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Dimensional ridge alterations following immediate implant placement in molar extraction sites: a six-month prospective cohort study with surgical re-entry

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Key words: alveolar bone, extraction socket, guided bone regeneration (GBR), immediate implants, surgical re-entry, transmucosal healing, wound healing

Abstract

Aim: To assess dimensional ridge alterations following immediate implant placement in molar extraction sites.

Material and methods: Twelve subjects received 12 immediate transmucosal implants in molar extraction sites. Peri-implant defects were treated according to the principles of Guided Bone Regeneration by means of a deproteinized bone substitute and a bioresorbable collagen membrane. Changes in vertical (IS-BD, CREST-BD) and horizontal distances (EC-I, IC-I) of alveolar bony walls to the bottom of the defects (BD) and to the implant surfaces (I) were compared between implant placement and surgical re-entry at 6 months.

Results: The implant survival rate at 6 months was 100%. Statistically significant differences ($P<0.01$) were observed in the mean changes in vertical distances IS-BD and CREST-BD between baseline and re-entry. At re-entry, all peri-implant marginal defects assessed from the internal socket wall to the implant surface (IC-I) were healed. The residual combined thickness of the buccal wall with the newly formed peri-implant bone at sites with an initial thickness of 1 mm was statistically significantly smaller ($P<0.05$) compared with that of sites with an initial buccal thickness of 2 mm (2.50 ± 0.76 vs. 4 ± 0 mm).

Conclusions: The marginal defects around immediate implants placed in molar extraction sites were completely filled after 6 months of healing through *de novo* bone formation. Bone resorption was observed from the external aspects of the buccal and oral socket walls. Dimensional changes of the external socket walls were mostly pronounced at the buccal aspects.

Animal experiments showed that alveolar bone structures are lost following tooth extraction (Araujo & Lindhe 2005) irrespective of the placement of an immediate implant (Araujo et al. 2005). Three months following tooth extraction without immediate implant installation, the height of the buccal alveolar wall was located 2.2 mm apically of its oral counterpart, whereas the corresponding height following immediate implant placement was located 2.4 mm apically compared with the height of the oral alveolar wall (Araujo et al. 2005). Outcomes from a follow-up animal experiment showed that bone-to-implant contact (i.e. osseointegration) established during the early phase of alveolar bone healing (e.g. after 4 weeks) following immediate implant placement was partially lost (e.g. after 12 weeks) due to continued tissue modeling of the alveolar bony walls (Araujo et al. 2006a).

Furthermore, differences in the reduction of the width of the alveolar walls after tooth extraction and immediate implant placement were observed when comparing premolar with molar sites (Araujo et al. 2006b). The reduction of the width of the alveolar walls was more pronounced at the thicker buccal walls of molar sites compared with that of the thinner walls of premolar sites (Araujo et al. 2006b). Although the peri-implant marginal defects were filled after 3 months, the bone modeling process in both the premolar and the molar areas was accompanied by horizontal and vertical reductions of the dimensions of both the buccal and the lingual alveolar walls.

Similar dimensional alveolar ridge alterations following tooth extraction were reported in retrospective and prospective studies in humans (Pietrokovski & Massler 1967; Schropp et al. 2003; Botticelli et al. 2004a; Pietrokovski et al. 2007). Pietrokovski & Massler (1967) used dental casts to compare the external contours of the buccal and oral aspects of the alveolar ridge at tooth sites and at contralateral edentulous sites by means of profilometric and imaging techniques. The amount of tissue resorption following single tooth loss was substantial and alveolar ridge alterations were more pronounced at buccal compared with oral aspects (Pietrokovski & Massler 1967). Outcomes of a prospective clinical and radiographic study reported changes of the alveolar bone dimensions 12 months following extraction of premolars and molars (Schropp et al. 2003). Changes in bucco-oral dimensions amounted to 30% during the first 3 months following tooth extraction and achieved a 50% reduction at the 12-month follow-up. Furthermore, after 12 months of healing, the buccal alveolar crest was located 1.2 mm apically of its oral counterpart (Schropp et al. 2003).

Evidence from studies on human alveolar ridge dimensional changes following tooth extraction and immediate implant placement is limited. Hard tissue alterations occurring in the alveolar ridge during a 4-month healing period following immediate implant placement into fresh extraction sockets were reported (Botticelli et al. 2004a). In that study, however, no attempt was made at the time of implant placement to fill the peri-implant marginal defects by applying the principles of Guided Bone Regeneration (GBR) (Botticelli et al. (2004a). The findings at the time of surgical re-entry (i.e. after 4 months of healing) indicated that implant placement into fresh extraction sockets without the use of grafting materials and barrier membranes did not prevent bone modeling and remodeling to occur on the external aspects of the buccal and oral alveolar walls. However, evidence of dimensional changes of the alveolar ridge following immediate implant placement into molar extraction sites in conjunction with regenerative procedures is still lacking.

Hence, the aim of this prospective cohort study was to assess, after 6 months of healing, the dimensional changes of alveolar bony walls at immediate transmucosal implants placed into molar extraction sites in conjunction with regenerative procedures.

Material and methods

Experimental design

The study was designed as a prospective cohort study with surgical re-entry 6 months following tooth extraction and immediate implant placement. Titanium oral implants of the SPI® System (Thommen Medical AG, Waldenburg, Switzerland) with a sandblasted and acid-etched (SLA) surface, a length of 11 mm, an endosseous diameter of 5 mm, a shoulder diameter of 6 mm and a height of the turned neck of 1.8 mm were immediately placed into molar extraction sockets (Fig. 1). Peri-implant marginal defects were treated according to the principles of GBR using deproteinized bovine bone mineral particles (BioOss®, Geistlich Biomaterials, Wolhusen, Switzerland) and resorbable collagen membranes (BioGide®, Geistlich Biomaterials, Wolhusen, Switzerland).

Subject population

A total of 12 subjects received 12 implants of the SPI® System (Thommen Medical AG). All subjects were recruited consecutively from the patient pool of the Department of Periodontology, University of Naples 'Federico II,' Naples, Italy.

The following inclusion criteria were applied:

- Age ≥18 years.
- Absence of relevant medical conditions contraindicating surgical interventions.
- Presence of a mandibular or maxillary molar to be extracted because of an endodontic failure, caries or vertical root fracture (Fig. 2).

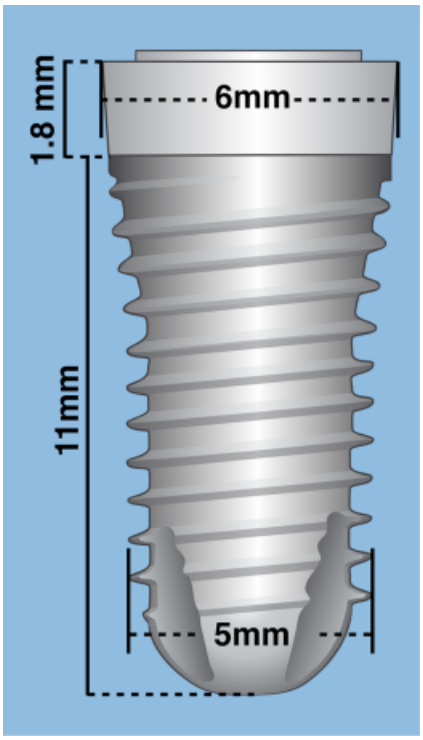

Fig. 1. Schematic illustration of a Contact® implant of the SPI® system (Thommen Medical AG) with a length of 11 mm, an endosseous diameter of 5 mm, a shoulder diameter of 6 mm and a height of the turned neck of 1.8 mm.

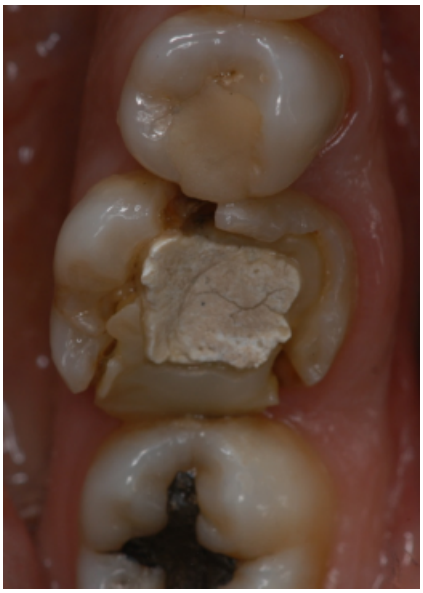

Fig. 2. Occlusal view of the fractured mandibular first molar.

- Integrity of extraction socket walls.
- Presence of buccal and oral alveolar bony walls with either 1 or 2 mm thickness at baseline.
- Presence of sufficient residual alveolar bone volume to achieve primary implant stability.
- Presence of a tooth mesially and distally to the extraction site.
- Full-mouth plaque score (FMPS) $\leq 25\%$ at baseline.
- Full-mouth bleeding score (FMBS) $\leq 25\%$ at baseline.
- Presence of ≥ 2 mm of keratinized tissue to allow flap management.

Subjects were excluded on the basis of:

- Pregnancy or lactation.
- Tobacco smoking.
- Extraction for periodontal reasons.
- Clinical and/or radiographic signs of periapical pathology contraindicating immediate implant placement.
- FMPS $> 25\%$ at baseline.
- FMBS $> 25\%$ at baseline.
- Untreated periodontal conditions.
- Extraction of third molars.

The study protocol was reviewed and approved by the Ethical Committee of the University of Naples 'Federico II,' Italy. Informed consent was obtained, and the study was performed according to the principles outlined in the Declaration of Helsinki on experimentation involving human subjects.

Experimental procedures

Clinical parameters

At baseline, the following parameters were recorded at six sites per tooth (i.e. disto-buccal, buccal, mesio-buccal, mesio-oral, oral and disto-oral):

- FMPS.
- FMBS using a manual periodontal probe (e.g. UNC-15 Color-Code Probe) and a probing force of 0.3 N.

Surgical procedures

After elevation of a mucoperiosteal flap extending one tooth in the mesial and one tooth in the distal direction, respectively, tooth extraction and implant placement were performed simultaneously. Following separation of the roots and careful root extraction, preparation of the implant bed in the area of the interradicular septum and implant placement were carried out (Figs 3 and 4). Implants of the SPI® System (Thommen Medical AG) with a SLA surface, a length of 11 mm, an endosseous diameter of 5 mm, a shoulder diameter of 6 mm and a height of the turned neck of 1.8 mm (Fig. 1) were placed according to the manufacturer's instructions. Primary stability was achieved in the apical portion of the interradicular septum. Before implants were placed, the thickness of the

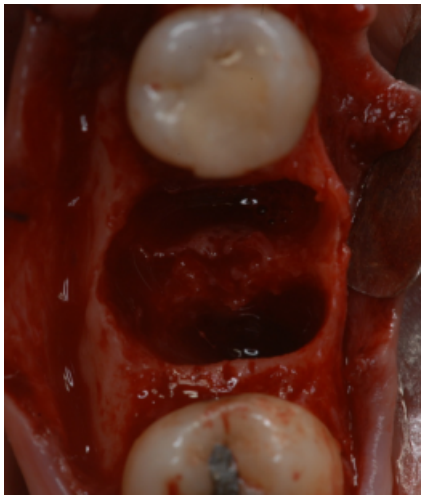

Fig. 3. Occlusal view of the extraction socket after hemisection and molar extraction without damages to the inter-radicular septum and the lingual and buccal walls, respectively.

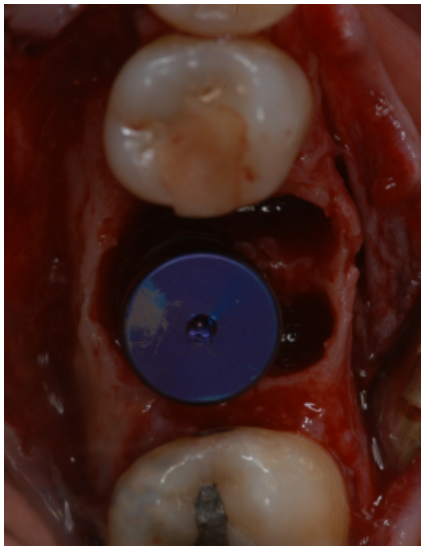

Fig. 4. Occlusal view after immediate placement of an SPI® implant (Thommen Medical AG) in the interradicular alveolar septum. Peri-implant marginal defects are present around all aspects of the implant.

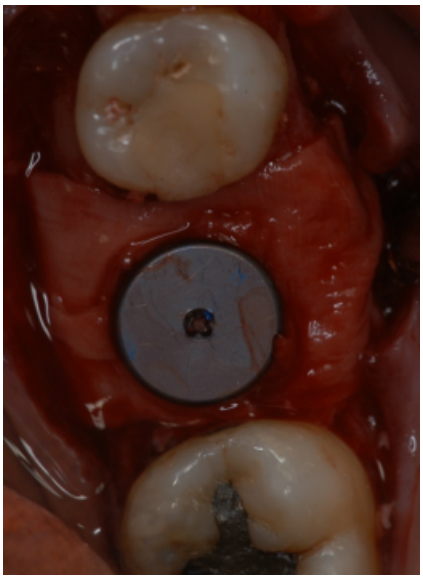

Fig. 5. Occlusal view after filling of the peri-implant defects with deproteinized bovine mineral particles and adaptation of a resorbable collagen membrane around the neck of the implant.

mid-buccal and mid-oral extraction socket walls was recorded at the level of the alveolar crest using a surgical calliper. The marginal defects between the implant and the internal walls of the extraction sockets were regenerated by the use of bioresorbable membranes supported by a bone substitute. Deproteinized bovine bone mineral particles with a size of 0.25–1 mm (BioOss®, Geistlich Biomaterials) were placed into the defect, followed by the punch and adaptation of a collagen membrane (BioGide®, Geistlich Biomaterials) around the neck of the implant (Fig. 5). The membrane extended 3–4 mm beyond the borders of the bony defect. After the insertion of a healing cap, the buccal and oral flaps were repositioned without any tension and sutured around the healing cap using 5–0 non-resorbable sutures (Ethibond® Excel, Ethicon, Johnson & Johnson, NJ, USA) aiming at a transmucosal wound healing.

Intrasurgical measurements

After implant placement and before regenerative procedures were carried out, the following distances were recorded to the nearest millimeter at six sites per implant (i.e. disto-buccal, buccal, mesio-buccal, mesio-oral, oral and disto-oral) (Fig. 6):

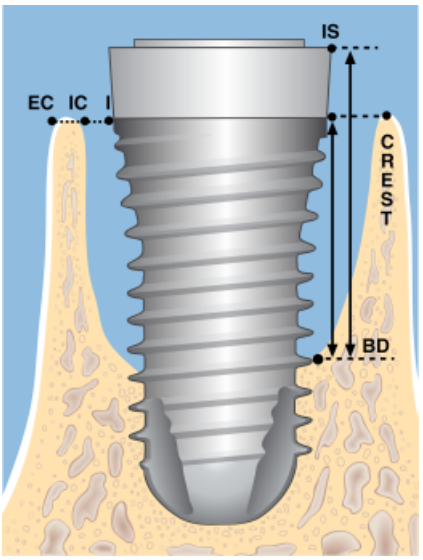

Fig. 6. Schematic illustration of the linear measurements (mm) of the peri-implant marginal defects assessed at baseline and at the time of surgical re-entry. IS-BD, vertical distance from the implant shoulder (IS) to the bottom of the bony defect (BD); CREST-BD, vertical distance from the most coronal extension of the alveolar crest (CREST) to the bottom of the bony defect (BD); EC-I, horizontal width from the external socket wall at the level of the alveolar crest (CREST) to the implant surface (I); IC-I, horizontal width from the internal socket wall at the level of the alveolar crest (CREST) to the implant surface (I).

- IS-BD: vertical distance from the implant shoulder (IS) to the bottom of the bony defect (BD).
- CREST-BD: vertical distance from the most coronal extension of the alveolar crest (CREST) to the bottom of the bony defect (BD).
- EC-I: horizontal width from the external aspect of the socket wall at the level of the alveolar crest (EC) to the implant surface (I).
- IC-I: horizontal width from the internal aspect of the socket wall at the level of the alveolar crest (IC) to the implant surface (I).

Post-surgical instructions and infection control

Post-operative pain and edema were controlled with Ibuprofen® (e.g. 600 mg immediately before the surgical intervention and after 4 h). In cases of contraindications to non-steroidal anti-inflammatory drugs, acetaminophen (e.g. 500 mg immediately before the surgical intervention and after 6 h) was prescribed. To help prevent wound infection, all subjects received systemic antibiotics (e.g. amoxicillin + clavulanic acid 1 g bid for 10 days). Subjects were instructed to rinse twice daily with 0.12% chlorhexidine digluconate for the first 2 weeks and to use modified oral hygiene procedures in the treated area for the first 4 post-operative weeks, according to Heitz et al. (2004). Four weeks after implant placement, subjects were instructed to resume normal oral hygiene practices. Sutures were removed after 2 weeks and all subjects were recalled after 1, 2, 3 and 4 weeks and after 3 and 6 months for a professional tooth cleaning with a rubber cup and chlorhexidine gel.

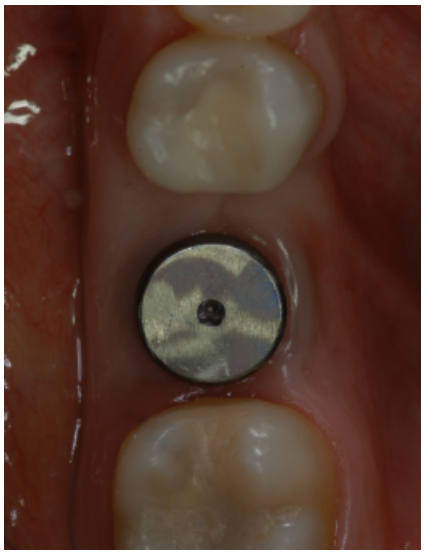

Fig. 7. Occlusal view of the peri-implant soft tissues after 6 months of healing before surgical re-entry.

Surgical re-entry

After 6 months of healing, a surgical re-entry procedure was performed. Full-thickness flaps were elevated to allow access to the marginal portions of the implants (Figs 7 and 8). The measurement of the distances IS-BD, CREST-BD, EC-I and IC-I was repeated at six sites per implant. Again, the mucoperiosteal flaps were sutured around the healing caps.

Delivery of fixed single-unit crowns

All implants remained unloaded until surgical re-entry. Three weeks after surgical re-entry, all implants were restored with a provisional acrylic single-unit crown. After 30 days, the provisional crown was removed and a porcelain-fused-to-metal single-unit crown was cemented.

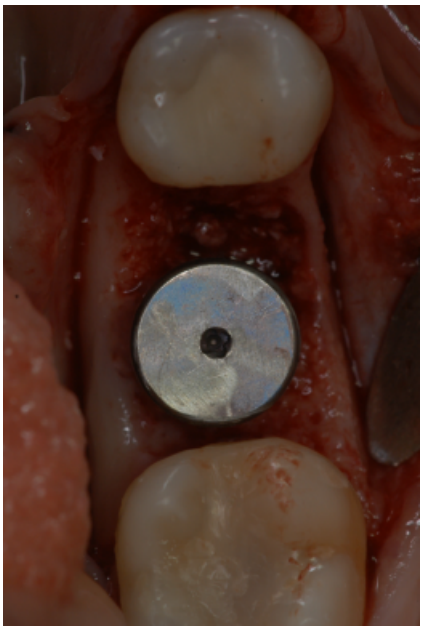

Fig. 8. Occlusal view at the time of surgical re-entry. A change in the buccal bony contour compared with that at the time of immediate implant placement (Fig. 3) is visible.

Data analysis

Descriptive statistics [e.g. mean ± standard deviation (SD)] were used to present the subject population. All variables were expressed in millimeters, with the exception of the FMPS and the FMBS which were expressed in percentages. The paired *t*-test was used to compare intra-group differences at baseline and at the 6-month surgical re-entry, while the unpaired *t*-test was used to compare inter-group differences. A *P*-value <0.05 was accepted to identify a statistically significant difference. The data analysis were performed using Statistical Software (NCSS-PASS®, Number Cruncher Statistical Systems, Kaysville, UT, USA).

Results

The characteristics of the subject population at baseline are presented in Table 1. After screening, 12 subjects (six male and six female) fulfilling the inclusion criteria were enrolled. The mean age of the subjects was 45.3 ± 6.1 years (range 35–54 years). At baseline, the mean FMPS was 17.9 ± 3.3% and the mean FMBS was 15 ± 3.2%. At the time of immediate implant placement, the thickness of the buccal and oral alveolar bony walls was

1 mm in six subjects, whereas in the other six subjects, the thickness was 2 mm.

Surgical outcomes

At 6 months, all implants were successfully osseo-integrated, yielding a survival rate of 100%.

Table 2 summarizes the mean changes ± SD in the vertical distances IS-BD and CREST-BD as well as in the horizontal distances EC-I and IC-I assessed at six sites per implant (e.g. disto-buccal, buccal, mesio-buccal, disto-oral, oral and mesio-oral) between baseline and surgical re-entry at 6 months. Statistically significant differences ($P<0.01$) were observed in the mean changes in vertical distances IS-BD and CREST-BD between baseline and re-entry. After 6 months, all peri-implant marginal defects assessed from the internal aspect of the socket wall at the level of the alveolar crest to the implant surface (i.e. IC-I) were completely filled.

Table 3 illustrates the mean changes ± SD in the vertical distances IS-BD and CREST-BD as well as in the horizontal distances EC-I and IC-I assessed at both mid-buccal and mid-oral sites with respect to the initial thickness of the alveolar bony wall (i.e. 1 or 2 mm). Statistically significant ($P<0.05$) mean changes were observed at both the mid-buccal and the mid-oral aspects for the vertical distances IS-BD and CREST-BD as well as for the horizontal distances EC-I and IC-I. Irrespective of the initial thickness of the alveolar wall, complete fill of the peri-implant marginal defects was observed between the internal aspect of the socket wall and the implant surface (i.e. IC-I) at both the buccal and the oral aspects.

Table 4 summarizes the mean changes ± SD in the vertical and horizontal dimensions of the buccal and oral walls with respect to the thickness of the alveolar bony wall (i.e. 1 or 2 mm) at the time of immediate implant placement. No statistically significant differences ($P>0.05$) were observed in the vertical and horizontal changes of the alveolar crest dimensions with respect to the initial socket wall thickness.

However, after 6 months, the residual thickness of the combined buccal wall and newly formed peri-implant bone at sites with an initial thickness of 1 mm was statistically significantly smaller ($P<0.05$) compared with that of sites with an initial buccal thickness of 2 mm (2.50 ± 0.76 vs. 4 ± 0 mm). No statistically significant difference ($P>0.05$) was observed between the residual thickness of the combined oral wall and newly formed peri-implant bone at sites with an initial thickness of 1 mm compared with that of sites with an initial oral thickness of 2 mm (3.17 ± 0.75 vs. 3.17 ± 0.75 mm).

Table 1. **Demographic characteristics of the subject population at baseline**

Subject number	Gender	Mean age (years)	Immediate implant site	Mean FMPS (%)	Mean FMBS (%)
1	M	35	36	21.4	18.3
2	M	44	46	16.3	12.5
3	F	54	26	12.2	10.2
4	M	44	26	20.3	16.3
5	F	53	17	15.8	14.3
6	F	42	16	21.1	18.1
7	M	39	37	14.2	12.6
8	M	40	16	15.3	13.1
9	M	45	36	16.7	12.4
10	F	52	47	21.8	19.5
11	F	44	26	18.4	12.6
12	F	52	36	21.5	19.7
Mean ± SD		45.3 ± 6.1		17.9 ± 3.3	15 ± 3.2

FMPS, full-mouth plaque score; FMBS, full-mouth bleeding score; SD, standard deviation.

Discussion

The outcomes of this 6-month prospective cohort study reported dimensional alveolar ridge changes following immediate transmucosal implant placement in molar extraction sockets in combination with

Table 2. **Mean changes ± standard deviations (SD) in the vertical distances IS-BD and CREST-BD and in the horizontal distances EC-I and IC-I assessed at six sites per implant between baseline and re-entry at 6 months**

$N=12$	Disto-buccal (mm)	Buccal (mm)	Mesio-buccal (mm)	Mesio-oral (mm)	Oral (mm)	Disto-oral (mm)
IS-BD baseline	11.17 ± 1.34	9.67 ± 1.23	11.42 ± 1.31	11.50 ± 1.51	9.25 ± 0.97	10.83 ± 1.27
IS-BD re-entry	1.58 ± 0.51	1.67 ± 0.49	1.25 ± 0.45	1.33 ± 0.49	1.50 ± 0.52	1.42 ± 0.51
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CREST-BD baseline	10.67 ± 1.23	9.50 ± 1.31	11.08 ± 1.16	11 ± 1.35	9.33 ± 0.89	10.50 ± 1.31
CREST-BD re-entry	0.42 ± 0.51	0.17 ± 0.39	0.58 ± 0.51	0.42 ± 0.51	0.25 ± 0.45	0.25 ± 0.45
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EC-I baseline	3.75 ± 0.45	5.58 ± 0.51	3.92 ± 0.79	3.58 ± 0.51	4.17 ± 0.39	2.58 ± 0.51
EC-I re-entry	3.58 ± 0.51	3.25 ± 0.97	3.67 ± 0.49	3.42 ± 0.51	3.17 ± 0.72	2.42 ± 0.51
P-value	NS	<0.05	NS	NS	<0.05	NS
IC-I baseline	2.58 ± 0.51	4 ± 0.43	3 ± 0.74	2.58 ± 0.51	2.67 ± 0.65	1.50 ± 0.52
IC-I re-entry	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

$\alpha=0.05$.

NS, not statistically significantly different from baseline; IS-BD, vertical distance from the implant shoulder (IS) to the bottom of the bony defect (BD); CREST-BD, vertical distance from the most coronal extension of the alveolar crest (CREST) to the bottom of the bony defect (BD); EC-I, horizontal distance from the external side of the bony wall at the level of the alveolar crest (CREST) to the implant surface (I); IC-I, horizontal distance from the internal side of the bony wall at the level of the alveolar crest (CREST) to the implant surface (I).

Table 3. **Comparison of the mean changes ± standard deviations (SD) in vertical distances IS-BD and CREST-BD and in horizontal distances EC-I and IC-I between baseline and surgical re-entry at 6 months at the buccal and oral aspects of the immediate implants with respect to the thickness (i.e. 1 or 2 mm) of the alveolar bony walls**

	Buccal aspect				Oral aspect			
	IS-BD (mm)	CREST-BD (mm)	EC-I (mm)	IC-I (mm)	IS-BD (mm)	CREST-BD (mm)	EC-I (mm)	IC-I (mm)
Baseline: thickness of bony wall = 1 mm ($N = 6$)	10.17 ± 1.47	10 ± 1.54	5.17 ± 0.41	4 ± 0.63	9.17 ± 1.17	9.17 ± 1.17	4.17 ± 0.41	3.17 ± 0.41
Re-entry: thickness of bony wall = 1 mm ($N = 6$)	1.50 ± 0.55	0 ± 0	2.50 ± 0.84	0 ± 0	1.67 ± 0.52	0.17 ± 0.41	3.17 ± 0.75	0 ± 0
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01
Baseline: thickness of bony wall = 2 mm ($N = 6$)	9.17 ± 0.75	9 ± 0.89	6 ± 0	4 ± 0	9.33 ± 0.82	9.50 ± 0.55	4.17 ± 0.41	2.17 ± 0.41
Re-entry: thickness of bony wall = 2 mm ($N = 6$)	1.83 ± 0.41	0.33 ± 0.52	4 ± 0	0 ± 0	1.33 ± 0.52	0.33 ± 0.52	3.17 ± 0.75	0 ± 0
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01

$\alpha = 0.05$.
IS-BD, vertical distance from the implant shoulder (IS) to the bottom of the bony defect (BD); CREST-BD, vertical distance from the most coronal extension of the alveolar crest (CREST) to the bottom of the bony defect (BD); EC-I, horizontal distance from the external side of the bony wall at the level of the alveolar crest (CREST) to the implant surface (I); IC-I, horizontal distance from the internal side of the bony wall at the level of the alveolar crest (CREST) to the implant surface (I).

Table 4. **Mean vertical and horizontal changes ± standard deviations (SD) at buccal and oral sites between baseline and surgical re-entry with respect to the thickness of the alveolar bony walls (i.e. 1 or 2 mm) at the time of immediate implant placement**

Buccal aspect (mm)			
Baseline: thickness of bony wall = 1 mm ($N = 6$)	Vertical change 1.50 ± 0.55	Horizontal change 2.67 ± 1.03	Residual wall thickness at re-entry 2.50 ± 0.76
Baseline: thickness of bony wall = 2 mm ($N = 6$)	Vertical change 1.83 ± 0.41	Horizontal change 2 ± 00	Residual wall thickness at re-entry 4 ± 0
P-value	NS	NS	<0.05
Oral aspect (mm)			
Baseline: thickness of bony wall = 1 mm ($N = 6$)	Vertical change 1.6 ± 0.52	Horizontal change 1 ± 0.89	Residual wall thickness at re-entry 3.17 ± 0.75
Baseline: thickness of bony wall = 2 mm ($N = 6$)	Vertical change 1.33 ± 0.52	Horizontal change 1 ± 0.89	Residual wall thickness at re-entry 3.17 ± 0.75
P-value	NS	NS	NS

$\alpha = 0.05$.
NS, not statistically significantly different.

regenerative procedures. The marginal peri-implant defects present at the time of implant placement were completely filled after 6 months of healing through *de novo* bone formation. Bone resorption was observed from the external aspects of the buccal and oral socket walls. Furthermore, dimensional changes of the external socket walls were mostly pronounced at buccal aspects.

Outcomes from an animal experiment showed that, after implant placement, the rate of healing and degree of resolution of peri-implant marginal defects were dependent on whether or not the defect was prepared in a healed alveolar ridge or presented as a void of a fresh extraction socket (Botticelli et al. 2006). Findings from that study (Botticelli et al. 2006) showed that, after 4 months, most defects prepared in healed alveolar ridges were completely filled, whereas healing of fresh extraction sockets was incomplete.

Clinical findings yielded that, at the time of surgical re-entry, 4 months after the extraction of single-rooted teeth and immediate implant placement, wide and deep peri-implant marginal defects at buccal and oral aspects were filled by new bone formation from the internal aspect of the socket and bone resorption from the external side of the alveolar ridge (Botticelli et al. 2004a). Although the findings of the present study are in agreement with those of Botticelli et al. (2004a), healing of the marginal peri-implant defects was achieved in the latter study without the use of a bone substitute and a barrier membrane. Collectively, the outcomes of that study (Botticelli et al. 2004a) showed that the dimensions of the alveolar ridge were reduced by >50% at buccal and approximately 30% at oral sites, respectively. The 5-year clinical and radiographic outcomes of that study (Botticelli et al. 2004a) were recently reported (Botticelli et al. 2008). All immediately placed implants survived, and the mean radiographic marginal bone levels were maintained or even improved over the 5 years (Botticelli et al. 2008). Owing to the fact that the subjects included in that long-term study (Botticelli et al. 2008) had been enrolled in a meticulous maintenance care program, the plaque and mucositis scores were low at baseline and at all follow-up appointments. Obviously, the quality of supportive care is essential for the long-term success of patients rehabilitated with implant-supported fixed dental prostheses (Wennström et al. 2004, 2005; Cecchinato et al. 2008).

Outcomes of a 12-month controlled clinical study demonstrated that wound

healing at immediate implants placed into molar extraction sites with buccal self-contained defects in conjunction with GBR resulted in less favorable outcomes compared with those around implants placed in healed alveolar ridges resulting in a lack of 'complete' osseointegration (Iorio Siciliano et al. 2009). Although surgical re-entry was not performed in that study (Iorio Siciliano et al. 2009), significantly worse clinical conditions (e.g. PPD and CAL) were observed around immediate transmucosal implants placed into molar extraction sites with buccal self-contained defects compared with those of implants placed in healed alveolar sites.

Findings from experimental studies indicated that 1–2.25-mm-wide self-contained peri-implant marginal defects were filled with newly formed bone after 4 months of healing without the use of grafting materials (Botticelli et al. 2003, 2004b). It should be noted, however, that the configuration of the marginal portion of artificial defects created in healed alveolar ridges played an important role during wound healing (Botticelli et al. 2004b). Buccally open peri-implant marginal defects of varying dimensions healed with less newly formed bone compared with the other aspects of the same defect (e.g. mesial, distal and oral). Hence, it may be postulated that the observed compromised bone fill at buccal aspects was related to an inadequate space-maintaining effect provided by resorbable barrier membranes without the concomitant use of grafting materials. In the present clinical study, however, a resorbable membrane had been adapted around the neck of all implants and was always supported by deproteinized bovine bone particles placed into the residual peri-implant marginal defects.

In conclusion, marginal defects around immediate implants in molar extraction sites were completely filled after 6 months of healing. Bone resorption was observed from the external aspects of the buccal and oral socket walls. Furthermore, dimensional changes of the external socket walls were pronounced mostly at buccal aspects. Randomized-controlled clinical trials with larger sample sizes are needed to further investigate the effects of regenerative procedures within the marginal peri-implant defects on dimensional alveolar ridge changes.

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References

Araujo, M.G. & Lindhe, J. (2005) Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *Journal of Clinical Periodontology* **32**: 212–218.

Araujo, M.G., Sukekava, F., Wennström, J.L. & Lindhe, J. (2005) Ridge alterations following implant placement in extraction sockets: an experimental study in the dog. *Journal of Clinical Periodontology* **32**: 645–652.

Araujo, M.G., Sukekava, F., Wennström, J.L. & Lindhe, J. (2006a) Tissue modeling following implant placement in fresh extraction sockets. *Clinical Oral Implants Research* **17**: 615–624.

Araujo, M.G., Wennström, J.L. & Lindhe, J. (2006b) Modeling of buccal and lingual bone walls of fresh extraction sites following implant installation. *Clinical Oral Implants Research* **17**: 606–614.

Botticelli, D., Berglundh, T., Buser, D. & Lindhe, J. (2003) The jumping distance revisited: an experimental study in the dog. *Clinical Oral Implants Research* **14**: 35–42.

Botticelli, D., Berglundh, T. & Lindhe, J. (2004a) Hard-tissue alterations following immediate implant placement in extraction sites. *Journal of Clinical Periodontology* **31**: 820–828.

Botticelli, D., Berglundh, T. & Lindhe, J. (2004b) Resolution of bone defects of varying dimension and configuration in the marginal portion of the peri-implant bone: an experimental study in the dog. *Journal of Clinical Periodontology* **31**: 309–317.

Botticelli, D., Persson, L.G., Lindhe, J. & Berglundh, T. (2006) Bone tissue formation adjacent to implants placed in fresh extraction sockets: an experimental study in dogs. *Clinical Oral Implants Research* **17**: 351–358.

Botticelli, D., Renzi, A., Lindhe, J. & Berglundh, T. (2008) Implants in fresh extraction sockets: a prospective 5-year follow-up clinical study. *Clinical Oral Implants Research* **19**: 1226–1232.

Cecchinato, D., Bengazi, F., Blasi, G., Botticelli, D., Cardarelli, I. & Gualini, F. (2008) Bone level alterations at implants placed in the posterior segments of the dentition. Outcome of submerged/non-submerged healing. A 5-year multicenter, randomized, controlled clinical trial. *Clinical Oral Implants Research* **19**: 429–431.

Heitz, F., Heitz-Mayfield, L.J. & Lang, N.P. (2004) Effects of post-surgical cleansing protocols on early plaque control in periodontal and/or periimplant wound healing. *Journal of Clinical Periodontology* **31**: 1012–1018.

Iorio Siciliano, V., Salvi, G.E., Matarasso, S., Cafiero, C., Blasi, A. & Lang, N.P. (2009) Soft tissues healing at immediate transmucosal implants placed into molar extraction sites with buccal self-contained dehiscences. A 12-month controlled clinical trial. *Clinical Oral Implants Research* **20**: 482–488.

Pietrokovski, J. & Massler, M. (1967) Alveolar ridge resorption following tooth extraction. *Journal of Prosthetic Dentistry* **17**: 21–27.

Pietrokovski, J., Starinsky, R., Arensburg, B. & Kaffe, I. (2007) Morphologic characteristics of bony edentulous jaws. *Journal of Prosthodontics* **16**: 141–147.

Schropp, L., Wenzel, A., Kostopoulos, L. & Karring, T. (2003) Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *International Journal of Periodontics and Restorative Dentistry* **23**: 312–323.

Wennström, J.L., Ekestubbe, A., Gröndahl, K., Karlsson, S. & Lindhe, J. (2004) Oral rehabilitation with implant-supported fixed partial dentures in periodontitis-susceptible subjects. A 5-year prospective study. *Journal of Clinical Periodontology* **31**: 713–724.

Wennström, J.L., Ekestubbe, A., Gröndahl, K., Karlsson, S. & Lindhe, J. (2005) Implant-supported single-tooth restorations: a 5-year prospective study. *Journal of Clinical Periodontology* **32**: 567–574.