CLINICAL ORAL IMPLANTS RESEARCH

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Factors influencing ridge alterations following immediate implant placement into extraction sockets

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Abstract

Aim: To identify factors that may influence ridge alterations occurring at the buccal aspect of the extraction site following immediate implant placement.

Material and methods: In 93 subjects, single-tooth implants were placed immediately into extraction sockets in the maxilla (tooth locations 15–25). A series of measurements describing the extraction site were made immediately after implant installation and at re-entry, 16 weeks later. The implant sites were stratified according to four factors: (i) implant location (anterior/posterior), (ii) cause of tooth extraction (periodontitis/non-periodontitis), (iii) thickness of the buccal bone walls ($\leq 1/>1$ mm) and (iv) the dimension of the horizontal buccal gap ($\leq 1/>1$ mm).

Results: (i) The location where the implant was placed (anterior/posterior) as well as (ii) the thickness of the buccal bone crest and (iii) the size of the horizontal buccal gap significantly influenced the amount of hard tissue alteration that occurred during a 4-month period of healing. At implant sites in the premolar segment, the fill of the horizontal gap was more pronounced than in the incisor–canine segment, while the vertical crest reduction was significantly smaller. Furthermore, at sites where the buccal bone wall was thick (>1 mm) and where the horizontal gap was large (>1 mm), the degree of gap fill was substantial.

Conclusions: The thickness of the buccal bone wall as well as the dimension of the horizontal gap influenced the hard tissue alterations that occur following immediate implant placement into extraction sockets.

It is well known that following single-tooth extraction, marked alterations occur in the edentulous site. Thus, not only the buccal–lingual/palatal dimension (about 50%) but also the height of the buccal bone crest will be decreased (e.g. Schropp et al. 2003; Botticelli et al. 2006). It has been suggested that the placement of an implant in the fresh extraction socket may – to some extent – counteract alveolar ridge contraction following tooth removal (Denissen et al. 1993; Watzek et al. 1995). This hypothesis was not validated in recent studies in humans and experimental animals (e.g. Botticelli et al. 2004; Araújo et al. 2005, 2006; Sanz et al. 2009).

Hard and soft tissue changes, as well as aesthetic outcomes at sites where implants were placed immediately into extraction sockets (Type I placement according to Hämmerle et al. 2004), were recently reported (Chen et al. 2007; Evans & Chen 2008). During an 18-month period after Type I placement, there was a 1.7 mm reduction of the radiographic bone height and about 1 mm recession of the buccal soft

tissue margin. In addition, Evans & Chen (2008) observed that the position of the implant immediately placed within the extraction socket as well as the tissue biotype were important factors determining treatment outcomes.

The objective of the present paper was to further describe factors that may potentially influence the ridge alterations that occur at the buccal aspect of the extraction site following immediate implant placement.

Material and methods

The study population included in the present material was described in detail (Sanz et al. 2009). In brief, in 93 subjects, single-tooth implants (Fixture MicroThread™ OsseoSpeed™, Astra Tech AB, Mölndal, Sweden) were placed immediately into extraction sockets in the maxilla. A series of measurements describing the extraction site were made immediately after implant installation and at re-entry, 16 weeks later (Fig. 1; see Sanz et al. 2009). All implants were placed in the maxilla between tooth locations 15 and 25.

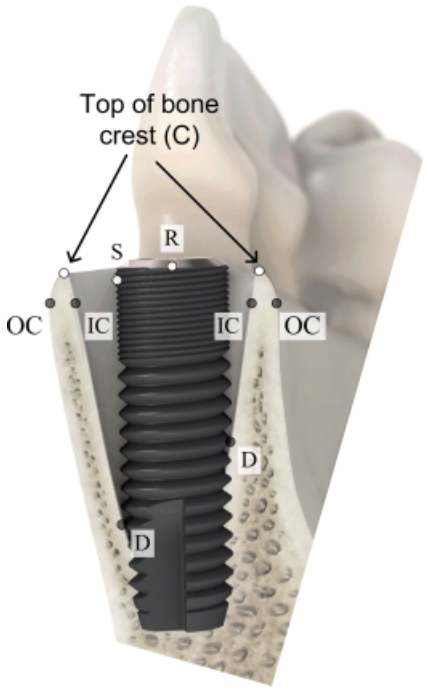

Fig. 1. Landmarks used to describe the dimension of the ridge as well as the size of the gap between the implant and the socket walls. •Surface of implant (S), •Rim of implant (R), •Top of the bone crest (C), •Outer border of the bone crest (OC), 1 mm apical of C, •Inner border of the bone crest (IC), 1 mm apical of C, •Base of the defect (D).

From the total implant population ($n = 93$), sites were stratified according to four factors: (i) implant location [anterior (incisors and canines)/posterior (first and second premolars)], (ii) main cause of tooth extraction (periodontitis/non-periodontitis), (iii) thickness of the buccal bone walls ($\leq 1 / > 1$ mm) and (iv) the dimension of the horizontal buccal gap ($\leq 1 / > 1$ mm).

For each aspect, the alterations that occurred between surgery and re-entry (16 weeks) were compared between the groups (Fig. 1):

- S to IC, the horizontal defect distance, i.e. the width of the gap between the implant surface and the bone crest (*S–IC buccal*).
- S to OC, the horizontal distance between the implant surface and the outer surface of the bone crest (*S–OC buccal*).
- R to D the vertical defect distance between the rim of the implant and the base of the defect (*R–D buccal*).
- R to C, the vertical distance between the rim of the implant and the top of the bone crest (*R–C buccal*. This measure could be assigned a positive or a negative value depending on whether R was located apical of (positive) or coronal (negative) to the bone crest (C).
- The thickness of the buccal one walls was measured at surgery 1 mm apical of the top of the bone crest.

Data analysis

In the previous publication from this clinical trial (Sanz et al. 2009), the null hypothesis and sample size calculation are described in detail. From the results reported in the current publication, we have assumed that the various alterations that occur during healing were independent of the group allocation (A or B), and therefore, we have aggregated data from both treatment groups and have stratified these data among the different factors that presumably may influence these changes.

Continuous variables were presented by mean and standard deviation (SD) and discrete variables by frequency and percentage.

The *P*-values were two sided and calculated by means of Student's *t*-test, and in addition, due to the nature of the data also by means of the non-parametric Wilcoxon's rank sum test. It was not possible to assume that a normal distribution was achieved in all groups after stratification. Thus, some samples were too small to satisfy the criteria of the central limit theorem. No adjustment for multiple tests was applied and hence the risk for multiplicity problems should be taken into account.

A two-sided *P*-value of $P \leq 0.05$ was considered to be statistically significant.

Results

The baseline characteristics of the extraction sites and the implants are presented in Table 1. Of the teeth extracted, 68% were removed due to caries/endodontic reasons and 17% due to advanced periodontal disease. Forty two per cent were anterior teeth (incisors and canines) and 58% were first and second premolars. The majority of the implants were 11–15 mm in length (92%) and 4–4.5 mm in diameter (92%).

Implant location (anterior/posterior)

Thirty-nine implants were placed in the anterior and 54 in the posterior region. Figures 2 and 3 illustrate cases where implants have been placed in the anterior segment (Fig. 2) or in the premolar area (posterior location) (Fig. 3). Following placement of the implant in the central incisor area, a large buccal gap occurred (Fig. 2b). At re-entry, 4 months later, the gap had been completely filled with newly formed bone. In this case the S–IC distance (Fig. 1) changed from 4 mm at baseline to 0 mm at 4 months. A change of the profile of the buccal bone wall could also be observed (Fig. 2d). In Fig. 3, the first premolar was removed and replaced with a cylindrical-shaped implant. Following implant installation, a large defect was present between the implant surface and the buccal bone wall (Fig. 3b). At re-entry, 4 months later, it was observed that the buccal defect had been resolved (Fig. 3c).

Horizontal ridge reduction (S–OC; Table 2)

The horizontal ridge dimension at baseline in the posterior sites was significantly greater than in the anterior sites (3.5 ± 1 vs. 2.3 ± 1 mm). The mean reduction of S–OC was 1 mm (42%) in the anterior sites and 1.1 mm (32%) in the posterior sites. This reduction between the two locations was not statistically significantly different.

Table 1. **Baseline characteristics at implant lacement**

Baseline characteristics	Total ($n = 93$)	
Reason for extraction (*n* and % of subjects)		
Trauma	10	11%
Caries/Endodontic	63	68%
Periodontitis	16	17%
Other	4	4%
Teeth extracted (*n* and % of subjects)		
Anterior (incisors and canines)	39	42%
Posterior (premolars)	54	58%
Implant length (mm) (*n* and % of subjects)		
9	3	3%
11	19	20%
13	42	45%
15	21	23%
17	7	8%
19	1	1%
Implant diameter (mm) (*n* and % of subjects)		
3.5	1	1%
4	44	47%
4.5	42	45%
5	6	6%

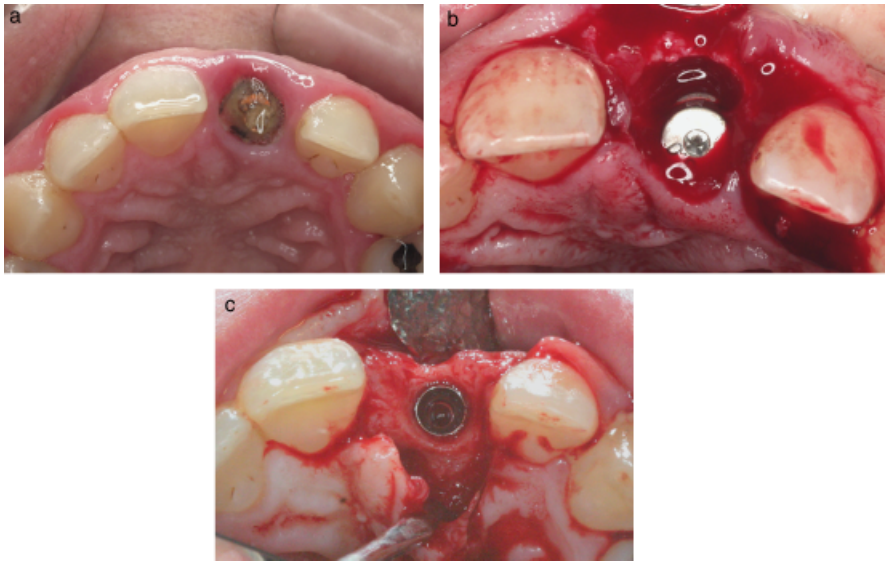

Fig. 2. A central incisor site from which the fracture root was removed (a). A cylindrical implant was placed in the fresh extraction socket (b). Note the presence of a large void between the implant and the buccal bone wall. At re-entry, 4 months later (c), the void has been filled with bone and no residual gap can be detected. Note also the change of the profile of the buccal bone wall.

Horizontal gap fill (S–IC; Table 2)

The mean thickness of the buccal bone wall (measured 1 mm apical of the crest) was 0.8 ± 0.4 mm in the anterior and 1.1 ± 0.5 mm in the posterior sites. This difference between the two locations was statistically significant. The size of the horizontal gap at baseline was greater at the posterior than at the anterior sites (2.5 ± 1.1 vs. 1.5 ± 0.8 mm; $P = 0$). The mean horizontal gap fill was significantly greater at the posterior sites than at the anterior sites (1.8 ± 1.2 vs. 1.1 ± 0.8 mm).

Vertical gap fill (R–D; Table 2)

The vertical gap at baseline at anterior and posterior sites was similar (7.5 ± 3.9 vs. 7.4 ± 3 mm). The amount of gap fill during healing was substantial (about 65%) and similar in the two sites (5 ± 4.4 vs. 5.3 ± 3.5 mm).

Vertical crest reduction (R–C; Table 2)

The reduction of the height of the buccal bone crest was twice as large at the anterior than at the posterior sites (−1.4 ± 2.5 vs. −0.7 ± 1.4 mm). This difference between the two locations was, however, not statistically significant.

Cause of tooth extraction (periodontitis/non-periodontitis)

Sixteen teeth were extracted due to advanced periodontitis (17%). Figure 4 illustrates a 'periodontitis site' in a central anterior tooth location. Note the advanced attachment loss that had occurred in adjacent teeth (Fig. 4a). A large defect was present between the implant and the buccal bone crest (Fig. 4b). The wound was closed with interrupted sutures to establish semi-submerged healing conditions (Fig. 4c). At re-entry after 4 months of healing, a residual defect was present. The finished reconstruction with an implant-supported single crown is presented in Fig. 4d and the corresponding radiograph in Fig. 4e.

Horizontal ridge reduction (S–OC; Table 3)

At baseline, the S–OC dimension at periodontitis and non-periodontitis sites was similar (2.9 ± 1.1 and 3 ± 1.1 mm). The mean horizontal ridge reduction between the two causes of extraction was also almost identical: 1.1 ± 0.8 mm (41%) and 1.1 ± 1.1 mm (35%).

Horizontal gap fill (S–IC; Table 3)

The size of the horizontal gap at baseline in both groups was 2.1 mm. The horizontal gap fill in the two locations was similar and amounted to about 70% of the original void: 1.3 ± 1.1 and 1.5 ± 1.1 mm.

Vertical gap fill (R–D; Table 3)

At baseline, the vertical depth of the buccal gap was significantly greater at the non-periodontitis than at the periodontitis sites (7.9 ± 3.5 vs. 5.3 ± 2.1 mm). The change of the vertical defect size in both groups was very pronounced and amounted to between 60% (periodontitis sites) and 83% (non-periodontitis) of the original defect depth. The amount of fill in the periodontitis sites was 2.9 ± 2.2 mm, while it was significantly greater (5.7 ± 4 mm) in the non-periodontitis sites.

Vertical crest reduction (R–C; Table 3)

In the non-periodontitis sites, the apical shift of the buccal crest during healing amounted to −1.1 ± 2.1 mm, while the corresponding height change in the periodontitis sites was −0.4 ± 1.2 mm.

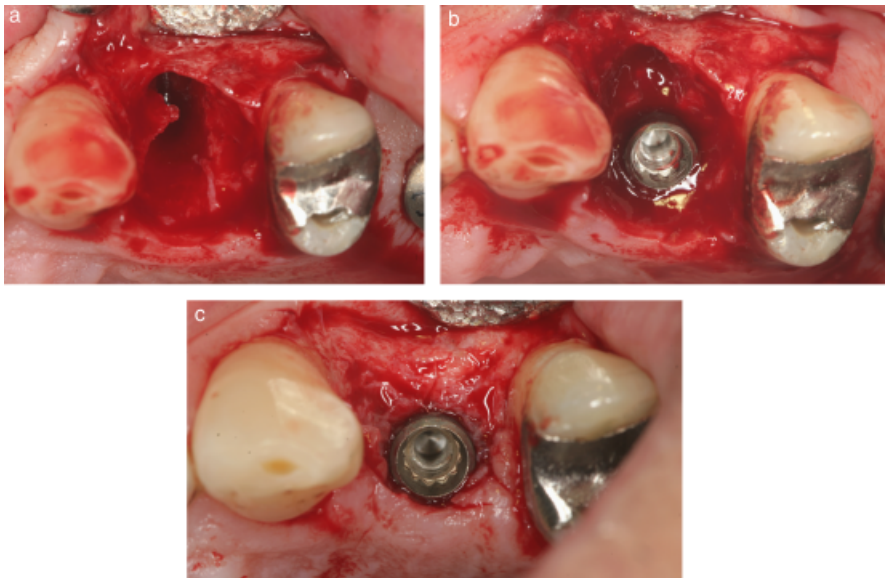

Fig. 3. A first premolar site after tooth extraction (a) and after immediate implant installation (b). Note the presence of a large void between the implant and the buccal bone wall. At re-entry, 4 months later (c), the void has been filled with bone.

***Table 2.* The influence of location of implant sites on various parameters describing treatment outcome**

	Anterior ($n = 39$)	Posterior ($n = 54$)	*P*
S–OC			
Surgery	2.3 ± 1	3.5 ± 1	0
Re-entry	1.4 ± 1.1	2.4 ± 1.1	0
Difference	1 ± 0.9	1.1 ± 1.1	0.4266
Mean % crest reduction	42 ± 46	32 ± 29	0.2132
Median % crest reduction	50	33	
S–IC			
Thickness buccal wall	0.8 ± 0.4	1.1 ± 0.5	0.0002
Surgery	1.5 ± 0.8	2.5 ± 1.1	0
Re-entry	0.4 ± 0.6	0.8 ± 0.8	0.045
Difference	1.1 ± 0.8	1.8 ± 1.2	0.0032
Mean % gap fill	75 ± 37	69 ± 38	0.4579
Median % gap fill	100	75	
R–D			
Surgery	7.5 ± 3.9	7.4 ± 3	0.884
Re-entry	2.5 ± 3	2.1 ± 2.2	0.4181
Difference	5 ± 4.4	5.3 ± 3.5	0.6843
Mean % gap fill	63 ± 45	70 ± 33	0.3607
Median % gap fill	82	83	
R–C			
Surgery	0.2 ± 0.8	0.3 ± 1.1	0.8203
Re-entry	−1.1 ± 2.6	−0.4 ± 1.2	0.0773
Difference	−1.4 ± 2.5	−0.7 ± 1.4	0.1039

For abbreviations see Fig. 1.

Dimension of the buccal bone wall (tb ≤ 1 vs. tb > 1 mm in thickness)

At 66 sites, the thickness of the buccal bone wall was ≤ 1 mm, while in 27 sites, the buccal wall was more than 1 mm thick. Figure 5 illustrates a site with a thin buccal bone wall and Fig. 6a shows a corresponding site with a thick buccal bone wall.

Horizontal ridge reduction (S–OC; Table 4)

At baseline, the S–OC dimension varied between 3.3 ± 1.3 mm (tb > 1 mm) and 2.9 ± 1 mm (tb ≤ 1 mm). The mean horizontal ridge reduction was 1.2 ± 1 mm at sites with a thin buccal bone wall, as compared with 0.9 ± 1.2 mm at sites with a thick wall. The percentage reduction of the S–OC dimension was significantly greater at thin wall sites than at thick wall sites (43% vs. 21%).

Horizontal gap fill (S–IC; Table 4)

The S–IC dimension at baseline was similar in the two groups. The horizontal gap fill as expressed in millimetres was similar in the two locations (1.4 ± 1 vs. 1.6 ± 1.4 mm). When the amount of gap fill was calculated as a percentage of the size of the baseline gap, it was demonstrated that sites with a thick wall had a significantly better fill than sites with a thin wall (84% vs. 67%).

Vertical gap fill (R–D; Table 4)

The R–D dimensions at baseline were 7.6 ± 3.3 mm (tb ≤ 1 mm) and 7.2 ± 3.8 mm (tb ≥ 1 mm). In the two groups, the vertical bone fill ranged between 5.1 and 5.4 mm (63% and 79%, respectively), with no significant difference between the groups.

Vertical crest reduction (R–C; Table 4)

The reduction of the height of the buccal bone crest was −1.2 ± 2.1 mm (tb ≤ 1 mm) and −0.4 ± 1.3 mm (tb ≥ 1 mm). This difference did not reach statistical significance ($P = 0.061$).

Size of the horizontal gap (S–IC ≤ 1 vs. S–IC > 1 mm)

At 33 sites, the buccal gap was ≤ 1 mm, while in 60 sites the corresponding gap was > 1 mm. Figure 7a illustrates a site after the extraction of a first premolar and once an implant has been immediately inserted, demonstrating a horizontal gap > 1 mm (Fig. 7b). At re-entry, 4 months later, this gap had been fully closed (Fig. 7c). Note, however, the significant horizontal ridge reduction.

Horizontal ridge reduction (S–OC; Table 5)

The dimensions of the baseline S–OC distance were 3.6 ± 0.9 mm in sites with large horizontal gaps and 2 ± 0.6 mm when S–IC was ≤ 1 mm. The mean horizontal ridge reduction at sites with a small horizontal gap was 0.8 ± 0.7 mm (43%), while at sites with a larger gap size, the reduction amounted to 1.2 ± 1.1 mm (32%).

Horizontal gap fill (S–IC; Table 5)

The dimension of the initial gap (S–IC) was 2.8 ± 0.9 mm (large gap) and 0.9 ±

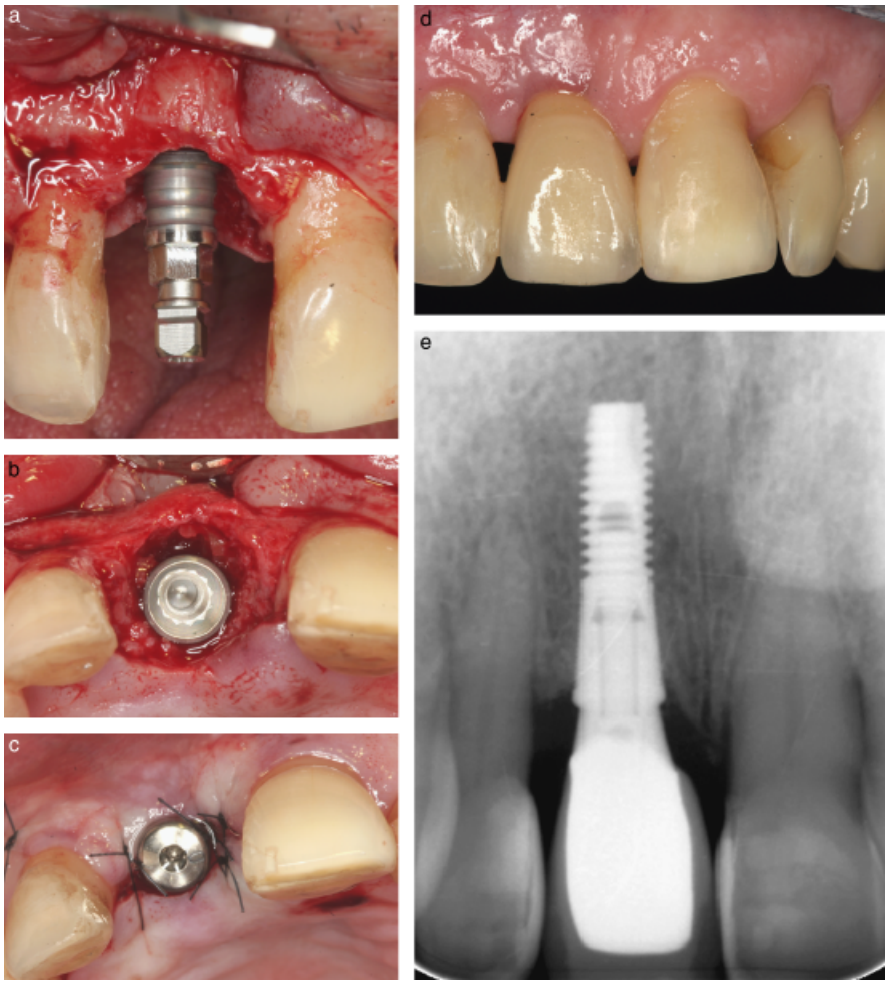

Fig. 4. A tapered implant was placed in the central incisor region and in a patient with periodontitis. Note the advanced loss of bone at the adjacent tooth sites (a). In an occlusal view (b), a large void between the implant and the buccal and approximal surfaces of the extractions site can be seen. Following implant insertion the flaps were sutured to allow semi-submerged healing conditions (c). (d)Finished case with an implant-supported single crown and the corresponding radiograph (e).

0.2 mm (small gap). The amount of horizontal gap fill during healing amounted to 1.9 ± 1.1 mm in the large defects, while the corresponding fill at sites with an initially smaller defect was 0.7 ± 0.6 mm. It should be observed, however, that the percentage of bone fill was somewhat greater at sites with an initially small than at sites with an initially large defect (77% vs. 69%).

Vertical gap fill (R–D; Table 5)

The R–D dimension was 8.4 ± 2.9 mm at sites with a large S–IC distance, and significantly smaller at sites with a smaller horizontal gap (5.8 ± 3.7 mm). The fill of the vertical gap during healing was 6.1 ± 3.4 mm at sites with a large horizontal gap and 3.5 ± 4.1 mm at sites with an initially small gap. When bone fill was expressed as percentage of the original R–D dimension, there was no difference between the groups (71% vs. 60%).

Vertical crest reduction (R–C; Table 5)

The reduction of the height of the buccal bone crest was − 1.4 ± 2.9 mm (S–IC ≤ 1 mm) and − 0.7 ± 1.2 mm (S–IC ≥ 1 mm). This difference was not statistically significant.

Discussion

The present investigation demonstrated that (i) the location where the implant was placed (anterior/posterior) as well as (ii) the thickness of the buccal bone crest and (iii) the size of the horizontal buccal gap significantly influenced the amount of hard tissue alteration that occurred during a 4-month period of healing following immediate implant placement into an extraction socket. Thus at implant sites in the premolar segment of the maxilla, the fill of the horizontal gap was more pronounced than in the incisor–canine segment, while the vertical crest reduction was significantly smaller than in the premolar region. Furthermore, at sites where the buccal bone wall was thick (> 1 mm) or where the horizontal gap was large (S–IC > 1 mm), the degree of gap fill was substantial. In most aspects, the current findings are in agreement with the data presented by Botticelli et al. (2004). These authors concluded that the marginal gap that occurred between the implant and the bone wall following immediate implant installation into an extraction socket may predictably heal with new bone formation and defect resolution.

Methodological issues

Measurements carried out in this study were performed at pre-determined locations at the mid-bucal aspect of the implant, immediately after immediate implant installation and at re-entry after 16 weeks of healing. It should be realized that these linear measurements depict a two-dimensional (2D) change, while in the bi-variate analysis used in the current study they were translated to represent a 3D alteration.

Anterior/posterior location

The finding that implant sites in the anterior segment of the dentition responded differently than premolar sites (horizontal ridge reduction, gap fill and vertical crest resorption) may be interpreted to indicate that anterior sites are more susceptible to ridge alterations at Type I implant placement than posterior sites. In some aspects, this explanation is in agreement with the results reported by Evans & Chen (2008). These authors studied soft tissue alterations following Type I single-tooth implant placement and related treatment outcomes to tissue biotype. They reported that 18 months after implant placement, there was a 1 mm recession of the soft tissue margin, but also that the soft tissue recession was most pronounced at sites belonging to a thin biotype. It may thus be inferred that at sites with a thin buccal soft and hard tissue, remodelling is apparently more substantial

Table 3. **The influence of cause of extraction (periodontitis vs. non-periodontitis) on various parameters describing treatment outcome**

	Periodontitis ($n = 16$)	Non-periodontitis ($n = 77$)	*P*
S–OC			
Surgery	2.9 ± 1.1	3 ± 1.1	0.5994
Re-entry	1.8 ± 1.1	2 ± 1.2	0.6194
Difference	1.1 ± 0.8	1.1 ± 1.1	0.9541
Mean % crest reduction	41 ± 29	35 ± 39	0.6089
Median % crest reduction	50	33	
S–IC			
Thickness buccal wall	1 ± 0.6	1 ± 0.5	0.8967
Surgery	2.1 ± 1.1	2.1 ± 1.1	0.8283
Re-entry	0.8 ± 0.9	0.6 ± 0.7	0.4783
Difference	1.3 ± 1.1	1.5 ± 1.1	0.4539
Mean % gap fill	67 ± 37	72 ± 37	0.6308
Median % gap fill	75	100	
R–D			
Surgery	5.3 ± 2.1	7.9 ± 3.5	0.004
Re-entry	2.4 ± 2.6	2.2 ± 2.6	0.8422
Difference	2.9 ± 2.2	5.7 ± 4	0.0077
Mean % gap fill	59 ± 40	69 ± 38	0.3737
Median % gap fill	60	83	
R–C			
Surgery	0.1 ± 1.1	0.3 ± 1	0.5522
Re-entry	−0.3 ± 1.4	−0.8 ± 2	0.3008
Difference	−0.4 ± 1.2	−1.1 ± 2.1	0.1874

For abbreviations see Fig. 1.

Table 4. **The influence of the thickness of the bucal bone wall (tb ≤ 1 mm; thin vs. tb ≥ 1 mm; thick) on parameters describing treatment outcome**

	Tb ≤ 1 ($n = 66$)	Tb > 1 ($n = 27$)	*P*
S–OC			
Surgery	2.9 ± 1	3.3 ± 1.3	0.1189
Re-entry	1.8 ± 1.2	2.4 ± 1	0.0139
Difference	1.2 ± 1	0.9 ± 1.2	0.2633
Mean % crest reduction	43 ± 37	21 ± 34	0.0095
Median % crest reduction	50	25	
S–IC			
Thickness buccal wall	0.7 ± 0.2	1.6 ± 0.3	0
Surgery	2.2 ± 1	2 ± 1.4	0.6574
Re-entry	0.7 ± 0.8	0.4 ± 0.6	0.061
Difference	1.4 ± 1	1.6 ± 1.4	0.4671
Mean % gap fill	67 ± 40	84 ± 28	0.0478
Median % gap fill	67	100	
R–D			
Surgery	7.6 ± 3.3	7.2 ± 3.8	0.6323
Re-entry	2.5 ± 2.6	1.8 ± 2.3	0.2497
Difference	5.1 ± 4	5.4 ± 3.6	0.7353
Mean % gap fill	63 ± 42	79 ± 27	0.0831
Median % gap fill	80	88	
R–C			
Surgery	0.3 ± 0.8	0.2 ± 1.4	0.8224
Re-entry	−0.9 ± 2.2	−0.1 ± 0.9	0.0744
Difference	−1.2 ± 2.1	−0.4 ± 1.3	0.061

For abbreviations see Fig. 1.

than at other sites. The findings obtained in the present study regarding the influence of site location in treatment outcomes may not solely be related to the location of the extracted site *per se*, but more to the thickness of the buccal bone wall as well as the size of the horizontal gap at the site following implant installation.

Size of the horizontal gap

The amount of bone fill in the horizontal gap was significantly related to the gap size at baseline. Thus, the larger the horizontal gap, the greater the amount of newly formed bone. This finding is in agreement with data reported previously (Botticelli et al. 2004) from a study on the outcome

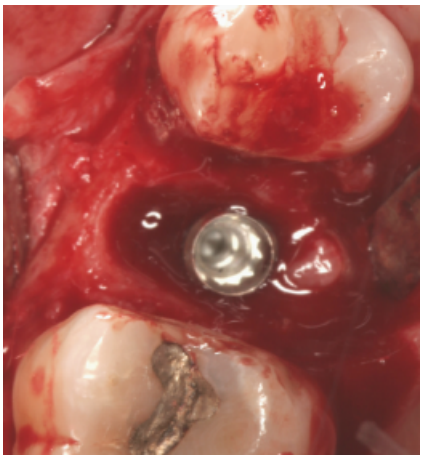

Fig. 5. A site with a thin buccal bone wall.

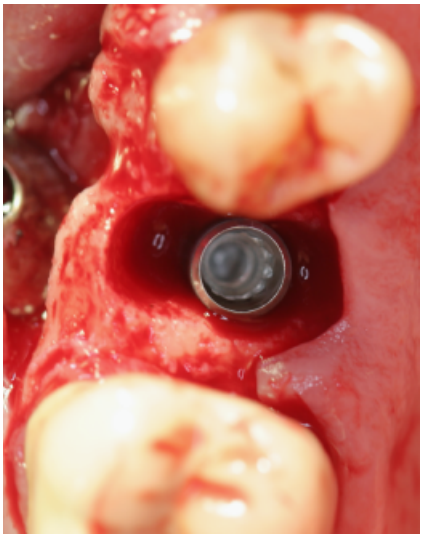

Fig. 6. A corresponding site with a thick buccal bone wall.

of implant placement in 21 'fresh' extraction sockets. At re-entry performed after 4 months of non-submerged healing, the authors observed that 'even the wider defects exhibited features of bone fill similar to that obtained in more narrow gaps'. The current observation also corroborates findings from a recent experimental study (Araújo et al. 2006), in which implants with a similar diameter were placed immediately into extraction sockets of third premolars and first molars in the mandible of dogs. This resulted in the establishment of a small buccal defect in the premolar site and a very large defect at the molar sites. In biopsies obtained after 3 months of healing, it was observed that the gaps in both the premolar and the molar sites were completely filled with newly formed bone.

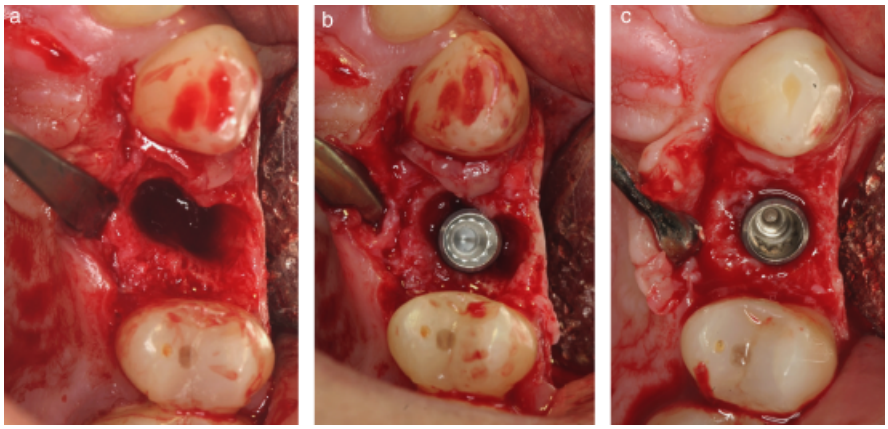

Fig. 7. A site after the extraction of a first premolar (a) and once an implant has been immediately inserted demonstrating a horizontal gap ≥ 2 mm (b). At re-entry, 4 months later, this gap has been fully closed (c). Note, however, the significant horizontal ridge reduction.

Table 5. **The influence of the thickness of the dimension of the horizontal gap (S–IC ≤ 1 mm vs. S–IC ≥ 2 mm) on parameters describing treatment outcome**

	S–IC ≤ 1 (*n* = 33)	*S–IC* ≥ 2 (*n* = 60)	*P*
S–OC			
Surgery	2 ± 0.6	3.6 ± 0.9	0
Re-entry	1.1 ± 0.8	2.4 ± 1.1	0
Difference	0.8 ± 0.7	1.2 ± 1.1	0.1144
Mean % crest reduction	43 ± 44	32 ± 32	0.1835
Median % crest reduction	50	33	
S–IC			
Thickness buccal wall	1 ± 0.6	1 ± 0.4	0.3887
Surgery	0.9 ± 0.2	2.8 ± 0.9	0
Re-entry	0.3 ± 0.5	0.8 ± 0.8	0.0002
Difference	0.7 ± 0.6	1.9 ± 1.1	0
Mean % gap fill	77 ± 50	69 ± 29	0.3541
Median % gap fill	100	67	
R–D			
Surgery	5.8 ± 3.7	8.4 ± 2.9	0.0003
Re-entry	2.3 ± 3.2	2.3 ± 2.2	0.9676
Difference	3.5 ± 4.1	6.1 ± 3.4	0.0016
Mean % Gap Fill	60 ± 52	71 ± 30	0.2041
Median % Gap Fill	83	82	
R–C			
Surgery	0.3 ± 0.8	0.3 ± 1.1	0.9152
Re-entry	−1.2 ± 2.9	−0.5 ± 1.1	0.1041
Difference	−1.4 ± 2.9	−0.7 ± 1.2	0.0976

For abbreviations see Fig. 1.

The results from the current study, however, also demonstrated that the degree of bone fill, as measured by percentage of horizontal defect resolution, was more pronounced in small defects. This observation indicates that large buccal gaps present following immediate implant installation will not predictably be completely resolved. Hence, in such situations, the use of grafting materials may improve treatment outcomes.

Thickness of the buccal bone wall

The thickness of the buccal bone crest significantly influenced not only the amount of horizontal gap fill but also the amount of vertical crestal resorption (Table 4). Thus, the wider the buccal bone, the more pronounced the fill of the buccal void (median 100% gap fill). Furthermore, in sites with a thick buccal bone crest, the mean amount of vertical resorption of the buccal crest was small (−0.4 ± 1.3 mm). The standard deviation of this measurement (R–C) indicated that a thick buccal bone wall will not consistently prevent crestal resorption. On the other hand, at sites with a thin buccal wall (tb ≤ 1 mm), there was a substantial loss of the vertical dimension (−1.2 ± 2.1 mm). This is in agreement with the data reported by Nevins et al. (2006). These authors studied the fate of the buccal bone wall of extraction sockets of teeth with prominent roots and reported that 71% of sites with a thin buccal ridge experienced significant (>20%) bone plate resorption during healing.

In conclusion, the analysis of the factors presumptively affecting the dimensional changes of the alveolar crest following immediate implant placement into extraction sockets revealed that the thickness of the buccal bone wall, as well as the dimension of the horizontal gap significantly influenced the hard tissue alterations.

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