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Stability of crestal bone level at platform-switched non-submerged titanium implants: a histomorphometrical study in dogs

Jürgen Becker[1], Daniel Ferrari[1], Ilja Mihatovic[1], Narja Sahm[1], Alex Schaer[2] and Frank Schwarz[1]

[1]Department of Oral Surgery, Westdeutsche Kieferklinik, Heinrich Heine University, Düsseldorf, Germany; [2]Camlog Biotechnologies AG, Basel, Switzerland

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Abstract

Objectives: To investigate the influence of platform switching on crestal bone level changes at non-submerged titanium implants over a period of 6 months.

Material and Methods: Titanium implants ($n = 72$) were placed at 0.4 mm above the alveolar crest in the lower jaws of 12 dogs and randomly assigned to either matching or non-matching (circumferential horizontal mismatch of 0.3 mm) healing abutments. At 4, 8, 12, and 24 weeks, dissected blocks were processed for histomorphometrical analysis. Measurements were made between the implant shoulder (IS) and the apical extension of the long junctional epithelium (aJE), the most coronal level of bone in contact with the implant (CLB), and the level of the alveolar bone crest (BC).

Results: At 24 weeks, differences in the mean IS–aJE, IS–CLB, and IS–BC values were 0.2 ± 1.2, 0.3 ± 0.7, and 0.3 ± 0.8 mm at the buccal aspect, and 0.2 ± 0.9, 0.3 ± 0.5, and 0.3 ± 0.8 mm at the lingual aspect, respectively. Comparisons between groups revealed no significant differences at either the buccal or the lingual aspects.

Conclusions: It was concluded that (i) bone remodelling was minimal in both groups and (ii) platform switching may not be of crucial importance for maintenance of the crestal bone level.

Key words: animal study; crestal bone level; histomorphometry; platform switching

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In recent years, the crestal bone-level changes that are frequently observed at titanium implants exposed to the oral environment have become a topic of growing interest. These alterations were particularly associated with two-piece implants during the first year of loading, resulting in mean bone changes of about 1.5–2.0 mm (Albrektsson et al. 1986, Smith & Zarb 1989, Jung et al. 1996). These alterations appeared to be more pronounced at the buccal than at the lingual aspect of the ridge (Araújo et al. 2005). From a clinical point of view, the exposure of structured titanium surfaces may result in an accumulation of bacterial plaque biofilms, which in turn causes inflammatory reactions in the implant supporting soft and hard tissue. The results from an experimental animal study provide histological evidence that the progression of peri-implantitis seems to be more pronounced at implants with a moderately rough surface than at implants with a polished surface (Berglundh et al. 2007b). Recently, the Consensus Report of the sixth European Workshop on Periodontology had classified rough implant surfaces as a potential risk indicator for peri-implant diseases (Lindhe & Meyle 2008).

Conflict of interests and source of funding

Becker, Ferrari, Mihatovic, Sahm, and Schwarz declare that they have no conflict of interests. The co-author Dr. Schaer provided an experimental implant design and is an employee of Camlog Biotechnologies AG, the manufacturer of the tested implant system.

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Several factors have been proven to be associated with changes in crestal bone height adjacent to titanium implants. These include a bacterial colonization of the micro-gap at the implant–abutment interface (Ericsson et al. 1995, Hermann et al. 2001), biologic aspects such as the establishment of an adequately dimensioned biological width (Berglundh & Lindhe 1996), or dis- and subsequent reconnections of the abutment component compromising the mucosal barrier (Abrahamsson et al. 1997). In addition, biomechanical aspects such as interfacial shear strengths (Rangert et al. 1989), the influence of the macrodesign (Zechner et al. 2004, Shin et al. 2006), as well as the location of the borderline between the machined and the structured implant surface (Hermann et al. 2000, Schwarz et al. 2008) have been discussed. In recent years, a concept termed platform switching was introduced and suggested to overcome some of these problems. Basically, this design strategy includes the connection of a smaller diameter abutment relative to the platform diameter of the titanium implant. It was hypothesized that this horizontal inward repositioning of the implant–abutment interface may increase the distance between the abutment inflammatory cell infiltrate and the alveolar crest, thus decreasing its influence on bone resorption. Moreover, with the increased surface area created by the exposed implant seating surface, there might be a reduction in the amount of crestal bone resorption necessary to expose a minimum amount of implant surface to which the soft tissue can attach (Lazzara & Porter 2006). Even though preliminary data from a prospective study showed that platform switching appears to limit crestal bone resorption (Hürzeler et al. 2007), only a few experimental studies have focused on the proof of principle that might be associated with this concept. In particular, biomechanical analyses provide some evidence that this specific implant–abutment configuration has the advantage of reducing stress translation to the crestal bone–implant interface (Maeda et al. 2007, Schrotenboer et al. 2008). The results of an experimental study performed in dogs have indicated that a circumferential horizontal mismatch of 0.5 mm was able to prevent the apical down-growth of the barrier epithelium over an observation period of 28 days, thus decreasing the epithelial component of the biological width. In comparison with matching control abutments, this resulted in a slight crestal alveolar bone preservation of 0.5 ± 0.5 mm at the buccal, and 0.1 ± 0.5 mm at the lingual aspect (Becker et al. 2007). However, a final conclusion regarding the stability of the peri-implant mucosa over time could not be drawn, because a maturation of the barrier epithelium and the organization of the collagen fibres in the subepithelial connective tissue may require a healing period of at least 6–8 weeks (Berglundh et al. 2007a).

Therefore, the aim of the present study was to histomorphometrically investigate the crestal bone-level changes at platform-switched non-submerged titanium implants over a period of 6 months in a dog model.

Material and Methods

Animals

Twelve fox hounds (age 15–16 months, mean weight 32.7 ± 3.7 kg) were used in the study. All animals exhibited a fully erupted permanent dentition. During the experiment, the dogs were fed once per day with a soft-food diet and water. Animal selection, management, and surgery protocol were approved by the Animal Care and Use Committee of the Heinrich Heine University and the Bezirksregierung Düsseldorf. The experimental segment of the study started after an adaption period of 4 weeks.

Study design

This study was performed in two surgical phases. In the first phase, extraction of the mandibular and maxillary second, third, and fourth pre-molar as well as first and second molar (P2–M2) was performed bilaterally. After 3 months of healing, sand-blasted and acid-etched screw-typed titanium implants with either matching or non-matching healing abutments were randomly assigned to the lower jaws according to a split-mouth design, including three implants per group. Three animals each were assigned to healing periods of 4, 8, 12, and 24 weeks.

Titanium implants and randomization procedure

A total of $n = 72$ experimental (E-K1057.3811) titanium implants (∅ 3.8 mm, length: 11 mm, Camlog® Screw-Line Implant, Promote® plus, Camlog Biotechnologies AG, Basel, Switzerland) were scheduled for the connection of either matching or non-matching healing abutments. The connection of diameter-reduced healing abutments (∅ 3.2 mm, height: 4 mm, Camlog®) resulted in a circumferential horizontal mismatch of 0.3 mm (CPS). Matching wide-body healing abutments (∅ 3.8 mm, height: 4.0 mm, Camlog®) served as control (CAM) (Fig. 1). Following placement of $n = 3$ implants in each side of the mandible, both types of abutments were randomly connected to the implants according to a split-mouth design (computer-generated list, RandList®, DatInf GmbH, Tübingen, Germany). Accordingly, each animal received a total of six implants, three CPS on one side of the mandible and three CAM on the other side.

Surgical procedure

Following intramuscular sedation with 0.17 mg/kg acepromazine (Vetranquil 1%, Ceva Tiergesundheit, Düsseldorf, Germany), anaesthesia was initiated using 21.5 mg/kg thiopental-sodium (Trapanal 2.5%, Altana GmbH, Konstanz, Germany). During all surgical

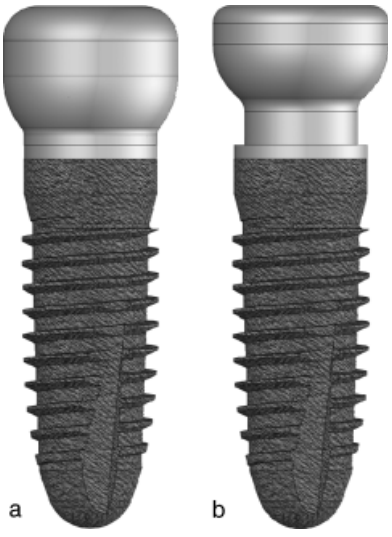

Fig. 1. An experimental titanium implant (∅ 3.8 mm, length: 11 mm) was used for the connection of either matching (∅ 3.8 mm, height: 4 mm) (a), or diameter reduced (∅ 3.2 mm, height: 4 mm) (b) healing abutments. The connection of non-matching healing abutments resulted in a circumferential horizontal mismatch of 0.3 mm.

procedures, inhalation anesthesia was performed using oxygen and nitrous oxide and isoflurane. To maintain hydration, all animals received a constant-rate infusion of lactated Ringer's solution while anaesthetized. Intraoperative analgesia was performed by an intravenous injection of 0.4 mg/kg piritramid (Dipidolor®, Janssen-Cilag GmbH, Neuss, Germany) and 4.5 mg/kg carprofene (Rimadyl®, Pfitzer Pharma GmbH, Karlsruhe, Germany). For post-operative treatment, piritramid and carprofene were applied subcutaneously for 3 days at the same dose as described before. Additionally, prophylactic administration of clindamycine (11.0 mg/kg body weight, Clerobe®, Pharmacia Tiergesundheit, Erlangen, Germany) was performed intra- and post-operatively for 3 days.

In the first surgery, P2–M2 were carefully removed bilaterally in both jaws after reflection of mucoperiosteal flaps and tooth separation. After wound closure by means of mattress sutures, the sites were allowed to heal for 3 months.

In the second surgery, midcrestal incisions were made and mucoperiosteal flaps were reflected to expose the respective sites for implant insertion into both jaws. Surgical implant sites were prepared bilaterally in the posterior region of the lower jaws, at a distance of 10 mm apart, using a low-trauma surgical technique under copious irrigation with sterile 0.9% physiological saline (Becker et al. 2007). Particular care was taken to preserve a residual thickness of the alveolar bone crest of at least 1 mm at both buccal and lingual aspects of each implant site. All implants were inserted with good primary stability (i.e. lack of clinical mobility) in such a way that the implant shoulder (IS) exceeded the buccal aspect of the alveolar crest for 0.4 mm (ID), as suggested in the surgical protocol of the manufacturer.

The abutments were connected (torque: 15 N cm) immediately following implant placement in both groups (Fig. 2a–c). Following irrigation, mucoperiosteal flaps were repositioned with mattress sutures (Resorba®, Nürnberg, Germany), and implants were left to heal in a non-submerged position (Fig. 2d). In order to prevent trauma to the peri-implant mucosa, oral hygiene procedures were omitted during the initial healing period of 7 days. Thereafter, a plaque control programme including tooth and implant cleaning just by the use of a toothbrush was initiated and performed twice per week without anaesthesia.

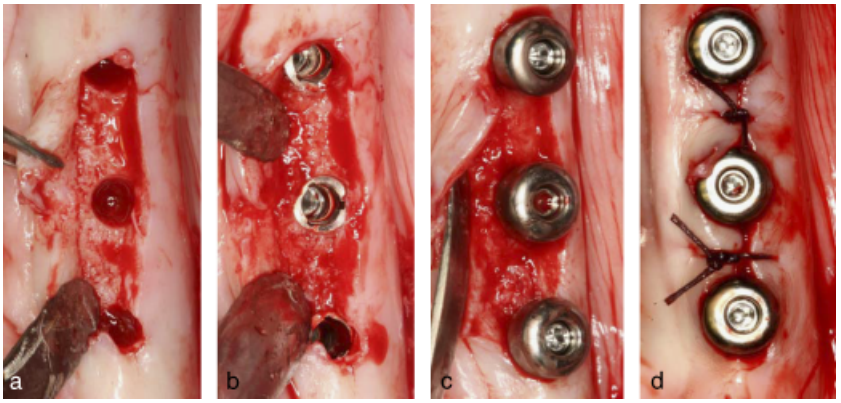

Fig. 2. (a) Surgical implant sites were prepared bilaterally in the posterior region of the lower jaws, at a distance of 10 mm apart, using a low-trauma surgical technique. (b) All titanium implants were inserted in such a way that the implant shoulder (IS) exceeded the buccal aspect of the alveolar crest for 0.4 mm (ID). Accordingly, the borderline between the machined and the structured implant surface coincided with the bone crest. (c) Following implant placement, matching and non-matching abutments were randomly allocated according to a split-mouth design. (d) The implants were left to heal in a non-submerged position.

Retrieval of specimens

The animals were sacrificed (overdose of sodium pentobarbital 3%) after a healing period of 4, 8, 12, and 24 weeks ($n = 3$ dogs each), respectively, and the oral tissues were fixed by perfusion with 10% buffered formalin administered through the carotid arteries. The jaws were dissected and blocks containing the experimental specimens were obtained. All specimens were fixed in 10% neutral-buffered formalin solution for 4–7 days.

Histological preparation

The specimens were dehydrated using ascending grades of alcohol and xylene, infiltrated and embedded in methylmethacrylate (MMA, Technovit 7200, Heraeus Kulzer, Wehrheim, Germany) for non-decalcified sectioning. After 20 h the specimens were completely polymerized. Each implant site was cut in the bucco-lingual direction along with the long axis of the implant using a diamond wire saw (Exakt®, Apparatebau, Norderstedt, Germany). Serial sections were prepared from the respective specimens, resulting in three sections approximately 500 µm in thickness each (Donath 1985). Subsequently, all specimens were glued with acrylic cement (Technovit 7210 VLC, Heraeus Kulzer) to opaque plexiglas and ground to a final thickness of approximately 30 µm. All sections were stained with Masson Goldner trichrome.

Histological analysis

Histomorphometrical analyses as well as microscopic observations were performed by one experienced investigator (N. S.) masked to the specific experimental conditions. For image acquisition, a colour CCD camera (Color View III, Olympus, Hamburg, Germany) was mounted on a binocular light microscope (Olympus BX50, Olympus). Digital images (original magnification × 200) were evaluated using a software program (analySIS FIVE docu®, Soft Imaging System, Münster, Germany).

The following landmarks were identified in the stained sections (Becker et al. 2007): IS, implant shoulder; aJE, the apical extension of the long junctional epithelium; aICT, the apical extension of the inflammatory cell infiltrate at the implant–abutment interface; CLB, the most coronal level of bone in contact with the implant; and BC, the level of the alveolar bone crest. Linear measurements were made by drawing a vertical line, following the long axis of the implant, from IS to aJE (IS–aJE), IS to CLB (IS–CLB), and IS to BC (IS–BC) at both buccal and lingual aspects.

Statistical analysis

The statistical analysis was performed using a commercially available software

program (SPSS 15.0, SPSS Inc., Chicago, IL, USA). The mean values and standard deviations among animals were calculated for each variable and group. The data rows were examined using the Kolmogorow–Smirnow test for a normal distribution. For the statistical evaluation of the changes within groups (i.e. buccal and lingual aspects, changes over time), the paired *t*-test was used. For the comparisons between groups, the unpaired *t*-test was used. The α error was set at 0.05.

Results

The post-operative healing was considered as generally uneventful in all dogs. No complications such as allergic reactions, abscesses, or infections were observed throughout the study period of 6 months.

Histological observations/ histomorphometrical analysis

The mean values of IS–aJE, IS–CLB, and IS–BC for both CAM and CPS implants at 4, 8, 12, and 24 weeks are presented in Tables 1 and 2. The differences in IS–aJE, IS–CLB, and IS–BC between both groups at the respective time points are presented in Table 3.

At 4 weeks, histomorphometrical analysis revealed that aJE basically tended to stop at the level of IS in both CAM and CPS groups. This was particularly true for CPS implants, because the horizontal mismatch of 0.3 mm supported the most apical epithelial cell layers, thus preventing their apical down-growth. In contrast, some CAM specimens revealed slightly increased IS–aJE values at either buccal or lingual aspects (Figs 3a and 4a). The difference between groups, however, did not reach statistical significance ($p > 0.05$; unpaired *t*-test) (Table 3). Both test and control implants exhibited a well-established bone-to-implant contact at the endosseous aspect. In particular, a mature woven bone had completely spanned the gap between the adjacent alveolar bone and the titanium implant surface. Considering the initial insertion depth (BTB), the mean IS–CLB and IS–BC values comparably increased at the buccal as well as the lingual aspect of both test and control implants. The differences between groups were statistically not significant ($p > 0.05$, respectively, unpaired *t*-test) (Figs 3a and 4a).

Table 1. Mean values (± SD) of IS–aJE, IS–CLB, and IS–BC (in mm ± SD) at CAM implants after 4, 8, 12, and 24 weeks of healing ($n = 3$ dogs per healing period)

Week	Site	IS–aJE	IS–CLB	IS–BC
4	Buccal	0.2 ± 0.8	1.0 ± 0.4	0.5 ± 0.4
	Lingual	0.1 ± 0.7	1.1 ± 0.4	1.1 ± 0.4
8	Buccal	0.3 ± 0.2	1.2 ± 0.3	0.5 ± 0.2
	Lingual	0.2 ± 0.4	1.4 ± 0.3	1.3 ± 0.4
12	Buccal	0.3 ± 0.3	1.3 ± 0.5	1.2 ± 0.4
	Lingual	0.2 ± 0.5	1.3 ± 0.3	0.8 ± 0.2*
24	Buccal	0.2 ± 0.3	1.2 ± 0.5	1.0 ± 0.6*
	Lingual	0.3 ± 0.5**	1.2 ± 0.6	1.1 ± 0.7

Comparisons within groups (to week 4):
*$p < 0.05$, **$p < 0.01$; paired *t*-test, respectively.

Table 2. Mean values (± SD) of IS–aJE, IS–CLB, and IS–BC (in mm ± SD) at CPS implants after 4, 8, 12, and 24 weeks of healing ($n = 3$ dogs per healing period)

Week	Site	IS–aJE	IS–CLB	IS–BC
4	Buccal	0.0 ± 0.4	1.1 ± 0.2	0.5 ± 0.6
	Lingual	0.0 ± 0.2	1.2 ± 0.2	1.1 ± 0.2
8	Buccal	0.0 ± 0.5	1.0 ± 0.4	0.5 ± 0.4
	Lingual	0.0 ± 0.1	1.0 ± 0.3	0.7 ± 0.4*
12	Buccal	0.0 ± 0.3	1.1 ± 0.2	0.7 ± 0.4**
	Lingual	0.0 ± 0.4	0.9 ± 0.4	0.4 ± 0.1
24	Buccal	0.0 ± 0.1	0.9 ± 0.4*	0.7 ± 0.5
	Lingual	0.1 ± 0.2	0.9 ± 0.4	0.8 ± 0.5

Comparisons within groups (to week 4):
*$p < 0.05$, **$p < 0.01$; paired *t*-test, respectively.

Table 3. Difference Δ (in mm ± SD) in IS–aJE, IS–CLB, and IS–BC between CAM and CPS implants after 4, 8, 12, and 24 weeks of healing ($n = 3$ dogs per healing period)

Week	Site	ΔIS–aJE	ΔIS–CLB	ΔIS–BC
4	Buccal	0.2 ± 0.9	− 0.2 ± 0.5	− 0.1 ± 0.7
	Lingual	0.1 ± 0.1	− 0.1 ± 0.4	0.0 ± 0.5
8	Buccal	0.3 ± 1.0	0.3 ± 0.3	− 0.1 ± 0.5
	Lingual	0.2 ± 0.2	0.4 ± 0.5	0.6 ± 0.8
12	Buccal	0.3 ± 0.7	0.2 ± 0.3	0.5 ± 0.7
	Lingual	0.2 ± 0.9	0.5 ± 0.4	0.4 ± 0.1*
24	Buccal	0.2 ± 1.2	0.3 ± 0.7	0.3 ± 0.8
	Lingual	0.2 ± 0.9	0.3 ± 0.5	0.3 ± 0.8

Comparisons between groups:
*$p < 0.05$; unpaired *t*-test, respectively.

At 8 weeks, wound healing at the endosseous aspect of both CAM and CPS implants was mainly characterized by a deposition of a parallel-fibred bone. Histomorphometrical analysis in the CAM group revealed slightly increased mean IS–aJE, as well as stable IS–CLB, and IS–BC values when compared with the respective values assessed at 4 weeks ($p > 0.05$; paired *t*-test). While the mean IS–aJE and IS–CLB also remained stable in the CPS group ($p > 0.05$; paired *t*-test) (Figs 3b and 4b), a significant increase was observed for mean IS–BC values at the lingual aspect ($p < 0.05$; paired *t*-test). The differences between both groups were statistically not significant ($p > 0.05$, respectively, unpaired *t*-test) (Table 3).

At 12 weeks, wound healing in both groups was mainly characterized by a deposition of a lamellar bone. Remodelling of the crestal alveolar bone was frequently observed at either buccal or lingual aspects (Figs 3c and 4c). Accordingly, within-group comparisons revealed significantly decreased IS–BC values at the lingual aspect of CAM implants ($p < 0.05$; paired *t*-test), and significantly increased IS–BC values at

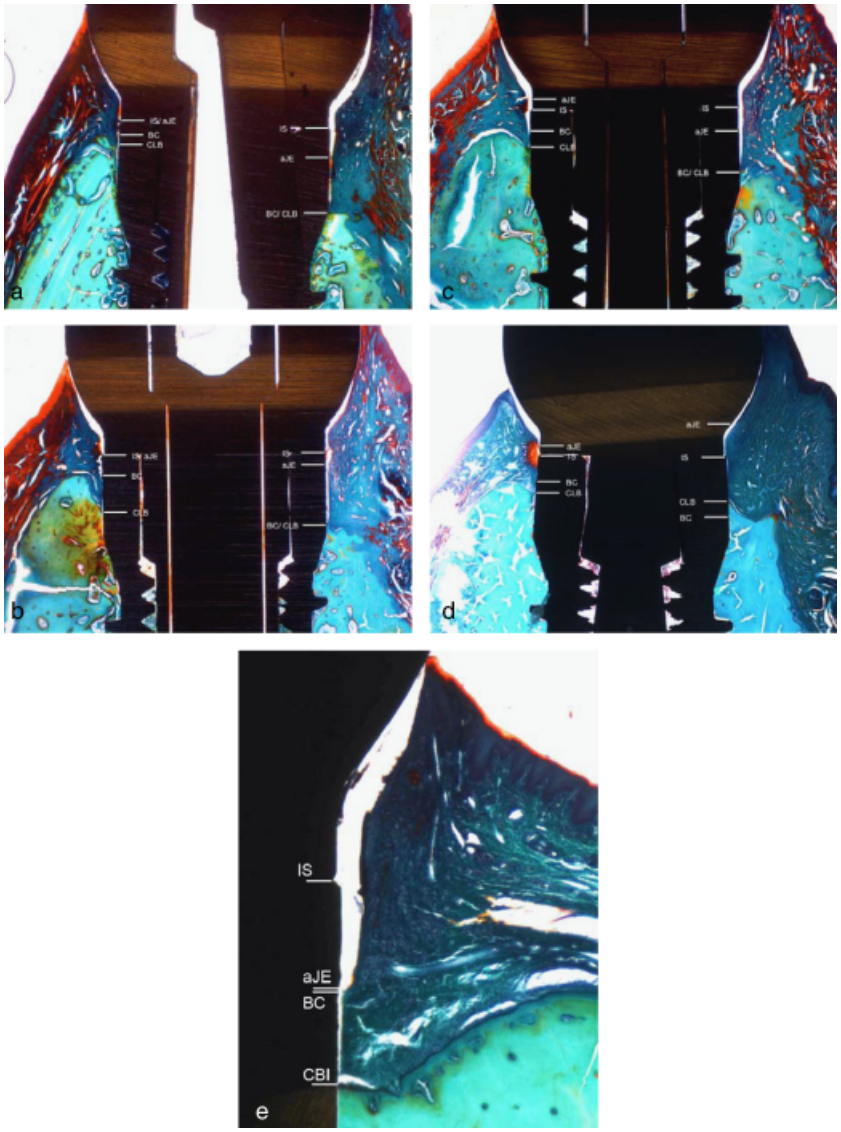

Fig. 3. Representative histological views (Masson Goldner stain) of wound healing at lingual (left) and buccal (right) aspects of CAM implants (original magnification × 25). The junctional epithelium was commonly located at or slightly below the level of IS. A remodelling of the crestal alveolar bone was mainly observed between 4 and 12 weeks of healing. (a) 4 weeks (original magnification × 25); (b) 8 weeks (original magnification × 25); (c) 12 weeks (original magnification × 25); (d) 24 weeks (original magnification × 25); (e) 24 weeks (original magnification × 45).

the buccal aspect of CPS implants ($p < 0.01$; paired *t*-test). A significant difference between both groups was observed for the mean IS–BC values assessed at the lingual aspect ($p < 0.05$; unpaired *t*-test) (Table 3).

At 24 weeks, bone remodelling at the crestal aspect of the alveolar bone in both groups appeared to be less pronounced when compared with the situation observed at 12 weeks (Figs 3d and 4d). CAM implants exhibited significant increases in the mean IS–aJE values at the lingual aspect ($p < 0.05$; paired *t*-test) and the mean IS–BC values at the buccal aspect ($p < 0.01$; paired *t*-test). Within-group comparisons at CPS implants revealed a significant decrease in the mean IS–CLB values at the buccal aspect. The differences in the mean IS–aJE, IS–CLB, and IS–BC values between test and control implants were statistically not significant ($p > 0.05$, respectively; unpaired *t*-test) (Table 3) (Figs 3e and 4e).

Over the entire study period of 24 weeks, histological observation revealed a mixed chronic inflammatory cell infiltrate in close proximity to the implant–abutment interface. The vertical dimension was comparable in both groups and varied between 0.34 ± 0.53 mm in the CAM and 0.41 ± 0.48 mm in the CPS group ($p > 0.05$; unpaired and paired *t*-test, respectively). In most of the specimens, BC and CLB were separated from the inflammatory cell infiltrate by a sound subepithelial connective tissue. Occasionally, however, its apical extension also reached the crestal level of the implant supporting alveolar bone (Fig. 5).

Discussion

The present study was designed to evaluate the influence of platform switching on crestal bone-level changes at non-submerged titanium implants over a period of 6 months in a dog model. Within its limitations, histomorphometrical analysis revealed a comparable pattern of soft and hard tissue healing at either CAM or CPS implants. In particular, the mean IS–aJE and IS–CLB values were not significantly different between both groups at either 4, 8, 12, or 24 weeks of healing. Similar results were also observed for the respective mean ΔIS–BC values, with only one exception at the lingual aspect after 12 weeks of healing. In this context, it must be emphasized that the lingual aspect of the alveolar crest did not serve as a reference point for IS during implant placement, and therefore, the difference noted at 12 weeks might also be attributed to the initial anatomical variations of the mean IS–BC values in both groups.

When interpreting the present results, it was also noted that both groups revealed only a minor bone remodelling over time. These changes were mainly related to the mean IS–BC values as observed between weeks 8 and 24. Considering the initial insertion depth of IS at 0.4 mm above the alveolar crest, mean IS–CLB values slightly increased after 4 weeks of healing but remained stable for the remaining study period of 5 months. Basically, these data are in accordance with the histomorphometrical results of a previous experimental study reporting on crestal bone changes at wide diameter (5.0 mm) CAM and CPS implants over a period of 28 days (Becker et al. 2007). The mean IS–aJE values assessed at 4 weeks varied from 0.9 ± 0.4 mm (buccal) to 1.1 ± 0.6 mm

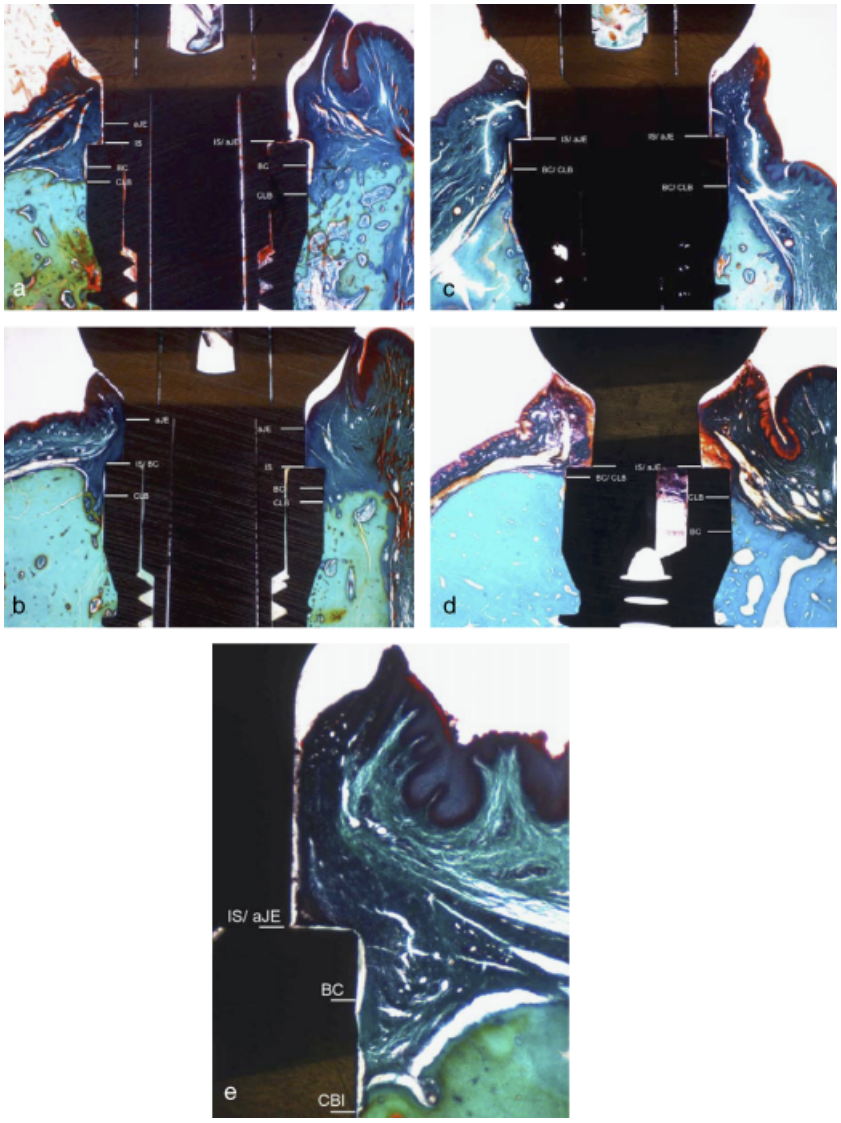

Fig. 4. Representative histological views (Masson Goldner stain) of wound healing at lingual (left) and buccal (right) aspects of CPS implants. Over the entire period of 24 weeks, the horizontal mismatch of 0.3 mm prevented an apical down-growth of the junctional epithelium. However, this was also associated with a slight remodelling at the crestal aspect of the alveolar bone. (a) 4 weeks (original magnification × 25); (b) 8 weeks (original magnification × 25); (c) 12 weeks (original magnification × 25); (d) 24 weeks (original magnification × 25); (e) 24 weeks (original magnification × 45). Figures 3 and 4. Landmarks for the histomorphometrical analysis: IS, implant shoulder; aJE, the apical extension of the long junctional epithelium; CLB, the most coronal level of bone in contact with the implant; BC, the level of the alveolar bone crest.

(lingual) in the CAM and from 0.2 ± 0.1 mm (buccal) to 0.1 ± 0.1 mm (lingual) in the CPS group. A comparable horizontal mismatch of 0.5 mm, consisting of an outer bevelled part of 0.3 mm and an inner horizontal part of 0.2 mm, was also able to prevent an apical down-growth of epithelial cells. In contrast to the present study, the mean IS–aJE values reached statistical significance at days 7, 14, and 28. Similar results were also observed with respect to the mean IS–CLB and IS–BC values. In particular, after 28 days of healing, CAM implants revealed mean IS–CLB values ranging from 1.8 ± 0.6 mm (buccal) to 1.9 ± 0.3 mm (lingual) and mean IS–BC values ranging from 0.9 ± 0.3 mm (lingual) to 1.7 ± 0.3 mm (buccal). In the CPS group, the mean IS–CLB values ranged from 1.2 ± 0.5 mm (lingual) to 1.3 ± 0.4 mm (buccal) and the mean IS–BC values ranged from 0.8 ± 0.2 mm (lingual) to 1.2 ± 0.2 mm (buccal). Even though both parameters tended to be lower in the CPS group, which was particularly true for the buccal aspect, these differences also did not reach statistical significance (Becker et al. 2007). Some slight discrepancies noted for the histomorphometrical parameters at 4 weeks in both studies might be related to potential differences in either implant diameter (3.8 *versus* 5.0 mm), design of the horizontal mismatch, or the implant–abutment interface (conical *versus* parallel) (Becker et al. 2007). Based on these preliminary data, it was hypothesized that the concept of platform switching may limit the epithelial portion of the biological width, thus potentially reducing crestal bone resorption following abutment connection. When interpreting the results of the present study, it was observed that the mean IS–aJE values in the CAM group tended to increase between 4 and 12 weeks of healing. This is in accordance with the results of a previous study aimed at evaluating the morphogenesis of the peri-implant mucosa at one-piece titanium implants in dogs. While the first signs of an epithelial proliferation were noted after 1–2 weeks of healing, a mature junctional epithelium was established between 6 and 8 weeks. In particular, the dimension of the epithelium increased from 0.5 mm at 1–2 weeks to 1.42 mm at 4 weeks, and 1.7–2.1 mm at 6 and 12 weeks. Similarly, the collagen fibres of the subepithelial connective tissue were organized after 4–6 weeks of healing (Berglundh et al. 2007a). The dimension of the mature barrier epithelium as reported in this study is in accordance with the present histological observations in the CAM group (data not included in the analysis but measured separately from the mucosal margin to aJE: 1.5–1.8 mm). A comparable extension of the junctional epithelium was also observed at the mesial and distal aspects of CAM implants (diameter: 3.8 mm) after 12 weeks of healing in beagle dogs (Schwarz et al. 2008). All these findings, taken together with the results of the present study, seem to provide a certain proof for the hypothesis that a horizontal mismatch of 0.3 mm may decrease the vertical dimension of the mature junctional epithelium. This concept, however, was not able to reduce crestal bone-level changes to a significant level, even though the mean IS–CLB and IS–CB values tended to be lower at CPS

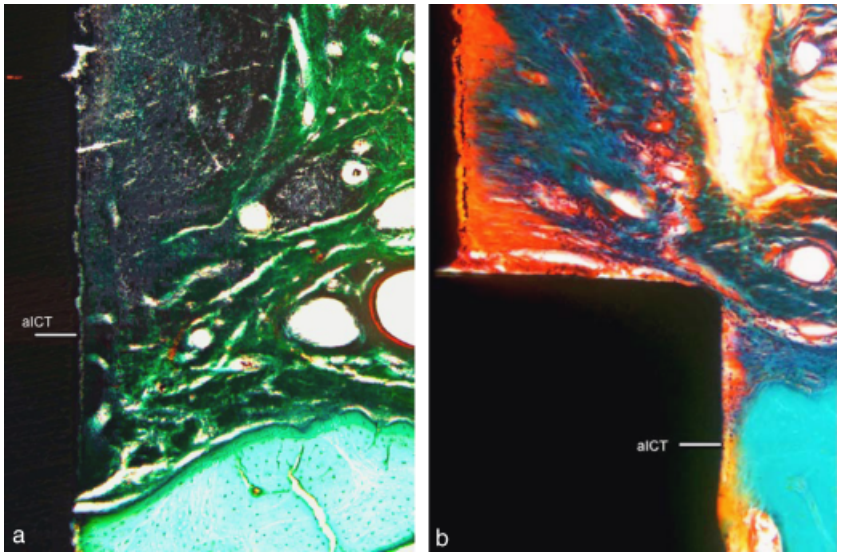

Fig. 5. Both groups commonly revealed a mixed chronic inflammatory cell infiltrate at the implant–abutment interface over the entire study period of 24 weeks. While its apical extension was separated from the adjacent alveolar bone by a non-infiltrated zone of connective tissue in most of the specimens, a few histological samples also revealed a close proximity to the implant-supporting bone. Basically, no differences were observed between the CAM and CPS groups. (a) CAM (24 weeks, original magnification × 100); (b) CPS (24 weeks, original magnification × 100). aICT, apical extension of the inflammatory cell infiltrate.

implants at either short (Becker et al. 2007), or longer observations periods of up to 6 months, as assessed in the present study. In this context, however, it must be emphasized that the lack of a statistical significance between CAM and CPS implants might also be due to the low number of animals that were used per healing period. Basically, the actual crestal bone loss (IS–CLB values – 0.4 mm) ranged from 0.5 mm in the CPS to 0.8 mm in the CAM group after 6 months of healing and tended to be lower than the respective values as reported in previous experimental studies using either CAM or CPS implants (Becker et al. 2007, Schwarz et al. 2008). This difference could be related to the experimental implant type used in the present study, which mainly accounted for a slight modification of the outer macrodesign (i.e. flattening of the bevel below the implant neck) as well as the implant–abutment connection. However, further studies aimed at comparing both types of implant designs may be required in order to clarify this issue. When interpreting the present results, one must also take into consideration that additional factors such as biomechanical stress, microbial leakage, and a difference in the convexity of matching and non-matching healing abutments might also have contributed to the slight crestal bone resorption in both groups. As described above, previous experimental studies provide some evidence that smaller diameter abutment configurations may shift the stress concentration area away from the crestal bone–implant interface (Maeda et al. 2007, Schrotenboer et al. 2008). So far, however, there is no finite element analysis available for either CAM or CPS implants as used in the present study. Secondly, one might assume that the wide-body healing abutments in both groups ensured a certain loading of the implants, which in turn might also have contributed to a bacterial leakage along the implant–abutment interface. The results of a previous in vitro study have shown that dynamic loading of CAM implants decreased the stability of the implant–abutment connection and thereby resulted in a bacterial penetration along the gap (Steinebrunner et al. 2005). This observation was also supported by histological data, indicating a slight inflammatory cell infiltrate in the connective tissue adjacent to the implant–abutment interface of CAM implants at either 2 or 12 weeks of healing (Schwarz et al. 2008). Even though conventional histological analysis may not be appropriate to draw any conclusion on microbiological leakage, the present study has also pointed to an inflammatory cell infiltrate in close proximity to the implant–abutment interface. Even though in most of the specimens its apical extension was located on a level above the implant-supporting bone, it is impossible to estimate to what extent this inflammatory infiltrate may have influenced bone remodelling and subsequently bone resorption during the initial stages of wound healing. Because the apical extension of the abutment inflammatory cell infiltrate was comparable in both CAM and CPS groups, it must be questioned whether the concept of platform switching may keep the adverse effects of microbial leakage away from the crestal alveolar bone (Lazzara & Porter 2006).

Within the limits of the present study, it was concluded that (i) bone remodelling was minimal in both groups and (ii) platform switching may not be of crucial importance for maintenance of the crestal bone level.

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Address:
Jürgen Becker
Department of Oral Surgery
Westdeutsche Kieferklinik
Heinrich Heine University
D-40225 Düsseldorf
Germany
E-mail: jbecker@uni-duesseldorf.de

Clinical Relevance

Scientific rationale for the study: The results of a previous experimental study have indicated that the concept of platform switching may be associated with a slight crestal alveolar bone preservation over a period of 4 weeks. The stability of these results, however, remains unknown.

Principal findings: Over the entire study period of 24 weeks, the horizontal mismatch of 0.3 mm prevented an apical down-growth of the junctional epithelium. However, this was also associated with a slight remodelling at the crestal aspect of the alveolar bone.

Practical implications: The influence of platform switching to preserve the crestal bone level over a period of 24 weeks seems to be limited.