Tissue Characteristics at Microthreaded Implants: An Experimental Study in Dogs

Ingemar Abrahamsson, DDS, OD; Tord Berglundh, DDS, OD

ABSTRACT

Purpose: The aim of the present study was to analyze bone tissue reactions at implants with and without a microthread configuration.

Materials and Methods: In six beagle dogs, one test and two control implants were installed in one side of the mandible. While both implant types had a similar dimension and surface roughness, the test implants were designed with a microthread configuration in the marginal portion. Abutment connection was performed after 3 months. Another 3 months later, fixed partial dentures (FPDs) were cemented to the maxillary canine and premolars and FPDs were connected to the implants in the mandible. Ten months later, the animals were sacrificed and biopsies from each implant region were processed for histological analysis. Radiographs were obtained at implant placement after FPD connection and at the termination of the experiment.

Results: The radiographic examination revealed that the marginal bone level was well preserved at both test and control implants during the entire 16-month period. The degree of bone-implant contact within the marginal portion of the implants was significantly higher at the test (microthread) implants (81.8%) than at the control implants (72.8%).

Conclusions: It was suggested that the microthread configuration offered improved conditions for osseointegration.

KEY WORDS: animal, bone level, histology, osseointegration, radiographs, titanium

Marginal bone loss is a frequently reported variable in the evaluation of dental implants (for review, see Berglundh and colleagues[1]), and certain threshold levels of marginal bone loss have been suggested for different criteria of implant success.[2] While findings from earlier clinical studies revealed that marginal bone loss was larger in the first year in function than during the subsequent years,[3–5] recent reports failed to confirm such patterns of bone loss.[6,7]

The geometry and surface roughness of the implant may influence the ability to obtain or preserve marginal bone support. Implants designed with an unthreaded, conical marginal portion (Brånemark System®, Nobel Biocare AB, Göteborg, Sweden) and commonly used in single-tooth replacements consistently demonstrated enhanced marginal bone loss in comparison to standard implants of the same implant system.[8–11] It was suggested that the variation in bone loss between the two types of implants was related to differences in geometry and that osseointegration may occur to a less extent to implant parts with a conical configuration. These findings are not consistent with data reported from studies on other implants with a conical marginal design. Implants outlined with a microthread configuration within the marginal conical portion (Astra Tech ST®, Astra Tech AB, Mölndal, Sweden) have been evaluated in prospective studies on single-tooth replacement over 5 years.[12,13] The data presented revealed that the marginal bone level changes over the 5-year periods were small and that sufficient osseointegration appeared to have occurred also at conical parts of the implants. The obvious difference between the two types of implants referred to previously is confined to the presence or absence of microthreads within the conical configuration of the implant.

The aim of the present study was to analyze the bone tissue reactions following implant placement and

Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy, Göteborg University, Sweden

Reprint requests: Ingemar Abrahamsson, Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy, Göteborg University, PO Box 450, SE 405 30 Göteborg, Sweden; e-mail: Ingemar.Abrahamsson@odontologi.gu.se

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during functional load at implants with and without a microthread configuration.

MATERIALS AND METHODS

The protocol of the present study was approved by the regional Ethics Committee for Animal Research, Göteborg, Sweden. Six beagle dogs, about 1 year old, were included. During all surgical procedures, the animals were under general anesthesia induced with propofol (10 mg/mL, 0.6 mL/kg) intravenously and sustained with $N_2O:O_2$ (1:1.5–2) and isoflurane employing endotracheal intubation. The experimental design regarding implant installation and prosthetic procedures was recently described.[14] In brief, at the start of the experiment, all mandibular premolars ($_4P_4$, $_3P_3$, $_2P_2$, $_1P_1$) were extracted. Three months later, a crestal incision was made and mucoperiostal flaps were raised in the edentulous premolar region in one side of the mandible. One test and two control implants were installed in a randomized order. Both implant types had a TiOblast™ (Astra Tech AB) surface, a diameter of 3.5 mm and were 8-mm long (Figure 1). The test implants had, in addition, a microthread configuration in the marginal portion, while the corresponding part of the control implant was devoid of threads. The implants were placed in such a way that the implant margin coincided with the bone crest (Figure 2).

Radiographs were obtained immediately after fixture installation using a custom-made film holder device connected to the posterior implant.[15] In the radiographs, the distance between the abutment/fixture junction (A/F) and the marginal bone level (B) was determined at the mesial and distal aspect of each implant. The measurements were carried out using a Leica DM-RBE® microscope (Leica, Germany) equipped with an image system (Q-500 MC®, Leica). Cover screws were placed and the flaps were sutured to cover the fixtures. The sutures were removed after 2 weeks.

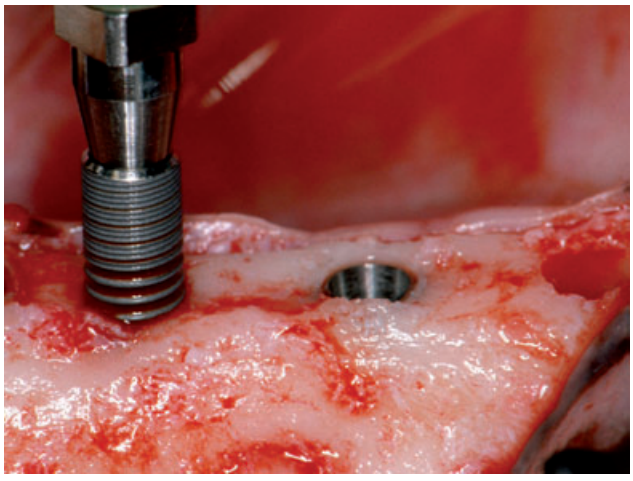

Figure 1 Placement of implants. One test implant during the installation process.

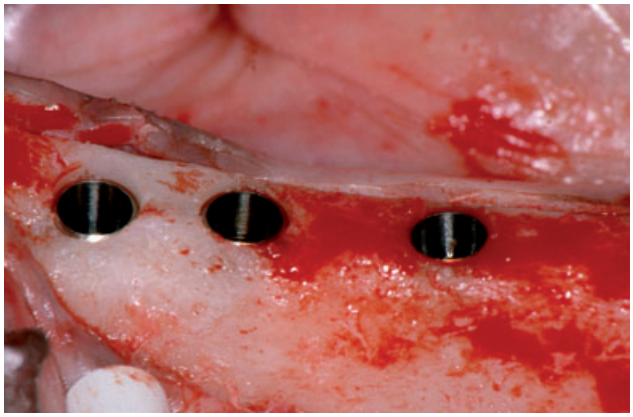

Figure 2 Clinical photo from the implant installation. One test and two control implants placed in level with the marginal bone.

Three months later, all implants were uncovered and Uni-abutments® (1.5 mm/20°; Astra Tech Implants® Dental System, Astra Tech AB) were connected. The flaps were sutured and a new set of radiographs was obtained. Sutures were removed 2 weeks later and a plaque control program (daily cleaning of all exposed implant surfaces and neighboring teeth using toothbrush and dentifrice) was initiated and maintained until the end of the experiment.

Full crown preparations were made to the antagonizing maxillary canine and premolars with a diamond bur. In the mandibular premolar regions, impression pickup copings were connected to the implants. Impressions from the maxillary and mandibular premolar segments were obtained using individual acrylic impression trays and polyether impression materials (Impregum® and Permadyne®; ESPE, Seefeld, Germany).

Three months after abutment connection fixed partial dentures (FPDs) made in gold were cemented to the maxillary canine and premolars using an adhesive resin-cement (Panavia® 21; Kuraray Co., Ltd., Osaka, Japan). FPDs were also connected to the implants in the mandible (Figure 3). Occlusal contact between the maxillary and mandibular premolar segment was established. Immediately after placement of the FPDs, a new set of radiographs from all implant sites was obtained.

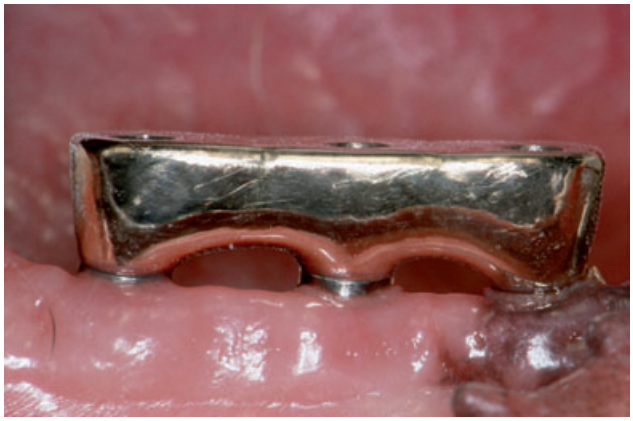

Figure 3 Fixed partial denture in gold connected to three mandibular implants.

The radiographic examination was repeated 10 months after the bridge connection, and a clinical examination including assessments of plaque and soft tissue inflammation was performed. The animals were sacrificed with an overdose of Sodium Pentothal™ (Abbot Scandinavia AB, Sweden) and perfused with a fixative through the carotid arteries. The fixative consisted of a mixture of 5% glutaraldehyde and 4% formaldehyde buffered to pH 7.2.[16] The mandibles were removed and placed in the fixative. Each implant region was dissected using a diamond saw (Exakt®, Kulzer, Germany) and further processed for ground sectioning. The tissue blocks were dehydrated in serial steps of alcohol concentrations and subsequently embedded in a methylmethacrylate resin (Technovit® 7200 VLC, Exakt; Kulzer). Using a cutting-grinding unit and a micro-grinding system (EXAKT®; Apparatebau, Norderstedt, Germany), the blocks were cut in a mesio-distal plane and two central sections were obtained. From the buccal part of the tissue block (containing 40 to 45% of the implant and the surrounding tissues), two central sections in a buccal-lingual plane were prepared. All sections were reduced to a final thickness of approximately 20 µm. Thus, from each implant block two mesio-distal and two buccal-lingual ground sections were obtained. The sections were stained in toluidine blue.[17]

Histological Analysis

The histometric and morphometric measurements were performed in a Leica DM-RBE microscope (Leica) equipped with an image system Q-500 MC (Leica). The following landmarks were used for the linear measurements (Figure 4): the marginal position of the peri-implant mucosa (PM), the apical termination of the barrier (junctional) epithelium (aJE), the marginal level of bone to implant contact (B), and the level of the abutment/fixture border (A/F). The distances between the various landmarks were determined.

The bone-implant contact (BIC%) measurements, that is, the length fraction (%) of mineralized bone that was in direct contact with the implant surface, were performed at a magnification × 100. The analysis was confined to the neck portion of both implants types, that is, the non-threaded part of the control implants and the corresponding dimension of the "microthreaded" part of the test implants (area I). A second area for BIC% assessments (area II) included the entire intraosseous portion of the implant.

The bone density (proportion of mineralized bone) analysis was carried out at a magnification × 200. A point-counting procedure was used to distinguish between mineralized and non-mineralized bone structures. A lattice comprising 100 light points was superimposed over the area to be examined and the various structures were identified using a mouse cursor. The bone density assessments were restricted to a 400-µm-wide zone lateral to the implant within area I.

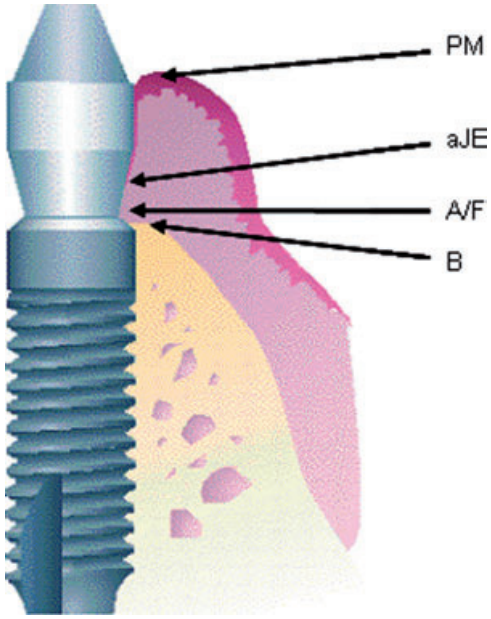

Figure 4 Schematic drawing illustrating the landmarks used for the histometric measurements. A/F = border between the abutment and the fixture part of the implant; aJE = level of the apical termination of the junctional epithelium; B = marginal level of mineralized bone in contact with the implant; PM = marginal portion of the peri-implant mucosa.

Statistical Analysis

Mean values were calculated for each variable and type of implant. Differences between the implant types were analyzed for each variable using the *t*-test for paired comparisons ($n = 6$). p values < .05 were considered as significant.

RESULTS

Clinical Observations

The healing following implant placement and subsequent abutment connection was uneventful at all implant sites but one. A minor abscess formation that resulted in a circumferential 3-mm-deep angular bony defect occurred in one of the control sites after fixture placement. This site was subsequently excluded from the radiographic and histological analysis. The PM at all remaining sites was found to be clinically healthy from the time of abutment connection and throughout the study period. No technical problems related to the tooth- or the implant-supported FPDs were observed during the 10-month period of functional load.

Radiographic Measurements

The results from the radiographic measurements are presented in Table 1. Marginal bone loss occurred during the 3-month healing period between implant installation and abutment connection (phase I) and amounted to 0.17 ± 0.25 mm at control implants, while at test implants the mean bone level change was 0.0 ± 0.16 mm. Between abutment connection and bridge connection (phase 2; 3 months), a gain of marginal bone support was detected at control implants (0.12 ± 0.27 mm), while the alteration in bone level at the test implant was negligible (0.01 ± 0.21 mm) during the same period. During the course of the 10-month functional load (phase 3), small amounts of marginal bone loss occurred at control implants (0.14 ± 0.31 mm), while a minute gain (0.06 ± 0.11 mm) was observed at test implants. The overall mean changes in marginal bone level throughout the entire study period tended to be larger at control implants than at test implants (–0.19 ± 0.32 vs +0.05 ± 0.06 mm, not significant).

TABLE 1 Results from the Radiographic Measurements

Phase	Control	Test
1	–0.17 (0.25)	0.00 (0.16)
2	0.12 (0.27)	–0.01 (0.21)
3	–0.14 (0.31)	+0.06 (0.11)
Total	–0.19 (0.32)	+0.05 (0.06)

Bone level alterations (in millimeters) during three phases. Phase 1 (3 months): fixture installation–abutment connection; phase 2 (3 months): abutment connection–bridge connection; phase 3 (10 months): bridge connection–biopsy.
Mean values and standard deviation.

TABLE 2 Histometric Analysis of Linear Measurements (in Millimeters) for Control and Test Implants

mm	Control		Test
PM–B	3.45 (0.63)	*	3.09 (0.53)
PM–aJE	2.08 (0.33)		1.91 (0.44)
A/F–B	0.48 (0.29)		0.20 (0.04)

*$p < .05$.
Landmarks used for measurements are described in Figure 4.
Mean values and standard deviation.
A/F = abutment/fixture junction; aJE = apical termination of the barrier (junctional) epithelium; B = marginal level of bone-implant contact; PM = marginal position of the peri-implant mucosa.

Histologic Observations

Soft Tissue Analysis. The results from the histometric measurements are presented in Table 2. The height of the PM (PM–B) was 3.45 mm at control and 3.09 mm at test sites. This difference was statistically significant. The barrier epithelium (PM-aJE) was 2.08- and 1.91-mm long and the B was located 0.48 and 0.20 mm "apical" of the A/F at the control and test implants, respectively.

Bone Tissue Analysis. Mesio-distal ground sections of control and test units are illustrated in Figures 5 and 6. The results from the bone tissue assessments are presented in Table 3. The degree of BIC% in area I (the marginal part) was significantly higher at test than at control sites (81.8 vs 72.8%). The BIC% in area II (the entire intraosseous portion) was similar for the two implant types, that is, 84.0% (control) and 83.0% (test). The bone density (area percentage of mineralized bone) in control and test sites varied between 80.2 and 78.0%.

DISCUSSION

In this animal experiment, the bone tissue formed at implants with a microthread design was analyzed. The radiographic examination revealed that the marginal bone level was well preserved at both test and control

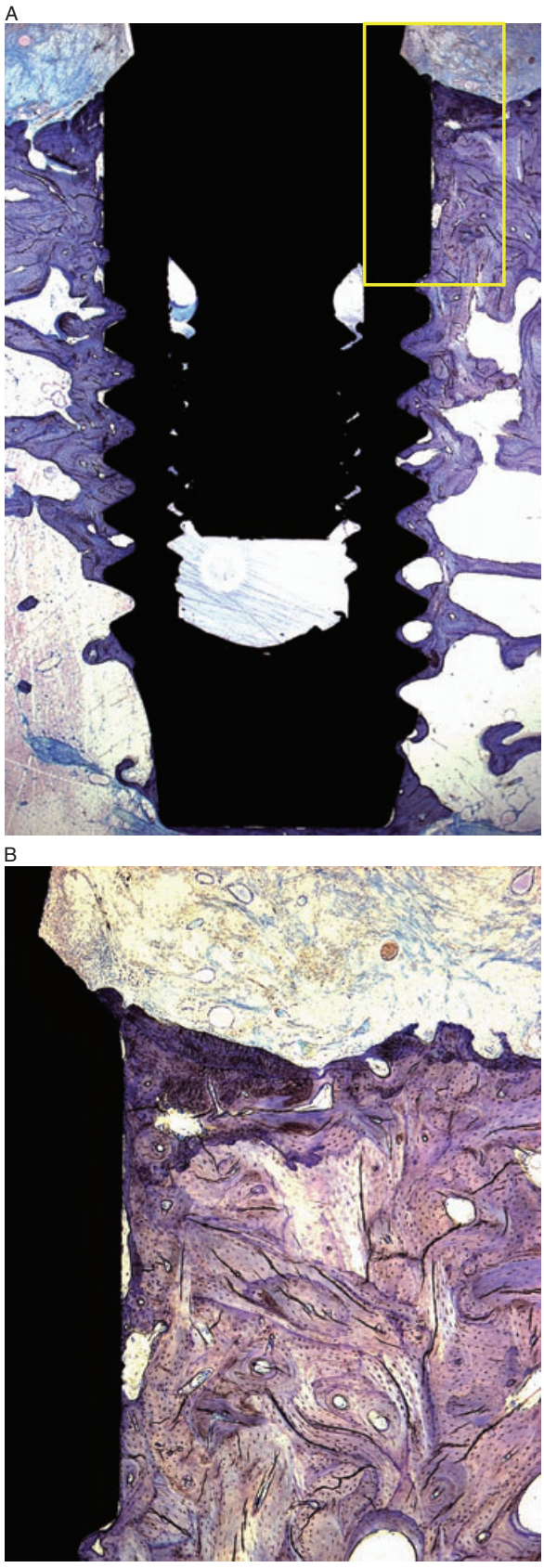

Figure 5 Mesio-distal cross sections of a control implant: (A) overview (original magnification × 16); (B) larger magnification of the marginal portion. Note the preserved marginal bone level and the degree of osseointegration.

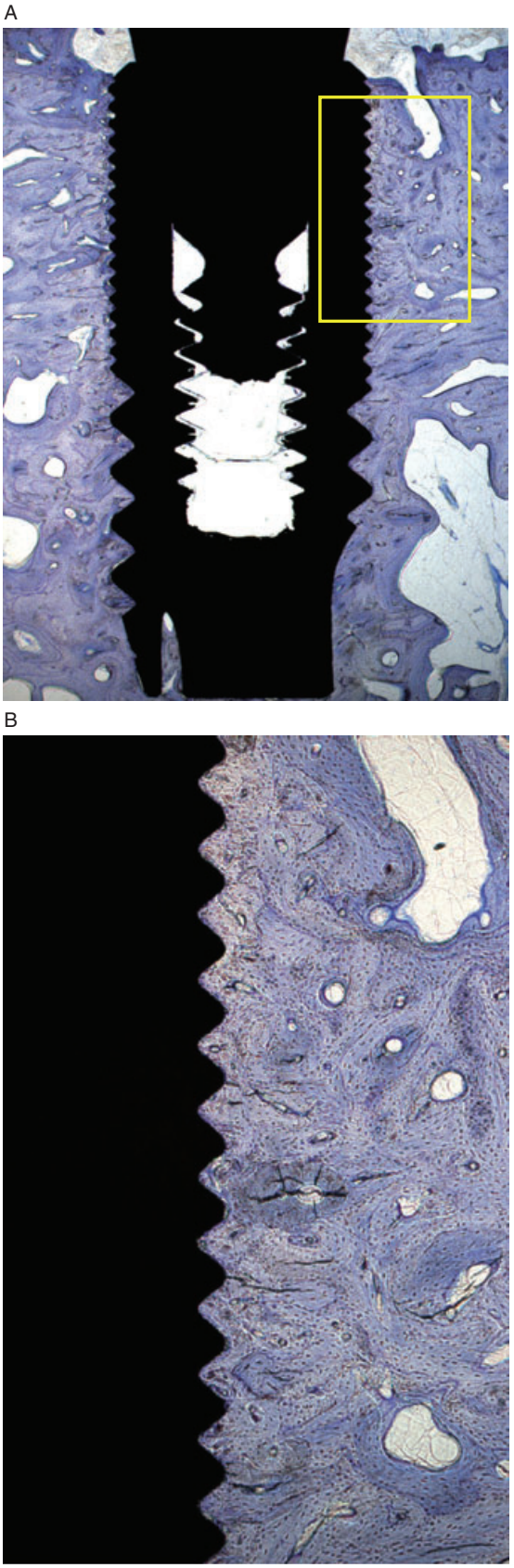

Figure 6 Mesio-distal cross sections of a test implant: (A) overview (original magnification × 16); (B) larger magnification of the marginal portion. Note the preserved marginal bone level and the high degree of osseointegration.

TABLE 3 Bone Tissue Analysis

%	Control		Test
BIC% (area I)	72.77 (9.30)	*	81.76 (7.77)
BIC% (area II)	83.95 (6.21)		82.96 (2.73)
Bone density (area I)	80.22 (3.97)		77.95 (7.40)

*$p < .05$.
Area I: the non-threaded part of the control implants and the corresponding dimension of the "microthreaded" part of the test implants; area II: the intraosseous portion of the implant.
Mean values and standard deviation.
BIC% = bone-implant contact measurement.

implants during the entire 16-month experimental period. The degree of mineralized bone in contact with the implant surface (BIC%) within the marginal portion of the implants was significantly higher at the test (microthreaded) implants (81.8%) than at the control implants (72.8%).

The finding in the present experiment that the marginal bone level at the implants with a microthread design remained stable during initial healing and during a 10-month period of functional load is consistent with observations reported in clinical studies. Karlsson and colleagues[18] in a 2-year follow up on 47 implants with a microthread design (Astra Tech ST) reported that the marginal bone loss amounted to 0.31 mm. Similar findings were presented by Norton[19] who followed 33 Astra Tech ST implants for 6 months to 4 years. Puchades-Roman and colleagues[20] in a 2-year retrospective study compared 15 Astra Tech ST and 15 Brånemark implants. It was reported that the marginal bone level at the Astra implants was consistently located closer to the A/F than at the Brånemark implants. Data from prospective studies of 5-year duration have also confirmed the marginal bone preservation at implants with a microthread design. Palmer and colleagues[12] evaluated 15 patients treated with Astra Tech ST implants in the anterior maxilla. It was reported that the radiographic bone level after 5 years was about 0.35 mm apical of the implant margin. In a recent 5-year prospective study on Astra Tech ST implants, Wennström and colleagues[13] analyzed 45 ST implants placed in 40 patients. The authors reported that the mean bone level change over the 5-year interval was –0.11 mm and that about 50% of the implants demonstrated no bone loss.

Histological evaluations of implants with a microthread configuration were performed by Rasmusson and colleagues.[21] They placed four microthreaded Astra Tech implants and two Brånemark implants in the mandible of each of six greyhound dogs. While buccal defects were produced at the implant sites in one side of the mandible in conjunction with the implant installation, the implant sites in the contra-lateral side were prepared under standardized conditions. Biopsies were obtained after 4 months and histometric measurements regarding the marginal bone level were presented only for the defect sites. A significantly higher bone level was observed at both types of microthreaded Astra implants than at the Brånemark implant, and it was suggested that the microthread design may contribute to the preservation of marginal bone. This finding is to some extent consistent with observations made in the present experiment. The histometric mesurements revealed that the distance between the A/F and the marginal bone level was twice as long at the control implant than at the test (microthread) implant. In this context, it should be realized that both test and control implants in the current study had a TiOblast surface, while the comparison made in the study by Rasmusson and colleagues[21] also included differences in surface roughness between the implants (TiOblast vs machined).

The histological assessments in the current study revealed that the marginal position of BIC% was identified at a distance of 0.20 and 0.48 mm apical of the fixture margin at the test and control implants, respectively. The results from the control implants are in agreement with data reported in a previous animal experiment.[15] Astra Tech implants with a TiOblast surface but without a microthread design were placed using either submerged or non-submerged installation techniques in beagle dogs. The marginal bone level assessed in histological ground sections following 6 months of healing was located at a distance of 0.68 and 0.85 mm apical of the fixture margin. While the implants in the study by Abrahamsson and colleagues[15] were not exposed to occlusal load during the experiment, the test and control implants in the present experiment were subjected to functional load during a period of 10 months. The current functional load model apparently did not result in negative consequences regarding the bone level neither at test nor control implants.

The experimental model used in the present study was recently described[14] and the primary intention was to examine the bone reactions to long-standing functional load at implants of two different systems (Astra Tech and Brånemark system). Berglundh and col-

leagues[14] reported that the largest amount of bone loss occurred following implant installation and abutment connection and that this loss was more pronounced at Brånemark than at Astra implants. Further, the bone level alterations that were observed at implants exposed to 10 months of functional load in both implant systems were small and did not differ from "unloaded" sites. The histological analysis revealed that implants exposed to functional load exhibited a higher degree of BIC% than unloaded implants in both implant systems. The finding that implants exposed to functional load revealed an enhanced degree of BIC% is interesting with regard to the comparison made in the present study. Both implant types were exposed to functional load and the compared areas of the test and control implants differed only with respect to the presence (test) or absence (control) of microthreads. Considering that the degree of BIC% was significantly higher at the test than the control implants, it may be suggested that the microthread configuration offered improved conditions for osseointegration.

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