid to condition dentin without success since 1980, this new category of adhesives emerged from 1990, with a bond strength of 17-25 MPa on healthy dentin. Their innovation was to incorporate a third compound called '**hydrophilic primer**', with HEMA that after acid etching easily penetrated the wet irregular surfaces of demineralised dentin. The other component called 'bonding', which is the adhesive itself, a pure hydrophobic flowable resin, serves to coat the primer and forms the actual bond with the composite resin afterwards. The key requirement for this technique is to maintain a certain amount of moisture in the dentin in order for the hydrophilic primer to penetrate, which is why it is also known as '**wet bonding**'[56].

Dr John Kanca[59]: In 1992 Dr. John Kanca published that by keeping the dentin moist after etching, bond strength improved: in a clinical study of 140 Class II restorations there was no postoperative sensitivity, and all teeth showed vitality after 18 months. It has since been determined that drying of the dentin causes a significant change in the collagen network, decreasing its volume and creating a relatively impermeable surface for dentin adhesives. Conversely, excess moisture during bonding procedures dissolves the adhesive components and also prevents proper penetration and polymerisation of the monomers into the demineralised dentin complex[59]. In other words, the success of the technique depends on the amount of moisture present during the bonding procedures.

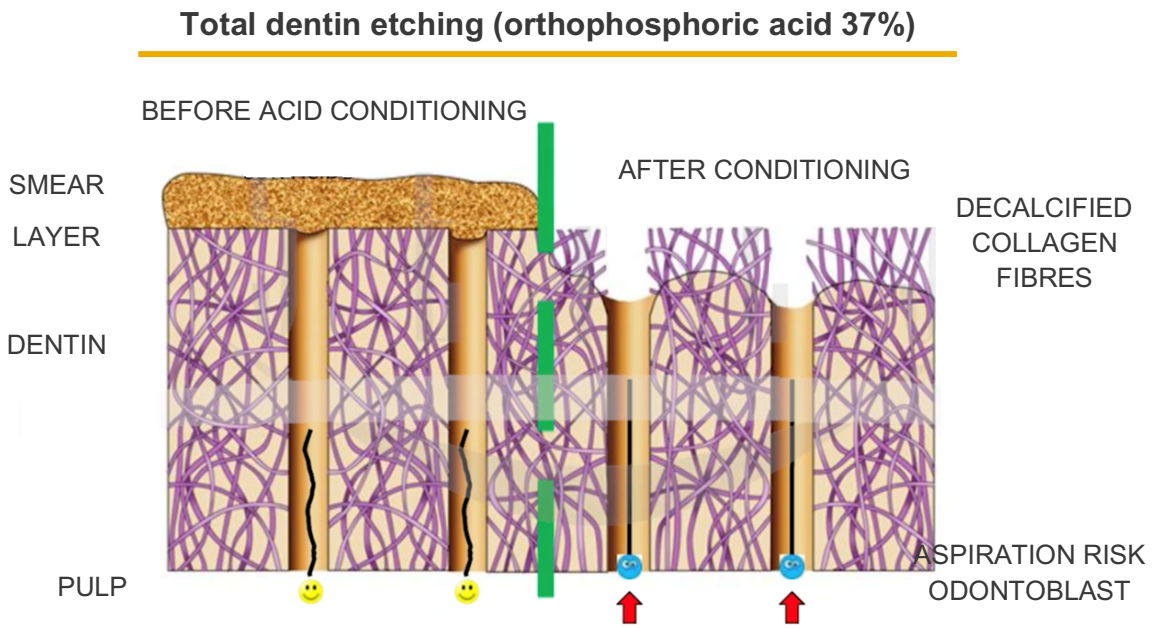


Figure 168. Diagram of the effect of total dentin etching with orthophosphoric acid. Made by Calvo AM.[60]

This generation is characterised by the hybridisation process at the dentin/resin interface. Hybridisation is the replacement of hydroxyapatite and water from the dentin surface with resin. This resin, combined with the remaining collagen fibres, constitutes the 'HYBRID LAYER', which is an area where there is natural collagen impregnated or encapsulated with hydrophilic and hydrophobic artificial monomers that seal the dentin/restorative material interface improving micromechanical retention, preventing the presence of hypersensitivity, as well as the incidence of recurrent caries[56].

› NOBUO NAKABAYASHI (1982), belonging to Fusayama's group, was the first to describe it, conditioning the dentin surfaces with a solution that did not yet contain phosphoric acid (10% citric acid and 3% ferric chloride) and applying an adhesive with hydrophilic and hydrophobic resins, observing a layer between 3-6 µm, which he called a 'hybrid layer'[55].

A big clinical question is whether primer should be used on enamel, as it was designed to be used on dentin. The difference between the two components is that the primer is a hydrophilic material or, in other words, compatible with water, which means that after the acid conditioning wash, the substrate will be wet and would benefit the final penetration by the adhesive or bond and could be in contact with

the enamel (the bonding, being water-repellent, would need a completely dry surface to reach the enamel).

The adhesion to the dry enamel is very similar when only the bonding is used or if in addition, as a previous step, the primer has been applied. In case the enamel is wet, the use of primer is important because it establishes the maximum value of the adhesion. But if the bonding process is exclusively on the enamel surface, the enamel can be completely dry and use only the bonding. In case the surface consists of enamel and dentin, since the use of hydrophilic primer is indispensable on dentin, the application should be extended to enamel[55].

This generation has been characterised and known as the **3-STEP** generation (Bayne et al., 2002) with many examples still available today: All Bond 2 (Bisco), Optibond FL (Kerr), Scotchbond Multiporpose Plus (3M), Syntac (Ivolcar-Vivadent)[56].

This generation is the current Gold Standard of 'total-etch' adhesives.

5th Generation 1995-1999: With adhesive strength between 19-25 MPa in dentine. In terms of effectiveness, these are very similar to the fourth generation[49] and arise from the effort of the commercial companies to reduce the time and number of steps in the adhesive technique. Therefore, by simplifying the technique, possible errors would be reduced. The difference lies in the use, which, unlike the 3 steps, consists of only 2 steps: starting with the conditioner (phosphoric acid) and combining the primer and the adhesive in a single bottle. These bond well to enamel, dentin, porcelain and metal.

At this point the question would be why use a 4th rather than a 5th generation adhesive for cementing RPAs (porcelain bonded restorations), or perform a Class IV restoration (with a lot of exposed dentine), when the former is more complex to handle. The answer is because the last hydrophobic layer of the 4th generation has a higher long-term stability of the hybrid layer, being thicker and more resistant to MMPs (matrix metalloproteinases) mediated degradation, although not invulnerable[56].

The solvents in these adhesives are usually alcohol derivatives that evaporate rather easily and favour the replacement of residual water in the etched dentin. When enamel or less collagenated dentin substrates predominate, such as sclerotic or tertiary dentin, the indication is to use solvent-based adhesives with acetone, which evaporates very easily, as there is no need to maintain a lot of moisture. In these cases, there is a tendency to properly dry before applying the adhesive and it is advisable to combine them with GLUMA to avoid sensitivity problems due to the drying of the collagen network[61-63].

In the past and even today, bonding agents of the 5th generation are the most popular adhesives since they are predictable and easy to use. Applying a material directly to the surface of the prepared tooth structure is technically insensitive. Example: Prime and Bond NT (Dentsply) or Scotchbond 1XT (3M). However, it should be noted that they have now been replaced by universal adhesives, which we will discuss below, but which have basically become widespread due to their versatility in application protocols and compatibility when combined with dual/universal resin cements.

6th Generation 2000-2002: **In 1994, Sano et al.**[64] already observed defects in the hybrid layer as a result of the overetching produced by the phosphoric acid and the consequent impossibility of reaching the entire demineralisation front with the resin. For this reason, they began to propose joining the conditioner to the primer, forming an acidic primer to try to homogenise the demineralisation to the monomeric infiltration and finally achieve a good complete wetting of the dentin. These 'primers' are known as 'self-etching' primers.

Since there is no risk of collapsing the collagen network when air drying and causing sensitivity by removing all the water from the dentin, this technique is also known as the '**dry bonding**' technique. The solvent in these adhesives is usually water, which in fact tends to reflocculate the collagen network, and these adhesives have the benefit of not leaving water-filled spaces under the hybrid layer, which slows down hydrolytic degradation over time.

- **AD-Concept bonding mechanism**

The monomeric MDP (10-methacryloyloxyalkylphosphate dihydrogenase) is responsible for the development of the 6th generation. This is the only monomer with a sufficient balance for dentin-enamel bonding as it has a hydrophobic and hydrophilic group that also has a phosphate end, which results in the mechanism known as AD CONCEPT (adhesion-decalcification concept)[61].

This mechanism takes place in the following way (the 10MDP mechanism will be explained as it is the most commonly used functional monomer in the various Self Etch adhesives and self-adhesive cementing agents).

The OH groups, which are two, upon contact with the dentin and mediated by water, which is also the main solvent of the "primer," dissociate, releasing hydrogen and generating the pH or hydrogen potential, lowering the acidity to 1.9. This causes demineralisation of the dentin, specifically of the hydroxyapatite, releasing phosphate and calcium ions. Calcium is a cation, which means that it has a positive

charge. It is worth emphasising that calcium has a positive charge because 10MDP, on releasing its hydrogen from the phosphate group, is negatively charged, becoming a polyatomic anion, in other words, a negatively charged molecule (oxygen, as is well known, has a negative charge).

Calcium (positively charged) and the functional end of 10MDP with oxygen (negatively charged), have an electrostatic attraction, which causes a reaction where the calcium provides electrons to the phosphate end. This anion reacts forming an **ionic bond** resulting in a salt that is very stable due to the long carbon chain; hence it is called 10MDP, as it has 10 carbons in its spacer chain, the hydrophobic part being separated from the hydrophilic end. Then this ionic calcium link and the phosphate group that lost the hydrogens form a polymeric structure leaving the methacrylate group (MA) at the other end, which by its **covalent** nature joins to another methacrylate of other 10MDP, perpetuating this chemical reaction until it stabilises[61,65].

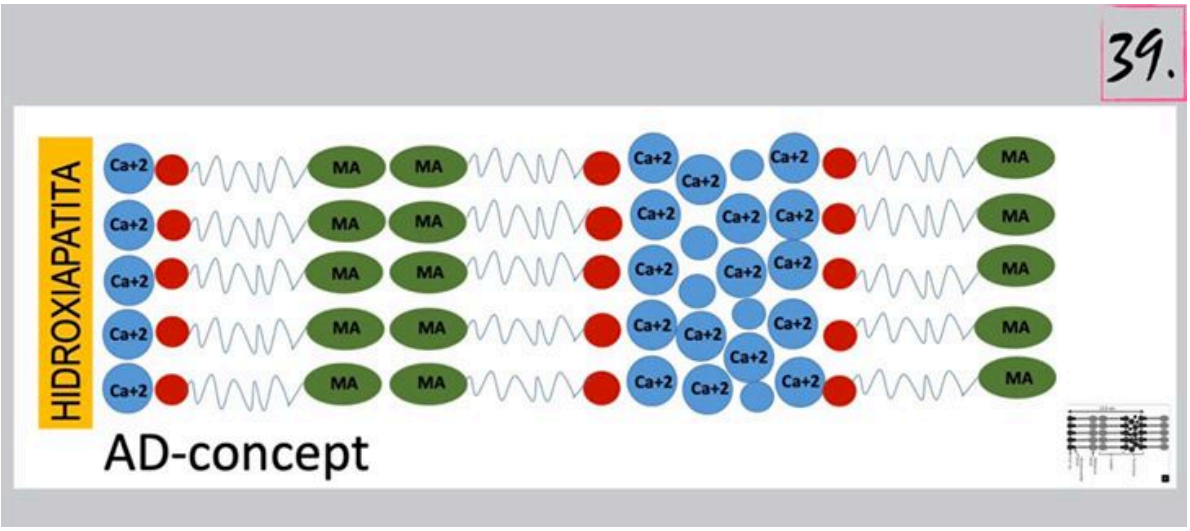


Figure 169. AD-concept diagram. Made by Tello R.

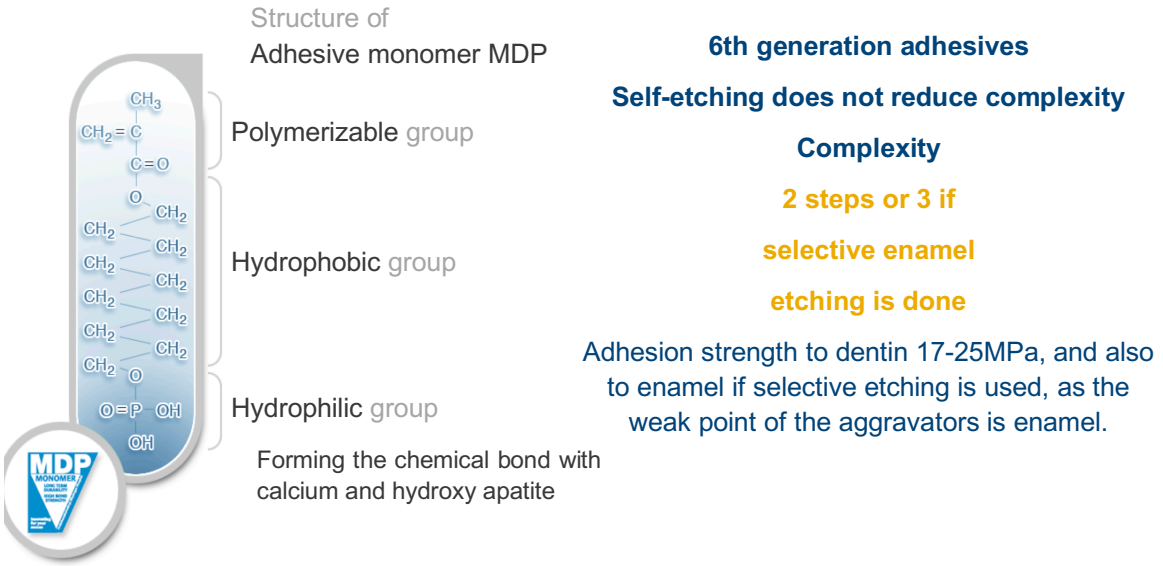


Figure 170. Original chemical structure of MDP monomer developed by the Kuraray company in 1981. (https://www.kuraraynoritale.eu/en/newsroom/mdp-since-1981). Made by Ferrando A.

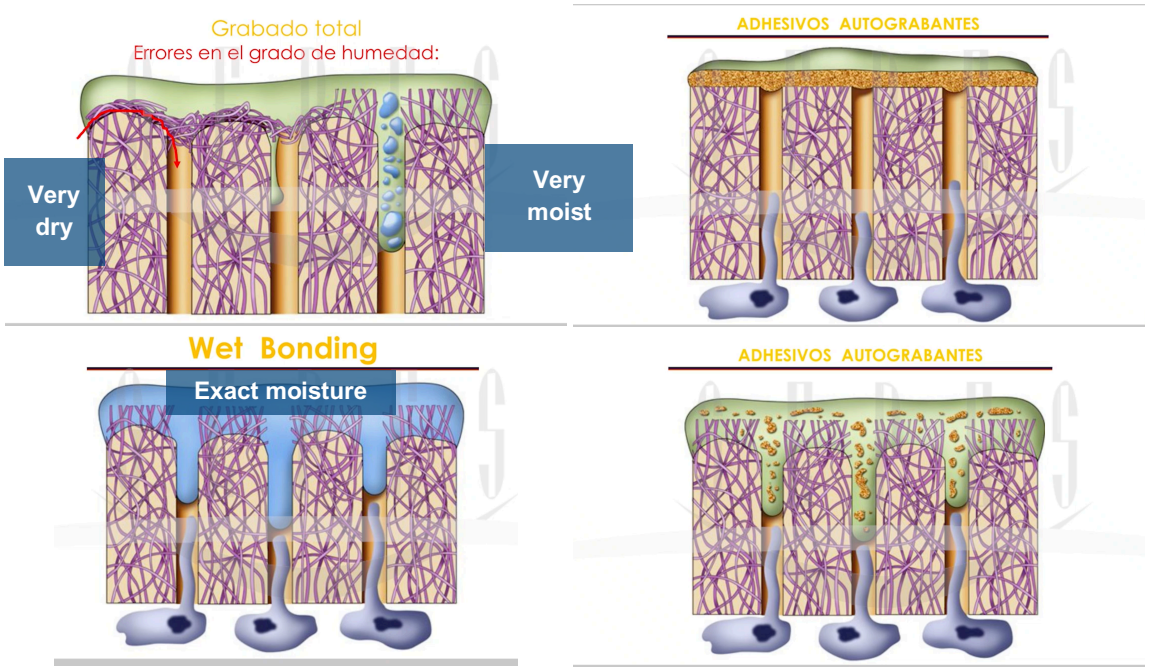


Figure 171. On the right, a diagram of total etch adhesives on dentin and different moisture conditions: dry, excessive and adequate. In the left column there is a dissolution of the smear layer by a self-etching system. Made by Padrós JL from SEPES online.

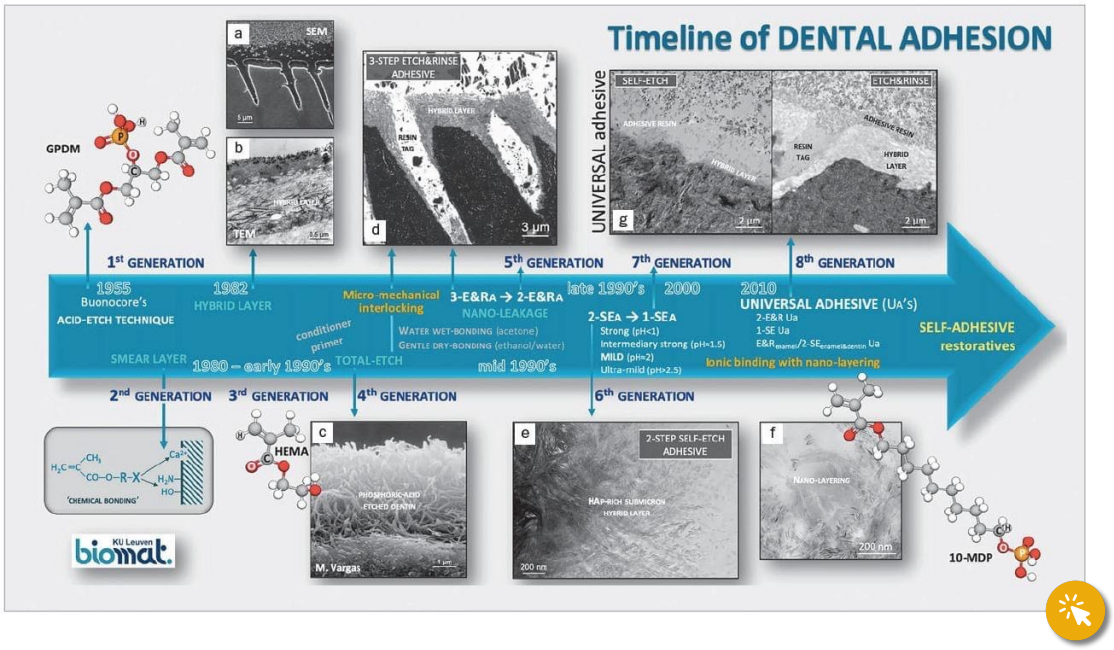


Figure 172. Timeline of the evolution of dentin adhesives. Made by Van Meerbeek B.[61]

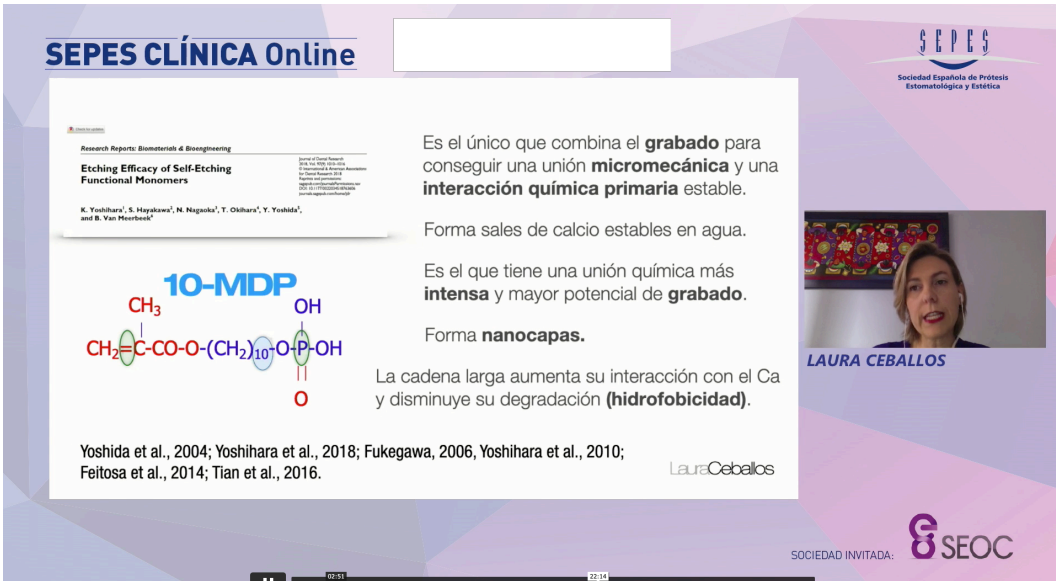


Figure 173. Most important properties of 10-MDP monomer. Made by Ceballos L from SEPES online.

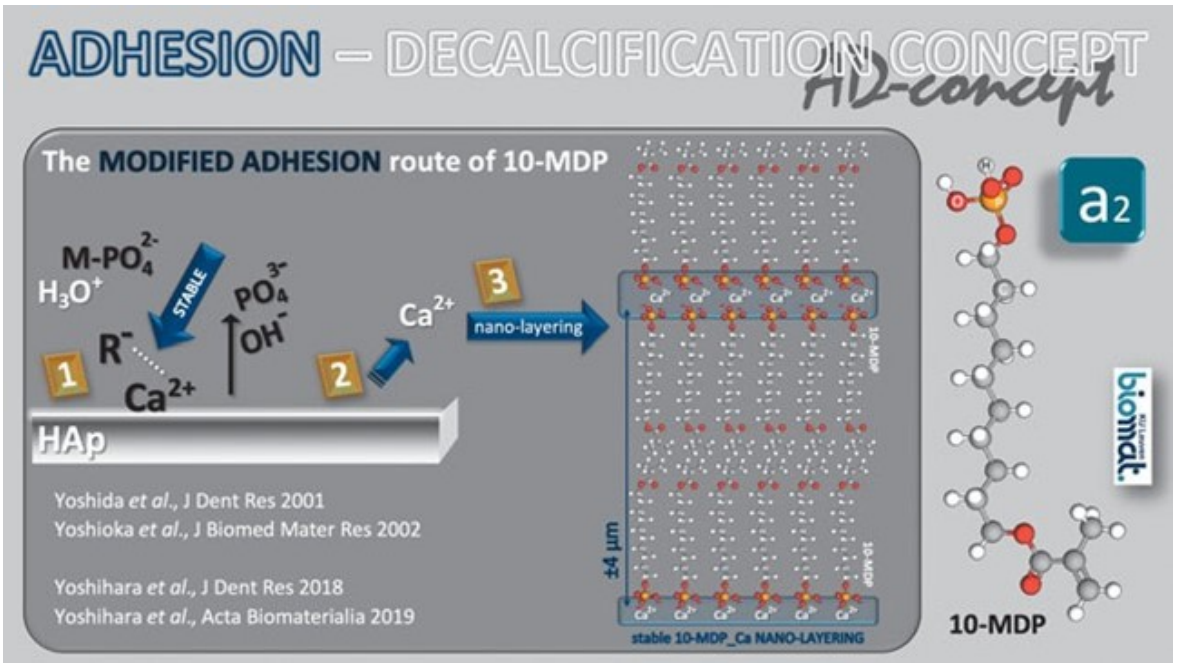


Figure 174. Diagram of the adhesion-decalcification concept of 10-MDP. Made by Van Meerbeek B.[61]

Interestingly, the adhesion to dentin remains strong over time, while the doubt arises regarding the adhesion to enamel without etching and preparation. Currently, '**selective etching to enamel**' with phosphoric acid is recommended to achieve the highest bond strength to enamel. **This generation is the current 'gold standard' of self-etching adhesives.**

7th Generation Late 2002: the industry's relentless push led to the development of 'single-step' adhesives, where acid, primer and adhesive are combined in a single bottle and named 'all-in-one' self-etching adhesives. Their use without any complementary dentine/enamel conditioning was controversial, the chemistry was not stable, polymerisation was insufficient, water-filled spaces were generated under a hybrid layer that remained semi-permeable, and increased microfiltration due to enzyme-dependent degradation was demonstrated.

Universal. 2010-Today. Some manufacturers have claimed credit for the introduction of eighth generation adhesives, but on closer inspection it turned out that they were chemically reconfigured previous generation adhesives re-launched for marketing purposes. It is true that they have clearly established themselves in clinical practice, and with the selective enamel etching strategy, they work well due to their improved chemical formulation (e.g., Scothbond Universal, 3M or Prime & Bond Active. Dentsply Sirona).



Figure 175. Overview of the direct adhesive protocols using universal adhesives (UA). Made by Van Meerbeek B.[61]

Referring to the following figure of direct adhesive protocols, it is easy to assign each of the existing adhesives to one of the four generations, from the fourth to the seventh.

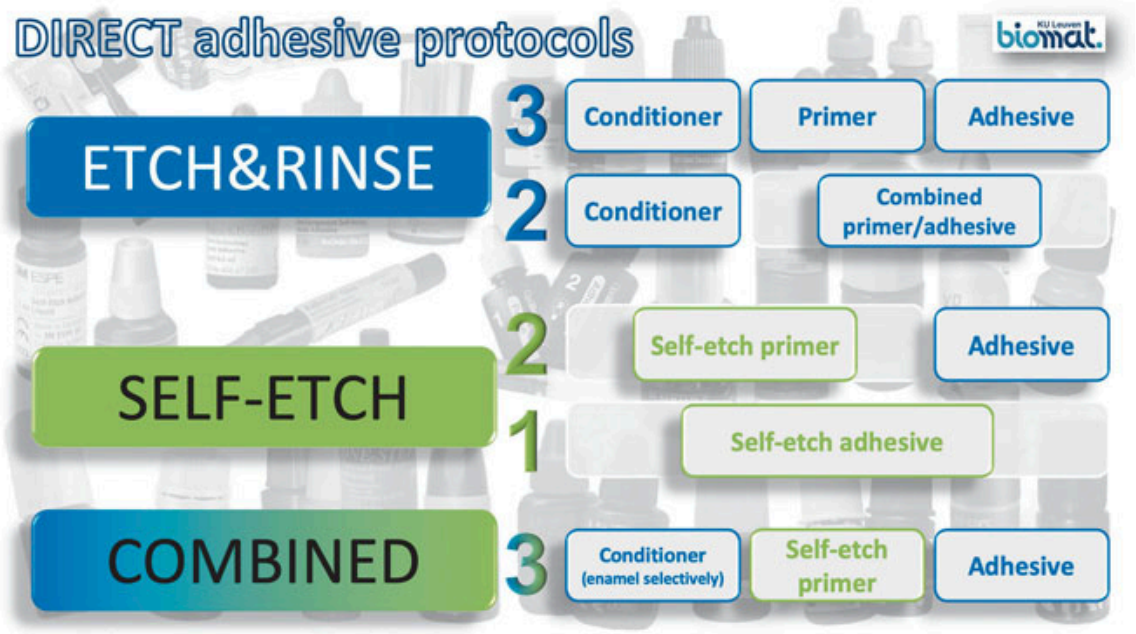


Figure 176. Overview of the direct adhesive protocols using conventional etch&rinse (E&R) and self-etch (SE) adhesives. Made by Van Meerbeek B.[61]

Given the aforementioned trends, it is easy to see that each of the generations has significantly reduced the bonding process: fewer components, fewer steps, less chair time, ease of use and probably greater predictability. However, there is a trend when using universals, which consists of applying two layers of adhesive and then adding a hydrophobic layer (a "bonding" or a "flow") in order to seal the adhesive layer well and improve performance, which would bring us back to the same number of steps and time required when compared to the 4th generation.

Certain commercial companies continue to focus on the development of two-step universals. In fact, the best adhesive values achieved with universals are usually found in the few two-step universal adhesives such as Optibond XTR and its evolution, eXTRA by Kerr, or G2-Bond by GC.

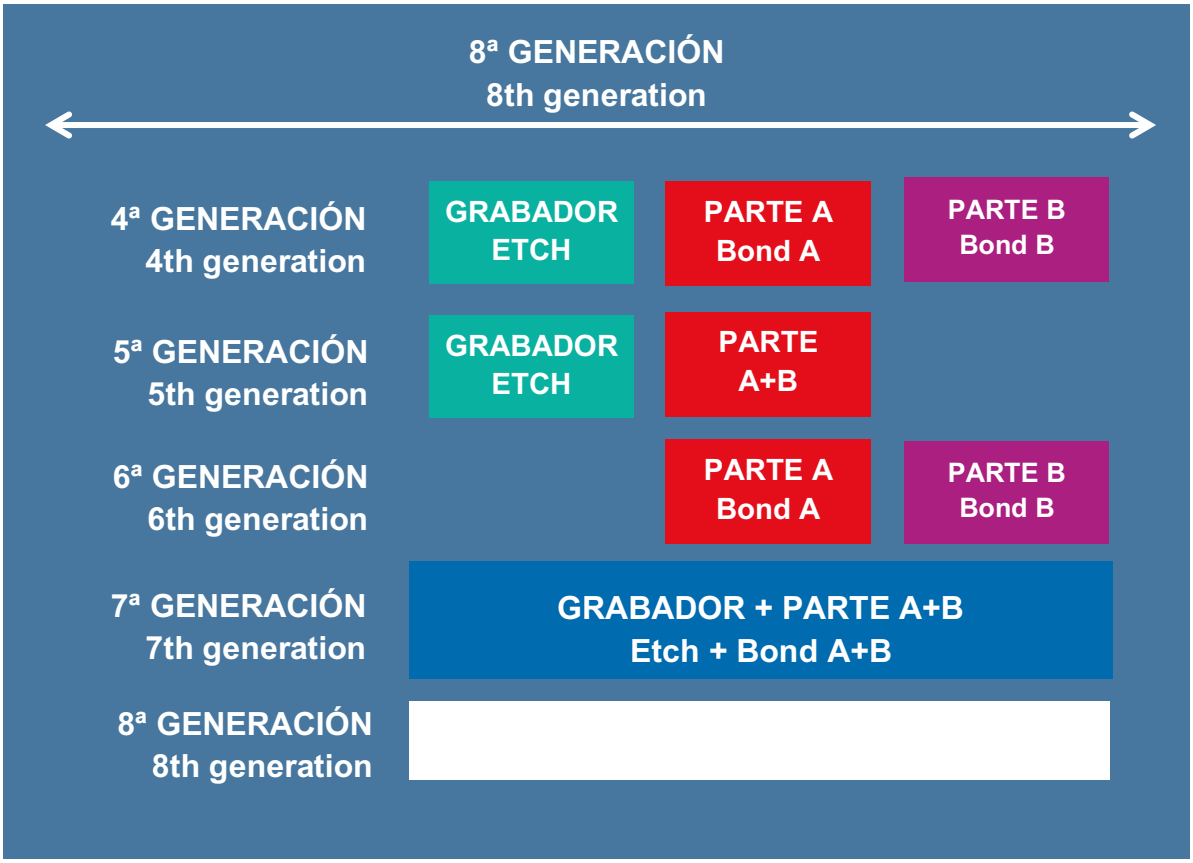


Figure 177. Diagram of the adhesive generations: What is the 8th generation adhesive? Made by Feedman G.[66]

An interesting question would be to consider is whether adhesion as a single component, single step and totally comfortable process could be improved. The answer is so simple that it is difficult to develop, but it would be to eliminate adhesives: 'zero steps'.

The only possible evolution is to eliminate the remaining component and have it all in one step. The next generation (8th generation) of adhesives will consist of no bottles and no components, at least as a distinct or separate clinical step. Today there is already an example of adhesive available that has been incorporated into the restorative material (Surefil One. Dentsply Sirona).

When the dentist inserts the restorative resin, the included adhesive will etch, prime and bond to both dentin and enamel, requiring only polymerisation to complete the restoration – Does this sound far-fetched? These substances are already available to the dental profession. For example, there are one-step resin cements and resins for self-etch, self-priming and self-bonding post cementation. The 8th generation will see the elimination of all these treatment processes as a separate step. The only task remaining is the incorporation of these eighth-generation adhesives into direct restorative materials. It is only a matter of time - even though research will place them in their true indications and remove or keep them on the market. At the moment there is no long-term literature to support their use.[66]

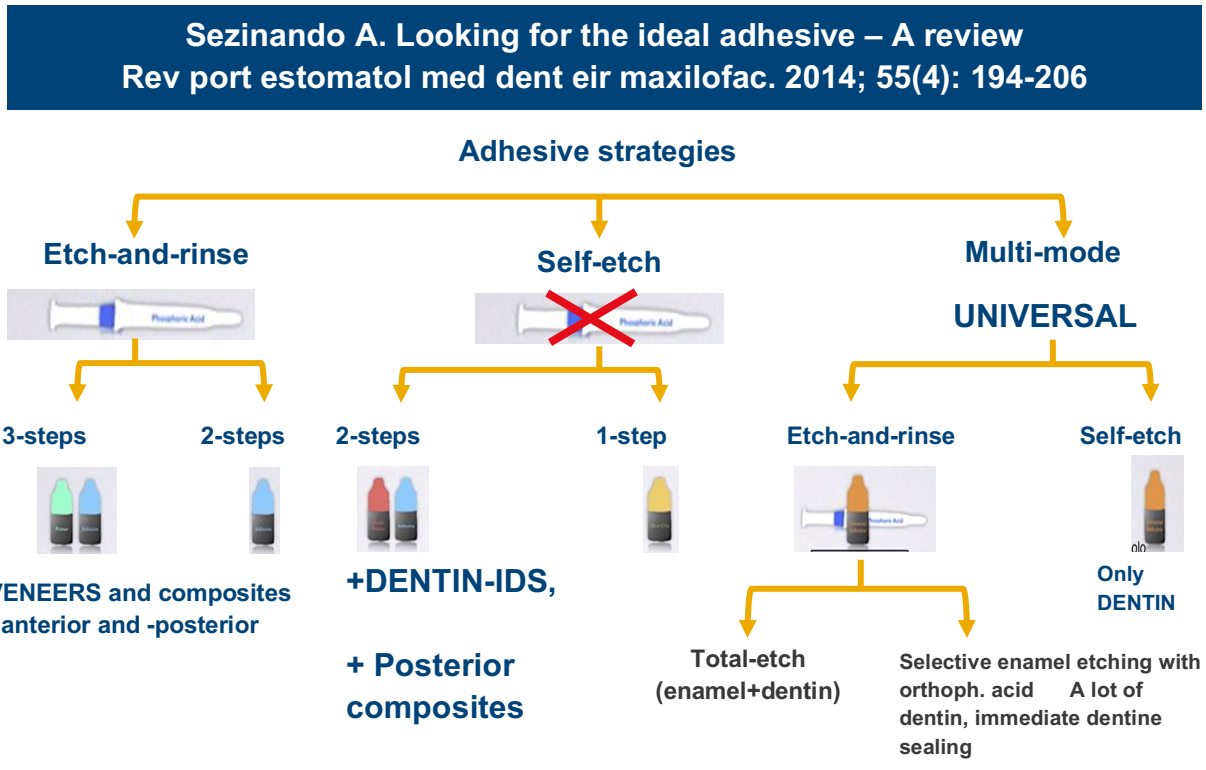


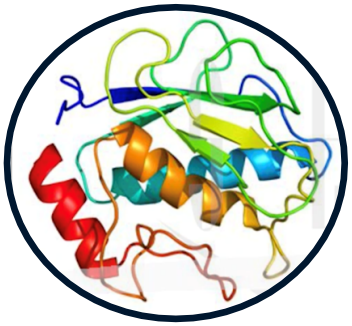
Figure 178. Diagram of adhesive strategies according to clinical indications. Made by Ferrando A from Sezinando A.[65]

7.6. Degradation of dentin adhesion

- **By hydrolysis**

Adhesive monomers are actually **unable to completely encapsulate the collagen matrix, leaving fully or partially exposed fibrils at the bottom of the hybrid layer (HL), without the protection of the polymerised resin, making them vulnerable to proteolytic attack**. In addition, there are hydrophilic monomers in adhesives that cause high water absorption and generate a HL that behaves like a permeable membrane after polymerisation, thus allowing water movement across the bonded interface (some 1- step or 'all-in-one' adhesives). Water movement begins as a diffusion mechanism, followed by the creation of large water-filled channels that rapidly degrade the hydrophilic phase of the adhesive. As the previously resin-infiltrated collagen matrix solubilises, the underlying insoluble collagen fibrils are fully exposed and become vulnerable to attack by proteolytic enzymes.[44] There are many matrix proteases that are hydrolases and add water through specific peptide bonds to break down the collagen polymer into smaller units.

When using ER adhesives, the presence of residual water in acid-etched dentin may additionally decrease the polymerisation of adhesive monomers, contributing to increased permeability within the adhesive layer. Although adhesives should theoretically encapsulate collagen fibrils completely, simultaneously with demineralisation, many studies have shown some nanofiltration within SE adhesives, even in the absence of a detectable exposed demineralised collagen zone. Furthermore, residual solvents in the HL contribute to incomplete infiltration of resin monomers into the water-filled collagen fibril matrices, even more water may enter the HL, not only during the bonding procedure, but also later on. As a result, there are portions of HL that always contain water- and resin-filled areas, as demonstrated by transmission electron microscopy (TEM) using water-soluble tracers[52].



Simplified self-etching adhesives activate Metalloproteinases

(Endogenous dentin enzymes)

Figure 179. Diagram representing the structure of a metalloproteinase. Made by Padrós JL from SEPES online.

- **MMPs and cysteine-cathepsins**

As stated in the previous picture, matrix metalloproteinases (MMPs) and cysteine-cathepsins are involved in the tooth development and are in a non-functional state. They are activated when the dentin undergoes an acidic process lowering the pH to around 2, i.e., when using acids in the bonding process (orthophosphoric or phosphate monomers or self-etching cements). These will degrade the collagen fibres that were not encapsulated in the first place[52].

There are many anti-degradation strategies: chlorhexidine 0.2-2%, which inhibits MMPs, although the literature has shown that its concentration decreases with time; **placing an extra layer** of bonding or hydrophobic adhesive[61], may also provide greater resistance to adhesive degradation in the case of using simplified adhesives; substances such as glutaraldehyde, riboflavin or **bioglass[67]** (silica-based glass), which dehydrates and remineralises, constitute alternative antidegradation strategies and are under continuous research[52].

COMMERCIAL ADHESIVE TYPES AND ADHESIVE STRATEGIES

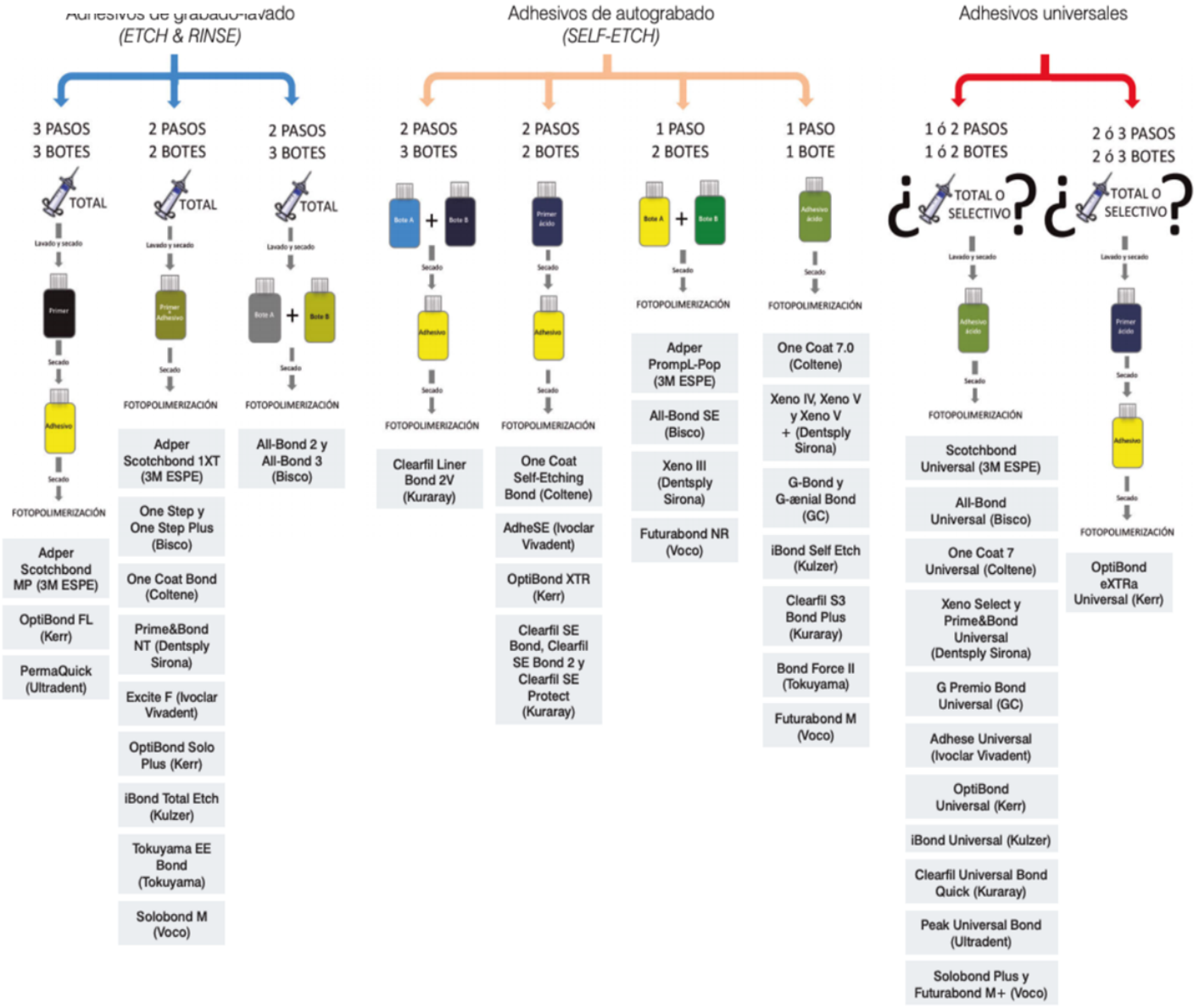
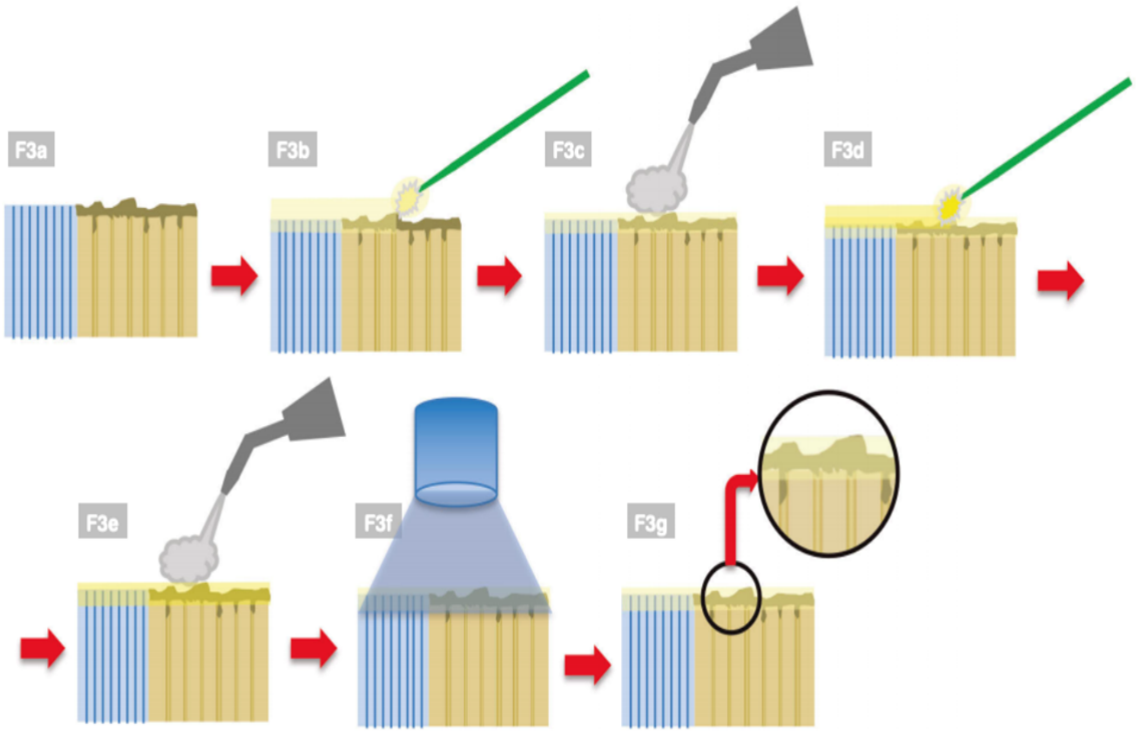


Figure 180. Classification of adhesives according to their clinical application and commercial names of the most prominent brands in each group. Some of them feature an additional bottle that makes them self-curing. Made by Calvo AM.[60]

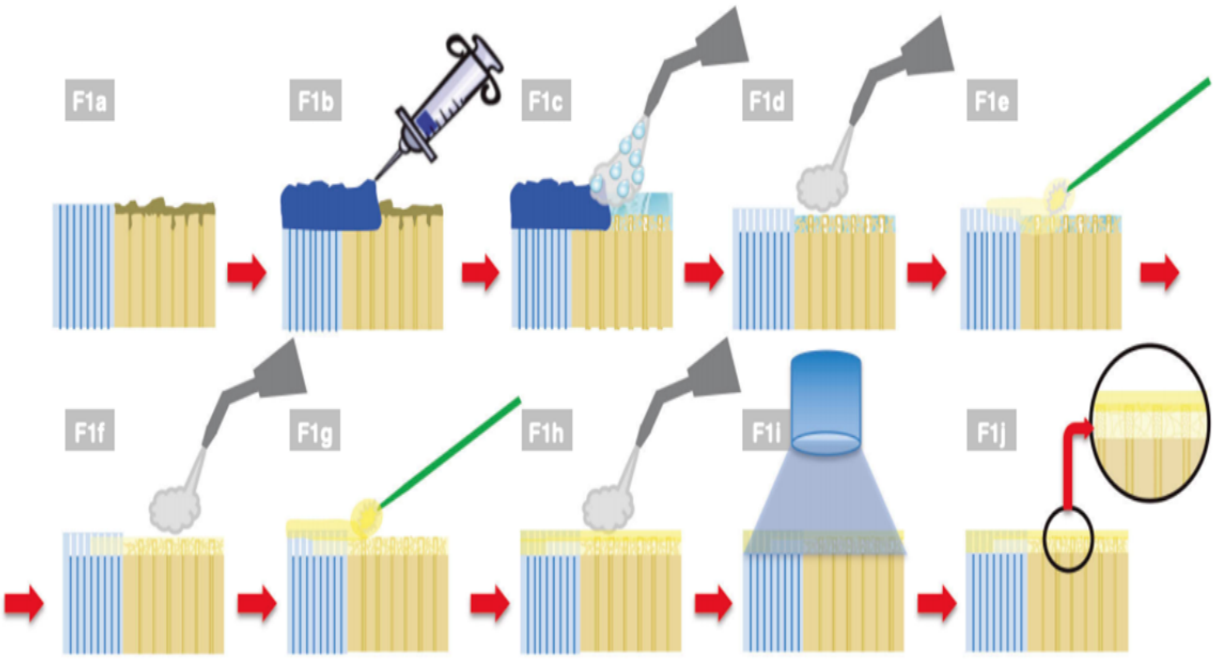
F3 Self-Etch adhesives.



This figure shows a diagram of the clinical steps required to use Self-Etch adhesives: **3a**. Initial situation. **3b**. Apply the primer, let it act for 30''. **3c**. Evaporate the solvent with a gentle air stream. **3d**. Apply the adhesive or bonding. **3e**. Distribute the adhesive layer with gentle air flow. **3f**. Photopolymerisation. **3g**. Final result. In simplified self-etch adhesives, as all components are in one bottle, primer + adhesive are applied at the same time in step 3b, avoiding steps 3d and 3e.

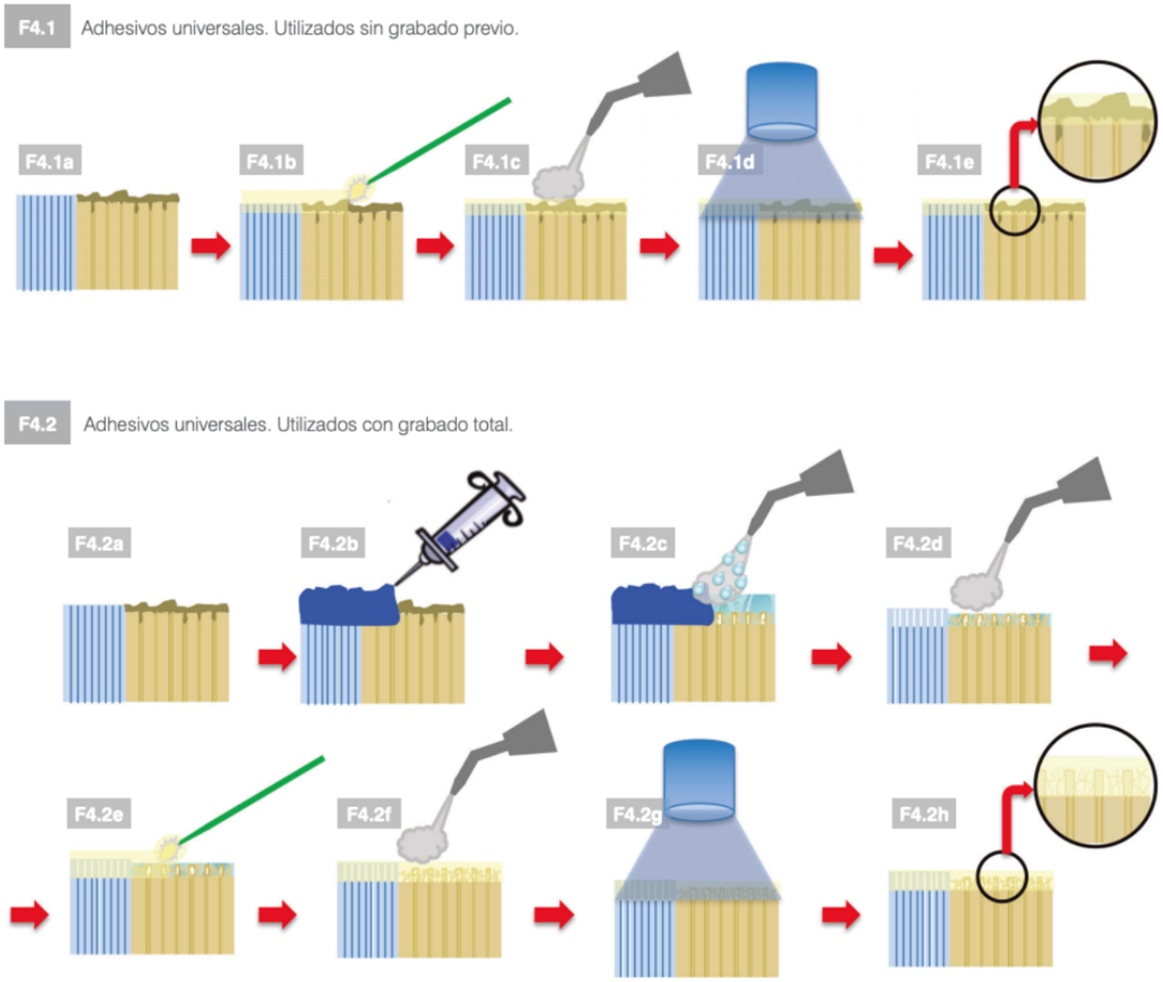
Figure 181. Protocol for the use of self-etching adhesives, step by step. Made by Calvo AM.[60]

F1 Etch&Rinse adhesives.



This figure shows a diagram of the clinical steps required to use Etch&Rinse adhesives: **1a**. Initial situation. **1b**. Apply orthophosphoric acid to enamel (30'') and dentin (15''). **1c**. Deep rinsing. **1d**. Drying (without drying the dentin). **1e**. Apply the primer by 'massaging' the dentin for at least 15''. **1f**. Evaporate the solvent with a gentle air stream. **1g**. Apply the adhesive or *bonding*. **1h.** Distribute the adhesive layer with gentle air flow. **1i**. Photopolymerisation. **1j**. Final result. In simplified etch-and-rinse adhesives, steps e and f are eliminated. Some manufacturers recommend applying two or more layers of the adhesive.

Figure 182. Protocol for the use of etch-and-rinse adhesives, step by step. Made by Calvo AM.[60]



This figure shows a diagram of the clinical steps required to use universal adhesives: **Fig. 4.1. Used without pre-etching. 4.1a.** Initial situation. **4.1b.** Apply the adhesive by rubbing the dentin and enamel for at least 15-20''.

4.1c. Evaporate the solvent with a gentle air stream for 15'' (the final layer must be glossy and without movement). **4.1d.** Photopolymerisation. **4.1e.** Final result. **Fig. 4.2. Used with total etching. 4.2a.** Initial situation. **4.2b.** Apply orthophosphoric acid to enamel and dentin for 15''. **4.2c.** Deep rinsing. **4.2d.** Drying (without drying out the dentin). **4.2e.** Apply the adhesive by rubbing enamel and dentin. **4.2f.** Evaporate the solvent with a air stream for 15'' (the final layer must be glossy and without movement). **4.2g.** Photopolymerisation. **4.2h.** Final result. **Fig. 4.3. Used with selective enamel etching. 4.3a.** Initial situation. **4.3b.** Apply orthophosphoric acid to only enamel for 15''. **4.3c.** Deep rinsing. **4.3d.** Drying (without drying out the dentin). **4.3e.** Apply the adhesive by rubbing the dentin and enamel for at least 15''. **4.3f.** Evaporate the solvent with a gentle air stream for 15'' (the final layer must be glossy and without movement). **4.3g**. Photopolymerisation. **4.3f.** Final result.

Figure 183. Protocol for the use of universal adhesives, step by step. Made by Calvo AM.[60]

FINAL CLINICAL CONSIDERATIONS
(Dr Ivo Krejci. University of Geneva)

1. Remove biofilm mechanically.
2. Remove prismatic enamel mechanically by sandblasting with aluminium oxide 29-50 microns.
3. Do not use caries detector or ferrous chloride-based haemostatic.
4. Contemporary adhesive systems do not require prior disinfectants such as hypochlorite or hydrogen peroxide.
5. Chlorhexidine 2% if total etch is used on fresh dentin, although long-term efficacy is questionable.
6. Evaporate the solvent of the self-etching depending on the product, Clearfil SE Bond (water solvent) is not the same as Pime and Bond NT (acetone).
7. Follow all steps (stirring and vertical application) and application times just before composite application...always slightly in excess.
8. Give the adhesive time to penetrate (20")...especially if it is self-etching, and on dentin apply several layers actively. On enamel only brush; forgetting to do this will result in early staining.
9. Remove excess with microbrush and/or soft air. A thin and homogeneous layer is intended.
10. Test the polymerisation light frequently.
11. Pre-curing of the adhesive in enamel is not required.
12. Check the spray of the equipment, water and air should ideally be kept separate.

FINAL MESSAGE

‘TRY TO SEPARATE DENTIN AND ENAMEL IN TERMS OF THE ADHESIVE PROCEDURE.’

Special thanks to Dr. Albert Verd Bertran for reviewing this chapter.

UCAM

Chapter 8



Vital and non-vital whitening

Guest Author: Natalia Álvarez-Maldonado

Photo by Dr. Álvaro Ferrando

8.1. Vital and non-vital whitening

Dental whitening or tooth bleaching is a conservative therapeutic alternative to treat teeth with pathological or abnormal discolouration, which can be used as a stand-alone treatment or as part of a broader aesthetic treatment plan. The aim is to restore teeth to an appropriate shade in accordance with the aesthetic demands of the patient. Therefore, the different indications and contraindications of this dental treatment must be understood in order to establish an appropriate treatment plan for each case, which will be determined by the type and degree of discolouration and the patient's characteristics.

A more correct term would be tooth 'lightening', since the value of the tooth is modified, and not so much the shade of the tooth[68,69].

Pre-treatment procedures:

1. The medical, dental and systemic history that have contributed to the discolouration of the patient's teeth, as well as the patient's aesthetic needs and degree of cooperation are to be ascertained from the **anamnesis**.
2. **Diagnosis** and treatment plan. Both the type of discolouration as well as selecting the most appropriate technique for each case must be clear. Prior to whitening, you must treat the patient's previous pathologies, such as caries, pulp pathologies, gingivitis...
3. **Colour determination**. It is essential to quantitatively record the evolution of the colour of the patient. By means of subjective systems such as shade guides (VITA classical, VITA toothguide 3D master, VITA Bleachedguide 3D masters), or objective recording systems such as spectrophotometers and colourimeters. Take reference photographs with the guide.
4. Provide the patient with the **informed consent** form to be signed and explain how the treatment should be carried out at home, if applicable, as well as the possible complications that may arise from it[68.69].

TYPES OF DISCOLOURATION

- **Extrinsic stains**: microbial, ingestion of chromogenic food or drink, tobacco, chlorhexidine. Most extrinsic tooth stains can be removed with prophylaxis procedures and then respond well to bleaching. They may eventually become intrinsic (e.g., a crack in the enamel of a smoker).
- **Intrinsic stains**: tetracyclines, fluorosis, genetic, restorative materials (silver amalgam).
  - Hereditary stains: amelogenesis imperfecta, dentinogenesis imperfecta. Bleaching is not indicated, as it would further weaken the tooth structure.
  - Acquired stains: Age, tetracyclines, superficial fluorosis and hypocalcification (in this clinical situation, microabrasion with hydrochloric acid and resin infiltration is indicated, e.g., ICON system), pulp aetiology, restorations (silver amalgam), caries, etc[68,69].

8.2. Bleaching agents. Action mechanism. Activation systems

BLEACHING AGENTS AND ACTION MECHANISM

In order to whiten teeth, oxidising agents are required which, when diffused into the tooth, dissociate to produce unstable free radicals (HO hydroxyl radicals, HOO perhydroxyl radicals, HOO- perhydroxyl anions and OO superoxide anions) which will attack the double bonds of the pigmented organic molecules within the tooth tissues. The change in double bond conjunction results in smaller and less pigmented components that increase the value of the tooth.

The products used for whitening contain active ingredients (hydrogen peroxide and carbamide peroxide) and inactive ingredients (thickeners, carriers, surfactants, pigment dispersants, preservatives and flavourings)[69-71].

- **Hydrogen peroxide:** having a low molecular weight, it diffuses through the organic matrix of enamel and dentin. This produces an oxidative reaction that breaks the bonds of the staining molecules.

$$2(H_2O_2) \rightarrow 2(H_2O) + O_2$$

- **Carbamide peroxide:** made of hydrogen peroxide and urea, which acts as a buffer, thus slowing down and prolonging the release of hydrogen peroxide.

10% carbamide peroxide = 6.5% urea + 3.5% hydrogen peroxide.

Hydrogen peroxide and carbamide peroxide have the same potency, but the ratio is 1:3.

The lower the concentration of the bleaching agent, the longer the required application time, but this does not reduce its efficacy[68,69].

Bleaching affects the enamel in a reversible way, as it recovers its properties two weeks after treatment[71].

There is a slight increase in the roughness of the resins[71,72].

Waiting 2-3 weeks after bleaching is recommended for adhesive restorations, as the definitive shade cannot be assessed before this time either[70-72].

INSTRUCTIONS FOR THE PATIENT

› Do not smoke 2 hours before and after treatment, due to the possible interaction with hydrogen peroxide. Nevertheless, it is recommended not to smoke at all during the whole whitening process and to try to reduce smoking as much as possible.

› Avoid coloured foods and drinks as much as possible. Coffee, tea, red wine, food colouring, beetroot, etc., for up to 2 weeks after the end of treatment. That said, following a “white diet” is not essential, but it is recommended for the success of the treatment. In fact, brushing immediately after breaking the diet (e.g., after drinking coffee) is suggested.

› Avoid cold, hot or acidic foods that may cause dental hypersensitivity. The patient should be aware not to ingest acids that contribute to demineralisation.

› Make sure to note that restorations in the anterior area do not bleach, and may need to be modified after treatment[68,69].

PRECAUTIONS TO BE TAKEN BY THE CLINICIAN

› Prophylaxis before bleaching treatment.

› Patients over 18 years of age.

› Do not apply to pregnant or breastfeeding women.

› Do not take silicone impressions while the treatment is being done and up to 2 weeks after finishing it, as they may stain the teeth.

› Do not apply to teeth with exposed dentine or defective restorations[68,69].

ACTIVATION SYSTEMS

Activation of peroxides can be done chemically, with light, heat or sonic waves. Chemical and light activation are currently the most commonly used.

- **Chemical activation**

Hydrogen peroxide in concentrations of 35-40% and carbamide peroxide in concentrations of 35% for in-office treatment.

This activation is achieved by means of chemical catalysts by mixing two components, which can be in powder-liquid or gel form.

- **Light and/or heat activation**

Hydrogen peroxide in concentrations between 25 and 37.5% in office treatments.

These accelerate the decomposition of hydrogen peroxide, which increases efficacy in less treatment time.

Do not exceed 55°C to avoid pulp damage.

Lamp types: halogen, diode or LED, argon laser, diode laser and plasma.

Bleaching with light has been shown to be more effective than bleaching without light[68,69].

8.3. Whitening of vital teeth. At-home and in-office whitening

AT-HOME WHITENING

The patient will be the one to apply the bleaching product, having been instructed by the professional. This method is more predictable and safer than in-clinic bleaching and lasts longer.

Advantages. Patient self-administration, shorter chair time, high level of safety, fewer adverse effects, low cost.

Carbamide peroxide is more stable than hydrogen peroxide. It breaks down more slowly and produces less sensitivity.

Disadvantages. Requires patient participation, requires discipline and drop-outs are frequent if the patient is not motivated.

Higher concentrations of carbamide peroxide do not result in greater whitening at the end of treatment. Using a higher concentration of product causes more sensitivity and does not improve efficacy.

The longer the patient uses it per day, the greater the efficacy tends to be, but the frequency of hypersensitivity also increases, so the application time must be readjusted and monitored as treatment progresses.

Types of at-home bleaching: toothpastes, varnish and brushes, plastic strips, preformed trays, individualised thermoplastic trays[68,69].

- **Technique with thermoplastic trays:**

The technique with thermoplastic trays is considered the gold standard in bleaching, due to its convenience, good results, safety and stability over time.

Hydrogen peroxide 3-6%: 1 or 2 applications 30-60 minutes. Daytime use.

Carbamide peroxide 10-16%: 1 or 2 applications. 90-120 minutes-8 hours. Day or night use.

The number of syringes varies depending on the patient. It is concluded when there is no change in colour in two consecutive check-ups. Ideally, this measurement is carried out with a spectrophotometer.

After two years there is a good stability of the whitening.

- Shades A and B: very good prognosis after 3-5 weeks of treatment.
- Shades C and D: worse prognosis. These need longer treatment time (6-8 weeks)[68,69].

- **Preparation of the bleaching trays:**

  - They should be between 1 mm and 0.5 mm thick, soft or rigid (preferable).
  - Make full-arch trays, even if no product is applied to the molars.
  - Scalloped or straight margins. 2 mm above the gingival margin.
  - Reservoirs: very thin or limited to the centre of the tooth.

STEP BY STEP...

1. At the first appointment, take alginate impressions of the patient and record the initial shade.
2. At the second appointment, the patient is given the trays and one or two bleaching syringes, and the at-home application procedure of the product is explained.
3. Check-ups are done every 1 or 2 weeks at which the colour change will be assessed with photographs or spectrophotometers (see appendix at the end).

The treatment is completed when there is no change in colour between two appointments.

- **Instructions for the patient:**
  - The teeth should be brushed before applying this product.
  - Apply very small amounts (half a grain of rice). Applying more product does not give a better result, but rather wastes the product.
  - You can apply it on one or all the teeth.
  - Syringes should ideally be stored in the refrigerator, not exposed to sunlight or high temperatures.
  - After use, rinse with cold water and brush teeth.

IN-OFFICE BLEACHING

The dentist performs the treatment in the clinic, with high concentrations of the whitening products. As a general rule, in-office whitening is less long-lasting than outpatient whitening, so it is recommended to use it in combination with trays at home.

Advantages. Faster results. Keep in mind that immediately after treatment, you will notice an increased whitening effect due to dehydration

Disadvantages. Greater hypersensitivity than home treatment, gingival and eve throat irritation has been reported, less stability over time[69-72].

- **Indications:**
  - Patients who need to obtain results as soon as possible.
  - Severe discolouration, as a preliminary step before a combined treatment.
  - Reduction of treatment times in combination with at-home bleaching.



Initial situation. Colour determination.

Figure 184. Initial situation. Made by Ferrando A.



Insulation Zoom. Phillips system. Apply 25% hydrogen peroxide activated with blue LED light in four 15-minute cycles.

Figure 185. Polarised photograph of the isolation for in-office bleaching, showing an intensification of the white spots due to dehydration. Made by Ferrando A.



Immediate result. The effect can be seen with the starter guide, despite dehydration.

Figure 186. Immediate result after 45 minutes of Zoom. Made by Ferrando A.



Stabilised result after two months. After the Zoom system session in-office. The patient later underwent combined home treatment with trays and 16% carbamide peroxide for 2 weeks.

Figure 187. On the left of the document is the final colour determination after one month. Made by Ferrando A.

- **Product application**

The application time varies depending on the product, concentration and activation system used. Each session is normally made up of 3-4 cycles of 8-20 minutes. A single session will not achieve the desired results, so several sessions will be necessary, as well as reinforcement at home with trays so that the result lasts over time.

Protocol with 35-40% hydrogen peroxide without light activation, only chemical.

1. Isolation of the soft tissues with rubber dam or light-curing resin and retractors.
2. Activation of the product and application in a thin layer according to the manufacturer's instructions. Let it act for 8-20 minutes (according to the manufacturer's instructions).
3. Remove the product with suction; if absolute isolation is not used, do not rinse to avoid dispersion of the gel in soft tissues.
4. Repeat the application 2 or 4 times, without exceeding the limit specified by the manufacturer, as long as the patient does not experience any dental discomfort or hypersensitivity at any time[69-72].

- **In-office whitening with thermoplastic trays**

Also called 'waiting room' whitening. The practitioner places high concentrations of 35-45% carbamide peroxide in thermoplastic trays similar to those used for outpatient bleaching. The patient waits supervised in the waiting room for half an hour, and the product is removed by the practitioner. Clinical efficacy is lower. This is recommended as an initial treatment or for corrections[69].

8.4. Tooth whitening. Endodontics. Dental preparation. Clinical techniques

Pulp haemorrhage is the most frequent cause of discolouration after trauma. Other causes of discolouration in endodontically treated teeth are necrosis and iatrogenic discolouration due to dental treatments and products. Discolouration due to metal ions from materials such as silver tips and amalgam fillings do not respond to bleaching[73].

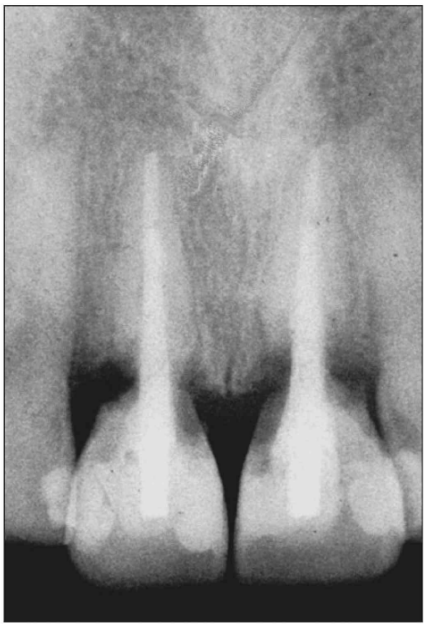


Figure 188. Example of periapical radiograph showing cervical external resorption. Made by Dahl.[72]

One of the most common complications of internal bleaching is cervical resorptions. To prevent them, the canal must be sealed with a material that impedes the penetration of the product into the canal or periodontal space, and misaligned restorations must be repeated prior to bleaching to ensure a proper marginal seal. Cervical resorptions may be related to several factors, in particular, to the lowering of the pH (due to the carbonyl acid released during bleaching), as well as to an excessive duration of treatment and heating of the bleaching agent.

Avoid heating the product and use low concentrations of the bleaching agent. Orthodontics, dental trauma and defects at the cementoenamel junction are some of the factors that may promote cervical resorption[73,74].

- Hydrogen peroxide 35%.
- Carbamide peroxide 45%.



Figure 189. Opalescence Endo. Made by Ultradent Inc. From https://la.ultradent.blog/2016/08/02/una-solucion-de-blanqueamiento-para-dientes-no-vitales-opalescence-endo

Prior to treatment, the patient must be informed of the risks and that there is no guarantee that the whitening will be successful. They should be aware that a new opening will make the tooth weaker, and that it should not be subjected to heavy loads, as there is a risk of fracture.

The long-term success rate in cases of internal bleaching with an outpatient technique can be as low as 50% or less.



Blanqueamiento interno ambulatorio

Figure 190. Photographic comparison of internal bleaching with twin flash, polarised and ring flash. Initial (bottom) and final situation (top). Made by Ferrando A.

STEP BY STEP (Walking bleach technique / outpatient bleaching)

1. Take the initial colour and record it with photographs.
2. Make access cavity under absolute isolation.
3. Lower the gutta-percha 2mm subgingivally (checking with a periodontal probe). Make sure that no gutta-percha is left in the pulp chamber, the cleanliness of the cavity can be further increased by sandblasting with alumina oxide.
4. Seal the canal with an impermeable material: Modified glass ionomer cement* (Vitrebond), zinc oxyphosphate (Fortex), flowable composite or self-etching/self-adhesive cement. The thickness of this material should be 2mm[74].

   *Do not use glass ionomer if bleaching with hydrogen peroxide[75].

5. Refresh the dentin with a tungsten carbide contra-angle ball bur or sandblast with alumina oxide.
6. Insert the bleaching product into the chamber (occupying 50% of the chamber), a cotton pellet or sponge and close the access cavity with a provisional filling such as Cavit, IRM, telium or composite.

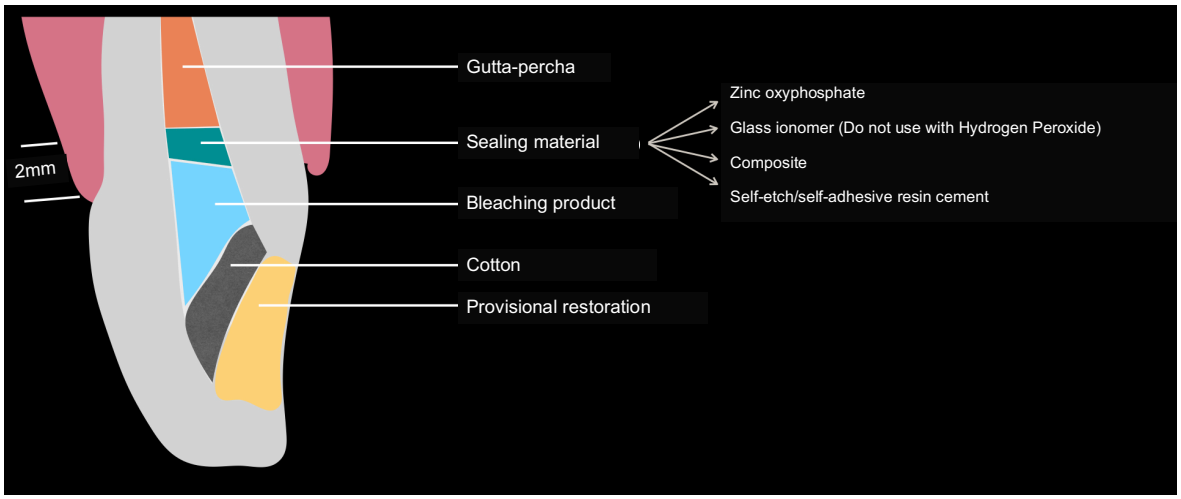


Figure 191. Internal bleaching diagram. Made by Álvarez-Maldonado N.

Control visits will be made every week, in which the change in value obtained will be assessed, and the product will be changed. If there is no evident change in colour after 2 or 3 sessions, stop the treatment and look for an alternative restorative solution (such as a porcelain or resin veneer)[76].

8.5. Bleaching side effects and how to prevent them

- Reversible / Irreversible pulpitis.
- Periodontal lesions. Necrosis of the periodontal ligament, ankylosis, root resorption (are rare, they have been linked to sustained temperatures over 40ºC).
- Post-treatment hypersensitivity and/or pain.
- Allergy.
- Occlusal disorders.
- Gum irritation (outpatient).
- Burns (clinical). Apply vitamin E oil or gel.
- Systemic effects: irritation of gastrointestinal mucosa, burning of palate and throat.
- Discolouration recurrence.
- Interference with adhesion.
- Bleachoxeria.

POST-TREATMENT HYPERSENSITIVITY

This is the most prevalent adverse effect in whitening treatments (more than 80% of cases). The peak is on the third day of treatment and is reversible in 1-2 days when the patient discontinues treatment. This is less frequent when carbamide peroxide is used, because the syringes usually contain desensitising agents (NK, NaF). The mechanisms of bleaching sensitivity are not known at present, but inflammatory mediators are known to play a major role. Ibuprofen is prescribed as a pre- and post-bleaching medication.

Causes

- Gel concentration.
- Exposure time. Instead of using it for 8 hours, you can use it for 2 hours.
- Tray design.
- Penetration of the tubules.
- Gel pH.
- Pulp size.

Desensitisers that can be used include fluoride, CCP (casein-phosphate) and ACP (amorphous calcium phosphate) pastes and potassium nitrate.

As for Potassium Nitrate (NK), so far:

- It does not reduce the effectiveness of the treatment.
- In patients with previous sensitivity, use the tray with 2% NK for 3 weeks prior to bleaching, 30 minutes per day. Treat with 10% carbamide peroxide 2 hours a day.
- Use toothpaste with 5% NK during treatments.

8.5.1. 'Over-the-counter' bleaching products.

Non-prescription whitening products have emerged as an inexpensive alternative to whiten teeth without the supervision of a dentist. Different over-the-counter products, such as rinses, small 'painting' brushes, toothpaste, chewing gum, dental floss and whitening strips, can be found in supermarkets, pharmacies or on the internet (especially in the US). Clinical evidence on the safety and efficacy of these products is lacking, and most studies are supported by the manufacturers. Basically, toothpastes, chewing gum and dental floss are surface stain removal agents. Rinses and 'painting' brushes with low levels of hydrogen peroxide have some whitening effect, but no clinical relevance. Strips have similar aesthetic results and side effects compared to whitening with 10% carbamide peroxide using trays; however, the studies were financially supported by the manufacturers and were based on short-term evaluations.

Legislation varies widely from country to country regarding over-the-counter tooth whitening. Concerns have been raised about the possible misuse of these self-medication agents, especially in young patients, with possible harmful results. Dentists ought to know about these types of products in order to be able to inform their patients.

To conclude, there is a need for independent clinical trials that provide sufficient evidence on the use of non-prescription whitening products[77].

Special thanks to Dr. José Amengual Lorenzo for reviewing this chapter.

UCAM

Chapter 9



The current state of dental porcelain

Classification and development. Ceramic veneers

Photo by Dr. Fernando Rey Duro

9.1. Ceramics in Dentistry. Concept

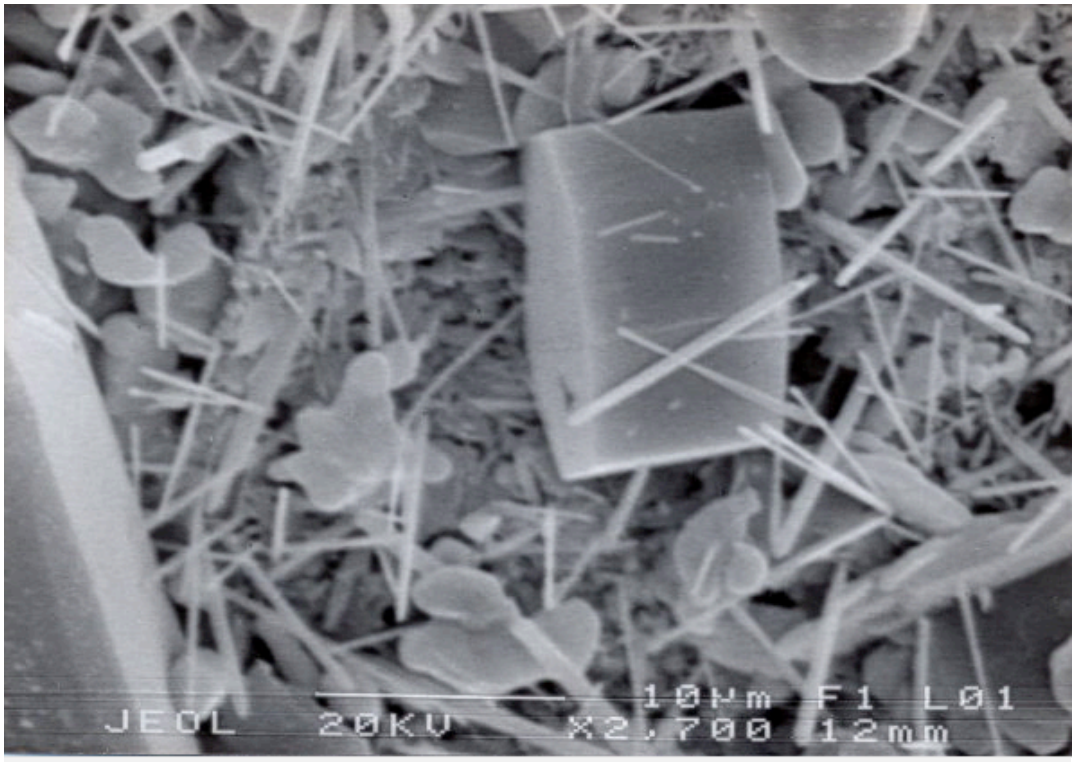
The term ‘ceramic’ is defined as an inorganic material of mineral origin, which is moulded at room temperature and whose shape is fixed with heat[1].

The terms porcelain and ceramics are often used interchangeably in everyday practice, although the former refers to high-quality, less porous, harder and stiffer ceramics with excellent appearance and surface qualities.

Etymologically, ‘ceramic' comes from the Greek κεραμικος (keramikos = ‘made of clay’). It is also associated with the Indo-European root ‘ker’ (fire or heat and ultimately burnt material). Thus, ceramics refers to ‘the art of making pots and other objects of earthenware and porcelain, of all kinds and qualities’. Porcelain, however, comes from the Italian ‘porcellana’, and refers to that kind of fine, transparent, clear earthenware created in China and imitated in Europe.

Porcelain, from a chemical point of view, is a densified product derived from a mixture: clay, quartz or silica and feldspar.

The microstructure is characterised by the presence of primary mullite crystals, secondary mullite, residual quartz in the form of α-quartz and a binder matrix phase originating from feldspar. Densification takes place in very high temperature temperatures ranging from 900-3000ºC[78].



Mullite crystallises in the orthorhombic crystal system, and it usually develops small prismatic or needle-shaped crystals with a crystal-like sheen on the surfaces. In its pure form, mullite is colourless and transparent. However, due to multiple refraction caused by lattice defects or polycrystalline formation, it may also appear white and, due to additions of substances, acquire a grey, light pink or red or violet colour, with a corresponding decrease in transparency.

Figure 192. SEM micrograph of Mullita. Made by Thomas Witzke.

Dental ceramics must have the following characteristics: biocompatibility, chemical stability, low thermal conductivity, corrosion resistance in the oral cavity and optical characteristics (translucency and light transmission) similar to the natural tooth.

The disadvantages that have classically been attributed to all-ceramic restorations, derived from their fragility, are currently under discussion due to the introduction of zirconia or lithium disilicate-based ceramics on the market. Therefore, it is essential to bear the need for a constant revision and updating of the subject in mind, as these materials are in continuous evolution[79].

9.2.Classification of dental ceramics

For the purposes of unifying criteria and improving communication, ceramics will be classified according to their chemical composition and, therefore, their intrinsic or mechanical resistance. Thus, typically there are two well-differentiated groups on the basis of their composition, their susceptibility to hydrofluoric acid and their ability to adhere to the dental substrate[80].



Figure 193. General classification of ceramics. Made by Ferrando A and inspired in Kina S.[80]

Ceramics in general, based on their composition, have two very distinct parts:

Vitreous phase or glass matrix:

60% silica, which is an amorphous binder, is chemically inert, stable over time to corrosion, does not degrade on the surface and can incorporate colour shades. In fact, it is responsible for most of the optical properties. Finally, it has low porosity, thus preventing biofilm (bacterial plaque) build-up. However, it has low mechanical strength[80].

Crystalline phase:

This is the one that changes, providing the mechanical strength characteristics and improving the optical properties! This is where the ceramic really gets its name[80].

In the case of oxide-based ceramics, the glass matrix disappears because it becomes completely saturated, or it is replaced by the crystalline phase, which is based on alumina or zirconium oxides. The latter is one of the materials that has undergone most development at present, since alumina ceramics have practically disappeared from the market[81].

From a clinical point of view, the two most relevant parameters when selecting a ceramic system are aesthetics, since most of the ceramic restorations are placed in the anterior sector; and secondly, mechanical or intrinsic strength, since they must be able to withstand functional and parafunctional occlusal loads, especially in the posterior sector. Both parameters are closely interrelated due to the fact that, in order to perform well mechanically, porcelains need to increase the crystal content in their composition. However, this higher crystal content generally led to a loss of the optical properties of the porcelain, making it opaquer, as in the case of the first zirconia materials that appeared on the market, 3Y-TZP. However, today there are ultra-translucent zirconia materials with good optical properties, so the evolution of ceramic materials does not allow us to make such a categorical analysis of the purely cosmetic aspect. That said, lithium disilicate HT is currently still more translucent than ultra-translucent zirconia.

In any case, the importance of high intrinsic mechanical strength lies in the fact that feldspathic porcelain cannot withstand even the slightest flexing (feldspathic porcelain is used to cover both metal copings and structures and zirconium oxide, and RPAs). This is why it is an important property to consider, especially when choosing a ceramic system for posterior crowns and/or bridges. In this regard, considering that 1MPa = 10N/mm² ±1Kg (of force) /mm², it would be completely inadvisable to choose classic feldspathic porcelain for an RPA with cusp coating on a second or first lower molar, as the masticatory force can reach 80kg/mm² (with variations of 50%). As we move towards the anterior sector, the force exerted during normal chewing decreases, and therefore the rest of the ceramic systems, which we will explain below, meet the functional mechanical requirements.

9.3. Classification according to strength and abrasiveness. Low, moderate and high

In terms of mechanical strength, porcelains can nowadays be classified into three groups: **low/moderate strength porcelains**, **highly abrasive** (classic feldspathic porcelain, reinforced with leucite IPS Empress Esthetic), **moderate/high strength porcelains, moderately abrasive** (lithium disilicate, e.max Press/CAD and reinforced with zirconium oxide, commercial example: Vita suprinity) and **high-strength porcelains**, **very low-abrasive** (zirconium oxide)[81]. However, this classification has nuances, as there are now super-translucent (4Y-TZP) and ultra-translucent (5Y-TZP) zirconia materials with a strength similar to disilicate, as well as combined materials with different crystalline compositions and/or raw materials, which we will look at below and which would place them in intermediate areas of the following classification.

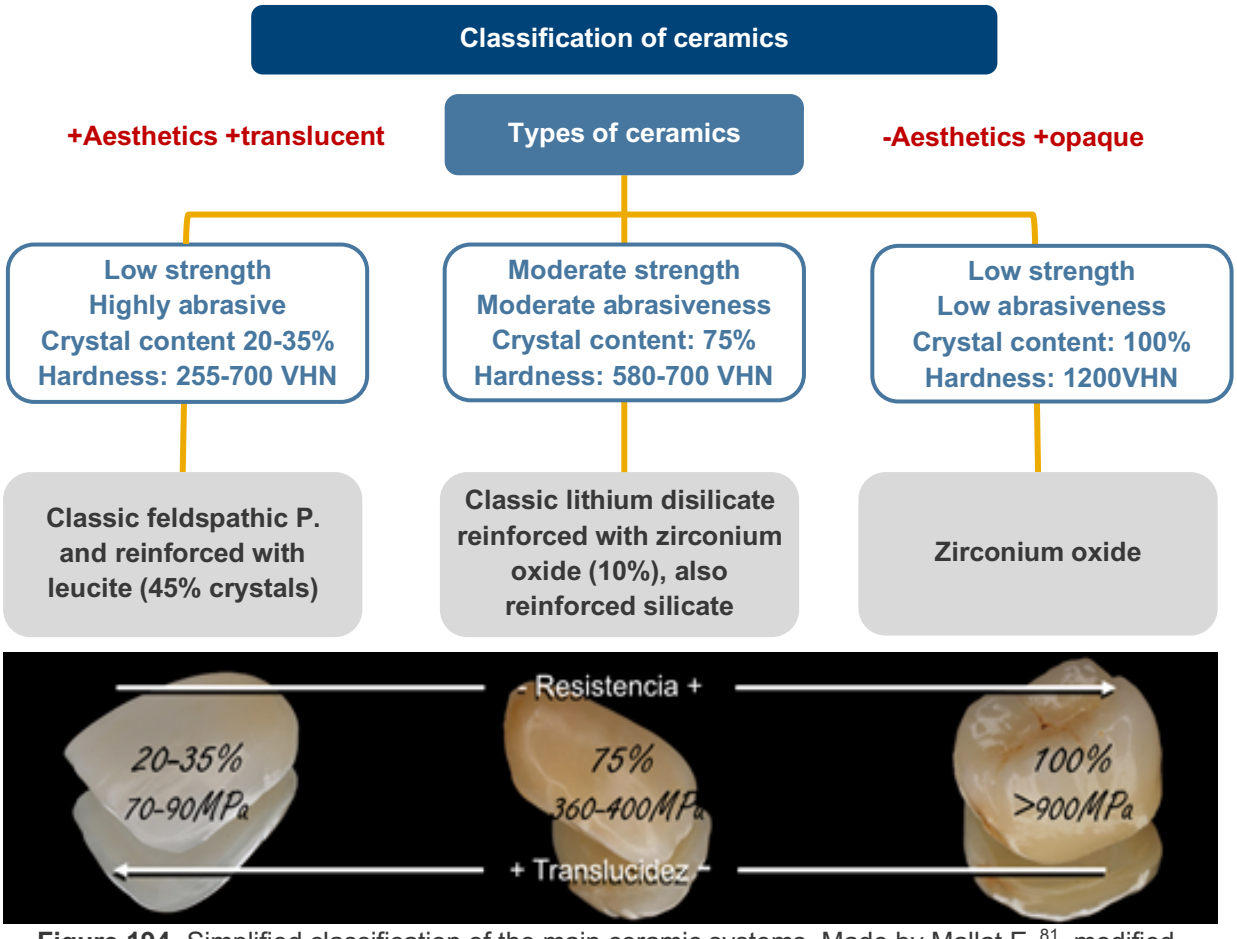


Figure 194. Simplified classification of the main ceramic systems. Made by Mallat E. [81], modified by Ferrando A.

With regard to the **abrasiveness and wear of the natural antagonist** of ceramic systems, the important aspects are **microstructure (proportion and size of crystals) and fracture resistance**. These aspects will determine **surface roughness**, which is why we must spend enough time polishing when retouching a ceramic in the mouth; hardness (VHN) will not serve as a clinical reference parameter. That said, according to the above classification, we can conclude that as the crystal content decreases, the proportion of glass matrix increases, and when porcelain is subjected to functional loading, microcracks can occur in it, which can cause crystals to detach, increasing surface roughness, which is ultimately responsible for inducing antagonist wear. Therefore, an increase in the crystalline phase will decrease antagonist wear.

In terms of **crystal size**, feldspathic and injected disilicate porcelains can reach 5-6 µm, CAD-CAM versions 0.5-3.5 µm, and finally zirconium oxide varies from 0.6 µm to 4 µm in the case of 5Y-TZP. The larger the crystal size, the greater the wear because the surface can become rougher.

Finally, it should be noted that the greater the **fracture resistance**, the more difficult it will be for microcracks to appear on the surface, and therefore the less abrasive the ceramic system will be.

To conclude, if one parameter had to be highlighted in terms of wear on natural enamel, it would be the presence or absence of a glass matrix. For this reason, classic feldspathic porcelain has everything it takes to be the most abrasive, while disilicate porcelain falls within the correct range between abrasiveness and wear in relation to enamel.

9.3.1. The first group, feldspathic porcelain

The low mechanical strength is due to the low crystal content. In feldspathic porcelain (e.g., IPS D-SIGN from Ivoclar Vivadent), with a flexural strength between 65-90MPa, there is the following composition:

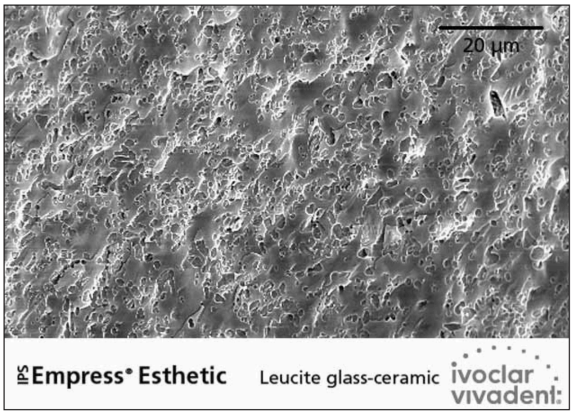
1º Feldspar (KzO-Al203-6SiO2): 75%-85%, the amorphous phase or matrix that binds the crystalline phase. It cools in vitreous form, making it translucent (on its own it would be transparent).

2º Silica or quartz (SiO2): 15%, the crystalline phase of porcelain.

3º Kaolin (aluminium silicate dihydrate): this is a minority component (3%-5%) and tends to be reduced more and more, since if it exceeds 10% of the composition it provides a high level of opacity. Feldspathic porcelain also contains other minority components such as pigments, metallic oxides etc.

Feldspathic porcelains, due to their low mechanical strength but good optical properties, should be used on metal or zirconium oxide copings, although they are also used for porcelain veneers as, **once bonded, the intrinsic strength becomes adhesive (x10), due to the intimate bonding with the enamel substrate**[82].

At the end of the 20th century and the beginning of the 21st century, feldspathic porcelains with higher strength, reaching 150-160 MPa, were emerging and becoming popular. This was ceramic reinforced with LEUCITE crystals.[83] One of the first ones to emerge in the 1990s was IPS Empress® I (Ivoclar): with 63% QUARTZ and 18% aluminium oxide. These owe their strength to a dispersion of leucite microcrystals, evenly distributed in the glass matrix. This difference in volume between the crystals and the amorphous mass generates residual stresses which are responsible for counteracting crack propagation. Currently, we have its evolution available under the name IPS Empress Esthetic for both injection and CAD-CAM, reaching 210 MPa.



CET (100–400°C) [10^{-6} /K]	16.6
CET (100–500°C) [10^{-6} /K]	17.5
Resistencia a la flexión (biaxial) [MPa]*	160
Resistencia a la fractura [MPa $m^{0.5}$]	1.3
Dureza Vickers [MPa]	6200
Solubilidad química [µg/cm^2]*	25

*de acuerdo con ISO 6872

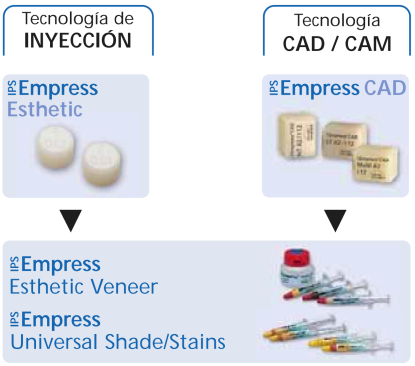


Figure 195. SEM micrograph and physicochemical properties of leucite-reinforced feldspathic porcelain. By Ivoclar Vivadent. From https://es.scribd.com/doc/125854226/IPS-Empress-Esthetic.

The evolution was IPS Empress® II (Ivoclar), the predecessor of lithium disilicate, which is now practically replaced by lithium disilicate with 57-80% quartz, 11-19% lithium oxide and 0-5% aluminium oxide. This system already included a feldspathic porcelain ceramic reinforced with 60% lithium disilicate and lithium orthophosphate reaching 350 Mpa, becoming popular for full porcelain crowns, classically known as porcelain "jackets" [79]. It is common to see cases in the clinic of anterior upper crowns (1.2-2.2) made from this ceramic system, which could be layered with classic feldspathic ceramic, associated with worn natural lower incisors, especially when there is also parafunction and/or overbite.

9.3.2. The second group, the popular lithium disilicate

In the second group there is the popular lithium disilicate, commercially known as IPS e.max® Press/CAD (Ivoclar). These new glass-ceramics are reinforced with lithium disilicate crystals only. Due to the higher homogeneity of the crystalline phase, they offer a higher fracture toughness than Empress® II. The saturation of the glass matrix is up to 70%. These ceramics can be used as a core as their flexural strength is up to 400MPa, whereby a conventional feldspathic porcelain can be applied for aesthetic veneering using the layering technique. Disilicate can be used as a coping or as a lowered structure for partial stratification or 'cut-back'. Lithium disilicate (e.max Press and its CAD-CAM version, e.max CAD) is the market leader in this group and is suitable for porcelain veneers in the most mechanically demanding situations, for the manufacture of anterior single crowns using the layering technique or for posterior crowns in monolithic and stained form. From an aesthetic point of view, monolithic restorations achieve good results, although they do not equal those of original feldspathic porcelains (in the case of veneers) or crowns with layered porcelain[81].

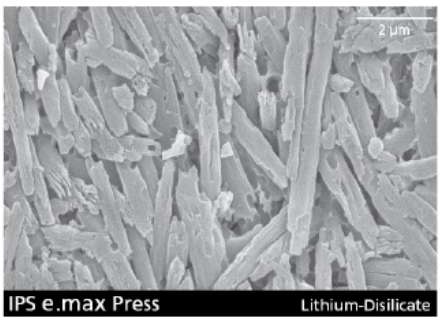


Figure 196. SEM micrograph of the IPSe.max Press lithium disilicate structure. By Ivoclar Vivadent. From https://www.dt-shop.com/fileadmin/media/ga/0358_ga_esp.pdf



Figure 197. Commercial presentation of lithium disilicate ingots. By Ivoclar Vivadent. From https://www.dt-shop.com/fileadmin/media/ga/0358_ga_esp.pdf

IPS. E max Press®

High fluorescence is only seen in the bleach-coloured ones and the other coloured MT (Medium Translucency). The others only have luminosity...

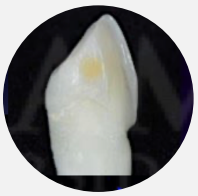




Figure 198.IPS. e.max Press fluorescence. There is more in the bleach ingots than in the HT (High Translucency), which is why HTs tend to grey in the clinic. By Ivoclar Vivadent.

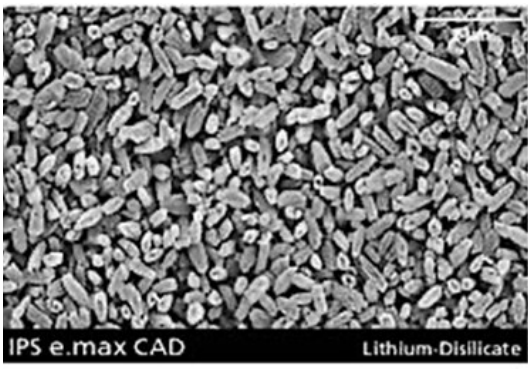


Figure 199. SEM micrograph of the IPSe.max CAD lithium disilicate structure. By Ivoclar Vivadent. From https://www.ivocalr.com/it_IT/CMS/ivoclar%20Vivadent/Clinical/Blocchetti/IPS-e-max-CAD-Documentaziones%20Scientifica.pdf



Figure 200. Commercial presentation of lithium disilicate blocks. Made by Ivoclar Vivadent. From https://www.ivocalr.com/it_IT/CMS/ivoclar%20Vivadent/Clinical/Blocchetti/IPS-e-max-CAD-Documentaziones%20Scientifica.pdf

In the case of e.max CAD, the material has lithium metasilicate crystals, which allows for easy processing without excessive wear on the milling cutter of the milling unit. This is available in the 'soft' or 'blue state' due to its bluish colour, containing 40% of metasilicate crystals in volume with an average crystal size of 0.5 µm. The final crystallised state contains a lithium disilicate microstructure, which provides its final mechanical and aesthetic properties. In this state, it contains more than 70% of lithium disilicate crystals in volume with an average size of 1.5 µm, but has slightly less strength than e.max press, reaching a maximum of 360MPa. As a clinical feature, HF generates less salt residue in the conditioning process.

Ivoclar's competitors have attempted to revolutionize the porcelain market by developing lithium silicates reinforced with 10% zirconium oxide (Suprinity® by VITA and Celtra® by Dentsply Sirona), which would also fall into the moderately resistant porcelain category, although they already reach 500 MPa[79,81]. Another example of this evolution are the "initial LiSi Block" blocks (GC.Japan), which are already crystallized and only require manual finishing and polishing, or those from Tessera (Dentsply Sirona.Germany), which only need rapid crystallization for 4.5 minutes, reaching 700Mpa.

9.3.3. The third group

In the third group there is zirconium oxide with a tetragonal structure partially stabilised with yttrium oxide. This is the group of the so-called high-strength polycrystalline porcelains, as there is no glassy matrix, only a crystalline phase. The main representative in this group is zirconium oxide, as the mechanical properties are superior to those of alumina oxide (which reaches 680MPa). The flexural strength of zirconium oxide reaches 900-1200MPa. It can be used to fabricate anterior crowns with feldspathic porcelain veneer or posterior crowns with feldspathic, monolithic or stained porcelain veneer. Recently, more translucent zirconia has appeared for this purpose, thus avoiding ceramic chipping, but they have lower or even similar flexural strengths to those of lithium disilicate, around 500MPa (e.g., KATANA® Kuraray Noritake). It can also be used for anterior and even posterior bridges, but in the latter case it will be essential to comply with the design requirements of the material, especially in terms of connector dimensions. In addition, it will be suitable for the fabrication of abutments for implant-supported prostheses and, due to its opacity, it will be very useful for masking dark stumps[79,83,84].

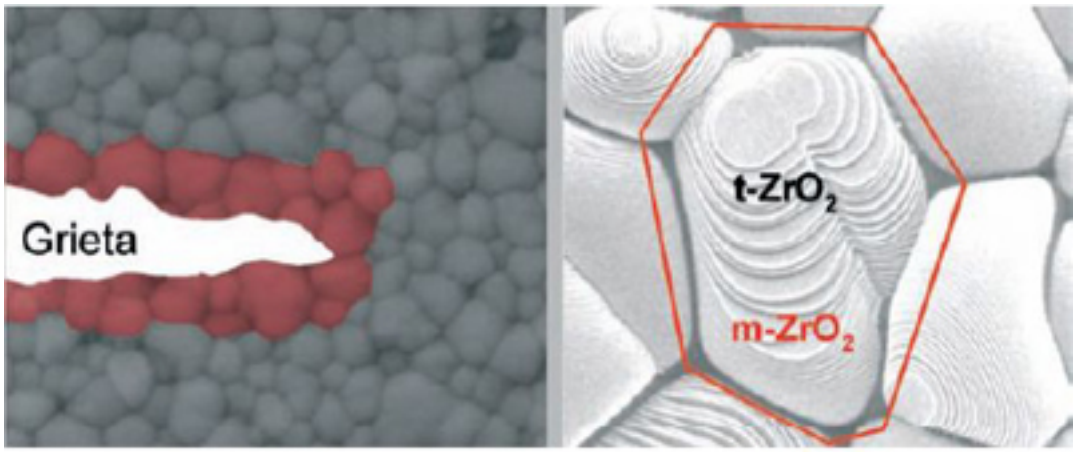


Figure 201. Crystalline phase transformation in zirconia. Made by Martínez Rus F.[79]

- **Clinical considerations for zirconium oxide**

Initially it was intended to replace metal due to its biocompatibility, but it is now starting to be used massively in monolithic-semitranslucent mode due to the problems of 'chipping' or flaking of the veneering ceramic.[85] It should be noted that zirconia is currently not able to adhere to the dental substrate in the same way as disilicate, as it is not susceptible to hydrofluoric acid. Nevertheless, adhesive protocols are being implemented, which have been tried and tested for years. They are based on a pre-treatment by sandblasting with 50μm aluminium oxide followed by primers with MDP and dual resin cements[86].

Handling is key and should always be done with water to avoid overheating of the structure. There is the question of 'low temperature degradation' (LTD) in the presence of humidity, an effect that remains unknown as to the clinical consequences it will have in the long term on restorations, but which can be summarised as a loss of density of the material in the monoclinic phase and, therefore, the creation of spaces between the crystals through which the water would infiltrate. Normally, for stress that does not exceed the fracture limit, the transformation from tetragonal to monoclinic phase avoids the propagation of cracks.[79] But this can become a problem if it happens massively, as it would change the volume of the particles, stopping the cracks in the beginning. Furthermore, changes in overall density occur, and therefore spaces appear in the structure that are susceptible to water filtration.

Nowadays the 1st and 2nd generation are more susceptible to LTD as their tetragonal phase transforms into monoclinic, thus making the structure more susceptible to ageing while theoretically halting the progression of cracking. The 3rd and 4th generation have significant percentages of cubic phase, and this does not

transform into monoclinic, so the propagation of cracks would not be prevented, but it would also be less susceptible to LTD.

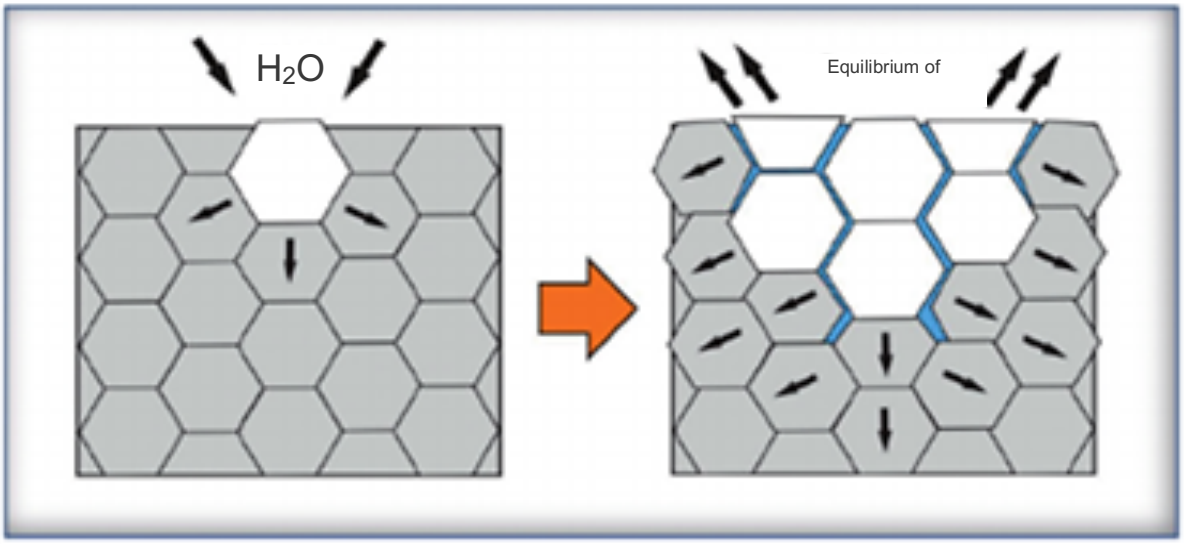


Figure 202. Diagram depicting H2O leaching due to massive phase transformation leading to a change in overall density and thus an increase in brittleness. Made by McLaren Ed.

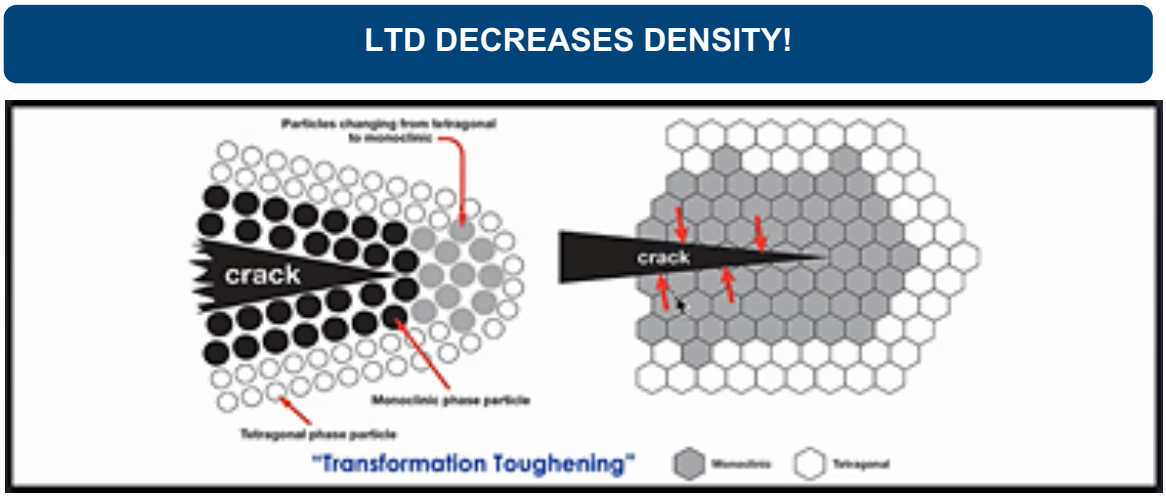


Figure 203. Diagram depicting the transformation toughening. Made by McLaren Ed.

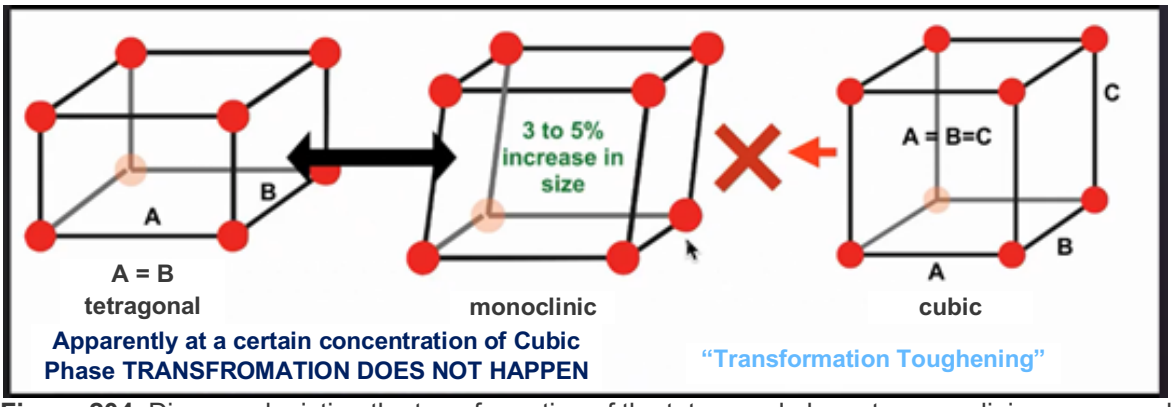


Figure 204. Diagram depicting the transformation of the tetragonal phase to monoclinic as opposed to cubic which does not transform. Made by McLaren Ed.

Table 3. Zirconium generations

	1st Generation 3Y-TZP	2nd Generation 3Y-TZP	3rd Generation 5Y-TZP	4th Generation 4Y-TZP
Zr_2O	>99.9	>99.9	>90.0	>92.0
Y_2O_3	4.5-5.6	4.5-5.6	<10	<6.0-7.0
Al_2O_3	0.25+-0.1	0.05+-0.02	0.01	0.01
Crystallographic structure	Tetragonal	Tetragonal	53% cubic 47% tetragonal	25% cubic 75% tetragonal
Flexural Strength (MPa)	+-1000	+-950	500-700	750-900
Use	PF ant, post and bridges	PF ant, post and bridges	PF unitary monolithic	PF unitary monolithic
Examples:	Lava Classic Prettau Zirconia Kavo Everest ZH IPS e-max ZirCAD MO Vita YZT	Lava Plus BruxZir Full-Streght Cercon ht Incoris TZI Katana HT/ML Vita YZ HT	Lava Esthetic BruxZir Anterior Cercon xt Katana UT/UTML	IPS e.max ZirCAD MT Katana ST/STML

Note. The four most important zirconium generations are classified, detailing the chemical composition. Special mention should be made of the decrease in strength as the cubic phase increases and thus the translucency. Use and main commercial examples were also included in the last row. Made by and courtesy of Mallat E and Villarroel M.

Currently, there are commercial zirconia products with **gradient** technology. For example, IPS e.max ZirCAD Prime and IPS e.max ZirCAD Prime Esthetic zirconia (Ivoclar-Vivadent) is composed of a combination of two ZrO2 raw materials: 3Y-TZP or 4Y-TZP for the cervical region and middle third, which provides high strength, and with more translucent 5Y-TZP for the incisal third. These presentations attempt to combine the best of the ultra-translucent (5Y-TZP) and the mechanically stronger (3Y-TZP or 4Y-TZP) materials, but the problem is that the presence of the more translucent material weakens the mechanically stronger material, so we would place them in the range of porcelains with moderate mechanical strength.

9.4. Veneers, crowns and partial restorations. Anterior and posterior sector

9.4.1. Feldspathic porcelain veneers

When considering a porcelain veneer treatment, the choice is between feldspathic porcelain or lithium disilicate with porcelain veneer. From an aesthetic point of view, a monolithic stained lithium disilicate veneer would not be the first choice, as either of the other two is better to achieve a 'natural integration and appearance'; but if there is a patient where the mechanical demands far exceed the aesthetic requirements, monolithic stained lithium disilicate veneers would be an excellent alternative, as well as being very realistic at the present time.

The classic indications for veneers with feldspathic porcelain are for moderate shade changes (maximum two shades, although in the hands of expert ceramists and with space for masking, 1.2-1.5 mm, severe discoloration can be managed), for a situation with low mechanical demands and where the incisal edge does not have to be lengthened by more than 2.5mm. Feldspathic porcelain should not be thicker than 2.5mm, as this weakens it and makes it more prone to fracture due to its low intrinsic mechanical resistance[79-83]. Currently, the indication for CAD-CAM leucite-reinforced feldspathic porcelain veneers is resurging due to the expansion and consolidation of the digital workflow.

9.4.2. Lithium disilicate ceramic veneers

The indications for using lithium disilicate to make veneers would be marked colour changes (three shades or more), non-uniform coloured substrate, incisal edge enlargements of more than 2mm and in situations of high mechanical stress (severe bruxism or severe overbite).

When using lithium disilicate for veneers, they should be at least 0.3mm thick if they are monolithic and injected, 0.4mm thick if they are monolithic and milled or at least 0.7mm thick when they are injected/milled and layered. In cases where feldspathic porcelain is layered over lithium disilicate, it should be noted that the thickness of the veneering ceramic should not exceed the thickness of the lithium disilicate coping or veneer, so it is currently advisable to limit reductions to the vestibular part of the structures, only to make "cutbacks" or stratification of the ceramic on the vestibular side, leaving the functional palatal part monolithic[79-81].

Variety in lithium disilicate according to translucency/opacity

Until recently, lithium disilicate came in four grades of translucency/opacity: HT (high translucency), LT (low translucency), MO (medium opacity) and HO (high opacity). Initially, HT and LT ingots are intended for veneers and inlays while MO and HO ingots are intended for crowns, although MO ingots can be used for veneers on teeth with tetracycline or other intense stains. HT ingots for veneers will be used when there is no need to mask the tooth preparation, when there is almost no need to change the base shade (maximum 1 shade), when high translucency is desired or in cases of multiple restorations where all teeth have similar conditions. By similar conditions, it means that, if an anterior group is all veneers, the HT ingots can be used, but if crowns and veneers are mixed, the LT ingots are the best choice. However, if the base colour of all the teeth is the same, HT ingots can be used; but if there are small differences, either on the entire vestibular side of one or more of them or only on some area of the vestibular side, LT ingots are preferable. LT ingots will also be used if the tooth preparation needs to be masked when more opacity is required or when the base shade needs to be changed by more than 1 shade; MO ingots are also a great option. Recently, MT (medium translucency) and Multi Shade ingots with colour degradation from cervical to incisal have appeared, clinically displacing LT in terms of their more natural look[81].

Table 4. Classification of lithium disilicate ingots according to translucency, processing technique and indications.

Grados de Translucidez	Técnica de Procesado			Indicaciones										
	Técnica de Maquillaje	Manual de estratifición												
		Técnica de cut-back	Técnica estratifición	Carillas Oclusales*	Carillas finas*	Carillas	Inlays	Onlays	Coronas parciales	Coronas anteriores	Coronas posteriores	Puentes de 3 elementos ¹	Pilar híbrido	Corona pilar híbrida
														
Multi	✓	✓				✓				✓	✓			✓
HT High Translucency	✓	✓		✓	✓	✓	✓	✓	✓					
MT Medium Translucency	✓	✓		✓	✓	✓			✓	✓	✓	✓		
LT Low Translucency	✓	✓				✓			✓	✓	✓	✓		✓
MO Medium Opacity			✓							✓	✓	✓	✓	
HO High Opacity			✓							✓	✓	✓		
I Impulse	✓	✓		✓	✓	✓								

Note. The main translucency options available in lithium disilicate and their possible indications (https://www.ivoclar.com/es_es/products/metal-free-ceramics/ips-e.max-press). Made by Ivoclar Vivadent. From https://www.passeidireto.com/arquivo/70435477/manual-ips-e-max-press-monolithic.

9.4.3. Crowns on anterior teeth

When it comes to anterior crowns, both **lithium disilicate with veneering porcelain** and **zirconium oxide with veneering porcelain** can be used. From a strictly aesthetic point of view, it is not a good option to use monolithic and stained disilicate crowns. If the restorative material is given the required thickness, the laboratory technician can achieve excellent aesthetic results with both materials[79-81].

9.4.4. Onlays in premolars and molars

When restoring with onlays, the material of choice is lithium disilicate, although it is possible to use leucite-reinforced feldspathic ceramic, both should be used in their monolithic and veneered versions. In these cases, it is recommended that the material be at least 1.2 mm thick (if it is bonded exclusively to enamel, the thickness can be reduced to 0.8 mm according to Fradeani M.). However, 2 mm thickness on the occlusal surface would be the safest thickness and the most widely documented in the literature. It is classically recommended to make horizontal preparations on the axial surfaces with a depth of 1 mm. The aesthetic results are excellent and the mechanical behaviour is adequate[79].

9.4.5. Crowns on premolars and molars

All-ceramic restorations have been shown to be suitable for use as single crowns in posterior teeth, as long as the minimum dimensions required to cope with the mechanical load are respected. In the study by Sun et al. (2014), the fracture resistance of metal ceramic restorations was compared with different all-ceramic restoration options. The results obtained show that all three options (monolithic and stained lithium disilicate, zirconium oxide with layered porcelain, monolithic and stained zirconium oxide) are perfectly valid. In any case, it is essential to give the restorative material the right thickness and that the zirconium oxide copings must be anatomical. In an aesthetic area we can opt for monolithic/layered “cut-back” disilicate or zirconium oxide with layered porcelain on the vestibular side; in the non-aesthetic area and if there is sufficient space, either of the two can be used; while in non-aesthetic areas with limited occlusal space for the restorative material, disilicate or zirconium oxide will also be the choice, although monolithic and

veneered. Mechanically ultra-polished zirconium oxide is a very antagonist-friendly option in terms of wear[81].

Monolithic and stained lithium disilicate provides good aesthetics, good marginal fit, high fracture resistance, is easy to fabricate and offers good occlusal fit without altering its mechanical properties. The aesthetics are good but always slightly better if a veneering feldspathic porcelain is used.[80.81]

The second option for posterior teeth is **zirconium oxide crowns with feldspathic porcelain veneers**. In these cases, zirconium oxide crowns and frameworks must follow design guidelines to avoid vestibular gingival margin recession, debonding or chipping of the porcelain veneer. It should be kept in mind that porcelain veneer chipping has been reported in up to 25% of restorations at 36-70 months. The design guidelines to be followed are as follows: always try to make the contact points of posterior and anterior teeth in pure zirconium oxide and provide adequate support with the structure to the cusps and/or incisal edges in case of stratification (prior wax-up planning is essential), as this is one of the main causes of the much-feared "chipping." [84,85].

Limited restorative space

Monolithic zirconia crowns can be produced when there is insufficient space. Although the hardness of zirconium oxide is very high (1200VHN), many studies show that the wear generated by zirconium oxide on the antagonist enamel is less than that produced by feldspathic porcelain as long as it is well polished[81,84].

9.4.6. Bridges (anterior or posterior)

Currently, the material of choice for all-ceramic bridges, whether anterior or posterior, is zirconium oxide (3Y-TZP), as its fracture strength is clearly superior to that of lithium disilicate. The use of lithium disilicate has been considered, but with the following limitations: only up to the first premolar and if they are monolithic, the pontic space should not exceed 11mm^2 in the anterior sector and 7mm^2 in the posterior sector, the connectors should be 12mm^2 in the anterior sector and 16mm^2 in the posterior sector. It is preferable that they are made of e.max Press (it has better mechanical properties than e.max CAD). However, the survival rate for lithium disilicate bridges with porcelain veneer is 50-78% at 2-10 years and the survival rate for monolithic bridges is 86-93% at 4-11 years[81].

In the case of zirconium oxide, it is important that the dimensions of the connectors are adequate, as this is the area where most fractures occur in all-ceramic bridges, especially when there is more than one pontic. The abutment-pontic connectors should have a cross-section of 7mm^2 for anterior zirconia bridges and 9mm^2 for posterior bridges. In the case of four-piece bridges with two pontics, it is necessary to increase the thickness of the central connector, which joins the two pontics, as this is the one that will be subjected to the greatest stresses. While the connectors joining each abutment to the adjacent pontic can have a surface area of 9 mm^2, the connector joining the two pontics should have a surface area of 12 mm^2 [81,84].

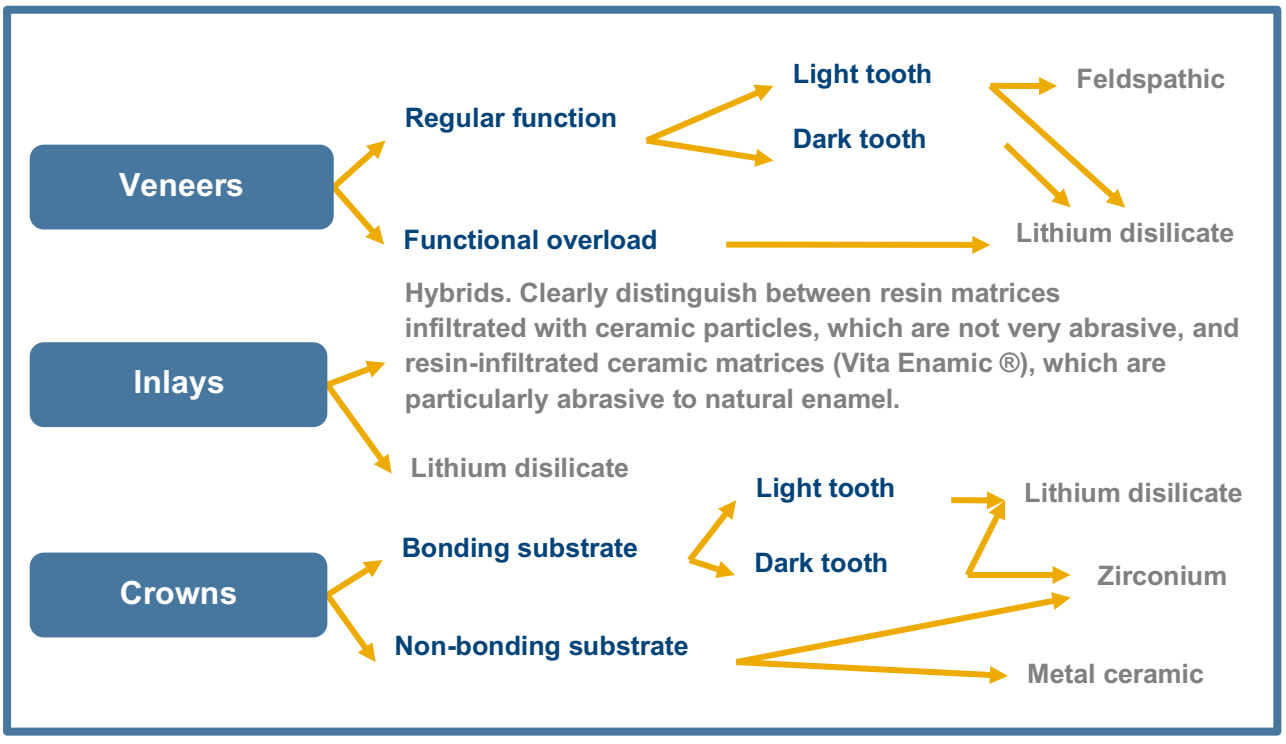


Figure 205. Outline of clinical indications and different materials. Made by Casas Terron J.[87]

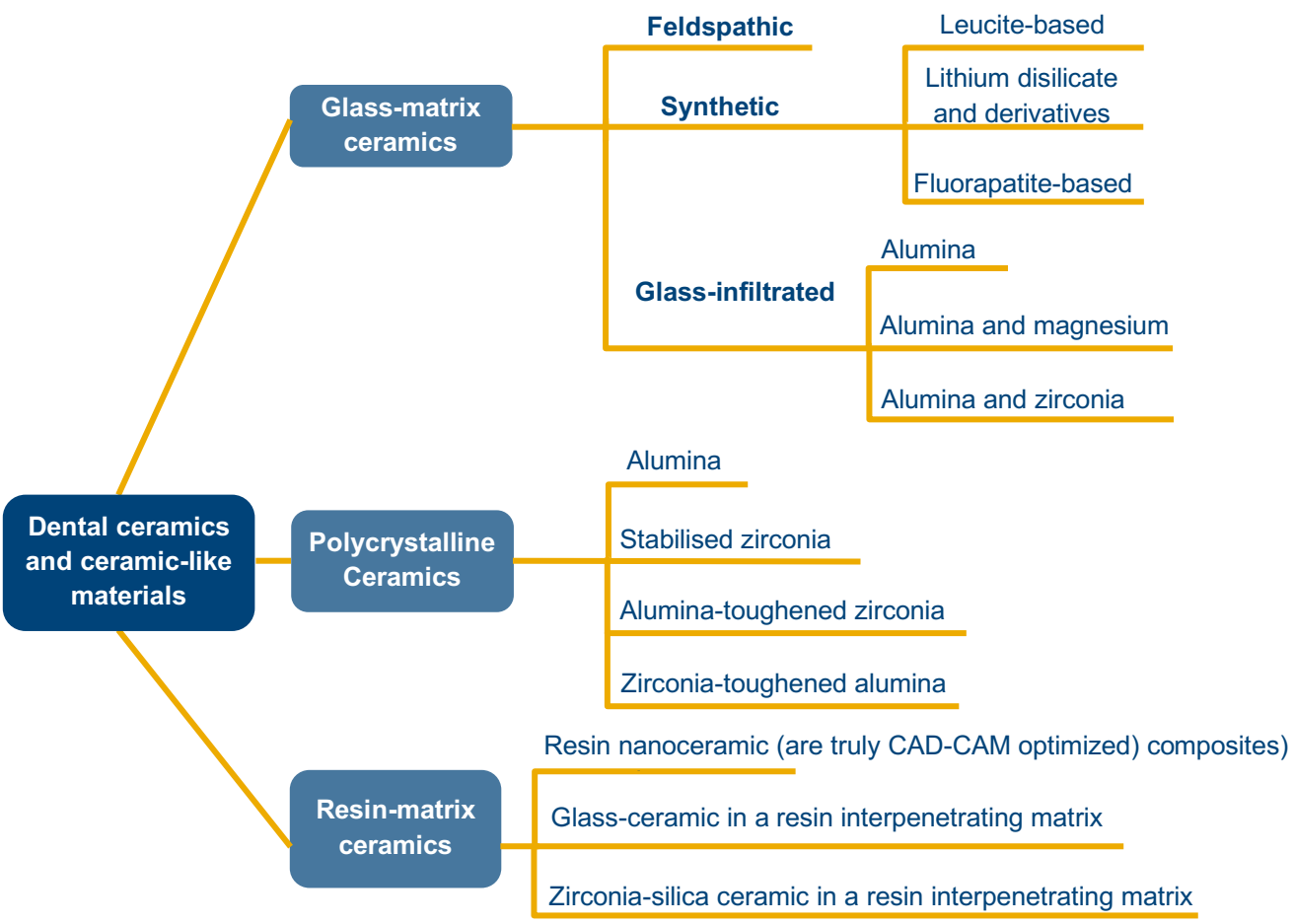


Figure 206. Classification of ceramic materials. Made by Gracis S in 2015, from Casas Terron J.[87]

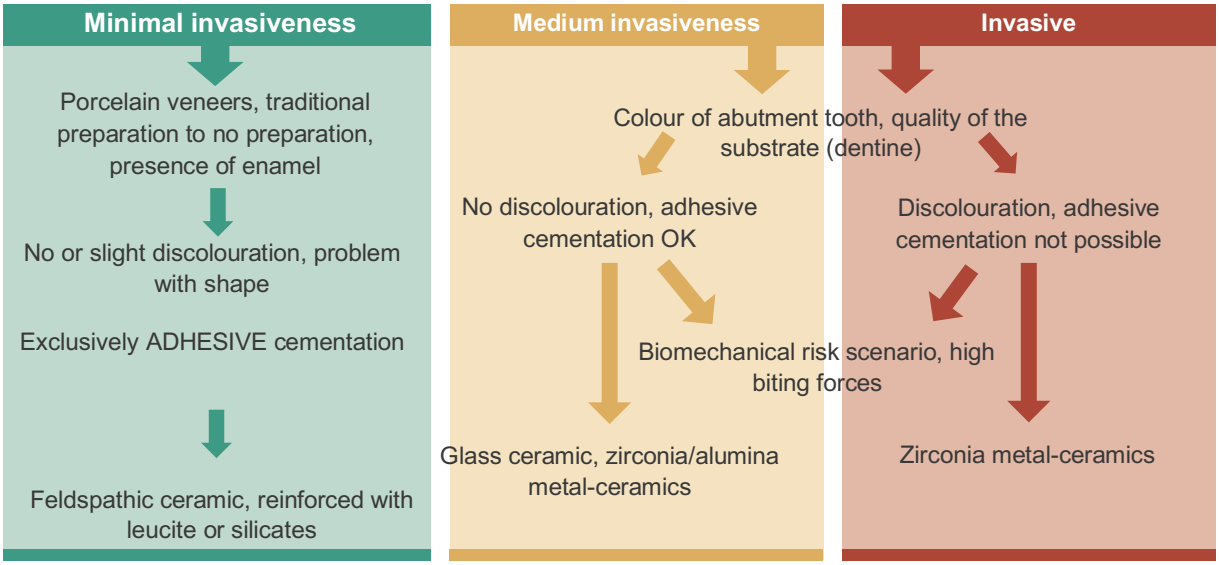


Figure 207. Decision-making for single-tooth restorations based on the invasiveness of the procedure. Made by Fehmer V in 2014. From Casas Terron J.[87]

Special thanks to Dr. Ernest Mallat Callís for reviewing this chapter.

UCAM

10 Chapter





Bonded partial posterior restauration

Guest Author: Natalia Álvarez-Maldonado

Photo by Dr. Fernando Rey Duro

10.1. Bonded posterior partial restorations

There are different treatment options for a loss of tooth structure in a posterior tooth: direct composite restoration, indirect restoration (inlay/onlay/overlay/endo-crown), or full veneer crown. Direct restorations have advantages, but also important limitations that make them not suitable for all cavities, mainly due to polymerisation shrinkage.[88] This shrinkage can lead to a gap or failure of adaptation of the restoration, secondary caries, propagation of tooth cracks up to cuspid fracture or postoperative sensitivity. These effects of shrinkage depend on cavity size and geometry, bonding technique and material application[89].

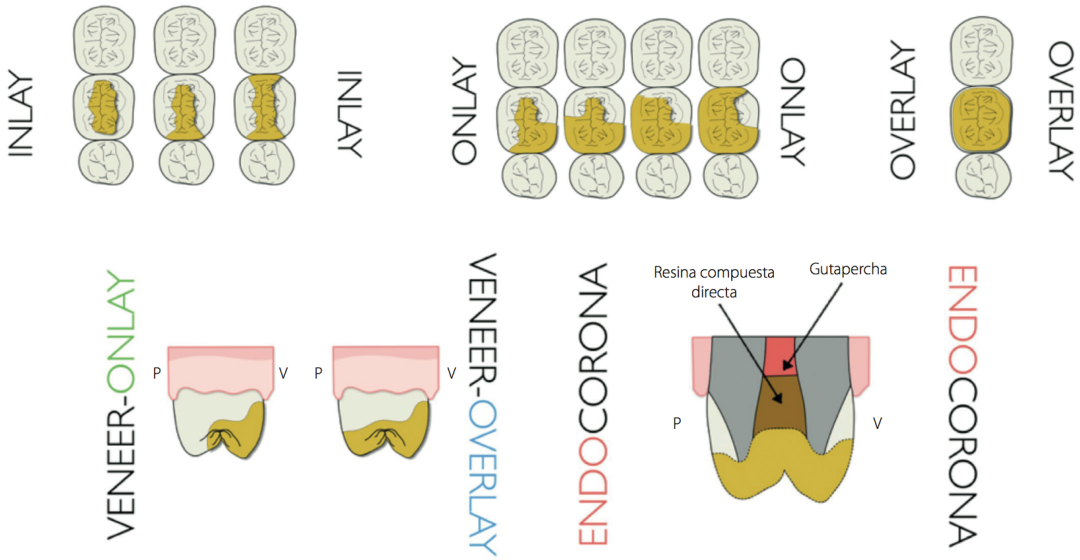


Figure 208. Types of indirect restorations. Made by SEPES[86] and Re D.

General considerations on materials

Even if you achieve an excellent aesthetic and functional long-term integration in the medium, **the ideal material does not exist**, there is still a long way to go to reproduce the natural model combining dentin and enamel in a restoration. This is because the materials used to restore are either resinous or ceramic in nature, which is why, for the time being, these procedures should be referred to, as described by Dietschi and Spreafico[90] in 2015, as biosubstitutes. Having said that, the key question to ask would always be: which material is best for indirect adhesive posterior restorations, resin or ceramic? As always, the answer is: it depends on the patient and clinical situation, as ceramics will generally provide greater rigidity, wear resistance, and stability against corrosion and discoloration, but greater abrasiveness of the antagonist [91,92]. Resinous materials, on the other hand, have greater flexion, repair capacity, and resilience, and are the gentlest on the antagonist in terms of abrasiveness[93,94]. Both have demonstrated phenomenal clinical behaviour in the medium to long term. In ceramics, there have been follow-ups of more than 10 years[95] and, with conventional microhybrid composite, indirectly treated, there is also a lot of literature with large samples and long follow-ups with excellent results. In 2014, Fennis[93] presented a comparison of direct and indirect composite at a 5-year follow-up with survival rates between 85-90% and without finding significant differences between the two procedures. Finally, and with regard to the long-term, it should be noted that Barabanti and Mangani[94] in 2015 published a 10-year follow-up of 48 indirect composite restorations with a success rate of 90%, evaluating all important parameters such as: surface texture, marginal integrity and discolouration, shade, secondary caries and anatomical shape.

Therefore, an accurate conclusion would be that ‘any material is valid’, but the reality is that it will depend very much on the clinical situation. If there are remaining cusps, composite is probably a great choice, but if there is a full occlusal face to be covered, the behaviour of ceramic will be better in the long term as it will restore the lost rigidity, and is more resistant to wear than composite, so in patients with bruxism, the vertical dimension of occlusion would be better maintained.

10.1.1. Definition and indications

- **Inlay**

Indirect restoration of porcelain, resin or hybrid materials adapted to the cavity of a tooth. This does not include cuspid veneer.

- **Onlay**

Indirect restoration of porcelain, resin or hybrid materials adapted to the cavity of a tooth. This includes partial or complete cuspid veneer depending on the type of onlay (see figures). There are several subtypes:

› Onlay: includes partial cuspid coating.

› Overlay: includes full cuspid coverage.

› Veneer-Onlay/Overlay or Vonlay: with preparation of the vestibular side for high aesthetic requirements.

› Endocrown: takes advantage of the pulp chamber without intraradicular retention to achieve a larger bonding surface and an anti-rotational element. Including complete cuspid liner[89].

INDICATIONS[89]

- **INLAY**

There is controversy regarding the indications for inlays, since, when the cavity is small, direct restorations are recommended, as the aim is to be as conservative as possible and inlays require a minimum thickness in width and depth, which would require a more aggressive approach. In addition, several authors do not recommend it due to the wedge effect generated in MOD cavities and because it makes it difficult to avoid the margins of the restoration in occlusal areas. Other authors state that it is justified when restoring a complete quadrant with more restorations at the same time.

Therefore, inlays will be used when restoring a full quadrant with more restorations at the same time.

- **ONLAY/OVERLAY**

  Large cavities.

  Walls less than 2-3 mm wide.

  Cusps with fracture lines at their base.

  When there are isthmuses of more than 2/3 of the intercuspal distance.

- **VENEER-ONLAY/OVERLAY OR VONLAY**

  Cases that compromise the aesthetic zone, in which the transition line is evident.

  Teeth discoloured by silver amalgam that compromise the vestibular side in terms of shade.

- **ENDOCROWN**

  Endodontically treated teeth where a complete cuspid covering has to be performed.

10.1.2. Materials

The choice of material to be used for the indirect restoration will depend on the mechanical and optical properties and the clinical survivability of the material.

CERAMIC

Conventional silicates (feldspathic porcelains): VITABLOCS Mark II, VITABLOCS TriLuxe, VITABLOCS TriLuxe Forte, VITABLOCS RealLife (VITA Zhanfabric), CEREC Blocks, CEREC Blocks PC, CEREC Blocks C-In and IPS Empress CAD (Detspy Sirona). These require a minimum thickness of 1.5 mm.

High-strength silicates: IPS e.max CAD (Ivoclar Vivadent. Lithium disilicate), VITA Suprinity, VITA Suprinity FC (VITA.pre-crystallised), CELTRA Duo, Tessera (Dentsply irona.pre-crystallised). LiSi Block (GC. crystallised) Require a minimum thickness of 1mm if bonded to enamel and 2mm if bonded to dentin due to flexural strength.

HYBRID MATERIALS

In recent years a number of materials have emerged that combine ceramics and polymers in varying concentrations. These require a minimum thickness of 1 mm, although they can be thinner occlusally compared to lithium disilicate ceramics, reaching as little as 0.5 mm. If there is little occlusal space (<0.8 mm in enamel or less than 1.2 mm in dentin), these would be the most suitable materials, as well as in situations of previous restoration of worn teeth in patients undergoing orthodontic treatment.

Polymer infiltrated ceramics: VITA Enamic (VITA).

Nanoceramic resins: Lava Ultimate (3M ESPE), Cerasmart (GC)[33], Voco Grandiobloc (VOCO), Brilliant Crios (Coltene) and Shofu blocs HC.

A good therapeutic approach to avoid material fractures in posterior teeth would be that the thinner the material, and especially in combination with exposed dentin, the more one should tend to choose resinous materials for their resilience.

10.1.3. Treatment procedure

10.1.3.1. FIRST VISIT

1. **Check occlusion.** The preparation margins are the weakest point of the preparation and should be placed outside the occlusal contacts. It is important to analyse the antagonist tooth in order to select the most suitable material.
2. **Shade selection.** Always before isolating and even before removing the provisional piece.
3. **Absolute isolation.** Always use a rubber dam.
4. **Measure and eliminate cusps** with a thickness of less than 2mm, reducing to where the minimum thickness is present. Always try to leave the necessary thickness for the cervical-coronal restorative material. Never leave non dentin supported enamel.

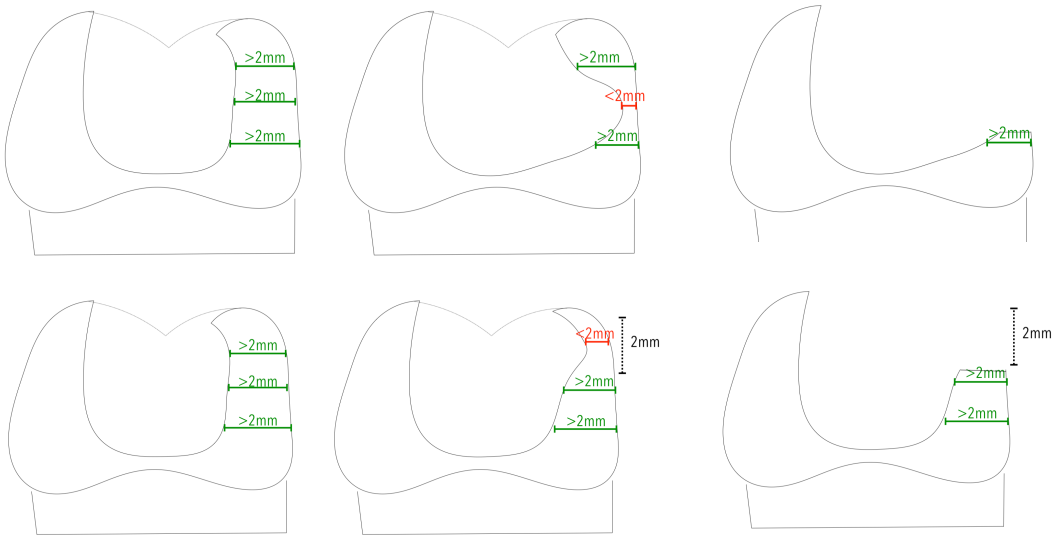


Figure 209. Diagrams representing the remaining cuspid thickness and the decision-making process at the time of cutting and veneering. Made by Álvarez-Maldonado N.

5. **Build-up.** This involves a composite reconstruction prior to the preparation, in order to cover the dentin, to achieve an Immediate Dentine Sealing (IDS) and an ideal geometry of the cavity. The aim is to leave a cavity with two substrates for cementation: enamel and composite. The use of a microhybrid/nanofilled composite is recommended[96].

IMMEDIATE DENTIN SEALING (IDS)

- Perfect sealing of the cavity. Protection of dentin tubules from bacterial contamination.
- Adhesion is established on freshly cut dentin without contamination.
- Eliminates sensitivity.

IDEAL CAVITY GEOMETRY

- Correct tapering.
- Elimination of undercuts.
- Supragingival transfer of restoration margins (Deep Margin Elevation).
- Adequate interocclusal space.

Figure 210. Objectives of Build-up. Made by Álvarez-Maldonado N from Rocca G.[96]

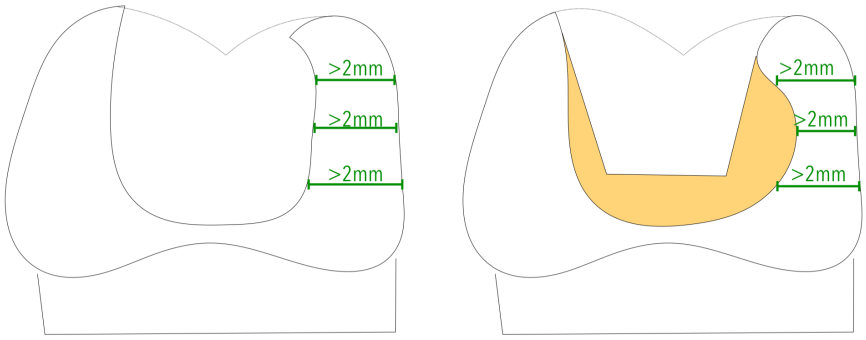


Figure 211. Comparison of cavity geometry without and with build-up. Made by Álvarez-Maldonado N.

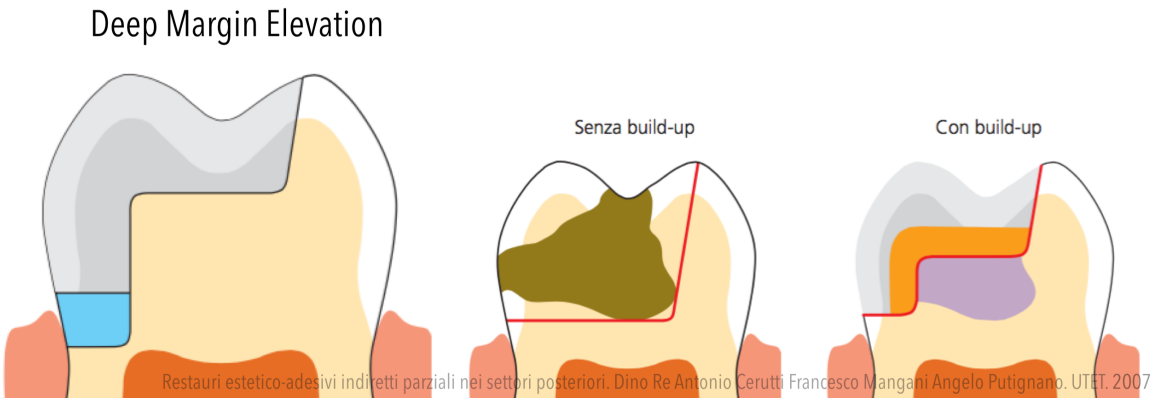


Figure 212. Deep margin elevation. Made by Re D.[97]

6. **Preparation**: the angle between the cavity walls must be expulsive towards occlusal and be between 6º and 10º. A minimum thickness of 1.5 mm must be achieved for the restoration (varies depending on the material). Residual walls should have a minimum thickness of 2mm along their entire length (some authors advocate 2.5-3mm in case of endodontic teeth). If the thickness is thinner, a cuspid capping should be performed. It is very important to make sure that the enamel is not covered by adhesive.

To avoid fracture of the restorative material, a 2.5 mm isthmus must be maintained. Finally, the milling should be polished and all angles rounded.

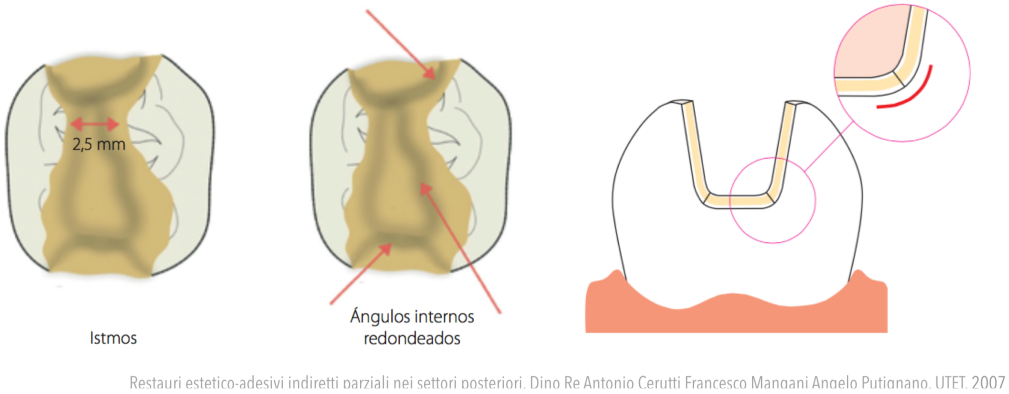


Figure 213. Diagram showing the isthmus between the boxes of an inlay, which must in turn have the corners of the base rounded. Made by SEPES[89] and R De.[97]

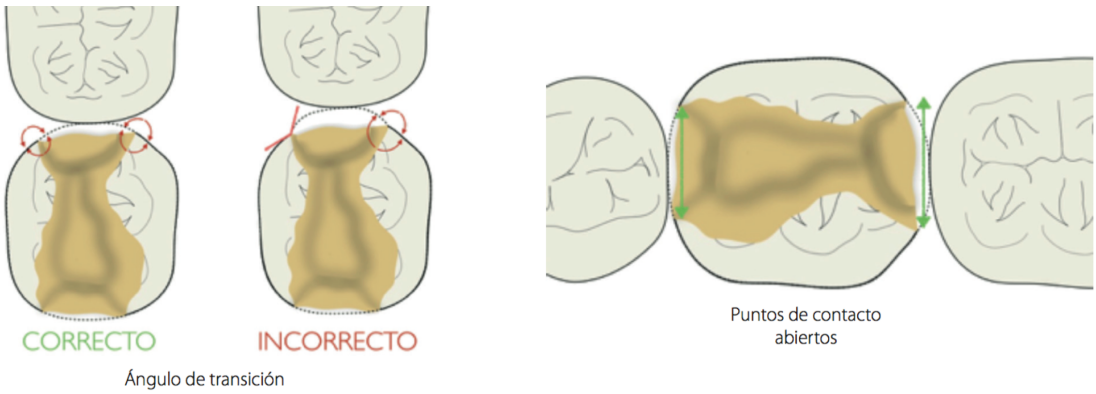


Figure 214. Diagram showing the transition angles, which must follow the contour of the tooth and the contact points, which in turn must not be preserved. Made by SEPES.[89]

In the interproximal box, the transition angle between the cavity and the tooth should be approximately 90° and be able to follow the anatomical contour of the tooth. When the adjacent tooth is too distant, open it up to give a more anatomical and hygienic shape to the inlay.

The cavo-superficial angle should be 90º. Do not bevel the margins. The preparation must follow the final anatomy of the occlusal face of the tooth to be restored.

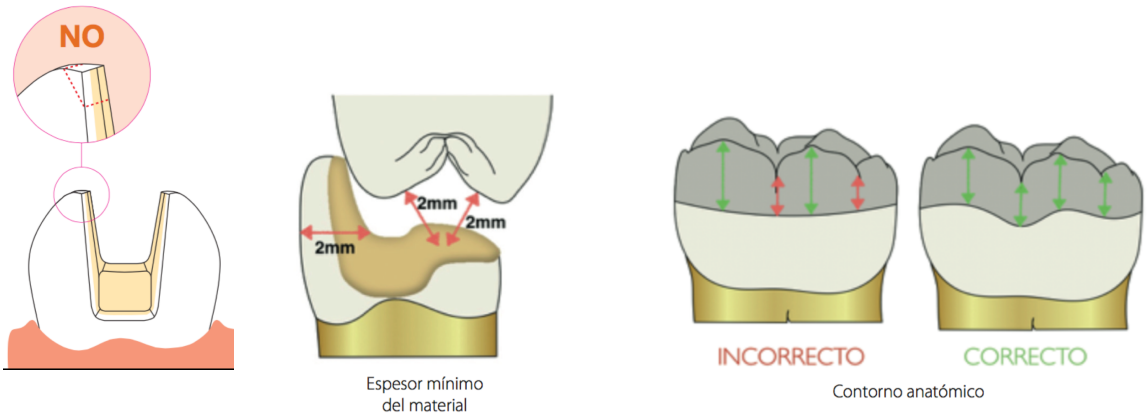


Figure 215. Diagram representing transition and cavosuperficial angles at 90º, with final preparation following occlusal anatomy. Made by SEPES[89] and R De.[97]

7. **Impressions.** A silicone impression is taken in the prepared arch, and an alginate impression is taken in the antagonist. If the occlusion is stable, bite records are not necessary. Nowadays, more and more dental professionals are using digital scanners for this step.

8. **Placement of a provisional restoration.** This protects the tooth and prevents unwanted shifting. A silicone key and bisacrylic resin or a temporary resin such as fermit or telio can be used. It is very important to have removed the inhibition layer to avoid the adhesion of the temporary resin to the build-up.

10.1.3.2.SECOND VISIT

1. Removal of the temporary restoration and **cleaning** of the preparation with a prophylaxis brush and pumice stone.

2. **Check the fit** of the restoration and contact points. Never check the occlusion at this stage as this may fracture the restoration.

3. **Isolation**. Once the field has been isolated, the restoration must be checked again. If you have to cement more than one, you should check the order of insertion that you will follow.

4. Adhesive protocol:

- Tooth: if the build-up and preparation are correct, there will only be two substrates to prepare, enamel and old composite. The bonding protocol is:

  I. Blasting with aluminium oxide particles or spraying the surface with a diamond ball end mill **(Figure 216)**.

  II. Etching of the surface (enamel and composite) 30 seconds. Etching the composite merely cleans the sandblasting residues but has no active effect on the surface for bonding.

  III. Primer (you can skip this step if you are sure that there is no exposed dentin).

  IV. Hydrophobic adhesive or bonding, blow and do not polymerise **(Figure 217)**.

Table 5. Tooth treatment

Substrate	Sandblasting (AO/ BG[1])	Orthophosphoric acid	Silane	Primer	Hydrophobic adhesive
Old composite	AO 29-50 µm ≈5mm 2-3bar 5-10s	30" and wash with H2O 30"	Wait 20 to 40" and activate with heat curing (light curing lamp) for 60".	No	Unpolymerised adhesive (4th generation final step)
Enamel[2]	Yes	30" and wash with H_2O 30"	No	No	Unpolymerised adhesive (4th generation final step)
Dentin[3]	Yes BG preferred if vital	No	No	6th generation self-etching/universal adhesive Scrub 20", air (twice), SCA.[4]	Unpolymerised adhesive (6th generation) Not required for universal adhesive.

Note. Treatment of each substrate when cementing an inlay. Made by Ferrando A and Álvarez-Maldonado N.

[1] AO: aluminium oxide (Al_2O_3). BG (bioactive glass, Na2O-CaO-SiO2-P2O5, also known as NovaMin, Bioglass 45S5 or calcium sodium phosphosilicate).

[2] If not sandblasted, the enamel surface must be cleaned with a brush and prophylaxis paste to ensure proper biofilm removal before applying orthophosphoric acid, regardless of whether it is for

the technique of total or selective etching. However, it is preferable to sandblast it at the same time as the composite with AO.

[3] For a vital tooth, if small areas of fresh dentin are exposed at the start of reconditioning and you want to use the total etching technique with 4th or 5th generation adhesives (e.g., OptiBond FL®, Scotchbond 1XT, Prime & Bond® NT), etch for 5 seconds in cases of deep dentin, while maintaining the 30 seconds of enamel etching. The shortened etching time is justified in cases of deep dentin, in order not to excessively demineralise the substrate. However, in the case of superficial dentin, the conventional 15 seconds etching protocol may be followed. It should not be forgotten that over-etching the dentin with orthophosphoric acid can lead to postoperative sensitivity (if drying is not controlled), as areas of dentin remain poorly infiltrated by the adhesive. To reduce this possibility, desensitisers such as GLUMA® based on 5% glutaraldehyde or sandblasting with BG (ProSylc®) can be used and, finally, the selected adhesive can be applied. To avoid postoperative sensitivity complications, self-etching systems on dentin are recommended.

If the dentin is not exposed, the total etching technique with homogeneous times can be used after cleaning the substrate with brushes + prophylaxis paste (pumice) and/or sandblasting with AO. This ensures the removal of biofilm and reactivates the composite that is part of the build-up.

[4] SCA: Self Cure Activator. Not indicated if universal adhesives and cements of the same commercial line are used.

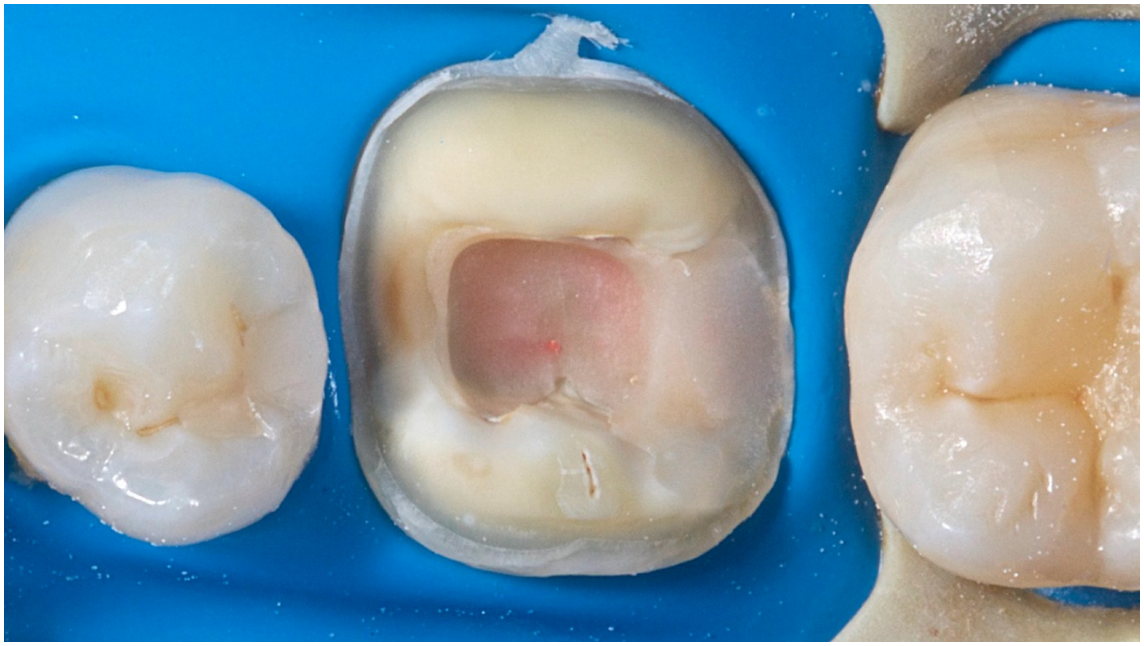


Figure 216. The preparation for overlay/endo crown of an endodontic tooth. There is a large amount of exposed dentin and composite sandblasted with AO 50µm. Made by Ferrando A. (Table 5).



Figure 217. Preparation of a vital tooth with exposed dentin. After sandblasting with bioactive glass, apply a 'universal' adhesive that will be blown to evaporate the solvent and will be left to polymerise (Prime & Bond Active Dentsply Sirona) to receive the restoration. Made by Ferrando A. (Table 5).

- **Restoration**: the preparation of the restoration will depend on the material chosen for the restoration:
  - Ceramics: ceramic materials must be treated with hydrofluoric acid at different concentrations and times, as described in the table 6, to achieve an adequate micro-retentive pattern. Subsequently, silane is applied to promote chemical bonding between the restoration (inorganic) and the cement (organic). **(Figure 217-218).**
  - Composites and CAD-CAM hybrids. The surface treatment protocol for these materials will be determined according to the table 6. **(Figure 219).**

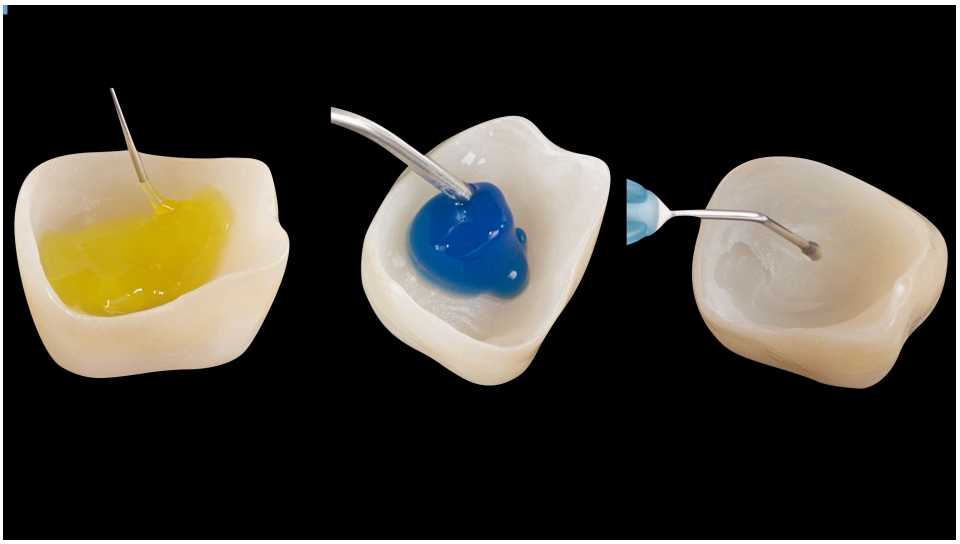


Figure 218. Surface treatment of lithium disilicate. The cleaning of the ceramic with orthophosphoric acid can be replaced or implemented by an ultrasonic bath with 95% alcohol for 4 minutes. Made by Ferrando A. (Table 6).



Figure 219. **Cleaning of a ceramic veneer** in an ultrasonic bath with 95% alcohol for 4 minutes and subsequent application of silane. Made by Ferrando A.

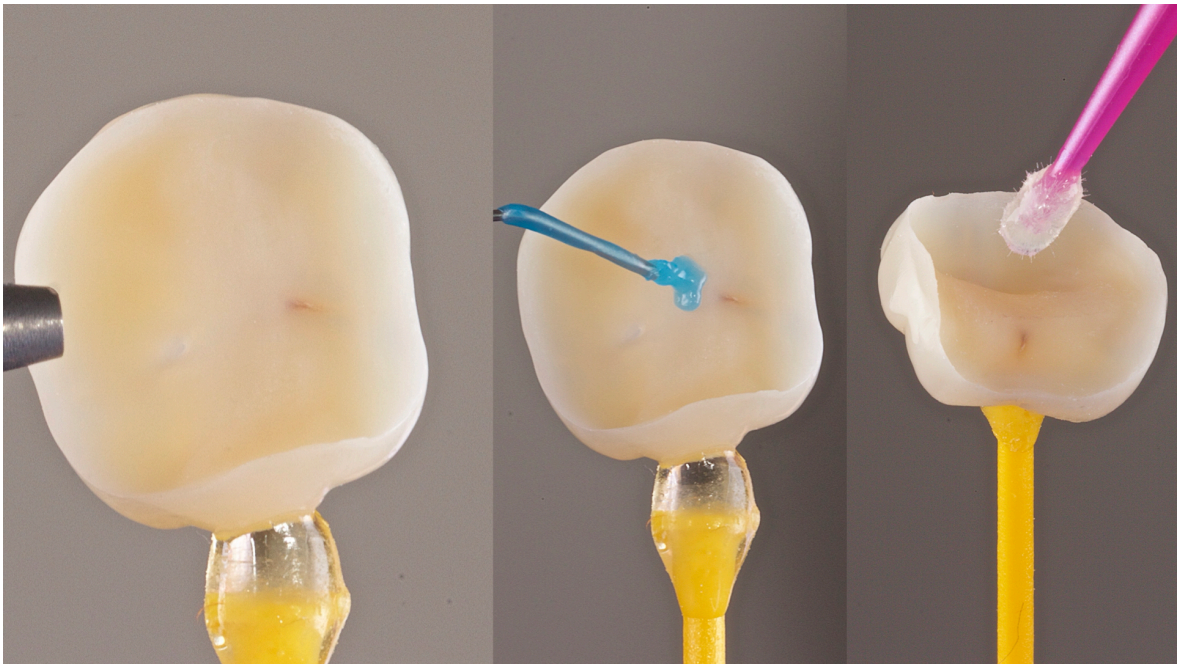


Figure 220. Surface treatment of CAD-CAM nano-ceramic resin. The phosphoric step could be avoided. In that case, simply wipe the surface with plenty of water to remove the aluminium oxide particles, but make sure that the surface is spotless and dry before silanising. Made by Ferrando A. (Table 6).

› Zirconium oxide has also been incorporated to provide a documented option for making adhesive vonlays[86] in cases of very unfavourable (dark) substrates.

Table 6. Restoration treatment

RESTORATION		Sandblasting (AO)	Etching with hydrofluoric acid (HF)	Cleaning with orthophosphoric acid (H_3PO_4) (1-2min)	Cleaning in ultrasonic tank with 95% alcohol (2-4min)[1]	Silane (wait 20-40" and activate with thermodry[2] at ≈100C, 60")	Hydrophobic adhesive
Silica-based ceramic materials	Low/moderate strength silicates (CAD-CAM feldspars or leucite reinforced)	Optional	9% 90-120"	Rub and wash with H_2O	Yes/alternative to H_3PO_4	Yes	No
	Moderate/high strength silicates (e.g., lithium disilicate)	Optional	9 or 5% 20" $LiSi_2$ 30" reinforced with zirconium oxide (ZrO_2)	Rub and wash with H_2O	Yes/alternative to H_3PO_4.	Yes	No
Composites or CAD-CAM hybrids [3]	Polymer infiltrated ceramics	Optional	9 or 5% 60"	Rub and wash with H_2O	Yes/alternative to H_3PO_4	Yes	No
	Conventional composites/ CAD-CAM nanoceramic resins	29-50µm ≈5mm 2-3bar 5-10"	No	Rub and wash with H_2O	Yes/alternative to H_3PO_4	Yes	Optional
Zirconium oxide based polycrystalline ceramic (ZrO_2)	Moderate/High strength	50µm ≈5mm 2-3bar 5-10s	No	No	No	No. Zirconium primer with 10-MDP[4]	No

Note. Surface treatment of the most common restorative materials. Made by Ferrando A and Álvarez-Maldonado N.

[1] If the ceramic has a lot of white residues (crystalline precipitates), orthophosphoric acid should be applied first, and ultimately the ultrasonic bath time will depend on the degree of cleanliness obtained in the previous step. If there is not much residue, the 4 min ultrasonic bath is enough.

[2] Thermo-drying in an oven. When using a hairdryer with low power, it is recommended to double the time to ensure the effect. A shiny surface after this process indicates an excess of silane, which would require repeating the process.

[3] CAD-CAM: Computer-Aided Design - Computer-Aided manufacturing).

[4]10-MDP: 10-methacryloyloxyalkylphosphate dihydrogen. This is a functional monomer with a proven affinity for metal ions and therefore indispensable if adhesion is to be achieved on zirconium oxide-based surfaces.

› Cement: resinous materials must be used. If the thickness of the restoration is sufficient, use either microhybrid composite/nanofiller preheated to 60-68º (a specific heater and ultrasonic tip are required)[85] **(Figure 218)** or light-curing resin cements (Variolink Esthetic, Nexus, RelyX Veneer, Calibra veneer). In case of uncertainty regarding the complete polymerisation of the cement, use dual or universal resin cements (dual versions of the above-mentioned cements).



Figure 221. Excess composite flowing out of the margins of the restoration. An ultrasonic tip at the bottom left of the picture assists in the settling of the restoration. Made by Ferrando A.

5. **Cementation**: once the restoration is in place, light 5 seconds per side, remove excess with a probe, curettes and dental floss. Subsequently, complete polymerisation with glycerine for the time indicated by the manufacturer[98].

6. **Occlusal adjustment and polishing**

Here is a link to a 2018 article by Prof Dr Álvaro Ferrando[99] from the SCO journal of Denstply Sirona (pages 17-22), where you can contrast the step-by-step of two clinical cases with posterior indirect partial composite restorations in vital teeth.

PDF **Solutions in Dentistry**

UCAM

Chapter 11





Horizontal retentive and adhesive restorative dentistry

Horizontal preparations and classic prosthetic designs. Crowns and veneers

Photo by Dr. Fernando Rey Duro

11.1. Introduction. General concepts of dental preparations for complete veneers

Tooth preparation or reduction is a fundamental and IRREVERSIBLE clinical phase of prosthetic rehabilitation and therefore requires the utmost attention in order to ensure **retention, strength, stability** and longevity of the future prosthetic restoration, while respecting the structural integrity of the tooth of the patient.

In the final preparation of the teeth, it is essential to continue the natural planes, 'the prepared tooth must look like a tooth.'[100] It must also create or guarantee the space to accommodate the definitive material, which is why you need a transparent tray or silicone keys that contain the information of the aesthetic diagnostic wax-up or the temporaries that should already have been working perfectly for some time. The temporary restorations offer the clinician the possibility to optimise the occlusal, vestibular and lingual-palatal thicknesses.

11.1.1. Principles of retention, strength and stability of anterior preparations

- Retention basically depends on the contact between the inner surfaces of the restorations and the outer surfaces of the prepared tooth.
- With long teeth the walls have to be more inclined, increasing the convergence to guarantee the path of insertion.
- In short teeth, on the contrary, the walls must be more parallel and, if necessary, use intracoronary retentions, such as rails or boxes, to guarantee the retention of the restoration.
- The shape given to the tooth prevents **dislocation** of the restoration and guarantees stability and resistance when subjected to oblique forces that can cause the restoration to rotate on the preparation.
- To prevent loss of retention of the future crown, the width of the core build-up should be as close as possible to its height, but always ensuring the path of insertion[100,101].

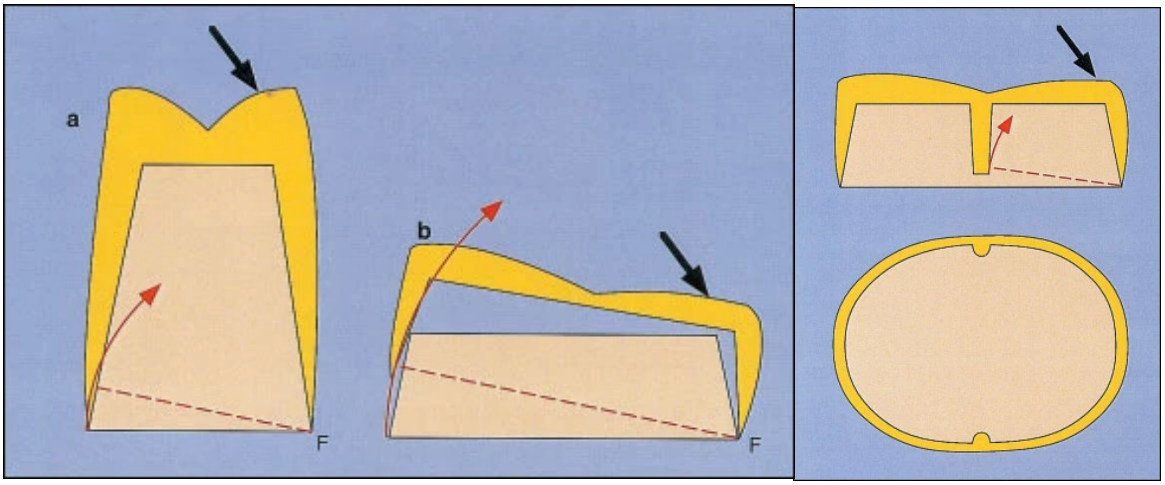


Figure 222. Application of oblique force to occlusal surface results in potential rotation of crown (a) around a fulcrum (f). Rotation is resisted by the cement above the arc of rotation of the base of the crown being thrown into compression – represented by arrow. Rotation of the shorter crown (b) results in tensile forces fracturing the cement lute. It is therefore important that the radius of rotation intersects the opposing axial wall. On the left, the placement of axial grooves increases resistance by effectively reducing the radius of rotation. Made by Hegdahl T, from Blair F.[101]

Retention and resistance videos

In the vestibular area, it is between 1-1.5 mm depending on the final material chosen. To withstand normal masticatory forces, the minimum thickness in the palatal area will be 1mm for the anterior sector and recommended 2mm on the occlusal surfaces of the posterior sector. When preparing 360º and with a horizontal margin, keep in mind that you are creating a lot of space so that the restoration can be aesthetically integrated (1-1.2mm) but at the cost of creating or guaranteeing space to accommodate the definitive material in the dentin, which can have biomechanical and biological consequences (pulp vitality) due to the sacrifice of enamel and DEJ[101].

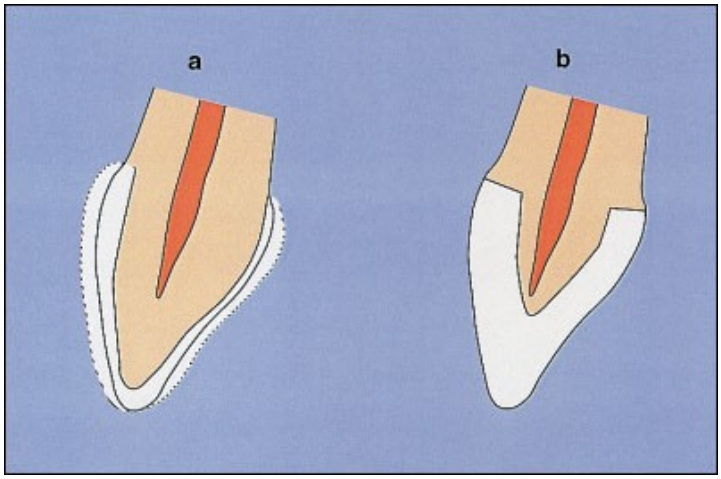


Figure 223. A comparative drawing shows (a) an under preparation where (a) there is an overcontour but the structure is preserved and (b) over preparation that compromises the tooth and pulp strength. The ideal result is the middle ground. Made by Blair FM.[101]

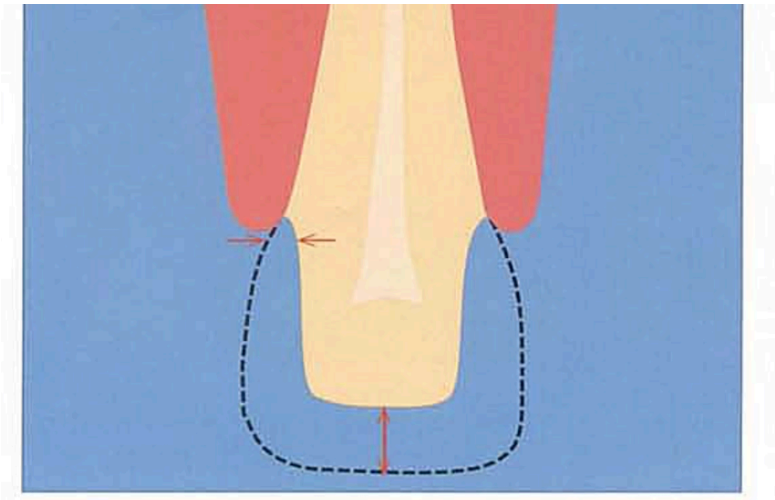


Figure 224. The contour of the preparation should be in harmony with the natural tooth, despite a deep shoulder or chamfer of approximately 1.3mm and a reduction of between 1.5 and 2mm. Made by Touati B.[102] From http://www.dropbox.com/scl/fi/i7cd6nlmxopuwx2u1wy2z/Odontología_estetica_y_restauraciones_ce.pdf?rlkey=wjs9arr7ta5nw092byekp58rc&dl=0h.

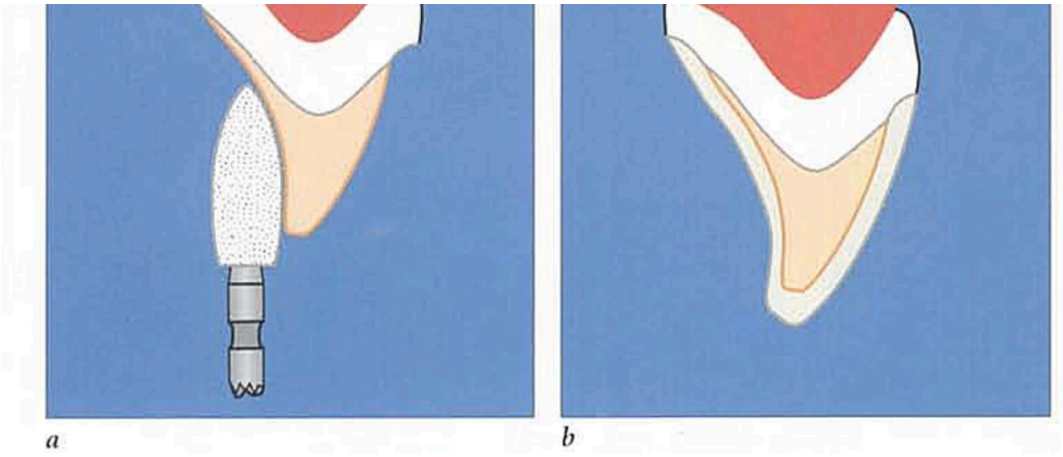


Figure 225. The same rules apply to the lingual surface of the tooth as to the labial surface. The tooth has to be reduced in order to allow sufficient space for the crown and to restore normal occlusal and protrusion relations. Made by Touati B.[102] From http://www.academia.edu/36554010/Odontolog%C3%ADa_estética_y_restauraciones_cerámicas

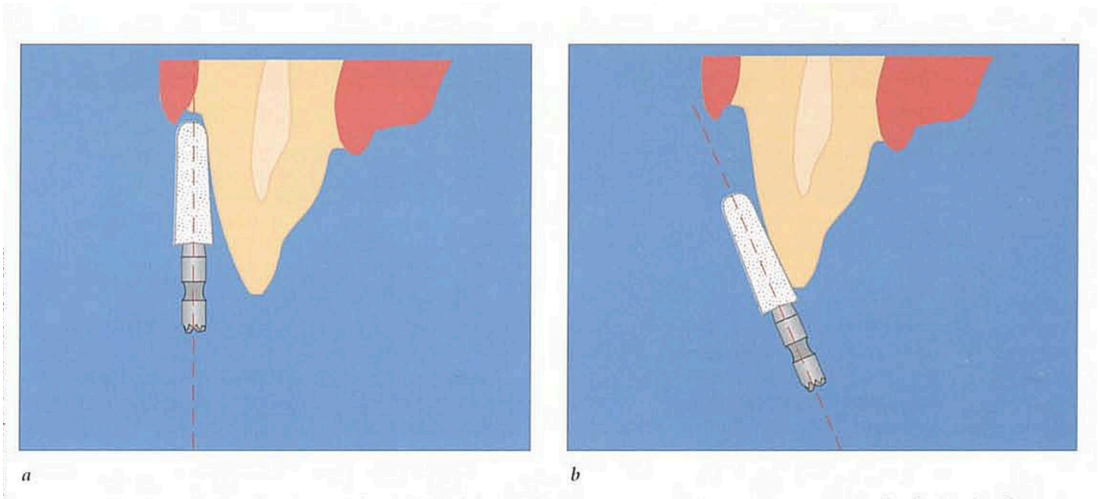


Figure 226. When reducing the vestibular surface of the tooth, the exact contour of the tooth must be imitated to avoid removing too much tissue and to obtain a crown of regular thickness. The drills shall be applied in two directions. A) The first orientation to the 2/cervicals of the tooth. B) The second, to the incisal third. Made by Touati B.[102] From htttp://www.academia.edu/3655010/Odontolo%C3%Ada_estética_y_restauraciones_cerámicas

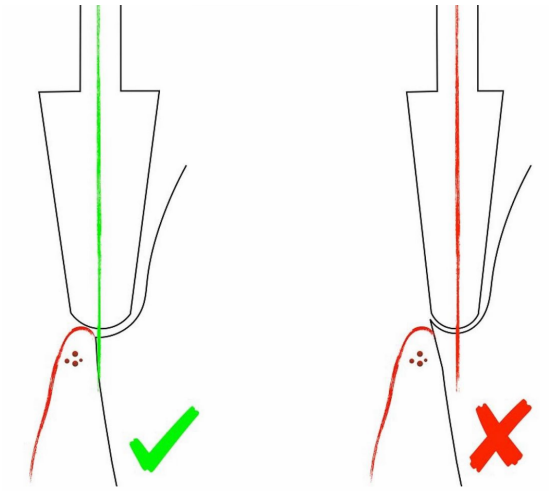


Figure 227. Comparison of correct chamfer execution and creation of retention due to excessive horizontal and vertical cutter insertion. Made by Cabra F. From http://www.instagram.com/cabralstrosi/

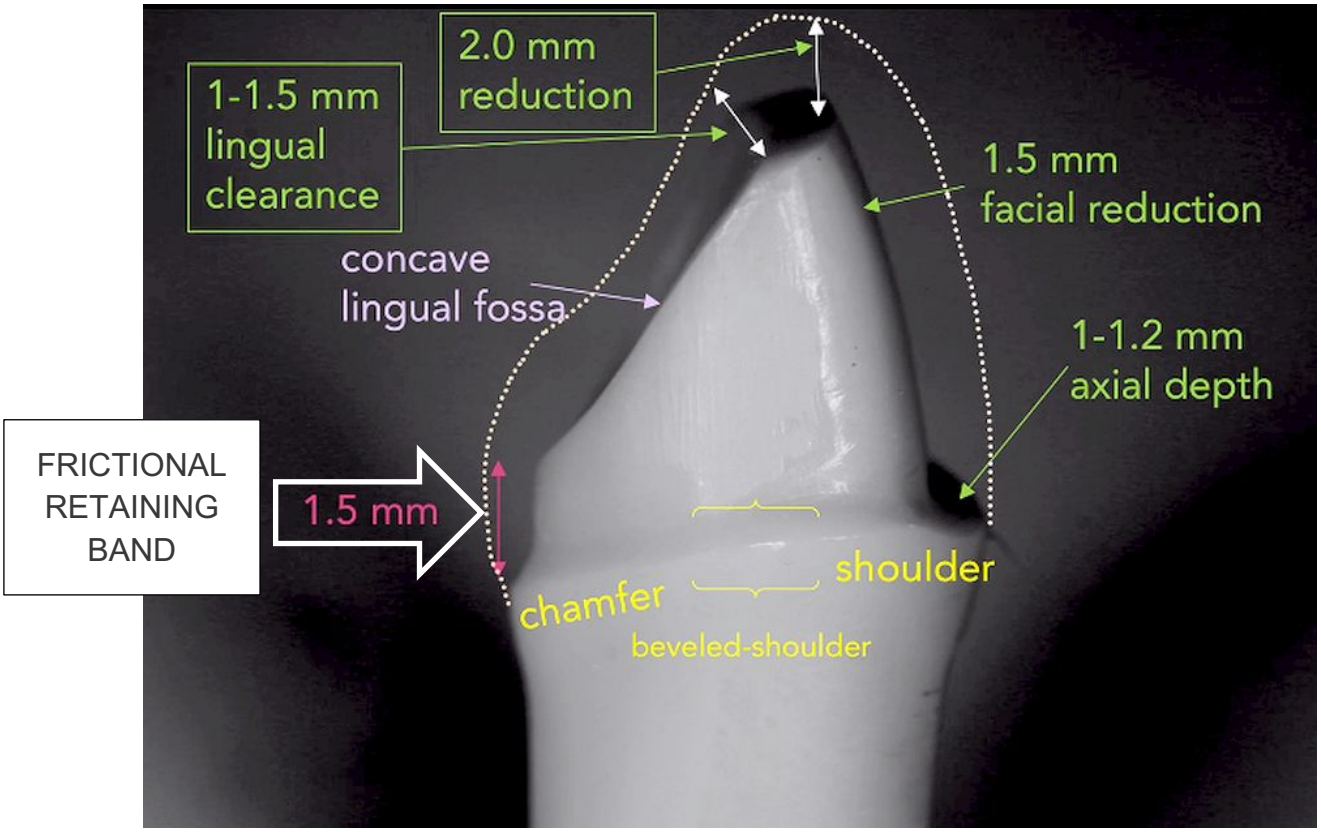


Figure 228. Thickness diagram for a classic porcelain fused to metal crown preparation. Made by Stevenson R. From http://www.tv.odontologiavirtual.com/2018/10/prosthodontics-anterior-pfm-preparation.html

11.2. Horizontal preparation of the anterior tooth for a crown

The general contours of the preparation should resemble the natural tooth as closely as possible, which will give the ceramic crown a uniform thickness and thus a certain homogeneity, allowing the tooth to recover its initial anatomy if required. In order to match the tooth anatomy, the preparation must also be done in different planes, especially on the vestibular surface of the anterior teeth.

Only two or three instruments are really required, 'rugby ball' drills for occlusal reduction and shoulder or chamfer drills for circumferential reduction. Naturally, there must be finishing and polishing elements available, which will be homologous drills with a smaller grain size together with polishing discs and rubbers[100-103].

The steps for the classical horizontal preparation for anterior crowns are[100-103]:

- Reduction of the incisal edge by 1.5-2 mm.
- Preparation of a deep bevel or chamfer, on average around 1.2mm.
- Double orientation of the vestibular surface.
- Section of the interproximal contact area, respecting the adjacent tooth.
- In-axis preparation, with an inclination or convergence of 6° to 8° to guarantee the vertical path of insertion and, at the same time, the stability and frictional retention of the cervical area.
- Reduction of the supracingular area by 1mm, anatomically adjusting to the functional space of the anteroinferior teeth.

11.2.1. Horizontal preparation of anterior teeth —Shoulder and Chamfer—

The pure flat shoulder is in disuse, especially since it has no place due to the development of CAD-CAM technology. With a rounded internal angle and added bevel it would present a great fit, better than without it, but it is difficult to execute.

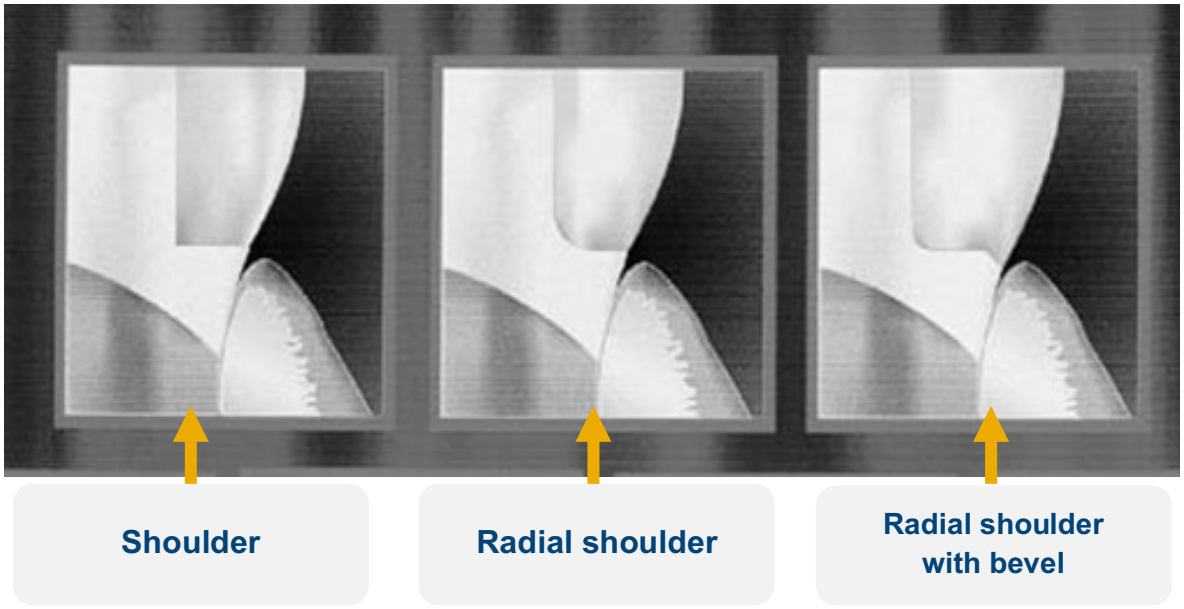


Figure 229. Different types of shoulder finish lines. Made by Shillingburg HT.[103] From https://www.slideserve.com/karma/integrantes-powerpoint-ppt-presentation.

Chamfer: a gingival preparation in obtuse angle or 1/4 circumference shape. The preparation has a rounded internal angle and an angular one that can range from 90°-135°. This is the most popular of the classic finishes due to its execution and clinical performance.

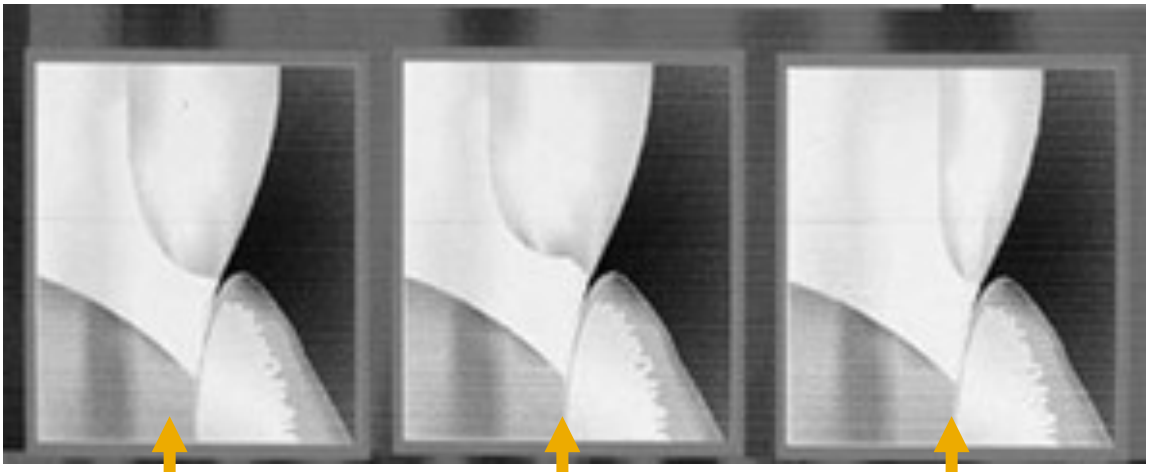
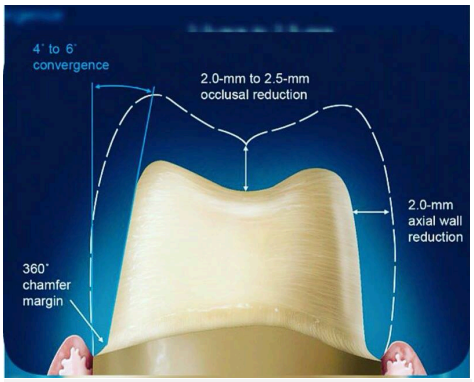


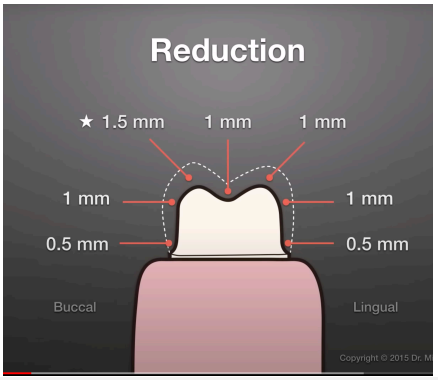
Figure 230. Different types of chamfer finish lines. Made by Shillingburg HT.[103] From https://www.slideserve.com/karma/integrantes-powerpoint-ppt-presentation.

Pictures illustrating the evolution of reduction thicknesses in posterior teeth



Classical preparation of posterior teeth

Figure 231. Classic preparation of posterior teeth. From https://id.pinterest.com/pin586101338992081ndicaci.



Contemporary preparation of posterior teeth for monolithic zirconia and lithium disilicate

Figure 232. Contemporary posterior tooth preparation for monolithic zirconia and/or lithium disilicate. These thicknesses were only described for metal. Made by Min-Hsun. From https:/www.youtube.com/watch?v=uzd6oBdt7xs

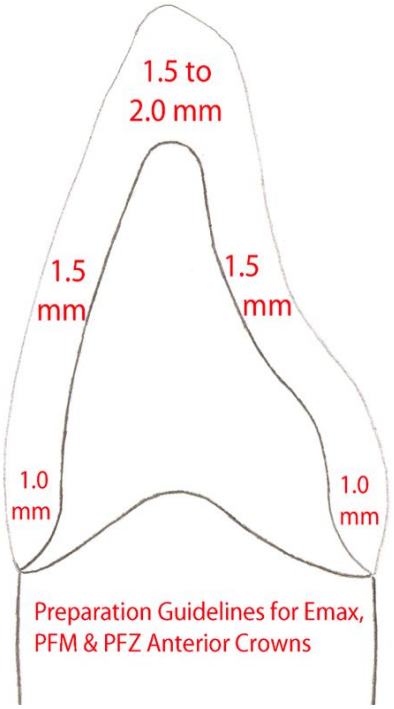


Figure 233. Classic preparation guidelines for anterior teeth for lithium disilicate and zirconium oxide (today the thicknesses can be reduced if the substrate is favourable). Made by Spear F. From www.speareducation.com.

11.3. Location of the margins of horizontal preparations[104]

The position of the preparation margin in relation to the gingival tissues is decisive for the preservation of periodontal health. The prosthetic margin can be positioned at 4 levels[104]:

- Supragingival.
- Juxtagingival.
- Intrasulcular.
- Subgingival.

11.3.1. Supragingival margin

Margins located at supragingival level facilitate the inspection of the edge of the finish, speeding up the execution of all the milling phases. This type of margin also provides a more favourable biological response than a margin in direct contact with the gingival tissues, although it has limitations of a mainly aesthetic nature.

From an aesthetic point of view, the visibility of this type of termination can be a problem, as many patients do not want the limit between their tooth and the restoration to be visible, although the development of ceramics nowadays allows a great optical mimicry with the dental substrate, even when the margin is supragingival.

This preparation is not indicated when there are black spaces between the teeth, 'black triangles' typical of periodontal patients. In these cases, the tissues must be extended into the sulcus in order to recontour the tissues with the restoration and solve the aesthetic deficit by changing the tooth shape to a more squared one.

11.3.2. Juxtagingival margin

This does not necessarily eliminate the aesthetic problem of the visibility of the termination in the anterior sector, although it is less visible than the supragingival, and it does not necessarily solve the problem of the 'black triangles' either because it is not able to recontour the interproximal soft tissues. This would be an option for posterior teeth, requiring greater expertise on the part of the clinician, although there can be no periodontal damage, the prosthetic overcontour at this level can create problems of plaque accumulation, favouring the appearance of gingivitis and/or periodontitis.

Table 7. Indications, advantages and disadvantages of the supra/juxtagingival location margin

SUPRAGINGIVAL MARGIN - JUXTAGINGIVAL	
INDICATIONS	
• Contained aesthetic demands • Cervical margins not visible when speaking and smiling • Sufficiently mechanically retentive teeth • No restorations or caries at the marginal level • Use of full ceramic materials	
ADVANTAGES	
• Easy to work with in the following phases	› Dental preparation › Impression taking › Rebasing of temporaries › Revision of the marginal seal of the restorations
• Maintenance of periodontal health	
DISADVANTAGES	
• Visibility of the margin • Difficult closure of interproximal spaces • Reduced mechanical retention	

Note. Summary of the most important indications, advantages and disadvantages of supra- and juxtagingival margins. From Fradeani M.[104]

11.3.3. Intrasulcular margin

The expression "intrasulcular" or "intra-crevicular" margin was adopted to indicate a termination limit located within the gingival sulcus which, while concealing the margin of the restoration, does not cause damage to periodontal structures. In fact, during the phases of dental preparation, especially when placing threads, aggression to the junctional epithelium is frequent, although it is usually reversible. Going further towards the connective tissue can lead to irreversible consequences such as intraosseous pockets and chronic gingivitis.

A healthy periodontium is essential. Remember that on the vestibular aspect the sulcus has a depth varying from 0.5-1mm, so you have to be very careful to hide the margin in the sulcus. On the interproximal aspect there are higher values, the depth varies from 1-3 mm, which is very useful when dealing with unsightly 'black triangles'.

To clinically achieve the intrasulcular preparation, a retractor wire of 000 or 00, depending on the periodontal biotope, must be placed, which will generate an apicalisation of the margin, between 0.2-0.5mm. Once the tissues have been dislocated, the new margin will be reprepared at this level, the thread being a barrier that must be respected so as not to create excessive gingival lacerations. Special care should be taken with thin phenotypes, in which case excessive depth should be avoided in the vestibular areas so as not to create gingival recession.

- *Summary of intrasulcular preparation steps[104]:*

1. Prepare at the juxtagingival level.
2. Perform periodontal mapping of the sulcus to select wire size and type.
3. Introduce thread according to the depth and tone of the sulcus.
4. Re-prepare to the new apicalised gingival level.



Figure 234. Diagram of how to sequentially and clinically achieve an intrasulcular margin. Made by Fradeani M.[104]

11.3.4. Subgingival margin

Nowadays, many clinicians deepen the final margin of the restoration for aesthetic reasons, in order to conceal the finish of the restoration. Insufficient mechanical retention, the presence of previous restorations or caries that extend beyond the margin push us to establish the deep limits. This situation requires that we probe the bone very well under anaesthesia to measure the biological width, which should be 3 mm in total to the crest; if this is not respected, inflammation will appear, and it is preferable to first perform a surgical crown lengthening to ensure periodontal health.

When grinding, it is common not to follow the scalloped anatomy of the margin and to go too deep into the interproximal areas, invading the biological space. Thus, in a thick periodontal biotope there will be infra-osseous pockets, inflammation and gingival hyperplasia at the end, while in a thin biotope there will be recession. However, in the interproximal spaces there is usually more space than in the vestibular space, around 3 or even 4mm, which allows for a certain margin of error in the preparation.

- **Subgingival margin problems**
  - Violation of the supracrestal attachment tissue (ligament and connective tissue).
  - Inadequate margins and contours.
  - Roughness or lack of finish at the marginal interface.
  - Evidence of excess cementum.
  - More pathogenic subgingival plaque.

11.4. Preparation of porcelain veneers or veneers

General considerations

Once the appropriate diagnostic steps have been strictly followed, where wax-up and aesthetic mock-up testing are essential, the fabrication of the restorations can begin with maximum confidence and predictability. With the final goal well defined, the effort will now focus on the technical procedures of the tooth preparation.

The design of the tooth preparation for porcelain bonded restorations (BPR) must allow for optimal marginal adaptation of the restoration and simultaneously reflect the high respect for hard tissue morphology that this type of restoration allows.

Tooth preparation for BPR differs from that used for traditional cement-bonded crowns, particularly with regard to the grinding of the retention and strength shapes.

The adhesive properties and physico-chemical characteristics of composite cements allow the tooth-restoration interface to withstand considerable stresses. Therefore, the geometrical and mechanical factors of tooth grinding are of secondary importance. The important thing is to create or secure a path of insertion for the future restoration.

This allows for greater preservation of healthy, mineralised tissue during tooth preparation and the end result is a very conservative treatment.[5,105]

- Therefore, the two questions to ask are[80,106]:

  1. **When to prepare**
  2. **How much to prepare**

1. When to prepare. Only if it is difficult to determine the insertion axis, if there is a need for space for restorative material or if there is severe colour alteration.
2. How much to prepare. On the basis of the future restoration, and this is where consideration should always be given to the type of ceramic restoration to be used.

A minimal amount of geometric preparation is still required in most clinical situations to facilitate the insertion and attachment of the ceramic during the final adhesive cementation procedure.

The preparation for veneers is not a simple procedure, nor does it deserve a ‘simplistic’ approach for being smaller than a crown. In fact, it requires practice and skill as it allows for few rectifications. The shallower the depth, the more magnification and the more specialised instruments for diameters and roughness. The ideal reduction on favourable substrates is between 0.3-0.5 mm. The concept of porcelain veneer is inseparable from that of controlled enamel preparation, which ultimately results in a prosthetic enamel substitute with optical, mechanical and biological properties that closely resemble those of natural enamel, hence the ‘biomimetic approach’[5,105]:

Table 8. Porcelain veneer grading system based on exposed dentin

Basis for New Veneer Classification System (Dentin Exposed)		
REDUCTION	**FACIAL**	**DENTIN EXPOSED**
CL-I No-Prep or Practically Prep-less	Detectable with magnification, with or without gingival finish line	0*
CL-II Modified Prep-less or Minimally Invasive	Up to 0.5mm	10% to 20%*
CL-III Conservative Design	0.5 mm to 1mm	20% to 50%*
CL-IV Conventional All-Ceramic Design	1+ mm	50%

*Enamel periphery of at least 70%

Note. There are 4 types depending on the amount of dentin exposed in the preparation, with IV being the least favourable for the adhesive procedure, and the one that a priori would cause the most problems in the long term. From LeSage B.[107]

Table 9. Porcelain veneer grading system based on the remaining enamel (opposite of the above).

Basis for New Veneer Classification System (Enamel Remaining)		
REDUCTION	**FACIAL**	**ENAMEL REMAINING**
CL-I No-Prep or Practically Prep-less	Detectable with magnification, with or without gingival finish line	95% to 100%
CL-II Modified Prep-less or Minimally Invasive	Up to 0.5mm	80% to 95%
CL-III Conservative Design	0.5mm - 1mm	50% to 80%
CL-IV Conventional All-Ceramic Design	1+ mm	<50%

Note. There are also 4 types depending on the amount of enamel remaining in the preparation, with IV being again the least favourable for the adhesive procedure, and the one that a priori would cause the most problems in the long term as it has less than 50% enamel. From LeSage B.[107]

As always, the shape of the instruments determines the preparation, and depth drills are essential. Bernard Touati[102] designed a milling cutter back in 1985 that can still be used today.

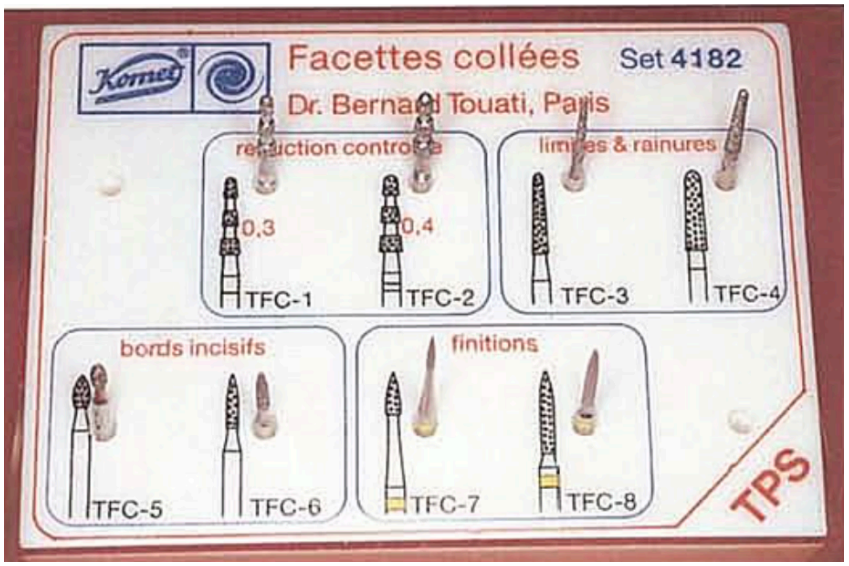


Figure 235. Brasseler TPS milling cutter for the preparation and finishing of porcelain veneers. Made by Touati B.[102]

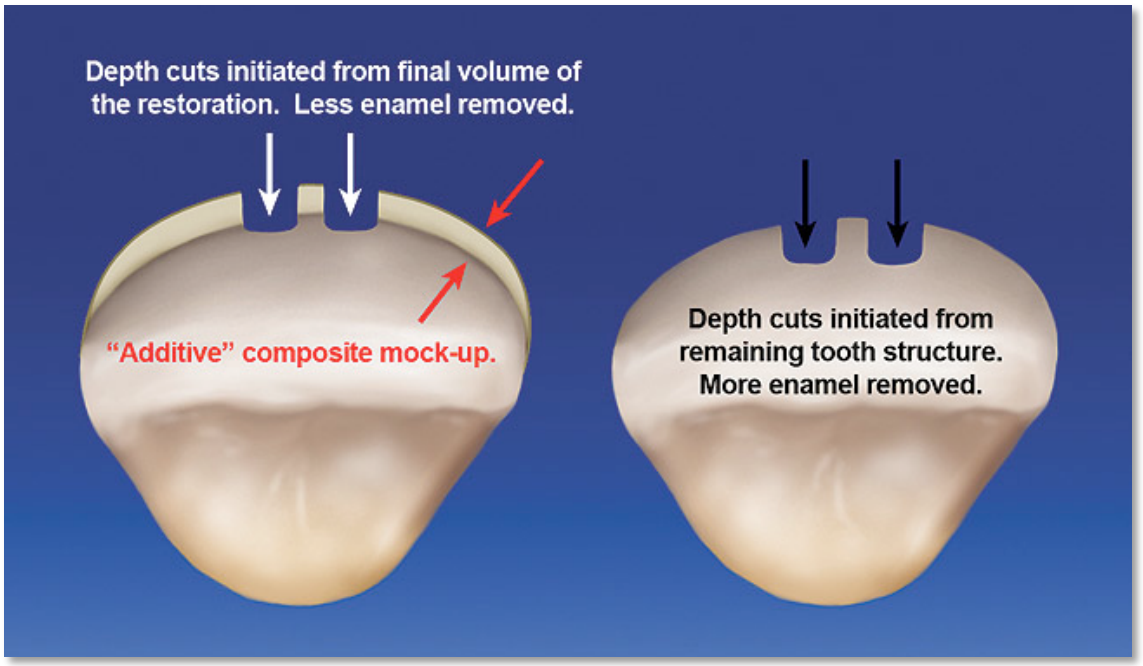


Figure 236. Diagram showing tooth preparation on mock-up compared to direct tooth preparation, clearly showing less preservation of structure in the preparation without mock-up. Made by Gregg A.[108]

11.4.1. Vestibular preparation thicknesses on porcelain veneers

The result of a uniform enamel preparation should be an average tissue reduction of about 0.5mm. In cases of extreme pigmentation, you may be inclined to increase the depth up to 0.7-0.8mm, considering that the final minimum thickness needed for the ceramic should be at least 1.2mm in order to opacify a substrate with tetracycline stains for example (in the hands of a great technician). In any case, it is safe to have 1.6 mm in total to be able to opacify without losing 'naturalness'.

In favourable cases, to try to change 2 or 3 shades, vestibular depths of 0.7 to 0.8mm for the incisal third and 0.6 for the middle will preserve a layer of enamel in most cases. Conversely, in the cervical area and without additive mock-up, depths of 0.3 mm and above can often expose areas of dentin, complicating the bonding procedure and the long-term prognosis of the restoration. As a general rule, for each shade to be lowered, 0.3mm must be gained either subtractively or additively.

11.4.2. Step-by-step preparation phases[102-109]

1º Aesthetic test or mock-up that marks the final target or point 0 and determines the final thickness of the restoration.

2º Horizontal grooves or 'pilot' depth, with the mock-up in the mouth, without removing it, and marked with mechanical pencil or fine indelible marker.

3º Incisal finishing: the types of finishing with respect to the incisal edge are:

a) 'Contact lens effect', preserving the incisal edge along its length. Horizontal insertion.

b) Butt joint or flat margin: covering the incisal edge, leaving a minimum ceramic thickness of 2 mm, but without involving the palatal side, it ends at the edge and there is no reduction, leaving a flat or slightly inclined palatal margin. These are currently the most common and advisable terminations for restoring worn or fractured teeth due to their technical simplification. Horizontal insertion.

c) Palatal mini-chamfer: with lingual reduction, this is a classic termination, bringing the ceramic termination towards the palatal side, but without entering the area of maximum concavity. A line is drawn with a spherical diamond bur to create a slightly concave line or palatal 'minichamfer' that will serve as a stop for the veneer. Slanted insertion. Not recommended.

d) The 3/4 preparation, which largely exceeds the incisal edge and almost covers the palatal side, has the disadvantage of including the area of greatest tensional stress, which may cause more biomechanical problems in the long term, although this choice will be predetermined according to the initial state of the tooth to be restored. Slanted insertion. Common in cases of vertical dimension increases to recover the anterior guide.

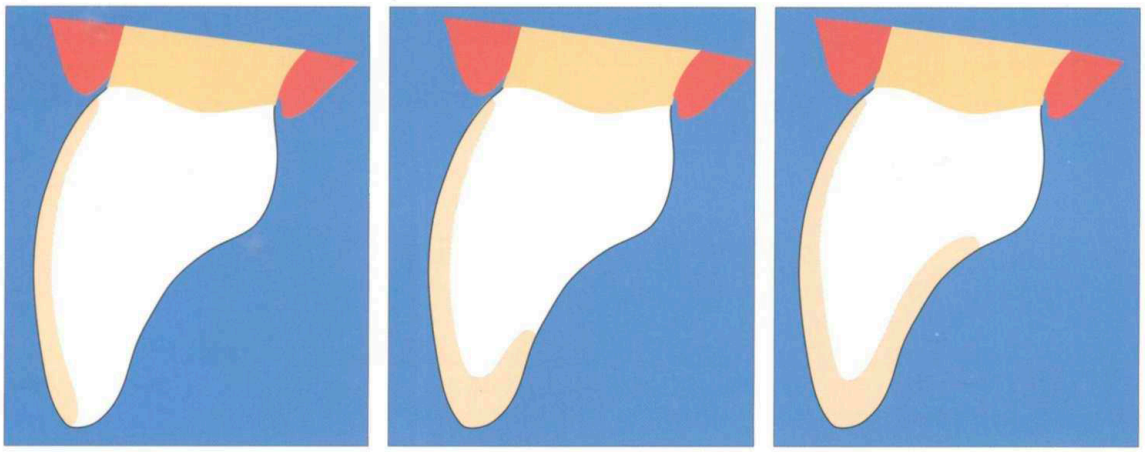


Figure 237. Different types of preparations for veneers: a) Preparation that does not go beyond the incisal edge (contact lens style), b) Preparation that goes beyond the incisal edge (classic palatal chamfer style), c) Preparation that goes well beyond the incisal edge (three-quarter style). Made by Touati B.[102]



This preparation for veneers is the most common in daily clinical practice, as there are many cases of wear. It has also prevailed over the classic palatal chamfer because it is easier to perform and more effective in terms of resistance to fracture (in vitro) according to the review by Chay SY et al[109] in 2018.

Figure 238. Butt joint preparation. Made by Chay SY.[109]

4º Massive axial reduction of enamel and remaining mock-up up to the grooves, always taking into account the double anatomical convergence that will ensure progressive restorative space towards the incisal.

5º Interproximal reduction: the contact areas can be preserved, in which case the veneers will have a completely horizontal insertion, or they can be eliminated with abrasive polishing strips or 'spearhead' shaped drills, especially when you have class III composite to encompass them, thus creating an insertion path that will be more slanted because it usually includes a greater palatal component, usually a 270º type restoration.

6º Definition of the cervical margin in the form of a chamfer or mini-chamfer, which will generally be juxtagingival, at a distance of 0.5mm from the retractor wire, or intrasulcular if there is an unfavourable substrate and the aim is to hide it. Subgingival margins are recommended only in the case of closing a diastema or an interdental triangle, so that the technician can create a progressive emergence profile.

7º Finishing. Preparations should not have sharp angles, as this improves the quality of both the carving (smooth contours, absence of indentations and undercuts) and the impressions, making the work of the dental technician much easier, reducing the thickness of the spacer in the model die and thus reducing the risk of cracks appearing after or during the adhesive cementation procedure (due to contractions of the resinous cement).

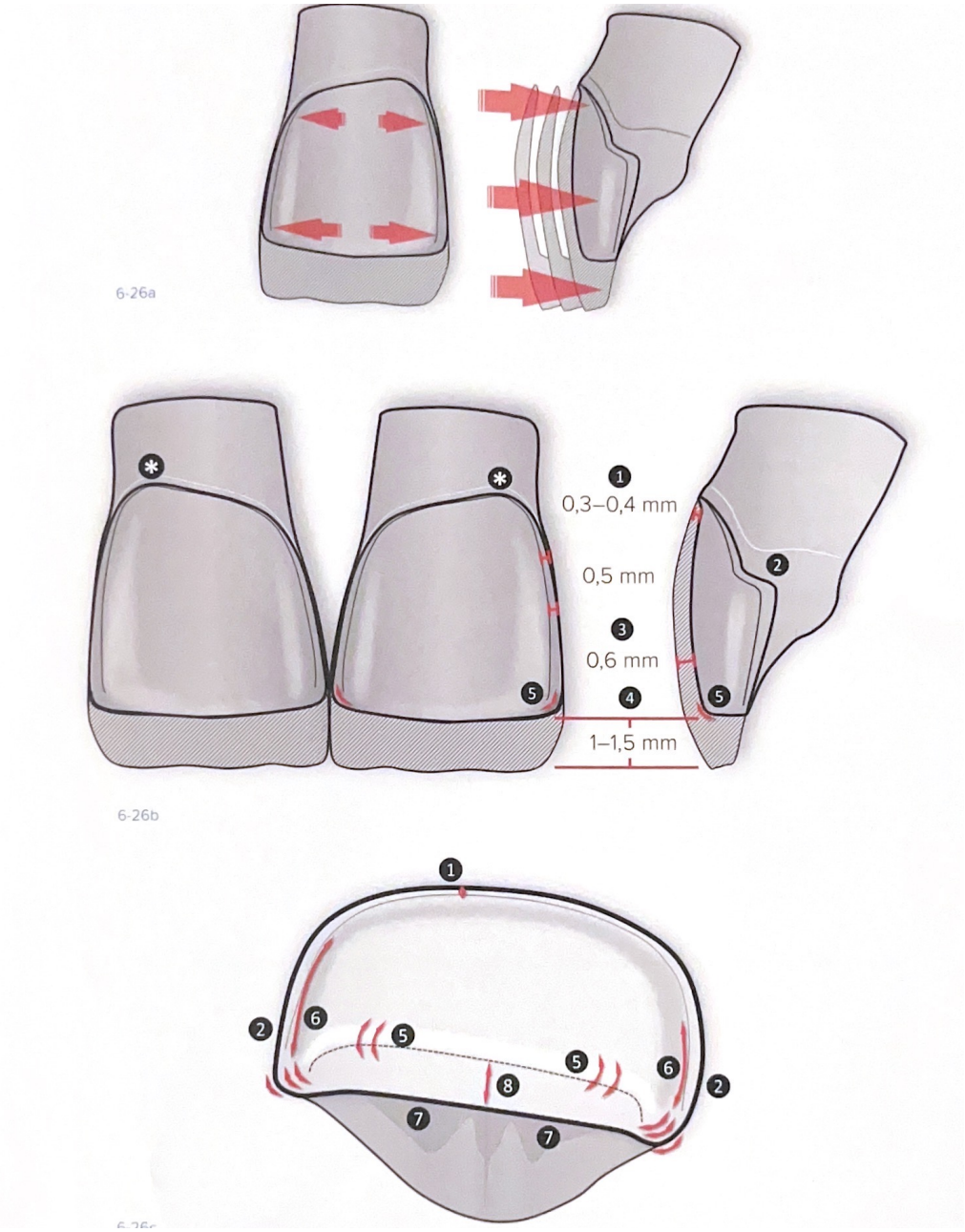


Figure 239. Basic elements of anterior tooth preparation. These sketch views show that the preparation can only respect the natural shape of the tooth if a horizontal frontal path of insertion is used (right): the mesiodistal dimension is narrower at the cervical level than at the incisal level (left). (b) Axial reduction can vary between 0.3 and 0.4mm at the cervical margins and up to 0.5 to 0.6mm at mid-height, but can exceed these values when discolourations have to be masked. The incisal clearance is approximately 1.0 to 1.5mm, but may extend to 5 to 7mm in the case of a fractured tooth. Note that the highest curvature (zenith) of the gingival margin is distal to the central incisors. When the gingival contour is too symmetrical (and lacks this distal displacement), the use of a retractor wire is recommended to extend the margin to the distogingival gingival sulcus and to obtain this effect with the contour of the restoration. It is extremely important to round all sharp edges (incisal view), which can be achieved with coarse-grained flexible discs. Made by Magne P.[105]

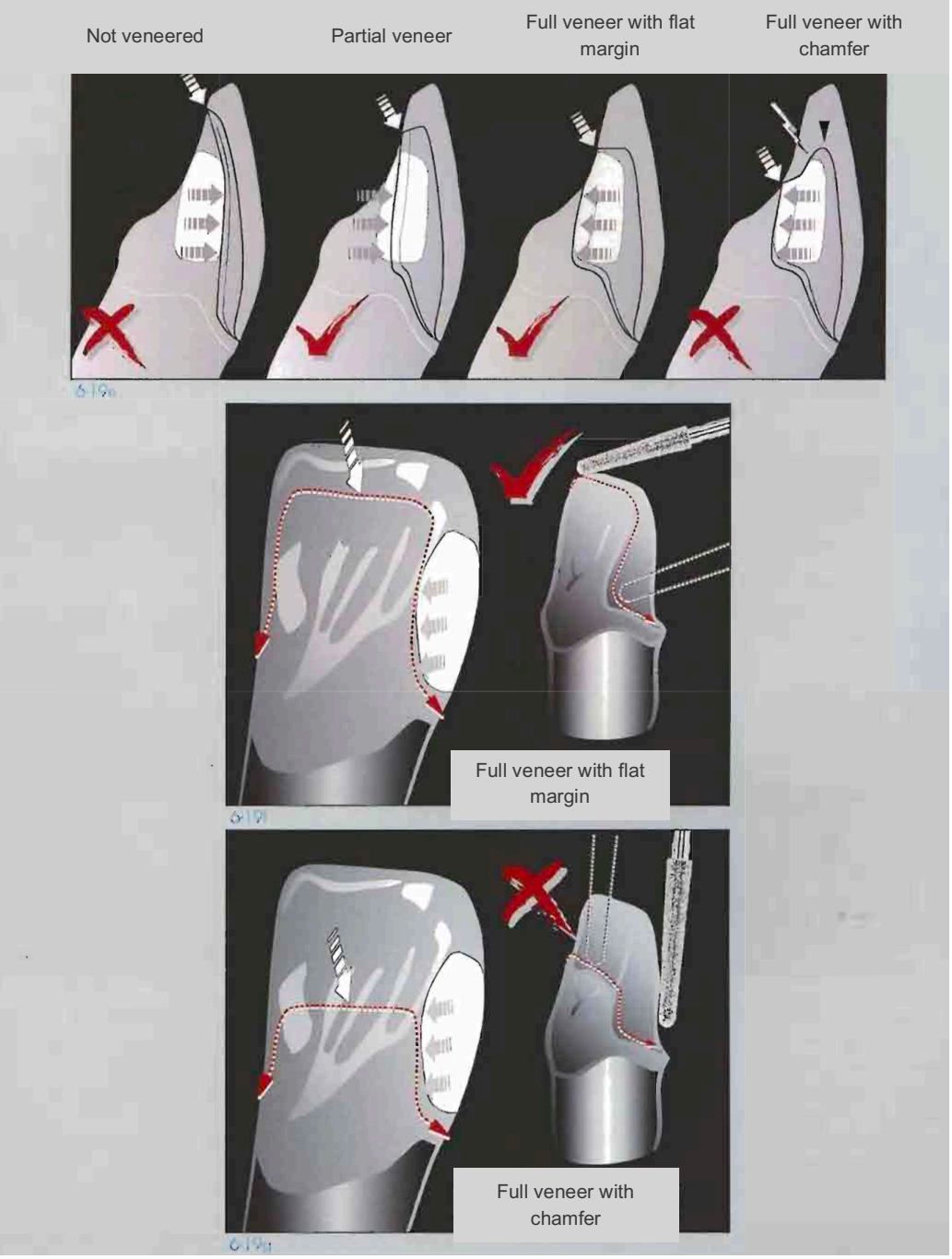


Figure 240. Envelope design in the presence of a pre-existing class 3 restoration. The white dotted arrow shows the level of the incisal preparation. The grey dotted arrows mark the interdental preparation level. An interdental extension ('right end of the picture) is recommended due to the limited aesthetics and potential thermal effects of the composite restoration favourable for both aesthetics and thermal stresses. The full envelope (centre left of the picture) can be a beneficial design, indicated when combined with a flat or slanted incisal margin. An extensive chamfer to the palatal fossa (left end and bottom of the picture) should be avoided due to functional stresses and because a sharp incisal edge is often generated. Made by Magne P.[105]

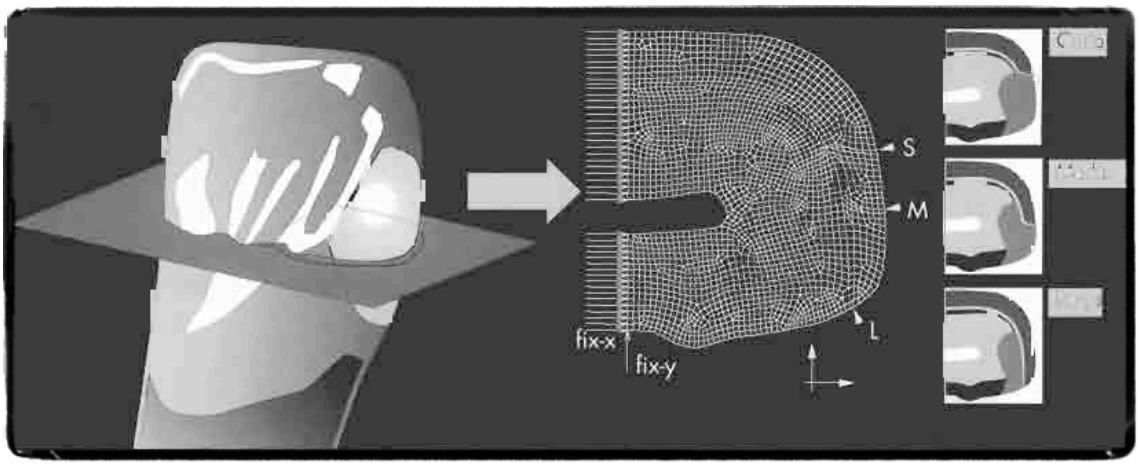


Figure 241. The different options for finishing the ceramic against a pre-existing Class III in an occlusal section. 'Partial or full veneering of pre-existing composite restorations reduces the thermal stress at the ceramic/composite interface.' In large and medium interdental veneers, part of the composite mass is replaced by ceramic, reducing the influence of expansion and contraction of the underlying filling composite and thus preventing future fractures that may occur at the ceramic interface. Made by Magne P.[105]

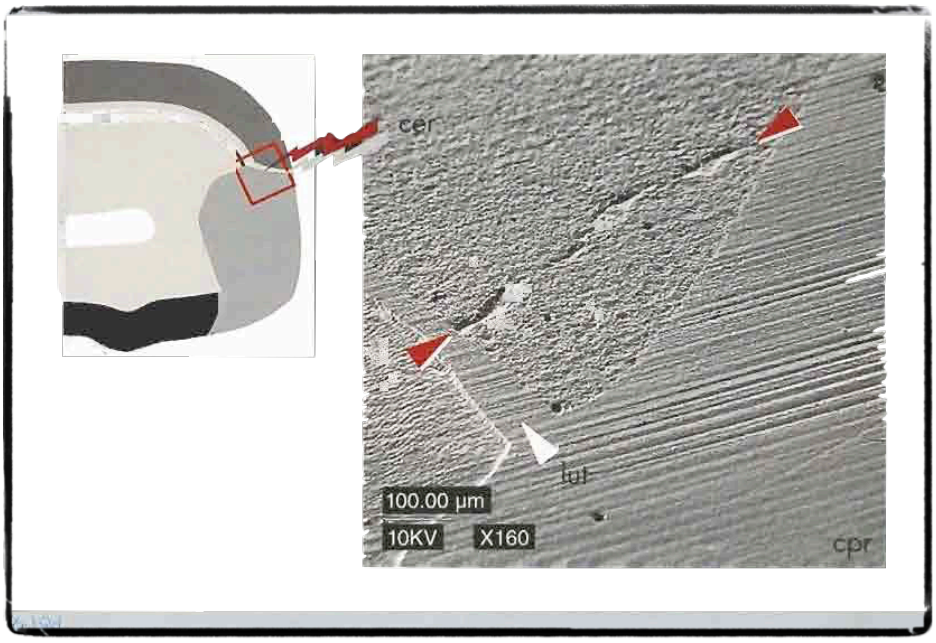


Figure 242. Close-up of a ceramic finish that does not encompass the pre-existing class III. Electron microscopy shows micro-fracture at the interface due to differences in the thermal coefficient of the materials. Made by Magne P.[105]

VENEER PREPARATIONS. KEY QUESTIONS TO CONSIDER

1. What is the colour of the patient and what do you want to achieve?
2. Can the vestibular volume of the tooth contour be increased?
3. What path of insertion should be chosen for the future restoration?
4. What type of material and fabrication technique will the technician use?

Figure 243. Four key clinical questions to be asked when dealing with a porcelain veneer case. Made by Clavijo V.[106]

11.5. Complete clinical case of porcelain veneers step by step of 1.2 - 2.2. Aesthetic diagnosis, preparation, impressions, feldspathic veneers, temporary restorations, cementation and finishing

By Dr Álvaro Ferrando and Mr Manuel Mínguez



Figure 244. Initial intraoral situation, periapical detailed x-ray of the 1.1 and smile, which is low. Made by Dr Álvaro Ferrando and Manuel Mínguez.



Figure 245. Detail of initial situation with 1.2 fractured in incisal, 1.1 darkened, reconstructed and endodontic, 2.1 fractured in incisal and 2.2 palatalised and very disproportionate in size due to a very open distoincisal angle.

PHASE OF INTERNAL AND EXTERNAL BLEACHING AND RECONSTRUCTION OF 1.1 (FIGURES 245 - 251)



Figure 246. Remove the metal post and seal the canal with new gutta-percha.



Figure 247. Etch and rinse approach. Seal the gutta percha with opaque white flowable composite (XBW.GC).



Figure 248. Internal bleaching with Opalescence endo (Ultradent Inc).



Figure 249. Before/after comparison of internal bleaching in 1.1. Detail of upper front.



Figure 250. Before/after comparison of internal bleaching in 1.1. In addition, at-home external bleaching was performed on the rest of the teeth. Intraoral detail.

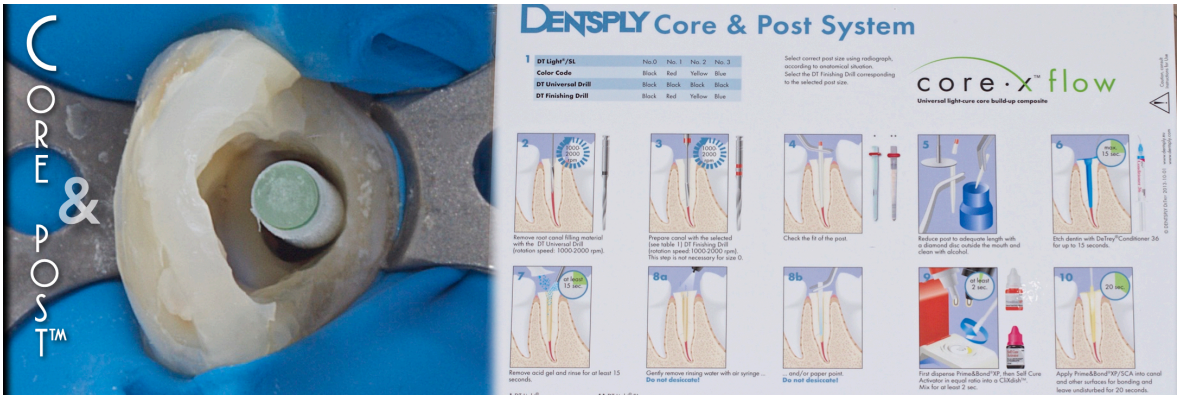


Figure 251. Test of a fibreglass post in tooth 1.1. The system chosen for adhesive cementation is detailed on the left side of the picture.

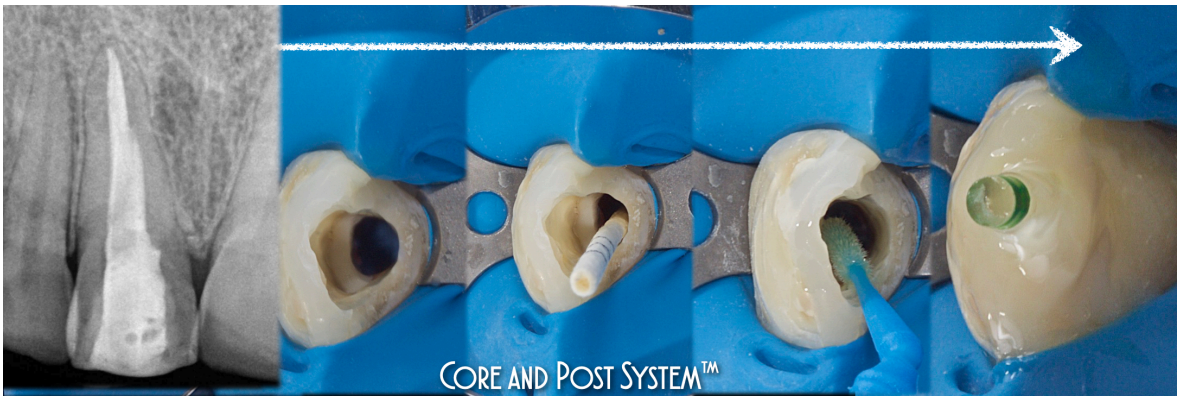


Figure 252. Periapical x-ray showing the result of the final restoration with the post. In addition, the sequence of the adhesive procedure. Total etching with orthophosphoric acid (nowadays it would be done with self-etching strategy), rinsing and drying of the canal with paper points. Placement of 5th generation adhesive, Prime and Bond NT+ SCA activator and cementing of the post with dual core x. flow resin cement.

AESTHETIC WAXING AND SILICONE KEYS PHASE (FIGURES 253-259)

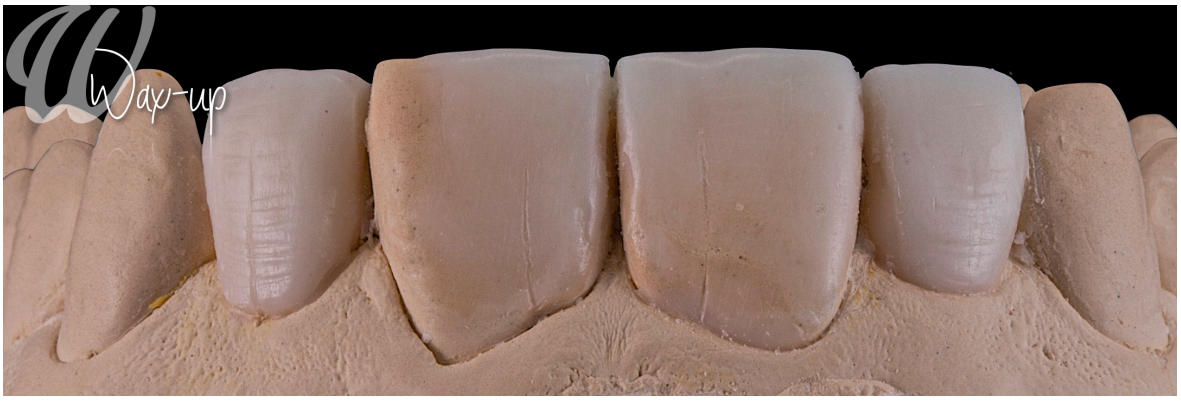


Figure 253. Semi-additive aesthetic wax-up of 1.2-2.2.



Figure 254. Aesthetic dental analysis of the wax-up; meets the requirements described in chapter 4.

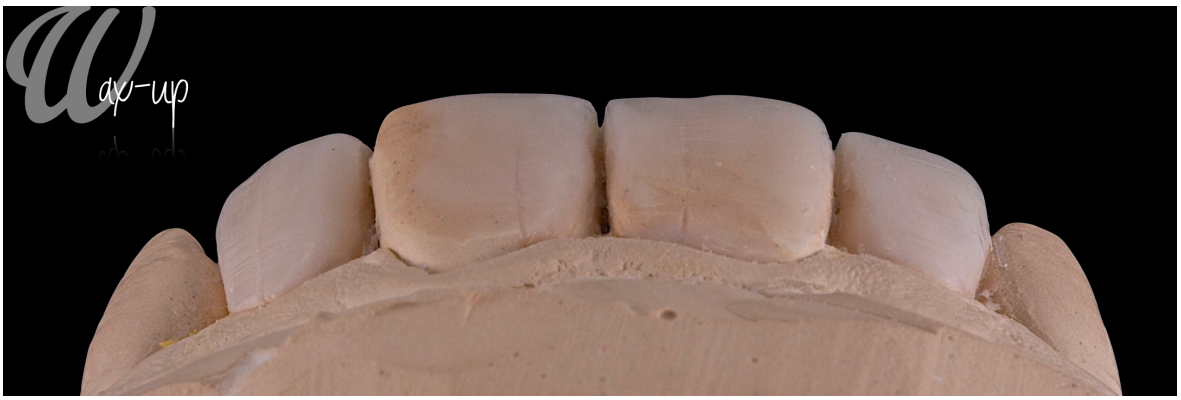


Figure 255. Wax-up detail.

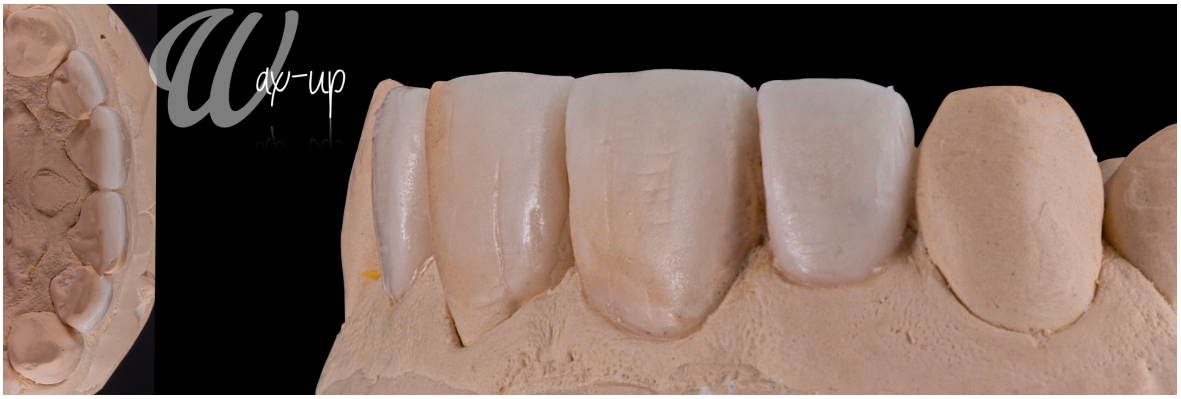


Figure 256. Wax-up detail.

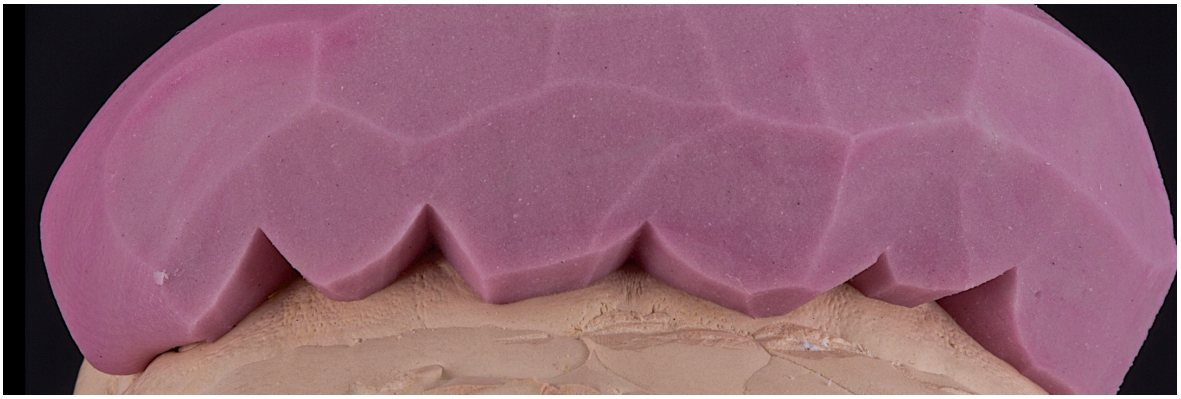


Figure 257. Condensation silicone key test (Zetalaabor.Zhermack) for mock-up on the wax-up.

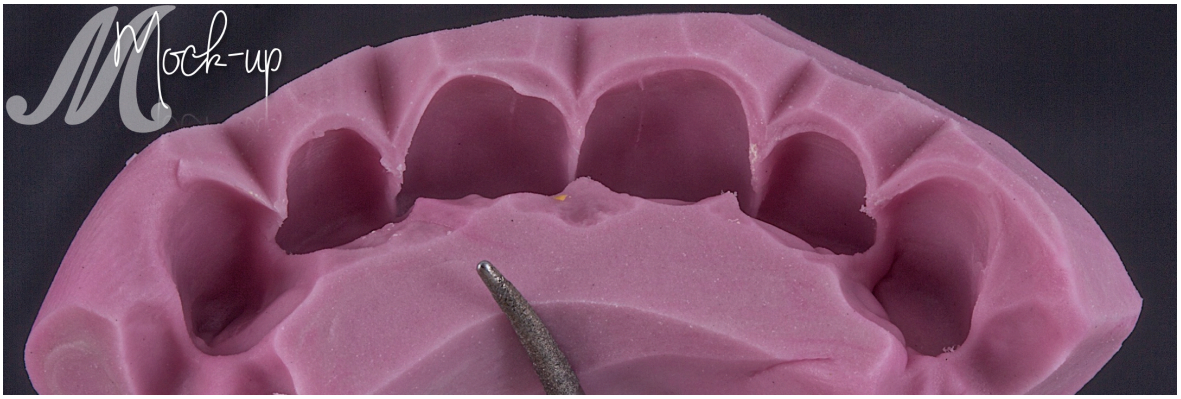


Figure 258. Detail of the condensation silicone key (Zetalaabor.Zhermack) for mock-up on the wax-up.



Figure 259. Detail of more silicone keys on the wax-up to control the preparations.

AESTHETIC MOCK-UP PHASE. DENTAL PREPARATIONS AND IMPRESSION (FIGURES 259-276)



Figure 260. Colour impression with VITA guide prior to the mock-up.



Figure 261. Detail of intraoral mock-up with bisacrylic resin.



Figure 262. Detail of mock-up smile with bisacrylic resin and correction with flowable composite in 2.2.



Figure 263. Detail of the anterior front of the mock-up with bisacrylic resin.



Figure 264. Detail of the burs and soflex disc used.



Figure 265. Preparation on mock-up, horizontal grooves.[108]

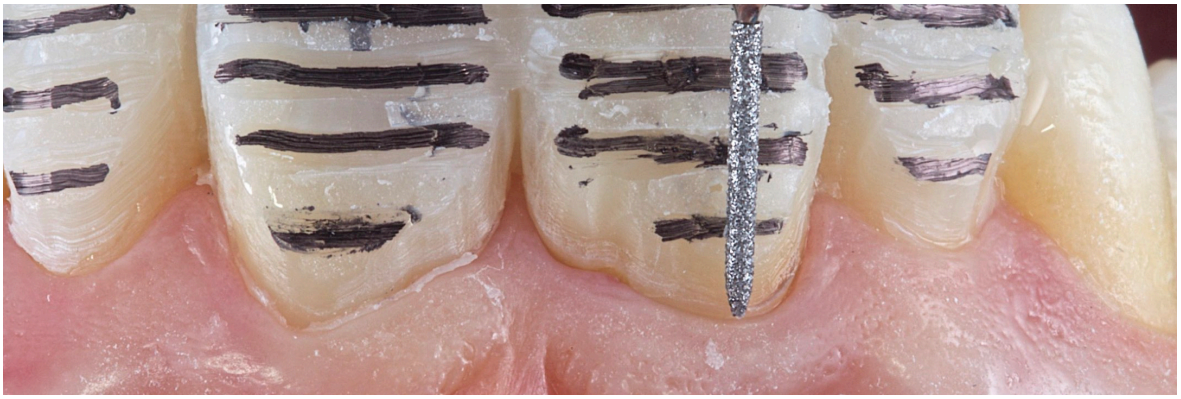


Figure 266. Preparation on mock-up, finishing area.



Figure 267. Evolution of preparation on mock-up; it can be seen that it is being lost by areas.



Figure 268. Preparation on mock-up, elimination of interproximal contact.

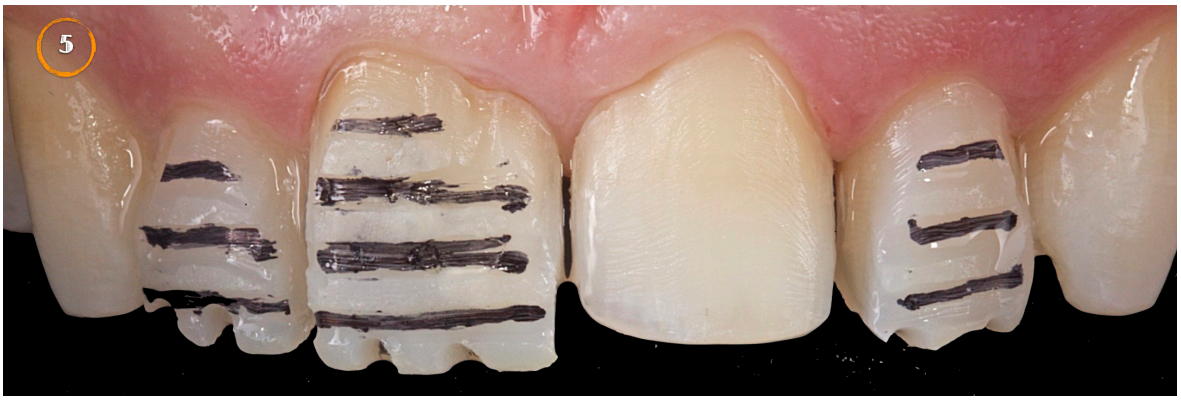


Figure 269. Preparation on mock-up, 2.1 can already be seen without it.

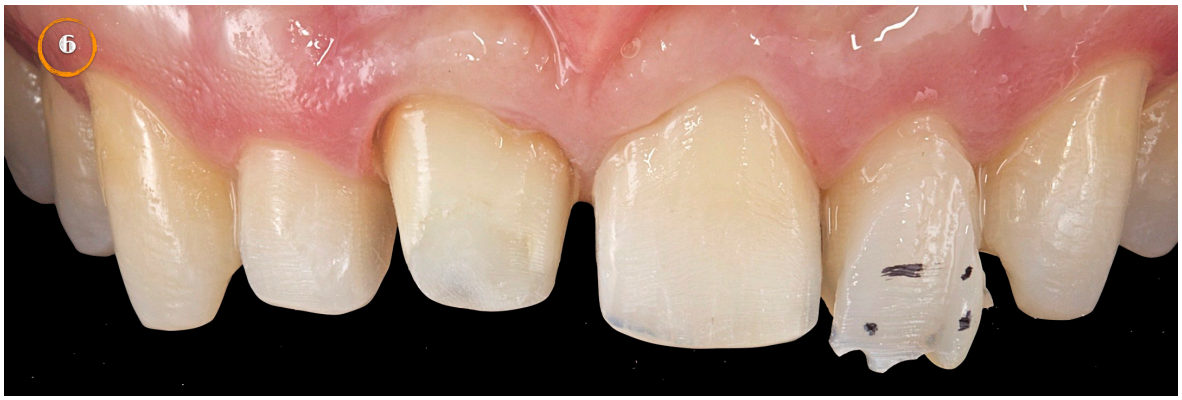


Figure 270. Evolution of the preparation on mock-up, showing that there is still a reduction in 2.2. In 1.1 a 4/4 preparation was chosen to include the palatal resin.[105]



Figure 271. Finished preparations with the termination still to be defined.



Figure 272. Preparations 1.2-2.2 with the retraction wire 00 in place and the cervical margin defined in the intrasulcular position.[104]



Figure 273. Thickness control with silicone key, it was decided to give more thickness to the technician in 1.1 because the substrate is a little less favourable than in 2.1. (despite the bleaching).



Figure 274. Thickness control with occlusal/vestibular silicone key. Comparison of the final space that the technician will have for the ceramic restorations (above) versus the space that existed at the beginning, before the preparations (below), showing that the key does not even fit.



Figure 275. Transmission of the final shade of the preparations to the technician.

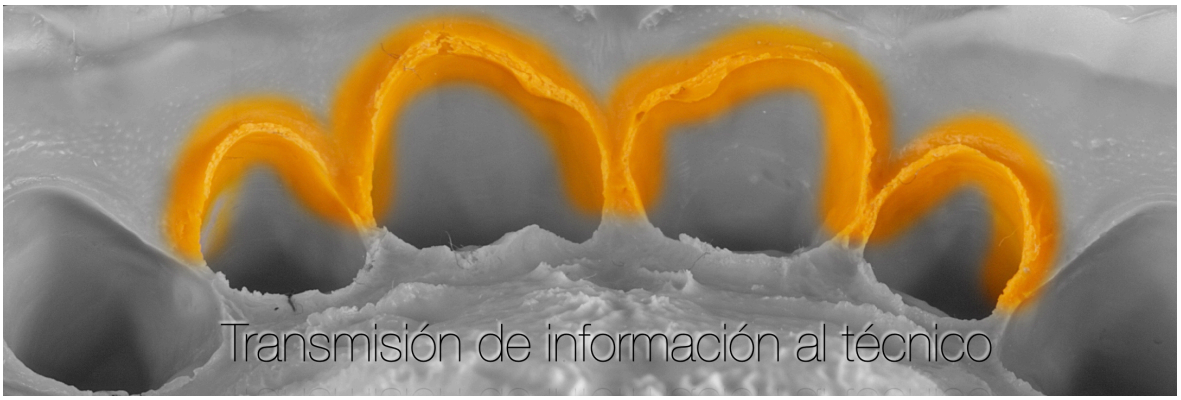


Figure 276. Two-step silicone impression. The margins are completely defined.



Figure 277. Comparative views of the mock-up with the final dental preparations.

PORCELAIN VENEER FABRICATION AND CEMENTING PHASE (FIGS. 278-295)



Figure 278. Manufacture of feldspathic porcelain veneer facets on platinum foil.



Figure 279. Checking the setting and adjustment of the porcelain veneer on the solid model.

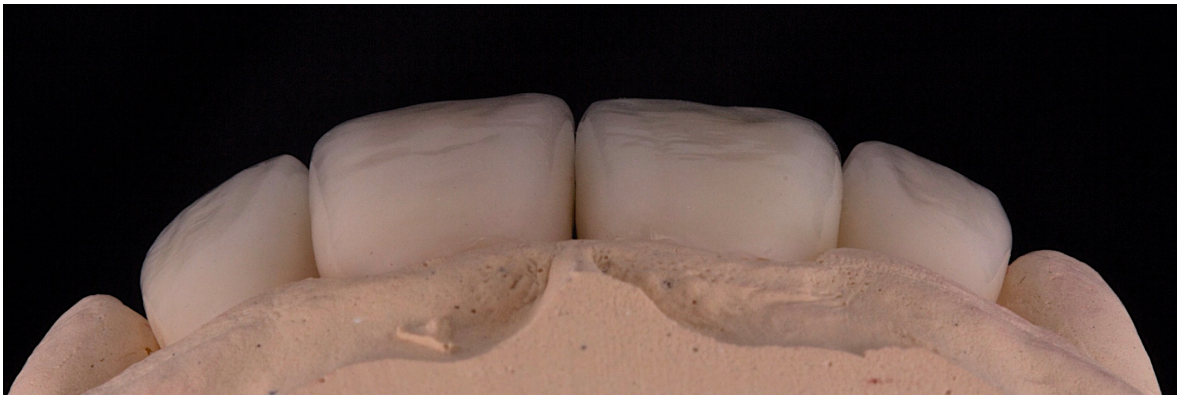


Figure 280. Anatomical detail of the feldspathic veneers.



Figure 281. Detail of the porcelain veneers, ready to be tried in and cemented.



Figure 282. Detail of the intraoral situation of the bisacrylic temporaries (Integrity. Dentsply Sirona) after three weeks.



Figure 283. Detail of the veneers try-in, 'dry' on the 1.2 and 2.2 sides, and with two different value try-in pastes on 1.1 (Calibra veneer try-in bleach. Dentsply Sirona) and 2.1 (Calibra veneer try-in translucent. Dentsply Sirona).

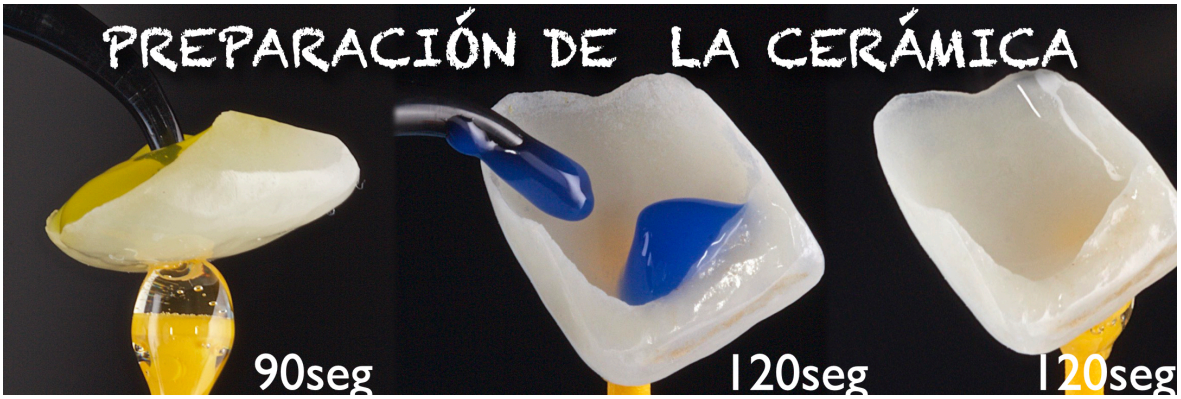


Figure 284. Surface treatment of the feldspathic porcelain as described in chapter 10.

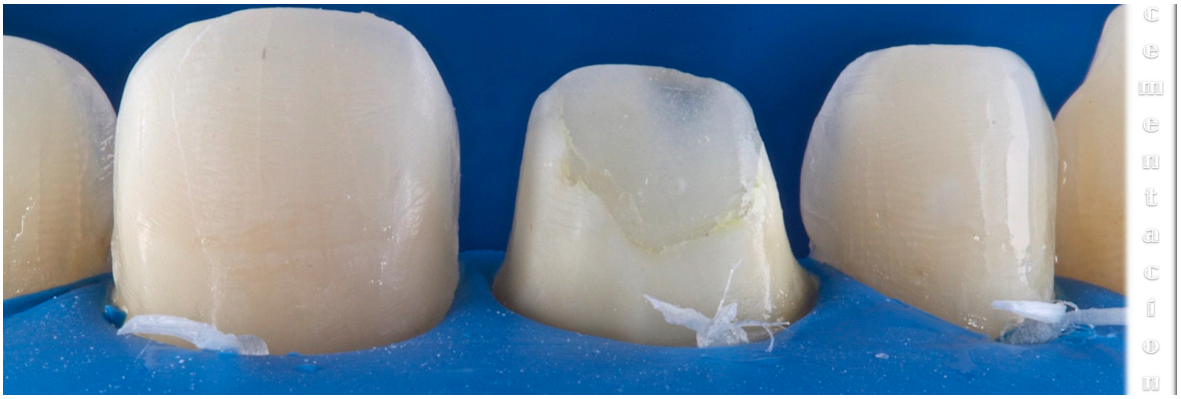


Figure 285. Detail of the isolated preparations under rubber dam (Optidam anterior .Kerr) with dental floss ligatures.



Figure 286. Detail of preparation 1.1 isolated under rubber dam (Optidam anterior .Kerr) and modified clamp No. 212.

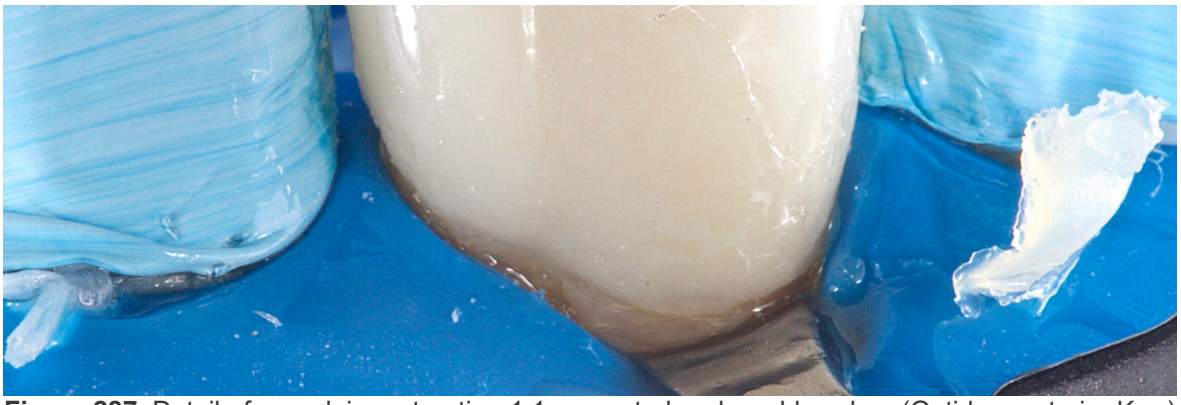


Figure 287. Detail of porcelain restoration 1.1 cemented under rubber dam (Optidam anterior.Kerr) and modified clamp nº 212. Excess cement has been removed at the bottom left.



Figure 288. Detail of the preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212 with dry seated porcelain restoration.

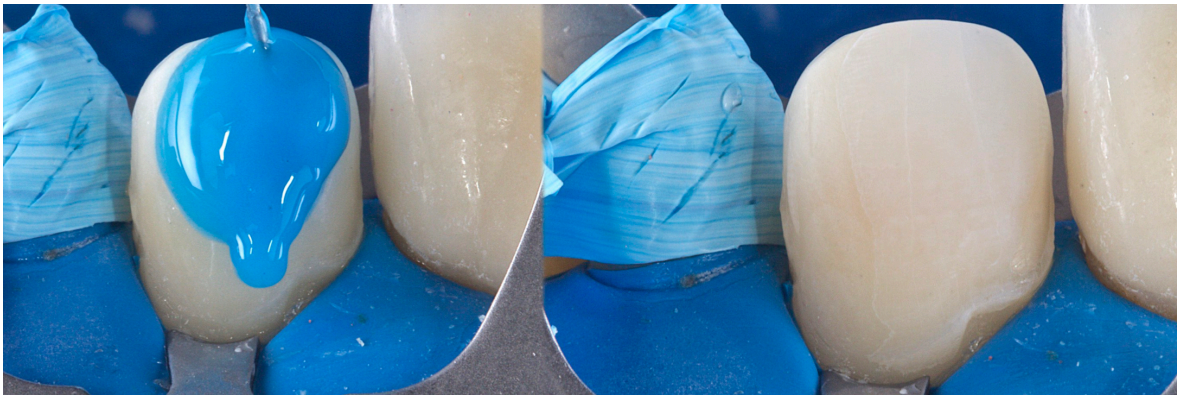


Figure 289. Detail of orthophosphoric acid conditioning of preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212.

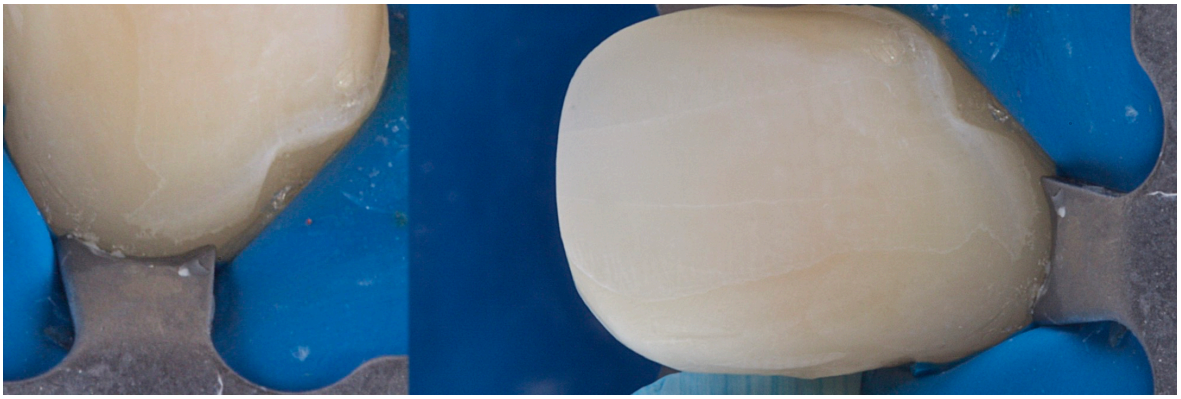


Figure 290. Detail of orthophosphoric acid conditioning of preparation 2.1 isolated under rubber dam (Optidam anterior.Kerr) and clamp no. 212. Note the large amount of enamel available, as well as the dentin-enamel junction.



Figure 291. Detail of the restoration cemented in 1.2 isolated under rubber dam (Optidam anterior.Kerr) and clamp nº 212 modified. On the right, the glycerine gel for the elimination of the inhibited layer during the final polymerisation and, and on the left, the detail of the adjustment.



Figure 292. Detail of the restoration cemented in 1.2 isolated under rubber dam (Optidam anterior.Kerr) and clamp nº 212. modified. Note the detail of the cervical adjustment.



Figure 293. Detail of the cemented restorations in 1.2, 1.1 and 2.2 isolated under rubber dam (Optidam anterior.Kerr). The preparation of 2.2 can be seen without the floss bonded restoration.

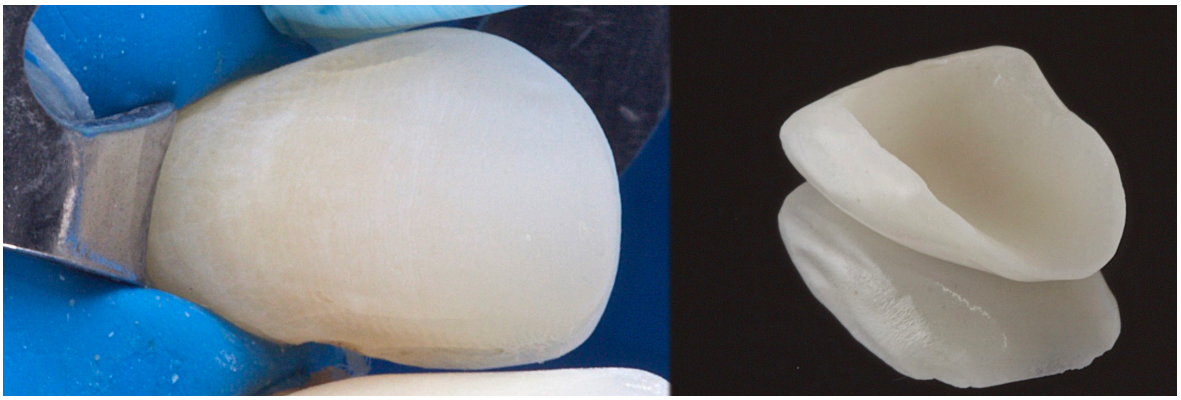


Figure 294. Detail of the preparation in 2.2 isolated under rubber dam (Optidam anterior.Kerr) and modified clamp no. 212. On the left of the composition, the detail of the porcelain restoration.

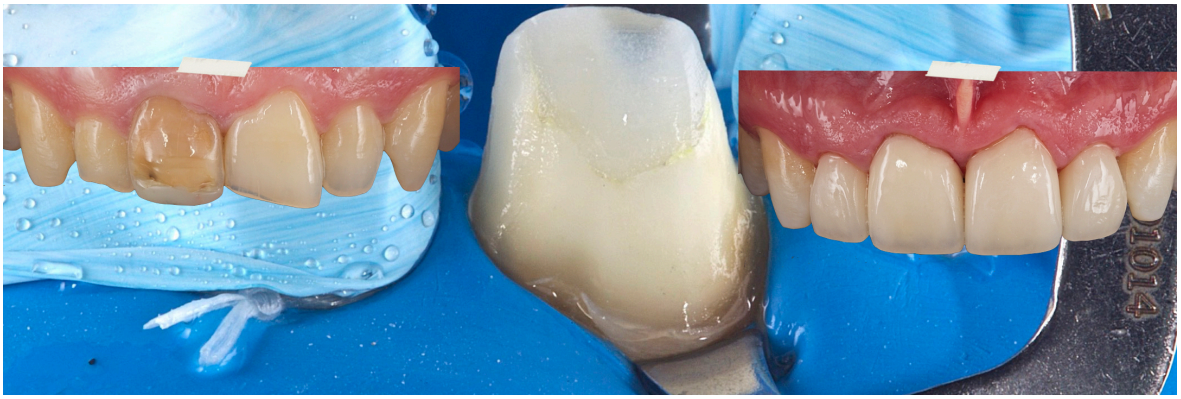


Figure 295. Photographic arrangement of Initial situation/ Finished result. The background is the preparation 3/4 of 1.1 under rubber dam (Optidam anterior.Kerr) and clamp nº 212. modified. The cervical margin can be seen in detail.

FINAL RESULT (FIGURES 296 - 301)



Figure 296. Detail of the anterior front of the cemented restorations after one month. Note the gingival health.



Figure 297. Intraoral detail of the cemented restorations after one month. Note the gingival health and integration with the rest of the teeth.



Figure 298. Intraoral comparison of the initial situation/final result.



Figure 299. Photographic composition of the final result in the occlusal view where the aligned veneers can be seen in comparison with the plaster model of the initial situation, showing the gyroversions of 1.2-2.2.



Figure 300. Photographic composition of initial situation/final result after 6 months.



Figure 301. Smile photographic composition. Initial situation/ Final result after 6 months.

> ‘In times of change, learners inherit the earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists.’
>
> **Eric Hoffer (1902 – 1983)**

Figure 302. Final or Take-Home Message.

In the following link you can read another complete clinical case of porcelain veneers by Prof Dr Álvaro Ferrando[110] in 2016.

PDF **‘Vintage’ porcelain veneers**

Special thanks to Prof. Román Moraleja Ruiz for reviewing this chapter.

UCAM

Chapter 12



Vertical retentive and adhesive restorative dentistry

Marginless preparations, crowns, BOPT protocol and veneers

Photo by Dr. Álvaro Ferrando

12.1. Introduction to vertical preparations for full veneers

Contextualisation and differences to horizontal preparations

Full veneer tooth-supported fixed prosthetic restorations (FPR) remain one of the most common treatments in dental practices to rehabilitate **severely damaged teeth or restored several times** and, despite the impact of dental implants, they are still widely used in clinical practice. The aim is to restore lost health, function and aesthetics, protecting the tooth and surrounding soft tissues, they must be in harmony with the neighbouring teeth, and their margins must remain stable over time. In short, the restoration must remain in the mouth for as long as possible and in the best possible condition[111].

Nowadays, teeth that are to receive an indirect restoration are most commonly prepared with juxtagingival or intrasulcular finishing lines. On these lines, technicians place the restorative materials. These FPRs have been extensively studied for decades, demonstrating their high predictability and long-term survival. However, certain problems have been described associated with the use of the lines, such as the difficulty of milling them homogeneously or reproducing them perfectly with conventional or digital impressions, especially when they are placed inside the sulcus. In addition, medium to long-term disadvantages have been described, such as **apical migration of the gingival margin**. This migration can lead to serious biological problems such as secondary caries, hypersensitivity, gingivitis, hyperplasia, periodontitis, as well as aesthetic consequences as the border of the restoration becomes evident[112].

In an attempt to solve these problems, a few years ago, the *biologically oriented tooth preparation technique* (**BOPT**) began to be discussed in Europe. This technique was described by Ignazio Loi and **Antonello Di Felice**[113] in 2013. In this technique, the millings have no finishing line, and the restorations take centre stage. **The aim of these preparations is to erase the cementoenamel junction (anatomical reference) of the tooth by grinding, leaving a smooth wall, so that the technician can create a new artificial cementoenamel junction in the prosthetic crown, onto which the periodontal tissues adapt**. According to the author, very good clinical results have been obtained since 1986. However, the use of lineless preparations is not new, it was already described by Morton Amsterdam in 1974, and since then, these have been used to restore periodontal teeth, with gingival recession and exposed tooth root, due to how conservative they are with the tooth structure. Other classic references that adopted vertical preparation in the

1980s come from the Italian school of Porta Mascarella (Bologna), such as **Di Febo**[114] and Carnevale.

Thanks to vertical preparations, it is possible to avoid grinding chamfers or shoulders in the exposed root areas, minimising the risk of abutment fracture and, in many cases, avoiding the need for pre-treatment of root canals. Thanks to the dissemination of Dr. Loi[113], their use has been extended to periodontally healthy teeth, based on the stability they offer to the soft tissues over time and the possibility of modifying the gingival scalloping with the prosthesis, without prior surgery, which is especially useful in aesthetic areas.

Therefore, following the rise of this technique, the dental community has been divided between horizontal and vertical preparations **(Fig. 215)**, two diametrically opposed concepts in terms of initial management of the surrounding periodontal tissues and marginal morphology of the restorations[111,112].

However, the classical principles of **retention, strength, stability** and longevity of the future prosthetic restoration combined with the utmost respect for the structural integrity of the tooth of the patient are COMMON to horizontal and vertical preparation.

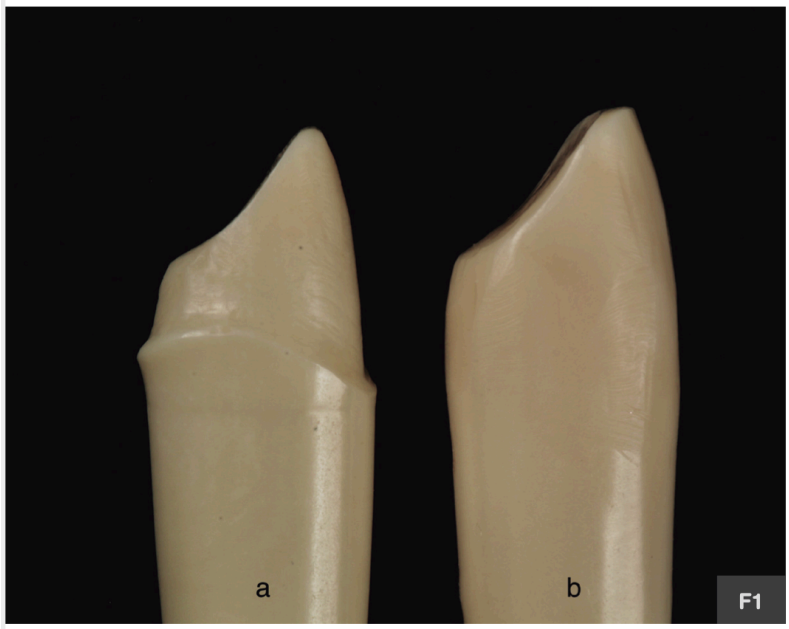


Figure 303. Preparations for full veneer crowns on an upper central incisor. Note the differences at the marginal level between a horizontal preparation with a chamfer (a) and a vertical preparation or one without a termination line (b). Made by Agustín-Panadero R.[111]

12.2. Biomechanical advantages of vertical over horizontal preparations

The biomechanical perspective in the tooth abutment design is intimately correlated with the concept of ferrule. The word 'ferrule' has been widely misunderstood over the years and not properly addressed. In common usage the word "ferrule" is referring to the residual dental structure in two dimensions when it really refers to the 'ferrule effect', which will be described and complemented below. It has been classically accepted that 2mm above the gingival margin is the minimum necessary to restore a tooth, but this parameter has been updated depending on the position of the tooth in the arch; for example, in anterosuperior teeth you can have a 'ferrule' below 2mm on the proximal walls, and the tooth with the prosthetic restoration would still be viable, as the important walls are the vestibulo-palatal walls, which are the ones that will absorb the incident forces.

- Ferrule is a corruption of Latin 'viriola' (small bracelet) under the influence of 'ferrum' (iron).

Ferrule is any of a number of objects used for fastening, joining or reinforcement. They are often narrow circular metallic rings. Thus, the ferrule in prosthetic dentistry is the PROSTHETIC CROWN, which is going to fasten the residual dental structure like a bracelet[115].

As in mechanical engineering, the ferrule in prosthetic dentistry should have been designed and built according to these two following features:

1º Being built in a material with modulus of elasticity larger than that of dental structure. The crown should be made in a material with high modulus of elasticity, as metals or zirconia. Material like composite or similar are not suitable for this goal.

2º Not being designed at the expense of residual dental structure. This means that you should not reduce residual dental structure, i.e. the dentin, especially the pericervical dentin (PCD). To distinguish common usage of ferrule from the remaining tooth structure, Clark and Khademi[102] refer to this remaining tooth structure as **3DF three-dimensional-ferrule**. The 3DF is an evaluation of the available dentin that will reinforce the crown. The 3 components are dentin height, dentin circumference (dentin thickness) and the design/relationship of the opposing axial walls or total occlusal vergence; buccal/lingual-palatal and mesial/distal.



Figure 304. Comparison of a vertical preparation of premorals with a horizontal preparation of incisors. In the bottom area representation, red indicates the highest concentration of stress, right at the cervical. The answer is that a vertical preparation is stronger where the stress is more concentrated as less structure is removed. Made by Ferrando A.

The primary problem with all 'horizontal' finish line designs is that the ferrule effect is created at the expense of the residual dental structure: the 3DF. This is further aggravated by more apically placed finish lines in a futile attempt to improve retention, as dentin thickness decreases. This is very detrimental, especially in endodontically treated teeth.

The shoulder version of the horizontal finish line is the worst scenario, because not only does it reduce the thickness of the 3DF but **it also creates a stress-concentration point at the shoulder itself undermining the ferrule effect it was attempting to provide.**

As a first approximation to give the clinician a sense of things, the shear strength of a brittle cylinder is primarily dependent on the cross section of the cylinder ($A = \pi r2$). Reduction (1mm) in a radius of a cylinder from 4.5mm to 3.5mm will result in a surface area reduction of 40%. Shoulder preparations require a minimum of 1mm in tooth reduction at the cervical level[115].

Assume a shoulder preparation for a porcelain jacket crown on a 10mm diameter root of a maxillary central incisor with a 1mm diameter pulp. A shoulder preparation of 1mm in depth will result in a 40% decrease in surface area (bulk) of the tooth at the finish line, compared to a 20% reduction in bulk that can result from a 0.5mm

finish line depth. Increasing the finish line depth from 0.5mm to 1mm will result in 50% reduction in shear strength of the prepared tooth.

Based on this example, shoulder preparations should be abandoned in favour of a shallow finish line preparation to preserve tooth bulk and maximize tooth resistance to cervical fractures **(Fig.302)**.

Failure in bending (snap-off) is most likely to occur as the shoulder acts as a stress concentration point[115].



Figure 305. Super imposition of different preparation designs: a vertical shoulderless preparation (less opacity) and two horizontal ones (chamfer of 0.4mm and 0.8mm). Clearly there is more structure in the vertical. Made by Tomorrow tooth group.[115]

The only way to prepare the ferrule without affecting the 3DF is to avoid any 'horizontal' invasion (like shoulder or chamfer), to create a shoulderless preparation.

12.3. Vertical preparation and BOPT technique. Are these the same?

Vertical preparation refers only to the geometry without a finishing line that a tooth must have in order to receive a restoration, be it a retentive crown or an adhesive veneer[115].

The BOPT technique, on the other hand, is not only a prosthodontic tooth preparation technique, but also a perio-prosthetic technique, since the primary intention is to manipulate the periodontal environment with the restoration. In 2010, Patroni et al[116] defined this tooth preparation without prosthetic margin as a dynamic technique, in which the gingival tissue can be modified solely with the prosthesis. To carry out a correct clinical execution of the technique, different protocols with different instruments and drills have been described in the literature, but they all have the same common denominator: eliminate the convexity of the anatomical crown of the tooth from its cementoenamel junction and stabilise the surrounding

gingiva with a provisional prosthetic crown that mimics the morphology and emergence profile of the crown of a natural tooth[111].

Clinical sequence to perform BOPT milling for crown[111]

1. **Double probing.** Measure the probing depth of the gingival sulcus (to rule out any periodontal problems) and the distance from the gingival margin to the bone crest. The exact millimetres down to the bone level must be detected, as this structure must not be touched when milling. When probing down to the bone, detect where the cementoenamel junction of the tooth is located, as this point will mark the depth of the grinding inside the periodontal sulcus.

2. **Supragingival tooth preparation.** Using the parameters already described for the horizontal preparation, reduce 2mm from the incisal edge or occlusal side of the tooth, bevelling the vestibular side of the incisal edge or the external side of the functional cusp with an angulation of approximately 45°. The axial walls of the tooth shall be ground supragingivally by 1mm with a diamond turbine bur, fitted on a multiplier, truncated cone with a particle size of approximately 100 microns and a diameter of 1.4mm and with a microchamfer finishing line. With this reduction you will create a supragingival termination line 1 to 2mm away from the gingival margin. At the interproximal level, make a scalloped preparation following the anatomy of the papilla without touching it. In cases of fixed prosthesis retreatments, this step should be omitted as the tooth is already prepared supragingivally.

3. **Subgingival tooth preparation.** Perform a simultaneous dental and gingival grinding (gingival rotary curettage) with a diamond 'flame' turbine bur (conical 862-863) with a particle size of 100 microns and a diameter of 1.2mm. The bur is inserted into the gingival sulcus at an oblique angle of 10-15° to the tooth axis, thus grinding the tooth with one side of the bur body and the gingival tissue with the contralateral side and the tip of the bur. Once the first millimetre of the emergence of the anatomical crown has been milled, and to avoid preparing the root of the tooth with the tip of the bur, change the inclination of the bur to position it parallel to the tooth axis. This way you eliminate the convexity of the anatomical crown starting from the cementoenamel junction. To finish the preparation, the bur is tilted slightly towards the occlusal/incisal to give the correct convergence (6°) to the axial walls of the tooth. **By grinding the tooth and the gingiva at the same time, a vertical axial plane of tooth preparation is created.**

During this grinding, the bur interacts at the same time with the tooth wall and with the epithelial component of the gingival insertion (up to the distance where the cementoenamel junction is located) performing a controlled de-epithelialisation of the free epithelial sulcus area and that of the junctional epithelium (Fig. 2). In the apical area of the preparation, a blood clot will be created and stabilised with a good design of the provisional prosthesis[117-119].

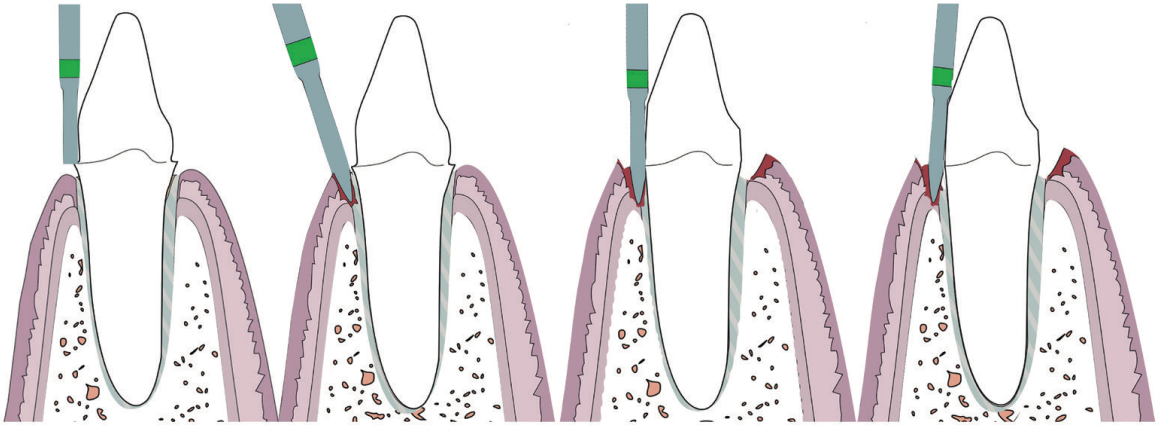


Figure 306. BOPT milling diagram. Made by Agustín-Panadero R.[111]

4. **Shaping of the provisional prosthesis.** One of the fundamental steps in the BOPT technique is the correct shaping of the provisional prosthesis in order to obtain the adequate response. The function of the provisional prosthesis will be to maintain the pericoronary tissues and stabilise the blood clot following grafting, facilitating cellular proliferation and differentiation.

   The function of the provisional prosthesis will be to form a new prosthetic angular component with a new artificial cementoenamel junction, which will be placed in the periodontal sulcus at a depth of 0.5-1mm (while respecting the biological space). The intrasulcular area of the temporary restorations supports the gingival margin circumferentially. The healing process determines the reinsertion and reorganisation of the gingival tissue, which will adapt to the new emergence profile like an ovoid pontic.[120] It is important to know that provisional crowns should not be removed from the teeth in the first four weeks to avoid interfering with gingival healing. Subsequently, until the soft tissue has fully matured (around 8-12 weeks), the provisional prosthesis can be reshaped until the

gingival margin is correctly remodelled and then finalised with the definitive ceramic restorations **(Fig. 312).**[117].

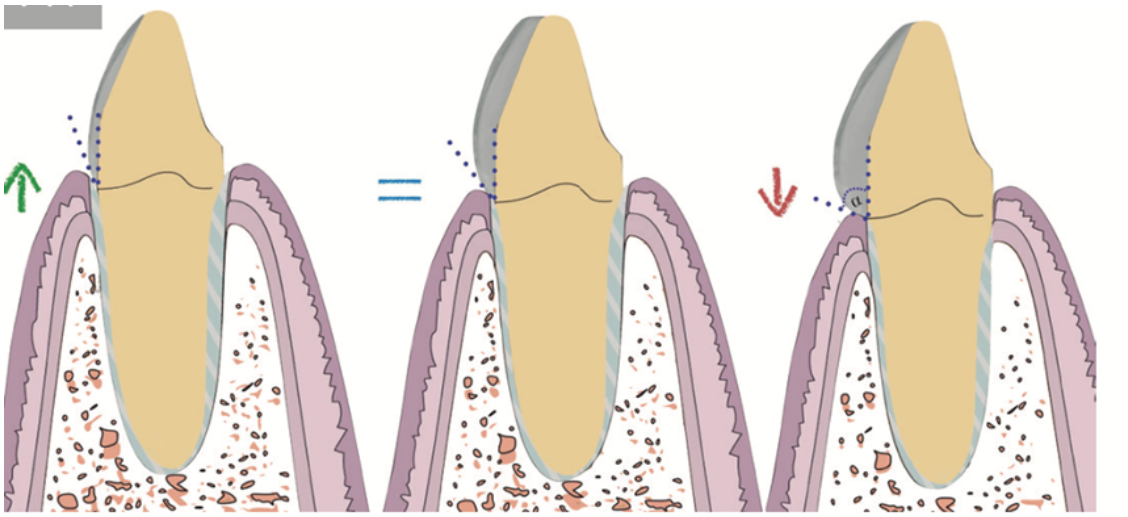


Figure 307. Diagram showing the modification of the gingival margin position according to the cervical angulation of the prosthetic restoration. The most common angle is around 45º. Made by Agustín-Panadero R.[111]

CLINICAL CASE Nº1. BIOPT



Figure 308. Initial situation of a clinical case of four misaligned porcelain-fused-to-metal crowns 1.2-2.2. Made by Ferrando A.



Figure 309. Vertical preparations, B.O.PT protocol, note the marks left by the temporary on the gingiva just after passing it.[119]



Figure 310. Internal aspect of the provisional just passed, clearly identifying two lines: an internal one corresponding to the limit of the dental preparation and an external one corresponding to the future gingival margin. Made by Ferrando A.



Figure 311. Filling the compensation area between the two lines to redefine the future prosthetic margin. Made by Ferrando A.



Figure 312. Adjustment, finishing and polishing of the overfilled temporary prosthesis. Made by Ferrando A.



Figure 313. Photographic composition showing the comparison between the initial and final situation with the newly installed provisional prosthesis.

This clinical example shows that this milling technique, without a finishing line, really seeks the interaction between the preparation, the restoration and the soft tissues, allowing the latter to adapt to the new shapes[119].



Figure 314. Detail of the maturation of the temporary prosthesis after 16 weeks, just before cementation of the final restorations. Made by Ferrando A.



Figure 315. Comparison of smile before/after BOPT protocol with 1.2-2.2 zirconia-reinforced lithium disilicate crowns. 1.4,1.5,1.3,2.3,2.5 and 2.6 are veneers. Made by Ferrando A.

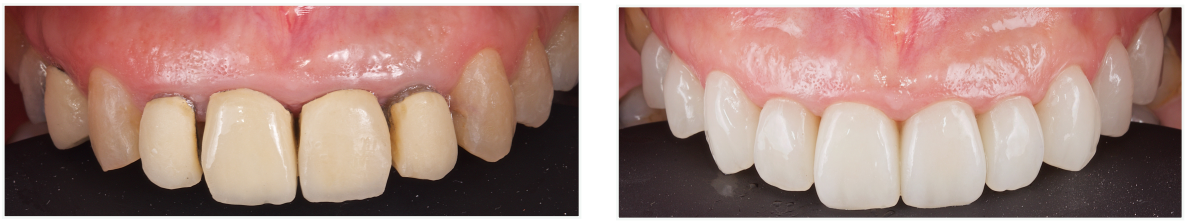


Figure 316. Comparison of anterosuperior front detail before/after BOPT protocol with 1.2-2.2 zirconia reinforced lithium disilicate crowns. 1.4,1.5,1.3,2.3,2.5 and 2.6 are veneers. Made by Ferrando A.

The advantages

The advantages of this technique are the greater preservation of tooth structure at the pericervical margin and the possibility of redesigning the emergence profile to create a correct gingival architecture. Other theoretical advantages have been presented from clinical evidence, although they have not yet been scientifically demonstrated in experimental studies, such as the ability to reposition the gingival margin apically or coronally, or to achieve increases in gingival thickness, theoretically offering greater long-term stability[121].

All these results depend on the correct management of the soft tissues in the interim phase. After tooth preparation, the tissues must be stabilised with the interim prosthesis, defining the end of the restoration. Following the overfilling of the provisional prosthesis, there should be an angular component at the cervical level

of approximately 45° but adjusted to phenotype, similar to that of the adjacent natural teeth. It is this inclination that stabilises the subgingival clot and guides the healing of the tissues to form the new emergence profile that will be transferred to the final restorations **(Fig 306 and 312)**.

The disadvantages

The most frequent problems would be irreversible pulpitis after grinding and periodontal disorders. These clinical alterations are very *operator-dependent*. The BOPT technique requires a learning curve of 8-12 months. The restorative dentist is not used to making a good temporary prosthesis that acts as a biological tool in the maturation of the gingival tissues; and, in addition, due to the social circumstances in which dentistry is currently operating in Spain, dedicating the necessary time to making a good temporary prosthesis and respecting the biological times is not usually economically profitable[111,121].

Design of restorations with vertical preparations

With vertical preparations for crowns you gain in fit, but lose in **seating**[122], with horizontal ones it would be the other way round. This is why you will have to change the classic design of restorations where the spacer was only placed in the occlusal and middle part of the die when preparing horizontal lines to ensure cervical friction **(Fig 315)**. With vertical preparations this should be reversed by yielding the friction and seating to the coronal part in favour of the spacer in the cervical portion. Otherwise, overheating of the material can occur by making it difficult for the cement to reach the margin, thus facilitating cervical fractures of the zirconia or silicates. The last reason is that the cervical portion is where most mistakes are made during preparation: if no spacer is placed, the clinician is forced to make multiple adjustments and tests to alleviate and ensure the final seating of the restoration.

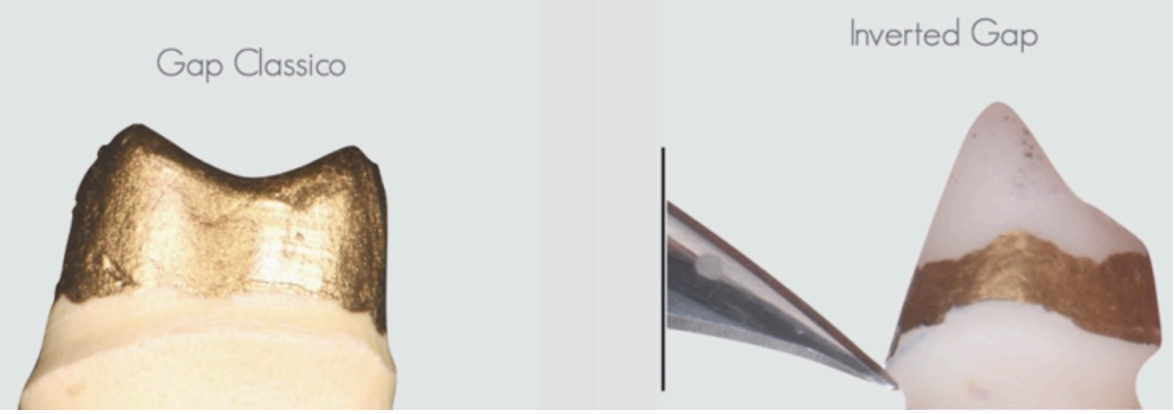


Figure 317. Diagram analogically depicting where the spacer for cement (gold dust) should be placed in horizontal and vertical preparations. Made by Maiolino M.



CLINICAL CASE Nº2. BOPT

Figure 318. Initial intraoral situation. Porcelain fused to metal crowns mismatched in 1.1 and 2.1.

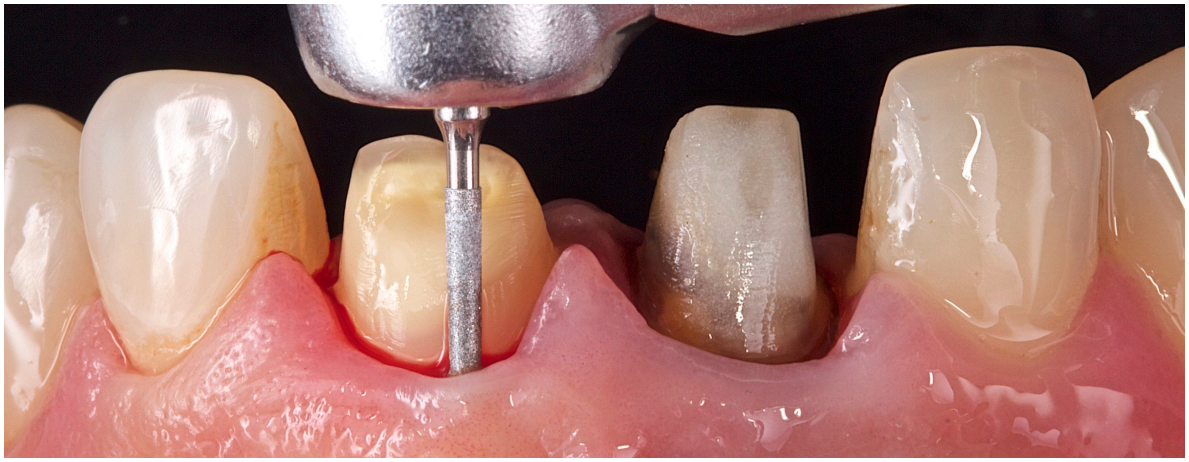


Figure 319. Vertical preparation with the flame-shaped bur in the gingival sulcus. Made by Ferrando A.



Figure 320. Emergence profile after removing the interim prosthesis. Made by Ferrando A.[119]



Figure 321. Final result with definitive restorations 1.1 and 2.1 (zirconium oxide). Made by Ferrando A.

The specific disadvantages of a poorly executed BOPT technique are as follows[115]:

1. Almost unavoidable undercuts or steps due to the morphology of the 'flame' shaped bur at the active tip.
2. Excessive taper of the prepared tooth in breach of the retention principle as a lot of manual dexterity and magnification is required.

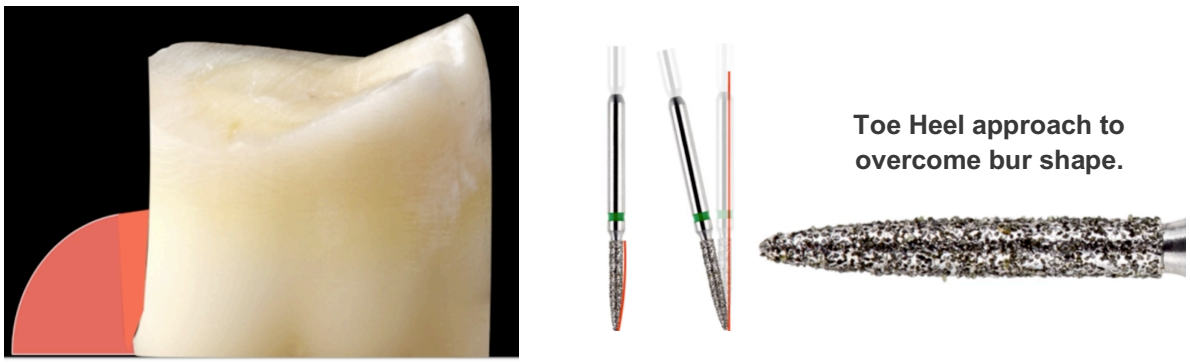


Figure 322. Diagram showing a subgingival 'step' accidentally made by tilting the active tip of the 862-864 'flame' bur too much towards the tooth (left part of the photo). Made by Tomorrow tooth group.[115]

3. Excessive connective tissue damage with profuse bleeding due to the search for new soft tissue gingitage.
4. Minimal 6-8 week wait, healing period or tissue stabilisation before impression.
5. Unpredictable soft tissue regeneration.
6. Increased number of 'trial-and-error' possibilities requiring extensive time with provisional prostheses during the healing period.
7. Absence of a clean, clear and defined finishing area or finishing lines which complicates or totally changes the work of the laboratory technician.

In order to avoid these problems, especially with the 'flame' bur, other vertical preparation approaches have been proposed, based on 'inactive tip' chamfer drills which are not intended to 'cure' the junctional epithelium extensively in a rotational manner and to guide healing with the provisional prostheses.



The World is **full** of *obvious* things that nobody *ever* takes **care** to **observe.**

Figure 323. Comparison of the 'flame' drill and the inactive tip drill. Made by Tomorrow tooth group.[115]

This approach is known as 'Shoulderless', also classically known as 'knife-edge', which was widely used in the days when gold crowns were made, thanks to the possibility of finishing the metal margins with minimal thickness. The shoulderless design has always been unanimously recognised **as the most conservative approach to tooth structure and the least prone to marginal seepage. This is because it has a better fit, but poorer seating compared to horizontal preparations, which have the best seating but poorer fit**[122].

12.4. Differences between the Shoulderless and the BOPT technique

With the shoulderless technique, violation of the 'biological width' is practically impossible because the non-cutting tip of the bur is calibrated not to touch the first millimetre of the root where the connective tissue fibres insert into the root cementum. In addition, the possibility of using a smaller tip compared to conventional vertical preparation techniques allows for rotary curettage involving only the epithelial component of the sulcus with less or no bleeding, and therefore faster subsequent healing. **In the shoulderless technique, the mission of the interim prosthesis is not to interfere with the natural healing process, it does not attempt to guide it in any way as in the BOPT protocol**.



Figure 324. Photographic composition of the inactive tip drill 857 (Intensiv. Switzerland) over the premolar stump and into the sulcus to ensure vertical preparation without scaling. Made by Ferrando A.

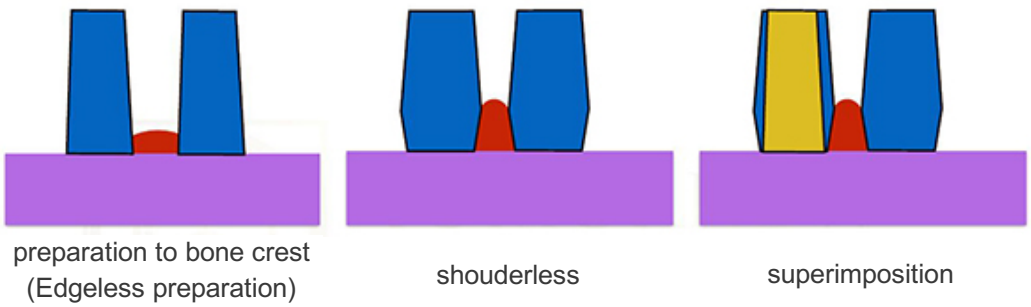


Figure 325. Comparison of the vertical preparation in the BOPT protocol, also called 'edgeless' compared to 'shoulderless'. There is more structure in the second one, thanks to the overlapping, and also better tissue behaviour at the level of the interproximal papillae. Made by Tomorrow tooth group.[115] From https://vk.com/wall-114971260_919.

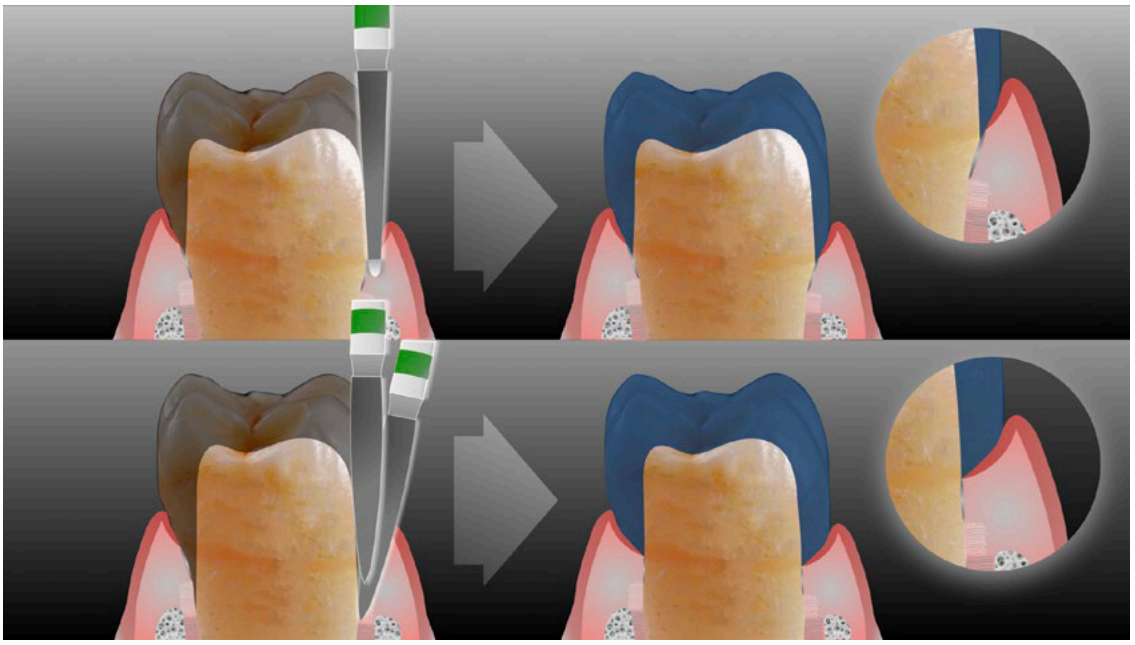
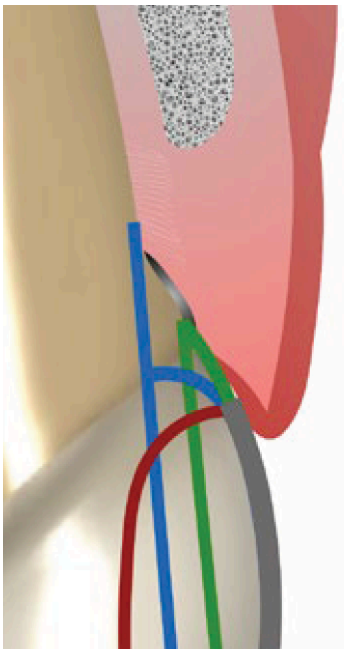


Figure 326. Differences between 'Shoulderless' and 'Edgeless' preparation designs. From Cardoso JA.[123]



	PREPARATION	CROWN MARGIN
VERTICAL EDGELESS	Connective tissue or junctional epithelium	Sulcus
VERTICAL SHOULDERLESS	Sulcus or junctional epithelium	Sulcus or junctional epithelium
HORIZONTAL SHOULDER	Sulcus	Sulcus

Figure 327. Vertical EDGELESS and SHOULDERLESS versus horizontal termination. Differences in the depth of preparation and the future margin of the restoration. From Cardoso JA.[123]

In periodontally healthy teeth the use of a **non-cutting tip** allows not only to do a better controlled invasion of the sulcus, but to accomplish two critical elements:

1) A more conservative preparation of the tooth allowing the pericervical enamel to be preserved at times.

2) The maintenance of a non-prepared area of the tooth. The convergence of the root with the neighbouring teeth keeps the same inter-root distance and allows to get better inter-proximal tissues.

The shoulderless approach. A new rationale in prosthetic dentistry[101]

12.5. Advantages of preparations with round-ended tapered diamond bur with a non-cutting end.

This bur is well known in the endodontic field as Batt-Bur.

This bur has the following advantages:

- Taper of about 2 degrees facilitates an optimal taper of the abutment.
- Coronal diameter of 1.2mm and apical diameter of only 0.7mm facilitate a very conservative approach.
- Non-cutting end of 1mm reduces or avoids the damage to the connective attachment.
- Non-cutting end of 1mm allows/facilitates a tooth-guided preparation procedure.
- Non-cutting end allows a bloodless gingitage, creating space for the immediate impression and an easy provisional relining.
- Non-cutting end allows to work in the presence of cord or teflon tape, without any tearing or impingement.
    - › Bur design allows even the non-expert clinician to avoid any undercuts into the prepped abutment.
    - › Non-cutting end allows to be used as a periodontal probe.

- Design differs from flame burs used in the approach of Mascarella's school and BOPT, allowing a pure geometrical frustum and true vertical finish lines.
- Encourages immediate impression and provisionalization, in contrast to the other approaches.

12.6. Vertical preparations for porcelain veneers

- **General considerations**

While vertical preparation is commonly indicated when periodontally involved teeth are used as abutments for fixed prostheses, this approach may represent a less invasive alternative to a horizontal margin in other clinical conditions such as veneers. **The vertical preparation technique, compared to other preparation techniques (chamfer, shoulder, etc.), is simpler and faster in terms of clinical steps, and perfectly applicable in porcelain veneer cases. It would be the first choice of preparation in cases of veneers + recessions, thus avoiding lines in the root cement, further exposing the tooth to future pulp problems[124].**

12.6.1. Vertical preparation technique for porcelain veneers (Imburgia M)[124]

1. Guided preparation through the mock-up. Without removing it from the mouth, perform the same steps as in the horizontal preparation for veneers, thus ensuring that the approach is semi-additive and, in most cases, preserving the cervical enamel.
2. Horizontal grooves or 'pilot' depth ensuring grooves with a minimum final thickness of 0.3 mm (gingival third), 0.5 mm (middle third) and 0.8 mm (incisal third).
3. Incisal termination preferably as a 'contact lens' or 'flat margin' covering the incisal edge by 2mm and allowing for horizontal insertion.
4. Massive axial reduction of enamel and remaining mock-up with the flame bur 862-863-012 (Intensiv.Switzerland) up to the grooves, always taking into account the double anatomical convergence that will ensure progressive restorative space towards the incisal.

5. Interproximal reduction: contact areas can be preserved, in which case the veneers will be inserted completely horizontally or eliminated with abrasive polishing strips or 'spearhead' shaped burs 859-010 or 'flame' shaped burs 862-863 but of smaller calibre 009. Ensure partial or complete veneer of pre-existing composite restorations.

6. No cervical margin definition. A retraction wire (000 or 00) depending on the phenotype is placed in the sulcus to move the gingival margin, and the anatomical cementoenamel junction is eliminated in the case of visible recessions with the flame bur, then you can use the chamfer bur with an inactive tip (851/857-010.Intensiv.Suiza) to finish securing the vertical wall.

CLINICAL CASE Nº3. SHOULDERLESS VENEERS



Figure 328. Initial situation of the anteroinferior sector worn and with recessions. Made by Ferrando A.



Figure 329. Shoulderless preparations of 3.2-4.2. Note the high definition of the sulcus depth with an analogue condensation silicone impression. Made by Ferrando A.

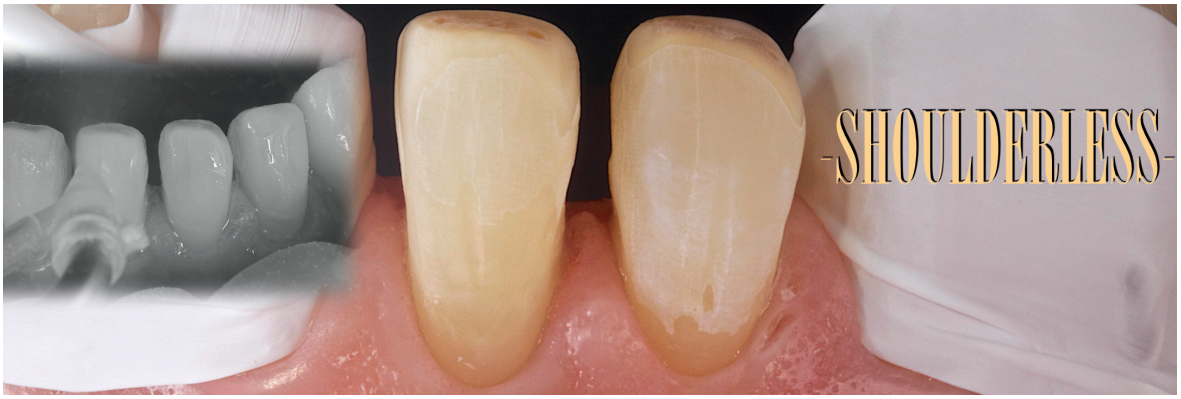


Figure 330. Detail of the preparation of the substrate for cementing the veneers (Table 5), the dentin-enamel junction can be seen in the 3.2 cervical. Made by Ferrando A.



Figure 331. Comparative photographic composition before/after treatment with lithium disilicate veneers on margin-free preparations in the lower arch. The periodontal health is remarkable, as well as the aesthetic result of the white part. Made by Ferrando A.

7. Finishing and polishing. Finally, silicone polishers or low speed arcansas stones with counter-angle can be used for finishing, as well as sof-lex discs to ensure that no sharp angles are left.

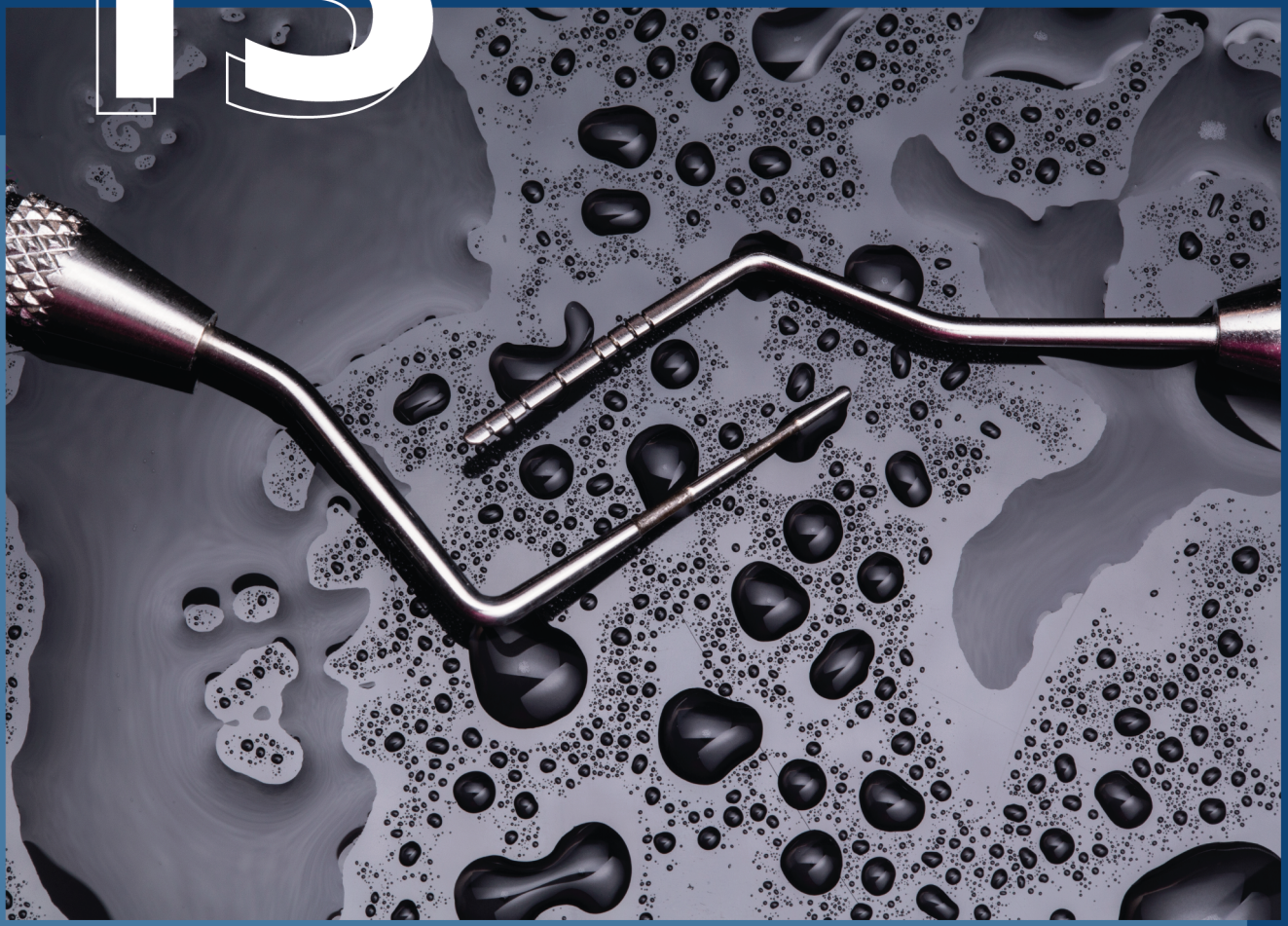


Figure 332. Photographic composition of the vertical preparations and the veneers placed in harmony with the soft tissues. Note the anatomical emergence profile of the BPRs, in accordance with the periodontal phenotype, emulating a cementoenamel junction but ARTIFICIAL.[125] Made by Ferrando A.

Minimally invasive vertical preparation design for ceramic veneers[124]

UCAM

Chapter 13



Aesthetic restorative dentistry and Periodontics

Photo by Dr. Fernando Rey Duro

13.1.Definition

The gingiva is composed of[126]:

1. FREE GINGIVA

   The free gingiva extends apically from the gingival margin to the cementoenamel junction, following the contour of the entire cervical perimeter.

2. ATTACHED GINGIVA

   The attached gingiva is the portion of tissue that extends from the most apical limit of the free gingiva to the mucogingival junction. Typically pink, distinguishing it from the alveolar mucosa, which is bright red. It is lined with keratinised epithelium.

3. ALVEOLAR MUCOSA

   The considerable amount of vascular support and the presence of non-keratinised epithelium give the alveolar mucosa a dark red colour and a smooth surface.

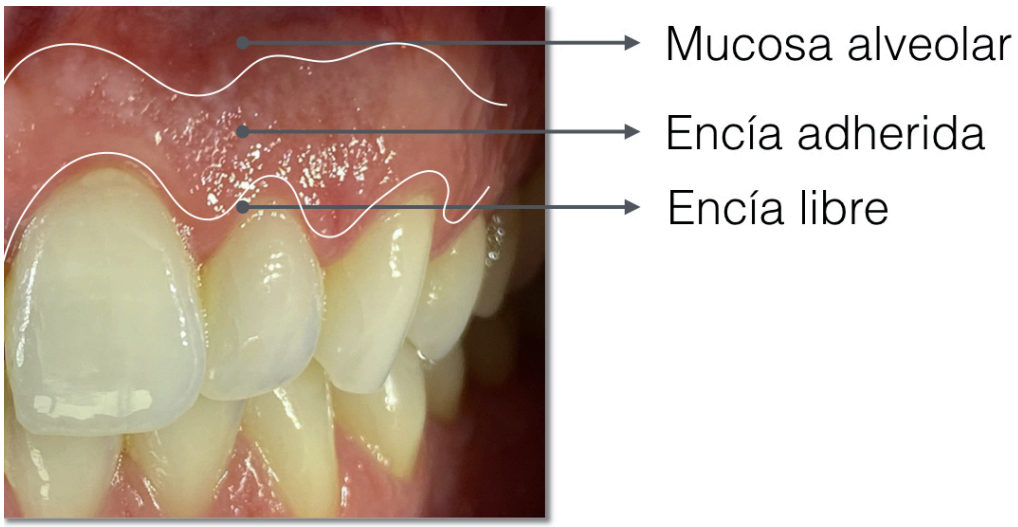


Figure 333. Outline of free gingiva, attached gingiva and alveolar mucosa. Made by Carmona JJ.

13.2. Oral aesthetics and Periodontics: 'gingival aesthetic criteria'

There are a series of periodontal parameters or criteria that need to be known in order to be able to successfully achieve them when treating patients. Especially in patients with a medium or high smile line[9].

A treatment that achieves excellence is one that manages to combine biological, structural, aesthetic and functional success over a prolonged period of time.

Gingival aesthetics

- Gingival health
- Gingival papillae
- Gingival contour zenith
- Balance of the margins



Figure 334. Aesthetic gingival parameters. Made by Carmona JJ, from Fradeani M.[9]

13.2.1.Periodontal parameters or criteria:

13.2.1.1.Gingival health

The healthy state of the tissue allows the aesthetic perception of the dentogingival complex to be optimised and is also, from a biological point of view, an essential prerequisite for any restorative treatment. Four anatomical characteristics determine healthy gingival tissue[9]:

1. Colour:

   Healthy gingival tissue is normally pink, although there is considerable variation between individuals. It becomes bright red when inflamed.

2. Stippling:

   In approximately 40% of individuals the soft tissue surface has an 'orange peel' appearance caused by adhesion of supracrestal fibres to the overlying epithelium.

3. Shape:

   Healthy gingival tissue is firmly attached to the deep layers. The shape is determined by gradual reduction in gingival thickness from the attached gingiva to the free gingival margin.

4. Architecture:

   In healthy tissue, the gingival margin and the alveolar ridge below follow the scalloped contour of the cementoenamel junction. In the vestibular region, the gingiva is positioned more apically compared to the interdental areas.



Figure 335. Parameters indicating gingival health. Made by Carmona JJ.

13.2.1.2.Interdental papilla

The typical gingival scallop architecture, which is parallel to both the underlying bone ridge and the cementoenamel junction, is characterised by the presence of papillae filling the interdental spaces. The papilla between the two central incisors appears longer than that of the adjacent teeth in relation to the position of the interproximal contact areas.

In teeth that are close together the papilla may appear elongated because its development is guided by the contour of the interproximal teeth. However, with a distance of less than 0.3mm (root proximity) it usually disappears due to the lack of

a bony peak underneath. However, if the roots are far enough apart, the papilla will appear flat and a diastema will occur between the teeth[9].

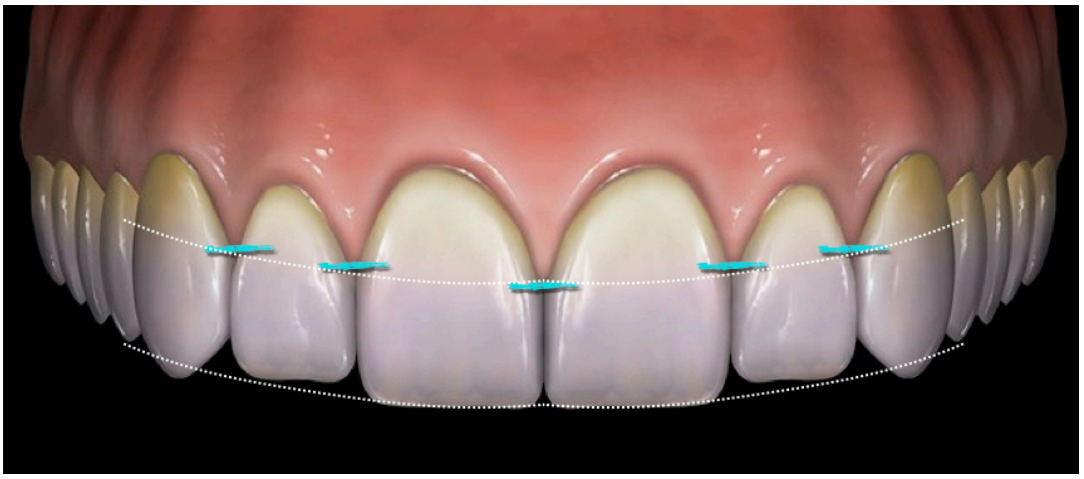


Figure 336. Ideal position of interdental papillae. From Fradeani M.[9]

13.2.1.3.Gingival contour zenith

The zenith is the most apical point of the gingival contour and, in maxillary teeth, is usually located distal to the tooth axis.

If the zeniths are not in their ideal position, especially in the maxillary central incisors, orthodontic or surgical correction should be considered before embarking on restorative treatment to obtain ideal harmony[9].

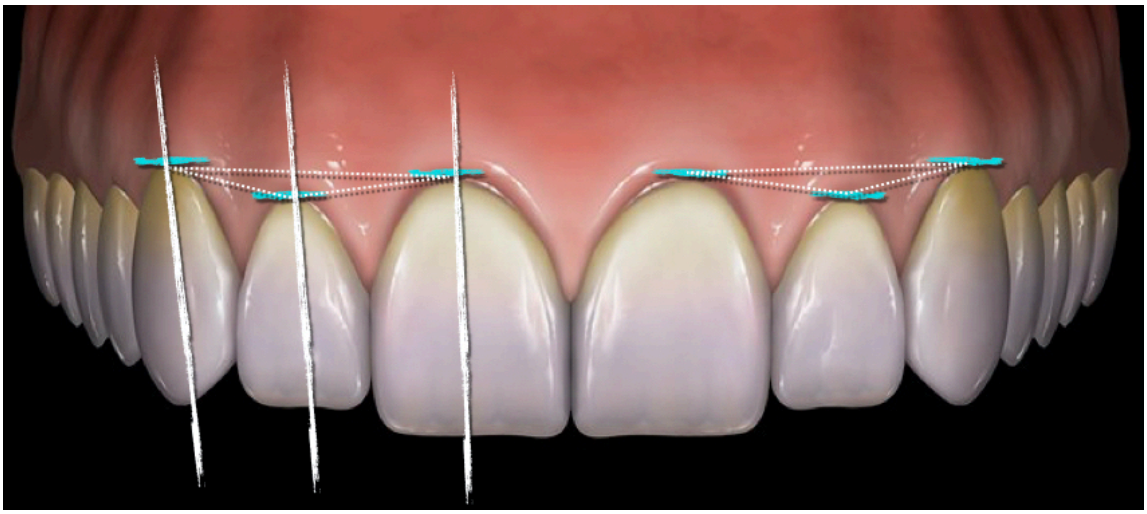


Figure 337. Ideal position of gingival zeniths. From Fradeani M.[9]

13.2.1.4.Balance of the margins

The contour of the gingival margins should be parallel to the incisal line and retain its reference to the horizontal lines of the face. In addition, a proper scalloped design should be visible, which is drawn cervically from the correct position of the gingival zenith and interproximally from the interdental papillae.

Parallelism. Ideally, the contour of the gingival margin is outlined by the cervical level of the canines and the maxillary central incisors, which should be parallel to the incisal edge and the curvature of the lower lip.

Symmetry. The margins of the maxillary central incisors and canines should be symmetrical and in a more apical position compared to the lateral incisors[9].

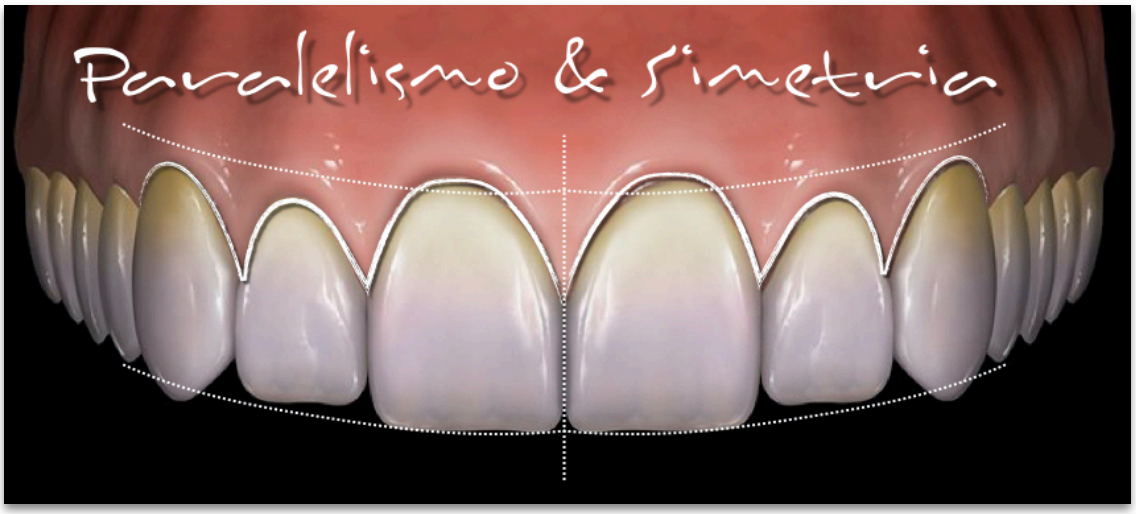


Figure 338. Parallelism and symmetry of gingival margins. From Fradeani M.[9]

13.3. Periodontal biological width

The biological width is defined as the dimension of the space that the tissues occupy over the alveolar bone. It is worth highlighting that in the average human being the connective tissue attachment occupies 1.07mm of space above the alveolar bone and that the junctional epithelium, below the base of the gingival sulcus, occupies 0.97mm[127].

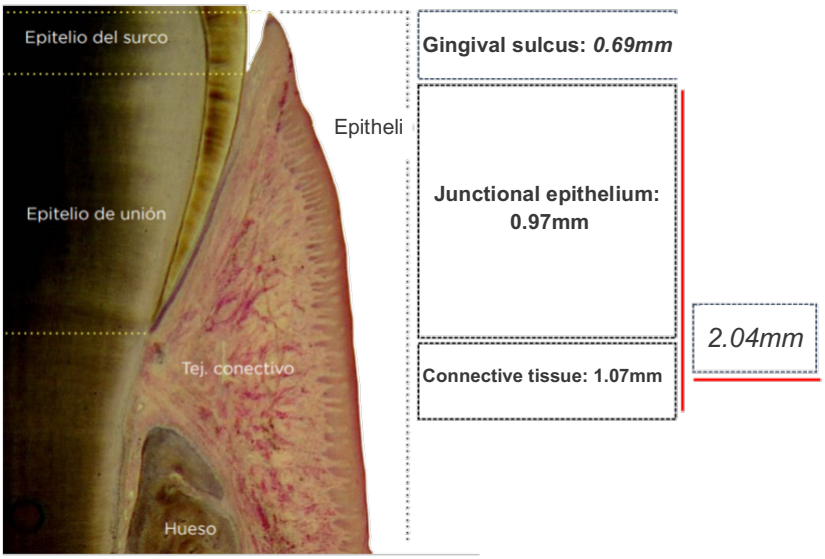


Figure 339. Biological width components. From Lindhe[127], modified by Hurtado A.

These two measurements constitute the biological width.

Gingival sulcus measurements may vary from patient to patient, with variations ranging from 0.69mm to 4.3mm. For this reason, the respective measurements should be determined for each patient in order to establish the location of the margins of the restorations[126,127].

13.3.1.Factors determining the aggression to the biological width

13.3.1.1.Finishing line:

The main characteristics of the finishing line in the restorations are related to:

1. Sharpness, with easy-to-observe grinding.
2. It must follow the contour of the gingiva. Do not involve the interdental papilla space, the gingival sulcus or the junctional epithelium.



Figure 340. Margins of tooth preparations respecting the biological width. Made by Carmona JJ.

The **subgingival location** of the margins constitutes a biological risk for periodontal tissues due to the difficulty of access for the final polishing of the restoration, and to the invasion of the biological width due to the location below the gingival ridge.

This invasion affects the gingival tissues causing two different reactions:

a) A bone loss with recession of the gingival margin, seeking to create a new space between the alveolar bone and the margin in order to make room for tissue reinsertion – this situation usually occurs when the bone surrounding the tooth is very thin and the recession takes place as a response to the trauma caused by the restorative technique. In this respect the gingival phenotype most susceptible to recession is the very scalloped and thin gingiva.

b) The bone height remains unchanged, but persistent gingival inflammation sets in.

Restorations with **supragingival margins** cause minimal injury to the periodontium as they are easier to prepare without traumatizing the soft tissues. They can be easily polished and kept free of plaque, facilitating impression taking and evaluation of the restoration at follow-up care[126,128].



Figure 341. Combination of endodontic and restorative treatment. Made by Carmona JJ.

13.3.1.2.Impressions: 'gingival separation'

Gingival separation can be achieved by mechanical, physico-chemical, electrosurgical and rotary methods. The aim is to laterally displace the soft tissue to allow access and provide sufficient thickness for the impression material. Each method has its advantages and disadvantages, as well as its risks for the periodontal tissues. Incorrect handling of the impression material and tissue displacement can damage the periodontium and cause irreversible damage.

The gingival tissue must be displaced very carefully with the physical or physico-chemical method in order to avoid irreparable damage. The retractor wire can be placed dry but must be moistened in situ before removal to prevent it from adhering to the internal sulcus epithelium and tearing the sulcus.



Figure 342. Preparations with the retractor wire in place. Made by Carmona JJ.

There is a wide variety of impression materials available today, each with advantages, disadvantages and indications. However, proper handling and evaluation in impression taking will ensure the health of the periodontal tissues. Evaluation of the gingival sulcus after impression taking is recommended in order to inspect the gingival sulcus for cleanliness of impression material residues.

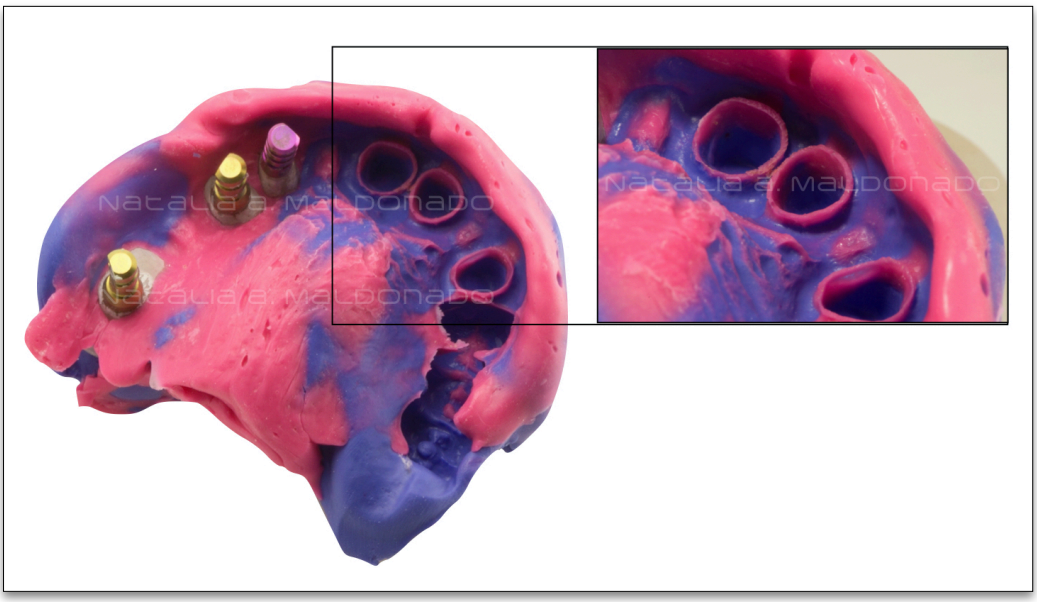


Figure 343. Silicone impressions of implants copying the emergence profile and tooth details. Made by Carmona JJ.

13.3.1.3. Temporary restorations:

To preserve periodontal health, the provisional restoration should have an adequate marginal fit, proper shape and a smooth, well-polished surface. This favours the removal of plaque, the primary aetiological factor of gingival inflammation; likewise, if the biological space is invaded by apical overextensions, an area of ischaemia is likely to appear which, if not corrected, can lead to inflammation, retraction and even necrosis. In fixed prostheses, inflamed and haemorrhagic gingival tissues hinder restorative procedures such as impression taking and cementing. In this regard, it is essential to ensure that no acrylic resin or temporary cement residue remains in the gingival sulcus.

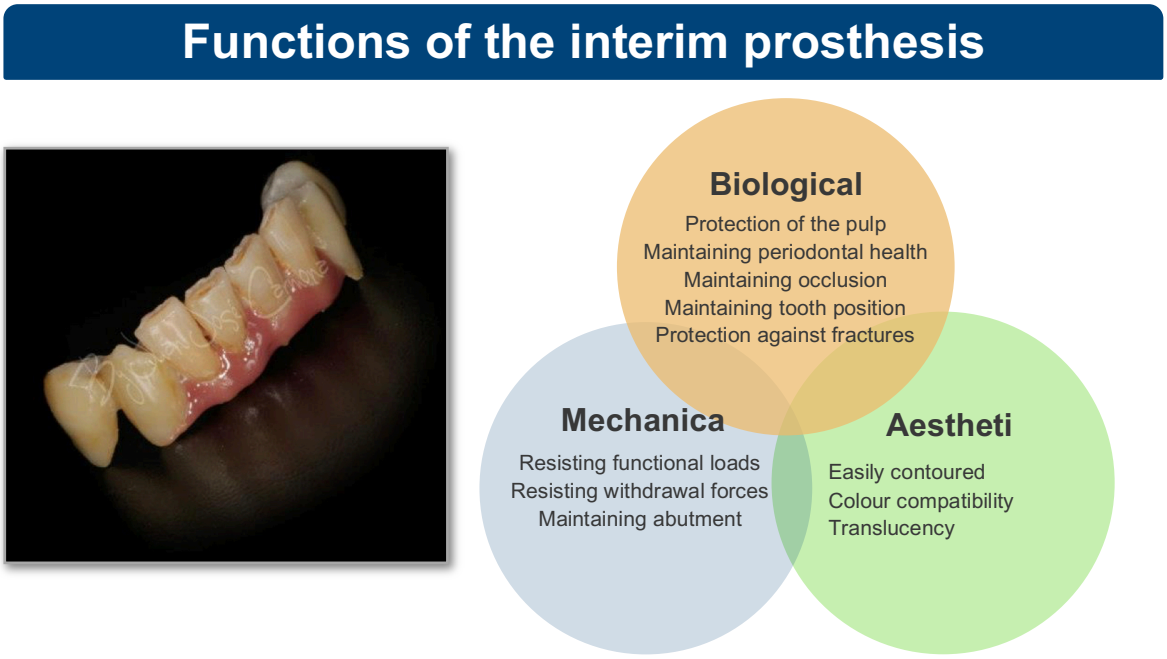


Figure 344. Functions of the interim prosthesis. Made by Carmona JJ.

13.3.1.4. Restoration design:

In terms of restoration design, two aspects of particular importance must be considered: the **contour and the contact point**.

1. CONTOUR:

The harmony observed in natural teeth and healthy periodontium is impossible to reproduce perfectly with dental prostheses, but it is possible to come close if the necessary knowledge is available to achieve a good fit, shape and contour.

Various classifications of crown contours have been proposed and, even today, Wheeler's classification[116] is the most widely used. The vestibular curvature of the natural tooth was studied and the importance of this curvature as protection and stimulation for the gingival margin during mastication processes was understood, thus establishing 3 categories: regular, undercontour and overcontour.

When an undercontour is shaped, the food hits directly on the gingival margin causing damage whereas, in the overcontour it is not possible to achieve mechanical stimulation and the retention of plaque is favoured, with the consequent gingival inflammation. Nonetheless, this classification of normal contour reproduction is possible to achieve when there is harmony between gingiva and tooth. However, when there is a long clinical crown due to bone loss and gingival recession, the situation changes and a slight undercontour is suggested, which favours self-cleaning and provides better access to plaque removal[129].

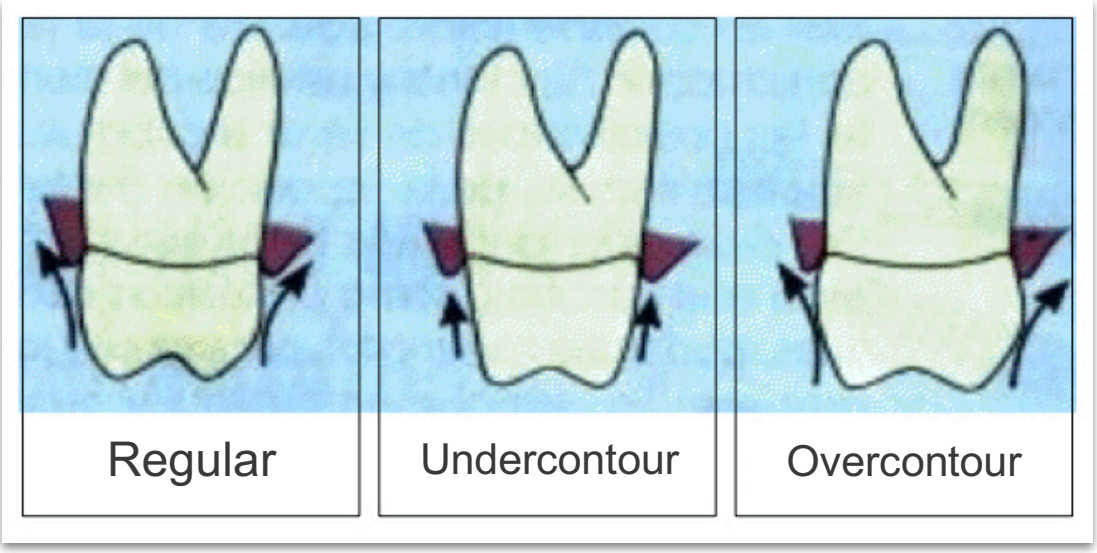


Figure 345. Wheeler classification. From Wheeler RC.[129]

2. CONTACT POINTS:

Another aspect to consider regarding the contour of the crown is the interdental space. When periodontal health exists, the interproximal spaces are occupied by bone tissue and vestibular and lingual soft tissue, joined by a concave portion in the vestibulo-lingual direction called 'col', which is determined by the point of contact. In the case of a deep point of contact, the concavity of the col is marked, whereas, when the location of the point of contact is more coronal, the concavity of the col is less marked, meaning that the col is more pronounced at the level of the posterior teeth. Additionally, it should be noted that the degree of keratinisation of this surface is inversely proportional to the width and height of the interproximal spaces[130].

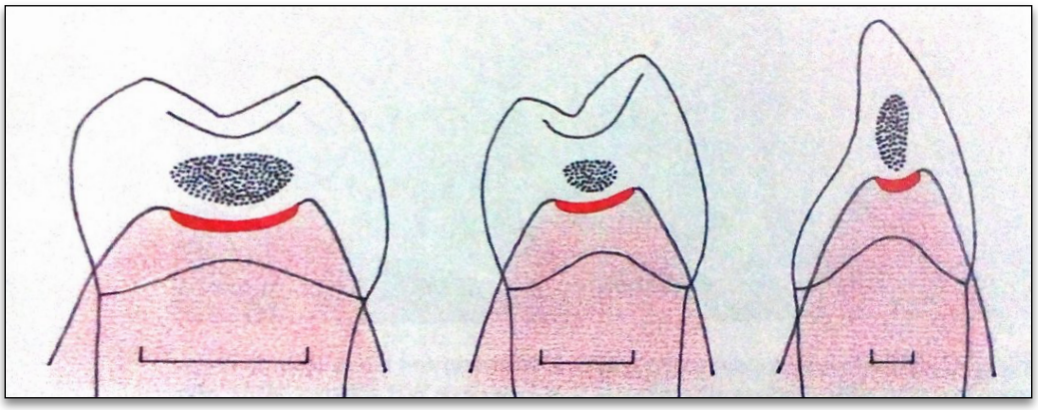


Figure 346. Schematic representation of the col. Taken from KH, EM Rateitschak.[130]

The triangular-shaped, concave interproximal niches, which in healthy dentition are occupied by the interdental papilla, are located around the contact point. The vestibular niche is shallower than the lingual niche and the papilla is more elongated in the anterior teeth and quadrangular in the posterior teeth. The niches house the papillary gingiva, which is very susceptible to bacterial attack, not only because it is an area of difficult hygiene, but also because of the presence of a stratified squamous epithelium with few cell layers and lack of keratinisation. It is important to ensure that they are properly present as, if the papilla is altered, it may be due to an incorrect gingival margin, an exaggerated proximal contour and generally very small niches.

13.4. Periodontal phenotype



Figure 347. Detail of anterior teeth profile. Made by Carmona JJ.

The periodontal phenotype is the thickness of the gingival margin.

The categorisation of the phenotype of the periodontium or soft tissues is one of the keys to success in periodontology, implantology and restoration because it provides a better understanding of how periodontal pathologies evolve in different situations. Depending on the differences in phenotypic behaviour, therapeutic manoeuvres need to be individualised to improve outcomes[126].

Two types of tissue pattern are defined: thin/scalloped and thick/straight. Table 10 compares **clinical parameters for categorisation of tissue phenotypes**[126]:



Figure 348. Thick biotype vs thin phenotype. Made by Carmona JJ.

Table 10. Differences between thin and thick phenotypes.

Thick and straight	Thin and scalloped
Dense, fibrous soft tissue	Thin, soft tissue
Broad band of keratinised tissue	Reduced band of keratinised tissue
Short and wide papillae	Long and narrow papillae
Loss of attachment associated with the presence of a periodontal pocket	Loss of attachment associated with the presence of gingival margin recession.
Contact area in mid/cervical thirds	Contact point in incisal/occlusal third
Square-shaped teeth	Triangular shaped teeth
Flat and thick underlying bone	Thin scalloped underlying bone

Note. Differences between thick periodontal phenotype and thin periodontal phenotype. Taken from Carvalho PF.[126]

Although the presence of these two types of tissue phenotypes is well established, it is common to examine patients who present features of both tissue phenotypes together. This means that they do not fit into any of the categories. A subjective but efficient criterion is the use of the millimetre probe inside the gingival sulcus. Thinner tissue patterns tend to have a shallower probing depth and the gingiva is transparent, while the probing depth of thicker patterns is greater, and the gingival colour is not altered[126].

13.5. Clinical situations: Gingival smile and recessions

13.5.1. Gingival smile

When smiling spontaneously, the position of the lower border of the upper lip delineates three distinct instances of tooth and gingival tissue exposure: low, average and high smile[9,126].



Figure 349. Smile classification according to dental and gingival exposure. From Fradeani M.[9]

It is important to differentiate between two terms that are often confused: gingival or gummy smile and high smile. All patients who have a gummy smile have a high smile line, but the opposite is not true, as a gummy smile is considered to be when the gingival exposure is greater than 3mm.

There is now consensus on the multifactorial origin of the aetiology of the gummy smile. This is why an interdisciplinary approach is needed, encompassing diagnosis as well as treatment planning, communication and implementation.

A diagnostic protocol has been established which involves determining the aetiology of the gingival smile in order to place it in the context of orofacial aesthetics, while identifying a limited range of therapeutic solutions that address both the aesthetic objectives and the restorative and functional needs of each case. Such a protocol consists of 4 steps[131]:

1- Facial assessment and definition of a priori objectives:

Prior to diagnostic records, communication and conversation with the patient for first contact with orofacial aesthetics and smile (video recording with frontal and oblique planes), assess muscular dynamics of the upper lip and facial expressiveness. Use this conversation to determine the patient's initial complexity, expectations and understanding of the case.

2- *Aetiological diagnosis of the gingival smile:*

Analyse all possible aetiological causes following the protocol described by Robbins in 1999 and modified by Juan Flores and Ignacio Sanz[131] in 2022:

Vertical excess of the maxilla

Presumptive diagnosis by Rule of Thirds. In a resting position, draw horizontal lines across the glabella, subnasal and soft chin defining the middle and lower facial thirds. If the lower facial third is increased in relation to the middle, you can provisionally assume a vertical excess of the maxilla (high probability). To do this, take a frontal photograph of the face resting as the only record. Draw a vertical line on the FM (facial midline) and assess the facial symmetry of the patient.

Dentoalveolar extrusion

Presumptive diagnosis by observing the gingival margins of anterosuperior teeth migrated coronally with respect to the posterior teeth. This is also indicative in the presence of wear of the upper incisal edges or overlapping of the upper incisal edges with the lower lip. Confirmatory diagnosis by cephalometric analysis (orthodontic treatment and/or orthognathic surgery necessary).

Upper lip hypermobility or muscle hyperfunctioning

Measured the displacement of the lower edge of the upper lip between rest and maximum smile. The norm is 6-8 mm in young women. If this range is exceeded the upper lip is considered to be hypermobile. The possibilities for aesthetic improvement offered by the treatment (ability to modulate its displacement and modify the gingival exposure in the smile and/or the presence of aesthetically improvable lip characteristics such as thickness or shape) will be the main consideration. In these cases, there are different treatment options: plastic procedures such as the implantation of silicone in the vestibule or respective procedures of the muscles that move the upper lip with Botox and hyaluronic acid.

Short lip

Measure the height of the upper lip at rest at midline level from vermilion to lower edge. The norm is 22-24 mm in young women. There are currently no effective and predictable long-term treatments.

Altered Passive Eruption (APE)

Determine the degree of overlap between the gingiva and the anatomical crown of the anterosuperior teeth (correlated with the patient's age), the classification of which will be detailed later. Pay attention to the scope for improvement offered by the treatment (tooth shape, size and proportion, gingival exposure and scalloping, as well as visible gingival prominence in the smile).

3- *Aesthetic smile diagnosis:*

After the aetiological analysis, assess the aesthetics of the smile and the restorative, functional and health needs. For this purpose, record and analyse 3 parameters:

Gingival margins

Evaluate scalloping, surface texture, colour, symmetry, parallelism with upper lip border and smile level, which together with the lip line determines gingival exposure.

Dental sizes and proportions

This allows you to evaluate its adequacy to the aesthetic framework and the margin for improvement, as well as its biological and economic cost.

Incisal edges

Assess their integrity, symmetry, optical properties and their level with respect to the curve of the lower lip in a smile, which should ideally lie parallel to these edges without obscuring them.

4- *Assessment of treatment options and definition of the treatment plan:*

Once the diagnosis has been made, an overall view is obtained that facilitates the identification of synergies between different techniques and disciplines, with the aim of defining and planning a treatment with which to achieve the established objectives, thus ensuring predictable results in the long term.

As previously mentioned, the intervention of a dentist/periodontist is required in the treatment of a gummy smile in situations of **altered passive eruption (APE)**. In these cases, facial proportions and lip length and mobility are normal. However, there is a large gingival exposure accompanied by short clinical crowns. Tooth eruption, determined by the eruption of the crown from the bony crypt, is considered

complete when the teeth reach the occlusal plane and come into function (active eruption). Associated with the eruption of the tooth, the soft tissues accompany this movement towards the end of this process and, subsequently, the gingiva migrates apically until it is located near the cementoenamel junction (passive eruption). When the gingiva does not return to its original position, it is called altered passive eruption. This can be classified according to the amount of keratinised gingiva and further subclassified according to the distance between the cementoenamel junction (CEJ) and the alveolar osseous ridge (AOR)[126].

- **APE classification:**

Table 11. Classification pf Passive Altered Eruption

Type 1	There is a broad band of keratinised gingiva.
Type 2	There is a limited band of keratinised gingiva.
Subgroup A	The AOR is located apically in relation to the CEJ at least 1.5mm, so that it is sufficient for adaptation of the conjunctival insertion.
Subgroup B	The distance between AOR and CEJ is less than 1mm, therefore insufficient for conjunctival adaptation.

Note. APE classification into Types 1 and 2 according to the presence or absence of keratinised gingiva, and subgroups A and B according to the location of the bone crest with respect to the cementoenamel junction. From Carvalho PF.[126]



Figure 350. Frontal smile analysis. Patient with APE. Made by Carmona JJ. Taken from Ferrando A.

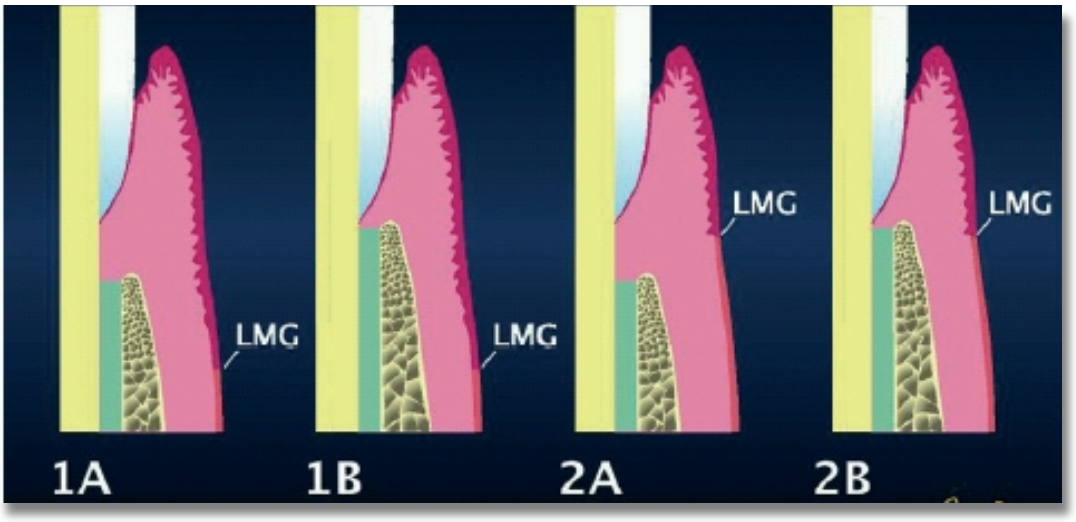


Figure 351. APE classification. Taken from Carvalho PF.[126]

The amount of keratinised tissue determines the type of incision, which determines whether or not it is possible to remove part of the keratinised tissue. The distance between the CEJ and the AOR defines the need for osteotomy/osteoplasty.

When there is abundant keratinised tissue in height, an internal bevel incision is made and then a 'ring' of tissue is removed. At least 3mm of keratinised tissue should be preserved. When no keratinised tissue is available, the intrasulcular incision should be made as well as a flap displaced to the apical[126].

Following transgingival bone probing, a millimetre probe should be used through the sulcus until contact is made with the bony ridge. If the distance between the gingival margin and the AOR is less than 1.5-2mm, a bone remodelling is indicated. Otherwise, this procedure is unnecessary[126].

The planning of all cases of aesthetic clinical crown augmentation should take into account whether or not prosthetic rehabilitation will also take place. In cases involving veneers or caps, the determination of the future position of the prosthetic margin will determine the need for a periodontal study to assess the amount of keratinised gingiva remaining on the future restoration and the need for bone remodelling.

The healing time necessary for the maturation of the soft tissues with formation of the gingival sulcus and dimensional stability of the gingival margin must be respected before the definitive dental milling is done. This time varies from 3 to 6 months, and can be up to a year, depending on the extent of the periodontal procedure[126].

In **cases of compound aetiology**, a multidisciplinary approach must often be adopted, and each of the aetiological factors present in the context of the clinical case and the steps of the treatment plan must be weighed individually to achieve a successful outcome.

- **Treatment options for gingival smiles:**

Table 12. Therapeutic options in cases of gummy smile

Clinical situation	Treatment options
APE type 1A	Gingivectomy; incision with internal bevel.
APE type 1B	Apically displaced flap with bone resection, associated with the internal bevel incision.
APE type 2A	Apical displaced flap without bone resection, associated with intrasulcular incision.
APE type 2B	Apically displaced flap with bone resection, associated with the intrasulcular incision.
Maxillary vertical excess grade 1 (2-4mm of visible gingiva)	Orthodontic intrusion. Orthodontics and periodontics. Periodontics and aesthetic restorative dentistry.
Maxillary vertical excess grade 2 (4-8mm of visible gingiva)	Periodontics and aesthetic restorative dentistry. Orthognathic surgery (the choice depends on the amount of root remnant covered by bone and crown-root ratio).
Maxillary vertical excess grade 3 (>8mm of visible gingiva)	Orthognathic surgery with or without additional periodontal surgery and aesthetic restorative treatment.
Short lip	Plastic surgery to lengthen the upper lip.
Hyperactive lip	Silicone implantation. Infiltration of hyaluronic acid and/or Botox. Myectomy.

Note. Treatment of gummy smile according to the aetiological cause. Multidisciplinary approach needed in most cases. Taken from Carvalho PF.[126]

- **Compensatory eruption due to wear and tear:**

An understanding of tooth eruption in its different phases becomes essential in order to have an adequate criterion when treating the alterations produced by its evolution. Gottlieb and Orban[126] theorised on the concept of 'continuous eruption', which they defined as the continuous occlusal movement of the teeth throughout life, without stopping at the contact of the antagonist tooth.

In patients with loss of tooth structure due to erosion or attrition, active eruption continues to occur for contact with the antagonist teeth, with the ideal position of the gingival margin being altered. When rehabilitating these patients, the same periodontal criteria that were considered for the APE should be applied[126].

Before proceeding with dental preparation and restoration of the teeth to their ideal position, an analysis should be made of the need for periodontal surgery to position the bone and gingiva at the correct level.

- **CLINICAL CASE:**
  - Diagnosis and Prosthodontics: Dr Natalia Álvarez-Maldonado.
  - Surgery and Periodontics: Dr Juan José Carmona.

    Patient comes to the dental clinic for anterior front restoration:

TREATMENT PLAN

1. Waxing.
2. Reconstructions 14-23.
3. Coronary lengthening 14-22 + BOPT grinding + interim prosthesis.
4. Composite veneers 33-43.
5. Final impressions crowns 14-23 + Re-ceramization 24, 25, 16 and 17 without implants.
6. Unloading split.

*In three years, the bottom will be changed and crowns 32-42 done and disilicate veneers on 33 and 43.

Figure 352. Treatment plan established in clinical case. Made by Carmona JJ.



Figure 353. Frontal analysis and Digital Smile Design. Made by Carmona JJ.

After performing a DSD, the next treatment is decided:

In the next step of the treatment, there is an evaluation of the future restorations with the mock-up obtained from the wax-up that the laboratory has made with the specifications that were sent in the DSD. In addition, a study of the gingiva is carried out, assessing the patient's phenotype, the amount of keratinised gingiva that will remain with the new restorations, the position of the osseous ridge, the balance of the margins, new zeniths and interdental papillae. This case was diagnosed as APE type 1B.



Figure 354. Placement of Mock Up and periodontal study. Made by Carmona JJ.

Once everything is evaluated, provisional prostheses are ordered from the laboratory with the ideal measurements decided after the corrections in the mock-up and the surgery is carried out to solve the periodontal problem.

The gum surgery, bone resection, dental carving and provisional placement are all carried out during the same appointment.



Figure 355. Step by step gingivectomy, bone resection, carving and provisionalisation of the case. Made by Carmona JJ, Álvarez-Maldonado N.

After a week and a half, the stitches are removed. The maturation time of the tissues is three months, so after this time, the patient is scheduled to see the final result of the gingiva. During this time the patient is scheduled monthly for evaluation.



Figure 356. Immediate situation after surgery. Made by Carmona JJ.



Figure 357. Situation after monthly re-evaluation. Made by Carmona JJ.

The following is evaluated at the monthly check-up: gingival health, interdental papillae, zenith of the restorations and gingival margin. After the periodontal 'ok', the final prosthodontic part proceeds.



Figure 358. Final re-evaluation prior to prosthodontic rehabilitation. Made by Carmona JJ, Álvarez-Maldonado N.

13.5.2. Gingival recession

This is defined as the apical migration of the gingival margin in relation to the cementoenamel junction (CEJ) exposing the root surfaces. In addition to altering aesthetics, recessions can predispose the individual to functional problems such as tooth hypersensitivity and root caries. This situation is extremely prevalent and is observed in populations with high or low oral hygiene indices. Gingival inflammation in response to dental biofilm accumulation or mechanical trauma from brushing has been identified as one of the main aetiological factors of these lesions. The thickness of the gingival tissue has an important effect on its evolution, in addition to other risk factors that may be involved. Therefore, it seems fair to state that the formation of recessions depends on the presence of gingival inflation when there is thin tissue and bone dehiscence[128].

Classification of gingival recessions as proposed by Miller[126, 128]:



Figure 359. Classification of gingival recessions described by Miller- Taken from Zucchelli G.[128]

Table 13. Classification of gingival recessions

CLASS I	Gingival recession not extending beyond the mucogingival line. No interproximal bone loss.
CLASS II	Gingival recession that goes beyond the mucogingival line. No interproximal bone loss.
CLASS III	There is interproximal bone loss, but coronal to the extent of gingival recession.
CLASS IV	There is interproximal bone loss, but apical to the extent of gingival recession.

Note. Classification of gingival recessions according to extension to the mucogingival line and presence or absence of interproximal bone loss. Taken from Zucchelli G.[128]

A variety of techniques can be used for the lining of single and multiple recessions with different types and designs of incisions, with or without relaxing vertical incisions and with or without the use of connective tissue grafts[128].

The clinical success of the veneer is defined by:

1. The integrity of the root surface.
2. Obtaining a borehole depth of less than 3mm.
3. The absence of gingival inflammation.
4. Colour/volume of tissue compatible with adjacent areas.

The aesthetic evaluation for the treatment of gingival recessions can also be defined by scores based on the assessment of 5 features[128]:



1. Level of the gingival margin.
2. Contour of the gingival margin.
3. Margin texture.
4. Orientation of the mucogingival line.
5. Colour of the gingival margin.

Figure 360. 1.3 root coverage. Made by Carmona JJ.

Of the techniques described, the coronal displaced flap, by itself or combined with a connective tissue graft, appears to be the most commonly used procedure. The clinical decision regarding the use of connective tissue grafting is based on careful assessment of each clinical situation and seems well justified when there are carious or non-carious cervical lesions, no or little keratinised tissue and thin gingival tissue. When the tissue is thicker, the use of grafting seems unnecessary, whereas in intermediate and thin phenotypes, grafting is important to increase the gingival dimensions (gingival thickness and band of keratinised tissue).[128]

The most important aspects for the long-term stability of the veneer results are: increasing gingival thickness and the keratinised tissue band, and correcting hygienic habits, especially the brushing intensity control.

In cases of **cervical concavities caused by carious and non-carious lesions**, the root surface can be restored with different materials before coronal displacement of the flap. Regardless of the material used, the restoration must be as polished as possible and performed prior to the surgical procedure session. On the other hand, the 'biological restoration', in which the connective tissue graft is placed directly on the root surface, seems a much more appealing option. When it is difficult to identify the UAC due to the presence of cervical coronal and root lesions, the anatomical landmarks of the adjacent and contralateral teeth should be observed. In addition, the radiographic projection of the AOR should be observed to allow restorative planning of just the coronal component, and a new position of the CEJ should be established for the subsequent performance of the surgical procedure[128].



Figure 361. Step-by-step treatment of 2.4 gingival recession. Made by Carmona JJ.

According to Zucchelli[128], the treatment of cervical abrasions associated with gingival recessions depends on the position of the maximum root coverage level (MRC) in relation to the position and extent of the eroded area.

Table 14. Classification of treatment options for gingival recessions associated with cervical abrasions proposed by Zucchelli

Type	Situation	Treatment
1	MRC > 1mm coronal to the abrasion.	Replacement flap.
2	MRC <_1mm coronal to abrasion.	Repositioning flap + connective tissue graft positioned at the level of the MRC.
3	MRC located at the deepest point of the abrasion.	Coronal odontoplasty + composite restoration up to MRC + root odontoplasty + repositioning flap.
4	MRC located within the abrasion area, apically to the deepest point.	Composite restoration up to MRC + reposition flap.
5	MRC located at the same level or apical to the abrasion.	Conservative treatment with or without access flap for isolation.

Note. Treatment options for cervical abrasions associated with gingival recession according to the position of the maximum root coverage level in relation to the extent and position of the abraded tooth area. Taken from Zucchelli G.[128]

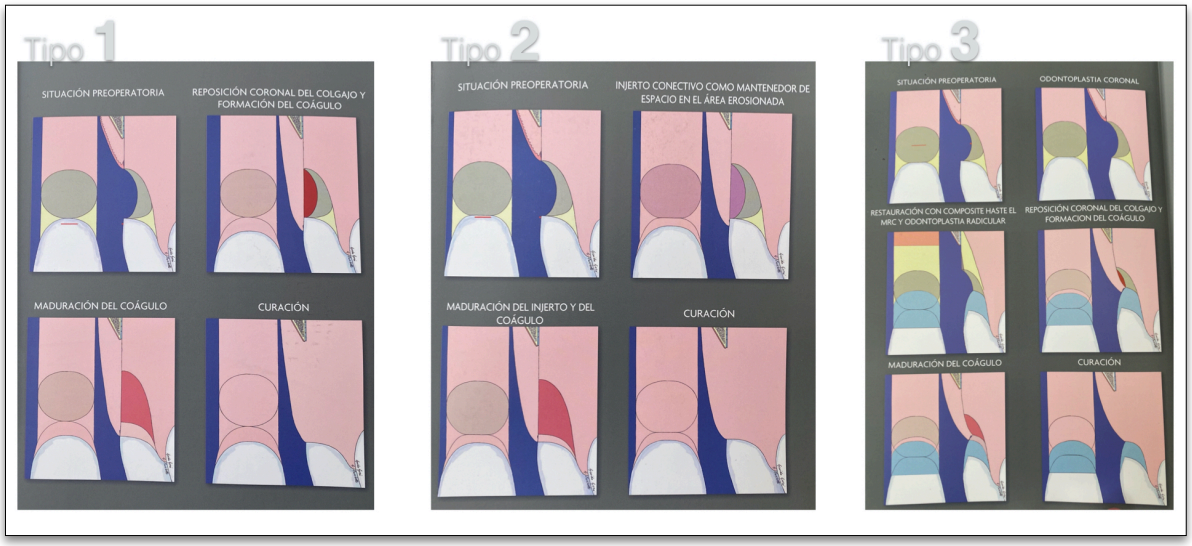


Figure 362. Graphical representation treatment types 1, 2 and 3. Taken from Zucchelli G.[128]



Figure 363. Graphical representation treatment types 4 and 5. Taken from Zucchelli G.[128]

Special thanks to Dr. Violeta Voicu for reviewing this chapter and the next one

UCAM

Chapter 14



Aesthetic restorative dentistry and Oral surgery

Photo by Dr. Herminio García Roncero

14.1.Exodontics vs Conservative dentistry

The loss or extraction of a tooth is an act/treatment that any patient hates, due to both the physical act of extraction itself, and the negative psychological connotation of losing a tooth, especially on the anterior front.

At the same time, Conservative Dentistry is one of the specialities most desired by patients, as repairing a fracture or dental pathology without having to resort to extraction is a very positive achievement in terms of the expectations of the patient.



Figure 364. Clinical crown 2.2 restoration with horizontal coronal fracture. Made by Carmona JJ.

14.2.Situations in which a tooth must be extracted:

1. Presence of advanced periodontitis with attachment loss greater than ½ of the average root length, depending on the tooth to be treated. This factor is highly variable.
2. Deep caries with furcation involvement in molars.
3. The impossibility of obtaining ferrule for the future restoration.
4. Fractures or microfractures that make the viability of the treatment impossible.
5. Endodontic failures with no further conservative treatment option.
6. Strategic extractions for orthodontic or prosthetic reasons.

14.3.Conservative approach:

The aim of dentistry today is to work towards the preservation of dental structures as long as possible, giving the option of repositioning with implants as the best option for those teeth that have already been lost or for those cases where conservative dentistry with a long treatment viability is impossible.

Lecturers in this course insist on the evolution and improvement of bonding procedures and restorative materials, which has already led to greater success in restorative dentistry treatments.

If a tooth has to be replaced, only very few dental laboratories are capable of faithfully reproducing an anterior front tooth, with the consequent aesthetic failure of the restoration. Therefore, if conservative dentistry with prosthetic restoration is required, it is not only essential to have a good dentist who follows a strict work protocol, but also a good dental technician who can achieve a mimic restoration.

14.4.Analysis of extreme situations:

When cases making you hesitate between performing an exodontia or conservative treatment appear in the dental clinic, you must resort to complementary tests which, together with the clinical visual examination and your knowledge, skill and professional ethics, will allow you to act in the correct way.

14.4.1. Root ratio

Root portion in a healthy and functional state that is left to be able to restore a tooth. The ideal crown-to-root ratio of an abutment tooth in fixed prostheses is 1/2, but the minimum acceptable ratio is 1/1.[132.133]



Figure 365. Ideal vs. minimum root ratios. Made by Carmona JJ.

'The concept of **critical mass**': volumetrically represents the ratio between the existing tissue that surrounds the tooth and acts as a support VS the total tissue that should be present. A tooth with a volume of less than 50% of critical mass will show increased mobility and would not be a good, fixed prosthetic abutment[132].

The 'root surface area', which is the area occupied by the insertion of the periodontal ligament that attaches the root to the bone, must be taken into account. The larger this surface area is, the more additional stress the restoration will be able to withstand. This area is linked to the amount of bone support, so all the necessary complementary tests must be carried out to be certain of the bone condition around the root. A periapical X-ray is recommended and, in case of doubt, a CBCT.

'ANTE's Law': the root surface or periodontal areas of the abutment teeth must be greater than or equal to that of the teeth to be replaced with pontics.

Regarding root configuration, root number, length and shape must be evaluated to determine the anchorage of the abutment to the alveolar bone. Roots that are wider

buccolingually than mesiodistally are preferable to those with a round cross-section. Divergent roots offer better periodontal support than convergent roots. Irregularly configured uniradicular teeth with some curvature in the apical third are preferable to those with almost perfect conicity.

14.4.2. Ferrule effect

To recall from chapter 12, this was commonly defined as the remaining tooth structure located above the gingival margin. However, the 'ferrule effect' is considered to be the actual reinforcement of the prosthetic restoration on the tooth structure. In other words, the protection of the tooth structure with the crown.

This clinical concept is of fundamental importance in the restoration of teeth affected by considerable loss of tooth structure. The ferrule is a major concept to consider when assessing the viability of the tooth.

There are several advantages to considering the 'ferrule effect' when restoring teeth that have little remaining tooth structure (normally their treatment will be endodontics + post + crown/inlay). Evaluation is necessary and, as the ferrule effect is non-negotiable, sufficient tooth structure must be available as this will determine the longevity of the restoration and thus the success of the restorative treatment[132-134].

- **Factors** related to the **ferrule**:

  1. **Ferrule height:**

     The ferrule height is a determining factor in the longevity of tooth restorations. The healthy tooth height has to be assessed 360° above the marginal gingiva.

     A 1mm vertical ferrule doubles the fracture resistance compared to teeth without ferrule.

     The best results have been described with a tooth structure height of 1.5-2mm.

2. Ferrule width:

The importance of the thickness of the **residual pericervical dentine** of the tooth stump must also be taken into account, as it is crucial for its contribution to the fracture resistance of the posterior restoration. This thickness must be at least 1mm.[132] Finally, it is essential to consider the total occlusal convergence (TOC) of the stump, which has already been described in the chapter on vertical preparations. As a reminder, this involves assessing the total inclination of the 2 opposite axial walls of the tooth prepared to receive a fixed crown. For example, a 10° net taper or TOC requires 3mm of vertical veneer, while a 20° TOC requires 4mm of vertical veneer.

3. Functional loading of the tooth:

One of the characteristics that distinguishes anterior teeth from posterior teeth is the direction and value of the functional load that each one receives as a result of occlusal loads.

Looking at the vector resulting from the functional load received by a tooth located in the anterior region, it has a non-axial, oblique direction, which impacts on the palatal surface of the upper teeth. It has a palato-vestibular direction, while in the lower teeth it has a reverse direction.

As you move towards the posterior sector of the arch, the direction of the occlusal load becomes perpendicular to the Frankfurt plane, resulting in a force vector with an occlusal-gingival direction.

In the case of restoring teeth with a functional compromise during excursive jaw movements, e.g., canines during lateral movements in case of canine guidance; a new force vector with a horizontal component is created during these movements, with an additional risk of damaging the restoration at the tooth-restoration interface. In fact, some authors recommend varying the occlusal model, creating a group function in the hemiarch to be treated[132].

The statements listed above correspond to an ideal occlusal pattern in the absence of malocclusions and parafunctions. Situations of overbite, reduced protrusion, interferences, presence of canine guidance, edge-to-edge occlusion or parafunctional habits should be taken into consideration when restoring lost function and aesthetics.

Root fractures are the main cause of failure in restored tooth, and they point out that the correct distribution of functional loads is an essential means of reducing their incidence[132].

- **Solutions in the absence of ferrule[132]:**

1. **Coronary lengthening:**

   This alternative aims to increase the length of the dental crown by removing the supporting periodontal structures, exposing the subgingival root surface. It is worth noting that, through this clinical procedure, it is possible to re-establish the biological width or supracrestal tissue attachment.

   If a surgical alternative is chosen, consideration should be given to aesthetic compromise, reduction of the crown-to-root ratio, loss of the interdental papilla and the potential risk of loss of support for adjacent teeth.

2. **Orthodontic traction:**

   This procedure pursues a similar aim by exerting active extrusive forces or light passive forces in order to provoke a forced eruption by means of orthodontic attachments. To further develop this technique, it is necessary to seek the advice of an orthodontist.

14.4.3. Clinical case

Patient comes to the clinic for a 3.4 tooth fracture. A clinical study of the situation and the relevant complementary tests are carried out in order to decide on a viable treatment plan. The decision is to perform a periodontal probing and a periapical X-ray.

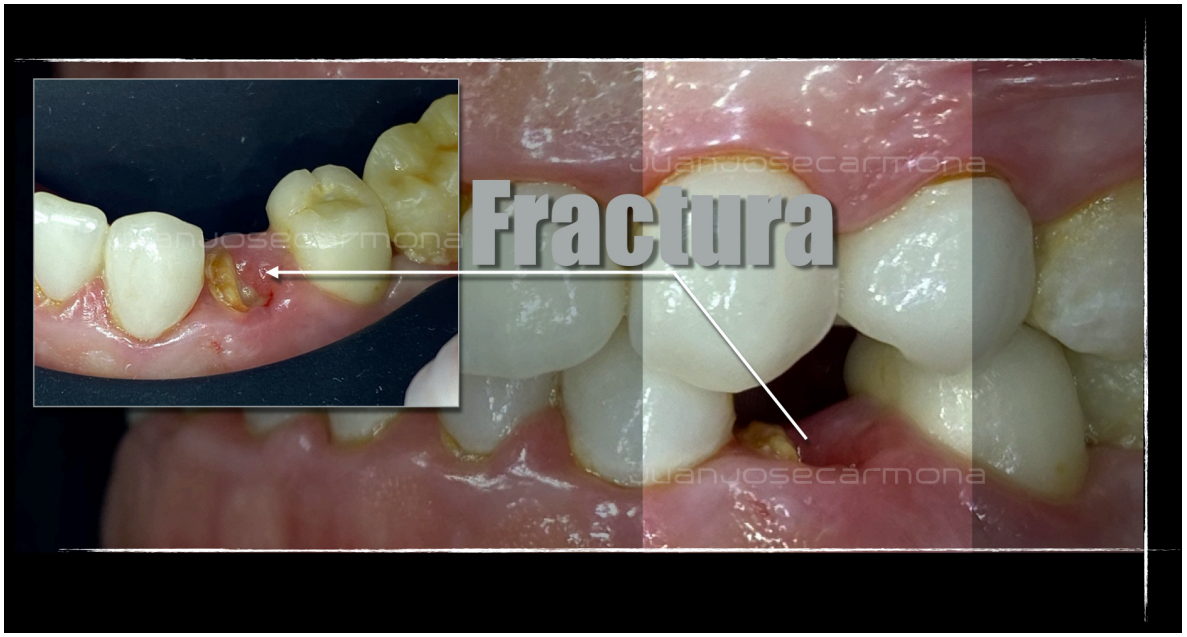


Figure 366. Clinical image of subgingival fracture in 3.4. Made by Carmona JJ.

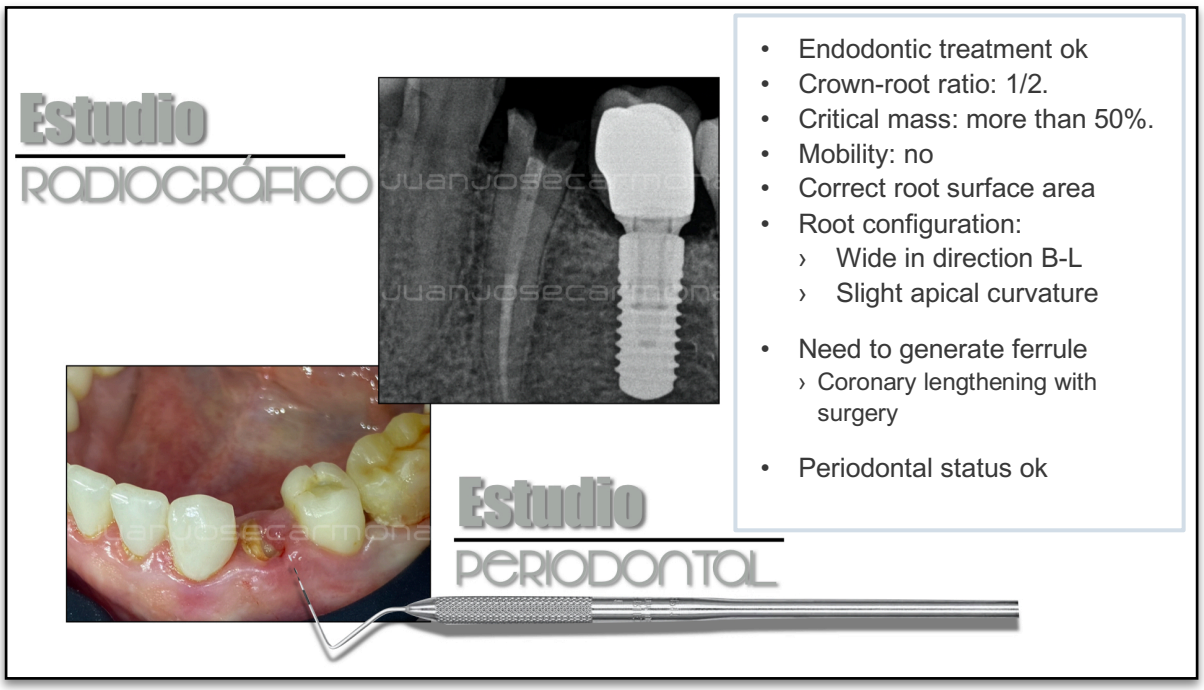


Figure 367. Periodontal and radiographic analysis of remaining tooth structure. Made by Carmona JJ.

The X-ray shows that the tooth has previously undergone endodontic treatment. It is asymptomatic with radiographic evidence of a good seal and complete canal filling. Re-endodontics is ruled out. However, the crown-root ratio is also assessed.

In the periodontal examination, the root to be restored is assessed as having no bleeding on probing and no mobility. The level of insertion of the gum and the position of the bony ridge around the tooth are assessed.

Having predicted that the root will be a good abutment to support the future restoration, coronary lengthening surgery is performed to achieve the correct ferrule.

A full-thickness flap is taken off around the tooth and the necessary osteotomy/osteoplasty is performed to obtain the correct ferrule height around 360º of the tooth. Once the surgery has been performed, sutures are stitched, and the core build-up can proceed. If the area where the surgery is performed has a thin phenotype and/or a small band of keratinised tissue, the placement of a connective tissue graft is indicated.

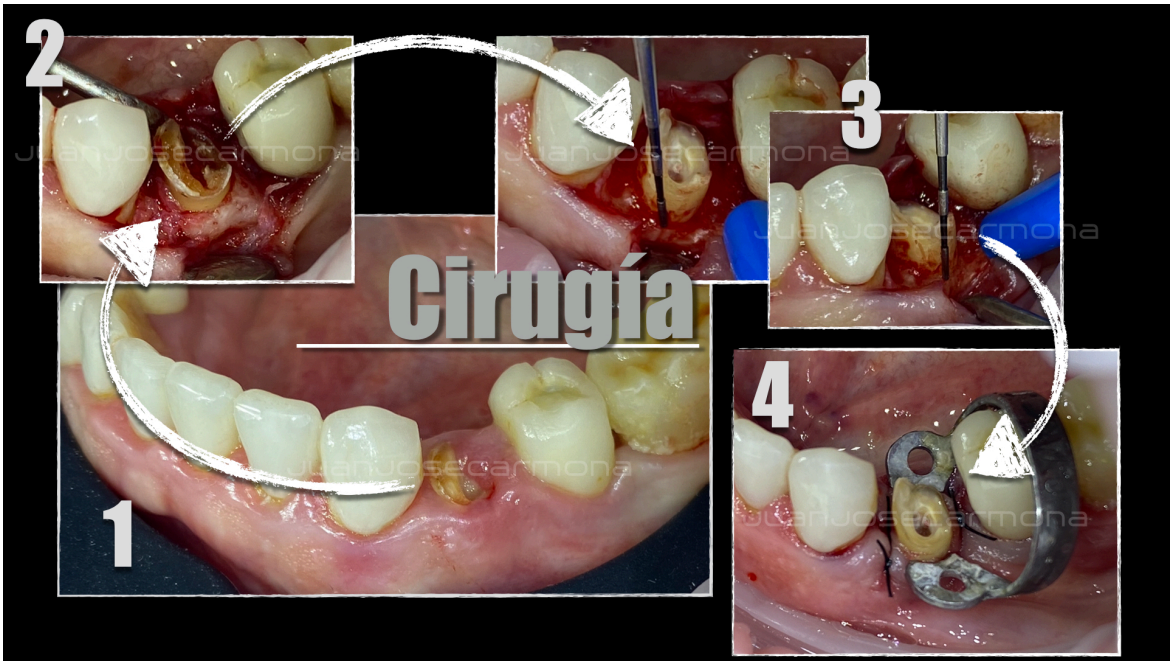


Figure 368. Full-thickness flap debonding surgery in order to perform bone resection and gain sufficient remaining tooth tissue to obtain ferrule and ensure the long-term prognosis of the final restoration. Made by Carmona JJ.

Following surgery, an absolute isolation with dike is prepared, followed by the preparation of the housing and subsequent placement of the fibre post. To do this, orthophosphoric acid is applied to prepare the surface containing enamel and to clean and disinfect the rest. Next step is the bonding protocol and the placement of the post. For cementation and subsequent core build-up it is advisable to use core build-up composite.



Figure 369. Absolute isolation with a rubber dam to avoid fluid filtration that could interfere with the bonding process (1). Acid etching of the tooth surface (2). Adhesive application (3). Placement of fibreglass post (4). Core build-up with resin (5). Made by Carmona JJ.

Dismantling of the isolation and preparation and grinding with the BOPT technique.

The provisional prosthesis is fabricated based, as always, on a digital wax-up prior to the treatment, which allows the following to be assessed: 1- aesthetic aspect (shape, texture and colour), 2- biological aspect (emergence profile and state of the gingiva) and 3- functional aspect (occlusal loads and disocclusions).



Figure 370. Tooth preparation with BOPT technique. Made by Carmona JJ.



Figure 371. Provisionalisation considering the aesthetic, biological and functional aspects. Made by Carmona JJ.

After three months of healing and stabilisation of the periodontium, measurements are taken with an intraoral scanner and sent to the dental laboratory for the manufacture of a zirconia crown.



Figure 372. Measurements are taken using digital flow with an intraoral scanner and communicated to the laboratory. Made by Carmona JJ.

Finally, the crown is placed in zirconia. To check:

1. Aesthetic aspect (shape, texture and colour).
2. Gingival area (tooth-prosthesis interface and pressure/ischemia on soft tissues).
3. Contour of the prosthesis.
4. Contact points (using dental floss).
5. Occlusion with the antagonist (occlusion and disocclusion).



Figure 373. Definitive cementation. Made by Carmona JJ.



Figure 374. Pre- and post-treatment comparison. Made by Carmona JJ.

14.5. Implants in the aesthetic zone

When tooth preservation is not possible, dental implants can be a predictable alternative with high success rates. In addition, by following well-defined surgical-prosthetic guidelines and protocols, tissue stability and proper biointegration can be achieved from an aesthetic point of view.

Anterior implant treatment has been classified as an advanced or complex procedure in the SAC classification (Dawson et al. 2009)[135].

Many patients have both a high risk of complications and a high expectation of an aesthetic result. If complications occur in these treatments, they are often difficult or impossible to resolve. Therefore, preventing these complications should be a major goal.

Chen and Buser[136] analysed the influence of the timing of implant placement and contour augmentation procedures and their effect on the aesthetic outcome. An aesthetic result can be achieved either when the implant placement is performed at the time of extraction or at a later time. It is important to apply the specific treatment protocol for each clinical situation.

Maintaining the gingival architecture after tooth extraction is essential for an optimal aesthetic result. Implant placement immediately after tooth extraction seems to be a valid treatment alternative to try to minimise the bone remodelling that follows extraction.

The clinical and radiographic requirements for immediate single tooth implant placement by an experienced clinician are:

- Intact alveolar walls.
- Vestibular cortex at least 1mm thick.
- Thick gingival phenotype.
- Absence of acute infection.
- Availability of bone apical and palatal to the socket for proper primary stability at the time of implant placement.

However, these clinical conditions are not always present in patients, so in such cases, deferred implant placement should be planned, accompanied by bone and soft tissue augmentation surgical procedures.

14.5.1. Digital planning

Correct diagnosis and careful planning play an important role in the success of implant treatment, especially in the aesthetic area.

To achieve an aesthetic treatment result, the positioning of the implant is just as important as the design of the temporary crown. The placement of a screw-retained temporary crown on the day of implant surgery aims to preserve the height and profile of the gingival margin. At this point, the design of the emergence profile plays a fundamental role in the healing of the peri-implant hard and soft tissues. Therefore, **it is the crown that will determine the ideal three-dimensional position of the implant**. Any change in implant depth, buccolingual position or platform height will directly influence the design of the emergence profile.

Current planning software allow the user to preview the three-dimensional positioning of the implant and design the screw-retained provisional crown prior to surgery by overlaying the CBCT with STL files. This information also helps diagnose hard and soft tissue defects that require further treatment.

Subsequently, with the three-dimensional position planned, a guided surgery splint can be fabricated to guide the implant placement on the day of surgery.

14.5.2. Emergence profile

Over the years, different emergence profile designs have been described for temporary cemented or screw-retained crowns, and different names have been used for the transition area between the implant platform and the gingival margin of the clinical crown.

The current trend is to create an emergence profile that respects the peri-implant hard and soft tissues and emulates the aesthetics of a natural tooth, both for immediate implants and for implants placed in healed bone.

In order to establish clear guidelines, the subgingival area needs to be divided into the deep zone, transitional zone and cervical zone[137] (in an apex-coronal direction) and, in turn, into the vestibular side, interproximal areas and palatal side.

14.5.3. Design of the emergence profile for implants in healed bone

Deep zone: in the deep zone, the main objective is to leave as much space as possible in the lateral direction for the correct adaptation of the connective tissue and crestal bone. The emergence profile of this zone should be straight or concave, with an ideal emergence angle of less than or equal to 15º. Angles of more than 45° should be avoided as they promote early bone loss.

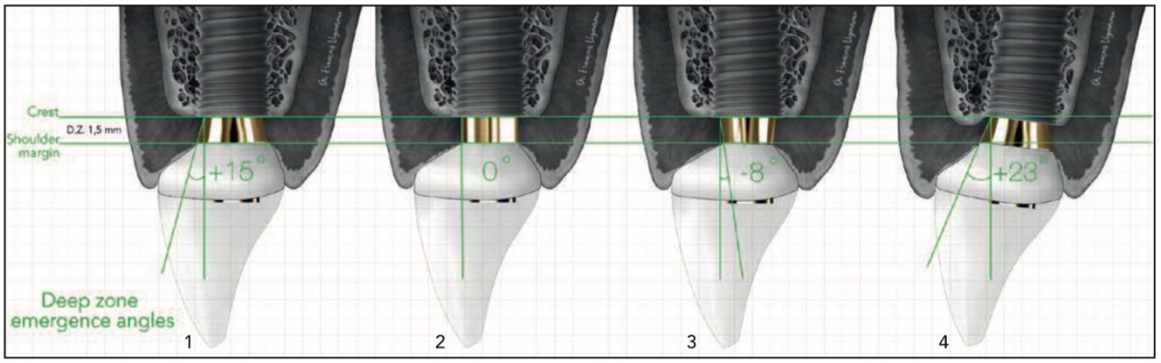


Figure 375. Lateral view of the emergence angle of the deep zone. (1) Straight profile with an emergence angle of more than 15 degrees. (2) Straight profile with an emergence angle of 0 degrees. (3) Straight profile with an emergence angle of -8 degrees. (4) The angled axis of the implant in relation to the axis of the prosthesis and to the bony ridge affects the emergence angle. Taken from Pelekanos S et al. [137]

Any change in the implant axis will directly affect the emergence angle.

Transitional zone: this zone varies greatly depending on the position of the implant platform.

- Vestibular: in cases of thick phenotype with soft tissue deficiency of the vestibular side, the design of this zone in the bucco-lingual direction would be convex, to generate a displacement of the soft tissues towards buccal. Conversely, if the phenotype is thick, but there are no tissue deficiencies, the

emergence profile design would be straight. For a thin phenotype where connective tissue grafting is performed, the ideal design would be concave.

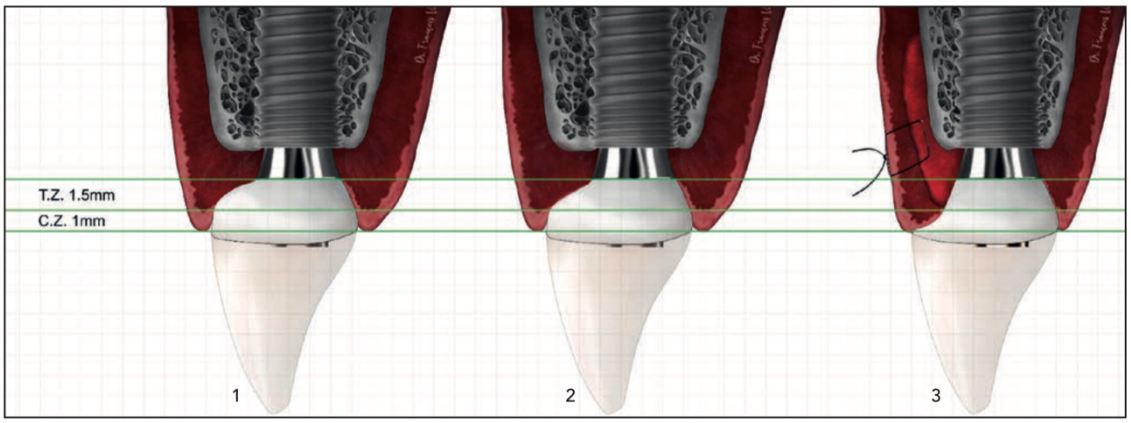


Figure 376. Lateral view of cervical and transition zone design options for implants placed in healed bone. (1) Convex. (2) Straight. (3) Concave. From Pelekanos S et al.[137]

- Interproximal: a minimum mesiodistal space of 1.5-2mm to the adjacent tooth must be respected to provide adequate support for the papillae and to allow the patient to sanitise properly. In case of papillae height loss, if more than 2-3mm is available, a slightly convex emergence profile could help the interproximal soft tissue to have a possible gain in height of up to 1mm at the papillae. In cases where this tissue deficiency does not exist, the interproximal emergence profile in the transition area would be straight or slightly concave.

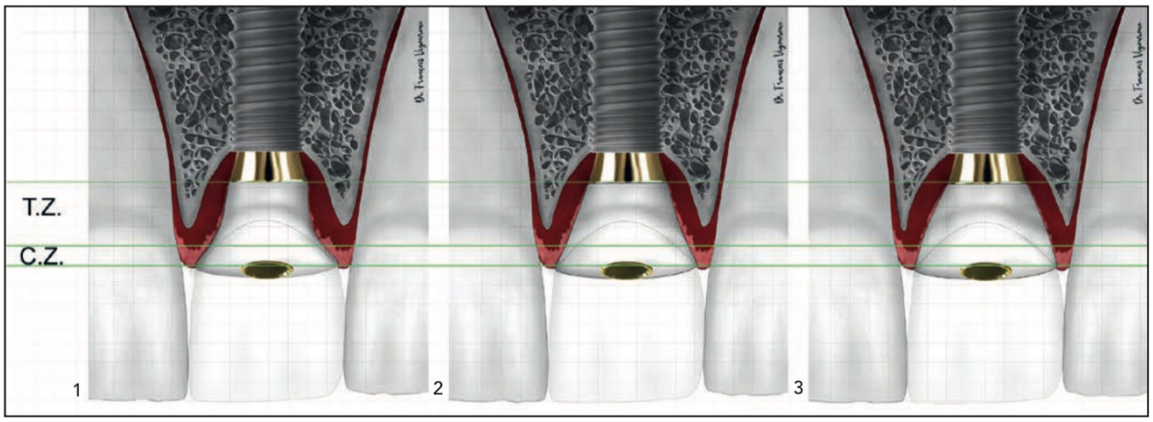


Figure 377. Proximal design of transitional and cervical zones in healed anterior sites, demonstrating the effect of critical proximal space on the final design. (1) Concave. (2) Straight. (3) Convex. Taken from Pelekanos S et al. [137]

- Palatal: at this level, the emergence design will mimic the natural tooth.

Cervical area: the shape will vary depending on the position of the gingival margin in relation to the ideal:

- Coronal position: this area of the emergence profile shall be overcontoured in a vestibule/apical direction to promote apical repositioning of the margin.
- Ideal position: the design will be similar to that of the natural tooth, with an emergence as similar as possible to the adjacent tooth to support the tissues.
- Apical position: if a coronal migration of the gingival margin is sought, the emergence design of the cervical area should be undercontoured.

14.5.4. Design of the emergence profile in immediate implants

In provisional crowns that are immediately placed after the implant placement, the emergence design is very similar to the one described above.

Deep zone: same as for implants in healed bone.

Transitional zone:

- Vestibular: the design should be as concave as possible to allow space for clot formation and bone filling materials.
- Interproximal: the design should be straight or concave, trying to leave as much space as possible for peri-implant tissues.
- Palatal: the design should be straight or concave.

Cervical area:

- Vestibular: the design should be made with a reduction of 0.5-1mm with respect to the natural tooth, in order to favour a coronal migration of the tissues in the initial phase of healing.

- Interproximal: the contour should be designed in the same way as the natural tooth, to support the papillae.
- Palatal: the contour shall be designed the same as the natural tooth.

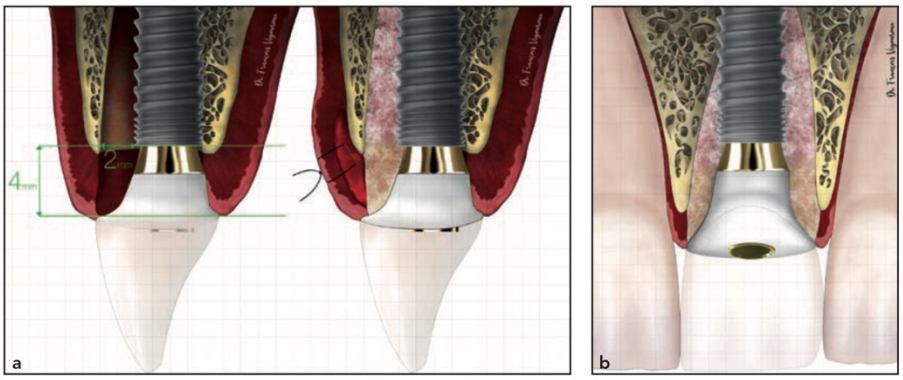


Figure 378. Lateral (a) and frontal (b) view of the design of the anatomical healing cap for immediate implants. From Pelekanos S et al. [137]

Changes in the three-dimensional position of the implant affect the design of the emergence profile, both convexity and angulation. Guided surgery facilitates prosthetically guided planning of the implant position and predictable implant placement surgery.

An implant placed too deep, too vestibular or mesiodistally in an incorrect position will condition the aesthetic result of the treatment.

While the ideal implant position is determined with the crown, there are certain generalities regarding the three-dimensional positioning of the implant[136]:

- **Apicocoronal positioning**: this depends on whether the implant is tissue-level or bone-level. In tissue-level implants, the implant shoulder should be located 2mm apical to the gingival margin. In bone-level implants, this distance is 4mm. Implants placed too deep seem to suffer vertical bone loss with subsequent soft tissue loss.
- **Vestibulo-lingual positioning**: the shoulder of the implant should be positioned 1.5-2mm palatally to the point of emergence of the future

crown. Incorrect bucco-lingual positioning can trigger bone loss or soft tissue recession.

- **Mesio-distal positioning**: the single implant must be placed in the centre of the available space. This position must respect a minimum distance of 1.5mm to an adjacent tooth or 3mm in the case of another implant. This means that for an implant with a narrow diameter (3-3.5mm) the available space in the mesiodistal direction must be at least 6mm to respect the minimum distance to adjacent teeth. The measurement should be taken at the level of the bone crest and not at the contact point. If there is a large discrepancy between the measurement at the bone level and the dental level, the patient may need orthodontic treatment before implant placement[138]:

- **Implant angulation**: the implant axis must be at least 1mm palatal to the incisal edge of the crown for the screw hole to emerge through the cingulum of the crown. If the implant has a vestibular angulation, the screw emergence will be in this part of the crown, with the negative aesthetic consequences that this entails. Nowadays, dynamic screws help correct incorrect angulations of up to 25 degrees, as long as the emergence of the screw is located in the incisal or middle third of the vestibular side. If, on the contrary, the emergence is located in the cervical third, the solution would be to make a cemented crown on a screw-retained abutment, instead of a cement-screw crown, which is considered ideal due to the clinical advantages it offers.

14.5.5. Clinical protocol

Emphasis has been placed on the importance of correct planning in these cases in order to perform the treatment in a predictable manner. These are the clinical steps to follow for the treatment of an implant in the aesthetic zone from the beginning to the placement of the final crown:

1. **Record taking**: digital planning requires the CBCT of the patient, an initial STL (or impression with silicone) and some photographs of the patient (intraoral and extraoral).



Figure 379. From left to right: CBCT, STL and photograph. From Muñoz M.

2. **Digital planning:** with all the initial records, the CBCT is overlaid with the initial and wax-up STLs in the planning software. The wax-up STL should contain the design of the provisional crown. In this step, different implant positions can be simulated until an ideal emergence profile is achieved for the provisional crown. Intermediate abutments can also be selected to preview their positioning on the computer.

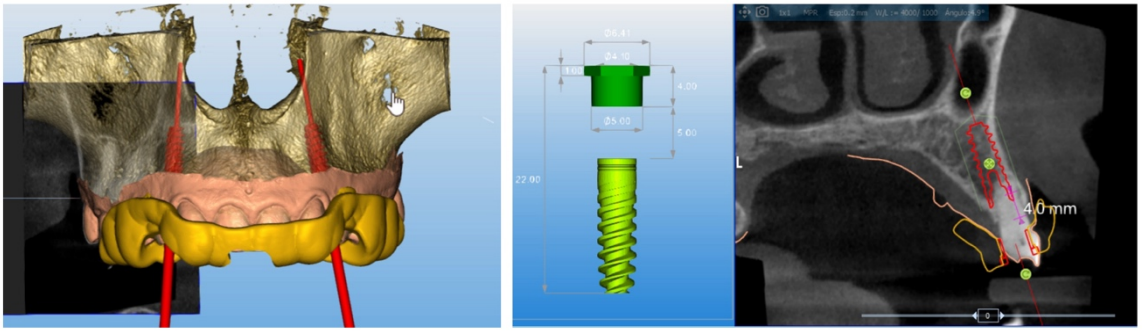


Figure 380. Planning the placement of an implant for the fabrication of a guided surgery splint. From Muñoz M.

3. **Production of guides and splints:** once the planning phase has been completed, the laboratory is asked to produce the guided surgical splint and the provisional crown. The provisional crown can be ordered to be sent finished or in the shape of an eggshell so that it can be relined in the mouth of the patient after the implant has been placed. The latter allows for variations in implant placement without having to fabricate another temporary crown.

4. **Surgery and provisionalisation:** with the help of the guided surgery splint, place the implant and then make the provisional crown (if ordered in eggshell), or place it directly if ordered as a finished crown.

5. **Final crown**: once the osseointegration period is over and the stability of the peri-implant tissues has been assessed, the impression is taken for the

manufacture of the final crown. It is essential to transfer the design of the emergence profile of the provisional crown so that the final crown is a copy of it. This transfer can be done digitally or analogically. Intraoral scanners have greatly simplified these protocols as they allow virtual copies to be made more quickly and easily than with silicone impressions. In the analogue protocol, this copy of the emergence profile would be made using the Hinds[139] technique. Nowadays, with the intraoral scanner it is possible to transfer much more information: scanning of the arch with the temporary crown in place, scanning without the temporary crown in place and scanning of the complete temporary crown out of the mouth. The transfer of the emergence profile to the laboratory is important as, from the moment the provisional crown is unscrewed until the impression/scan of the tissues is taken, the gingiva undergoes a collapse. This way, even if the collapse occurs, you know how the gingiva has healed.

14.5.6. Evaluation of the aesthetic result

The aesthetic success or failure of an implant-supported restoration must be assessed with objective and subjective parameters.

Objective aesthetic scores have been developed to evaluate the results of the treatment with respect to the peri-implant tissues (Pink Esthetic Score, PES) and the restoration (White Esthetic Score, WES)[140,141].

Furhauser's **PES** evaluates the following variables:

- Mesial papilla.
- Distal papilla.
- Curvature of the facial mucosa.
- Level of the facial mucosa.
- Root convexity / soft tissue colour and texture.

Belser's **WES** focuses on the visible part of the implant-supported crown and is based on the following parameters:

- General tooth form.
- Outline and volume of the clinical crown.
- Colour (including hue and value).
- Surface texture.
- Translucency and characterisation.

These variables are scored between 0 and 2 points each, with a total of up to 20 points.

Dentists work towards a score of 20 but several publications state that many consider a score of 12/20 to be more than acceptable in most clinical situations.

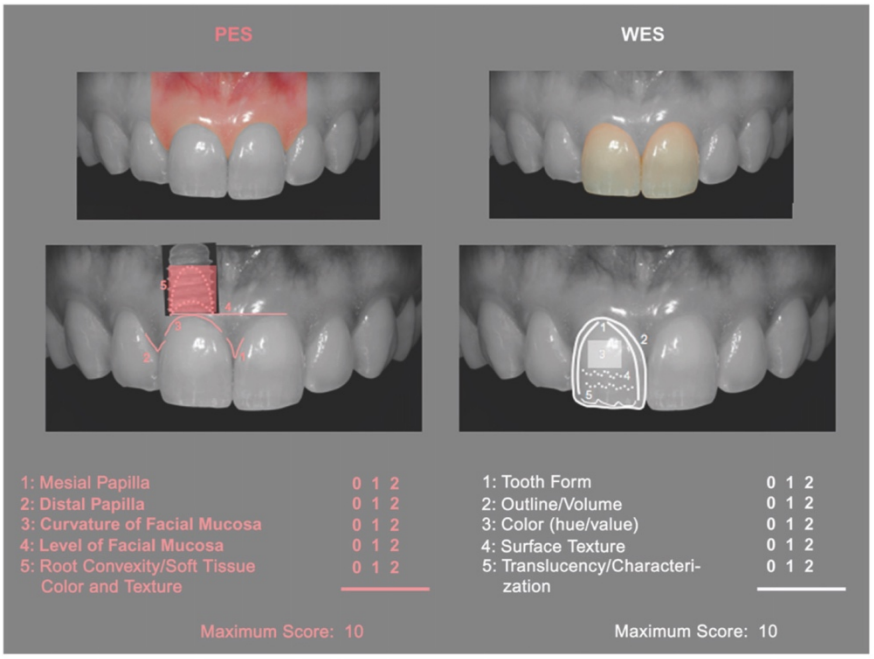


Figure 381. Guide for the use of PES/WES based on the virtual presentation of an optimal single-tooth implant restoration. From Belser UC et al.[141]

14.6. Laser in Dentistry

There are different types of lasers that can be used in dentistry. Some of them find their indications for use in different subspecialties of the dental field and the laser, as such, should be considered a tool with a transversal application in modern dentistry[142,143].

Not all lasers produce the same effects; nor does the same laser produce the same effect on different tissues and, depending on the emission parameters used, even the same laser can produce different effects on the same tissue. To be able to incorporate lasers into daily practice, the professional must know, the indications, counter-indications and method of use of the type or types of lasers to be used, among other things, before applying them in the clinic[142,143].

Lasers can be classified in multiple ways. In relation to their active medium, according to their wavelength, form of emission or other criteria. Yet, the most common way to classify them is perhaps by the power at which they are used. Thus, it is common to refer to two major groups of lasers[142,143]:

- Low power laser.
- High power laser.

Low-power lasers are mainly used for their biostimulant, analgesic and anti-inflammatory action. The most widely used are:

- As, Ga (Gallium arsenide).
- As, Ga, Al (Gallium aluminium arsenide).
- He, Ne (Helium-Neon).

High-powered lasers produce visible physical effects and are used as substitutes for cold scalpel or conventional rotary instrumentation. The high-power lasers available on the dental market are:

- Argon
- Diode
- Nd:YAG
- Nd:YAP
- Ho:YAG
- Er, Cr:YSGG
- Er:YAG
- CO_2

Table 15. Types of lasers used in dentistry

Type	Use	Precautions
Argon	Coagulation, vascular lesion surgery and photopolymerisation.	Poorly absorbed by tissues. Not widely used in surgery.
Diode	Soft tissue surgery.	Poorly absorbed at the surface. When used for cutting, a deep cumulative thermal effect is produced.
Nd:YAG	Vascular lesion surgery, soft tissue surgery, endodontics and periodontics.	Same as Diode.
Nd:YAP	Same as Nd:YAG	Same as Diode and Nd:YAG.
Er,Cr:YSGG	Cutting surgery, bone surgery, osteotomy, ostectomy. Conservative dentistry and periodontics.	Due to its low thermal effect, there is no effective coagulation.
Er:YAG	Same as Er,Cr:YSGG. Used for debonding porcelain veneers	The laser produces the least thermal effect; therefore, the bleeding is similar to that produced by the cold blade scalpel.
CO2	Soft tissue surgery. Coagulates vessels no larger than 0.5mm in diameter.	Vessels larger than 0.5mm in diameter may haemorrhage. Not to be used for hard tissues.

Note. Main indications and precautions to be taken according to the type of laser to be used in dentistry. Made by Carmona JJ.

While the use of different lasers has been described as a substitute for the scalpel, in the surgical extraction of teeth, including periapical surgery or other interventions in which an incision is made in order to elevate a mucoperiosteal flap, many authors find the incision with the conventional cold blade more precise. The scalpel acts selectively cutting the soft tissues and does not affect the hard tissues; in contrast, the laser, when it has finished cutting the soft tissues, can continue to irradiate the underlying bone, with the risk that this may imply, depending on the laser used[142,143].

When bone needs to be removed or cut, the lasers that can be used are Er,Cr:YSGG and Er:YAG. There are references that recommend the preferential use of these lasers rather than conventional rotary systems, as bone repair after surgery is quicker and there is less inflammatory response in the manipulated tissues.

After surgical extraction of included third molars, a more favourable postoperative course with less oedema and pain is observed when the entire surgical procedure has been performed with the Er, Cr:YSGG[142] laser.

In combined orthodontic-surgical treatment of included teeth, the bracket can be placed intraoperatively, conditioning the tooth enamel with Er,Cr:YSGG or Er:YAG lasers. This avoids the need to use the orthophosphoric acid gel within the operative field, thus eliminating the risk of it spreading to adjacent tissues[142].

More than one laser can be used simultaneously in periapical surgery: Er,Cr:YSGG or Er:YAG lasers for hard tissues and Nd:YAG or diode lasers to eliminate, as far as possible, pathogenic microorganisms that may exist both in the periapical area and the tooth. Low power lasers can also be used to reduce postoperative symptoms and signs. The use of the Nd:YAG laser has been proposed to vitrify the dentin in the apicoectomy area prior to retrograde filling. The retrograde obturation box is usually made with ultrasonic tips[142].

There are many clinical situations that require the removal of a buccal frenulum, whether upper labial, lower labial or lingual. In the case of the upper labial frenulum, the clinician may decide to remove it with the laser, as long as there is no compromise with the lip where it is inserted. In the case of lips with a hypoplastic or atrophic appearance, 'short' lips, or in patients with incomplete lip sealing, other techniques such as Z-plasty should be used to obtain a significant increase in the depth of the vestibular fundus, allowing the muscular structures to acquire normal functionality and appearance. Any of the surgical lasers mentioned above can be used, although the one that offers the greatest speed, and the greatest control of intraoperative bleeding is the CO_2 laser. The Er,Cr:YSGG and Er:YAG lasers, however, achieve faster healing[142].

Er:YAG laser for the removal of ceramic veneers.

The erbium:YAG (Er:YAG) laser, with a wavelength of **2940 nm**, has established itself as an ideal tool for the **conservative removal of adhesive ceramic restorations**, especially veneers. Its principle of action is based on the **high affinity of this wavelength for water and the hydroxyl groups present in the resin cement matrix**, which allows selective absorption of the laser energy at the adhesive interface[144]. In this way, the energy passes through the ceramic with

virtually no absorption, and it is the cement that undergoes softening or degradation, facilitating the removal of the restoration without compromising either the enamel or the structural integrity of the porcelain.

This approach **redefines the minimally invasive philosophy** in restorative dentistry. Traditionally, veneer removal involved mechanical methods—diamond burs, multilaminate tips, or rotary systems—which, even when performed with expertise, carried a **high risk of enamel loss and restoration fracture**.
In contrast, the use of the Er:YAG laser **minimizes these risks and preserves both the dental tissue and the possibility of reusing the removed veneer**, something unthinkable with conventional techniques.

The clinical benefits documented in recent literature include[145]:

• **Pulp safety**: intrapulpal temperature increases are minimal and remain within biologically safe margins.

• **Tissue preservation**: unnecessary wear of enamel and dentin is avoided, in line with the principles of minimal intervention.

• **Clinical efficiency**: the veneer can be removed in a matter of seconds to minutes, depending on its thickness and degree of translucency, with precise control by the operator.

• **Versatility**: it has been proven effective not only on lithium disilicate veneers, but also on zirconia restorations and CAD/CAM composites.

• **Possibility of recementation**: as the porcelain remains intact, there is the option of adjusting and reusing the restoration, which represents added value in biological, aesthetic, and economic terms.

REFERENCES

1. Gurel G. The science and art od porcelain laminate veneers. London: Quintessence; 2003.
2. Ericson D. What is minimally invasive dentistry? Oral Health Prev Dent. 2004; 1:92-287.
3. Spear FM, Kokich VG, Mathews DP. Interdisciplinary management of anterior dental esthetics. JADA. 2006; 137(2):9-106.
4. Spear FM, Kokich VG. A multidisciplinary approach to esthetic dentistry. Dent Clin N Am. 2007; 51:487-505.
5. Magne P, Belser U. Biomimetic Restorative Dentistry,Volume 1: Fundamentals and Basic Clinical Procedures. Quintessence Publishing; 2021.
6. Tonali Vazquez S. Biomimetic Study Club. Xochimilco, Ciudad de México, México [imagen]. [Citado el 1 de octubre de 2022]. Disponible en: https://www.biomimeticstudyclub.com/affiliates?. Recuperado a partir de https://www.instagram.com/biomimeticstudyclub.mexico/?hl=es.
7. Andreasen FM, Daugaard-Jensen J, Munksgaard EC. Reinforcement of bonded Crown factured incisors cith porcelain veneers. Endod Dent Traumatol. 1991; 7(2):78-83.
8. Scopin de Andrade, Borges GA, Kyrillos M. Moreira M, Calicchio L, Correr-Sobrinho L. The Area of Adhesive Continuity:A New Concept for Bonded Ceramic Restorations. QDT. 2013; 36:9-26.
9. Fradeani M. La Rehabilitación Estética en Prostodoncia Fija. vol. 1, Análisis estético. Barcelona: Quintessence Publishing Co; 2006. 352 p.
10. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Part I. Am J Orthod Dentofacial Orthop. 1993; 103(4): 299-312.
11. Powell N, Humphreys B. Proportions of the aesthetic face. [imagen]. 1984 [citado el 28 de septiembre de 2020]. Disponible en: https://aparatosbelleza.com/wp-content/uploads/2020/04/angulo-nasofrontal.jpg. Tomado de Ruiz Gaitán F.
12. Unidad de Anatomía Normal, Facultad de Ciencias de la Salud, Universidad de Talca, Chile. Tomado de Estébanez Gastón B. [imagen]. [Citado 17 de Octubre de 2011]. Disponible en: https://www.pixelmedical.es/?s=Analisis+facial.

13. Robbins JW, Rouse JS. Global Diagnosis: a new vision of Dental Diagnosis and Treatment Planning. Hanover Park: Quintessence Publishing Co; 2019.

14. Coachman C, Calamita MA, Sesma N. Dynamic Documentation of the Smile and the 2D/3D Digital Smile Design Process. Int J Periodontics Restorative Dent. 2017; 37(2):183-193.

15. Kois DE, Kois JC. Comprehensive Risk-Based Diagnostically Driven Treatment Planning: Developing Sequentially Generated Treatment. Dent Clin North Am. 2015; 59:593-608

16. Silva BP, Mahn E, Stanley K, Coachman C. The facial flow concept: An organic orofacial analysis—The vertical component. J Prosthet Dent. 2019; 121:189–94.

17. Saavedra C, Soto R, García Baeza D. LA angulación de la línea media interincisiva. Concepto de asimetría facial armónica (AFA) (Parte I). Quintessence.2015; 3(3):182-190.

18. Saavedra C, Soto R, García Baeza D. LA angulación de la línea media interincisiva. Concepto de asimetría facial armónica (AFA) (Parte II). Quintessence. 2015; 3(5):340-347.

19. Cassi D, De Biase C, Tonni I, Gandolfini M, Di Blasio A, Piancino MG. Natural position of the head: review of two-dimensional and three-dimensional methods of recording. Br J Oral Maxillofac Surg. 2016; 54:233-40.

20. Fradeani M. Evaluation of dentolabial parameters as part of a comprehensive esthetic analysis. Eur J Esthet Dent. 2006; 1:62-9.

21. Kois JC. Occlusal Vertical Dimension: Alteration Concerns. The Journal of Prosthetic Dentistry. 1994; 18(12):1169-1177.

22. Mahn E, Sampaio SS, Pereira da silva B, Stanley K, Valdés AM, Gutierrez J, y cols. Comparing the use pf static versus dynamics images to evaluate a smile. J Prosthet Dent. 2020; 123(5):739-746.

23. Atsu SS, Aka PS; Cenker H, Kilicarslan MA, Atakan C. Age-related changes in tooth enamel as measured by electron microscopy: implications for porcelain laminate veneers. J Prosthet Dent. 2005; 94(4):41-336.

24. Kokich VO; Kiyak HA, Shapiro PA. Comparing the perception of dentists and lay people to altered dental esthetics. J Esthet Dent. 1991; 11(6):24-311.

25. Paolucci B, Calamita M, Coachman C, Gürel G, Shayder MA, Hallawell CP. Visagism: The Art of Dental Composition. QDT. 2012; 35(1):1-14.

26. Rambabu T, Gayatri C, Sajjan GS, Karteek Varma PV, Srikanth V. Correlation between Dentofacial Esthetics and Mental Temperament: A Clinical Photographic Analysis Using Visagism. Contemp Clin Dent. 2018; 9:83-87.

27. Paolucci B, Calamita M. Il visagismo, l'arte di comporre i denti. Quintessenza Odontotecnica 2013; 5:28-41.

28. Editorial E. Revista Completa. BRAC [Internet]. 2 de febrero de 2017 [citado 13 de julio de 2023]; 5(1):1-129. Recuperada de https://es.wikipedia.org/wiki/Archivo:Electromagnetic_spectrum-es.svg

29. Lafuente D. Física del Color y su utilidad en Odontología. Revista Científica Odontológica. 2008; 4(1):10-5.

30. Chen H, Huang J, Dong X, Qian J, He J, Qu X, y cols. a systematic review of visual and instrumental measurements for tooth shade matching. Quintessence Int. 2012; 43(8):59-649.

31. Miyajiwala JS, Kheur MG, Patankar AH, Lakha TA. Comparison of photographic and conventional methods for tooth shade selection: A clinical evaluation. J Indian Prosthodont Soc. 2017; 17:273–281.

32. Hein S, Tapia J, Bazos P. eLABor_aid: a new approach to digital shade management. Int J esthet Dent. 2017; 12(2):186-202.

33. Chiche GJ, Pinault A. Esthetics of anterior fixed prosthodontics. 1st. Chicago, IL, USA: Quintessence Publishing; 1994.

34. Ricketts RM. The biologic significance of the divine proportion and Fibonacci series. Am J Orthodont 1982; 81:351-70.

35. Ward DH. Proportional smile design using the recurring esthetic dental (red) proportion. Dent Clin North Am. 2001; 45(1):54-143.

36. Manzano Saiz A. Valoración estética de diferentes cambios en la poporción de los dientes anteriores [Tesis Doctoral]. Valencia: Universidad de Valencia; 2015. Disponible en: http://roderic.uv.es/bitstream/handle/10550/50946/TESIS%20comp.pdf?sequence=1&isAllowed=y

37. Adolfi D. Procedimientos de Ajuste Funcionales, Estéticos y Morfológicos para Dientes Anteriores. Quintess Dent Technol; 2009.

38. Coachman Ch, Calamita MC. Digital Smile Design. A Tool for Treatment Planning and Communication in Esthetic Dentistry. Quintess Dent Technol. 2012; 35:103-111.

39. Ferrando Cascales, Á, Astudillo-Rubio D, Pascual Moscardó A, Delgado-Gaete, A. A facially driven complete-mouth rehabilitation with ultrathin CAD-CAM composite resin veneers for a patient with severe tooth wear: A minimally invasive approach. J. Prosthet. Dent. 2020; 123: 537-547.

40. Hirata R. Tips, claves en Odontología estética. Buenos Aires: Medica Panamericana; 2012.

41. Manauta J, Salat A. Layers: un atlas de estratificación de composites. Barcelona: Quintessence; 2013.

42. Opdam NJM, Van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, y cols. Longevity of posterior composite restorations: a systematic review and meta-analysis. J Dent Res. 2014; 93(10):9-943.

43. Da Costa J, Fox P, Ferracane, J. Comparison of various resin composite shades and layering technique with a shade guide. J. Esthet. Restor. Dent. 2010, 22:114–124.

44. Dietschi D, Fahl JrN. Shading concepts and layering techniques to master direct anterior composite restorations: an update. Br Dent J. 2016; 221(12): 765-771.

45. Manauta J, Salat A, Putignano A, Devoto W, Paolone G, Hardan LS. Stratification in anterior teeth using one dentine shade and a predefined thickness of enamel: a new concept in composite layering—Part I. Odontosmatol Trop. 2014; 37(146):5-16.

46. Devoto W, Saracinelli M, Manauta J. Composite in everyday practice: how to choose the right material and simplify application techniques in the anterior teeth. Eur J Esthet Dent. 2010; 5(1):24-102.

47. Jefferies SR. The art and science of abrasive finishing and polishing in restorative dentistry. Dent Clin North Am. 1998; 42(4):27-613.

48. De la Macorra JC. La adhesión. Rev Int Prótesis Estomatol. 2020; 22(3):7-8.

49. Mante FK, Ozer F, Walter R, Atlas AM, Saleh N, Dietschi D, et al. The current state of adhesive dentistry: A guide for clinical practice. Compend Contin Educ Dent. 2013; 34(9):2–8.

50. Cascales ÁF, Moscardó AP, Toledano M, Banerjee A, Sauro S. An in-vitro investigation of the bond strength of experimental ion-releasing dental adhesives to caries-affected dentine after 1 year of water storage. J I Dent. 2022; 119:104075.

51. Sattabanasuk V, Burrow MF, Shimada Y, Tagami J. Resin adhesion to caries-affected dentine after different removal methods. Aust Dent J. 2006; 51(2):162–9.

52. Ferrando Á. Evaluación “In Vitro” del comportamiento en dentina afectada por caries de un adhesivo bioactivo/biomimético experimental frente a diversos sistemas comerciales [Tesis doctoral]. Valencia, España: Universitat de València; 2020. Disponible en: https://roderic.uv.es/items/b50450c4-d7c7-4652-a990-4f292dad4195

53. Avery J. Oral Developmentand Histology. Second Edition. New York: Thieme Medical Publishers Inc; 1994.

54. Costa C. Compatibilidad dentino-pulpar de los sistemas adhesivos. Odontología clínica a fines del milenio. Argentina: Ed. Ket-von Düring; 1997.

55. Henostroza G, editor. Adhesión en odontología restauradora. 1ª ed. Brasil: Maio; 2003.

56. Camps I. La evolución de la adhesión a dentina. Av Odontoestomatol 2004; 20:11-17.

57. Toru Nikaido. In memoriam: Nobuo Nakabayashi (1936-2021). ‘’Discoverer’’ of the Hybrid Layer. J Adhesive Dent. 2022; 24(1).

58. Mancuso E, Durso D, Mazzitelli C, Maravic T, Josic U, D'alessandro C, Generali L, Checchi V, Breschi L, Mazzoni A. Glutaraldehyde-based desensitizers' influence on bonding performances and dentin enzymatic activity of universal adhesives. J Dent. 2023; 136:104643.

59. Kanka J III. A method for bonding to tooth structure using phosphoric acid as a dentin – enamel conditioner. Quintessence Int. 1991; 22(4):90-285.

60. Miguel Calvo A. Los misterios de la adhesión dentaria. ¿autograbado, grabado ácido total o selectivo? Rev Int Prótesis Estomatológica. 2020; 22:10-29.

61. Van Meerbek B, Yoshihara K, Van Landuyt K, Yoshida Y, Peumans M. From Buonocore's Pioneering Acid-Etch Technique to Self-Adhering Restoratives. A Status Perspective of Rapidly Advancing Dental Adhesive Technology. J Adhes Dent. 2020; 22:7-34.

62. Van Landuyt KL, Snauwaert J, De Munck J, Peumans M, Yoshida Y, Poitevin A, Coutinho E, Suzuki K, Lambrechts P, Van Meerbeek B. Systematic review of the chemical composition of contemporary dental adhesives. Biomaterials. 2007; 28:3757-85.

63. Ishihata H, Kanehira M, Nagai T, Finger WJ, Shimauchi H, Komatsu M. Effect of desensitizing agents on dentin permeability. Am J Dent. 2009; 22:143-6.

64. Sano H, Chowdhury AFMA, Saikaew P, Matsumoto M, Hoshika S, Yamauti M. The microtensile bond strength test: Its historical background and application to bond testing. Jpn Dent Sci Rev. 2020; 56:24-31.

65. Sezinando A. Looking for the ideal adhesive – a review. Rev port estomatol med den cir maxilofac. 2014; 55(4):194-206.

66. Feedman G, Kaver A, Afrashtehfar KI. Evolución de la adhesión dental: pasado, presente y futuro [Sede Web]. [Actualizada el 1 de septiembre de 2019]. Disponible en: https://dentistaypaciente.com/investigacion-clinica-133.html

67. Salvatore Sauro, David H. Pashley. Strategies to stabilise dentine-bonded interfaces through remineralising operative approaches – State of The Art. Int J Adhes Adhes. 2016; 69:39-57.

68. Amengual J, Forner L. Atlas terapéutico de blanqueamiento dental. 3º ed. Barcelona: Ediciones Especializadas Europeas, 2013.

69. Amengual J, Oteo J, Creagh J, Iturralde J, Giraldez I, Llambés G. Libro blanco del blanqueamiento dental. Aral; 2019.

70. Alqahtani MQ. Tooth-bleaching procedures and their controversial effects: A literature review. Saudi Dent J. 2014; 26(2):33-46.

71. Li Y, Greenwall L. safety issues of tooth whitening using peroxide-based materials. Br Dent J. 2013; 215(1):29-34.

72. Dahl JE, Pallesen U. Tooth bleaching--a critical review of the biological aspects. Crit Rev Oral Biol Med. 2003; 14(4):292-304.

73. Zimmerli B, Jeger F, Lussi A. Bleaching of nonvital teeth. A clinically relevant literature review. Schweiz Monatsschr Zahnmed. 2010; 120(4):306-320.

74. Traviglia A, Re D, de Micheli L, Bianchi AE, Corani C.Speed bleaching: the importance of temporary filling with hermetic sealing . Int J Esthet Dent. 2019; 12(3):214-228.

75. de Camargo FLL, Lancellotti AC, de Lima AF, Geraldo Martins VR, Gonçalves LS. Effects of a bleaching agent on properties of commercial glass-ionomer cements. Restor Dent Endod. 2018; 43:32.

76. Ferrando Cascales Á, Abella Sans F, Agustín-Panadero R, Amengual Lorenzo J. Multidisciplinary conservative management of a severely discolored nonvital tooth. J Prosthet Dent. 2023; S0022-3913(23):410-9.

77. Demarco F, Masotti A. Over-the-counter whitening agents: a concise review. Braz Oral Res. 2009; 23:64-70.

78. Caro Bellido A. Diccionario de términos cerámicos y de alfarería. Cádiz: Agrija Ediciones; 2008.

79. Martínez Rus F, Pradíes Ramiro G, Suárez García M, Rivera Gómez B. Cerámicas dentales: clasificación y criterios de selección. RCOE. 2007; 12: 253-63.

80. Kina S. Equilibrium: casos clínicos en cerámicas adhesivas. Editorial Médica Panamericana; 2011.

81. Mallat E. ¿Qué sistema cerámico estará indicado en cada caso? [imagen]. 2017. Disponible en: http://prosthodonticsmcm.com/que-sistema-ceramico-estara-indicado-en-cada-caso-2/

82. Peumans M, de Munck J, Fiews S, Lambrechts P, Vanherle G, Van Meerbeek B. A prospective ten-year clinical trial of porcelain veneers. J Adhes Dent. 2004; 6(1):65-76.

83. Fons-font A, Solá MF, Granell-Ruíz M, Labaig-Rueda C, Martínez-González A. Choice of ceramic for use in treatments with porcelain laminate veneers. Med Oral Patol Oral Cir Bucal. 2006; 11:297-302.

84. Mallat E, Decálogo de uso del óxido de zirconio en prótesis fija [imagen]. 2016. Disponible en: http://prosthodonticsmcm.com/decalogo-de-uso-del-oxido-de-zirconio-en-protesis-fija/

85. Sailer I, Pjetursson BE, Zwahlen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses. Clin Oral Implants Res. 2007;18 :86-96.

86. Blatz MB, Alvarez M, Sawyer K, Brindis M. How to Bond Zirconia: The APC Concept. Compend Contin Educ Dent. 2016; 37:611-617.

87. Casas Terrón J, Suárez Tuero C. Selección del material cerámico a utilizar en Odontología restauradora basada en sus propiedades. Maxillaris. 2021; 260: 10-23.

88. Nikolaenko S, Lohbauer U, Roggendorf M, Petschelt A, Dasch W, Frankenberg R. Influence of c-factor and layering technique on microtensile bond strength to dentin. Dent Mater. 2004; 20(6):85-579.

89. Teixidó, J, editor. Tratamiento del sector posterior con restauraciones independientes adhesivas CAD/CAM: Guía de uso. SEPES. Barcelona: Quintessence; 2015.

90. Dietschi D, Spreafico R. Evidence-based concepts and procedures for bonded inlays and onlays. Part I. Historical perspectives and clinical rationale for a biosubstitutive approach. In J Esthet Dent. 2015; 10(2):210-27.

91. Politano G, Fabianelli A, Papacchini F, Cerutti A. The use of bonded partial ceramic restorations to recover heavily compromised teeth. Int J Esthet Dent. 2016; 11: 314–36.

92. Holme W. Gold versus ceramic - which will last longer for posterior indirect restorations? Evid Based Dent. 2022; 23:166–7.

93. Fennis WM, Kuijs RH, Roeters FJ, Creugers NH, Kreulen CM. Randomized control trial of composite cuspal restorations: five-year results. J Dent Res. 2014; 93:36-41.

94. Barabanti N, Preti A, Vano M, Derchi G, Mangani F, Cerutti A. Indirect composite restorations luted with two different procedures: A ten years follow up clinical trial. J Clin Exp Dent. 2015; 07:54-9.

95. Magne P, Belser U. Porcelain versus composite inlays/onlays: effects of mechanical loads on stress distribution, adhesion, and crown flexure. Int J Periodontics Restorative Dent. 2003; 23:543-555.

96. Rocca G, Krejci I. Bonded indirect restorations for posterior teeth: from cavity preparation to provisionalization. Quintessence Int. 2007; 38:9-371.

97. Re D. Cerutti A, Magnani F; Putignano A. Restauri estetico-adesivi indiretti parziali nei settori posteriori. Italia: UTET; 2007.

98. Alharbi A, Rocca G, Dietschi D, Krejci I. Semidirect composite onlay with cavity sealing: a review of clinical procedures. J Esthet Dent. 2014; 26(2): 97-106.

99. Ferrando Cascales A, Dias W,Pascual Moscardó A. ¿Existe hoy espacio para la artesanía en la restauración adhesiva indirecta del sector posterior?. SCO. 2018; 11:17-22.

100. Potts RG, Shillingburg HT, Duncanson MG. Retention and resistance of preparations for cast restorations. J Prosthet Dent. 1980; 43:303-8.

101. Blair, F., Wassell, R. & Steele, J. Crowns and other extra-coronal restorations:Preparations for full veneer crowns. Br Dent J .2002; 192:561-571.

102. Touati B, Miara P, Nathanson D, Giordano R, Martins SL. Odontología estética y restauraciones cerámicas. Masson; 2000.

103. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE. Fundamentals of fixed prosthodontics. Chicago, IL, USA: Quintessence Publishing Company; 1997.

104. Fradeani M, Barducci G. Rehabilitación Estética en prostodoncia fija. Vol. 2, Tratamiento protésico. Barcelona: Quintessence Publishing Co; 2009.

105. Magne P, Belser U. Biomimetic Restorative Dentistry,Volume 2: advanced clinical techniques, maintenance, and repair of bonded restorations. Quintessence Publishing; 2021.

106. Clavijo V, Bocabella L, Schertel L, Duarte S. Reproducing Optical Properties of Anterior Teeth after Ultra-Conservative Preparation. 2016; 28:267-276.

107. LeSage B. Establishing a classification system and criteria for veneer preparations. Compend Contin Educ Dent. 2013; 34:34-117.

108. Gregg A. Porcelain Laminate Veneer Preparations: The Additive Contour Technique. Inside dent. 2009; 5.

109. Chai SY, Bennani V, Aarts JM, Lyons K. Incisal preparation design for ceramic veneers: A critical review. J Am Dent Assoc. 2018; 149:25-37.

110. Ferrando A, Pascual A, Mínguez M. Facetas de porcelana “vintage”: el retorno de la lámina de platino. SCO; 2016.

111. Agustín-Panadero R, Mallat E, Salido Rodriguez-Manzanaque MªP. Debate: ¿Preparaciones dentales horizontales o verticales? Rev Int Prótesis Estomatol. 2019; 21:31-48.

112. Paniz G, Zarow M, Nart J, Peña M, Coltro G, Tomasi C, Bressan E. Dual-Center Cross-Sectional Analysis of Periodontal Stability Around Anterior All-

Ceramic Crowns with a Feather-Edge or Chamfer Subgingival Preparation. Int J Periodontics Restorative Dent. 2020; 40:499-507.

113. Loi I, di Felice A. Biologically oriented preparation technique (BOPT): a new approach for prosthetic restoration of periodontically healthy teeth. Eur J Esthet Dent. 2013; 08:10-23.

114. DiFebo, G., Carnevale, G. and Sterrantino, S.F. Treatment of a case of advanced periodontitis: clinical procedures utilizing the" combined preparation" technique. Int J Periodontics Restorative Dent.1985; 5: 52-62.

115. Ramos R M, Clark D, Mazza M. The shoulderless approach: a new rationale in prosthetic dentistry. Tomorrow Tooth J. 2017; 1:1-29.

116. Patroni S, Chiodera G, Caliceti C, Ferrari P. CAD/CAM technology and zirconium oxide with feather-edge marginal preparation. Eur J Esthet Dent 2010; 5: 78-100

117. Loi I. Técnica B.O.P.T: Líneas generales y guía práctica. SEPES y Quintessence; 2018.

118. Agustín-Panadero R, Solá-Ruiz MF. Vertical preparation for fixed prosthesis rehabilitation in the anterior sector. J Prosthet Dent. 2015; 114(4):8-474.

119. Ferrando Cascales Á, Ferrando Cascales R, Lacal Luján J, Abella Sans F. Forced orthodontic extrusion for an apparently hopeless anterior tooth by using a simplified approach. J Prosthet Dent. 2022; 20:S0022-3913(22)00429-2.

120. Dewey K. An experimental study of tissue reactions about porcelain roots. J Dent Res. 1993; 13:459-472.

121. Serra Pastor B. Comportamiento periodontal de restauraciones de recubrimiento completo sobre preparaciones dentarias sin línea de terminación: Estudio clínico prospectivo a 6 años [Tesis doctoral]. Valencia, España: Universitat de València; 2020.

122. Gavelis JR, Morency JD, Riley ED, Sozio RB. The effect of various finish line preparations on the marginal seal and occlusal seat of full crown preparations. The Journal of prosthetic dentistry.1981; 45(2):138-45.

123. Cardoso JA, Venuti P, Almeida PJ, Costa R, Lapa HC, Afonso L. Clinical guidelines for posterior restorations based on Coverage, Adhesion, Resistance, Esthetics, and Subgingival management. Int J Esthet Dent. 2023; 18(4):346-65.

124. Imburgia M, Canale A, Cortellini D, Maneschi M, Martucci C, Valenti M. Minimally invasive vertical preparation design for ceramic veneers. Int J Esthet Dent. 2016; 11(4):460-471.

125. Ruiz-de-Gopegui J, Piedra-Cascón W, Oteo-Morilla C. Esthetic Integration Area concept to improve the emergence profile of fixed restorations: A dental technique. J Prosthet Dent. 2022; S0022-3913(22)00438-3.

126. Joly JC, de Carvalho PF, de Silva RC. Reconstrucción estética de tejidos: Procedimientos plásticos y regenerativos periodontales y periimplantarios. Editorial Médica Panamericana; 2011.

127. Lindhe Jan KT, Lang Niklaus P. Anatomía del periodonto. Periodoncia clínica e Implantología Odontológica. 4ª edición. Buenos Aires. Ed. Panamericana; 2005.

128. Zucchelli G. Cirugía estética mucogingival. Editorial Quintessence; 2020.

129. Wheeler, RC.Complete crown form and the preiodontium. J Prosthet Dent 1964; 11:722-734

130. Klaus H. Rateitschak; Herbert F. Wolf. Color atlas of Periodontology. 3º ed. Thieme Medical Pub; 2004.

131. Flores J, Sanz I. Una visión actualizada e interdisciplinar de la sonrisa gingival: protocolo de diagnóstico y planificación. Perio Clínica. 2022; 122-136.

132. Macho AZ. Importancia del ferrule en la reconstrucción del diente endodonciado. Gaceta Dental. 2012; 235: 94-100.

133. Polly SM, Nicholls JI, Junge T, Phillips KM. Load fatigue of teeth with different ferrule lengths, restored with fiber posts, composite resin cores, and all-ceramic crowns. J Prosthet Dent 2009; 102:229-234.

134. Massa F, Dias C, Bios CE. Resistence to fracture of mandibular premolars restored using post and core systems. Quintessence Int. 2010; 41:49-57.

135. Dawson A, Martin WC, Polido WD, editors. The SAC classification in implant dentistry. Quintessenz Verlag; 2022.

136. Buser D, Chappuis V, Kuchler U, Bornstein MM, Wittneben JG, Buser R, Cavusoglu Y, Belser UC. Long-term stability of early implant placement with contour augmentation. J Dent Res. 2013; 92(12):176-82.

137. Pelekanos S, Vergoullis I. Clinical Advances in Implant Transmucosal Contouring for Single Implant Sites: Prosthetic and Biologic Considerations. Int J Periodontics Restorative Dent. 2023; 43(3):301-310.

138. Sailer I, Fehmer V, Pjetursson B. Fixed Restorations A Clinical Guide to the Selection of Materials and Fabrication Technology. Quintessence Publishing 2021.

139. Hinds KF. Custom Impression coping for an exact registration of the healed tissue in the esthetic implant restoration. Int J Periodontics Restorative Dent 1997; 17(6): 584-91

140. Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. Clin Oral Implants Res. 2005; 16(6):639-44.

141. Belser UC, Grütter L, Vailati F, Bornstein MM, Weber HP, Buser D. Outcome evaluation of early placed maxillary anterior single-tooth implants using objective esthetic criteria: a cross-sectional, retrospective study in 45 patients with a 2- to 4-year follow-up using pink and white esthetic scores. J Periodontol. 2009; 80(1):140-51.

142. España-Tost AJ, Arnabat-Domínguez J, Berini-Aytés L, Gay-Escoda C. Aplicaciones del láser en Odontología. RCOE 2004; 9(5): 497-511.

143. España-Tost AJ, Sáez de la Fuente I, Arnabat-Domínguez J, Bowen Antolín A, Chémez MB, Pérez PB, de Castro GL, Rodríguez MP, Grifoll DE. Protocolos y guías de práctica clínica de Láser en Odontología. Sociedad Española de Láser y Fototerapia en Odontología [sede Web]. 2014. Disponible en: https://consejodentistas.es/wp-content/uploads/2023/05/41_Protocolos-y-guias-de-practica-clinica-de-laser-en-odontologia.pdf

144. Zhang X., Dong H., Guo C., Zhang X., Zhang D., Wu X., Zhao J. Effects of laser debonding treatment on the optical and mechanical properties of all ceramic restorations. Lasers Med. Sci. 2021; 36:1497–1504.

145. Villalobos-Tinoco J. et al. A Narrative Review and Clinical Study on Er:YAG Laser Debonding of Ceramic and Composite Veneers. Biomimetics. 2025 May 6;10(5):295.

146. Schropp Lars. Shade Matching Assisted by Digital Photography and Computer Software. J Prosthodont. 2009; 18(3):235-241.

Appendix 1 - Photography in Aesthetic Dentistry.

1.INTRODUCTION. DENTAL PHOTOGRAPHY

Photography is essential to communicate with the patient, the laboratory, and to learn from work protocols. It is the best defence against any problem with the aesthetic result of a clinical case, and it also serves to create an archive of material that can be used for educational purposes.

TAKING PHOTOS IS THE BEST WAY TO LEARN DENTISTRY.

When you compare taking colour subjectively with guides only versus taking pictures there is quite a difference.

Without photography, there is a lot of variability depending on the operator, age, lighting, or experience, so there is a lot of inaccuracy. Therefore, quantitative and instrumental methods are recommended[30].

Digital imaging and photography software outperforms subjective visual methods with colour guides only, and is the alternative to colorimeters[31].

Photography is also a realistic alternative to spectrophotometers[146] even though this method is the most reliable method for measuring colour according to the scientific literature.

2. EQUIPMENT AND PARAMETERS IN DENTAL PHOTOGRAPHY

2.1. Equipment

Digital SLR cameras, Macro 100 with stabilizer, a twin flash, and an optional small diffuser are used in aesthetic dentistry. Black contrasts, spacers and mirrors are essential. The ring flash is recommended for colour shooting, but polarised light is most highly recommended.



Figure 1.1. Photography with polarised light. Made by Ferrando A.

Polarised light is achieved with a polarising filter, and thus eliminating glare or specular reflection, thereby allowing you to delimit the dental substructure, mamelons, stains, characterisations or cracks. In short, pure colour (eLABor_aid system with grey card).

Current colorimeters with spectrophotometric technology based on polarized photos

Optishade® (https://www.smileline.ch/es/produtos/optishade-styleitaliano), is a simplified color-matching system that, according to a recent publication by Kutkut N et al. in 2024, provides reliability and accuracy values similar to other spectrophotometers. https://doi.org/10.1111/jerd.13311.

Comparison between OptiShade and VITA Easyshade.

ChatGPT. Differences between VITA Easyshade and OptiShade in dental color measurement. OpenAI; March 12, 2025. Available at: https://chat.openai.com/

Feature	VITA Easyshade	OptiShade
Device type	Digital dental colorimeter (spectrophotometric technology)	Colorimeter with spectrophotometer-based technology
Measurement technology	Measures colour in a wide spectrum of visible wavelengths and translates it into standard colour systems (VITA Classical, VITA 3D-Master, L*a*b*)	Uses reflectance spectrum–based technology and analyses RGB and L*a*b* values in real time
Accuracy	High accuracy in shade selection based on predefined libraries. **Does not display the full spectrum** or export it	Higher personalized accuracy, without relying on preset libraries
Dependence on colour libraries	Yes (VITA Classical, VITA 3D-Master)	No, allows comparison of any colour without being limited to a system
Interface and usability	Touchscreen, proprietary software	Integration with SmileCloud™ for advanced analysis and customization
Colour comparison function	Yes, based on matches with predefined shade guides	Yes, allows colour comparison with customized references or with other measurements from the same patient

- **VITA Easyshade** is ideal for those who seek a colour selection based on standard VITA guides and want a direct reference for prefabricated materials.
- **OptiShade** is more flexible and advanced in terms of analyzing the actual colour of the tooth, allowing you to customize the colour without relying on

a specific library. It is useful for those who work with advanced colour customization techniques in restorations.

2.2. Camera parameters

- **Iso**: this is the signal-to-noise ratio and has to be forced or increased in low light conditions, when the shutter speed and aperture are insufficient, resulting in more light but rather 'artificial'. In aesthetic dentistry an ISO 100-125-200 is normally used, rarely or never more than 350. Above 350-400 the 'grainy' effect increases too, and the image quality is ultimately lost.

- **Aperture:** this determines the amount of light that enters the sensor through the lens. The parameter (f) also controls the depth of field.

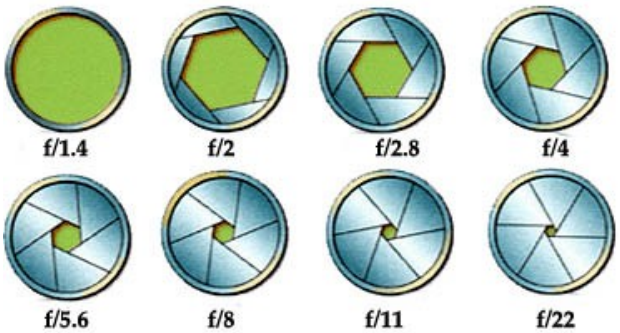


Figure 1.2. Diaphragm aperture determined by parameter *f*. Courtesy of Rubio J.



Figure 1.3. Depth of field determined by parameter *f.* Courtesy of Rubio J.



Figure 1.4. Shutter speed. Courtesy of Rubio J.

- **Shutter speed:** when working with flashes, which is common in dentistry, the speed is limited by the sync speed of each camera with its flash. The flash will always prevent the picture from being blurred. However, the exposure time can be increased by lowering the speed to get movement.

0.004 seconds 0.03 seconds 0.16 seconds

- **White balance:** this must always be set to flash and will also be edited with digital development programs.
- **Measurement**: always spot-on and in manual mode.

The position relative to the patient should always be dominant or slightly above so that the picture is straight.



Figure 1.5. Ideal position of the camera in relation to the patient. Courtesy of Rubio J.

The storage and format in aesthetic dentistry should be RAW, so that the pictures can always be developed better as this format has more information than a JPEG.

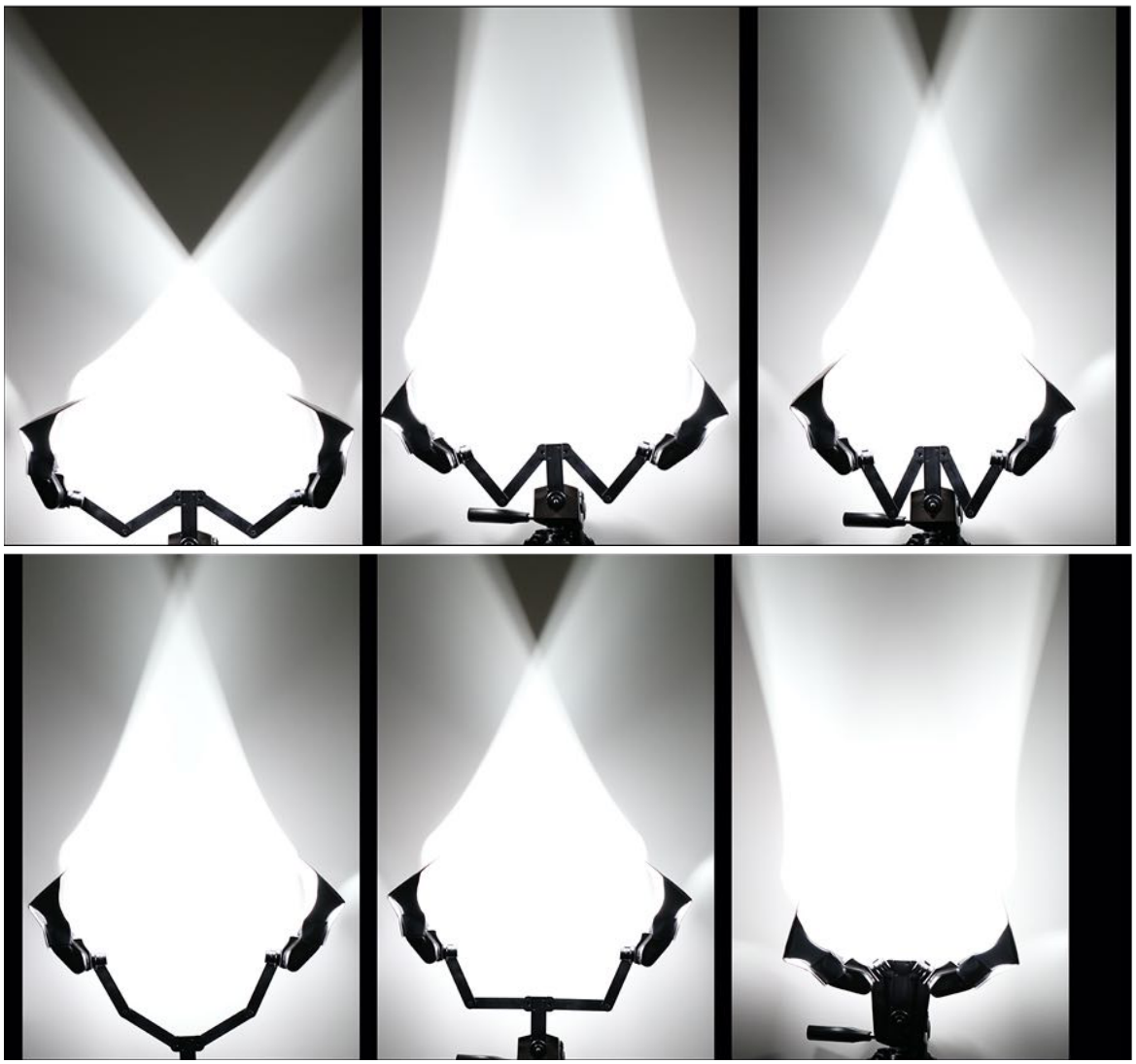


Figure 1.6. Use of flashes. From https://agpac.co.jp/photomedr2bracketbuncer/.

Background effects



Figure 1.7. Contrasters (black background) for intraoral photography. From https://www.smileline.ch/es/productos/smile-lite



Figure 1.8. Black Fexipalette form A. From https://www.smileline.ch/es/productos/smile-lite

To distinguish enamel and dentine shades. Analysis of tooth shape. To study the white and opalescent characteristics.

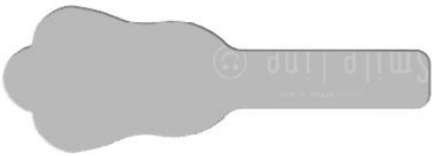


Figure 1.9. Flexipalette Colour Match. From https://www.smileline.ch/es/productos/smile-lite

To detect changes in tonality.

PHOTOGRAPHY WITH SMARTPHONE

This is a quick and easy substitute for professional equipment with more complex accessories, although light-enhancing auxiliary devices (e.g., smilelite lamp or MDP) are also needed.



Figure 1.10. Ring flash. From https://www.smileline.ch/es/productos/smile-lite



Figure 1.11. Smile Lite. From https://www.smileline.ch/es/productos/smile-lite



Figure 1.12. Smile Lite. From https://www.smileline.ch/es/productos/smile-lite



Figure 1.13. Smile Lite MDP. From https://www.smileline.ch/es/productos/smile-lite

SMILE LITE MDP

MOBILE DENTAL PHOTOGRAPHY

The Smile Lite MDP is a very easy to use plug and play device which requires no particular App, no calibration procedure and no specific training. This allows you to make full use of all the potential of your smartphone's camera, with complete simplicity.

It will soon become a mandatory tool for you:

- **Photos for shade taking.**
- **Everyday communication with the lab.**
- **Short video clips.**
- **Patient documentation.**
- **Artistic photographs.**

Figure 1.14. Smile Lite MDP applications. Made by Carmona JJ.



Figure 1.15. Smile Lite MDP. From https://www.smileline.ch/es/productos/smile-lite

La Smile Lite MDP puede ser considerada como un "mini estudio fotográfico".
La lámpara está provista de tres grupos de LEDs (light emitting diodes): cada grupo puede ser encendido individualmente y la intensidad de la luz puede ser también regulada (4 niveles de potencia).



Smile Lite MDP con los tres grupos de LEDs que pueden ser regulados individualmente.

El reverso de la Smile Lite MDP está provisto de un adaptador universal ajustable que permite insertar cada modelo de smartphone que tenga un ancho incluido entre 55 y 85mm.

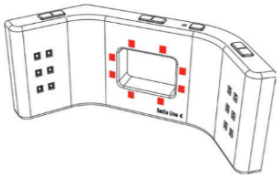


Smile Lite MDP con el adaptador universal que se ajusta a la mayoría de los smartphones.

Figure 1.16. Smile Lite MDP. From https://www.smileline.ch/es/productos/smile-lite

Possibilities with MDP.

1.- Cirugia frente anterior y ortodoncia.

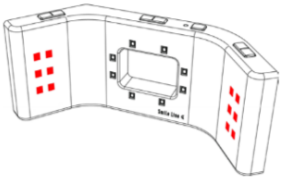


MDP con LEDs centrales a máxima potencia,
LEDs laterales apagados.
Con contrastador Flexipalette y retractor de labios.



Figure 1.17. MDP indications. Anterior front and orthodontics. From https://www.smileline.ch/es/productos/smile-lite

2.- Estética frente anterior, DSD y ortodoncia.



MDP con LEDs laterales a máxima potencia,
LEDs centrales apagados.
Con contrastador Flexipalette y retractor de labios.



Figure 1.18. MDP indications. Anterior front, DSD and orthodontics. From https://www.smileline.ch/es/productos/smile-lite

Documentation and colour determination

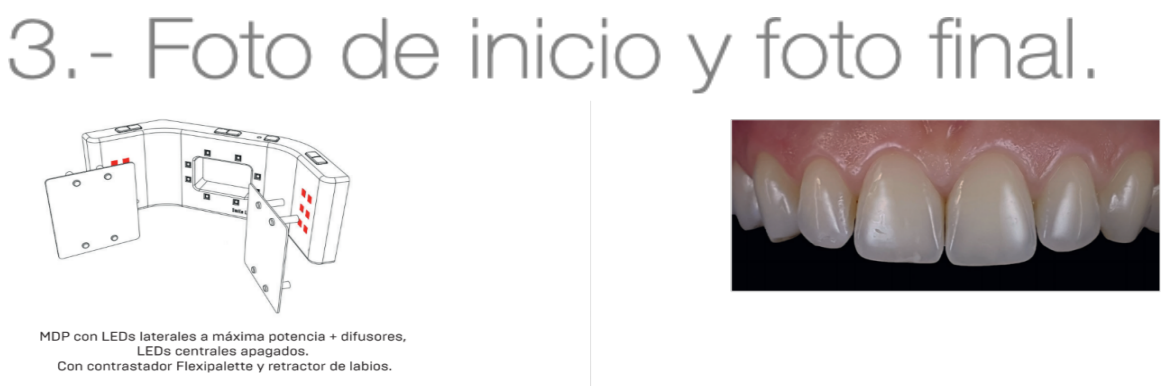


Figure 1.19. MDP indications. Starting and final situation pictures. From https://www.smileline.ch/es/productos/smile-lite

Case presentation

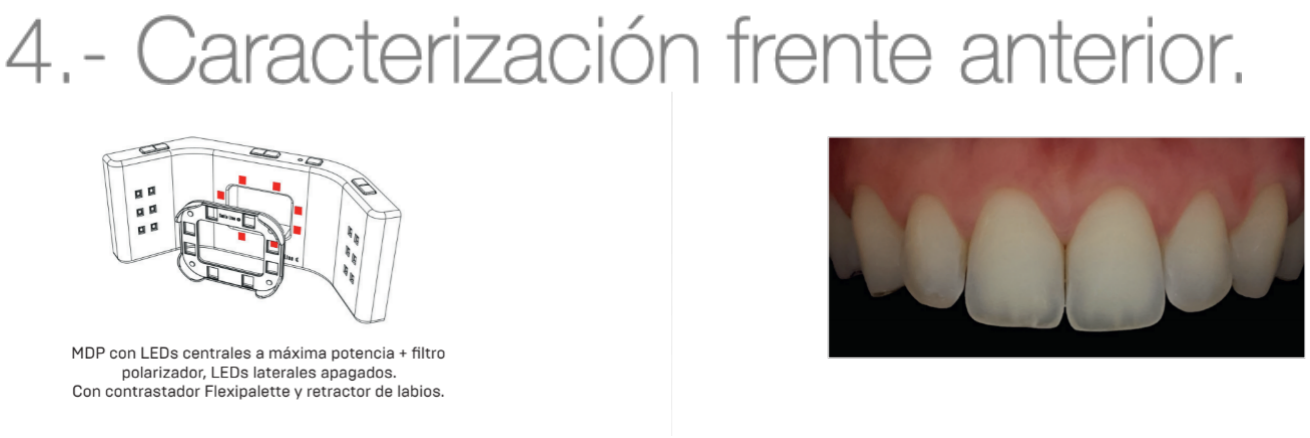


Figure 1.20. MDP indications. Characterisation of the anterior front. From https://www.smileline.ch/es/productos/smile-lite



Figure 1.21. MDP indications. Posterior sectors. From https://www.smileline.ch/es/productos/smile-lite

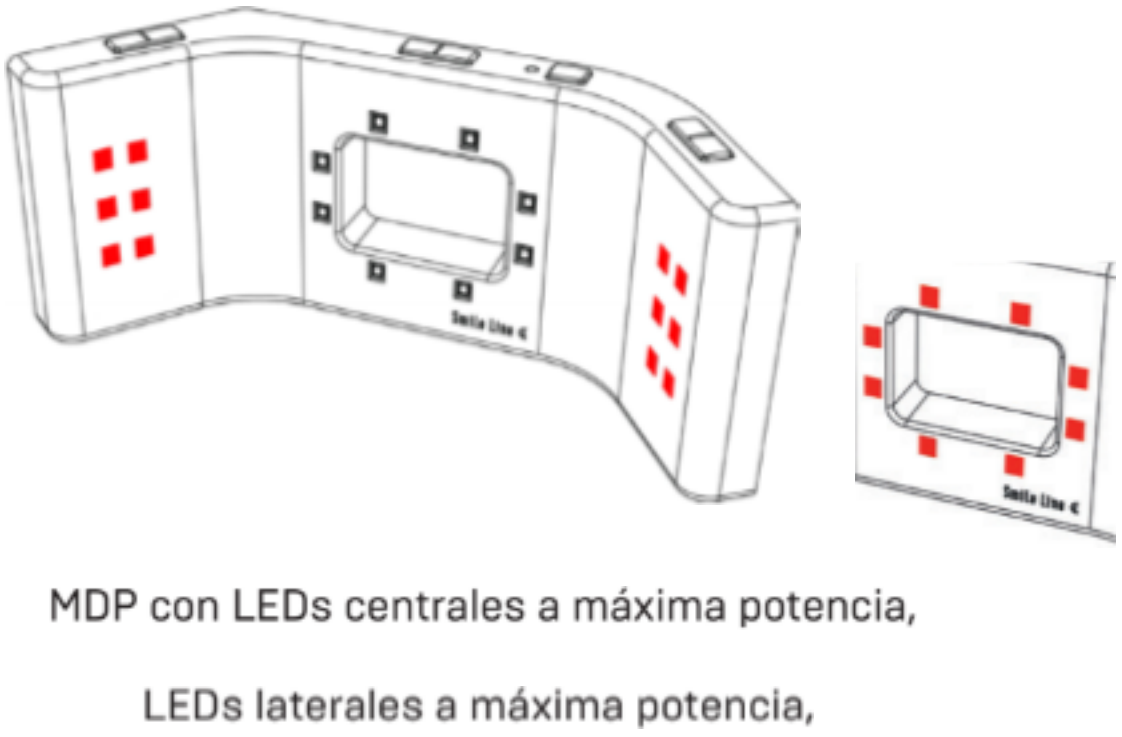


Figure 1.22. MDP indications. Posterior sectors. From https://www.smileline.ch/es/productos/smile-lite

"Per aspera ad astra"

“Through hardship, to the stars.”

Only through effort, sacrifice, or adversity can greatness and success be achieved.