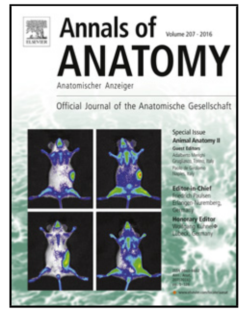

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Author: José Luis Calvo Guirado PhD Miguel Troiano PJ. López-López María Piedad Ramírez-Fernandez PhD José Eduardo Maté Sánchez de Val PhD Jose Manuel Granero Marin Sergio Alexandre Gehrke PhD

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Different configuration of socket shield technique in peri-implant bone preservation: An experimental study in dog mandible

José Luis Calvo Guirado, PhD[a], Miguel Troiano[b], López-López PJ.[c], María Piedad Ramírez-Fernandez, PhD[d], José Eduardo Maté Sánchez de Val, PhD[e], Jose Manuel Granero Marin[f], Sergio Alexandre Gehrke, PhD[g*]sergio.gehrke@hotmail.com

[a]Full Professor and Director of International Dentistry Research Cathedra. Faculty of Medicine & Dentistry, San Antonio Catholic University of Murcia (UCAM), Murcia, Spain.

[b]Professor of Master in Implant Dentistry. University of Buenos Aires. Argentina.

[c]Associate Professor of International Dentistry Research Cathedra. Faculty of Medicine, San Antonio Catholic University of Murcia (UCAM), Murcia, Spain.

[d]Associate Professor of International Dentistry Research Cathedra. Faculty of Medicine, San Antonio Catholic University of Murcia (UCAM), Murcia, Spain.

[e]Senior Lecturer. International Research Cathedra. UCAM, Universidad Católica San Antonio, Murcia, Spain.

[f]Vicen Dean Faculty of Medicine and Dentistry, UCAM, Universidad Católica San Antonio, Murcia, Spain.

[g]Professor, Director of Biotecnos Research Center, Santa Maria, Brazil; Director of Biotechnology Cathedra of the University Catholica San Antonio de Murcia (UCAM) Murcia, Spain.

Department of Research, Biotecnos – Technology and Science, Rua Dr. Bozano 571, CP 97015-001, Santa Maria, RS, Brazil. Phone: +55 55 32227253; fax: +55 55 32227253

Abstract

The aim of this study was to evaluate the influence of the residual root and peri implant bone dimensions on the clinical success of the socket shield technique. Thirty-six dental implants were installed in 6 dogs. The clinical crowns of teeth P3, P4 and M1 were beheaded. Afterwards, the roots were worn down 2 to 3 mm in apical direction until they were located at crestal level. Posterior implant beds were prepared in the center of the roots passing by 3 mm apically forming 6 groups in accordance to the remaining root thickness. Radiography of the crestal bone level was performed on day 0 and after 12 weeks. Histomorphometric analyses of the specimens were carried out to measure the crestal bone level, the bone to implant contact and the buccal and lingual bone thickness at the implant shoulder portion. Correlations between groups were analyzed through nonparametric Friedman test, statistical significance was set as $p<0.05$. All 36 implants were osseointegrated, but 3 samples showed a clinical inflammatory reaction and some radicular fragments presented a small resorption process. On the buccal and lingual side, the radicular fragment was attached to the buccal bone plate by a physiologic periodontal ligament. In the areas where there was space between the implant and the fragment, newly formed bone was demonstrated directly on the implant surface. Within the limitations of an animal pilot study, root-T belt technique may be beneficial in preserving and protecting the bundle bone and preservation of soft tissues. If the thickness of the buccal bone is 3mm, and the thickness of the remaining root fragment is 2mm, the socket shield technique is more predictable and the bone contours can be maintained.

Keywords

Alveolar bone preservation; Immediate implant; Socket shield; Radicular retention; Crestal bone behavior.

1. Introduction

Tooth extraction is followed by dimensional changes in the alveolar ridge contour (Araújo & Lindhe 2005, Fickl et al. 2008b). The marked alterations after tooth extraction appear to be attributable to the loss of periodontal ligament and the consecutive trauma in particular at the buccal bone plate in which the resorption is more pronounced than in the lingual aspect of the extraction socket (Araújo & Lindhe 2005).

Immediately following implant placement in the aesthetic zone the hard tissues are subject to volumetric changes as they undergo a remodeling process, the resorption is highest in the buccal tissues (Botticelli et al. 2004).

Socket preservation is a suitable technique for socket augmentation with the capacity to maintain the ridge dimension to a certain amount (Araújo et al. 2008, Fickl et al. 2008a, Araújo et al. 2009). Buccal overbuilding with bone grafting materials and a collagen barrier can only partly compensate but not prevent the resorption process and, therefore, a better solution is desirable to retain the healthy periodontium, because is limited, horizontal and vertical augmentations are frequently accompanied by subsequent tissue shrinkage (Esposito et al. 2009).

In order to overcome the negative consequences of tooth extraction, various treatment approaches such as immediate implants (Botticelli et al. 2004, Araújo et al. 2005), graft materials (Nevins et al. 2006, Araújo et al. 2008, Fickl et al. 2008a, Araújo et al. 2009), and/or barrier membrane (Lekovicet et al. 1998) are in use. It has been shown that the resorption of the buccal plate could not be completely avoided by incorporation of biomaterials. Today, is not yet possible maintain the volume after tooth extraction with the available materials. Neither, with guided bone regeneration nor guided tissue regeneration is it possible to maintain the volume. Nowadays, the socket preservation techniques can only compensate, but not avoid the resorption process.

A peri-implant bone remodeling is when implants are placed on the remaining roots (Andersson et al. 2003, Sapir & Shapira 2008).

In the literature we can find some techniques that maintain the gingival tissues and keep the crestal bone at its original level preserving the root, or part of it, in the alveolar process.

The "socket-shield technique" described by Hürzeler et al. (2010), used the retained buccal root in an attempt to preserve the buccal bone and tissues, which is the mainly desired effect, after immediate implant placement. This approach allowed the buccal cortical bone to be successfully preserved.

Another modification of the socket-shield technique has been described which may offer a feasible treatment option to procedures using the socket-shield technique in vertically fractured teeth. The case report indicates that it may also be used without severe adverse events and that the desired effect of buccal maintenance might also be achieved in human tissues (Baumer et al. 2015).

Root-T-Belt technique consists of placing the implant in the preserved tooth root, which will surround the implant entire circumference thereof. tooth structure, formed by periodontium, dentin and cement will create a protective structure as a belt, which prevents any movement and maintains the peri-implant system structure. (Troiano et al. 2014).

The aim of this study was to evaluate the influence of the residual root and peri implant bone dimensions on the clinical success of the socket shield technique.

1. Materials and methods

1.1. Study design

Six American foxhound dogs of approximately 1 year of age, each weighing 14-15 kg were used in this study. The Ethics Committee for Animal Research at The University of Murcia (Spain) approved the study protocol, which followed the guidelines established by the European Union Council Directive of February 1st 2013 (R.D.53/2013). Approval number of Ministry of Animal health (Murcia Goverment) was A1320141102. The dogs were evaluated by a veterinary surgeon who determined that all the animals were in good general health. The clinical crowns of teeth P3, P4 and M1 were beheaded. Afterwards, the roots were worn down 2 to 3 mm in the apical direction until they were at subcrestal level. A total of 6 implants were placed per dog according to a randomization program of distribution (www.randomization.com). A sample size of 36 implants, 6 implants per dog were used for this study (Fig. 1).

1.1. Surgical procedure

The animals were pre-anesthetized with acepromazine 0.12%–0.25 mg/kg, buprenorphine 0.01 mg/kg, and medetomidine 35 lg/kg. with 10% zolazepam at

0.10 ml/kg. This mixture was injected intramuscularly in the femoral quadriceps. Animals were then taken to the operating theater, where an intravenous catheter was inserted (diameter 22 or 20 G) into the cephalic vein, and propofol (0.4 mg/kg/ min) was infused.

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. P3, P4 and M1 were horizontally cut and the crowns were beheaded. Then the root was worn down by means of a round pumice handpiece, creating a concave shape and positioning the root at crestal level.

Afterwards, a Lindeman zirconium bur (MIS - Technologies, Tel-Aviv, Israel) was inserted at the center of the root canal without passing the apex, so as to make sufficient space for the 2 mm zirconium spearhead bur (MIS - Technologies, Tel-Aviv, Israel), which then went passed the apex until the appropriate depth was reached. The procedure was repeated with a 3 mm zirconium spearhead bur before taking up the disposable, high-speed steel bur. Immediate implants of 3.3 and 3.75 mm in diameter and 10 mm in length (MIS® Implants - Technologies, Tel-Aviv, Israel) were placed in the center of the root passing by 3 mm apically to the root, after that we placed an anatomic healing screw without suture (Fig. 2).

Following surgery, the animals received antibiotics (Enrofloxacin 5 mg/kg twice daily) and analgesics (Meloxicam 0.2 mg/kg, three times a day) via the systemic route. The dogs were fed a soft diet for 7 days following the surgical procedure. Healing was evaluated weekly, and plaque control was maintained by the application of a chlorhexidine spray. The animals were kept in kennels and in concrete runs at the university's field laboratory; they were provided with free access to water and fed with moistened balanced dog chow. The wounds were inspected daily for clinical signs of complications. The animals were sacrificed after 12 weeks by means of an overdose of Pentothal Natrium (Abbot Laboratories, Madrid, Spain) and perfused through the carotid arteries with a fixative containing 5% glutaraldehyde and 5% formaldehyde. The mandibles were dissected, and block sections including the implant site and surrounding soft and hard tissues were removed with a saw. Specimens were washed in saline solution and fixed in 10% buffered formalin.

1.1. Histological analysis

The specimens were processed to obtain thin ground sections with the Precise 1 Automated System (Assing, Rome, Italy). Specimens were dehydrated in an ascending series of alcohol solutions and embedded in a glycol methacrylate resin (Technovit 7200 VLC; Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned along the longitudinal axis with a high-precision diamond disk, at about 150 lm down to 30 lm with an Exakt 400 s CS grinding device (Exakt Apparatebau, Norderstedt, Hamburg, Germany). A total of 2 slides were obtained for each implant. The slides were stained with toluidine blue and fuchsine, and observed in a normal transmitted light microscope and a polarized light microscope (Leitz, Wetzlar, Germany).

To obtain a single digitally processable overview image of the implants per site, four images of the same implant were taken with a 109 objective and assembled into a single image. A 1-mm-wide zone around the implant surface reaching up to the original implantation level was defined as the region of interest (ROI). Within the ROI, the hard tissue was digitally defined into old bone and newly formed bone. To improve the differentiation between native and newly formed bone, light and dark blue chromaticity was enhanced by digital images.

1.1. Histomorphometrical analysis

Histomorphometric analysis was performed using calibrated digital images at 910 magnifications (Leica microscope Q500Mc, Leica DFC320s, 3088 9 2550 pixels, Leica Micro-systems, Barcelona, Germany). The most central sagittal section of each implant was taken for histomorphometric analysis using MIP 4.5 software (Microms Image Processing Software, CID, Consulting Image Digital, Barcelona, Spain) connected to a Sony DXC- 151s 2/3-CCD RGB Color Video Camera.

Bone-to-implant contact (BIC) was determined in each histological section calculated by measuring the length of the implant surface in contact with bone tissue, compared with the total length of the implant surface, and expressed as a percentage.

Buccal bone wall resorption in comparison with lingual bone wall resorption was expressed as a linear measurement. The buccal (Bc) and lingual (Lc) bone plates were measured from the implant shoulder to the first BIC and to the top of the bone crest. The BIC percentage measured throughout the implant perimeter between the coronal end of osseointegration at the buccal and lingual aspects (Fig. 3).

To facilitate understanding, the remaining bone and the root thickness was evaluated in order to obtain a classification distributed as 6 study groups, (group 1: root thickness < 2 and < 3 mm Bone; group 2: root thickness 2 to 4 mm and < 3 mm Bone; group 3: root thickness > 4mm and < 3 mm Bone; group 4: root thickness < 2 and >3 mm Bone; group 5: root thickness 2 to 4 mm and >3 mm Bone and group 6: root thickness > 4mm and > 3 mm Bone) which are summarized in the **Table 1**.

1.1. Radiographical evaluation

Conventional dental radiographs were taken at the time of implant placement and after the integration healing period to evaluate changes in the postsurgical crestal bone levels. The images were digitalized and analyzed. The distance between the fixture shoulder and the apical level of the marginal bone in contact with the implant were measured at 8x magnification, in accordance with the scheme of Fig. 4. The length of the implants was used for calibration purposes. The measurements were made at the medial and distal aspects of each fixture, and the mean values for each case were calculated.

1.1. Statistical analysis

Descriptive statistics; i.e., mean, medians and standard deviations were used. Correlations between subgroups were analyzed through nonparametric Friedman test for related samples. For all performed tests, the significance level was set as $p < 0.05$.

1. Results

1.1. Radiolographic analysis

Results of distances between the Implant shoulder and the first bone contact were registered. Furthermore, the results observed are confluent with histomorphometrical results and better behavior can be expected in the cases of wide peri-implant bone and less remaining root. Better values were observed in group 1 (IS-Bc, 3.13 ± 0.54; IS-Lc, 2.84 ± 1.32) compared with Group 6 (IS-Bc, 6.01 ± 2.23; IS-Lc,5.79 ± 1.45). The values measured and the statistical analyses are summarized in the **Table 4**.

1.1. Histological and histomorphometrical analysis

Samples were classified into 6 groups to perform the analysis based on the remaining bone and in the residual root shape. From histological images, better results can be observed in the situation of wide peri-implant bone (> 3mm) and with < 2 mm of remaining root, the apposition of connective tissue was successful and the apical migration of bone was minimized at the peri-implant area. As the time that the peri-implant bone is reduced and the remaining root is more than 2 mm, the histological findings suggest that the bone loosening and the connective tissue attachment are most critical, figures 4 and 5.

Histomorphometrical results of bone remodeling and peri-implant BIC are presented in **Table 2**.

Better BIC results were obtained in the cases of > 3 mm of residual bone and in the cases of < 2 mm of root. (BIC%) for group 1 were 52.12 ± 8.43). The distance from the implant shoulder to the first contact was registered for all the groups and better bone preservation was observed in the same group of > 3 mm of residual bone and < 2 mm of root, (IS-Bc (mm), 3.05 ± 0.11; Is-Lc (mm), 2.95 ± 1.02) with the values measured and the statistical analyses are summarized in the **Table 3**. Groups 4 and 5 were that better results obtained with statistical difference (P <0.001). Figures 4 and 5

1.1. Clinical results

The bucco-lingual overview illustrated the presence of a tooth fragment located buccally and lingually to the implant (Figure. 3).

The 360 º tooth fragment consisted of a large root portion of cement and an up to 0.5 -1 mm wide piece of root dentin. On its buccal, lingual, mesial and distal side, the tooth fragment was still attached to the bone plate by a physiologic periodontal ligament.

Towards the implant, there was a small, up to 0.5-1 mm-wide gap filled with new bone tissue interposed between the tooth fragment and the implant.

The implant was completely osseointegrated into the alveolar bone because we have to have a primary stability, 3 mm pass by the tooth apex. The height of the alveolar bone crest was identical in the bundle bone preservation in 360^o. The peri-implant soft tissue revealed a physiologic junctional epithelium and was free of any inflammatory reaction. (Fig. 3).

At the time of sacrifice, all implants were successfully integrated. Out of a sample of 36 implants, 3 presented mucositis and peri-implantitis. The remaining 33 implants healed uneventfully. All of the 36 implants were included in radiographic, histologic and histomorphometric analysis.

1. Discussion

The success of osseointegration of the implant placed immediately in fresh socket (Botticelli *et al*.2006; Covani et al. 2004; Araujo et al. 2005, 2006; Rimondini et al. 2005; Caneva et al. 2010; Mangano et al. 2011; Vignoletti et al. 2012) is well described in the literature, but, in most cases, this technique leads to buccal plate resorption with moderate aesthetic results and/or the need of subsequent reconstruction. It should be emphasized that the technique of peri-implant shield does not guarantee higher survival values in the implant, but tries to minimize vertical peri-implantary bone reduction. The aim is maintaining buccal bone, and is focused on the three-dimensional preservation of the peri-implant bone in this area. Situations, in which the buccal wall bone is minimal and the process of extraction would produce remodeling, justify the possibility of applying this technique in which <l prevents the trauma of tooth extraction bone loss and also helps in periodontal tissue preservation.

In this paper, one of the differentiating factors as to previous studies has been the inclusion of different dimensions of preserved roots surrounding the implants. This will directly influence the results, since it determines the amount of bone remaining peri-implant and also proper implant placement. For this reason, it the obtained results have been standardized in order to avoid bias resulting technique. Getting thin and short roots that are going to get a better result and greater predictability of the technique, probably because the remaining bone is greater. With this technique, one can avoid the resorption and modification on bundle bone and can preserve the volume of soft tissues. The modification described in this paper consisting of peri-implant root preservation surrounding the implant may directly influence the outcomes of the clinical behavior of the implants; but the preservation of more root quantity surrounding the implant lead to worse results than expected. The obtained results are in the direction that, if the remaining root exceeds 2 mm of thickness, then the bone remodeling surrounding the implant is not beneficial as could be expected. In this study, great bone remodeling was observed in the samples that preserved more than 2 mm of root and the bone apical migration was greater than in the conditions of less root. On the other hand, the thickness of peri-implant bone directly influences the results obtained. In this direction, when peri-implant bone preserved was more than 3 mm of thickness, the behavior of the peri-implant tissue was better than in the cases of thin bone.

One of the deficiencies of this technique can be observed In some histological images where there are small root fractures, probably due to the milling procedure established for the placement of implants and also to the difference in diameter between the drills and the implant placed. To avoid this situation, it is necessary to use a small compensation with the drilling technique, where the last drill must have the same diameter as the implant.

In the most favorable cases, new bone formation can be observed in the internal part of the roots, when enough space is created to allow new cell migration and the bone remodeling process in this area, this can be seen in accordance with the study of Bäumer et al. (2015), which observed the presence of cementum between implant and tooth segment and concludes that this effect is desired. These authors also evaluate the effect of separating the buccal shield in the extraction socket in two pieces before immediate implant placement and, observed that it may offer a feasible treatment option for vertically fractured teeth.

In other studies, decoronation may be considered a type of guided bone regeneration due to the fact that the remaining residual root will undergo a resorptive process by osteoclasts from the adjacent bone marrow and gradually be replaced by bone. Multiple studies have shown, that the decoronation of ankylosed teeth predictably preserves the alveolar ridge contour (Malmgren 2000; Filippi et al. 2001; Cohenca & Stabholz 2007; Sapir & Shapira 2008).

The results of the present study illustrate that a nonankylosed tooth fragment does not appear to undergo resorption processes. Furthermore, the retained root appears to preserve its characteristics with particular respect to its periodontal ligament and the supra-periosteal attachment for conserve the volume of soft tissues.

Nevertheless, the buccal root retention fragment does not compensate the papillae retraction following multiple adjacent tooth extractions, whereas it may be obtained with proximal root retention fragments, the combination of the SST and the proximal root retention has allowed the full-three-dimensional preservation of alveolar architecture around these two implants (Cherel et al. 2014).

The presence of new bone between the implant and the dentine can be observed. It may be possible that it can prevent the resorption of the bundle bone and conserve the soft tissue in the aesthetic zones.

The aims of implant placement after drilling over roots are to prevent the traumatic dilaceration of the alveolar bone and the need for bone grafting and to obtain the same advantages of time, reduction in procedures and less surgical morbidity of the implant immediately placed in a fresh socket (Cardoso et al. 2014).

Otherwise, these techniques present the disadvantage of the difficulty of its procedure, separating the root portions and leaving only one part of the root in the alveolar socket.

1. Conclusions

Within the limitations of an animal pilot study, root-T belt technique may be beneficial in preserving and protecting the bundle bone and preserve soft tissues. However it is a matter for study, and needs more histological evidence and long term follow-up before application as a technique. If the thickness of the buccal bone is 3mm and the thickness of the remaining root fragment is 2mm the socket shield technique is more predictable and the bone contours can be maintained.

1. Conflict of interest

The authors declare that they have no conflict of interest.

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Thickness	**< 2 mm root**	**2-4mm root**	**> 4mm root**
< 3 mm Bone	Group 1	Group 2	Group 3
> 3 mm Bone	Group 4	Group 5	Group 6

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Fig. 1 Clinical and experimental protocol: (a) preclinical situation, (b) Crown preparation, (c) drilling protocol and, (d) impant placement.

Fig. 2 Image of the implant installed (a) and radiograph image (b).

Fig. 3 Factors related with group clasification. New bone (NB), remaining root (R), periimplant bone (B).

Fig. 4 Diagram to explain the measurement positions of the bone loss using the software Image Tool. Yellow lines = measurements from implant shoulder to the first bone-implant contact.

Fig. 5 Histological images of samples, from group 1 to group 6. Magnificarion 200 **x.**

Table 1 Sample distribution in relation to root thickess and remaning bone.

Table 2 Bone thickness and remaining root measurements. Mean ± Sd and Medians. Friedman Test was applied to the comparison of the medians. P < 0.05.

Table 3 Histomorphometrical analysis of the samples. Values as Mean ± Sd and

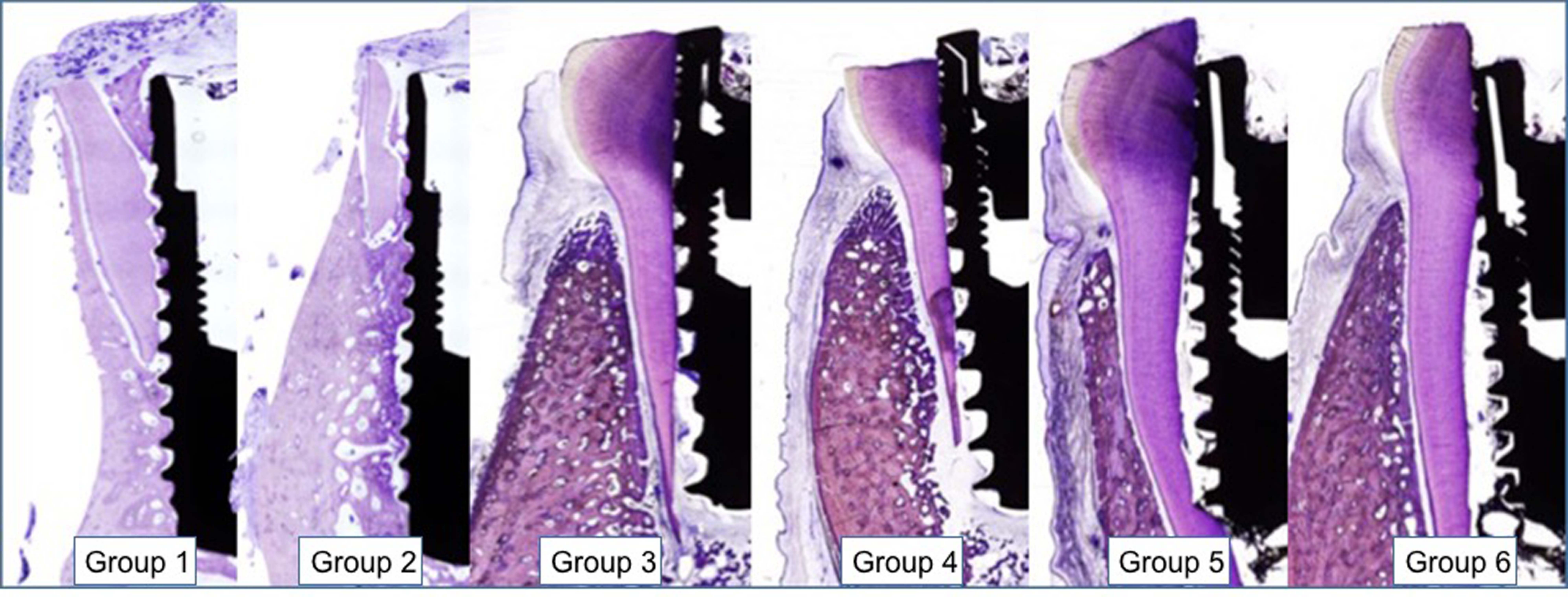
Thickness (mm)	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Gr**
Root	1.1 ± 1.02	2.53± 0.93	4.31 ± 1.05	1.63 ± 0.43	2.37 ± 0.53	5.12
Bone	1.93 ± 0.23	2.13 ± 0.64	1.65 ± 1.02	3.09 ± 0.43	3.63 ± 1.19	4.24

medians (x). Friedmann Test was applied to comparison of the medians. P < 0.05.

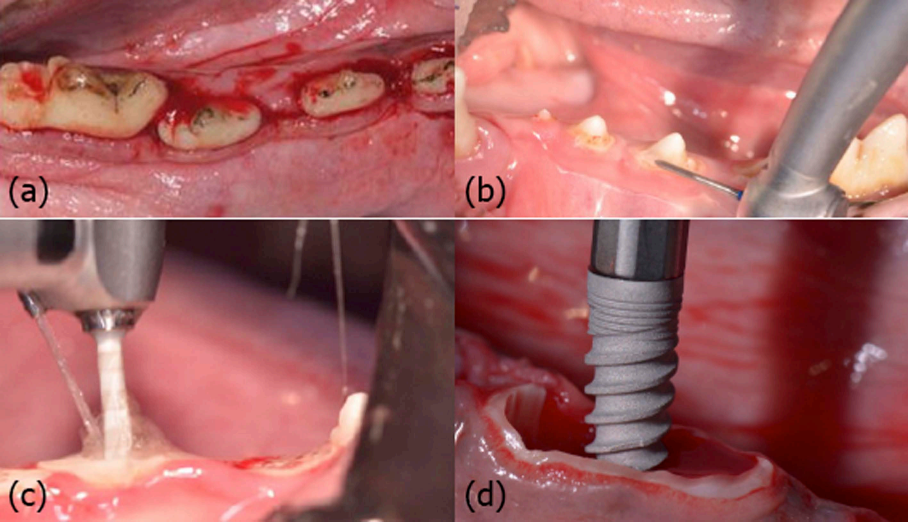
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	P value
BIC (%)	52.12 ± 8.43 (52.11)	48.54 ± 1.94 (48.54)	42.37 ± 10.03 (42.33)	65.34 ± 5.16 * (65.34)	61.74 ± 3.12 ** (61.74)	54.14 ± 4.83 (54.15)	* 0.032 ** 0.024
IS-Bc (mm)	3.05 ± 0.11	3.71 ± 0.26	6.31 ± 3.11*	2.65 ± 0.53	2.95 ± 0.47	5.57 ± 1.73**	* 0.008 ** 0.011
Is-Lc (mm)	2.95 ± 1.02	3.64 ± 2.03	5.92 ± 3.01*	1.93 ± 0.14	2.08 ± 2.01	5.04 ± 2.10**	*0.003 **0.032

Table 4. Radiological analysis of lineal measurements. Values as Mean ± Sd and Medians (x). Friedmann Test for comparison of medians. P < 0.05.

(mm)	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**P value**
IS-Bc	3.13 ± 0.54	3.89 ± 2.01	5.93 ± 2.11*	2.74 ± 2.01	3.01 ± 0.64	6.01 ± 2.23**	* 0.024 **0.003
IS-Lc	2.84 ± 1.32	3.74 ± 0.84	5.99 ± 1 02*	1.95 ± 0.93	2.87 ± 1.05	5.79 ± 1.45**	*0.013 **0.024


Group 1
Group 2
Group 3
Group 4
Group 5
Group 6


NB
NB
R
R
B
B


(a)
(b)
(c)
(d)