J Clin Periodontol 2005; 32: 645–652 doi: 10.1111/j.1600-051X.2005.00726.x
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Journal of Clinical Periodontology

Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog

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Araújo MG, Sukekava F, Wennström JL, Lindhe J. Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. J Clin Periodontol 2005; 32: 645–652. doi: 10.1111/j.1600-051X.2005.00726.x. © Blackwell Munksgaard, 2005.

Abstract

Objective: To study dimensional alterations of the alveolar ridge that occurred following implant placement in fresh extraction sockets.

Material and Methods: Five beagle dogs were included in the study. In both quadrants of the mandible, incisions were made in the crevice region of the third and fourth pre-molars. Buccal and minute lingual full-thickness flaps were elevated. The mesial root of the four pre-molars root was filled and the teeth were hemi-sected. Following flap elevation in $_3P_3$ and $_4P_4$ regions, the distal roots were removed. In the right jaw quadrants, implants with a sand blasted and acid etched (SLA) surface were placed in the fresh extraction sockets, while in the left jaws the corresponding sockets were left for spontaneous healing. The mesial roots were retained as surgical control teeth. After 3 months, the animals were examined clinically, sacrificed and tissue blocks containing the implant sites, the adjacent tooth sites (mesial root) and the edentulous socket sites were dissected, prepared for ground sectioning and examined in the microscope.

Results: At implant sites, the level of bone-to-implant contact (BC) was located 2.6 $\pm$ 0.4 mm (buccal aspect) and 0.2 $\pm$ 0.5 mm (lingual aspect) apical of the SLA level. At the edentulous sites, the mean vertical distance (V) between the marginal termination of the buccal and lingual bone walls was 2.2 $\pm$ 0.9 mm. At the surgically treated tooth sites, the mean amount of attachment loss was 0.5 $\pm$ 0.5 mm (buccal) and 0.2 $\pm$ 0.3 mm (lingual).

Conclusions: Marked dimensional alterations had occurred in the edentulous ridge after 3 months of healing following the extraction of the distal root of mandibular pre-molars. The placement of an implant in the fresh extraction site obviously failed to prevent the re-modelling that occurred in the walls of the socket. The resulting height of the buccal and lingual walls at 3 months was similar at implants and edentulous sites and vertical bone loss was more pronounced at the buccal than at the lingual aspect of the ridge. It is suggested that the resorption of the socket walls that occurs following tooth removal must be considered in conjunction with implant placement in fresh extraction sockets.

Key words: bundle bone; modelling; re-modelling; wound healing

Accepted for publication 25 October 2004

The extraction of multiple teeth results in an overall diminution of the size of the edentulous ridge (e.g. Atwood 1962, 1963, Johnson 1963, 1969, Carlsson & Persson 1967, Tallgren 1972, Ulm et al. 1992). Also, following the removal of a single tooth, marked hard- and soft-tissue alterations will take place within the affected region of the alveolar ridge (Pietrokovski & Massler 1967, Schropp et al. 2003). Further, tissue modelling following multiple as well as single tooth extractions apparently resulted in more pronounced bone loss in the buccal than in the lingual/palatal portions of the ridge (Pietrokovski & Massler 1967).

In experiments in the dog, Cardaropoli et al. (2003) and Araújo & Lindhe (2005) studied bone tissue reaction to tooth extraction and monitored both intra-alveolar and extra-alveolar processes. It was observed that (i) the intra-alveolar portion of the extraction site became occupied by woven bone that, following the formation of a cortical hard-tissue ridge, became replaced mainly by bone marrow and (ii) both the lingual and the buccal hard-tissue walls underwent marked change. Thus, through the combined effect of surface resorption and loss of bundle bone, in particular, the buccal bone wall was reduced in thickness as well as in height (Araújo & Lindhe 2005).

It was recently suggested (Paolantonio et al. 2001) that the placement of implants in fresh extraction sockets would prevent re-modelling and hence maintain the original shape of the ridge. Paolantonio et al. (2001) stated that ''early implantation may preserve the alveolar anatomy and that the placement of a fixture in a fresh extraction socket may help to maintain the bony crest structure''. Findings reported from a clinical study by Botticelli et al. (2004), however, failed to support this hypothesis. Thus, the authors reported that at sites where implants had been placed immediately following single tooth extraction, the buccal as well as the lingual bone walls during healing underwent marked re-modelling and resorption. In the 4-month interval between implant installation and re-entry surgery, the distance between the implant surface to the outer surface of the buccal and lingual bone walls was markedly diminished (buccal aspect: -50%; lingual aspect: -25%).

The aim of the present dog experiment was to study whether the placement of an implant in a fresh extraction site could interfere with hard-tissue alterations that otherwise would occur in the alveolar ridge following the removal of a tooth.

Material and Methods

The ethical committee of the University of Maringa approved the research protocol. Five beagle dogs about 1-year old and weighting about 12–13 kg each were used. During surgical procedures, the animals were anaesthetized with intravenously administered Pentothal Natrium® (30 mg/ml; Abbot Laboratories, Chicago, IL, USA). Throughout the experiment, the animals were fed a pellet diet. In both quadrants of the mandible, the third and fourth pre-molars ($_3P_3$ and $_4P_4$) were used as experimental sites. A rubber dam was placed around $_3P_3$ and $_4P_4$ and was retained with clamps. The pulp tissue of mesial roots of $_3P_3$ and $_4P_4$ was extirpated and the canals were filled with gutta-percha. The coronal portion of the pulp chamber was filled with a composite material.

In both the left and right quadrant of the mandible, continuous ''sulcus'' incisions were placed along the buccal and lingual aspects of the third and fourth pre-molars and mesial aspect of the first molar. On the buccal as well as on the lingual aspect of the ridge, full-thickness flaps were elevated to disclose the marginal 10–15 mm of the hard-tissue wall of the ridge. $_3P_3$ and $_4P_4$ were hemi-sected with the use of a fissure bur. The distal roots were carefully removed using elevators and forceps. The buccal–lingual dimension of the fresh extraction sockets (Fig. 1) was measured using a sliding caliper. The mean buccal–lingual width of the $_3P_3$ sites was 3.5 ± 0.2 mm and the corresponding dimension of the $_4P_4$ sites was 3.9 ± 0.3 mm.

In the two extraction sites of the *right jaw quadrant*, implants (Straumann®; Standard Implant; 4.1 mm in diameter and 6–8 mm long; Straumann® Dental Implant System; Straumann, Waldenburg, Switzerland) were installed. The recipient sites were prepared for implant installation according to the guidelines provided by the manufacturer. The floor of the socket was penetrated with round burs. Subsequently, the recipient site was prepared with pilot drills and finally the canal was tapped by hand using a tap and a ratchet. The implants were placed so that the marginal level of the sand blasted and acid etched (SLA)-coated surface was flush with the buccal bone crest (BC) (Fig. 2). A healing cap (Straumann® Dental Implant System) was attached to the implant. The mobilized buccal and lingual flap tissues were replaced to allow a semi-submerged healing (Fig. 3a) of the implant sites (*implant sites*) and neighbouring mesial tooth portions (*involved tooth sites*). The wound margins were stabilized with interrupted sutures.

The corresponding extraction sites in the *left jaw quadrants* were left without implant placement (*edentulous sites*). The buccal and lingual flaps were stabilized with interrupted sutures to provide soft-tissue coverage of the extraction sockets (Fig. 3b).

The second mandibular pre-molars in both mandibular quadrants ($_2P_2$) were not involved in the surgical procedures but the distal roots were used as controls (*non-involved tooth sites*).

The dogs were placed on a plaque control regimen that included tooth and implant cleaning three times per week with the use of toothbrush and dentifrice. During the first week after surgery, the animals received Amoxicillin (500 mg, twice daily) via the systemic route.

After 3 months of healing, the dogs were sacrificed with an overdose of Pentothal Natrium® and perfused,

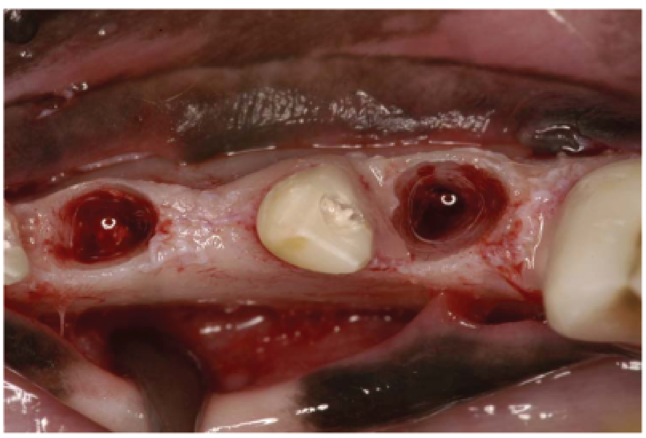

Fig. 1. Clinical photograph illustrating the extraction sockets – distal roots – of the third and fourth mandibular pre-molars immediately after root extraction. Note that the buccal–lingual width of the extraction socket of the fourth pre-molar is wider than that of the third pre-molar.

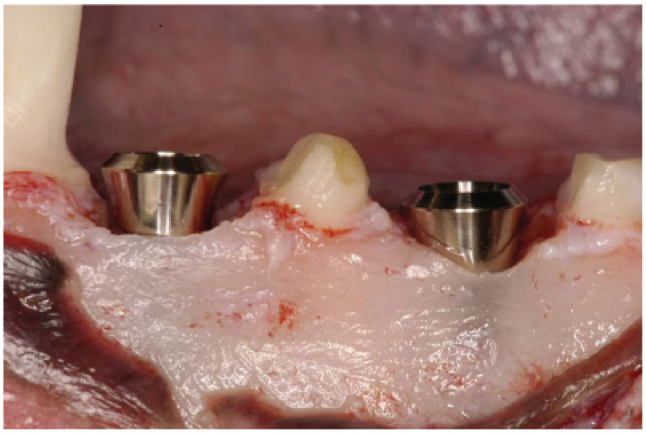

Fig. 2. Clinical photograph illustrating the experimental sites immediately after implant installation. Note that the border of the sand blasted and acid etched-coated surface of the implants was flush with the buccal bone crest.

Fig. 3. (a) Clinical photograph illustrating the wound in the third and fourth pre-molar region after sutures had been placed. Two implants and the adjacent ''involved'' teeth. Note that the healing caps at the implants project above the mucosa. (b) The corresponding edentulous site and adjacent mesial roots of third and fourth pre-molars.

through the carotid arteries, with a fixative containing a mixture of 5% glutaraldehyde and 4% formaldehyde (Karnovsky 1965). The mandibles were dissected and placed in the fixative. Each implant, tooth and edentulous site was removed using a diamond saw (Exact® Apparatebeau, Norderstedt, Hamburg, Germany). The biopsies were processed for ground sectioning according to the methods described by Donath & Breuner (1982) and Donath (1993). The samples were dehydrated in increasing grades of ethanol and infiltrated with Technovit® 7200 VLC-resin (Kulzer, Friedrichrsdorf, Germany). Following embedding in acrylic resin, the biopsy samples were polymerized and sectioned in a buccal–lingual plane using a cutting–grinding unit (Exact® Apparatebeau).

From each implant, edentulous and tooth site, one buccal–lingual section representing the central area of the site was prepared. By micro-grinding and polishing, the sections were reduced to a thickness of about 20 μm and stained in toluidine blue. The histological examination was performed in a Leitz DM-RBE® microscope (Leica, Germany) equipped with an image system (Q-500 MC®, Leica).

Histometric measurements: The following landmarks were identified (Fig. 4):

Implant sites

S: the shoulder of the implant
SLA: marginal border of the SLA-coated surface that was located 2.8 mm apical of S
BC: the margin of the BC (buccal, lingual)
PM: margin of peri-implant mucosa
aBE: apical cells of barrier epithelium

At the buccal and lingual aspects, the following distances were measured and expressed in millimetres: (i) PM–BC, (ii) PM–aBE, (iii) aBE–BC and (iV) SLA–BC.Tooth sites (involved and non-involved)

CEJ: cemento-enamel junction
BC: bone crest (buccal/lingual)
GM: margin of gingiva
aJE: apical cells of the junctional epithelium

At the buccal and lingual aspects, the following distances were measured and expressed in millimetres: (i) GM–BC, (ii) GM–CEJ, (iii) CEJ–BC and (iV) CEJ–aJE. At the *edentulous sites*, the vertical distance between margins of the buccal and lingual bone walls was determined in the following way: a line parallel to the long axis of the healed socket was drawn (C–C) in the centre of the section to separate the buccal and lingual compartments. Subsequently, horizontal lines (L, lingual and B, buccal) perpendicular to C–C were

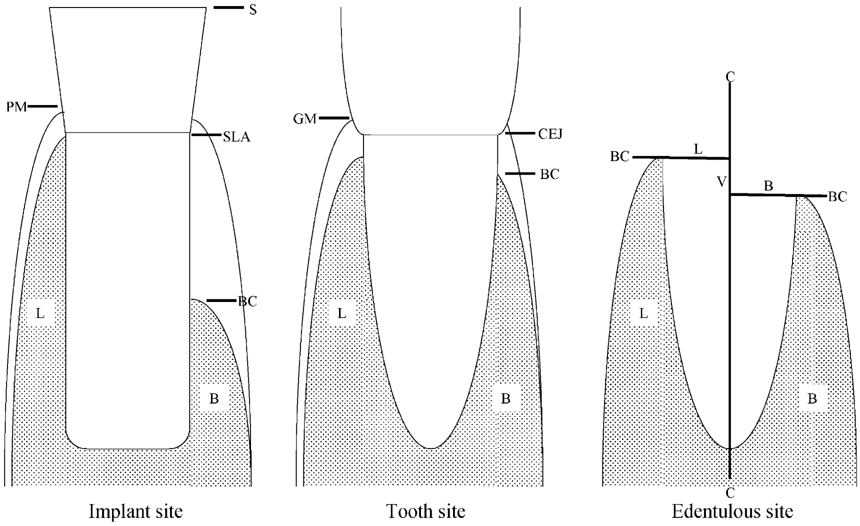

Fig. 4. Schematic drawing presenting the locations of the various histometric measurements were performed. For details regarding abbreviations, see text.

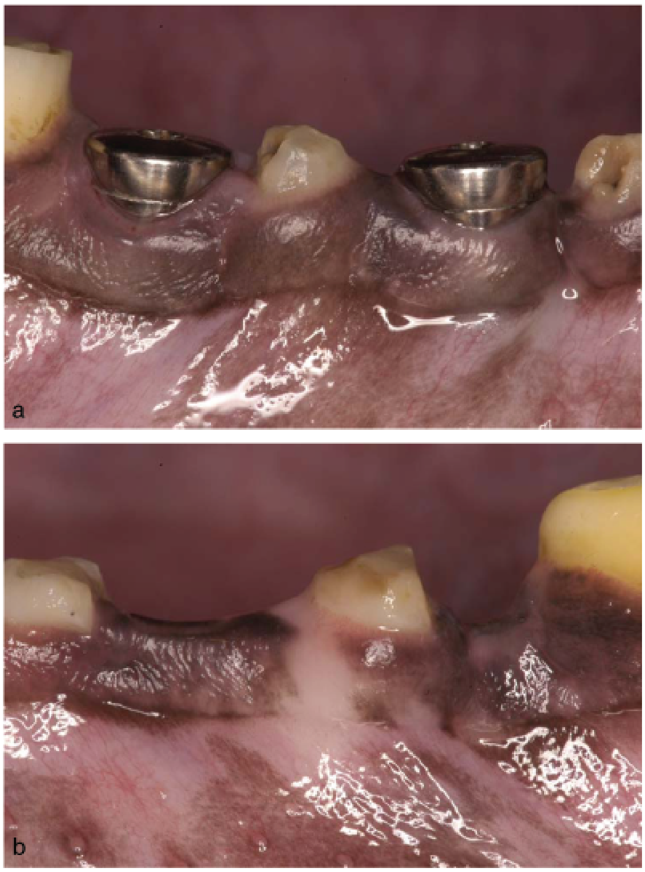

Fig. 5. (a) Clinical photograph illustrating one experimental site (two implants and two ''involved'' roots) after 3 months of healing. Note that the peri-implant mucosa as well as the gingiva show no overt signs of inflammation. The margin of the mucosa resides at the smooth portion of the implant. (b) Clinical photograph of two edentulous sites and adjacent ''involved'' tooth sites after 3 months of healing.

drawn to project the most coronal portions of the buccal and lingual BC to C–C. The vertical distance (V) between the buccal and lingual intersections with C–C was measured and expressed in millimetres.Mean values and standard deviations were calculated for each animal, experimental group and variable.

Results

Clinical observations

All experimental sites healed uneventfully. Overt signs of soft-tissue inflammation (swelling and redness) were seen during the first few weeks of healing, but at 3 months the mucosa adjacent to most implants and teeth, as well as the soft tissue that covered the edentulous ridge appeared to be clinically healthy (Fig. 5a, b).

As assessed by clinical means, all 10 implants were properly osseointegrated. The SLA surface at the *lingual* aspect of the implants was covered by mucosa at all sites. At two of the 10 implant sites (both located in the fourth pre-molar site), the marginal 1 mm of the *buccal* SLA surface was exposed.

The gingival margin (GM) at the buccal and lingual aspects of the involved and non-involved teeth was found to be coronal to the CEJ.

Histological observations

Implant sites

The histological examination revealed that the mucosa at the buccal and lingual aspects of the implant sites was covered by a keratinized oral epithelium that was continuous with a thin barrier epithelium facing the titanium rod. Apical of this barrier epithelium there was a zone of fibre-rich connective tissue (''connective tissue attachment'') that established an apparently tight contact with the implant. At both the buccal and lingual aspects of the implant sites, the connective tissue immediately lateral to the barrier epithelium contained small infiltrates of inflammatory cells, while the more apically located ''connective tissue attachment'' was devoid of such leucocyte accumulations.

The central and outer portions of the buccal and lingual bone walls were comprised of lamellar bone that was characterized by densely packed secondary osteons. The bone tissue immediately lateral to the implant surface appeared to be less mature than the bone in the outer portions of the hard-tissue walls (Fig. 6). This newly formed bone that was separated from the old bone by well-defined reversal lined (Fig. 7)

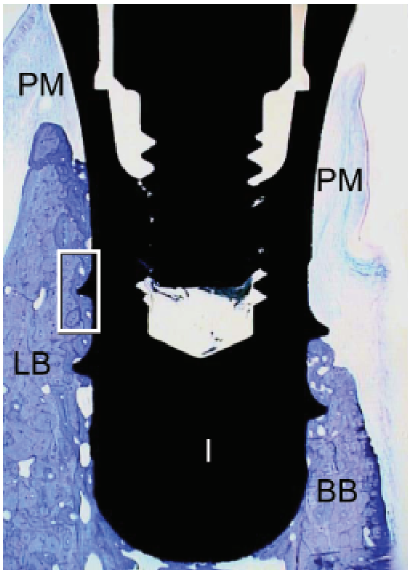

Fig. 6. Buccal–lingual section representing one implant site after 3 months of healing. Note the location of the bone crest at the buccal and lingual aspects of the implant. BB, buccal bone wall; I, implant; LB, lingual bone wall; PM, peri-implant mucosa. Outlined area = detail presented in Fig. 6. Toluidine blue staining; original magnification × 16.

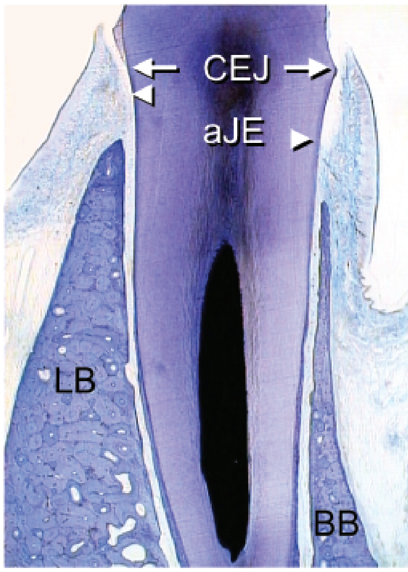

Fig. 8. Buccal–lingual section representing an involved tooth site. Note that the lingual bone crest is closer to the CEJ (arrows) at the lingual than at the buccal aspect of the tooth. The apical level (aJE) of the junctional epithelium (arrowheads). BB, buccal bone wall; LB, lingual bone wall; CEJ, cemento-enamel junction. Toluidine blue staining; original magnification × 16.

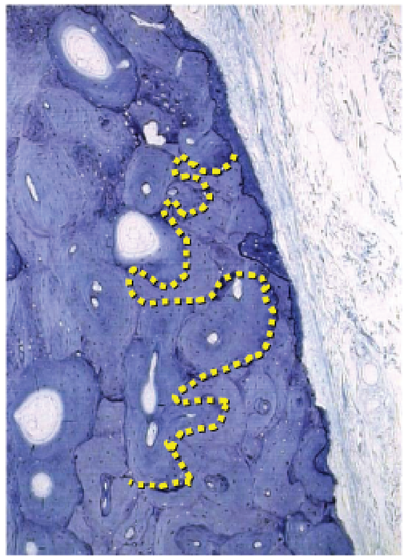

Fig. 10. Buccal–lingual section. Magnified microphotograph of (b) the buccal aspect of the crest identified (outlined area) in Fig. 8. The dotted line represents the borderline between the old and newly formed bone. Toluidine blue staining; original magnification × 100.

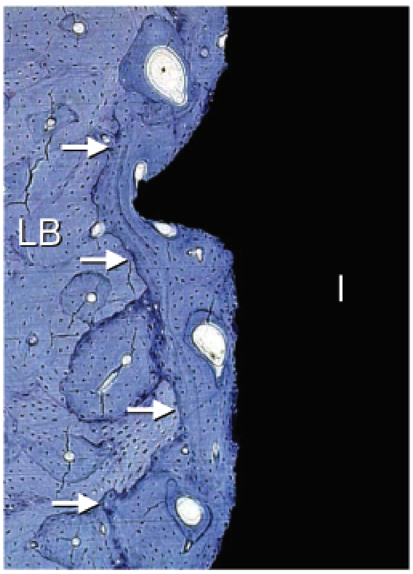

Fig. 7. Higher magnification of the area outlined in Fig. 5. LB, lingual bone wall; I, implant. Arrows indicate the presence of a typical reversal line. Toluidine blue staining; original magnification × 100.

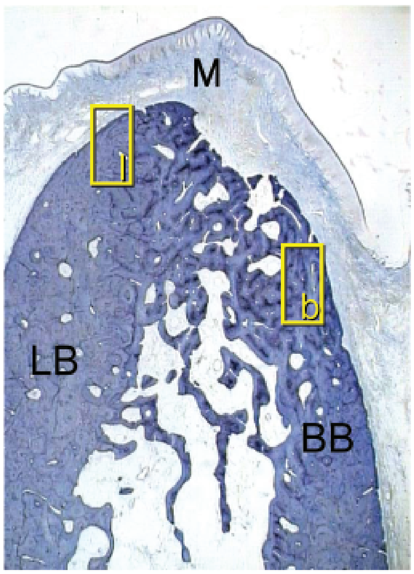

Fig. 9. Buccal–lingual section representing an edentulous site. Note the location of the original bone crest (outlined area) at the buccal (b) and lingual (l) aspects of the alveolar crest. BB, buccal bone wall; LB, lingual bone wall; M, mucosa of the edentulous ridge. Toluidine blue staining; original magnification × 16.

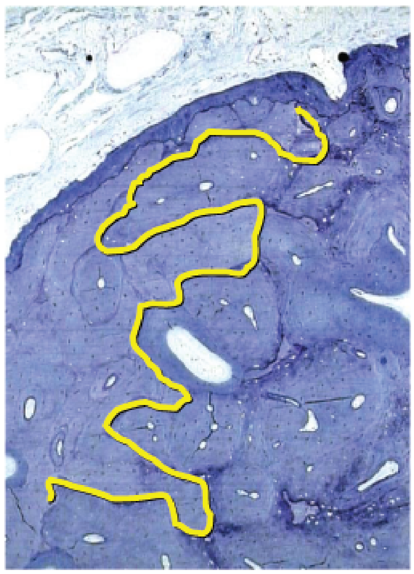

Fig. 11. Buccal–lingual section. Magnified microphotograph of (l) the lingual aspect of the crest identified (outlined area) in Fig. 8. The dotted line represents the borderline between the old and newly formed bone. Toluidine blue staining; original magnification × 100.

contained a large number of bone multicellular units.

The bone tissue that was in direct contact with the *lingual aspect* of the implant consistently extended to, or close to, the marginal border of its SLA-modified portion. In seven out of 10 sites, a small hard-tissue defect (< 1 mm in depth) could be observed between the lingual bone wall and the implant. On the *buccal aspect* of all implants, the marginal termination of the osseointegrated portion of the newly formed bone was consistently found at a level markedly apical of the marginal SLA level. The ''exposed'' portion of the SLA surface was in apparent close contact with the barrier epithelium and/or the connective tissue of the mucosa.

Tooth sites

Involved teeth. Both at the buccal and lingual aspects of the *involved teeth*, the GM was located coronal to the CEJ. The soft tissue at the buccal and lingual aspects of such teeth contained small infiltrates of inflammatory cells. These infiltrates consistently appeared in the connective tissue immediately lateral to the junctional epithelium. The aJE was at the *lingual aspect* of all teeth located close to the CEJ (Fig. 8). At the buccal aspect, however, without fail aJE was located a varying distance apical of CEJ. The bone wall was markedly wider at the lingual than at the buccal aspect of the involved teeth. The buccal BC was located at a longer distance from the CEJ than the corresponding lingual BC.

Non-involved teeth. Both at the buccal and lingual aspects of the *non-involved teeth*, the GM was located coronal to the CEJ. The gingiva at the buccal and lingual aspects of such teeth was consistently devoid of pertinent infiltrates of inflammatory cells. The aJE was at the *buccal* and *lingual aspect* of all teeth located at the CEJ. The buccal bone wall was thinner than the lingual wall but the crests were located at a similar distance from CEJ.

Edentulous sites

The mucosa covering the healed socket was lined by an oral epithelium that harboured a well-keratinized surface layer. The underlying, connective tissue was characterized by its densely packed collagen fibres and lack of infiltrates of inflammatory cells. A newly formed hard-tissue bridge covered the entrance of the extraction socket (Fig. 9). This marginal ridge was mainly made up of woven bone, although small areas of lamellar bone could also be observed. The newly formed hard-tissue bridge extended a varying distance into the extraction socket. Apical of the bridge, the edentulous region was comprised of cancellous bone dominated by its bone marrow.

The surface of the buccal and lingual bone walls, was in most portions, covered by a periosteum and exhibited only minute signs of re-modelling. The marginal termination of the original buccal bone wall was located apical of its lingual counterpart (Figs 10 and 11).

Table 1. Results of the histometric measurements (mm) at the implant sites

	PM–BC	PM–aBE	aBE–BC	SLA–BC
Buccal	3.9 (0.5)	1.9 (0.9)	1.8 (0.8)	2.6 (0.4)
Lingual	2.6 (0.4)	1.9 (0.4)	0.7 (0.2)	0.2 (0.5)

Mean (SD). PM, margin of peri-implant mucosa; BC, bone-to-implant contact; aBE, apical cells of barrier epithelium; SLA, sand blasted and acid etched.

Table 2. Results of the histometric measurements (mm) at the non-involved and involved sites

	Buccal				Lingual			
	GM–BC	GM–CEJ	CEJ–BC	CEJ–aJE	GM–BC	GM–CEJ	CEJ–BC	CEJ–aJE
Non-involved site	2.6 (0.2)	1.7 (0.2)	0.8 (0.1)	0 (0.0)	2 (0.1)	1.3 (0.1)	0.7 (0.2)	0 (0.0)
Involved site	2.8 (0.5)	1.0 (0.3)	1.8 (0.7)	0.5 (0.5)	1.6 (0.6)	0.9 (0.6)	0.8 (0.1)	0.2 (0.3)

Mean (SD). GM, margin of gingiva; BC, bone-to-implant contact; CEJ, cemento-enamel junction; aBE, apical cells of barrier epithelium.

Histometric measurements

Implant sites (Table 1)

The mean distance between the PM and the BC at the buccal aspect was 3.9 ± 0.5 mm. The corresponding dimension at the lingual aspect was 2.6 ± 0.4 mm. The length of the barrier epithelium (PM–aBE) was on the average 1.9 ± 0.9 mm (buccal) and 1.9 ± 0.4 mm (lingual). The mean distance between aBE and BC was 1.8 ± 0.8 mm (buccal) and 0.7 ± 0.2 mm (lingual). The level of BC was located 2.6 ± 0.4 mm from the SLA level at the buccal aspect and 0.2 ± 0.5 mm at the lingual aspect of the site.

Tooth sites (Table 2)

Non-involved teeth. The mean distance between the GM and the BC was 2.6 ± 0.2 mm (buccal) and 2.0 ± 0.1 mm (lingual), while the corresponding distance between GM and CEJ was 1.7 ± 0.2 mm (buccal) and 1.3 ± 0.1 mm (lingual). The BC was located on the average 08 ± 0.1 (buccal) and 0.7 ± 0.2 mm (lingual) from the CEJ. The aJE were located at or close to the CEJ both at the buccal and lingual aspects.

Involved teeth. The distance GM–BC was 2.8 ± 0.5 mm long at the buccal and 1.6 ± 0.6 mm at the lingual aspect of the involved teeth. At both the buccal and the lingual aspect, the distance GM–CEJ was about 1 mm high. The distance between CEJ and BC was on the average 1.8 ± 0.7 mm at the buccal and 0.8 ± 0.1 mm at the lingual aspect. The mean amount of attachment loss (CEJ–aJE) was 0.5 ± 0.5 mm (buccal) and 0.2 ± 0.3 mm (lingual).

Edentulous sites

The mean vertical distance (V) between the marginal termination of the buccal and lingual bone walls was 2.2 ± 0.9 mm.

Discussion

The present experiment demonstrated that marked dimensional alterations had occurred in the edentulous ridge of dogs after 3 months of healing following the extraction of the distal root of mandibular pre-molars. The placement of an implant in the fresh extraction site obviously failed to prevent the re-modelling that occurred in the walls of the socket. The resulting height of the buccal and lingual walls at 3 months was similar at implants and edentulous sites and the vertical bone level change was more pronounced at the buccal than at the lingual aspect of the ridge. It is suggested that the resorption of the socket walls that occurs following tooth removal must be considered in conjunction with implant placement in fresh extraction sockets.

In the current experiment, it was observed that re-modelling following tooth extraction was more pronounced in the buccal than in the lingual bone wall. This is in agreement with data previously reported (e.g. Pietrokovski & Massler 1967, Schropp et al. 2003, Botticelli et al. 2004, Araújo & Lindhe 2005). In the present study, it was further documented that the ''apico-coronal'' height of the buccal hard-tissue wall was reduced considerably more than that of the lingual wall of the same extraction socket. This finding is consistent with data from a dog experiment by Araújo & Lindhe (2005), who studied healing of extraction sockets in biopsies sampled 1, 2, 4 and 8 weeks following the careful removal of the distal roots of hemi-sected third and fourth mandibular pre-molars. The histological examination revealed that in the 8-week specimens, the marginal termination of the buccal wall was located 1.9 mm apical of its lingual counterpart. The authors suggested that this difference between the buccal and lingual bone walls was related to the following:

(i) the early disappearance of the bundle bone that, in the presence of a tooth, occupies a larger fraction of the marginal portion of the bone wall in the buccal than in the lingual aspect of the socket.
(ii) the additional surface resorption that will have a more pronounced effect on the delicate buccal than on the wider lingual bone wall of the socket.

In this context, it must be realized that the surgical trauma inflicted along with flap elevation, root extraction and implant installation may have resulted in bone re-modelling that, to a different extent, may have influenced the walls of the sockets. In order to study the effect of flap elevation per se on hard- and soft-tissue re-modelling, two different tooth categories were selected as controls. One category (*positive control*) was represented by the mesial roots of the mandibular third and fourth premolars, i.e. roots that were included in procedures such as rubber dam application as well as sulcus incision and flap elevation. The distal roots of the second mandibular pre-molars represented the second category of controls (*negative controls*) and included teeth that were not included in the surgical field and had not been instrumented prior to or during the experiment. The histological examination of the control sites demonstrated that the untreated teeth were associated with a normal periodontium (Table 2). On the contrary, all involved tooth sites exhibited signs of attachment loss (CEJ–aJE) and bone loss (CEJ–BC). This finding is consistent with data by Wood et al. (1972) and Bragger et al. (1988) and illustrates that surgical trauma that includes the separation of the periosteum from the bone surface will induce re-modelling of the surface layer of the alveolar bone in the exposed area.

The examination of the involved tooth sites further revealed that there was more attachment and bone loss at the buccal than at the lingual aspect of the roots (CEJ–aJE: 1.8 *versus* 0.2 mm, CEJ–BC: 0.8 *versus* 0.1 mm). The reason for this difference is presently not properly understood but may be related to the thicker bone wall that was present on the lingual surface of the mandibular premolars. This suggestion is in agreement with Wood et al. (1972), who studied alveolar crest reduction in humans ''following full- and partial-thickness flaps''. The authors reported that that ''Loss of crestal alveolar bone height in response to full-thickness flaps occurred in each of the seven patients surgically re-evaluated and varied from a mean of 0.23 mm to a mean of 1.6 mm''. Further, the authors concluded that ''In our patients, teeth with the thinnest radicular bone consistently demonstrated the most bone loss postoperatively''.

The main finding of the present study was that the placement of an implant in the fresh extraction socket failed to influence the process of re-modelling that occurs in the buccal and lingual hard-tissue walls of the socket that followed tooth removal. Thus, after 3 months of healing, the amount of buccal bone height reduction (in comparison with lingual bone alteration) was similar at implant sites and edentulous sites. Thus, the vertical discrepancy between the buccal and lingual bone margins was in both category of sites >2 mm: edentulous sites $= 2.2$ mm and implant sites 2.4 mm. In other words, the resorption of the buccal bone wall of the socket was three times as great as that observed at the buccal aspect of the surgically involved control teeth. This observation is in agreement not only with Araújo & Lindhe (2005) but also with results from a study in humans by Botticelli et al. (2004). They examined dimensional alterations that occurred in humans during a 4-month interval following implant placement in fresh extraction sockets. The authors reported that during healing, the width of the marginal portion of the buccal bone wall was reduced markedly more than the corresponding lingual wall.

The fresh extraction socket of the third pre-molar had a smaller buccal–lingual dimension than that of the fourth pre-molar. This means that during the preparation of the site for implant installation in the third pre-molar region, more bone had to be removed from the marginal portions of the hard-tissue walls than was the case at the site of the fourth pre-molar. Thus, following implant placement, the remaining buccal bone wall at the third pre-molar site was considerably thinner than that in the fourth pre-molar site. Despite this difference between the third and fourth pre-molar locations regarding the width of the buccal bone wall following surgery, the vertical reduction of the walls was following similar healing at the two sites (2.6 ± 0.5 *versus* 2.6 ± 0.3 mm). This means that factors other than the thickness of remaining bone must play important roles in bone tissue re-modelling following implant installation.

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