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Biologic Width around one- and two-piece titanium implants

A histometric evaluation of unloaded nonsubmerged and submerged implants in the canine mandible

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Date:
Accepted 29 November 2000

To cite this article:
Hermann JS, Buser D, Schenk RK, Schoolfield JD, Cochran DL. Biologic Width around one- and two-piece titanium implants. A histometric evaluation of unloaded nonsubmerged and submerged implants in the canine mandible
Clin. Oral Impl. Res. **12**, 2001; 559–571

ISSN 0905-7161

Key words: animal study, titanium implants, endosseous, unloaded, one-piece, two-piece, soft tissue, histometry, Biologic Width, esthetics

Abstract: Gingival esthetics around natural teeth is based upon a constant vertical dimension of healthy periodontal soft tissues, the Biologic Width. When placing endosseous implants, however, several factors influence periimplant soft and crestal hard tissue reactions, which are not well understood as of today. Therefore, the purpose of this study was to histometrically examine periimplant soft tissue dimensions dependent on varying locations of a rough/smooth implant border in one-piece implants or a microgap (interface) in two-piece implants in relation to the crest of the bone, with two-piece implants being placed according to either a submerged or a nonsubmerged technique. Thus, 59 implants were placed in edentulous mandibular areas of five foxhounds in a side-by-side comparison. At the time of sacrifice, six months after implant placement, the Biologic Width dimension for one-piece implants, with the rough/smooth border located at the bone crest level, was significantly smaller ($P<0.05$) compared to two-piece implants with a microgap (interface) located at or below the crest of the bone. In addition, for one-piece implants, the tip of the gingival margin (GM) was located significantly more coronally ($P<0.005$) compared to two-piece implants. These findings, as evaluated by nondecalcified histology under unloaded conditions in the canine mandible, suggest that the gingival margin (GM) is located more coronally and Biologic Width (BW) dimensions are more similar to natural teeth around one-piece nonsubmerged implants compared to either two-piece nonsubmerged or two-piece submerged implants.

In 1921, Gottlieb initially described the ''epithelial attachment'' around a natural tooth by covering distinct areas of the enamel surface or the cementum and not by just being attached to the cemento-enamel junction at a certain point or level, respectively (Gottlieb 1921). Later on, these findings have been confirmed (Orban & Mueller 1929), and in addition, the ''gingival crevice'' or sulcus has been defined. Subsequently, Feneis showed that connective tissue consists of three-dimensionally oriented fibers firmly connecting tooth structures to the surrounding gingiva (Feneis 1952). Thus, it became clear that both epithelial as well as connective tissue attachment contribute to a 'protection mechanism' in a most challenging area where the natural tooth penetrates the ectodermal integrity of the body. Sicher confirmed these findings in 1959 and called this functional unit the ''dentogingival junction'' (Sicher 1959). In 1961, Gargiulo et al. found out that the vertical dimension of the dentogingival junction, comprised of sulcus depth (SD), junctional epithelium (JE), and connective tissue attachment (CTA), is a physiologically formed and stable di-

mension, subsequently called ''Biologic Width'', and that this unit forms at a level dependent on the location of the crest of the alveolar bone (Gargiulo et al. 1961).

Taking these biological principles into consideration, two major clinical procedures have been derived from these findings and are widely used today, one being the ''forced eruption'' (Ingber 1976) and the other one being the ''surgical lengthening of the crown'' (Ingber et al. 1977). Both procedures are based upon the understanding that changing the level of the alveolar bone will move the complete dentogingival junction as a unit on a predictable basis towards the same direction (apically or coronally, respectively). These procedures have great impact as to the location of the gingival margin (tip of the papilla) and, therefore, provide a major tool to achieve stable and esthetic gingival harmony around a healthy natural crown or a tooth-borne restoration.

In the early years of implant dentistry, research mainly focused on hard tissue integration. Based upon positive long-term results with implant-borne fixed partial dentures as well as overdentures using submerged as well as nonsubmerged implants (for review see Cochran 1996), implant-borne single tooth restorations became more and more popular during the 1990s. As a consequence, increasing attention was given to study periimplant crestal bone as well as soft tissue reactions. Thus, Berglundh and coworkers (Berglundh et al. 1991; Berglundh & Lindhe 1996) and Abrahamsson and collaborators (Abrahamsson et al. 1996; Abrahamsson et al. 1997; Abrahamsson et al. 1999) presented histometric data on two-piece, submerged as well as nonsubmerged implants. Cochran et al. (1997) and Hermann et al. (2001) first published periimplant histometric results based upon an experimental study analyzing and confirming the Biologic Width dimensions around a natural tooth with those around a one-piece, nonsubmerged implant. This same research group also compared crestal bone reactions around one- and two-piece titanium implants placed according to a nonsubmerged or submerged technique in a side-by-side comparison (Hermann et al. 1997; Hermann et al. 2000b, Hermann et al. 2001), showing significant changes in crestal bone reactions dependent on the implant design and/or technique used (one-piece *vs.* two-piece implant; nonsubmerged *vs.* submerged approach), which, in part, has also been confirmed in a series of case reports involving 11 patients (Hämmerle et al. 1996).

The purpose of this study was to analyze the dimensions of the Biologic Width around implants of varying designs: one-piece implants with a rough/smooth border *vs.* two-piece implants with a microgap (interface) as well as surgical technique used (nonsubmerged *vs.* submerged). In addition, the relationship of the gingival margin (GM) to the implant was of particular interest since its location and stability is important for periimplant soft tissues, and the resulting esthetics of the implant-borne restoration.

Material and methods

Implant design and surfaces

All six different experimental implants (types A-F; Figs la, lb) were based on a cylindrical full-body screw design and were made from cold-worked, grade-IV commercially pure titanium (Institut Straumann AG, Waldenburg/BL, Switzerland). The outer diameter (thread tips) measured 4.1 mm, whereas the inner diameter was 3.5 mm at a total length of 9 mm. The coronal portion of each one-piece implant and the abutments in two-piece implants consisted of a machined, relatively smooth titanium surface. The apical part of each implant had a sand-blasted (large-grit) and HCI/H_2SO_4 acid-etched surface (SLA) with two levels of roughness, one at 20–40 μm peak to

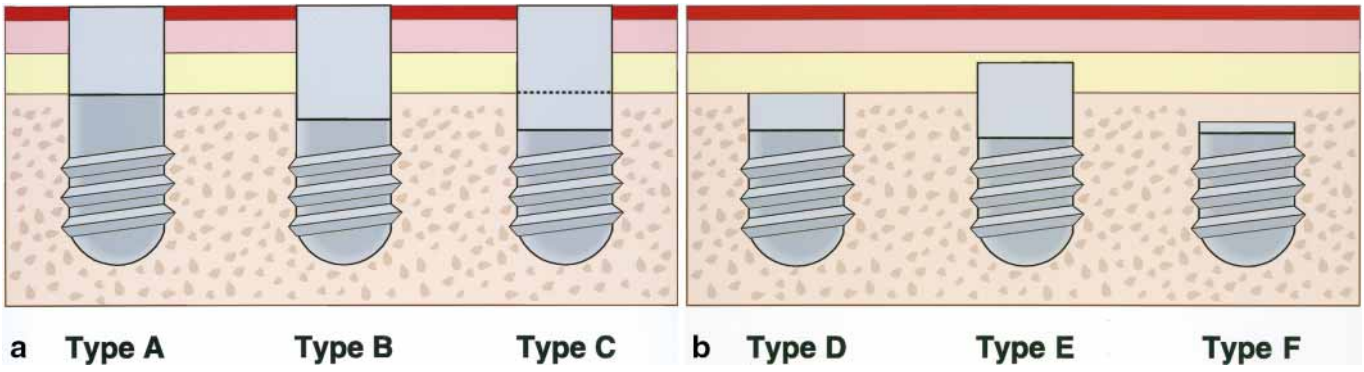

Fig. 1. a. Schematic (true to scale) of implant types A–C at time of implant placement in relation to soft tissues and bone. Soft tissue dimensions are adapted from the literature (Cochran et al. 1997; Hermann et al. 2000a). The dark red compartment represents the vertical dimension of the sulcus depth (SD), the pink compartment the junctional epithelium (JE), and the yellow compartment the connective tissue contact (CTC). The solid black line delineates the border between rough and smooth implant surface, whereas the dashed line shows the location of the microgap (interface). Note that all three types (A–C) were inserted according to a nonsubmerged approach. Implant types A and B are one-piece implants exhibiting no microgap (interface), while type C implants are two-piece implants with a microgap (interface) located at the bone crest level. b. Schematic (true to scale) of implant types D–F at time of implant placement in relation to soft tissues and bone. Soft tissue dimensions are adapted from the literature (Cochran et al. 1997; Hermann et al. 2000a). The dark red compartment indicates the vertical dimension of the sulcus depth (SD), the pink compartment the junctional epithelium (JE), and the yellow compartment the connective tissue contact (CTC). Note that all these implants were placed using a submerged technique. Implant types D–F are two-piece implants with a microgap (interface) located at different levels in relation to the crest of the bone.

peak, and a superimposed second one at 2–4 μm peak to peak.

The apical, rough portion (SLA surface) of type A implants was 6.0 mm in length with the rough/smooth implant border clinically placed at the alveolar crest. Type B implants had a 5.0 mm long SLA portion, with the rough/smooth border placed 1.0 mm below the crest. For all other implants (types C-F), the rough implant surface (SLA) was 4.5 mm in vertical dimension with the rough/smooth implant border located about 1.5 mm below the crest (Figs 1a and 1b). Type A and B implants were one-piece implants without a microgap (interface) present, while implant types C-F consisted of two pieces, with a clinically relevant microgap (interface) of about 50 μm in size (Binon et al. 1992; Keith et al. 1999) between the implant and the secondary component, the abutment. The location of the microgap (interface) was defined to be clinically at the bone crest level for types C and D, however, for types E and F, the microgap (interface) was located 1 mm above or 1 mm below the crest, respectively. Implant types A-C were placed according to a nonsubmerged technique, whereas types D-F were inserted using a submerged approach.

Study animals

For this study, five lab-bred, male American foxhounds were used. Prior to the start of the experiment, the protocol was approved by the 'Institutional Animal Care and Use Committee' of the University of Texas Health Science Center at San Antonio (UTHSCSA). The dogs were approximately two years of age at the beginning of the study and had a body weight of about 30–35 kg. None of the dogs had heart worms and all of them were quarantined before the experiment was started.

Surgeries – Extraction

The extraction technique removing all mandibular premolars and the first molar bilaterally has already been described in detail and published recently (Hermann et al. 1997; Hermann et al. 2000b).

Surgeries – Implant placement

Nonsubmerged and submerged implants (types A–F) were placed after a healing period of 6 months (Fig. 2), under the same surgical conditions as tooth extraction had been performed (operating room, anesthesia, sterility). A crestal incision was performed maximizing keratinized gingiva on each side of the incision. Full-thickness flaps were carefully reflected on the lingual and buccal aspect. Foramina mentalia were dissected and exposed. The edentulous osseous ridge was carefully flattened utilizing an acrylic bur combined with copious irrigation with chilled sterile physiologic saline. Measurements were made using a boley gauge to help distribute six test implants on each side of the mandible. Implant site preparations were carried out with low-torque reduction rotary instruments at 500 rpm using chilled saline. Implant types A–C were placed according to a nonsubmerged approach (Fig. 1a), *i.e.* for type C, implants and abutments were screwed together at the time of first-stage surgery. Implant types D–F were placed according to a submerged technique (Fig. 1b). Finally, one of each kind of test implant was placed per side in a randomized fashion. Thus, no implant type had a biased position in the arch. Periosteal releasing and contouring incisions were carried out on the buccal and lingual aspects of each implant in order to obtain tension-free adaptation of the wound margins for close adaptation of the gingiva to the transgingival portion of the nonsubmerged one-piece implants (types A and B), and the abutment of type C implants. Wound closure over the submerged implants (types D–F) was achieved using horizontal mattress combined with interrupted sutures. At the day of surgery, the dogs received 20 mg Nubain® (nalbuphine 10 mg/ml – Astra Pharmaceutical Products Inc., Westborough, MA, USA) s.c. *BID*. Three ml Pen-B® (benzathine penicillin 150,000 I.U. combined with procaine penicillin G 150,000 I. U. – Pfizer Inc., Lee's Summit, MO, USA) were given s.c. *SID* every 48 h for 14 days. On day 1, 100 mg of the antibiotic Gentocin® (gentamicin 50 mg/ml – Schering-Plough Animal Health Corp., Kenilworth, NJ, USA) were administered s.c. *BID*, and the same amount *SID* from day 2–10. To reduce swelling, the foxhounds received 2 ml of the antiinflammatory Dexaject® (dexamethasone 2 mg/ml – Burns Veterinary Supply, Oakland, CA, USA) i.m. *SID* day 1 and at day 4. Suture removal was carried out after 7–10 days as described above. To minimize loading, the animals were fed a softened diet for the duration of the study. Mechanical and chemical plaque control was carried out three times per week, using a soft toothbrush and a soft sponge in combination with PlakOut® Gel (chlorhexidine digluconate 0.2 % – Hawe-Neos AG, Bioggio/TI, Switzerland).

Surgeries – Abutment connection

Second-stage surgery was performed three months after implant placement, and abutments were connected for submerged implant types D–F. Surgical conditions were the same as described above. First, the surgical sites were disinfected and the local anesthesia given. Over the top of these implants, a midcrestal incision was used combined with a small vertical relieving incision at the buccal and lingual aspect. Implants were uncovered after the elevation of a full-thickness flap. In the case of implants partially covered with bone (mostly in type F implants) a minor osteotomy was performed using hand instruments (chisel, mallet).

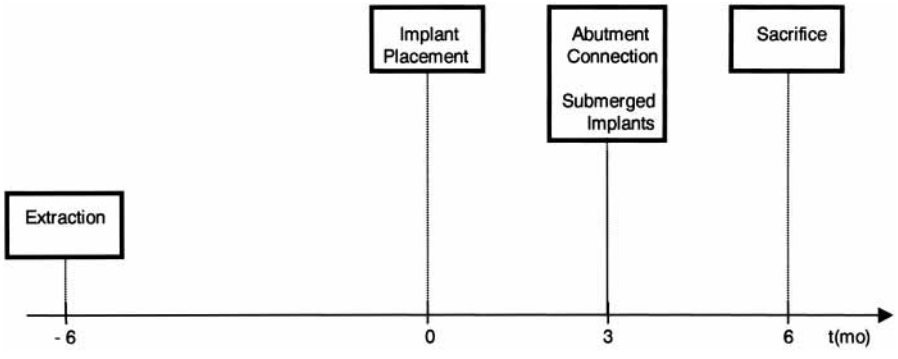

Fig. 2. Study design.

This osteotomy likely had little effect on the outcome as the bone was quite thin, as evidenced by no changes during the submerged healing phase as shown in an earlier study of these implants (Hermann et al. 1997). Consequently, flat-head cover screws could be removed in the submerged implant group. Abutments of individual lengths were connected specific for each implant type so that after abutment connection all implants emerged to the same level. Interrupted sutures combined with a small V-shaped gingivectomy were used for wound closure around the abutments. Postoperative care and suture removals were done the same way as after extraction.

Abutments on type C–F implants were loosened and immediately tightened afterwards at four, eight, and ten weeks after second-stage surgery to imitate the placement of another healing abutment, impression taking, as well as the placement of the final prosthetic component.

Surgeries – Sacrifice

All dogs were sacrificed three months after abutment connection of the submerged implants (Fig. 2). Euthanasia was carried out with an overdose of Euthanasia-5® Solution i.v. (pentobarbital sodium 0.2 ml=65 mg/kg bw. – Henry Schein Inc., Port Washington, NY, USA). Mandibles were block-resected with an oscillating autopsy saw (Stryker Co., Kalamazoo, MI, USA). The recovered segments with the implants were immersed in a solution of formaldehyde 4% combined with $CaCl_2$ 1% for histologic preparation and analysis.

Nondecalcified histologic analysis – preparation

Each implant with surrounding tissues was prepared for nondecalcified histology (Schenk et al. 1984). Specimens were carefully dehydrated and embedded in methyl methacrylate. Per implant, first one well-centered mesio-distal section was cut with a diamond saw (Vari/Cut VC-50®, Leco Corporation, St. Joseph, MI, USA). The two remaining blocks were then glued together with an interposed plastic spacer (cyanoacrylate; Miocoll®, Migros Company, Zürich, Switzerland), and subsequently sectioned in an oro-facial direction, resulting in up to five oro-facial sections. All sections were ground to a final thickness of approximately 80 µm and superficially stained with toluidine blue and basic fuchsin (Figs 4a–9b).

Nondecalcified histologic analysis – histometry

Histometric quantification was carried out using a light microscope (Vanox-T®, Olympus, Tokyo, Japan) at different magnifications (×40–×200) to best locate anatomical reference points. The microscope was connected to a high-resolution video camera (CCD-Iris® Color Video Camera, Sony Corp., Fujisawa, Japan) and interfaced to a monitor (Multisync® XV17+, NEC, Itasca, IL, USA) as well as a personal computer (Vectra VL®, Hewlett Packard, Palo Alto, CA, USA). This optical system was associated with a digitizing pad and a bone histometry software package with image capturing capabilities (Image-Pro Plus®, Media Cybernetics, Silver Spring, MD, USA). Finally, the following measurements/calculations were performed at each implant site (Fig. 3):

1. Distance between the gingival margin (GM) and the most coronal point of the junctional epithelium (cJE)=sulcus depth (SD)
2. Distance between cJE and the most apical point of the junctional epithelium (aJE)=junctional epithelium (JE)

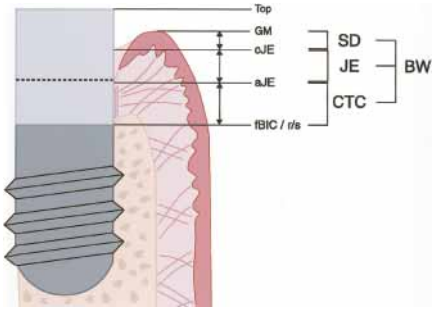

Fig. 3. Composite schematic (not true to scale) of histometric evaluation with the following measurements/calculations: Distance between the gingival margin (GM) and the most coronal point of the junctional epithelium (cJE)=sulcus depth (SD). Distance between cJE and the most apical point of the junctional epithelium (aJE)=junctional epithelium (JE). Distance between aJE and the first bone-to-implant contact (fBIC)=connective tissue contact (CTC). SD + JE + CTC=Biologic Width (BW). Distances between the top of the implant (Top) and the GM, cJE, aJE, rough/smooth border (r/s), and the fBIC.

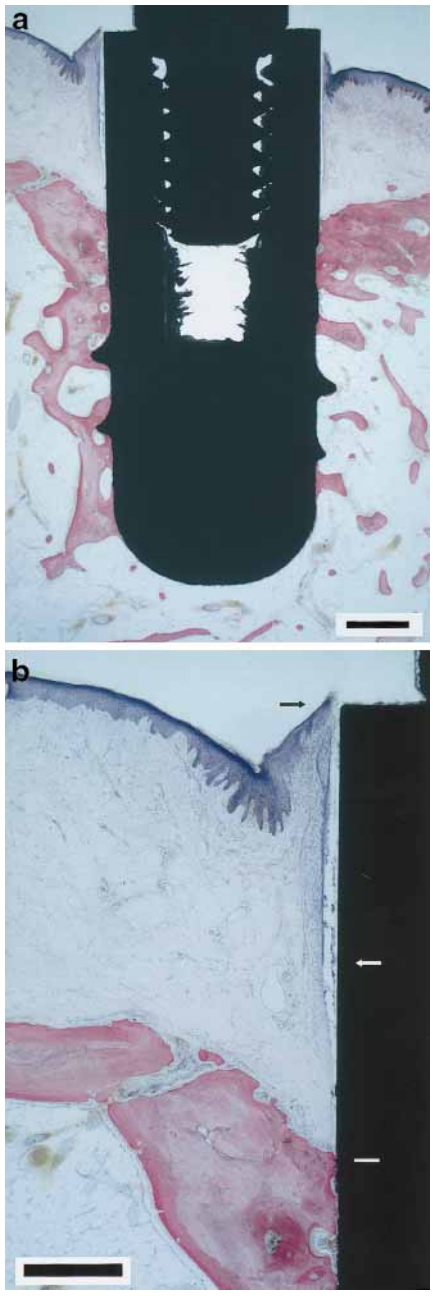

Fig. 4. a. Mesio-distal section (overview) of a type A implant (one-piece, nonsubmerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 4a. Left (distal) aspect of type A implant (one-piece, nonsubmerged). Note mild signs of peri-implant inflammation. The white bar indicates the level of the first bone-to-implant contact (fBIC), the white arrow the most apical cell of the junctional epithelium (aJE), and the black arrow the top of the implant (Top). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification×8; black bar=0.5 mm.

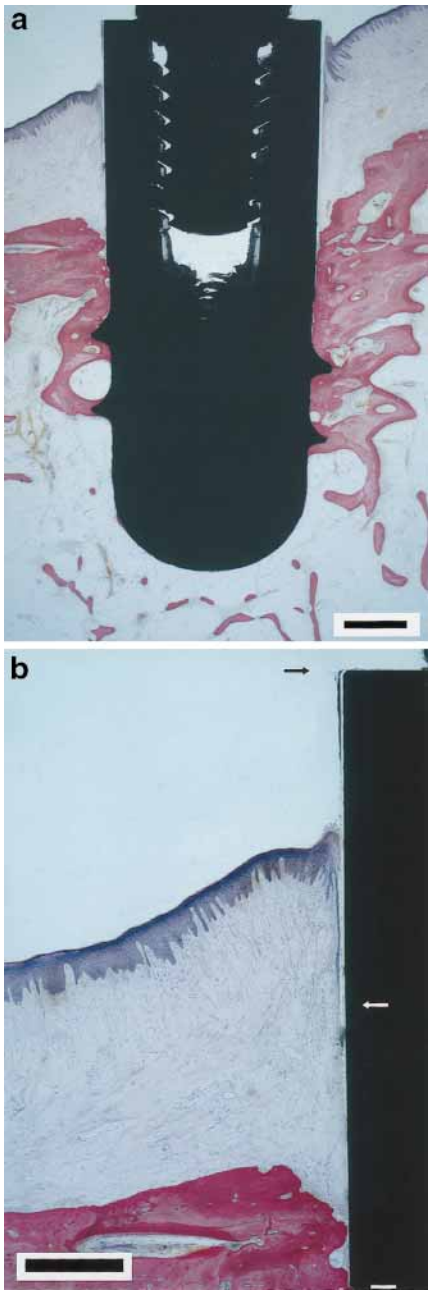

Fig. 5. a. Mesio-distal section (overview) of a type B implant (one-piece, nonsubmerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 5a. Left (mesial) aspect of type B implant (one-piece, nonsubmerged). Note mild signs of periimplant inflammation. The white bar shows the level of the first bone-to-implant contact (fBIC), the white arrow the most apical cell of the junctional epithelium (aJE), and the black arrow the top of the implant (Top). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification×8; black bar=0.5 mm.

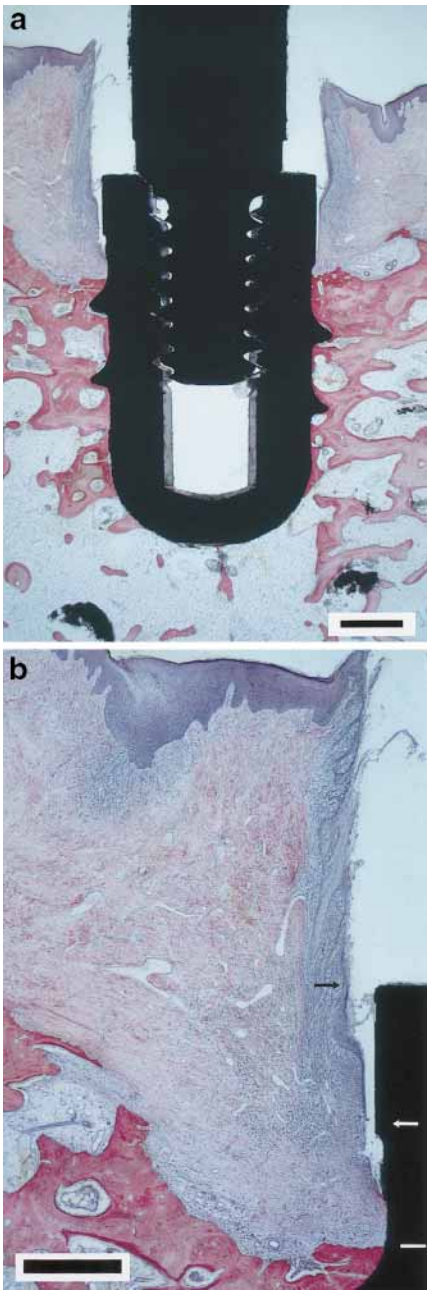

Fig. 6. a. Mesio-distal section (overview) of a type C implant (two-piece, nonsubmerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 6a. Left (distal) aspect of type C implant (two-piece, nonsubmerged). Note moderate to severe signs of periimplant inflammation. The white bar delineates the level of the first bone-to-implant contact (fBIC), the white arrow the most apical cell of the junctional epithelium (aJE), and the black arrow the microgap (interface). Note that the abutment is not visible due to proper histological processing. Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification×8; black bar=0.5 mm.

3. Distance between aJE and the first bone-to-implant contact (fBIC)=connective tissue contact (CTC)
4. SD + JE + CTC=Biologic Width (BW)
5. – 9. Distances between the top of the implant (Top) and the GM, cJE, aJE, the rough/smooth border (r/s), and the fBIC.

Statistical analysis

The two principal soft tissue measures of interest for this study were the determination of the Biologic Width dimensions (Fig. 3) and the location of the gingival margin in relation to the implant. Each implant had one to three mesio-distal and up to five oro-facial sections yielding a total of 566 sites for histometric examination. In order to verify that the soft tissue values obtained from the histometric evaluation were not influenced by examiner bias, the primary examiner obtained two measures, as did a second examiner, for a subsample of 51 sites taken from six implants. The results of the comparison of the four readings of BW measures indicated the histometric evaluation was highly calibrated, with the four readings differing by less than 0.20 mm for 46 (90.2%) of 51 sites, with a maximum difference of 0.42 mm.

Data were unavailable for 22.4% of sites (including all sites of one type C and one type E implant) that were unreadable due to histological processing (16.8%) or the degree of periimplant inflammation (5.6%). Also, the first bone-to-implant contact (fBIC) for buccal sites tended to be lower than that for the corresponding lingual, mesial, or distal sites obtained from an implant. Biologic Width measures for nonbuccal sites within an implant generally ranged within 0.5 mm, but buccal sites tended to have distances 0.5 to 1.0 mm larger than any of the nonbuccal sites obtained from the same implant. Consequently, buccal sites tended to have BW values that were extreme outliers relative to the overall distribution of BW values for sites within an implant. These results indicated that only lingual, mesial, and distal sites should be used in this study to calculate mean values of the Biologic Width for each implant. For the purposes of consistency, buccal sites were also excluded in the calculation of mean values for each implant of all soft tissue meas-

urements. The remaining four to six sites per implant provided a sample sufficient to develop precise individual implant measures after averaging.

A mixed-model Analysis of Variance was performed for each soft tissue measurement to check if implant types differed in a consistent fashion for each dog. If the resulting F-test was significant ($P<0.05$), then Bonferroni-corrected pairwise comparisons were made to identify implant type differences. Also, separate mixed-model ANOVAs were performed to ensure that position on the arch and side of the mandible did not influence the implant type results.

Results

Clinical observations

One out of the possible 60 implants could not be placed since the implant recipient site was too soft and, therefore, primary stability could not be achieved. All other 59 implants were clinically stable and no complications occurred during healing or during the follow-up period. In a recent publication based on the same data set analyzing radiographic changes on a monthly basis over time, no periimplant radiolucencies were found around any of the implants, however crestal bone loss could be detected dependent on specific implant designs (one-piece *vs.* two-piece implants) and techniques (nonsubmerged *vs.* submerged) used (Hermann et al. 1997). Thus, all implants achieved hard tissue integration by clinical as well as radiographic means. Although a meticulous combination of mechanical and chemical plaque control was carried out three times per week, different degrees of periimplant inflammation could be identified when comparing one-piece (types A and B; Figs 4b, 5b) *vs.* two-piece implants (types C-F; Figs 6b, 7b, 8b, 9b) with types A and B exhibiting minimal signs of inflammation, as opposed to types C–F showing moderate to severe degrees of inflammation.

Histometric analysis

Light microscopic evaluation of the bone-to-implant contact in nondecalcified sections showed that hard tissue in-

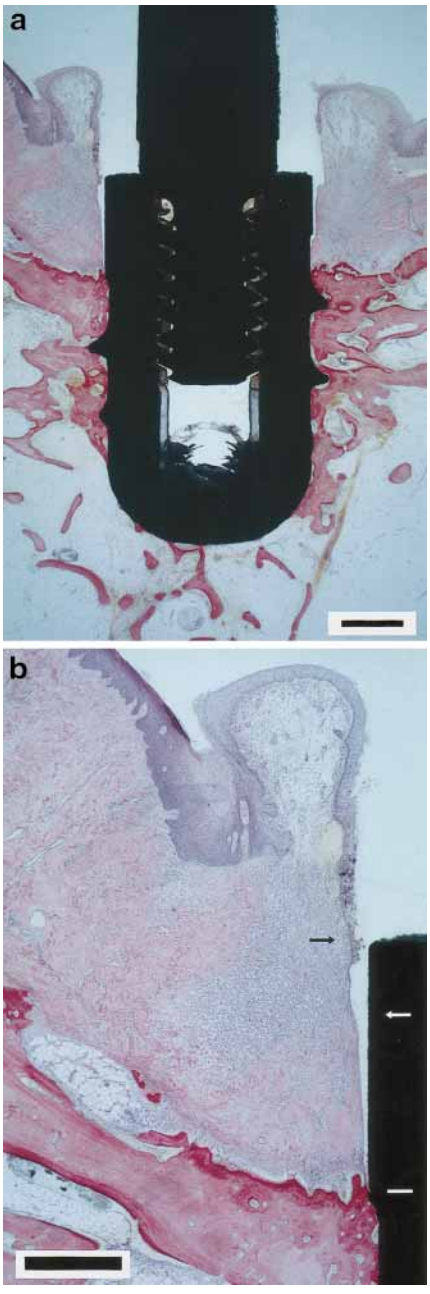

Fig. 7. a. Mesio-distal section (overview) of a type D implant (two-piece, submerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 7a. Left (mesial) aspect of type D implant (two-piece, submerged). Note moderate to severe signs of periimplant inflammation. The white bar reveals the level of the first bone-to-implant contact (fBIC), the white arrow the most apical cell of the junctional epithelium (aJE), and the black arrow the microgap (interface). Note that the abutment is not visible due to proper histological processing. Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×8; black bar=0.5 mm.

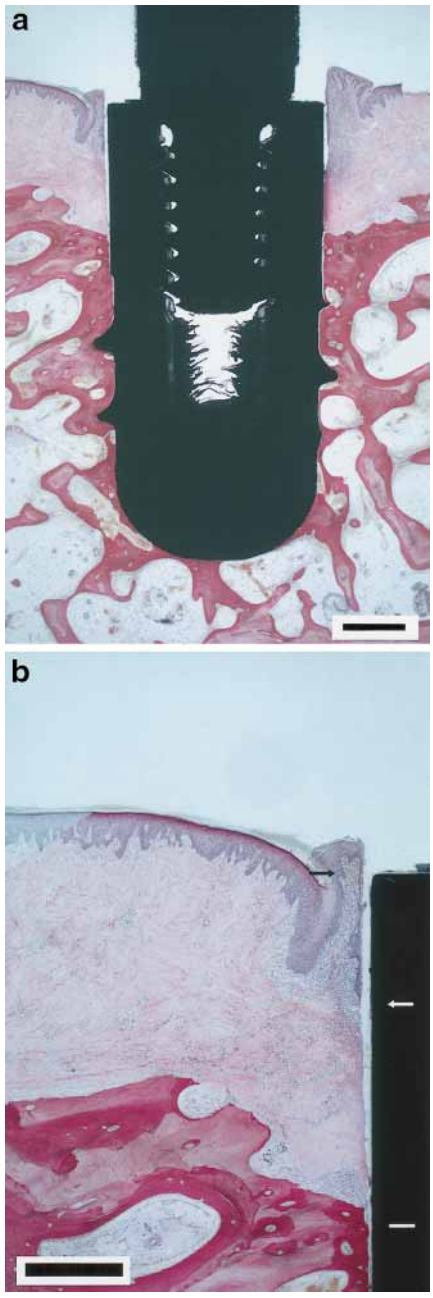

Fig. 8. a. Mesio-distal section (overview) of a type E implant (two-piece, submerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 8a. Left (mesial) aspect of type E implant (two-piece, submerged). Note moderate to severe signs of periimplant inflammation. The white bar represents the level of the first bone-to-implant contact (fBIC), the white arrow the most apical cell of the junctional epithelium (aJE), and the black arrow the microgap (interface). Note that the abutment is not visible due to proper histological processing. Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×8; black bar=0.5 mm.

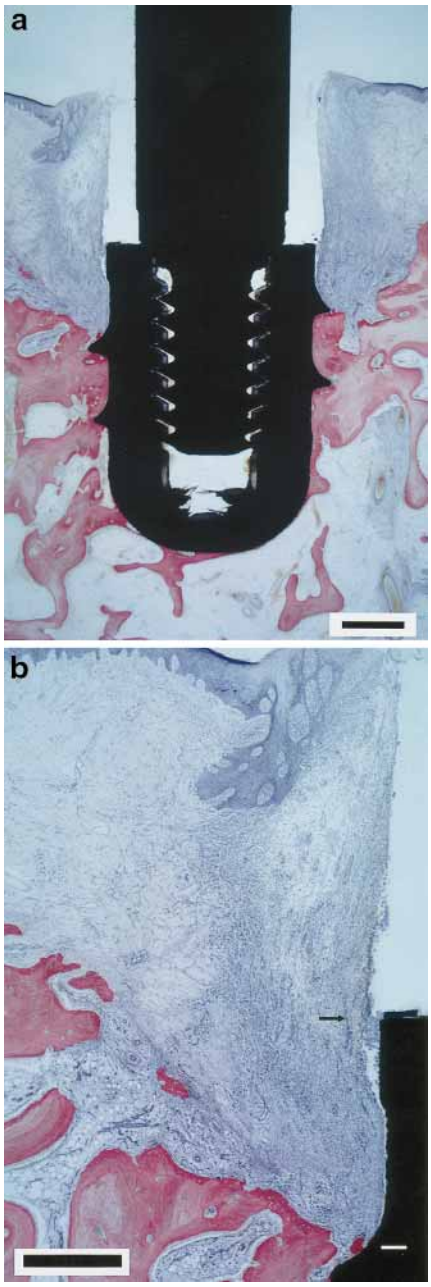

Fig. 9. a. Mesio-distal section (overview) of a type F implant (two-piece, submerged). Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification ×2.5; original inner/outer implant diameter=3.5 mm/4.1 mm; black bar=1 mm. b. Close-up view of Fig. 9a. Left (mesial) aspect of type F implant (two-piece, submerged). Note moderate to severe signs of periimplant inflammation. The white bar exhibits the level of the first bone-to-implant contact (fBIC), and the black arrow the microgap (interface). Due to the severe degree of inflammation, the most apical cell of the junctional epithelium (aJE) could not be detected. Note that the abutment is not visible due to proper histological processing. Nondecalcified histologic section; toluidine blue and basic fuchsin stain; original magnification×8; black bar=0.5 mm.

tegration was achieved (Figs 4a-9b). For all implants (types A–F), an intimate contact of bone was found directly adjacent to the sandblasted (large-grit) and acid-etched surface (SLA). As expected, dense cortical bone had large areas of bone-to-implant contact compared to cancellous bone areas where more marrow space was found. In more cancellous bone, however, osseous tissue was found along the SLA surface demonstrating and confirming the excellent osteoconductive nature of this specific surface. In the most coronal area, however, different crestal bone loss patterns could be found dependent on different implant types. These results have already been described and discussed in detail recently in three other publications (Hermann et al. 1997; Hermann et al. 2000b; Hermann et al. 2001).

Nine one-piece, nonsubmerged implants (type A; Fig. 1a) with 37 histological sections and 45 measurable implant sites were analyzed. The Biologic Width dimension (BW) measured 2.84±0.28 mm (standard deviation) and the mean distance between the top of the implant (Top) to the gingival margin (GM) was 0.32±0.58 mm (Figs 4a, 4b, 11, Table 1). Ten one-piece, nonsubmerged implants (type B; Fig. 1a) with 39 histological sections and 50 readable implant sites were studied. For this implant group, the BW was 3.57±0.61 mm whereas the mean distance from the top of the implant (Top) to the gingival margin (GM) was 0.42±0.52 mm (Figs 5a, 5b, 11, Table 1). For the third nonsubmerged group, nine two-piece implants (type C; Fig. 1a) with 33 histological sections and 40 sites could be analyzed. The dimension for BW in this group was 3.38±0.36 mm with a distance from the top of the implant (Top) to the GM of 1.38±0.43 mm (Figs 6a, 6b, 11, Table 1).

Table 1. **Histometric data for the three different implant groups A–C (nonsubmerged approach) six months after implant placement. Mean values±standard deviation [mm]; (n_i)=number of measured implants/(n_{is})=number of measured implant sites. "Top" refers to the most coronal aspect of the implant for types A and B and the coronal aspect of the abutment on type C.**

Variables	A (n_i=9/n_{is}=45)	B (n_i=10/n_{is}=50)	C (n_i=9/n_{is}=40)
SD	0.23±0.16	0.21±0.11	0.24±0.08
JE	1.33±0.31	1.74±0.37	1.75±0.46
CTC	1.28±0.28	1.62±0.48	1.39±0.16
BW	2.84±0.28	3.57±0.61	3.38±0.36
Top: GM	0.32±0.58	0.42±0.52	1.38±0.43
Top: cJE	0.54±0.47	0.64±0.46	1.62±0.46
Top: aJE	1.87±0.60	2.38±0.66	3.37±0.26
Top: r/s	2.80±0.12	3.89±0.19	4.30±0.04
Top: fBIC	3.13±0.38	3.99±0.46	4.77±0.15

Table 2. **Histometric data for the three different implant groups D–F (submerged approach) six months after implant placement, or three months after abutment connection, respectively. Mean values±standard deviation [mm]; (n_i)=number of measured implants / (n_{is})=number of measured implant sites. "Top" refers to the coronal aspect of the abutments.**

Variables	D (n_i=10/n_{is}=48)	E (n_i=9/n_{is}=47)	F (n_i=10/n_{is}=50)
SD	0.14±0.05	0.13±0.10	0.14±0.11
JE	2.11±0.60	1.50±0.29	2.31±0.34
CTC	1.41±0.28	1.70±0.40	1.35±0.26
BW	3.67±0.67	3.33±0.34	3.80±0.39
Top: GM	1.03±0.80	1.42±0.24	1.55±0.58
Top: cJE	1.17±0.77	1.55±0.30	1.69±0.64
Top: aJE	3.28±0.38	3.06±0.42	4.00±0.46
Top: r/s	4.26±0.05	4.58±0.07	4.36±0.05
Top: fBIC	4.70±0.21	4.75±0.22	5.35±0.40

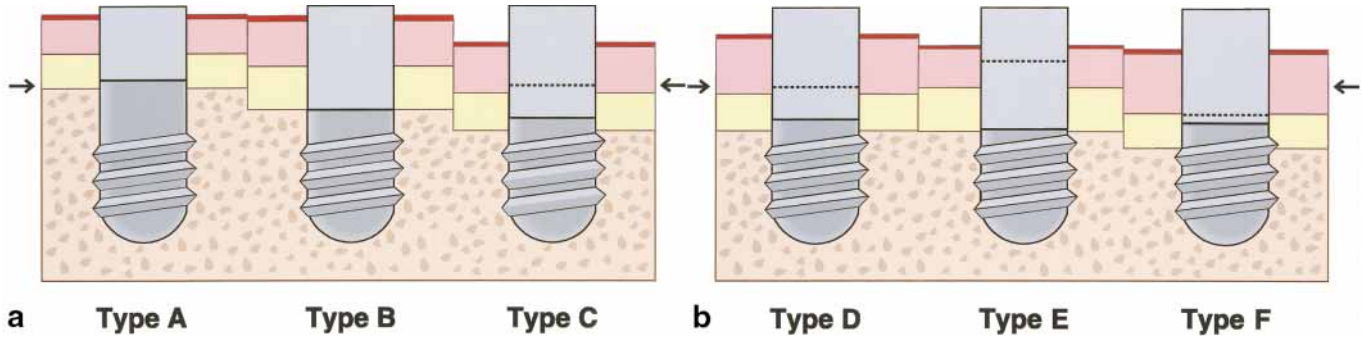

Fig. 10. a. Schematic (true to scale) of soft and hard tissues around nonsubmerged implant types A–C at time of sacrifice in relation to the rough/smooth border (solid black line) as well as the location of the microgap (interface; dashed black line). The dark red compartment shows the vertical dimension of the sulcus depth (SD), the pink compartment the junctional epithelium (JE), and the yellow compartment the connective tissue contact (CTC). Note that for one-piece titanium implants (types A, B), the tip of the gingival margin (GM) was significantly located more coronally ($P<0.04$) as compared to two-piece implants (types C–F; see also Fig 10b). Arrows indicate the level of the crest of the bone at the time of implant placement. b. Schematic (true to scale) of soft and hard tissues around submerged implant types D–F at time of sacrifice in relation to the rough/smooth border (solid black line) as well as the location of the microgap (interface; dashed black line). The dark red compartment exhibits the vertical dimension of the sulcus depth (SD), the pink compartment the junctional epithelium (JE), and the yellow compartment the connective tissue contact (CTC). Note that for two-piece titanium implants (types C–F), the tip of the gingival margin (GM) was significantly located more apically ($P<0.04$) as compared to one-piece implants (types A, B; see also Fig. 10a). Arrows indicate the level of the crest of the bone at the time of implant placement.

In the submerged group, ten two-piece implants (type D; Fig. 1b) with 38 histological sections and 48 readable sites could be measured. The dimension for BW was 3.67±0.67 mm with a mean distance from the top of the implant (Top) to the GM of 1.03±0.80 mm (Figs 7a, 7b, 11, Table 2). Nine submerged implants of type E (Fig. 1b) based on 39 histological sections and 47 measurable sites were analyzed. In this submerged group, the BW dimension was 3.33±0.34 mm. The mean distance from the top of the implant (Top) to the GM was 1.42±0.24 mm (Figs 8a, 8b, 11, Table 2). For the third submerged implant group, type F (Fig. 1b), ten implants with 40 sections could be analyzed based on 50 readable sites. The BW measured 3.80±0.39 mm with a mean distance from the top of the implant (Top) to the GM of 1.55±0.58 mm (Figs 9a, 9b, 11, Table 2).

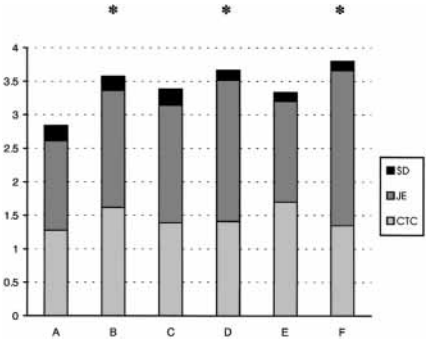

Fig. 11. Histometric data for the six different implant groups A–F six months after implant placement (mean values [mm]). Comparison among Biologic Width (BW) dimensions revealed significantly higher values for implant types B ($P<0.04$), D ($P<0.02$), and F ($P<0.005$; see asterisks) as compared to type A implants. No significant changes ($P>0.05$) were evident comparing the sulcus depth (SD) as well as the connective tissue contact (CTC) dimensions among all implant types (A–F). However, the dimensions for junctional epithelium (JE) were significantly lower comparing type A with type F implants ($P<0.005$), type A with type D ($P<0.03$), type E with type F ($P<0.02$).

F-tests comparing implant types (A–F) were significant for BW, junctional epithelium (JE), and the distance between the top of the implant (Top) to the GM ($P<0.005$). No significant differences ($P>0.10$) across implant types could be found for the dimensions of sulcus depth (SD), and for connective tissue contact (CTC). Comparing the implant type means for BW (Fig. 11), the mean dimension for type A implants was significantly smaller than that for types B ($P<0.04$), D ($P<0.02$), and F ($P<0.005$). Differences among implant type means for junctional epithelium (JE) were observed, with type D implants significantly greater than type A ($P<0.03$), and with type F implants significantly greater than types A ($P<0.005$) and E ($P<0.02$). Finally, the distance between the top of the implant (Top) to the GM was significantly lower for one-piece implants (types A and B) compared to all two-piece implants (types C, D, E, and F; $P<0.05$). The side of the mandible and position on the arch did not influence the results ($P>0.20$).

Discussion

The results of this study indicate that the dimensions of the periimplant soft tissues (*i.e.* the Biologic Width), as evaluated by histometric measurements, are significantly influenced by the presence/absence of a microgap (interface) between the implant and the abutment, and the location of this microgap (interface) in relation to the crest of the bone. Furthermore, there was no difference in the soft tissue dimensions comparing two-piece implants that had been placed utilizing a submerged technique as opposed to placing them using a nonsubmerged approach. In addition, the tip of the gingival margin was significantly located more coronally for one-piece compared to two-piece titanium implants. Thus, the significant factor that influences soft tissue dimensions is the presence/absence of a microgap (interface) between components and not the surgical technique used (submerged *vs.* nonsubmerged).

A comparison of the Biologic Width

(linear vertical dimension of connective tissue, junctional epithelium, and sulcus depth) among different implant types (A–F) indicated that one-piece, nonsubmerged implants with a rough/smooth border at the alveolar crest had the smallest value of the six implant designs tested, and resulted in the gingival margin closest to the top of the implant six months after placement. The Biologic Width dimension around natural teeth, as measured in the classic work by Gargiulo and coworkers (Gargiulo et al. 1961) was 2.73 mm, and thus very similar to the 2.84 mm measured for the type A implants. Consequently, of all implant types examined in this study, the one-piece, nonsubmerged implant with a rough/smooth border placed at the alveolar crest resulted in soft tissue dimensions most like the natural dentition. Moving the rough/smooth border on the implant (type B) more apically (approximately 1.0 mm) resulted in a larger Biologic Width (average increase of 0.73 mm). This alteration occurred through both an increased junctional epithelium (average 0.41 mm) and connective tissue dimension (average 0.34 mm), supporting an earlier study on changes in these dimensions over time (Hermann et al. 2000a). The gingival margin was only slightly displaced apically (0.10 mm) in type B implants compared to type A implants that were also one-piece and nonsubmerged. These findings suggest that the placement of a one-piece, nonsubmerged implant with a rough/smooth border placed 1.0 mm below the alveolar crest will have approximately the same gingival level and an increased Biologic Width dimension compared to a similar implant where the rough/smooth border is placed at the level of the alveolar crest. The clinical implication of these findings is that slightly submerging the rough/smooth border on a one-piece, nonsubmerged implant will not significantly jeopardize the location of the gingival margin for the final restoration.

A significant alteration of the soft tissues occurs when a clinically relevant sized microgap (interface) of about 50 μm is introduced according to several *in vitro* reports which have shown that microgap (interface) sizes of implant/abutment combinations currently used vary from around 100 μm (Sorensen et al. 1991), to about 50 μm (Binon et al. 1992; Keith et al. 1999), or even below 10 μm (Besimo et al. 1994; Keith et al. 1999). The influence of the microgap (interface) was independent of whether implants were placed in a nonsubmerged (type C implant) or in a submerged technique (type D implant), by connecting an abutment to the top of the implant. This occurred even when the microgap (interface) was located at the alveolar crest, *i.e.* the top of the implant is at the alveolar crest and the abutment extends from the top of the implant through the soft tissues serving as a transgingival component. The type C implant was essentially the same as the type B implant (both were placed in a nonsubmerged technique) except that a microgap (interface) existed, making the type C a two-piece implant placed in a nonsubmerged technique. This approach has been discussed/recommended for clinical use in recent years, trying to apply the advantage of just one surgical procedure (as traditionally used for one-piece, nonsubmerged implants) when employing a two-piece implant technique (Ericsson et al. 1994; Bernard et al. 1995; Ericsson et al. 1996; Levy et al. 1996; Becker et al. 1997; Ericsson et al. 1997; Schnitman et al. 1997; Tarnow et al. 1997; Collaert & De Bruyn 1998; Abrahamsson et al. 1999). In this case, although the Biologic Width dimension was similar to the type B implant, a significant loss of gingival height (approximately 300%) occurred (1.38 mm *vs.* 0.42 mm). This finding can be explained by the fact that the alveolar bone level has moved apically in the type C implant compared to the type B implant. With the type B implant, the crestal bone level was located at the rough/smooth border (Fig. 1a, Table 1; see also Hermann et al. 1997; Hermann et al. 2000b), while in the case of the type C implants, the crestal bone level was located apical to the rough/smooth border. These findings, furthermore, suggest that the influence of the microgap (interface) is greater than the effect of the rough/smooth border as it relates to the first bone-to-implant contact on the implant. Consequently, these histological findings also reinforce the radiological findings around these implants and the similar conclusion that the microgap (interface) has a significant influence on crestal bone levels around two-piece implant systems (Hermann et al. 1997).

A comparison of the soft tissue dimensions around the type C and D implants allows a comparison between the surgical placement techniques (nonsubmerged *vs.* submerged). Both implant types were identical in regards to location of the microgap (interface) and the rough/smooth border with the only difference being that the type D implants were submerged for three months after which they were uncovered and the abutments placed. After abutment connection, these implant types were identical. Thus, the difference was when the implants and abutments were exposed to the oral cavity (*i.e.* immediately upon placement of type C implants, while type D implants were exposed three months later). The difference in tissue measurements between these two types of implants ranged only from 0.02 mm to a maximum of 0.45 mm indicating that the surgical placement of the implants as two-piece, nonsubmerged implants (type C) or as two-piece, submerged implants (type D) did not have a significant effect on crestal bone levels as well as soft tissue dimensions. Because the type D dimensions were similar to type C and not similar to the dimensions around type A or B implants reinforces the suggestion that the presence of a microgap (interface) significantly influences hard and soft tissue levels around an implant. The clinical implication for these findings is that if an abutment is connected to a traditionally submerged implant system at the time of implant placement (Becker & Becker 1990; Ericsson et al. 1994; Bernard et al. 1995; Becker et al. 1997; Ericsson et al. 1997; Schnitman et al. 1997; Tarnow et al. 1997; Collaert & De Bruyn 1998), thus creating a two-piece, nonsubmerged implant approach, crestal bone levels and soft tissue dimensions should be the same as if the implant is initially submerged during first-stage surgery, and three months later uncovered and abutments connected during second-stage surgery (*i.e.* crestal bone loss will occur and the gingival margin will move apically). Contradictory reports from experimental studies

have been published in the 1990s (Berglundh et al. 1991; Abrahamsson et al. 1996; Berglundh & Lindhe 1996; Abrahamsson et al. 1999) where different two-piece, submerged implants have been investigated in animal studies not experiencing the same amount of crestal bone loss and apical migration of the gingival margin as observed clinically in previous studies. An important detail in that regard seems to be the fact that according to the protocol in the present study, abutments on all two-piece implants (types C–F) were disconnected and immediately tightened afterwards, trying to imitate clinically relevant steps like the exchange of a healing abutment, impression taking, and the insertion of the superstructure. These steps were not carried out in the four above-mentioned studies. However, once the same research group repeated their experiments (Abrahamsson et al. 1997), including the disconnection/tightening of the abutments, the same amount of crestal bone loss, apical migration of the gingival margin, as well as overall dimension for the Biologic Width could be observed and, thus, the results of this study group were confirmed (Hermann et al. 1997; Hermann et al. 2000b; Hermann et al. 2001).

The type E and type F implants were designed to test the hypothesis that if tissue levels were influenced by a microgap (interface), then moving the interface coronally one millimeter from the alveolar crest (type E) should minimize its influence on the tissues, and moving the interface apically one millimeter (type F), would result in more significant tissue changes. These values could then be compared to type D implants where the interface was located at the alveolar crest. ln type E implants, the crestal bone was found to be located at the rough/smooth border similar to the type B implant. In this case, the first bone-to-implant contact reacted as if no microgap (interface) was present, *i.e.* moving the interface coronally minimized its influence on the crestal bone level (Hermann et al. 1997; Hermann et al. 2000b; Hermann et al. 2001). In regards to the soft tissues, the type E implants had the smallest Biologic Width dimension of all the submerged implant types. Additionally, the length of the junctional epithelium was the smallest (1.50 mm) of the submerged implants, and the connective tissue dimension the largest (1.70 mm). In comparison to the type B implants which were similar to type E implants except that there was no microgap (interface), the differences in values for sulcus depth, junctional epithelium, and connective tissue contact around type E implants were 0.08 mm, 0.24 mm, and 0.08 mm, respectively, indicating that moving the microgap (interface) coronally minimized its influence on the soft tissues with the result that the tissues were more similar to a one-piece implant (an implant without a microgap/interface).

The type F implants had the microgap (interface) located one millimeter below the alveolar crest. As predicted by the hypothesis, this arrangement resulted in the most significant tissue changes around the six different implant types and confirmed the radiographic findings (Hermann et al. 1997). The Biologic Width dimension had the largest value (3.80 mm) of all the implants, both submerged and nonsubmerged, as did the length of the junctional epithelium (2.31 mm). Furthermore, the top of the implant to the gingival margin, the top of the implant to the apical extent of the junctional epithelium, and the top of the implant to the first bone-to-implant contact were the largest recorded for all six implant types. These findings indicate that the apical placement of a microgap (interface), as recommended clinically in order to achieve a harmonious emergence profile in areas of esthetic concern (Saadoun et al. 1994; Palacci et al. 1995; Spiekermann 1995; Nevins & Stein 1998), has the most significant influence on the hard and soft tissues with the largest Biologic Width dimension, the most apical location of the crestal bone, small connective tissue contact area, very long epithelial attachment, and the most apical location of the gingival margin. The clinical implications for such an implant design and placement are that a recession of the gingival margin should be expected using such a submerged implant technique with the appropriate consequences as to an impaired esthetic result, and a more difficult maintenance as the epithelial contact will extend apically at least to the level of the microgap (interface) which was placed below the alveolar crest. Since it has been reported clinically that microgaps (interfaces) in two-piece implant systems show bacterial colonization (Quirynen & van Steenberghe 1993; Persson et al. 1996), a more apical location of such flora may tend to favor a more pathogenic, anaerobic composition of bacteria and accordingly, a more severe degree of periimplant inflammation. This approach (type F implants) creates an infrabony defect since at the time of abutment connection, the interface is created below the crestal bone level. These histometric findings demonstrate that tissue changes will occur such that the crestal bone will resorb to a level below the microgap (interface), and that the junctional epithelium will extend towards this level with a resulting small connective tissue contact area. These data confirm the changes in tissues around submerged and nonsubmerged implants discussed by Cochran and Mahn (Cochran & Mahn 1992), and the results by other investigators (Weber et al. 1996; Abrahamsson et al. 1997; Hermann et al. 1997; Hermann et al. 2000b).

The precise cause of the tissue changes that were observed around implants in this side-by-side comparison of implant types is not known. One possible explanation is that the microgap (interface) represents a site of infection, and the host reacts with an inflammatory response. Consequently, alveolar bone loss combined with an apical migration of the junctional epithelium beneath this area, tries to protect the internal part of the body from this source of inflammation by reestablishing the ectodermal integrity of the body. This is similar to what occurs in cyst formation, such as that found around the apices of nonvital teeth that become infected. Furthermore, it is clear that the microgap (interface) of a two-piece titanium implant is contaminated with bacteria (Quirynen & van Steenberghe 1993; Persson et al. 1996), possibly through microbial leakage through the transocclusal screw access hole (Jansen et al. 1997; Guindy et al. 1998; Gross et al. 1999) or due to bacterial colonization along the abutment. Thus, the tissue changes demonstrated

could be the result of the inflammation associated with the bacterial contamination of the microgap (interface). This is reinforced by the fact that a meticulous mechanical as well as chemical plaque control has been performed throughout the present study, and by examining the soft tissue histologically around implant types A and B (Figs 4b, 5b) exhibiting minimal signs of periimplant inflammation, as opposed to the soft tissue status around implant types C-F (Figs 6b, 7b, 8b, 9b) showing moderate to severe degrees of periimplant inflammation. Thus, if one wants to choose an implant design with the least inflammation, and consequently the smallest resultant tissue changes, a one-piece implant design should be selected.

There are several clinical consequences to the histometric tissue changes demonstrated in this study. One such consequence is when implants are being placed in an area where minimal bone height is available to support the implant such as in the posterior mandible above the mandibular canal and nerve, and in the posterior maxilla below the maxillary sinus. In these indications it would be important to use an implant design that will not result in crestal bone loss as the amount of supporting bone is already compromised. Furthermore, in areas of esthetic concern, an implant design that results in soft tissue dimensions similar to natural teeth (Cochran et al. 1997; Hermann et al. 2000a), with minimal alveolar bone crest changes (Hermann et al. 1997; Hermann et al. 2000b) and the least effect on the gingival margin (this study) would be advantageous. Stable bone levels result in stable soft tissues as was demonstrated in a one-year, longer-term experimental animal study analyzing unloaded as well as loaded implants (Cochran et al. 1997; Hermann et al. 2000a). These data have been recently confirmed in humans by precisely examining alveolar bone levels over eight years in patients (Buser et al. 1999). In that study, out of 97 patients analyzed, a distribution of bone changes around these one-piece, nonsubmerged implants indicated that more implants actually gained than lost crestal bone. These findings can be contrasted to another implant design which utilizes a microgap (interface) placed at or below the alveolar crest (two-piece, submerged approach), where one major success criterion is the expected crestal bone loss of 1.5 mm after one year of loading (Albrektsson et al. 1986; Smith & Zarb 1989). Taken together, these findings support the experimental results in the present study and demonstrate that there are important clinical consequences to the implant design chosen.

Conclusions

The findings from the present experimental study show that significantly increased amounts of crestal bone loss around two-piece *vs.* one-piece implants also result in a significant more apical position of the gingival margin. In addition, Biologic Width dimensions vary depending on implant design. Biologic Width around one-piece implants is more similar to natural teeth dimensions as compared to two-piece implants, either being placed according to a submerged or a nonsubmerged technique. Additionally, the degree of inflammation in periimplant tissues is less around one-piece implants compared to two-piece implants. These results may have important implications when dealing with esthetic implant-borne restorations, which are based on healthy and vertically constant soft tissue dimensions over time.

Acknowledgements

Sonja A. Bustamante, H.T. (ASCP), University of Texas Health Science Center at San Antonio (UTHSCSA), is greatly acknowledged for her continuous and valuable support throughout the study. The authors also would like to thank Richard J. Haines, DVM, Clinical Veterinarian, and his team, Laboratory Animal Resources, UTHSCSA, for exemplary care of the animals. In addition, the authors would like to express their gratitude to James P. Simpson, B.Sc. (Eng), Ph.D., and the Institut Straumann AG, Waldenburg/BL, Switzerland, for manufacturing the test implants. Last but not least, we would like to express our appreciation for the superb work by Britt Hoffmann, H.T., University of Bern School of Dental Medicine, preparing the histological sections. This investigation has been supported by two grants from the ITI (International Team for Oral Implantology)-Foundation for the Promotion of Oral Implantology (# 16–95/094, # 20–97/134), Waldenburg/BL, Switzerland, and by stipends from the Swiss Society of Periodontology, Bern, Switzerland, the Swiss National Science Foundation, Basel, Switzerland, the Swiss Foundation for Medical and Biological Stipends, Bern, Switzerland, as well as the University of Basel Committee for the Promotion of *Philosophiae Doctor* candidates, Basel, Switzerland.

Résumé

L'esthétique gingivale autour des dents naturelles est basée sur une dimension verticale constante des tissus mous parodontaux sains qui porte le nom de Largeur Biologique. Cependant lorsque des implants endo-osseux sont placés, différents facteurs influençent les réactions tissulaires paroïmplantaires des tissus dur et mou qui ne sont pas toujours bien comprises. Le but de cette étude a été d'examiner histomorphométriquement les dimensions des tissus mous paroïmplantaires sur les différentes localisations, soit d'implants en une pièce au niveau de la frontière lisse/rugueuse soit d'implants en deux parties au niveau du micro-interstice (interface), en relation avec la crête osseuse; les implants en deux parties ayant été placés suivant la technique enfouie ou non-enfouie. Cinquante-neuf implants ont ainsi été placés dans les aires mandibulaires édentées de cinq chiens dans une comparaison par site. Au moment de tuer les chiens, six mois après le placement des implants, la dimension de la Largeur Biologique pour les implants en une pièce avec la limite lisse/rugueuse placée au niveau de la crête alvéolaire était significativement inférieure ($P<0.005$) comparée à celle des implants en deux parties qui avaient leur interface placée au niveau ou en-dessous de la crête osseuse. De plus pour les implants en une pièce, le sommet de la gencive marginale était placé significativement plus en coronaire ($P<0.005$) comparé aux implants en deux pièces. Ces découvertes évaluées par histologie de coupes non-décalcifiées sans charge dans la mandibule du chien suggèrent que la gencive marginale est située plus coronairement et que les dimensions de la Largeur Biologique sont plus semblables aux dents naturelles autour des implants non-enfouis en une pièce qu'au niveau des implants en deux parties qu'ils soient non-enfouis ou enfouis.

Zusammenfassung

Die rote Ästhetik um natürliche Zähne basiert im Wesentlichen auf einer Konstanten in der vertikalen Dimension der gesunden parodontalen Weichgewebe, der sogenannten biologischen Breite. Wenn enossale Implantate eingesetzt werden beeinflussen aber verschiedene Faktoren, welche bis heute noch nicht im Detail bekannt sind, die Reaktionen der periimplantären Weich- und crestalen Hartgewebe. Das Ziel dieser Studie war es daher, die periimplantären Weichgewebsdimensionen in Abhängigkeit der Lokalisationen eines Implantatüberganges von der glatten zur rauhen Oberfläche beim einteiligen Implantat, oder des Mikrospaltes (Verbindungsstelle) beim zweiteiligen Implantat histometrisch zu untersuchen. Insbesondere besprach man die Relationen zum Knochenkamm, wenn das zweiteilige Implantat mit einem submukö-

sen oder aber einem transmukösen Operationsprotokoll gesetzt worden war. Es konnten 59 Implantate im direkten Vergleich beidseits in die zahnlosen Unterkieferregionen von fünf Jagdhunden eingesetzt werden. Bei Abschluss der Studie, sechs Monate nach der Implantation, war die "Biologische Breite" bei einteiligen Implantaten (Grenzlinie zwischen rauher und glatter Oberfläche direkt an der Knochenlinie) signifikant kleiner ($P<0.05$) als bei zweiteiligen Implantaten mit der Mikrospalte (Schnittstelle kommt direkt an oder leicht unter die Knochenlinie zu liegen). Dazu kommt, dass bei einteiligen Implantaten der Gingivalsaum (GM) signifikant deutlich koronaler zu liegen kam ($P<0.005$) als bei zweiteiligen Implantaten. Die Analysen von nichtentkalkten histologischen Schnitten dieser unbelasteten Implantate im Unterkiefer des Hundes lassen vermuten, dass der mehr koronal gelegene Gingivalsaum (GM) und die Dimensionen der "Biologische Breite" (BW) bei einteiligen transmukösen Implantaten den Verhältnissen eines natürlichen Zahnes weit näher kommen, als es bei den zweiteiligen transmukösen oder submukösen Implantaten der Fall ist.

Resumen

La estética gingival alrededor de dientes naturales esta basada sobre una dimensión vertical constante de los tejidos blandos periodontales sanos, la anchura biológica. Cuando se colocan implantes endooseos, de todos modos, existen diversos factores que influyen en las reacciones de los tejidos blandos periimplantarios y tejidos duros crestales, que no han sido bien comprendidos hasta la fecha. Por lo tanto, el propósito de este estudio fue examinar histometricamente las dimensiones de los tejidos blandos periimplantarios dependiendo de varias localizaciones de un borde de implantes de una sola pieza rugoso/liso o un microespacio (interfase) en implantes de dos piezas en relación con la cresta ósea, con implantes de dos piezas colocados tanto con la técnica sumergida como con la no sumergida. De este modo, se colocaron 59 implantes en áreas mandibulares edentulas de cinco foxhounds en una comparación lado a lado. En el momento del sacrificio, seis meses después de la colocación de los implantes, la dimensión de la anchura biológica para implantes de una pieza, con el borde rugoso/liso localizado en el nivel de la cresta ósea, fue significativamente menor ($P<0.05$) comparado con los implantes de dos piezas con un microespacio (interfase) localizado en o por debajo la cresta ósea. Además, para implantes de una pieza, el extremo del margen gingival (GM) se localizó significativamente mas coronal ($P<0.005$) comparado con los implantes de dos piezas. Estos hallazgos, evaluados por histología no descalcificada bajo condiciones sin carga en la mandíbula canina, sugieren que el margen gingival (GM) esta localizado mas coronal y dimensión de la anchura biológica (BG) es mas similar a dientes naturales alrededor de implantes de una pieza no sumergidos comparados con tanto los implantes de dos piezas no sumergidos como los de dos piezas sumergidos.

要旨

天然歯周囲の歯肉の審美性は、一定の垂直寸法すなわち生物学的幅径を有する健全な歯周組織の存在に依拠している。骨内インプラントを埋入する場合には、幾つかの要因がインプラント周囲の軟組織と歯槽頂硬組織の反応に影響を及ぼすが、今日まで解明されてはいない。本研究では、ワンピース・インプラントの粗面／研磨面の境界、あるいはツーピース・インプラントの微小空隙（界面）から歯槽頂までの異なる位置関係によるインプラント周囲軟組織の寸法の違いを、組織学的に検討した。ツーピース・インプラントには、埋入式か非埋入式のいずれかの術式を採用した。５匹のフォックスハウンド犬の下顎無歯顎領域に、５９本のインプラントを入れて、並列式の比較を行った。

インプラント埋入６ヵ月後に動物を屠殺した際、骨頂に粗面／研磨面の境界を置いた場合のワンピース・インプラントの生物学的幅径は、ツーピース・インプラントの微小空隙（界面）を骨頂あるいはそれより深いところに置いた場合より有意に小さかった（P＜０．０５）。さらにワンピース・インプラントでは、歯肉縁（GM）の頂点は、ツーピース・インプラントに比べて有意に歯冠側に位置していた（P<０．００５）。犬の下顎において非荷重の条件下で非脱灰切片を組織学的に評価したこれらの所見は、非埋入式ワンピース・インプラントの周囲では、歯肉縁（GM）は非埋入式または埋入式のツーピース・インプラントよりも歯冠側に位置しており、生物学的幅径（BW）は天然歯により類似している事を示唆している。

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