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Evaluation of surrounding ring of two different extrashort implants design in crestal bone maintanence: A histologic study in dogs.

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Abstract: The aim of this study was to compare the implant stability and bone resorption & formation of two different extra short implants design with different diameter rings placed in dog´s maxilla. Thirty six extrashort 5 mm ∅ x 4 mm lenght (Short DM® ,Bioner Sistemas Implantológicos, Spain) delayed implants were placed in each hemimaxilla of 6 dogs at the bone crest level. Eighteen implants of each design (wide and narrow ring) were installed. After 8 and 12-weeks of healing period, histomorphometric analyses of the specimens were carried out to measure the crestal bone level values and the tissue thickness around wide and narrow ring implants design. In the microscopic analysis less buccal bone resorption was observed in narrow ring implants with statistical significance ($P < 0.001$). For peri-implant tissues thickness, the distance from the implant shoulder to the external portion of the epithelium was significantly higher for implants installed with wide ring with statistical significance ($P < 0.001$). Our findings suggests that the amount of peri-implant tissues (crestal bone loss) after remodeling over a period of 12 weeks was smaller in narrow ring extra short implant installed in healed maxilla compared with wide ring extrashort implants.

Keywords: extrashort dental implants; implant survival; marginal bone loss; dogs experiment; wide ring; narrow ring

1. Introduction

At the atrophic jaw the amount of cortical bone remains stable while most of the resorption occurs at expenses of cancellous bone [1-2]. The maxillary sinus and the inferior alveolar nerve in the posterior maxilla and mandible limits in many cases the availability of bone to place standard implants [3-4]. To solve these cases several surgical techniques have been proposed: guide bone regeneration, sinus lift, bone distraction, alveolar nerve transposition, angled implants, zygomatic and pterygoid and short implants among others [5-7]. Although there is high success rate with these methods, several drawbacks are asocciated with those procedures such as high morbidity, increase in cost, more surgical procedures and the appearance of post operative complications after these methods such as nerve paresthesia, sinusitis, bone graft exposure, swelling , pain, among others [8-13].

Many definitions have been proposed for short implants and also for extrashort implants. It is accepted nowadays that short implants are those of less than 8 mm [14].

Short implants (less than 8 mm) have been proposed as a less invasive alternative to treat the posterior atrophic jaws [8–13]. Some authors used extrashort implants in atrophic maxilla with GBR and suggests that short implants may be cheaper and faster treatment compared with longer implants in augmented atrophic maxillary bone [15].

Short implants present the advantage of being less traumatic and is proposed as the treatment of choice for reduce processing time, cost, and morbidity for the patient [16–19].

The survival, success and bone loss rate of the short implants (≤8.5 mm long) was 90% in all groups at 3 years of follow-up. It seems that the design of the implant can influence the behavior of the peri-implant bone at crestal level [20].

Extra-short implants are considered those less than 5mm length (Slotte et al. 2012) [21]. Short implants present long term succes rate comparable with standard implants. Although many short implants present unfavorable Crown to Implant ratio, they present high succes rate comparable with standard implants [21-22]. There have been numerous studies focused on the biomechanics of short implants. In these previous studies it is concluded that higher rates of bone stress occur independently of the length of the implants and there is a greater involvement of the implant diameter [23]. Also, it has been reported by previous studies that the width of the implants has more influence on osseointegration and survival rate than the presence of additional length

In these implants, due to their small contact surface with bone compared with normal implants, macro and micro design is a crucial aspect to be considered [24].

The development of new surface treatments increases the surface area of the implant, allowing for more bone to implant contact also most works still favour surface treatment of dental implants producing good substrate surfaces for osseointegration, with a great surface roughness . The reduction of the total length of the implant because it increases the bone-implant contact due to surface roughness[25-28].

Calvo-Guirado et al. showed that extrashort implants can support individual fixed bridges and overdentures in patients with posterior bone resorption with narrow ridges.[29].

Some studies describe the tendency of short implants to have a high failure rate during the first year[30]. Its proposed that this occurs due to lower primary stability because of less bone contact during healing period [16].

In a short implant most of the primary stability lies on the cortical bone. Therefore, adding a ring to the cervical area of a short implant design, increases the contact area and support with dense cortical bone.

The aim of this study is to evaluate the crestal bone resorption around two different extrashort implants design in animals.

2. Materials and Methods

It is an experimental study that was conducted in animal facilities at Murcia University. The manuscript was prepared following the ARRIVE guidelines

Six Beagle dogs of approximately one to one and half years of age were used in this study. The Ethics Committee for Animal Research at the University of Murcia (Spain) approved the study protocol, which followed guidelines established by the European Union Council Directive of February 2013 (R.D.53/2013). The number of procedure was A1320141102 (Animal Health Service, Murcia, Spain).

In the clinical examination all the animals had a good general health; the maxilla of them was intact with minimal resorption without major oral lesions.

The animals were given vaccines and vitamins against rabies, and then were putting them in quarantine. The dogs were kept in individual cages throughout the project and they also received adequate veterinary care. After each surgery (two procedures), animals received antibiotics 6 mg / kg Clindamycin (Clindaseptin 75 mg, Chanelle Pharmaceuticals,20 Ireland) twice daily and anti-inflammatory 0.30 mg / kg Caprox Vet 100 mg (Vibrac, Spain.) three times per day systemically.

2.1. Surgical Procedure

The animals were pre-anaesthetized with acepromazine (0.12%–0.25 mg/kg), buprenorphine (0.01 mg/kg), and medetomidine (35µg/kg). The mixture was injected intramuscularly in the femoral quadriceps. Animals were then taken to the operating theater where, at the earliest opportunity, an intravenous catheter was inserted (diameter 22 or 20 G) into the cephalic vein, and propofol was infused at the rate of 0.4 mg/kg/min at a slow constant infusion rate. Conventional dental infiltration anesthesia (articaine 40 mg, 1% epinephrine) was administered at the surgical sites. These procedures were carried out under the supervision of a veterinary surgeon. Maxilary premolar extractions (P2, P3, P4) were performed bilaterally. After two months of healing crestal incisions were performed bilaterally in the premolar region of the maxilla. Full-thickness mucoperiosteal flaps were elevated, and recipient sites in the premolar regions on both sides of the maxilla were prepared for the present experiment, while the other regions were used for different experimental purposes, the results of which are reported elsewhere. The healed bone were prepared to place extra-short implants with two different type of rings. The tested implant is a tissue level implant with a 1.9 mm smooth neck therefore leaving space for biological width and reducing marginal bone loss this helps us meassuring marginal bone reaction to the tested ring device.

Thirty six implants Short DM (Bioner, Sistemas Implantológicos, Barecelona, Spain) of 4 mm long by 5 mm in diameter were placed . One implant used with a narrow cervical ring of 4.2 mm diameter and the other with a wide cervical ring of 5.3 mm diameter (**Fig. 1)**.

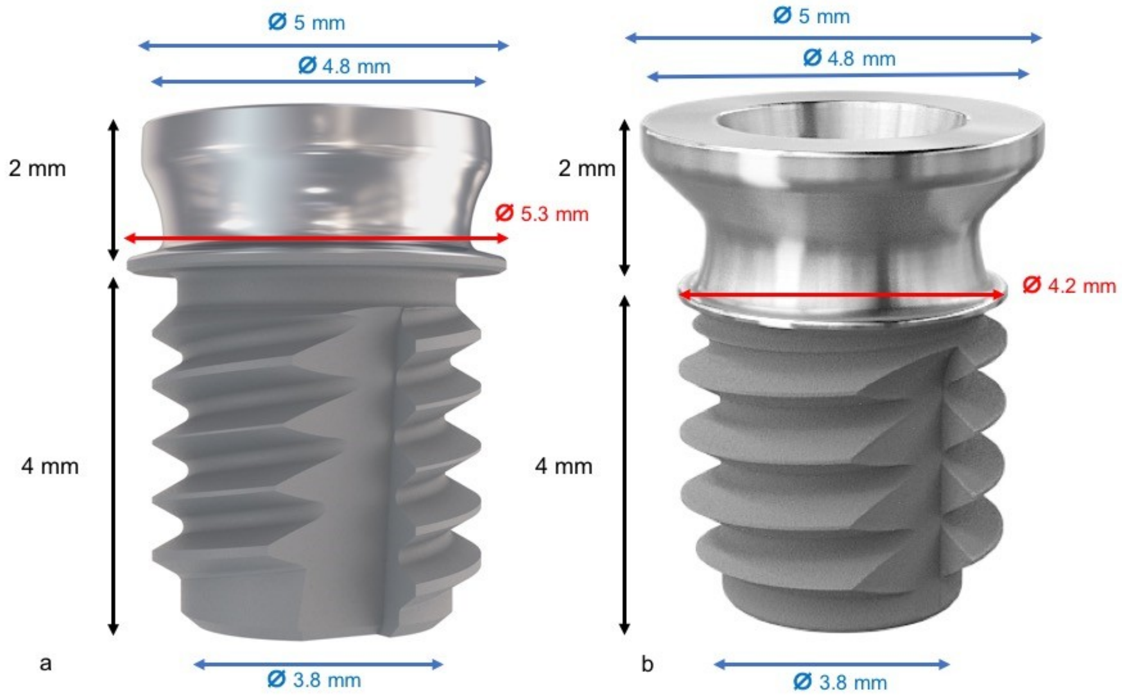

Figure 1. a) extrashort implant with wide cervical ring of 5.3 mm diameter; b) extrashort implant with a narrow cervical ring of 4.2 mm diameter.

According to the ARRIVE, information about allocation/randomization must to be provided.According to the ARRIVE, information about allocation/randomization a total of 36 implants were randomized installed . Eighteen extrashort dental implants, six per dog, were with wide diameter ring (5.3mm) and 18 with a narrow diameter ring (4.2 mm) were installed in healed maxilla **(Figure. 2 & Figure. 3).**

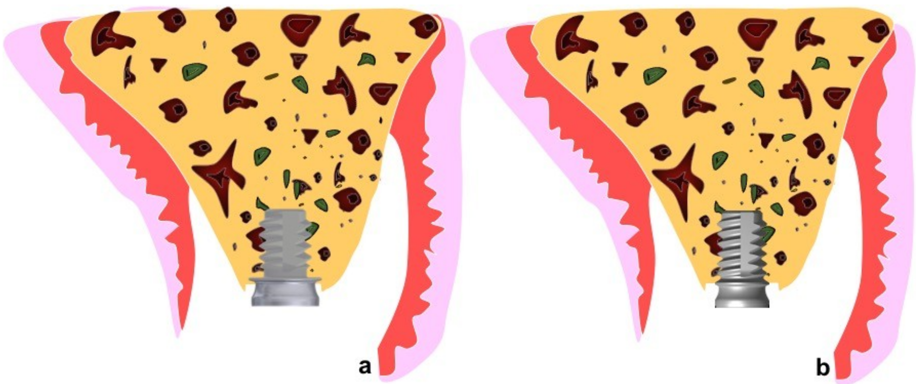

Figure 2. Wide and narrow ring extrashort implants installed in maxilla.

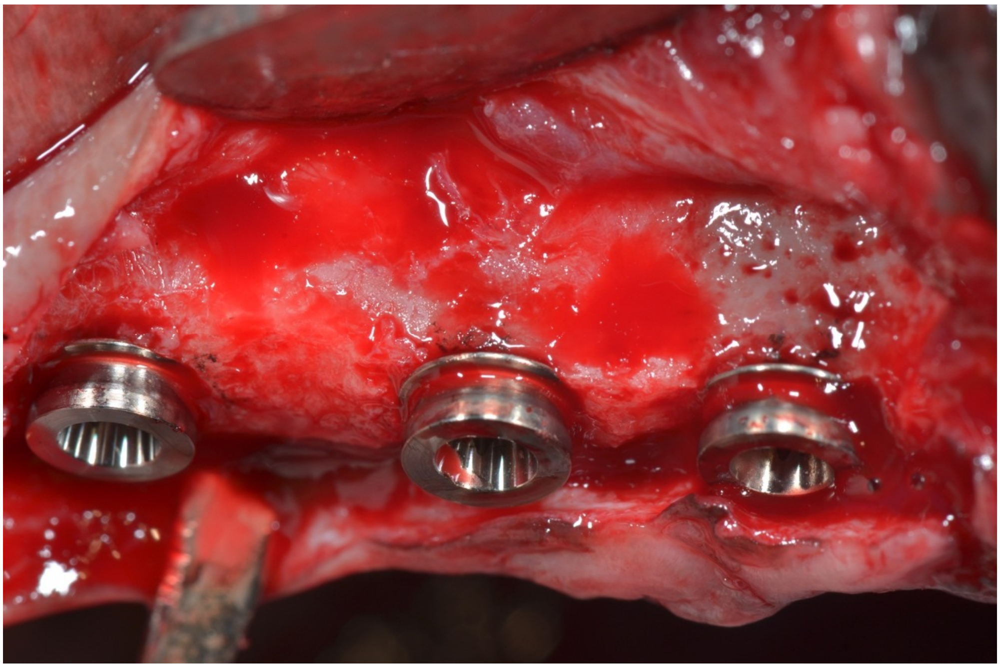

Figure 3. Clinical approach of wide and narrow ring extrashort implants installed in maxilla.

The flaps were sutured with silk 4.0 (Lorca Marin, Lorca Murcia, Spain). After the surgical procedures, the animals received antibiotic treatment (Amoxicillin 500mg, twice a day) and analgesics (ibuprofen 600mg, three times a day) systemically. In addition, dogs were fed a soft diet for seven days and plaque control was maintained by the application of Sea4 Encías® (Blue Sea Laboratories, Alicante, Spain). Wounds were inspected daily for postoperative clinical complications. Two weeks after surgery, sutures were removed

2.2. Histological and histomorphometric analysis

Three animals were sacrificed at 8 weeks and the other three animals were sacrificed at 12 weeks after insertion of the implant through an overdose of Pentothal Natrium® (Laboratorios Abbot, Madrid, Spain) and perfused through the carotid arteries with a fixative containing 5%

glutaraldehyde and 5% formaldehyde. Radiographs were taken after sacrifice at 60 days for the first three dogs and at 90 days those three that are left. (Figure 4)

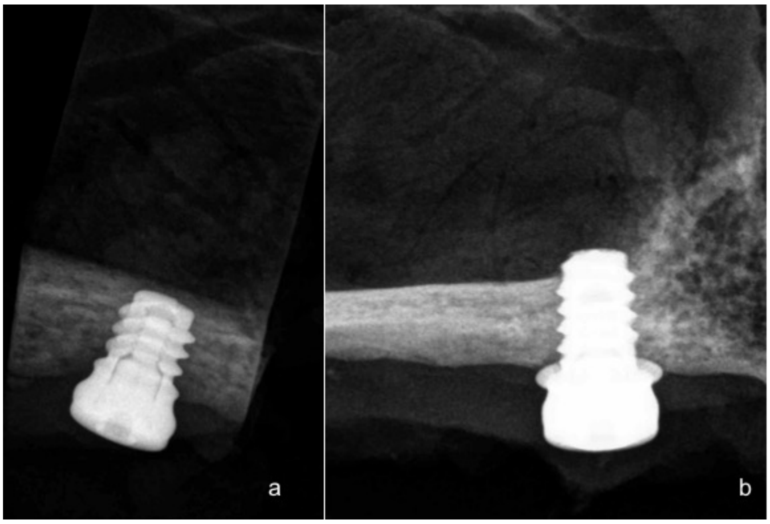

Figure 4. Radiographs were taken after sacrifice at 60 days for the first three dogs and at 90 days.

The specimens were washed in saline and fixed in 10% buffered formalin. The specimens were processed to obtain a thin section of soil with the automated system Precise 1 (Assing, Rome, Italy). The specimens were dehydrated in ascending series with alcohol and embedded in a glycol methacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned along their longitudinal axis with a high precision diamond disk, at about 150 μm to 30 μm. A total of two slides were obtained for each implant **(Fig. 5)**.

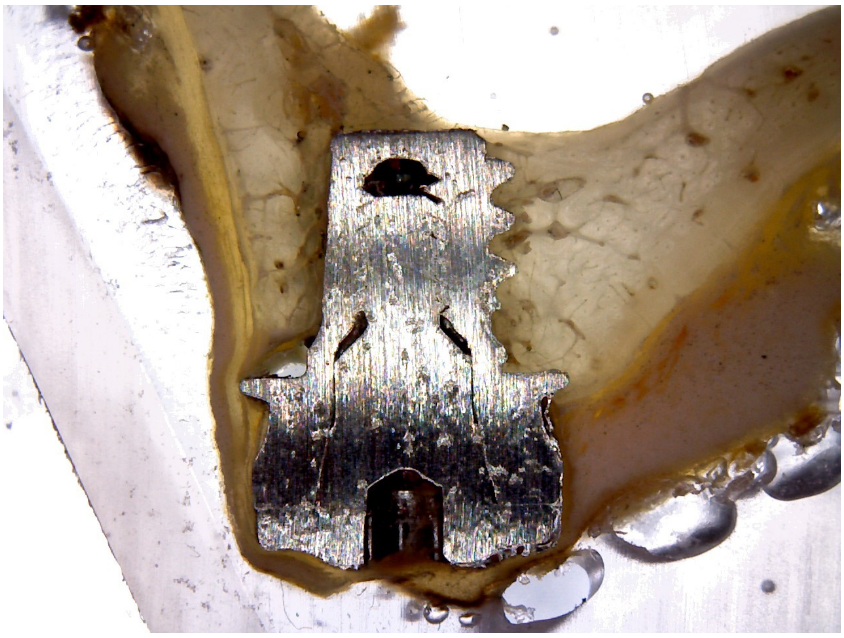

Figure 5. After polymerization, the specimens were sectioned along their longitudinal axis with a high precision diamond disk, at about 150 μm to 30 μm.

The slides were stained with toluidine blue and observed under a normal transmitted light microscope and a polarized light microscope (Leitz, Wetzlar, Germany)

The histological preparation evaluates the distance from the top of the implant collar to the first contact of buccal and lingual bone (BBC and LBC), as well as the heights of the buccal and lingual bone ridges with respect to the neck of the implant (**Figure. 6 & Figure.7**). Resorption of the buccal bone wall compared to reabsorption of the lingual bone wall was expressed as a linear measure.

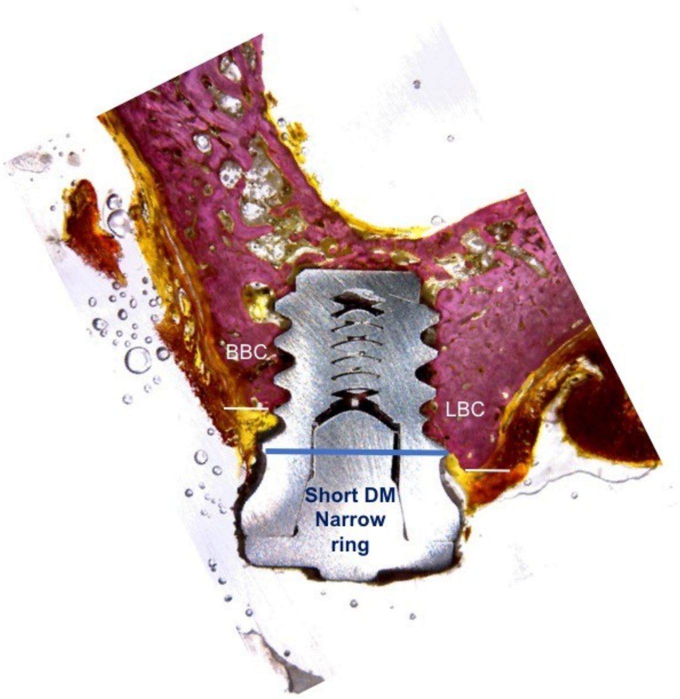

Figure 6. Narrow ring extrashort implant.

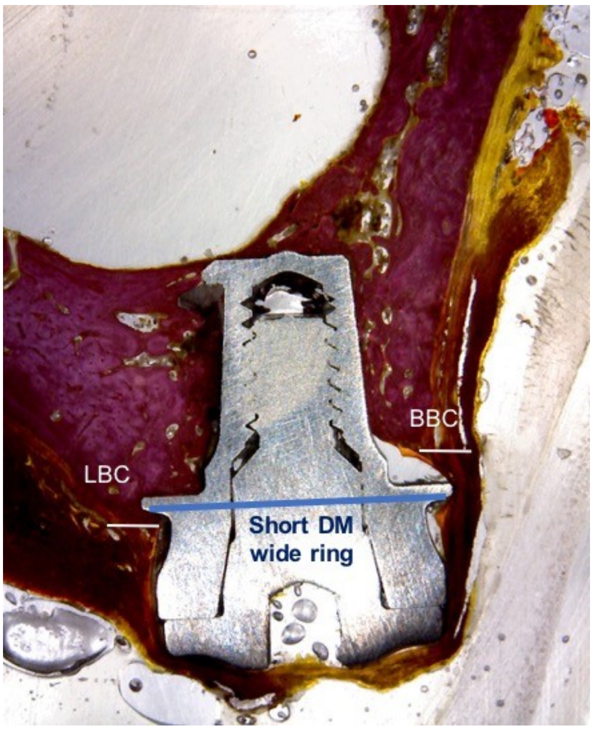

Figure 7. Wide ring extrashort implant.

The buccal and lingual bone plates were measured from the implant shoulder to the first BIC and to the top of the bony crest. The percentage of BIC of native bone was also measured along the perimeter of the implant between the coronal end of osseointegration in the buccal and lingual aspects. The apical portion of each implant was excluded from the measurement. The total amount of bone in contact with the implants was calculated as the sum of native bone and newly formed bone (BIC%). Histomorphometry of BIC percentages was performed using a light microscope (Laborlux S, Leitz) connected to a high resolution video camera (3CCD, JVC KY-F55B, JVC®, JVC, Yokohama, Japan) and interconnected to a monitor and PC (Intel Pentium III 1200 MMX, Intel ®, Intel, Santa Clara, CA, USA). This optical system was associated with a scanning pad (Matrix Vision GmbH, Oppenweiler, Germany) and a software package for histometry with image capturing capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc., Immagini & Computer Snc, Milano , Italy). The total amount of bone in contact with the implants was calculated as the sum of native bone and newly formed bone.

2.3. Statistic analysis

The data were compared using the one-way ANOVA statistical tests (α = 5%), because we had tywo different period of time evaluation (8 and 12 weeks) and two different types of implants .

Mean values and standard deviations were calculated using a BIC descriptive test and bone resorption measurements. Values were recorded as mean ± standard deviation. Wilcoxon test was applied to the comparison of mean averages and to quantify relationships between differences with 95% interval of confidence. Bruner and Langer non parametric were applied also to the mean values for crestal and subcrestal implants. All histomorphometric parameters were analyzed using descriptive methods (SPSS 19.0, SPSS, Chicago, IL, USA). For all the tests performed, the significance level chosen was 5% ($p < 0.05$).

3. Results

Operative surgical sites healed without incident. All of the implants were available for histological analysis.

The mean insertion torque for the implants was 40.21±0.87 Ncm in P2, 42.87 ± 0.11 in P3 and 44.68±0.17 Ncm in P4. Using a paired two-sample t-test, significant difference between the average insertion torques was found (p=0.005) (Table 1).

Table 1. Maximum insertion torque and median insertion torque of extrashort wide and narrow ring implants.

Short DM Implant Position	Mean maximum insertion torque IT (SD)	Median Insertion Torque	P value
P2	40.21 ± 0.87	40	0.824
P3	42.87 ± 0.11	42	0.456
P4	44.68 ± 0.17	44	0.012*

The mean ISQ values were above from 70 ISQ wich indicate high primary stability and were increasing from Day 0 to Day 90. We could see in Table 2 and Table 3 ISQ values for wide ring implants and narrow ring implants.

Table 2. ISQ mean values at day, at 60 days and 90 days of extrashort wide ring implants.

Short DM Implant Position	**Mean (SD) ISQ Day 0**	**Median ISQ Day 0**	**Mean (SD) ISQ 60 days**	**Median ISQ 60 days**	**Mean (SD) ISQ 90 days**	**Median ISQ 90 days**	**P value**
P2	72.23 ± 0.72	69.22-71.56	73.22 ± 0.34	72-70-77.16	74.29 ± 0.11	72.57 – 76.23	0.782

P3	76.56 ± 0.12	75.34 – 77.23	80.17 ± 0.62	79.37-83.28	80.56 ± 0.12	78.67 -82.22	0.923
P4	78.33 ± 0.37	76.31 – 80.12	80.11 ± 0.39	78.14-83.12	82.34 ± 0.17	80.34 -85.23	0.672

Table 3. ISQ mean values at day, at 60 days and 90 days of extrashort narrow ring implants.

Short DM Implant Position	Mean (SD) ISQ Day 0	Median ISQ Day 0	Mean (SD) ISQ 60 days	Median ISQ 60 days	Mean (SD) ISQ 90 days	Median ISQ 90 days	P value
P2	70.52 ± 0.41	69.81-72.76	73.45 ± 0.11	72-89-75.26	75.99 ± 0.76	74.38 – 78.33	0.782
P3	74.78 ± 0.11	73.22 – 76.18	78.66 ± 0.62	77.37-80.12	80.14 ± 0.89	78.67 -82.78	0.923
P4	76.38 ± 0.22	74.11 – 78.11	79.81 ± 0.39	77.14-80.34	81.11 ± 0.34	80.34 -83.14	0.672

Mean bone loss for narrow ring implants is 0.75 ± 0.22 at 60 days and 0.89 ± 0.18 at 90 days in P2, 0.78 ± 0.19 at 60 days, and 0.86 ± 0.59 at 60 days in P3, and 0.71 ± 0.11 at 60 days and 0.75 ± 0.11 at 90 days in P4 which indicate more bone loss at 90 days that at 60 days. (Table 4)

Table 4. Bone Loss at 60 days and 90 days of extrashort narrow ring implant.

Time of Measurements	Mean (SD) bone loss at short implants P2 (mm)	Median short implants P2 (mm)	Mean (SD) bone loss at short implants P3 (mm)	Median at short implants P3 (mm)	Mean (SD) bone loss at short implants P4 (mm)	Median at short implants P4 (mm)	P value
60 days	0.75 ± 0.22	0.7	0.78 ± 0.19	0.7	0.71 ± 0.11	0.7	0.012*
90 days	0.89 ± 0.18	0.8	0.86 ± 0.59	0.8	0.75 ± 0.52	0.7	0.134*

Mean bone loss for wide ring implants is 0.82 ± 0.11 at 60 days and 0.97 ± 0.91 at 90 days in P2, 0.80 ± 0.56 at 60 days, and 0.89 ± 0.23 at 60 days in P3, and 0.79 ± 0.25 at 60 days and 0.79 ± 0.67 at 90 days in P4 which indicate more bone loss at 90 days that at 60 days. (Table 5). In the microscopic analysis of the crestal bone remodeling, the distance from the implant shoulder to the first bone-to-implant contact was higher for implants installed with small ring in the buccal aspect with statistical significance ($P < 0.001$). For peri-implant tissues thickness, the distance from the implant shoulder to the external portion of the epithelium no differeces and no statistical significance were found in both types of implants.

Table 5. Bone Loss at 60 days and 90 days of extrashort wide ring implant.

Time of Measurements	Mean (SD) bone loss at short implants P2 (mm)	Median short implants P2 (mm)	Mean (SD) bone loss at short implants P3 (mm)	Median at short implants P3 (mm)	Mean (SD) bone loss at short implants P4 (mm)	Median at short implants P4 (mm)	P value
60 days	0.82 ± 0.11	0.8	0.80 ± 0.56	0.8	0.79 ± 0.25	0.7	0.382

90 days	0.97 ± 0.91	0.9	0.89 ± 0.23	0.8	0.79 ± 0.67	0.7	0.572

4. Discussion

Short (length ≤ 8 mm) implants offer a minimally invasive alternative in the rehabilitation of atrophied alveolar bone [5].

Short implants present similar success rate than conventional ones[14,29-31]. Those implants depend specially on cortical bone anchorage because they are mainly used in highly resorbed areas where the amount of cortical bone remains stable in comparisson to trabecular bone [32]. The main drawbacks of short implants are on one hand, the lack of primary stability due to it small size [16]and the unfavorable crown to implant ratio [33-34], therefore adding elements to maximize contact area and mechanical retention in dense cortical bone can be beneficial. In this experimental study in dogs we tested a new short implant design in which a ring is added to the implant cervical area to improve support and primary stability at the cortical bone level in a similar way to extraoral implants [35]. The addition of the ring would also prevent the implant from being inserted deeper than planned, which is very important when working next to delicate anatomical structures such as the inferior alveolar nerve. The top of the ring is polished and the bottom has a rough surface so it can become osseointegrated. To achieve homogeneous seating of the ring on the bone crest we use a round flattening reamer to achieve a flat surface where the ring can rest homogenously.

Although a cervical ring can have some advantages from a mechanical point of view, it is important to test the biological behavior of this element, because the osseointegration of the botton surface of the ring can increase BIC area of the implant and improve load transmission but if the bone dont adhere to the rough bottom surface of the ring, marginal bone loss will be increased and higher incidence of peri-implantitis can be expected. No previous studies on the addition of such a ring on the osseointegration of this device have been published so far. There are very few animal studies on short implants [36-37], and they are in mandible not in maxilla like this study. Our group published in 2016 a pilot study wityh 60 extrashort 4 mm implants in posterior mandible splinted with 10 mm length implants with 100 % success rate at 1 year follow up [38]. All the implants of this study were correctly integrated, which is in line with studies in humans which have a high success rate [39]. The perfect flattening of the bone crest is technically difficult and if the ring and the osteotomy are not perfectly aligned the implant stops at the first bone contact. This fact explains that when measuring the total values of marginal bone loss some higher values can appear. This would explain why the data have a lot of rank and in the same implant there are areas with much more bone loss. If the meassures are made from the first bone implant contact the results will show different values. The later is an important finding because adding a circular element to the cervical area of a tissue level implant with a 2.0 mm neck is going to maintain the bone and therefore can provide a clinical benefit of more primary and greater stability surface area of the implant in contact with the bone. More studies are needed with a smaller diameter ring more adapted to the animal´s jaw of experimentation and modificating the technique of insertion to be able to validate this assertion. Another issue is the long term stability of the marginal bone in the ring area and the bone reaction to loading. Within the limitations of this study crestal bone resorption was reduced in narrow extrashort ring implants design compared with wide ring implants in healed maxilla. Those data could be an important factor for humans , due to the use of short implants with rings in soft and resorbed bone can be used with high predictibiliy but managed with skillful technique.

More long term studies with loading protocols and different ring sizes must be performed.

5. Conclusion

Our findings suggests that the amount of peri-implant tissues (crestal bone loss) after remodeling over a period of 12 weeks was smaller in narrow ring extra short implant installed in healed maxilla compared with wide ring extrashort implants.

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Conflict of interest: The authors declare that they have no conflict of interest.

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