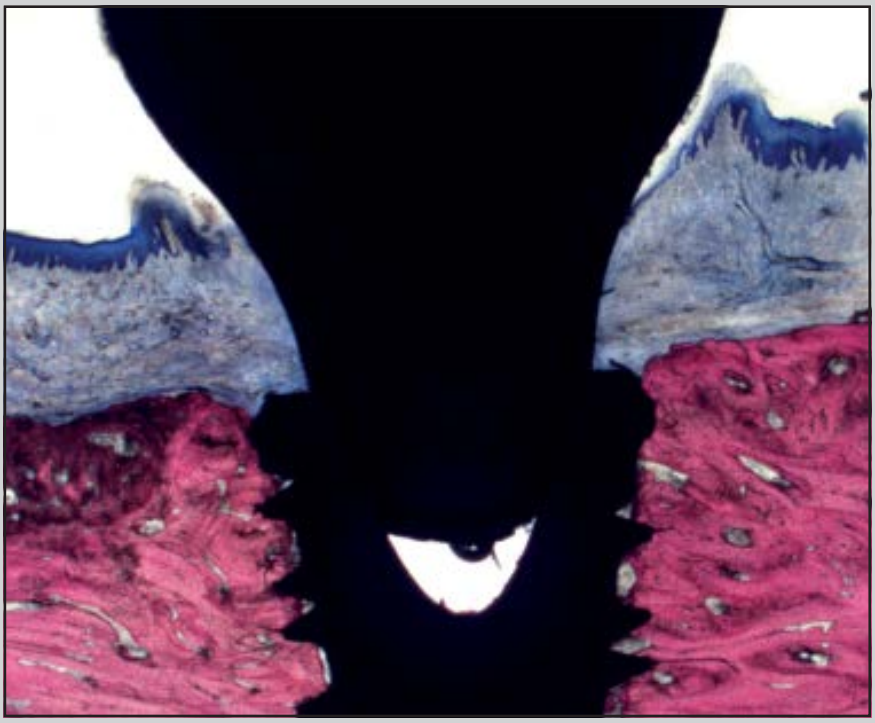

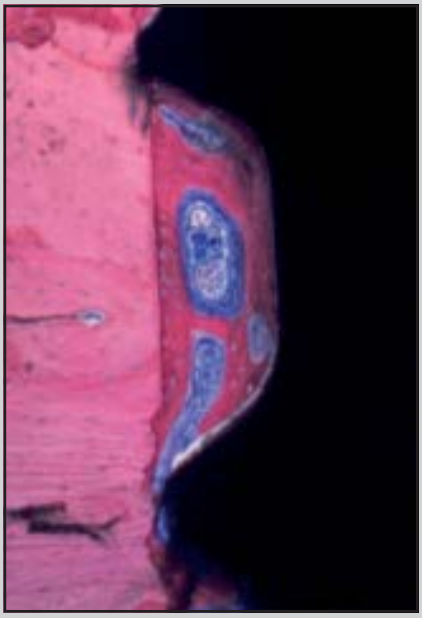

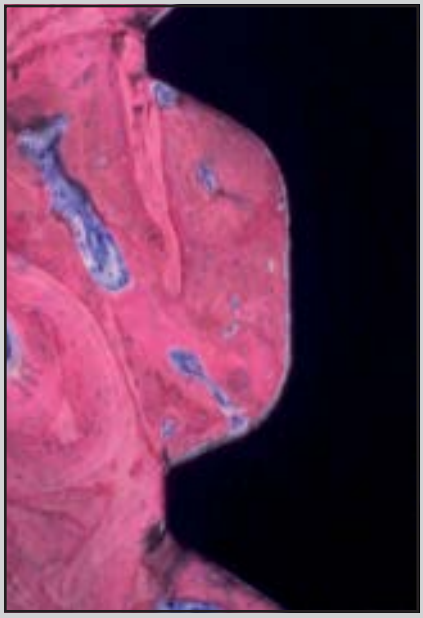

Soft Tissue and Marginal Bone Adaptation on Platform-Switched Implants with a Morse Cone Connection: A Histomorphometric Study in Dogs

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The purpose of this study was to investigate peri-implant tissue adaptation on platform-switched implants with a Morse cone–type connection, after 3 and 12 weeks of healing in dogs. Ten weeks after mandibular premolar extractions, eight beagle dogs received three implants each. At each biopsy interval, four animals were sacrificed and biopsies were processed for histologic analysis. The height of the peri-implant mucosa was 2.32 mm and 2.88 mm, respectively, whereas the bone level in relation to the implant platform was −0.39 mm and −0.67 mm, respectively, after 3 and 12 weeks of healing. Within the limits of the present study, platform-switched implants exhibited reduced values of biologic width and marginal bone loss when compared with previous data. Int J Periodontics Restorative Dent 2016;36:221–228. doi: 10.11607/prd.2254

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Esthetic and functional long-term success of implant-supported rehabilitations relies on the preservation of the peri-implant tissue levels in the most coronal position. Thus, the achievement of an efficient protective mucosal seal and the preservation of the peri-implant marginal bone during the first weeks of healing are essential to prevent long-term implant failures.

Soft tissue healing around implants requires 6 to 12 weeks after implant surgery.[1] A minimum width of soft tissue, called *biologic width*, is needed. During healing, bone loss may occur to accommodate the soft tissues until the adequate dimensions are restored.[2]

In the past, a physiologic marginal peri-implant bone loss of 1.5 mm to 2 mm was reported around two-part implants.[3,4] This was mainly due to bacterial infiltration in the microgap at the implant-abutment interface causing an inflammatory process[5] responsible for marginal bone loss,[4,6,7] biologic width lengthening, and marginal recession.[8]

Internal connections, especially Morse cone–type connections with a closer fit than the conventional butt-joint connections have been proposed to limit bacterial infiltration at the implant-abutment interface.[9,10] The platform-switching concept was also introduced:[11] an inward horizontal mismatch of the

Fig 1 *The In-Kone (Tekka) implant has a two-piece design with an internal conical connection.*

implant-abutment junction may move the inflamed connective tissue area away from the marginal peri-implant bone and thus reduce marginal bone remodeling. It may also provide a horizontal healing space for the connective tissue, thus reducing the marginal bone loss due to soft tissue adaptation.

Systematic reviews and meta-analyses[12–15] have suggested that platform switching at two-part implants may help preserve marginal bone levels. Positive outcomes were reported in histologic studies,[16–21] whereas other studies[22–24] failed to demonstrate any specific advantage of platform switching in reducing marginal peri-implant bone loss. Becker et al found no influence of platform switching on biologic width characteristics,[22,23] while Baffone et al and Farronato et al reported a reduced height of biologic width at platform-switched implants.[19,20]

Based on these data, the purpose of the present study was to investigate the soft tissue and marginal bone adaptation on platform-switched implants with a Morse cone–type connection, after 3 and 12 weeks of unloaded nonsubmerged healing in the beagle dog model.

Materials and methods

The Committee of Ethics of the National Veterinary School of Lyon (VetagroSup) approved the experimental protocol, and the surgeries were performed in a center dedicated to preclinical trials (Claude Bourgelat Institute, Marcy l'Etoile, France).

Eight beagle dogs (weighing approximately 10 kg and 10 to 12 months old) with a fully erupted permanent dentition were included in this study, according to the ARRIVE guidelines.[25] The dogs were fed a soft diet and housed in cages (two dogs per cage) for the duration of the experimental period. Following an adaptation period of 2 weeks, tooth scaling was performed and a plaque control program was initiated (tooth brushing with 0.2% chlorexidine gel three times per week).

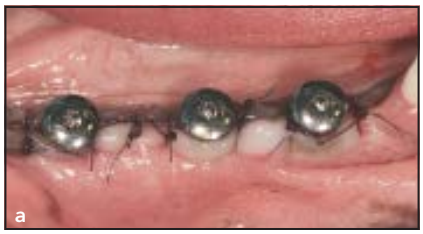
Titanium implants

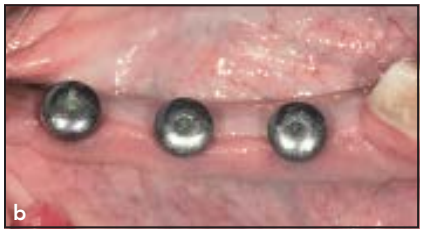
A commercially available sandblasted Ti-6Al-4V two-piece implant (In-Kone, Tekka) with an internal Morse cone–type connection was selected (Fig 1). The implants were 8.5 mm long, with a conical-cylindrical screw-type shape (3.6 mm diameter). The horizontal mismatch between the implant body and the healing screw was 0.4 mm. The implants were threaded to the top with twin threads in the cervical portion. The sandblasted rough surface (sprayed with corundum micropowder) extended to the chamfered shoulder of the implant.

Study design and surgical procedure

All the mandibular premolars were extracted. After a healing period of 10 weeks, three implants per dog were randomly inserted in the residual mandibular left or right ridge at a distance of 10 mm apart (Fig 2a), with the implant platform located at the crestal bone level in the proximal aspect. The other sides of the mandibular edentulous ridge were used for other experimental purposes, the results of which will be reported in a future article. The healing abutments were connected and the flaps sutured.

The surgical procedures were performed in an operating room under general anesthesia and sterile conditions. For sedative purposes the animals received an injection of benzodiazepine (0.5 mg/kg), acepromazine (0.1 mg/kg), and glycopyrrolate (0.01 mg/kg). General anesthesia was provided with ketamine (5 mg/kg injected intravenously) and maintained with isofluorane inhalation. During the surgeries, the dogs were monitored with an electrocardiogram. To prevent infection, a combination of amoxicillin and clavulanic acid (200 mg/50 mg) was given to the animals twice a day for 10 days. For pain management, three injections





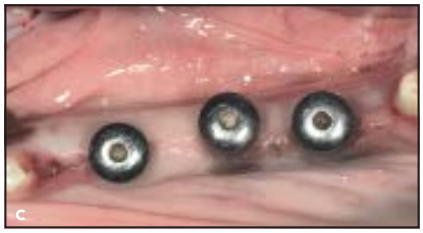


Fig 2 *Implants in the alveolar mandibular ridge.* (a) *After insertion and flap suturing.* (b) *After 3 weeks of healing, the soft tissue healing process is well advanced with good wound closure.* (c) *After 12 weeks of healing, the peri-implant mucosa is clinically mature.*

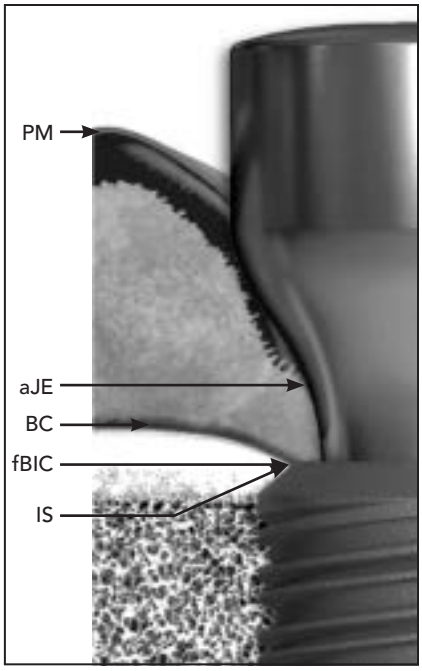


Fig 3 (right) *Schematic representation of the landmarks used for histologic measurements: the marginal portion of the mucosa (PM), the apical extent of the junctional epithelium (aJE), the top of the bone crest (BC), the first bone-to-implant contact (fBIC), and the implant shoulder (IS).*

of morphine were given to the dogs (0.2 mg/kg, intravenously): before surgery, at the end of surgery, and 4 hours postsurgery. In addition, a fentanyl transcutaneous patch (75 µg/h) was placed on the day of surgery, and the animals received meloxicam for 10 days (0.2 mg/kg/j the first day and 0.1 mg/kg/j the next 9 days). At each biopsy interval (3 or 12 weeks), four animals were sacrificed with an overdose of pentobarbital. The implants and surrounding tissues were harvested using a trephine under profuse irrigation.

Histologic preparation and measurements

The biopsies were fixed in 2% glutaraldehyde, 2% paraformaldehyde in a sodium cacodylate buffer for 1 week, then dehydrated in increasing concentrations of ethanol, and finally embedded in methyl methacrylate. Nondecalcified ground sections were obtained using a method adapted from Donath and Breuner.[26] One central mesiodistal section was cut to a thickness of about 40 mm by microgrinding and polishing, using an Exakt grinding unit (Apparatebau). The sections were stained with a modified Paragon.

Using a light microscope (Axioskop, Zeiss) equipped with digital imagery software (Bone Morpho Expert, Explora Nova), the following landmarks were identified: the marginal portion of the mucosa (PM), the apical extent of the junctional epithelium (aJE), the first bone-to-implant contact (fBIC), the implant shoulder (IS), and the top of the bone crest (BC) (Fig 3). The PM-aJE, aJE-fBIC, PM-fBIC, IS-BC, IS-fBIC, and BC-fBIC linear vertical distances were measured following the long axis of the implant on both mesial and distal aspects of the sections, and expressed in mm.

Statistical analysis

Data were considered hierarchical with two replicated measurements (mesial view, distal view) nested in location on the arch (anterior, middle, posterior) nested within each dog. Eight dogs were randomly assigned to two groups with 3- and 12-week healing periods, respectively. Data were available for 46 observations of 6 measurements (PM-aJE, aJE-fBIC, PM-fBIC, IS-BC, IS-fBIC, BC-fBIC). For one dog, all 6 variables were missing for 2 observations corresponding to 2 views on the same location. No data imputation was performed. Data probability law was checked graphically and using the normality Agostino test.

Table 1 Results from the histomorphometry

Implant group	n	IS-fBIC (mm)*	BC-fBIC (mm)	IS-BC (mm)
3 weeks	24	−0.39 (0.25)	−0.50 (0.42)	0.11 (0.35)
12 weeks	24	−0.67 (0.35)	−0.69 (0.55)	0.02 (0.49)
Implant group	**n**	**PM-aJE (mm)***	**aJE-fBIC (mm)**	**PM-fBIC (mm)**
3 weeks	21	1.12 (0.32)	1.19 (0.56)	2.32 (0.56)
12 weeks	24	1.63 (0.59)	1.24 (0.36)	2.88 (0.65)

Data are expressed as average (standard deviation). n = number of measured sites; PM-aJE = epithelial tissue; aJE-fBIC = connective tissue; PM-fBIC = biologic width; IS-fBIC, BC-fBIC, IS-BC = peri-implant crestal and marginal bone levels.
*$P < .05$.

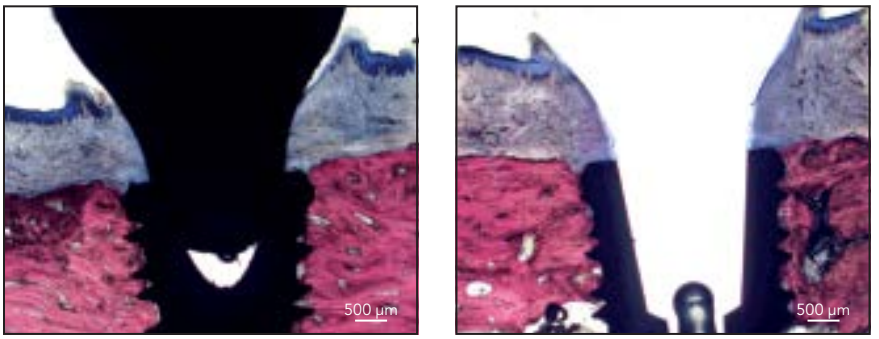


Fig 4 *Light microscopy images of mesiodistal nondecalcified ground sections, modified Paragon staining.* (left) *After 3 weeks of healing.* (right) *After 12 weeks of healing.*

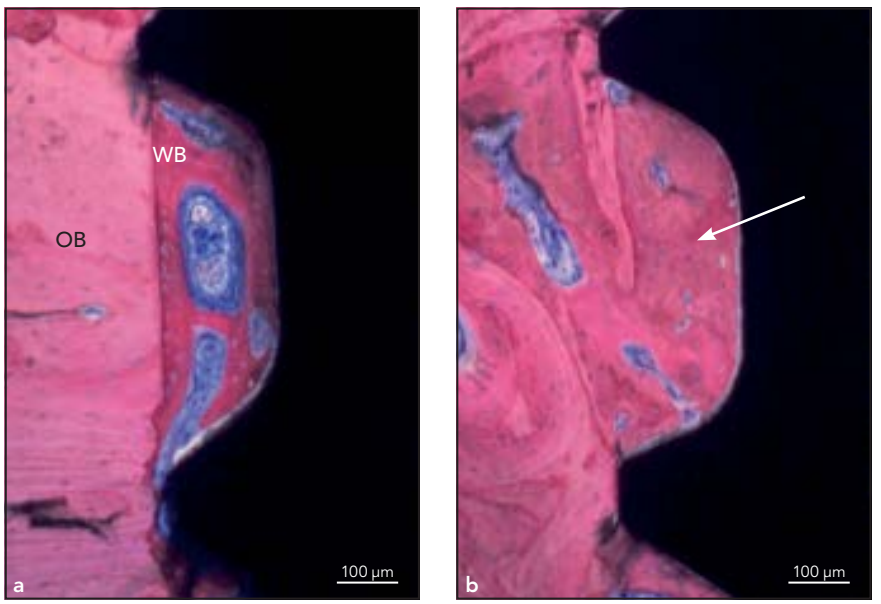


Fig 5 *Light microscopy images of ground nondecalcified mesiodistal sections with modified Paragon staining illustrating the osseointegration process.* (a) *In the cortical bone compartment, after 3 weeks of healing, woven bone is present both on the implant surface and on the old bony bed.* (b) *After 12 weeks of healing, woven bone is replaced by lamellar osteons* (indicated by white arrow). *WB = woven bone; OB = old bone.*

A hierarchical three-level mixed-effects model was adjusted for each variable to assess the healing period effect on each of the variables. Only the random dog effects and the random location within dog effects on the outcome were taken into account, considering the healing period effects constant for all dogs and location for each dog.

A significance level of 5% was selected. Statistics were performed using the R language, version 3.0.2 (http://cran.r-project.org). The function lme of the R package nlme was used for the mixed-effects models.

Results

The average and standard deviation of PM-aJE, aJE-fBIC, PM-fBIC, IS-BC, IS-fBIC, and BC-fBIC at 3 and 12 weeks are shown in Table 1 and the corresponding histologic views are shown in Fig 4.

Postoperative healing was uneventful for all dogs, and no complications such as allergy or infection occurred throughout the experimental period (Figs 2b and 2c). After 3 weeks of healing, areas of new bone apposition were observed both on the implant surface (contact osseointegration) and on the old bony bed (distant osseointegration). The presence of numerous osteoblasts was associated with an active synthesis of bone matrix (Fig 5a). After 12 weeks, the peri-implant space contained new dense bone. Remodeling had started, and woven bone was replaced by lamellar bone organized in primary osteons (Fig 5b).

At 3 weeks, as expected, the old bony bed in the coronal portion of the implant was still detectable. Intense bone apposition and bone remodeling were ongoing (Fig 6a). At 12 weeks, the crestal remodeling and osseointegration were completed, and new bone had established the most coronal contact with the implant body (Fig 6b). After 3 weeks, the first bone-to-implant contact was located 0.39 mm below the implant platform. After 12 weeks, the location of the most coronal bone-to-implant contact within the implant platform was −0.67 mm. The marginal bone level was statistically located more apically after 12 weeks of healing compared with the 3-week period (average: −0.67 mm vs −0.39 mm). The BC-fBIC value was −0.50 mm after 3 weeks of healing and −0.69 mm after 12 weeks. The difference was not significant.

After 3 weeks of healing, a nonkeratinized junctional epithelium had started to form and lined 48% of the mucosal interface with titanium. The connective tissue exhibited early signs of organization with numerous fibroblasts and collagen fibers. After 12 weeks, the soft tissue maturation and collagen fiber organization were achieved. The junctional epithelium was in close contact with titanium and lined 57% of the transmucosal interface. The relationship between the junctional epithelium and the connective tissue are shown in Fig 7. The connective tissue interposed between the apical extent of the junctional epithelium and the marginal bone (Fig 8a) was dense, rich in fibroblasts and collagen fibers, and in close contact with the titanium. Collagen fibers were laterally inserted into the crestal bone and running medially toward the healing abutment in a perpendicular direction (Fig 8b). Small areas of inflamed connective tissue were observed along the sulcular epithelium, and occasionally close to the implant-abutment interface. The PM-aJE was statistically

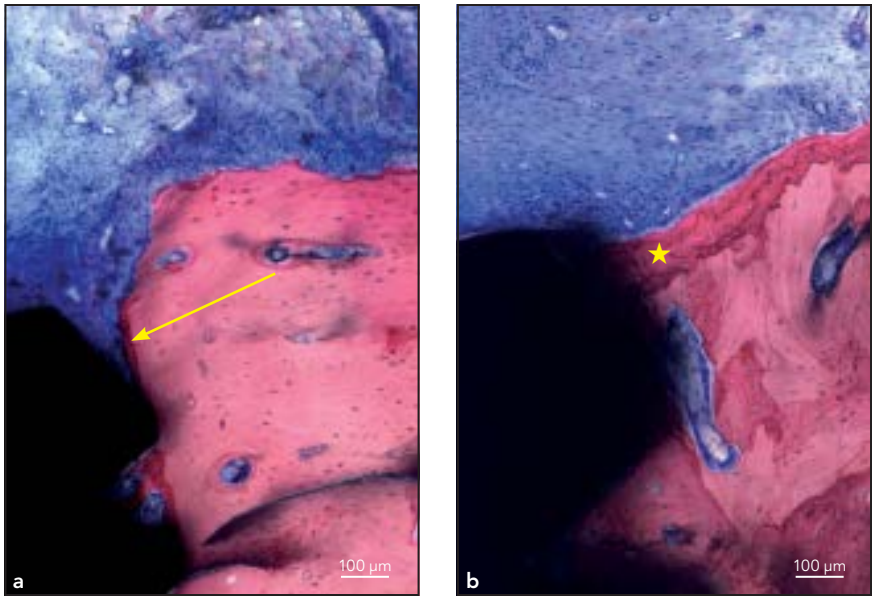


Fig 6 *Light microscopy images of ground nondecalcified mesiodistal sections with modified Paragon staining illustrating marginal bone healing.* (a) *After 3 weeks of healing, the marginal bone remodeling is ongoing, the first pitch of the implant thread is in contact with the old bony bed* (light pink), *and woven bone* (dark pink) *is detectable on the old bony bed.* (b) *After 12 weeks, the new bone has established the most coronal contact with the implant body. The yellow arrow indicates the old bony bed; the yellow star indicates woven bone.*

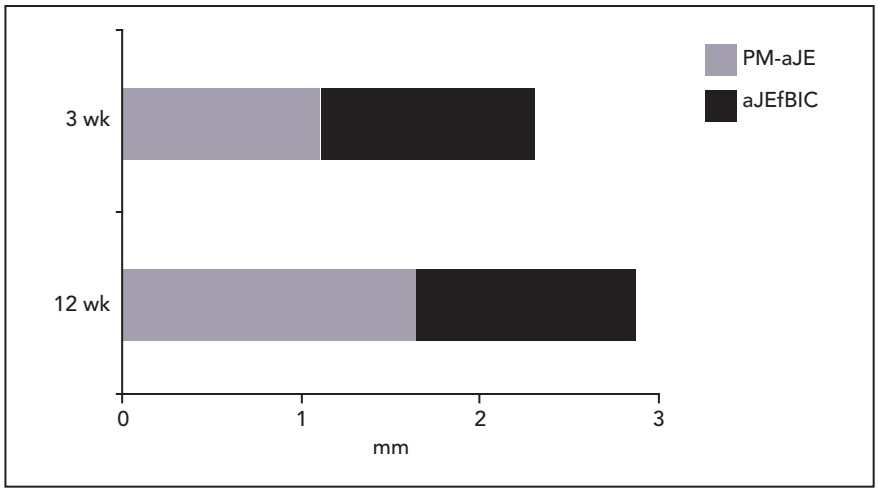


Fig 7 *Histogram representing the vertical distribution of the peri-implant soft tissues after 3 and 12 weeks of healing. PM-aJE = epithelial tissue; aJE-fBIC = connective tissue.*

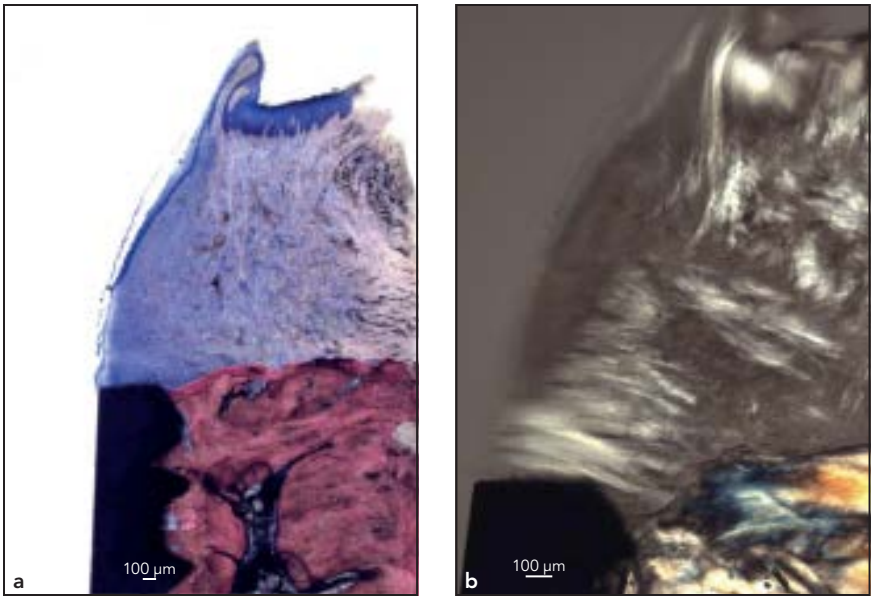


Fig 8 *Soft tissue organization.* (a) *Light microscopy image with modified Paragon staining of ground nondecalcified mesiodistal section after 12 weeks. The junctional epithelium is in close contact with the titanium, and a dense connective tissue is interposed between the apical extent of the junctional epithelium and the first bone-to-implant contact.* (b) *Light polarized microscopy image with modified Paragon staining of ground nondecalcified mesiodistal section after 12 weeks. Collagen fibers are inserted into the crestal bone and run perpendicular to the abutment.*

longer after 12 weeks of healing (1.63 mm vs 1.12 mm at 3 weeks), the aJE-fBIC value remained constant (1.24 mm vs 1.19 mm at 3 weeks), and the PM-fBIC was longer after 12 weeks of healing (2.88 mm vs 2.32 mm at 3 weeks), but the difference was not statistically significant.

Discussion

The purpose of this study was to investigate the soft tissue and marginal bone adaptation on platform-switched implants with an internal conical connection after 3 and 12 weeks of unloaded nonsubmerged healing in the beagle dog model.

After 3 weeks, a nonkeratinized junctional epithelium had started to form and lined 48% of the mucosal interface with titanium. The junctional epithelium extended apically during the healing and lined 57% of the transmucosal interface at 12 weeks. The overall peri-implant mucosa dimensions varied from 2.32 mm after 3 weeks to 2.88 mm after 12 weeks. Evidence of peri-implant tissue maturation and collagen fiber organization was observed after 12 weeks. In the bone compartment after 3 weeks, intense bone apposition and bone remodeling were ongoing, while after 12 weeks the crestal remodeling and osseointegration were completed. The healing dynamics in the present study were generally in accordance with the histologic observations reported by Berglundh et al in a study about morphogenesis of the peri-implant mucosa.[1]

In the present investigation, the overall dimensions of the peri-implant mucosa were lower compared with previous histologic findings at bone-level implants with matching abutments. Indeed, Berglund et al[27] and Hermann et al[8] reported that the biologic width at two-piece cylindrical implants with a matching abutment was 3.8 mm. The results of the present study are in agreement with the outcomes of former histologic studies on platform switching. Baffone et al[19] and Farronato et al[20] reported that an inward horizontal mismatch was associated with smaller values of biologic width compared with conventional matching restorations. Becker et al failed to demonstrate a reduction of the biologic width on platform-switched implants after 28 days and 6 months of healing.[22,23] However, the authors had positioned the implant-abutment junction 0.4 mm supracrestally, which therefore minimized the possible advantages of platform switching. Thus, the present findings, when compared with the data published in the literature, suggest that platform switching may reduce the vertical area required to establish the biologic width.

After 3 and 12 weeks, a limited amount of marginal bone loss was observed. Marginal bone remodeling at platform-switched implants has been extensively studied in histologic experiments. However, great heterogeneity exists in implant transmucosal configurations, experimental protocols, and results. Positive outcomes have been reported: some histologic studies reported small values of marginal bone loss, and bone

reformation was even depicted on the implant platform in some biopsies[10,16,18,28,29]; other studies reported moderate bone loss, which was limited compared with conventional matching implant-abutment configurations[17,19,20,30]; and other studies failed to demonstrate any specific advantage of platform switching.[22–24] Five parameters in the implant-abutment configuration may have influenced the results in those studies. The amount of marginal bone loss appeared to be inversely related to the extent of the implant-abutment mismatch[12,19,24] and to the width of the transmucosal component.[28] Then, the use of Morse cone–type connection with a close fit might play a crucial role in reducing inflammation and subsequent bone loss.[7,16,17,30] Bone reformation on the implant platform close to the implant-abutment junction of two-part implants seems to depend on the treatment surface characteristics of the implant collar, platform, and abutment.[10] The fifth parameter is the apicocoronal position of implants in relation to the crestal bone. Although there is clear evidence that the subcrestal placement of conventional two-part implants results in more pronounced marginal bone loss,[6] a subcrestal placement (1.5 mm) of implants with a Morse cone connection might be more efficient in preserving the peri-implant marginal bone compared with an equicrestal placement.[16,17,29,31] Koutouzis et al reported in a clinical study that implants with a Morse taper connection exhibited less bone loss below the implant platform when placed in a subcrestal position.[32] Nevertheless, Jung et al, in an animal study, showed a limited amount of marginal bone loss that increased with the positioning depth.[33] According to Koutouzis et al, these results are related to an inflammatory infiltrate at the implant-abutment junction.[32] In a randomized controlled multicenter clinical trial, De Angelis et al reported that platform switching seems to reduce crestal bone loss.[34] Four systematic reviews and meta-analyses[12–15] have suggested that platform switching at two-part implants may help preserve marginal bone levels; however, some of them focus on the fact that other parameters are to be taken into consideration, such as the extent of the mismatch,[12–14] the apicocoronal positioning,[13] and the implant neck microtexture.[13] In another systematic review, Romanos and Javed concluded that discussion about the role of platform switching in minimizing marginal bone loss is still ongoing, and that bone loss seemed to be ruled by other factors, such as implant design, micromotion at the implant-abutment interface, positioning depth, and width of the bone crest.[35] The contribution of platform switching to marginal bone preservation and the importance of several technical and anatomical aspects are not yet clearly elucidated in the clinical or animal literature.

Focusing on these data, some hypotheses may be suggested to explain the marginal bone loss reported in our study. Because inflammation was only occasionally observed close to the implant-abutment interface, the presence of an implant-abutment junction may have a minimal influence on marginal bone loss after 3 and 12 weeks of healing in the protocol followed. The increasing marginal bone loss combined with an increased biologic width between the two healing periods may indeed indicate that the narrow transmucosal configuration combined with the horizontal mismatch of 0.4 mm allows for small biologic width values, but not small enough for the entire formation of the mucosal seal above the implant shoulder when the implant platform is placed at the crestal bone level, which results in limited marginal bone loss. The equicrestal placement of the implant might be involved. It would be interesting to investigate the consequences of a deep (about 1.5 mm) subcrestal placement. Further studies are necessary to clarify the etiology of such peri-implant marginal bone loss.

Conclusions

Within the limits of the present study, platform-switched implants placed at the crestal bone level exhibited reduced biologic width and marginal bone loss when compared with previous data.

Acknowledgments

The authors greatly appreciated the advice of Prof Jacqueline Trouillas, Dr Carole Auger, Dr Hélène Follet, Ms Catherine Simi, and Mr Jean-Paul Roux during histologic investigations. They are also very grateful to the Tekka Global D team for their collaboration. The study was partially supported by a research grant from Tekka, Global D, Brignais, France. The authors reported no conflicts of interest related to this study.

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