Bone and Soft Tissue Integration to Titanium Implants with Different Surface Topography: An Experimental Study in the Dog

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The aim of the present experiment was to study the peri-implant soft and hard tissues formed at titanium implants with 2 different surface configurations and to give a topographic description of the surfaces examined. In 5 beagle dogs, the mandibular premolars were extracted. Three months later, 4 self-tapping standard implants (SI) and 4 Osseotite implants (OI) of the 3i Implant System were placed. The marginal 3 mm of the OI is turned, while the remaining part has an acid-etched surface structure. Abutments were connected after 3 months. A plaque control period was initiated, and after 6 months block biopsies were obtained. From each animal 2 units of each implant type were processed and embedded in EPON. The remaining biopsies were processed for ground sectioning. The histometric measurements performed on the EPON sections revealed that the peri-implant soft tissues and the marginal level of bone-to-implant contact were similar for SI and OI sites. In the ground sections, bone-to-implant contact (BIC%) and bone density assessments were made in 2 different zones. Zone I represented the contact area measured from the marginal level of bone-to-implant contact (B) to a position 4 mm above the apex of the implant, and zone II represented the apical 4 mm of the implant. For the SI sites, the BIC% was 56.1% in zone II and 58.1% in zones I + II. The corresponding figures for the OI sites were 76.7% and 72.0%. The BIC% was significantly larger at OI than at SI sites. Bone density values were similar at the SI and OI sites. (INT J ORAL MAXILLOFAC IMPLANTS 2001;16:323–332)

Key words: *acid etching, bone density, histometry, osseointegration, surface topography, titanium implants*

Clinical studies have documented that the rehabilitation of completely and partially edentulous patients with endosseous dental implants made of commercially pure titanium (cpTi) is a safe and predictable procedure. A good long-term prognosis of implant therapy is related to sustained osseointegration and a proper mucosal/implant barrier protecting the bone tissue from factors released from the oral environment.[1–4] Findings from prospective and retrospective studies have documented that the survival data of implants placed in the posterior maxilla are inferior to those characterizing implants placed in the anterior mandible,[5,6] where the bone quality is frequently high. The demand for improved implant survival at sites with poor bone quality and/or quantity[7] prompted the search for surface characteristics of an implant that would enhance bone-to-implant contact.

Thomas and Cook[8] studied 12 different implant-related factors that could potentially influence osseointegration. The authors concluded that the surface texture of the implant was the only feature that significantly affected parameters such as the amount of bone-to-implant contact and the interface shear strength. The observations by Thomas and

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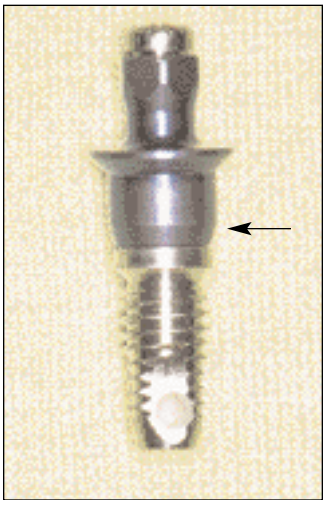


Fig 1 Photograph of a standard implant (SI) and implant mount *(blue).* The arrow indicates the reference mark for placement depth.

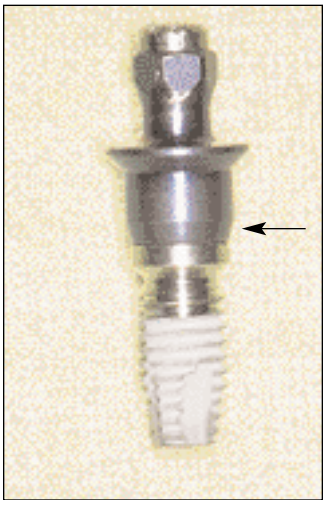


Fig 2 Photograph of an Osseotite implant (OI) and implant mount *(blue).* The arrow indicates the reference mark for placement depth.

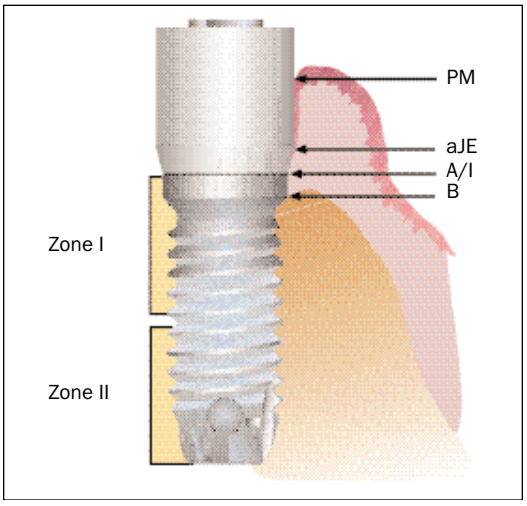


Fig 3 Schematic drawing illustrating the landmarks used for the histometric measurements. PM = marginal portion of the peri-implant mucosa; aJE = level of the apical termination of the junctional epithelium; B = marginal level of bone-to-implant contact; A/I = abutment/implant junction. Zone I represents the contact area measured from B to a level 4 mm above the apex of the implant, and zone II represents the apical 4 mm of the implant.

Cook[8] were subsequently confirmed in experiments that indicated that a certain degree of surface roughness favored osseointegration, as evaluated by removal torque tests.[9–14] It was proposed that the altered surface texture increased the retention between the implant and the host bone by enlarging the contact surface, increasing biomechanical interlocking between the implant and the bone, and enhancing the metabolic activity of osteoblasts, thereby leading to earlier formation of lamellar bone.

The aim of the present experiment was to study the peri-implant soft and hard tissues formed at titanium implants with 2 different surface configurations and to give a topographic description of the surfaces examined.

MATERIALS AND METHODS

Five beagle dogs, each approximately 1 year old, were included in the present study. The protocol of the present study was approved by the regional Ethics Committee for Animal Research, Göteborg, Sweden. The mandibular premolars (1P1, 2P2, 3P3, and 4P4) and the first, second, and third maxillary premolars were extracted. Three months later, buccal and lingual full-thickness flaps were raised, and 8 titanium implants of the 3i Implant System (Implant Innovations Inc, West Palm Beach, FL) were placed in the mandibular premolar regions of each dog. Two types of implants with different surface characteristics were used: the self-tapping standard implant (SI) (Fig 1) and the Osseotite implant (OI) (Fig 2). Both implants were made of cpTi and had similar dimensions (3.75×8.5 mm). The marginal 3 mm of the OI has a turned surface, while the surface of the remaining part is dual–acid-etched. Two implants of each type were placed in a randomized order in each mandibular premolar region. The 40 implants were inserted to a depth indicated by a reference mark on the implant mount (Figs 1 and 2), ie, to a position in which the rim of the hexagonal part of the implant was about 0.5 mm below the bone crest. The implants were provided with cover screws. The flaps were resutured and radiographs of the implant sites were obtained using a modified Eggen technique.[15] In the radiographs, the distance between the most coronal part of the implant (A/I) (Fig 3) and the most coronal bone judged to be in contact with the implant surface (B) was determined at the mesial and distal aspect of each implant. The measurements were carried out using a Leica DM-RBE microscope (Leica, Mannheim, Germany) equipped with an image system (Q-500 MC, Leica).

Three months subsequent to implant placement, abutment connection was performed and a new set of radiographs was obtained. The abutments were tightened using a torque controller (DEA 020) connected to a drill controller (DEA 032) of the Brånemark System (Nobel Biocare AB, Göteborg, Sweden) set at 32 Ncm.

A plaque control program was initiated. This included cleaning of all teeth and exposed implant surfaces using a toothbrush and dentifrice and was repeated 3 times a week. After 6 months, a new set of radiographs was obtained and a clinical examination performed. This included the assessment of plaque and soft tissue inflammation.

The animals were sacrificed with an overdose of thiopental sodium and perfused by a fixative through the carotid arteries. The fixative consisted of a mixture of glutaraldehyde (5%) and formaldehyde (4%), 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, Wehrheim, Germany). From each animal, 4 implant units (2 SI and 2 OI) were processed using a modification of the fracture technique[17] as described by Berglundh and coworkers.[18] The remaining biopsies (n = 20) were processed for ground sectioning.[19,20]

EPON Sections

The biopsies selected for the fracture technique were placed in EDTA. Before the decalcification was completed, incisions were made at the mesial and distal aspects of the implants. Cuts penetrating the entire peri-implant tissue were made parallel to the long axis of the implants. Each specimen was divided into 1 buccal and 1 lingual unit. The units were further separated into 1 mesiobuccal, 1 distobuccal, 1 mesiolingual, and 1 distolingual portion. Decalcification was completed in EDTA and dehydration performed in serial steps of ethanol concentrations. Secondary fixation in osmium tetroxide was carried out, and finally, the units were embedded in EPON[21] (Fluka Chemie AG, Buchs, Switzerland). Sections were produced from each tissue unit with the microtome set at 3 µm. The sections were stained in periodic acid–Schiff and toluidine blue.[21] Five sections, selected to represent the peri-implant tissues of each of the 4 units, ie, a total of 20 sections from each implant unit, were used for the histologic examination.

Ground Sections

Implant sites selected for ground sectioning were dehydrated in serial steps of alcohol concentrations and subsequently embedded in methyl methacrylate resin (Technovit 7200 VLC, Exakt, Kulzer). With a cutting-grinding unit (Exakt Apparatebau, Norderstedt, Germany) and a micro-grinding system (Exakt Apparatebau), the blocks were cut and ground in a buccolingual plane until 2 central sections from each implant had been reduced to a final thickness of approximately 20 µm. The largest part of the tissue block (about 40% to 45% of the implant and the surrounding tissues) was subsequently rotated 90 degrees, and 3 sections of the mesial or distal aspect were prepared in a similar manner. Thus, from each implant block, 2 buccolingual and 3 mesial or distal ground sections were obtained. The sections were stained in toluidine blue.[22]

Topographic Surface Analysis

Three used SI and OI implants (retrieved from the biopsies exposed to the fracture technique) and 3 pristine SI and OI implants (from the package delivered by the manufacturer) were subjected to a surface roughness analysis. The retrieved implants were stored in an EDTA solution for about 5 months and then cleaned in an ultrasonic bath before exposure to surface analysis. No tissue remnants were visible on the implant surface when checked in a charge-coupled device camera immediately before measurement. Nine sites, including 3 thread tops, 3 thread valleys, and 3 flank areas, were examined on each implant. The measurements were made using a confocal laser profilometer (TopScan 3D, Heidelberg Instruments, Heidelberg, Germany). The instrument uses a helium-neon laser as an optical stylus with an approximate diameter of 1 µm. Each measurement covered an area of 245×245 µm and included 80 scans. The horizontal and vertical resolutions were 0.5 µm and 26 nm, respectively.

A Gaussian filter with a size of 50×50 µm was used to exclude form and waviness, as recommended for 3-dimensional measurements.[23] Three different parameters were used to numerically characterize surface roughness: one height-descriptive parameter (S_a), one spatial-descriptive parameter (S_{cx}), and one parameter that included information about height and spatial direction (S_{dr}). S_a equals the average height deviation measured from a mean plane and is expressed in µm; S_{cx} measures the average distance in µm between the individual irregularities crossing the mean plane; and S_{dr} gives the ratio of the developed surface area and the projected sampling area, expressed as a percentage.

Histologic Examination

The histologic examination was performed using a Leica DM-RBE microscope (Leica) equipped with the image system Q-500 MC (Leica).

Histometric Analysis. In the EPON sections, the following landmarks were identified and used for linear measurements (Fig 3): the marginal portion of the peri-implant mucosa (PM), the apical termination of the junctional epithelium (aJE), the marginal level of bone-to-implant contact (B), and the abutment/implant border (A/I). The distances between

Table 1 Bone Level Changes (in mm) Measured During Phase I, Phase II, and Overall

	Standard implants		Osseotite implants	
Phase	Mean	SD	Mean	SD
I (implant placement to abutment connection)	–0.96	0.29	–0.93	0.52
II (abutment connection to sacrifice)	–0.25	0.19	–0.24	0.17
Total	–1.21	0.35	–1.17	0.44

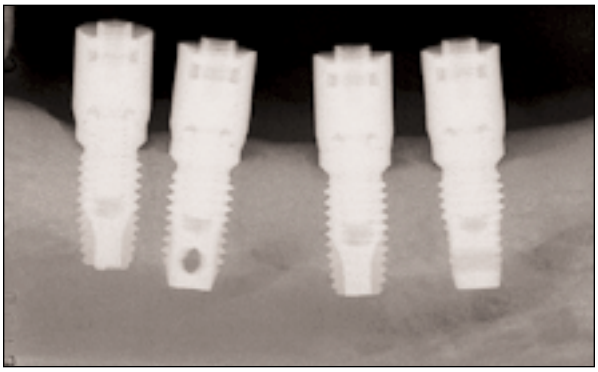


Fig 4 Radiograph from one of the test areas, obtained at the final examination. *Left to right:* OI, SI, OI, and SI implants.

the landmarks, assessed in a direction parallel to the long axis of the implants, were measured.

Bone Tissue Analysis. The ground sections were used for measurements describing bone-to-implant contact (BIC%) and bone density.

The analysis of bone-to-implant contact, ie, the length fraction (%) of mineralized bone that was in direct contact with the implant surface, was performed at magnification ×100. The assessments were made in 2 different zones. Zone I represented the contact area measured from B (Fig 3) to a level 4 mm above the apex of the implant, and zone II represented the apical 4 mm of the implant.

Bone density (proportion of mineralized bone) analysis was carried out at magnification ×200. A point-counting procedure was used to distinguish between mineralized and non-mineralized bone tissue. 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 tissue located between the threads of the implant and a 400-µm-wide zone lateral to the threads was included in the examination. The assessments were carried out within the threaded areas of zones I and II.

Statistical Analysis

Mean values were calculated for each variable and dog. Differences between the 2 implant types were analyzed using the Student *t* test for paired comparisons (n = 5). The null hypothesis was rejected at $P < .05$.

RESULTS

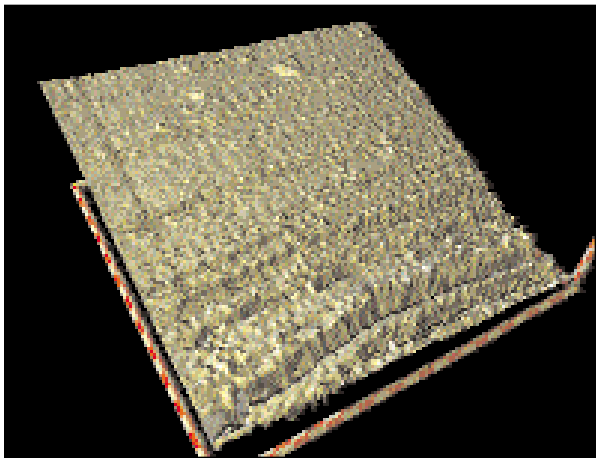
Healing following implant placement and subsequent abutment connection was uneventful in all dogs. The clinical examination performed at the end of the experiment revealed that all abutment surfaces were virtually free of visible plaque and that the peri-implant mucosa at all implant sites appeared to be healthy.

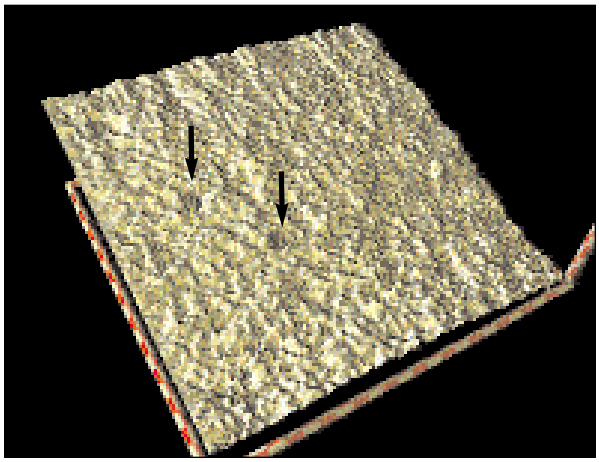
Radiographic Measurements

The radiographic measurements are presented in Table 1. The level of bone-to-implant contact (B) in the radiographs obtained at the time of implant placement coincided with the marginal rim of the implants, ie, in both SI and OI it was positioned at the abutment/implant border (A/I). Between Day 0 (implant placement) and 3 months (abutment connection) the mean radiographic bone level had decreased in both groups of implants. Hence, B was positioned 0.96 mm apical to A/I in the SI sites and 0.93 mm apical to A/I in the OI sites. At the end of the experiment (9 months), B was located 1.21 mm and 1.17 mm apical to A/I on the SI and OI sites, respectively (Fig 4).

Topographic Surface Analysis

Surface topography differed between the pristine SI and OI implants in terms of orientation, height, and spatial deviation. The turned SI surface (Fig 5a) exhibited anisotropic characteristics, ie, clearly oriented irregularities, while the OI surface was isotropic (Fig 5b), ie, devoid of any orientation of irregularities. The average height deviation (S_a) was 0.53 µm for the SI surface and 0.94 µm for the OI surface. Corresponding values for the S_{cx} parameter were 8.60 µm and 11.68 µm, respectively. The increase in surface area (S_{dr}) was 15.38% for the SI surface and 19.89% for the OI surface (Figs 6a to 6c). In broad terms, the surface roughness of the retrieved and the pristine implants was similar.





Figs 5a and 5b Topographic photos of flank areas of a standard implant *(left)* and an Osseotite implant *(right).* The arrows in Fig 5b indicate larger pits in the isotropic surface. Each red and white section of the bar represents 10 µm.

Figs 6a to 6c Histograms describing the results from the surface topography assessments of SI (standard implants) and OI (Osseotite implants), both pristine and retrieved.

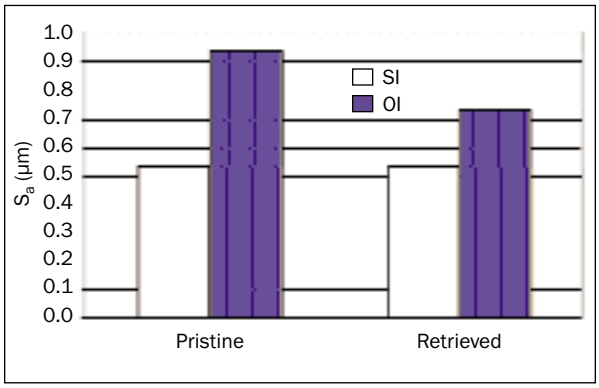


Fig 6a S_a values (in µm), representing the average height deviation measured from a mean plane.

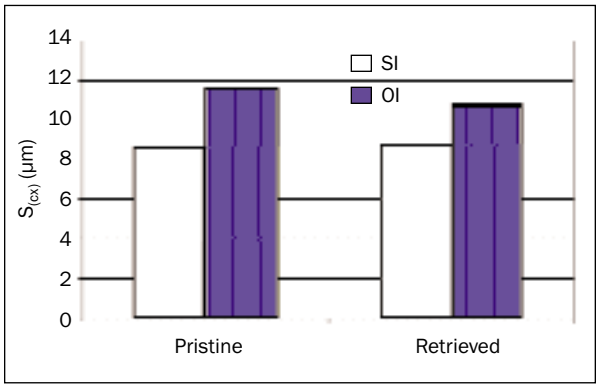


Fig 6b S_{cx} values (in µm), representing the average distance between the individual irregularities crossing the mean plane.

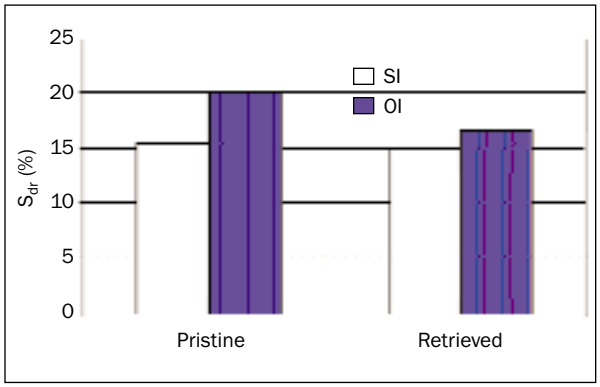


Fig 6c S_{dr} values, representing the ratio of the developed surface area to the projected sampling area (expressed in percentages).

Table 2 Histometric Measurements (in mm)

	Standard		Osseotite	
Measurement	Mean	SD	Mean	SD
PM-B	3.78	0.79	4.09	0.28
PM-aJE	2.14	0.70	2.57	0.54
aJE-B	1.64	0.57	1.52	0.37
A/I-B	1.22	0.49	1.08	0.37

Landmarks used for measurements are described in Fig 3.

Histologic Observations

Soft Tissue Analysis. The surface of the mucosa surrounding the implants demonstrated a well-keratinized oral epithelium that was continuous with a barrier epithelium facing the implant. The connective tissue lateral to the barrier epithelium contained large amounts of collagen, few vessels, and only scattered inflammatory cells. The portion of the peri-implant mucosa that was located between the junctional epithelium and the bone crest was dominated by collagen fibers, was poor in vascular structures, and contained few cells. A small, well-defined inflammatory infiltrate was frequently observed in the connective tissue immediately lateral to the abutment/implant junction.

The results of the histometric measurements (Fig 3) are described in Table 2. The height of the peri-implant mucosa (PM-B) varied between 3.78 mm and 4.09 mm for the SI and OI sites. The barrier epithelium (PM-aJE) at the SI sites was 2.14 mm long, while the corresponding dimension at the OI sites was 2.57 mm. The height of the connective tissue in contact with the implant surface (aJE-B) varied between 1.64 mm (SI) and 1.52 mm (OI). The marginal level of bone-to-implant contact (B) was located 1.22 mm and 1.08 mm apical of the abutment/implant junction (A/I) at the SI and OI implants, respectively. No statistically significant differences were found between the 2 implant types regarding the soft tissue dimensions examined.

Bone Tissue Analysis. The bone tissues adjacent to SI and OI implants are shown in Figs 7 and 8. In Table 3, the BIC% measurements for the entire implant (zones I + II) (Fig 3) are presented as mean values for the implants and separately for the buccolingual and the proximal surfaces. The BIC% value for the SI was 58.1% (buccolingual 57.5%; proximal 58.5%) and for OI 71.8% (buccolingual 71.6%; proximal 71.9%). The BIC% differences between the SI and the OI samples were statistically significant.

The results of the BIC% measurements for zone II (Fig 3) are reported in Table 3. The mean BIC% value was 56.1% for the SI samples (buccolingual 51.2%; proximal 61.0%) and 76.7% for the OI samples (buccolingual 76.4%; proximal 77.0%). The BIC% differences between the SI implants and the OI implants were statistically significant.

The density of the bone tissue located between the threads of the SI in zone I was 75.8% (buccolingual 80.9%; proximal 70.7%), while the corresponding value for the OI was 78.7% (buccolingual 78.6%; proximal 78.8%) (Table 4). The bone density in the 400-µm-wide zone lateral to the implant in zone I was 88.3% for the SI (buccolingual 92.1%; proximal 84.5%) and 88.2% for the OI (buccolingual 90.0%; proximal 86.4%) (Table 4).

In zone II, the SI implants had a bone density of 77.4% between threads (buccolingual 79.4%; proximal 73.4%), while the corresponding variable for the OI implants was 78.2% (buccolingual 74.9%; proximal 81.5%) (Table 5). The bone density in a 400-µm-wide area lateral to zone II varied between 87.6% for the SI (buccolingual 89.8%; proximal 85.4%) and 84.0% for the OI (buccolingual 83.9%; proximal 84.1%) (Table 5).

DISCUSSION

The present experiment in a dog model demonstrated that, after healing following implant placement, a higher degree of bone-to-implant contact (BIC%) was established to the dual–acid-etched surface of an Osseotite implant than to an implant with a turned surface. The varying surface topography, however, had no apparent influence on the height or density of the peri-implant bone outside the immediate contact zone.

The finding that a rough surface promoted the establishment of a higher degree of bone-to-implant contact than a turned surface corroborates results from previous experiments in animals[10,14,24–28] and from one study in humans.[29]

In an experiment utilizing miniature pigs, Buser and coworkers[24] compared the bone contact that was established after 3 and 6 weeks of healing at 6 different implant surfaces. The authors stated that the greatest extent of bone-implant contact occurred at implants with either a sandblasted and acid-etched surface (SLA, Straumann AG, Waldenburg, Switzerland) or a hydroxyapatite-coated surface. At implants with relatively smoother (eg, electropolished or sandblasted, medium-grit) or rougher (eg, TPS [titanium plasma-sprayed], Straumann AG, Waldenburg, Switzerland) surfaces, less direct bone contact was

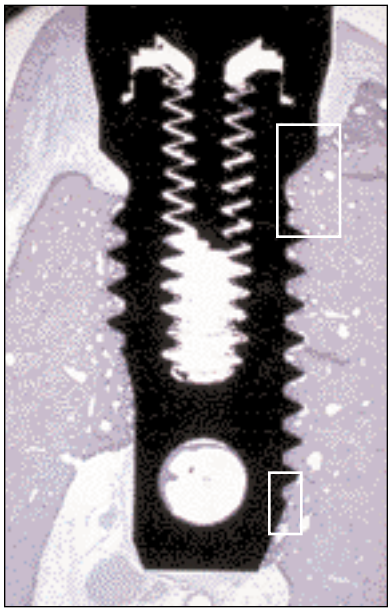


Fig 7a Mesiodistal ground section of one SI and the surrounding soft and hard peri-implant tissues. Rectangles indicate areas illustrated in Figs 7b and 7c (toluidine blue; original magnification ×16).

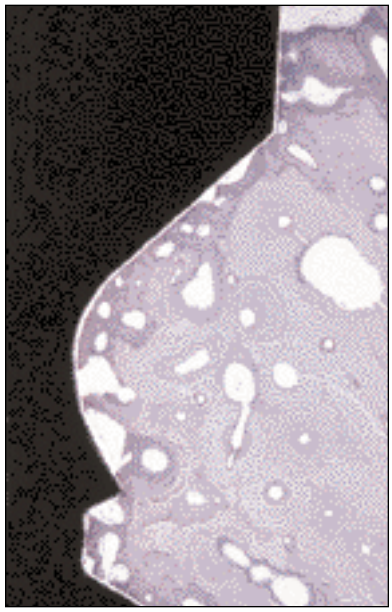


Fig 7b Detail from Fig 7a illustrating the bone-implant interface in the marginal part of zone I (original magnification ×100).

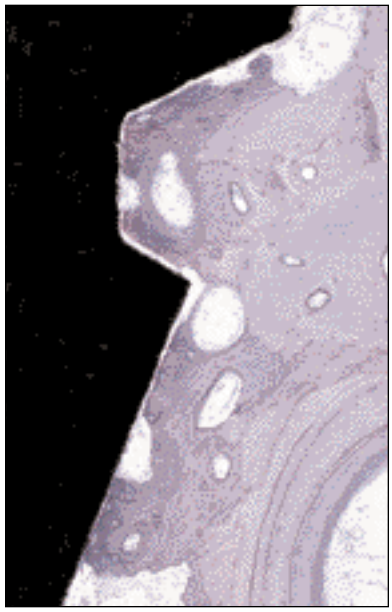


Fig 7c Detail from Fig 7a illustrating the bone-implant interface in zone II (original magnification ×200).

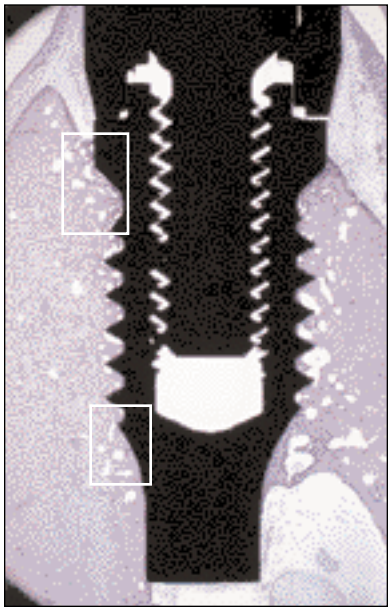


Fig 8a Mesiodistal ground section of an OI and the surrounding soft and hard peri-implant tissues. Rectangles indicate areas illustrated in Figs 8b and 8c (toluidine blue; original magnification ×16).

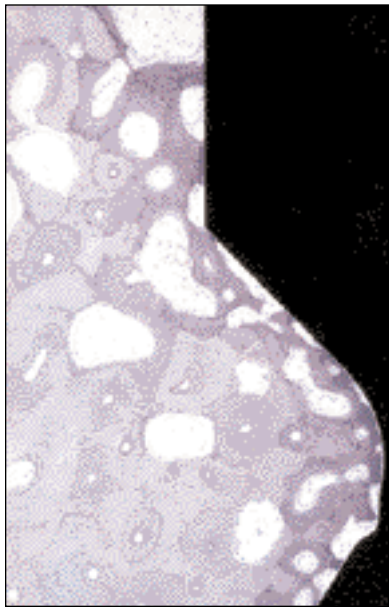


Fig 8b Detail from Fig 8a illustrating the bone-implant interface in the marginal part of zone I (original magnification ×100).

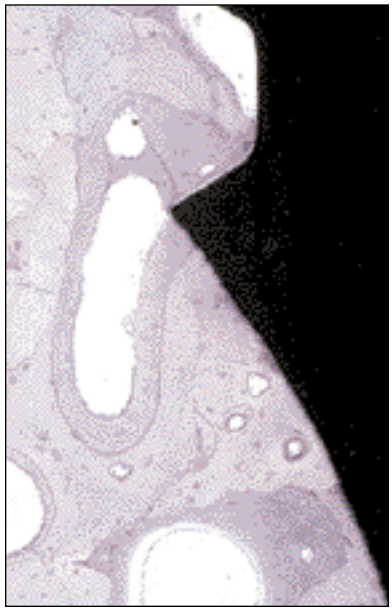


Fig 8c Detail from Fig 8a illustrating the bone-implant interface in zone II (original magnification ×200).

Table 3 Bone-to-Implant Contact (%)

	Zones I + II				Zone II			
	Standard		Osseotite		Standard		Osseotite	
Location	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Buccolingual surfaces	57.47	3.39	71.63*	4.89	51.24	4.09	76.39*	6.14
Proximal surfaces	58.51	8.30	71.92*	6.99	61.01	7.28	77.00*	5.47
All surfaces	58.05	3.51	71.79*	5.48	56.13	3.69	76.70*	4.88

*Indicates statistically significant difference ($P < .05$).

Table 4 Bone Density (%) in Zone I

	Between threads				Outside threads			
	Standard		Osseotite		Standard		Osseotite	
Location	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Buccolingual surfaces	80.93	3.98	78.57	5.64	92.13	2.51	89.95*	2.88
Proximal surfaces	70.68	7.08	78.81	4.44	84.48	5.06	86.35	4.06
All surfaces	75.80	4.40	78.69	4.64	88.31	3.30	88.15	2.76

*Indicates statistically significant difference ($P < .05$).

Table 5 Bone Density (%) in Zone II

	Between threads				Outside threads			
	Standard		Osseotite		Standard		Osseotite	
Location	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Buccolingual surfaces	79.39	5.40	74.88	7.40	89.77	5.46	83.89	6.72
Proximal surfaces	73.44	13.89	81.49	8.57	85.44	9.31	84.14	5.84
All surfaces	77.35	8.17	78.18	6.94	87.63	7.03	84.02	5.57

established during healing. In a study of beagle dogs, Ericsson and associates[25] claimed that increased bone-to-implant contact could be achieved at sites where the implant surface had been roughened by the use of a titanium oxide– (TiO_2) blasting procedure. In a series of experiments in the rabbit, Wennerberg and colleagues[14,26–28] studied bone healing at implants with different, well-defined surface characteristics. They reported that a titanium surface with an average height deviation (ie, S_a value) of about 1.4 µm allowed the formation of a higher degree of bone-to-implant contact than titanium surfaces with either smoother (S_a of 0.7 to 1.2 µm) or rougher (S_a of 2.2 µm) features.

Lazzara and coworkers[29] presented findings from a study in which experimental implants were placed in the posterior segments of the maxilla in 11 human volunteers. The titanium implants were designed with one mesial (or distal) surface that was turned, while the other side (distal or mesial) was dual–acid-etched (Osseotite). Biopsies of the implant sites were obtained after 6 months of submerged healing. Histologic examination revealed that the Osseotite surface had more than twice the amount of bone-to-implant contact than the turned surface (34% versus 73%).

Several experimental studies have been performed using removal torque testing to assess the quantity and the quality of implant osseointegration.[9,10,12–14,30] Gotfredsen and coworkers,[9] in a dog experiment, compared cpTi implants with a machined surface to similar implants that had been TiO_2-blasted. They reported that a positive correlation existed between the increased surface roughness and the removal torque values. However, no correlation seemed to exist between the roughness parameters and the amount of bone-to-implant contact. The authors concluded that, as a result of the surface irregularities, a higher removal torque was required for the rough implants because of *(1)* the interlocking between the surface and the ingrowing bone and *(2)* the increased surface area.

In a study performed in rabbits, Gotfredsen and associates[10] compared some characteristics of

osseointegration that occurred at turned and TiO_2-blasted implants. The authors found that the TiO_2-blasted implants received higher values on both removal torque testing and bone-to-implant contact assessment than the implants with a turned surface. Similar observations were also made recently in a study in rabbits.[30] The authors demonstrated that the removal torque values were higher at rough TiO_2-blasted and TPS implants versus implants with a turned surface. In a rabbit study, Wennerberg and colleagues[14] reported increasing torque removal values when S_a values of TiO_2-blasted implants increased up to about 1.4 µm. Similar findings were reported by Klokkevold and associates,[13] who compared acid-etched and turned implant surfaces in rabbit experiments. They reported that the acid-etched implants required torque removal forces that were about 4 times higher than those needed for implants with a turned surface.

In an experiment in the miniature pig, Buser and coworkers[12] compared the removal torque value for a sandblasted and acid-etched implant surface (SLA) with that of a dual–acid-etched implant surface (Osseotite). They concluded that the SLA implants required a higher removal torque than the Osseotite implants. The difference between the 2 implants may be explained by a difference in the degree of bone-to-implant contact (%) and/or by an increased mechanical interlocking to the somewhat rougher SLA surface.

The observation that the surface topography of an implant may influence peri-implant tissue healing is confirmed from findings made in in vitro experiments. Thus, Meyle[31] reported in a review article that the character of the protein film that is first deposited on the implant is influenced by surface properties such as wettability and texture. Furthermore, the composition of the protein film and the orientation of the molecules that are adsorbed on the implant surface may also be affected by the surface roughness. Meyle[31] also stated that a rough titanium surface delays the adhesion and spreading of epithelial cells, while the corresponding features of fibroblasts and osteoblasts are enhanced. Schwartz and colleagues[32] stated in a review paper that the surface topography of, eg, a titanium implant may affect the accumulation of cells and their production of cytokines and growth factors, which may in turn modulate and accelerate bone formation.

An important observation made in the present animal experiment was that the proportion of mineralized bone present between threads and outside the threaded region was nearly identical at SI and OI sites. This seems to indicate that the surface characteristics of the implant may influence bone tissue reactions during healing only in a narrow interface zone close to the titanium body.

In the current study, it was observed that the soft tissue dimensions (PM-B, PM-aJE) and the marginal level of the peri-implant bone (A/I-B) were similar at sites with standard and Osseotite implants and also similar to data previously reported from comparable animal experiments.[33–40] In this context it must be remembered that *(1)* the marginal portion (3 mm) of the Osseotite implant has a surface that is identical to that of the standard implant, and *(2)* a standard abutment with a turned surface was placed on both types of implants. In other words, in the marginal portion, the 2 types of implants were identical.

CONCLUSIONS

The vertical dimensions of the peri-implant soft tissues and the marginal bone level were similar in the 2 types of implants examined. The degree of bone-to-implant contact was significantly higher at Osseotite surfaces than at turned surfaces. The density of the peri-implant bone was similar in the 2 implant groups.

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