Bone Response to Submerged, Unloaded Implants Inserted in Poor Bone Sites: A Histological and Histomorphometrical Study of 8 Titanium Implants Retrieved From Man

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Key Words

Bone healing
Contact osteogenesis
Implant surfaces
Retrieved implants
Submerged implants

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An important parameter that influences the long-term success of oral implants is the bone quality of the implant bed. Posterior areas of the jaws have been avoided in implant dentistry because of their poor bone quality, higher chewing forces, and presumed higher implant failure rates. Several researchers have deemed soft bone implant sites to be a great potential risk situation, and most failures have been found in sites where the bone density was already low. The inferior success rates in the posterior maxilla have been attributed to a lower bone density and a lesser bone-implant interface. The aim of the present study was a histological and histomorphometrical analysis of the bone response to submerged implants inserted in posterior areas of the human jaws and retrieved, for different causes, after healing periods varying from 6 weeks to 12 months. Eight submerged implants that had been retrieved for different causes after different healing periods were evaluated in the present study. All implants were submerged and unloaded. Three implants had been removed for inadequate patient adaptation, 2 for inability of the implant to meet changed prosthetic needs, 1 for not optimal position from esthetic and hygiene aspects, and the last 2 for pain and dysesthesia. All the implants were retrieved with a 5-mm trephine bur. Newly formed peri-implant bone was found in all implants even after shorter healing periods. The bone-implant contact percentage varied from 30% to 96%. In conclusion, some surfaces have an improved characteristic of contact osteogenesis in soft bone, with coverage of the implant surface with a bone layer as a base for intensive bone formation and remodeling. We documented osseointegration of implants with a rough surface even after an insertion period of less than 2 months, both in the mandible and in the maxilla. From these results, we tentatively extrapolate that these implants might be carefully loaded after 2 months of healing, even when inserted in soft bone. A higher removal torque value might lead to a more predictable use of shorter implants, to a support of a prosthesis with fewer implants, or to shorter healing periods.

INTRODUCTION

An important parameter that influences the long-term success of oral implants is the bone quality of the implant bed.[1] Posterior areas of the jaws have been avoided in implant dentistry because of their poor bone quality, higher chewing forces, and presumed higher implant failure rates.[2] Several researchers have deemed soft bone implant sites to be a great potential risk situation, and most failures have been found in sites where the bone density was already low.[2] The inferior success rates in the posterior maxilla have been attributed to a lower bone density and a lesser bone-implant interface.[3] Glauser et al[4] reported a higher failure rate in implants inserted in the posterior maxilla and in implants inserted in bone quality types 3 and 4: 34% of the implants inserted in the posterior maxilla failed, compared with 9% of the other implants inserted in other portions of the jaws. A clinical recommendation for such areas was to allow for a longer healing period.[5] The type of osseointegration in cancellous bone is often not as satisfying as the very dense appearance of osseointegration in an area of cortical lamellar bone.[6]

Increasing the rate of early endosseous integration is a critical goal to achieve improved success rates.[3] Increasingly, the surface microtexture of the implants has been shown to be of relevant importance in the early stages of osseointegration.[3] Moreover, because 2-month loading of a dual acid-etched implant has been reported to be successful, it is certainly interesting to determine in retrieved human implants what percentage of bone-implant contact is present at 2 months and to consider this value as a minimum requirement for successful clinical outcomes.[7] Although the critical bone-implant contact percentage to guarantee implant success has not been defined,[8,9] it has been reported that about 50% bone-implant contact appears to be necessary for implant success.[7]

The sequence of events during the early phases of tissue integration has not been assessed,[9,10] and the time point at which the bone healing is sufficient to resist implant rotational torque is not completely understood.[11] The implant surface microstructure may also contribute significantly to primary implant stability,[1] and evidence of faster bone apposition to textured surfaces has been reported.[12]

Moreover, a significantly higher bone-implant contact rate in implants with rougher surfaces in areas of low bone quality compared with machined surfaces has been reported in dogs.[5] A threshold anchorage seems to be important to obtain the clinical advantages reported for rougher surfaces.[13] When the implant is sandblasted before etching, a macroroughness of 10 to 20 μm is superimposed on top of the 0.5 to 3 μm produced by the etching process.[14] According to Szmukler-Moncler et al,[14] it is the etching and not the sandblasting that provides the important surface modification.

The aim of the present study was a histological and histomorphometrical analysis of the bone response to submerged implants inserted in posterior areas of the human jaws and retrieved, for different causes, after healing periods varying from 6 weeks to 12 months.

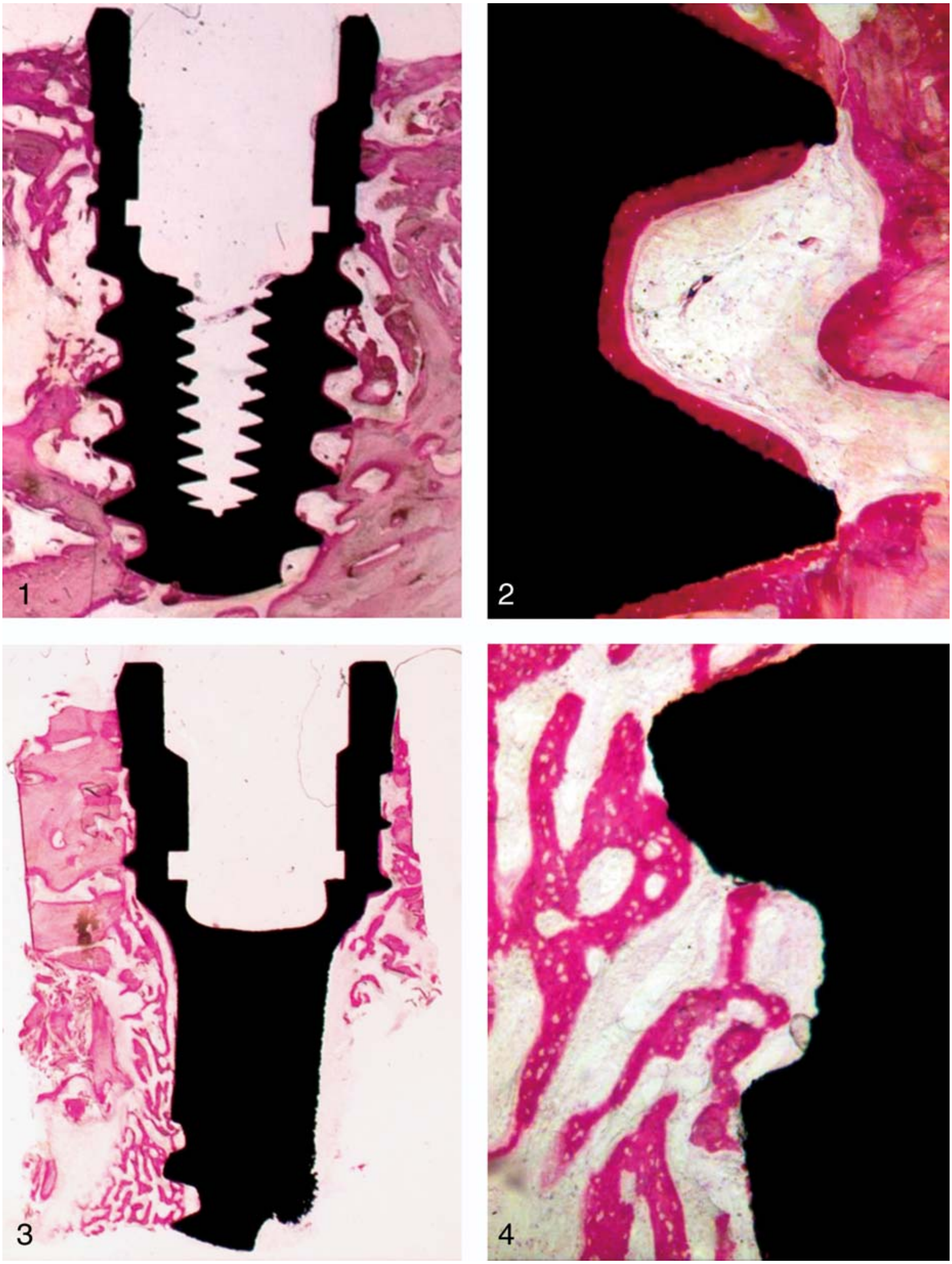
MATERIALS AND METHODS

In 5 years' worth (1999–2004) of records from the Implant Retrieval Center of the University of Chieti-Pescara, we found 8 submerged implants that had been retrieved for different causes after different healing periods. All implants were submerged and unloaded. Three implants had been removed for inadequate patient adaptation, 2 for inability of the implant to meet changed prosthetic needs, 1 for not optimal position from esthetic and hygiene aspects, and the last 2 for pain and dysesthesia. All the implants were retrieved with a 5-mm trephine bur and immersed in 10% buffered formalin to be processed for histology.

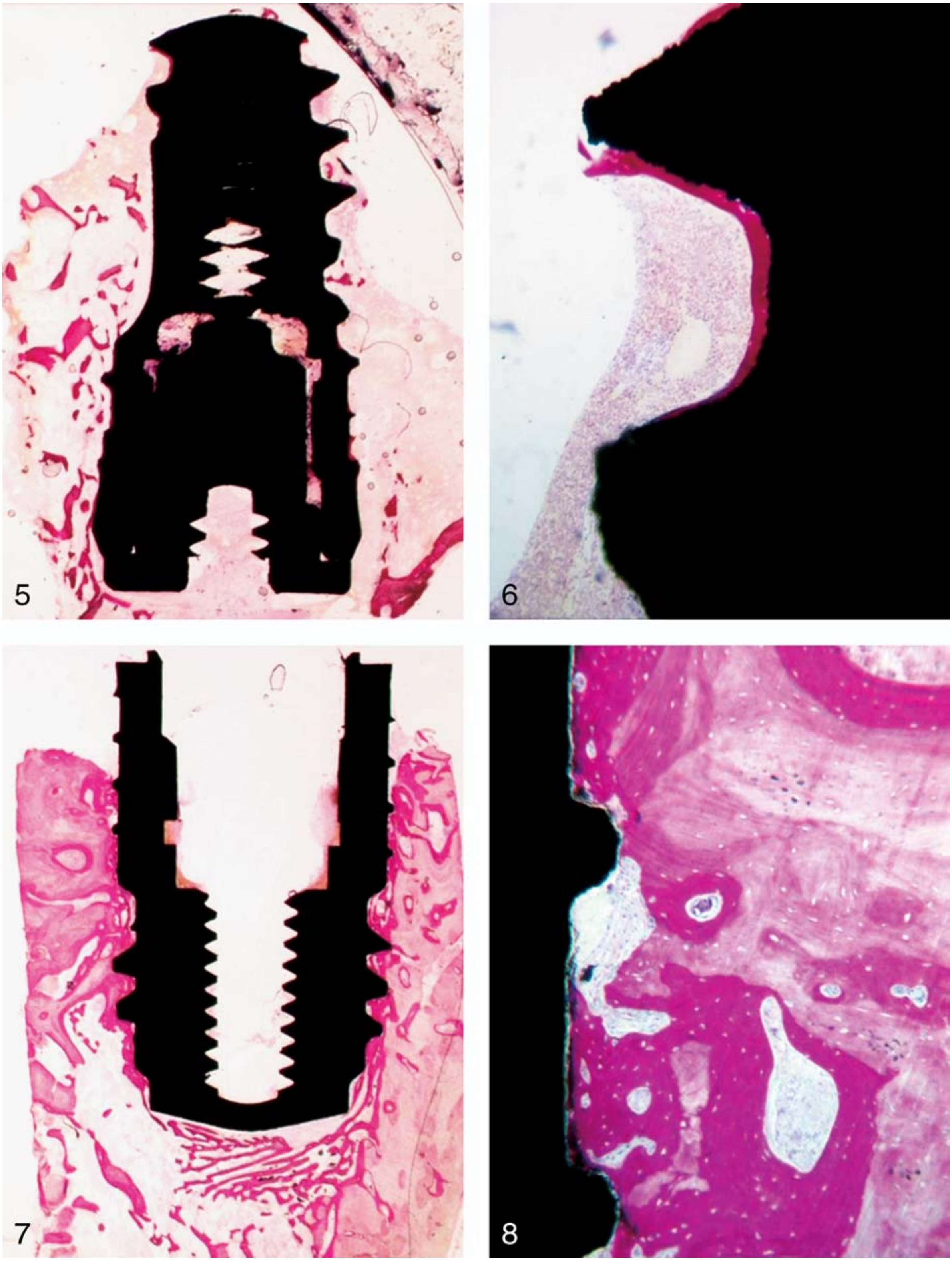
Processing of specimens

The implants and the surrounding tissues were stored immediately in 10% buffered formalin and processed to obtain thin ground sections with the Precise 1 Automated System (Assing, Rome, Italy).[15] The specimens were dehydrated in an ascending series of alcohol rinses and embedded in a glycolmethacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned longitudinally along the major axis of the implant with a high-precision diamond disc at about 150 μm and ground down to about 30 μm. Three slides were obtained for each implant. The slides were stained with basic fuchsin and toluidine blue. A double staining with von Kossa and acid fuchsin was done to evaluate the degree of bone mineralization. After polishing, 1 slide was immersed in AgNO3 for 30 minutes and exposed to sunlight. The slides were then washed under tap water, dried, immersed in basic fuchsin for 5 minutes, and washed and mounted.

Histomorphometry of bone-implant contact percentage was carried out with a light microscope (Laborlux S, Leitz, Wetzlar, Germany) connected to a high-resolution video camera (3CCD, JVC KY-F55B; JVC, Yokohama,



FIGURES 1–4. FIGURE 1. Lamellar bone with small osteocyte lacunae was present around and in contact with the implant surface (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 2. Newly formed trabecular bone, osteoblasts, and osteocytes near the implant surface (acid fuchsin and toluidine blue, original magnification ×50). FIGURE 3. Many newly formed bone trabeculae in the apical portion of the implant. Cortical mature bone was present around the coronal portion of the implant (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 4. Higher magnification of the coronal portion of the bone-implant interface. Cells were actively secreting osteoid matrix (acid fuchsin and toluidine blue, original magnification ×100).



FIGURES 5–8. FIGURE 5. A few bone trabeculae present around implant. No osteoblasts were observed (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 6. Higher magnification of the coronal portion of the bone-implant interface. A single bone trabecula in direct contact with the implant surface (acid fuchsin and toluidine blue, original magnification ×100). FIGURE 7. Mature bone with many haversian canals was present around the implant. The central core of each osteon was a canal containing nerves and blood vessels (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 8. Lamellar and woven bone were observed

Japan) and interfaced to a monitor and personal computer (Intel Pentium III 1200 MMX; Intel, Santa Clara, Calif). This optical system was associated with a digitizing pad (Matrix Vision GmbH; Matrix Vision, Oppenweiler, Germany) and a histometry software package with image-capturing capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc, Immagini & Computer Snc, Milano, Italy).

Implants were retrieved at varying times based on type and location of implant. XiVE Plus implants (DENTSPLY-Friadent, Mannheim, Germany) were retrieved from the posterior mandible after 6 and 7 weeks respectively, and from the posterior maxilla after 8 weeks. Frialit-2 Synchro implants (DENTSPLY-Friadent, Mannheim, Germany) were retrieved from the posterior mandible after 6 months. Restore resorbable blast material implants (Lifecore Biomedical, Chasta, Minn) were retrieved after 6 months from the posterior maxilla, and XiVE deep profile surface implants (DENTSPLY-Friadent, Mannheim, Germany) were retrieved from the posterior maxilla after 12 months.

Results

XiVE Plus implants retrieved after 6 weeks (posterior mandible)

The preexisting bone was type D3 to D4 with large marrow spaces. The mean thickness of the bone trabeculae around the implant perimeter was 150 to 200 µm. Osteoblasts were found around the bone trabeculae located on the implant surface (Figure 1). These osteoblasts were depositing osteoid matrix that was undergoing mineralization (Figure 2). Some osteocyte lacunae were delimited in part by bone and in part by the implant surface. The newly formed bone was in tight contact with the implant surface and adapted perfectly to the microirregularities of the implant surface. Bone was always found in the interthread concavities and was in direct contact with the implant surface. No infrabony pocket, active bone resorption, osteoclasts, or inflammatory cell infiltrate were present. No gaps or dense fibrous connective tissue were present at the bone-implant interface. No apical epithelial downgrowth was present. Bone-implant contact percentage was 96% ± 2.1%.

The newly formed bone had a higher staining affinity for dyes, and it was possible to see that the implant had only partial initial contact with the existing bone at placement. The evaluation under larger magnification (×20) showed newly formed bone all along the complete implant perimeter. The layers of newly formed bone appeared to have formed from the implant surface toward the original bone bed, and the solitary islands that were present on the implant surface.

XiVE Plus implants retrieved after 7 weeks (posterior mandible)

The preexisting bone was low quality (D3–D4). About 4 mm of coronal cortical bone was present (Figure 3). Only newly formed bone was present at the implant interface. Many newly formed bone trabeculae were present near and in contact with the bone surface (Figure 4). Many wide osteocyte lacunae were present in this newly formed bone. The bone-implant contact percentage was 55% ± 3%. The first bone-implant contact was present about 1 mm from the implant shoulder. No osteoclasts were present in the cortical bone. In some areas of the bone-metal interface, it was possible to observe that a portion of the osteocyte wall consisted of the surface of the implant.

XiVE Plus implants retrieved after 8 weeks (posterior maxilla)

At low magnification, the specimen showed a D4 bone quality with a very small amount of mineralized bone matrix in the area around the implant (Figure 5). Very high osteoconductivity was present. The mean thickness of the bone trabeculae on the implant surface was about 90 to 100 µm. In many cases, osteoblasts were producing osteoid matrix directly on the implant surface (this was the proof of the contact osteogenesis) (Figure 6). Bone-implant contact percentage was 68% ± 1.8%.

The overview showed only a very few number of direct bone bridges to the implant surface. However, the evaluation in larger magnification (×20) showed newly formed bone along the implant surface. Especially impressive were some solitary bone bridges found originating from the implant surface with an outward direction toward the marrow spaces.

Frialit-2 Synchro implants retrieved after 6 months (posterior mandible)

The implant was located between the 2 cortical bones. The preexis-

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in direct contact with the implant surface. No gaps or connective tissue were present at the bone-implant interface. The preexisting bone quality was type D4. No apical epithelial migration was found. No inflammatory infiltrate was present around the implant (acid fuchsin and toluidine blue, original magnification ×100).

ting bone was low quality (D4). In the coronal portion, between the preexisting cortical bone and the implant surface, it was possible to observe the presence of newly formed bone (Figure 7). This newly formed bone was strongly stained with acid fuchsin and showed a trabecular structure. In some fields it was possible to observe the presence of some osteoblasts (Figure 8). Some osteoclasts, located in their resorption lacunae, were present at the level of the crestal bone. The first bone-implant contact at the level of the crestal bone was located about 2 mm from the shoulder of the implant; in this area it was possible to find epithelial and connective tissue cells. In the apical portion of the implant, it was possible to observe woven bone with large osteocytic lacunae. Most of these bone trabeculae were in close contact with the implant surface. On the other hand, at the apex of the implant, many bone trabeculae were present but were not in contact with the implant surface. These bone trabeculae were mainly composed of woven bone and were arranged in a random way. No bone remodeling was present, and only a few osteoclasts and osteoblasts were present. Many large-diameter blood vessels were present between the bone trabeculae. In many fields, in close contact with the implant surface, many osteoblasts and osteocyte lacunae were present. In other fields small capillaries were found near or in contact with the surface. Resorption lacunae were absent at the apex of the threads. No differences were found in the quality of the bone located at the upper and lower halves of the threads. Only a few marrow spaces were present. The bone-implant contact percentage was 70% ± 5%.

Restore resorbable blast material implants retrieved after 6 months (posterior maxilla)

The quality of preexisting bone was D4. The first bone-implant contact was located about 1 mm from the implant shoulder; epithelial and connective tissues were present in this area. No bone remodeling was present (Figures 9 and 10). In some fields newly formed bone trabeculae were in contact with the implant surface. The bone-implant contact percentage was 35% ± 4%.

Restore resorbable blast material implants retrieved after 6 months (posterior maxilla)

The quality of the preexisting bone was D4. The first bone-implant contact was located about 1.5 mm from the implant shoulder. Woven bone without lamellar organization was present (Figure 11). Osteoid matrix was in contact with the implant surface only in a few areas. No gaps or inflammatory infiltrate were present at the interface. Many threads concavities (interthread space) were filled by newly formed bone. The bone-implant contact percentage was 66% ± 7%.

XiVE deep profile surface implants retrieved after 6 months (posterior mandible)

Preexisting bone was D3 to D4 quality with wide marrow spaces. An infrabony pocket of about 2 mm was present on 1 side of the implant with no osteoclasts (Figure 12); it was possible to observe the presence of bone remodeling on the other side. Newly formed bone was separated from preexisting bone by a cement line. Bone-implant contact percentage was 51% ± 6%. The bone in contact with the implant was mainly mature lamellar with small osteocytic lacunae. This bone was lined by newly formed bone, strongly stained by acid fuchsin, and had wide osteocytic lacunae. No gaps or fibrous tissue were present at the interface. No epithelial downgrowth was present.

XiVE deep profile surface implants retrieved after 12 months (posterior maxilla)

A small gap was present between the implant and the preexisting bone in the coronal portion. The first bone-implant contact was located about 4 mm from the implant shoulder (Figure 13). In many areas small bone trabeculae were present on the implant surface, and some osteoblasts were visible. Some bone trabeculae were present near or in contact with the implant surface. The bone-implant contact percentage was 30% ± 10%.

Discussion

Animal studies can be correlated only with extreme caution to the human clinical conditions.[16] Retrieved implants removed for reasons not influencing their anchorage, such as autopsy specimens and implants removed because of inadequate patient adaptation, are rare in the literature compared with implants retrieved for implant failures. A relevant question for the clinician is the histological response in poorer bone quality sites.[17] It also seemed relevant to evaluate the quality and quantity of the bone response at dental implants after shorter healing periods.[12]

We have already reported on the peri-implant bone response around immediately loaded implants.[18–21]

Even if the present results of these specimens are case studies and are nonhomogenous because they have been retrieved and sent by different clinicians, clinically important conclusions can be drawn because it was clearly demonstrated that new bone formation, following the principles of contact osteogenesis, was present around implants inserted in soft bone sites even after shorter healing periods. All the implants reported in the present study have a rough surface, even though surface roughness was obtained by different techniques and the roughness values were different: the restore resorbable blast material implant surface was obtained by a blasting technique with hydroxyapatite particles, the Frialit-2 Synchro and XiVE deep profile surfaces were obtained by a blasting technique with aluminum oxide particles followed by acid etching treatment, and the XiVE Plus implant surface was obtained by a grit treatment followed by an acid treatment at high temperature.[22–27] It would have been interesting to have evaluated an implant with a different surface characteristic (eg, machined), but this surface was not present in our specimens. The percentage of bone in areas such as the posterior maxilla has been determined to be very low (around 20%),[5] but in our speci-

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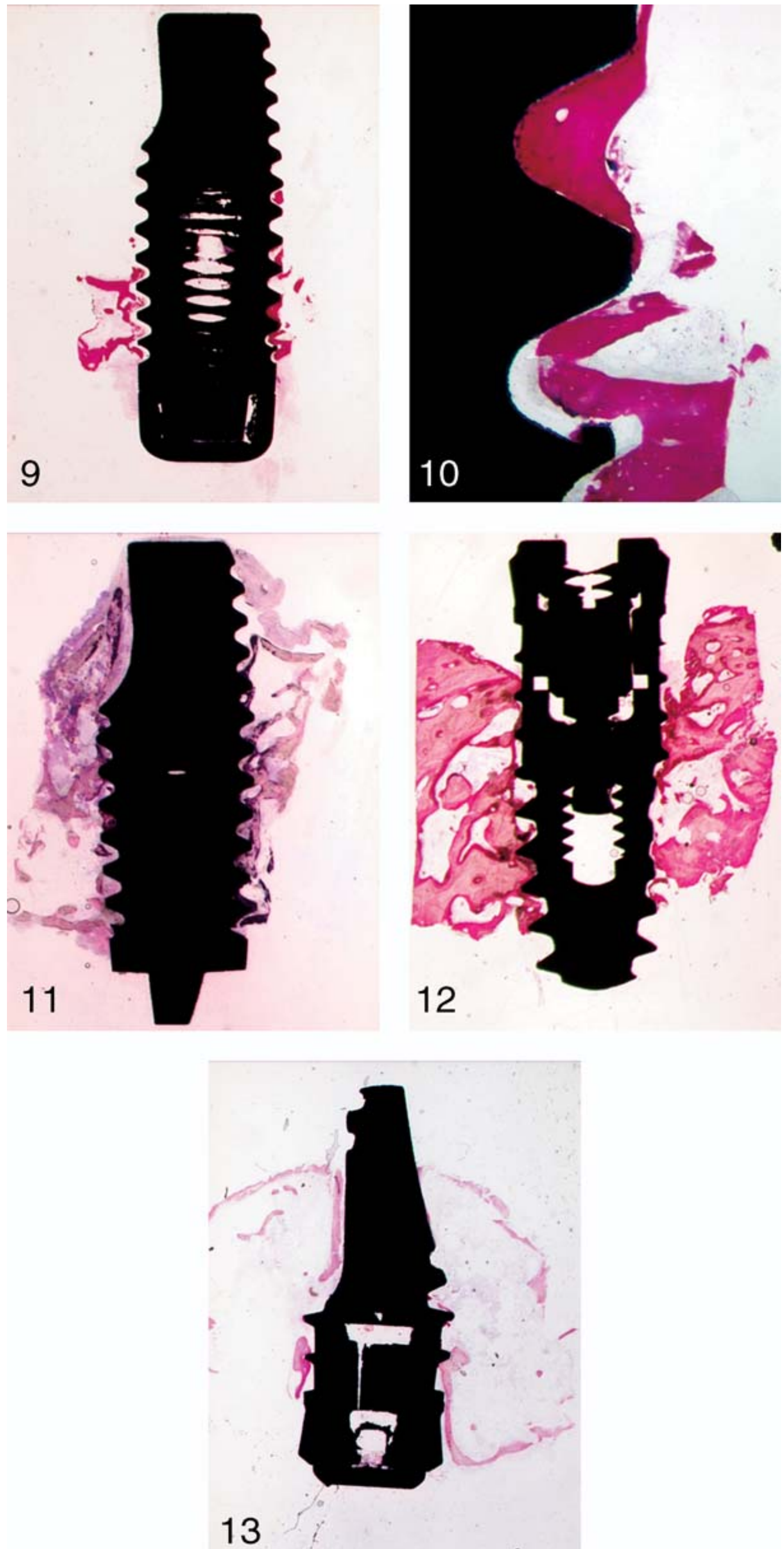

FIGURES 9–13. FIGURE 9. Few bone trabeculae were present around the implant (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 10. Mature bone was in close contact with the implant surface. Woven bone was also observed (acid fuchsin and toluidine blue, original magnification ×100). FIGURE 11. The implant was surrounded by lamellar and woven bone. The bone was in close contact with the implant surface (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 12. The first bone-implant contact was found at about 3 mm from the shoulder of the implant. The preexisting bone quality was type D4 (acid fuchsin and toluidine blue, original magnification ×12). FIGURE 13. Low-density bone around the apical portion of the implant. A large marrow space was present around the implant (acid fuchsin and toluidine blue, original magnification ×100).

TABLE

Retrieval times, sites, types of implants, and bone-implant contact (BIC) percentage of retrieved implants*

Retrieval Time	Site	Type of Implant	% BIC
6 wk	Mandible	XiVE Plus	96
7 wk	Mandible	XiVE Plus	55
8 wk	Maxilla	XiVE Plus	68
6 mo	Mandible	Frialit-2 Synchro	70
6 mo	Maxilla	Restore RBM	35
6 mo	Maxilla	Restore RBM	66
6 mo	Mandible	XiVE DPS	51
12 mo	Maxilla	XiVE DPS	30

*RBM indicates resorbable blast material; DPS, deep profile surface.

mens, even in D4 maxillary bone, a high percentage of bone-implant contact was found after a reduced healing period (8 weeks) (Table). Also, the results of an implant inserted in the posterior mandible after a healing period of 6 weeks with a nearly complete coverage of the implant perimeter (about 95%) were extremely satisfying.

The current literature shows bone-implant contact values of human-retrieved implants with early or immediate loading mainly after a 6-month healing period. An intraindividual study of machined and dual-etched implant surfaces in humans in the maxilla after a shorter healing period (8 weeks) in soft bone showed a bone-implant contact of about 50% for the rougher surface.[7]

Abrahamsson et al[10] found that the early formation of mineralized bone to devices with a sandblasted, large grit, acid-etched (SLA) surface may allow shorter healing times for functionally loading the implants.

Our histological findings in humans are supported by the results of the recently presented in vitro and animal studies utilizing the XiVE Plus implant surface.[24–26,28] This surface is produced with large grit and differentially acid etched in time- and temperature-controlled processes.[24] The XiVE Plus implant surface shows a regular microroughness with pores in the micrometer dimension overlaying a macroroughness structure caused by the grit blasting.[26] This results in a porous topography with an hierarchical surface structure.[24] The spatial parameters have shown a first macroscopic level of roughness in the dimensions of 100 μm, then a second level of grooves in the dimensions of about 12 to 75 μm, each of which embraces an arrangement of smaller round-shaped groups with diameter of about 1 to 5 μm.[24] In an animal study, Papalexiou et al[26] showed that the percentage of marked bone was statistically greater for the XiVE Plus implant surface in a period between 3 days and 8 weeks. Sandblasting may provide pockets of bony ingrowth that function as a series of miniretentive grooves or pits.[29]

In conclusion, some surfaces have an improved characteristic of contact osteogenesis in soft and dense bone, with coverage of the implant surface with a bone layer as a base for intensive bone formation and remodeling.[30–37] In a recent meta-analysis, Stach and Kohles[37] stated that Osseotite implants can be used in soft bone and that the implants' performance and duration of failure-free function was not compromised. Moreover, these authors stated that the potential for osseointegration provided by this surface may give an advantage to long-term implant success in poor bone sites as well. We documented osseointegration of implants with a rough surface even after an insertion period of less than 2 months, both in the mandible and in the maxilla. From these results we can extrapolate the fact that these implants might be carefully loaded after 2 months of healing, even when inserted in soft bone. A higher removal torque value of dental implants might lead to a more predictable use of short implants, to a support of a prosthesis with fewer implants, or to shorter healing periods.

ACKNOWLEDGMENTS

This work was partially supported by the National Research Council (CNR), Rome, Italy; by the Ministry of Education, University, Research (MIUR), Rome, Italy; and by AROD (Research Association for Dentistry and Dermatology), Chieti, Italy.

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