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Bone volume changes after immediate implant placement with or without flap elevation

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Key words: bone dimensions, bone graft, cone beam computer tomography, immediate implant

Abstract

Objectives: The aims of this prospective study were to evaluate bone dimensions after immediate implant placement with simultaneous grafting of the buccal gap, to determine if initial buccal bone width had an influence on bone remodelling and to compare bone volume changes using a flap or a flapless approach after 6 months of healing.

Material and methods: This prospective study included patients who required an extraction and a subsequent immediate implant placement at a non-molar site. In those cases where tooth extraction was not feasible with a flapless approach (test group) a mucoperiosteal flap was carefully elevated (control group). After extraction, a cone beam computed tomography (CBCT) was taken. Then, an implant was placed and the buccal gap was grafted using anorganic bovine bone. After 6 months of healing, a second CBCT was performed. A blinded investigator superimposed both images and performed a series of measurements to determine bone volume changes between the two time points.

Results: Thirty-five patients were included in this study, 20 of which belonged to the test group. All together, the differences between baseline and 6 months in buccal plate height, lingual plate height and in ridge width at 2, 4 and 6 mm were 0.48 ± 1.35; 0.58 ± 1.51; 0.64 ± 0.81; 0.59 ± 1.36 and 0.52 ± 1.16, respectively. Only a moderate correlation was observed between initial buccal plate width and buccal plate height at 6 months ($P = 0.0001$). No statistically significant differences were observed between flap and flapless approach.

Conclusions: A mean reduction of around 0.5 mm in height and width after placing immediate implants and filling the residual gap with anorganic bovine bone may be expected. No significant association between initial buccal bone width and ridge width at 6 months was seen. No statistically significant differences were found between the two treatment protocols although more ridge reduction was observed for the flap group.

Dental implants are a consolidated treatment for replacing missing teeth, allowing the restoration of chewing function, speech, and aesthetics. Implants are inserted into the jawbone in order to support a dental prosthesis and remain stable due to the bone growth onto their surface. Such direct, structural and functional connection between the living bone and the implant surface, termed osseointegration (Branemark et al. 1969), has surely been one of the most significant scientific breakthroughs in dentistry over the past 40 years.

Traditionally, before placing dental implants, compromised teeth are removed and the extraction sockets are left to heal for several months. However, alveolar ridge resorption after tooth extraction may considerably reduce the residual bone volume (Van der Weijden et al. 2009; Tan et al. 2012) and compromise the favourable implant positioning required for an optimal prosthetic restoration. Such aspect is even more pronounced in the anterior maxilla, where ridge resorption is more pronounced in the buccal wall (Van der Weijden et al. 2009; Tan et al. 2012) leading to an unfavourable buccolingual discrepancy between the implant and the prosthesis.

On the other hand, a shortened treatment time between tooth removal and implant placement as well as a reduction in the amount of surgical procedures is becoming

an essential requirement of patients in our daily practice. Therefore, the placement of implants immediately after tooth extraction has been proposed. This concept was already introduced in the late 1970s (Schulte & Heimke 1976) and has been extensively reviewed during the last decades (Lazzara 1989; Werbitt & Goldberg 1992; Watzek et al. 1995; Ferrus et al. 2010; Cosyn et al. 2011; Benic et al. 2012; Lang et al. 2012; Chen & Buser 2014). It was first thought that, to place and implant at this timepoint, would avoid bone remodelling (Werbitt & Goldberg 1992; Watzek et al. 1995) but clinical and experimental evidence has shown that a reduction in height and width - especially of the buccal plate- will still take place (Araújo et al. 2005, 2006; Ferrus et al. 2010). From an aesthetic point of view, these dimensional changes may lead to midfacial recession in the long-term (Chen & Buser 2014). It seems clear that a careful case selection -intact socket walls, a medium to thick biotype-, lingualized positioning of the implant and adequate primary stability as well as well as clinician's expertise are essential in order to achieve a stable aesthetic outcome (Lang et al. 2012; Chen & Buser 2014). Furthermore, in the past years different strategies have been developed in order to minimize the risk of mucosal recession. First, some authors have tried to regenerate the missing bone between the implant surface and the socket walls using various bone augmentation techniques such as autogenous bone grafts (Becker et al. 1994a,b), bone substitutes (Cosyn et al. 2011; Benic et al. 2012), guided bone regeneration with resorbable (Koh et al. 2011) or non-resorbable barriers (Becker et al. 1994a,b) and various bone promoting molecules such as enamel matrix derivative (Cangini & Cornelini 2005). In addition, some have advocated to thicken the soft tissues by placing a connective tissue graft at the time of surgery (Bianchi & Sanfilippo 2004; Miglioratti et al. 2015). Last but not least, experimental studies in dogs have suggested that a flapless approach could minimize buccal bone resorption because the blood supply coming from the periosteum is kept unaltered (Blanco et al. 2008).

The aims of the present study were (i) to evaluate alveolar bone dimensions after immediate implant placement in sockets with an intact buccal plate, grafting the gap between the implant and the socket wall with anorganic bovine bone graft (ii) to determine if initial buccal bone width has an influence on bone volume changes (iii) to compare the bone volume changes using a flap or a flapless approach after 6 months healing.

Material and methods

Patient selection

This prospective study was performed between January 2012 and January 2014 at the Dental Clinic of the University of Padova. The study was approved by the University of Padova Ethical Committee (Ref. 2571-P, 12-03-2012) and was in accordance with the Helsinki Declaration of 1975, as revised in 2008. Written informed consent was obtained from all the subjects included in the study.

The patient inclusion criteria were as follows: (i) dentate patients having one non-molar tooth planned for extraction (ii) full mouth plaque score (FMPS) and full mouth bleeding scores (FMBS) <25% at study baseline; (iii) eventual loss of attachment limited only to areas different from the sites included in the study and (iv) a primary stability of at least 35N at implant placement.

Patient exclusion criteria were as follows: (i) patients with medical history in which any dental intervention would be contraindicated; (ii) any local or systemic disease, conditions or medications that might compromise healing and/or affect the periodontium; (iii) smoking habit; (iv) inability or unwillingness to return for follow-up visits and (v) presence of a dehiscence or fenestration in the buccal wall after tooth extraction.

Sample size calculation

Sample size calculation was performed before patient enrolment and was based on the main study outcome: bone dimensions changes at 6 months. A paired difference in bone width of 1 mm between groups was considered clinically relevant. Assuming an alpha risk of 5% and a beta risk of 20% in a two-sided test, a total of 30 patients (15 subjects in each group) were necessary to recognize as statistically significant a difference equal or >1 mm. A common standard deviation between 1.1 mm was considered (Ferrus et al. 2010).

Surgical procedures

One hour before the surgical procedure, patients began a prophylactic antibiotic regimen consisting of 2 g of amoxicillin and clavulanic acid (Augmentin®, Roche, Milan, Italy). All procedures were performed under local anaesthesia (articaine chlorhydrate 4% and adrenaline 1:100000 -Alfacaina N, Weimer Pharma, Rastat, Germany-) and sedation was arranged if needed. First, tooth extraction was performed in a gentle way to minimize the mechanical trauma onto the surrounding bone. If tooth extraction was not feasible with a flapless approach due to root fracture or a complete destruction of the coronal third of the root, a mucoperiosteal flap was carefully elevated. The periodontal ligament attached to the bone in the socket walls was left undisturbed. If present, granulation tissue was carefully removed from the socket.

Immediately after the extraction a CBCT (Kodak 9000, Kodak Dental System, Rochester, NY, USA) was taken in order to evaluate the integrity of the facial wall of the socket. If a full-thickness flap was needed in order to remove the tooth, the patient was allocated to the control group. Otherwise, when flapless extraction was feasible, the patient was allocated to the test group.

Control Group (flap approach)

An immediate implant installation (NT Osseotite® 3i, Palm Beach, FL, USA) was performed. The existing gap between the implant and the facial wall was filled with small granules of anorganic bovine bone graft (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland). No membrane was used. A healing abutment was placed and the flap sutured around it after being repositioned (Fig. 1).

Test Group (flapless approach)

An immediate implant installation was performed with a flapless approach. Again, the gap was filled with small granules of anorganic bone substitute graft and a healing abutment was placed (Fig. 2).

All implants were placed 3 mm apical to the margin of the prosthetic crown and oriented towards the cingulum of the future implant supported crown of incisors and canines or the centre of the oclusal aspect in the case of premolars.

Post-operative care

A Maryland provisional prosthesis was placed immediately after the surgery. Patients received antibiotic therapy with 1000/62.5 amoxicillin/clavulanic acid (Augmentin Plus®, Roche) twice a day for 6 days. Ibuprofen 400 mg was prescribed three times per day if needed.

Follow-up visits

Suture removal was scheduled 1 week after surgery. Patients were then scheduled for a follow-up visit 1, 3 and 6 months after surgery. By the end of the fifth month, all implants were loaded.
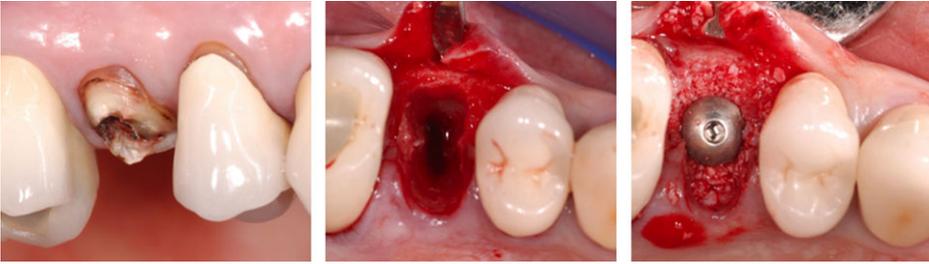
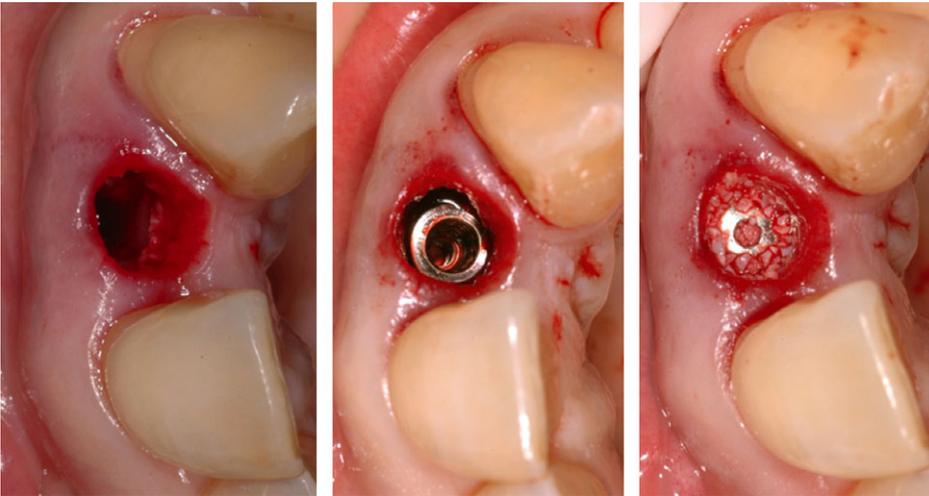Fig. 1. Implant placement in the flap group.

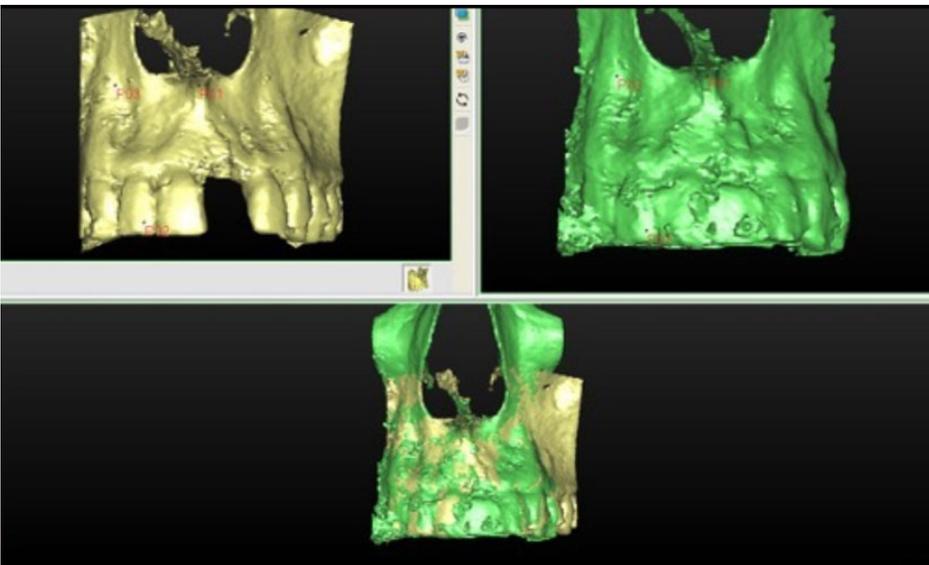
Fig. 2. Implant placement in the flapless group.

Fig. 3. Superposition of CBCT1 and CBCT 2 using the infraorbital foramen, the anterior nasal spine and the incisal edge of 11 as a reference.

At 6 months, a second CBCT was performed. At this point, a clinical evaluation was made and standardized periapical radiographs were taken in order to evaluate the peri-implant baseline bone levels.

Surgical and prosthetic complications were recorded any time they occurred. Patients were recalled at 3 and 6 months after prosthesis delivery.

CBCT analysis

A first CBCT (Kodak 9000, Kodak Dental System) (CBCT1) was taken immediately after extraction and before implant placement and a second CBCT (CBCT2) was taken at 6 months at final prosthesis delivery. The 3D reconstructions of both CBCTs were superimposed using Simplant Pro® 2011 (Dentsply Spain, S.L.) according to the technique described by Jung et al. (2013). At least three anatomical reference points were established on each 3D image in order to match CBCT1 and CBCT2 (Fig. 3). A manual adjustment was applied when necessary to fit small discrepancies at the final superposition. The measurements were made at baseline and at 6 months using the same reference points and lines (Fig. 4). A horizontal reference line was drawn at the base of the socket and a perpendicular line from this reference was used in the centre of the extraction socket as the vertical reference. The baseline buccal plate width (BW) was assessed at 1 mm, 3 mm and 5 mm below the most coronal aspect of the buccal bone crest in a coronal section of CBCT1. Height was measured from the most coronal aspect of the buccal and lingual bone crest in CBCT1 and CBCT2 to the horizontal reference line. Then, the difference between measurements was calculated to express the dimensional change in height between groups. The width of the ridge was measured in CBCT 1 and CBCT 2 at 2 mm, 4 mm and 6 mm below the most coronal aspect of the buccal bone crest of CBCT1 in a coronal view, and then the width difference was calculated for each group and expressed in mm to assess the width dimensional changes at 6 months (Figs 5 and 6).

Investigators calibration

An examiner (D.J.) was trained on the use of the proposed measurements systems and was blinded with respect to the treatment group (flap and flapless). All needed clarifications were provided before the study. Each selected site was evaluated twice, independently and blindly. Bone level changes were recorded for each treated site. There was no time restriction during the procedure.

Intra-examiner reliability was conducted by the repeated examination of the buccal plate thickness at 1, 3 and 5 mm in 5 patients, 24 h apart, before beginning the study. Considering that 90% of the recordings could be reproduced within a difference of 0.5 mm, a high reliability was observed (Cronbach's alpha 0.995).

Statistical evaluation

For description of the data, mean values, standard deviations (SD) and frequencies were used. Patients lost to follow-up examinations were censored. All testing was per-
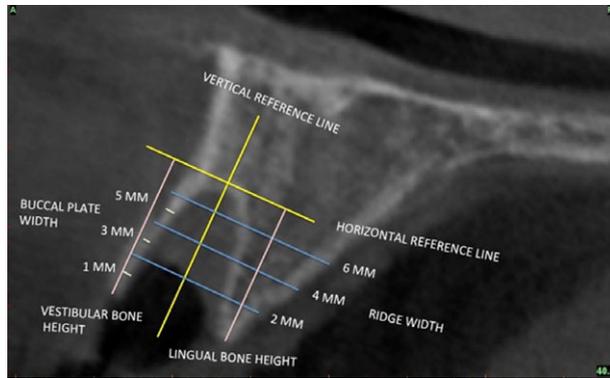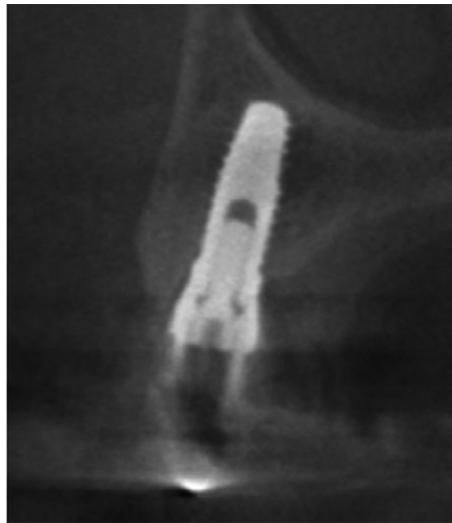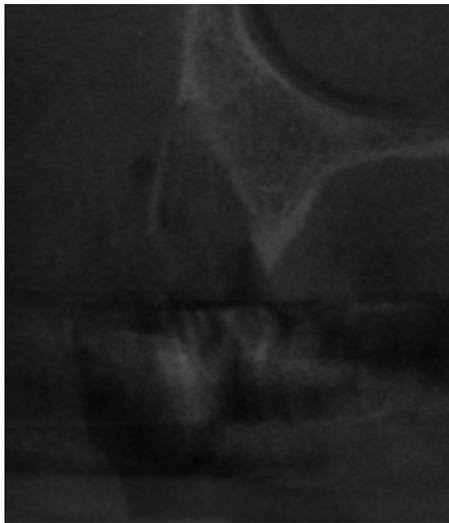
Fig. 4. Measurements taken on the CBCT scans.

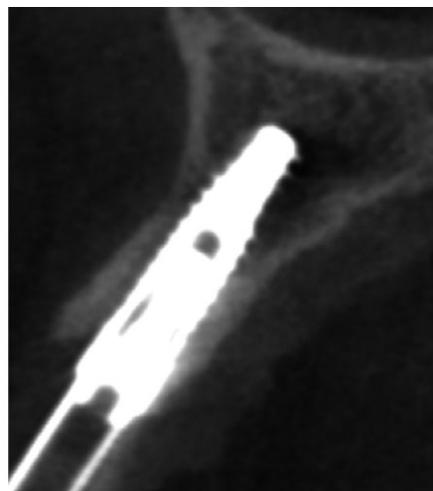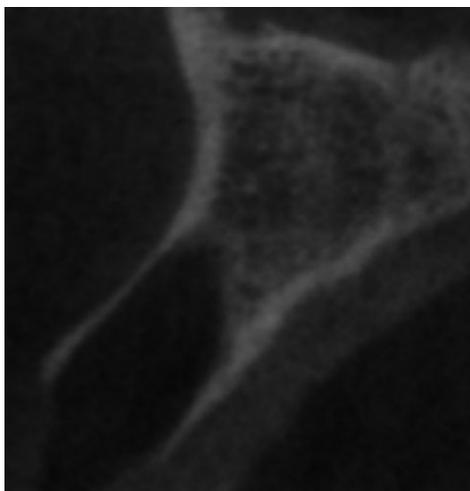*Fig. 5.* CBCT1 and CBCT2 in the flap group.

Fig. 6. CBCT1 and CBCT2 in the flapless group.

formed by the use of SPSS 22.0 software package (SPSS inc., Chicago, IL, USA).

Kolmogorov–Smirnov test was used to determine the distribution of continuous variables. Continuous variables were expressed as means ± standard deviation and compared at baseline by the U Mann–Whitney test. Mean changes between 6 months

(CBCT2) and baseline measurements (CBCT1) were analysed using Wilcoxon test and mean changes between 6 months (CBCT2) and baseline measurements (CBCT1) between groups were analysed by U Mann–Whitney Test. A Spearman test was used to evaluate correlations between baseline buccal plate width and ridge width and between baseline buccal plate width and buccal plate height at 6 months. Significance was set at alpha = 0.05 in all tests.

Results

A total of 35 patients were recruited (22 women/13 men, mean age: 54 ± 19.7 years). Of the 35 inserted implants, 20 belonged to the flapless group and 15 to the flap group. Implant locations and reasons for extraction are detailed in Table 1. All patients completed the study and no complications occurred during any of the surgical procedures or during the 6-months follow-up.

General analysis
During the entire observation period, a reduction in buccal and lingual alveolar bone height, as well as in ridge width was seen (Table 2). The differences between baseline and 6 months in buccal plate height, lingual plate height and in ridge width at 2, 4 and 6 mm were 0.48 ± 1.35; 0.58 ± 1.51; 0.64 ± 0.81; 0.59 ± 1.36 and 0.52 ± 1.16 respectively.

When analysing the influence of the initial buccal plate thickness on volume changes at 6 months, a moderate positive linear relationship (rho: 0.561, $P = 0.001$) was observed between baseline buccal plate width at 1 mm and a reduction in buccal plate height. However, no correlation was observed between baseline buccal plate width at 3 mm and 5 mm and ridge width at 6 months (Table 3).

Flap vs. flapless approach
No statistically significant differences were found between groups at baseline. Table 4 shows the mean dimensions at baseline and at 6 months in both treatment groups. In the control group, a mean difference of 1.03 ($P = 0.006$) in vestibular height was observed while the ridge width decreased 0.84 mm ($P = 0.003$), 1.09 mm ($P = 0.005$) and 0.91 mm ($P = 0.024$) at 2, 4 and 6 mm, respectively. A reduction in width of $9.07 \pm 8.52\%$ at 2 mm, $9.09 \pm 11.61\%$ at 4 mm and $7.22 \pm 9.51\%$ at 6 mm was observed. In the flapless group on the other hand, the only statistically significant bone

dimension changes between the two observation time points were detected for lingual plate height (mean decrease of 0.91 mm; $P = 0.018$) and ridge width at 2 mm (mean decrease of 0.48 mm; $P = 0.028$). Ridge width decreased $5.44 \pm 9.88\%$, $2.02 \pm 9.57\%$ and $2.89 \pm 10.99\%$ at 2, 4 and 6 mm, respectively. The differences from baseline to 6 months in ridge height and width between treatment groups did not reach statistical significance (Table 5).

Discussion

An adequate bone housing of implants has been associated with long-term peri-implant soft tissue stability and, in consequence, with an aesthetic outcome (Grunder et al. 2005). For this reason, different strategies have been developed in order to minimize bone loss around implants. The results of this investigation show that immediate implant placement with simultaneous grafting does not entirely avoid bone resorption. Thus, a mean reduction of around 0.5 mm in height and width were observed. These values are in accordance with the outcomes presented in a recent meta-analysis, where a mean vertical reduction of 0.78 mm in the buccal wall and 0.50 mm on the lingual plate were reported (Lee et al. 2014). Interestingly, ridge preservation procedures, originally intended to maintain the bone volume after tooth extraction, have also shown some reduction in height and width (Vignoletti et al. 2012). Jung et al. (2013) using CBCTs showed a mean horizontal reduction of 0.6 mm and a vertical reduction from 0.0 to 1.2 mm at extraction sites filled with anorganic bovine bone with no flap elevation at 6 months of healing. Although immediate implant placement may lead to a similar reduction in width as ridge preservation, it limits the number of surgical interventions and chair-time, increasing thereby patients' satisfaction.

The buccal plate receives blood supply from the periodontal ligament, the bone marrow and the outer periosteum (Carranza et al. 1966). If we take into account that the buccal bone wall in maxillary anterior teeth is in most cases <1 mm thick (Huynh-Ba et al. 2010), the bone at this site will be mostly comprised by cortical bone. When a tooth is removed, the blood supply coming from the periodontal ligament disappears and the only remaining reservoir comes from the periosteum. Furthermore, if a flap is raised, this last source vanishes and, as a consequence, the buccal plate may resorb. For this reason, it seems reasonable to hypothesize that: a) a thinner buccal plate at baseline may lead to a more pronounced bone resorption and b) flap-less surgeries could minimize bone loss. With respect to the first hypothesis, a moderate positive correlation was found between the initial buccal bone plate thickness 1 mm

Table 1. Tooth type and reason for extraction in both treatment groups

Variables	Baseline (CBCT1) mean (SD)	6 months (CBCT2) mean (SD)	P value*
Buccal plate width 1 mm	1.205 (1.0)		—
Buccal plate width 3 mm	1.26 (0.81)		—
Buccal plate width 5 mm (n = 32)	1.095 (0.77)		—
Buccal height	19.5 (4.7)	19.0 (4.2)	0.045[†]
Lingual height	17.9 (2.9)	17.3 (3.2)	0.036[†]
Ridge width 2 mm (n = 31)	9.2 (1.8)	8.4 (1.6)	0.001[†]
Ridge width 4 mm (n = 34)	9.6 (2.0)	9.0 (1.7)	0.005[†]
Ridge width 6 mm (n = 34)	10.0 (2.3)	9.4 (2)	0.008

*Wilcoxon test for paired samples.
[†]Statistical significance.

Table 2. Mean height and width values at baseline and 6 months

	Difference ridge width 2 mm (6 months)	Difference in ridge width 4 mm (6 months)	Difference in ridge width 6 mm (6 months)
Rho Spearman			
Baseline buccal plate width 1			
Correlation coeficient	0.110	0.203	0.561
Sig. (bilateral)	0.586	0.250	0.001*
N	27	34	34
Baseline buccal plate width 3			
Correlation coeficient	0.238	0.058	0.246
Sig. (bilateral)	0.232	0.743	0.160
N	27	34	34
Baseline buccal plate width 5			
Correlation coeficient	0.000	0.044	0.046
Sig. (bilateral)	0.998	0.815	0.803
N	24	31	32

*Statistical significance.

Table 3. Correlations between baseline buccal plate width at 1 mm, 3 mm and 5 mm and ridge width at 2 mm, 4 mm and 6 mm at 6 months

	Baseline			6 months			
	Flap Mean (SD) n = 15	Flapless Mean (SD) n = 20	P value*	Flap Mean (SD) n = 15	P value[†]	Flapless Mean (SD) n = 20	P value[‡]
Buccal plate width 1 mm	1.15 (0.6)	1.24 (0.9)	0.458				
Buccal plate width 3 mm	1.35 (0.6)	1.19 (0.9)	0.635				
Buccal plate width 5 mm (n = 32)	1.35 (0.9)	0.89 (0.6)	0.156				
Buccal height	21.12 (4.8)	18.34 (4.5)	0.080	20.09 (4.4)	0.006	18.26 (4.0)	0.841
Lingual height	17.25 (3.3)	18.33 (2.7)	0.730	17.10 (3.6)	0.691	17.41 (2.9)	0.018
Ridge width 2 mm (n = 31)	9.88 (1.8)	8.66 (1.7)	0.059	8.51 (1.3)	0.003	8.35 (1.8)	0.028
Ridge width 4 mm (n = 34)	10.21 (2.1)	9.05 (1.9)	0.104	9.11 (1.3)	0.005	8.85 (1.9)	0.205
Ridge width 6 mm (n = 34)	10.74 (2.6)	9.42 (1.26)	0.138	9.80 (1.7)	0.024	9.17 (2.3)	0.198

*U Mann–Whitney test.
[†]Wilcoxon test (related analysis in flap group).
[‡]Wilcoxon test (related analysis in flapless group).

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