Periimplant Bone Response in Human-Retrieved, Clinically Stable, Successful, and Functioning Dental Implants After a Long-Term Loading Period: A Report of 17 Cases From 4 to 20 Years

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Objective: This study aimed at a histologic and histomorphometric analysis of the perimplant tissues and bone-titanium interface reactions in successfully osseointegrated, clinically stable, and immobile human titanium dental implants retrieved after a long loading period.

Materials and Methods: In the last 30 months (2013–2015), 21 implants, retrieved from individuals for different causes after a loading period ranging from 4 to 20 years, were sent to the Implant Retrieval Center, University of Chieti-Pescara, Italy. In 4 cases, almost all the bone had been lost during the retrieval, whereas in the remaining 17 cases, mineralized bone was still present.

Results: Around the majority of the implants, mature compact bone with few marrow spaces was found. The trabecular bone, constituted by a few thin bone trabeculae, was in a perimplant location around only a few implants. A high percentage of bone-implant contact (BIC) (compared between 32 ± 4.1% and 83 ± 2.9%) was present. In almost all implants, the space within the threads was almost completely filled by compact lamellar bone or by a thin layer of bone. Close and tight contact between bone and implant surface was observed in all specimens with no gaps or connective tissue at the interface.

Conclusions: All implants appeared to be well integrated in the surrounding mineralized bone, and all of them showed adequate bone-to-implant contact percentages. (Implant Dent 2016;25:380–386)

Key Words: bone-to-implant contact, histomorphometry, osseointegration, removed implants

Osseointegration has been reported to be a dynamic process, and the perimplant bone has to adapt to the functional loading of the implants and improve the system biomechanics.³³ A hypothesis is that the longer an implant is functionally loaded, the higher is the percentage of bone-implant contact.
Table 1. Feature Report of Each of 17 Retrieved Dental Implants Described in the Present Case Series

<table>
<thead>
<tr>
<th>Samples</th>
<th>Site</th>
<th>Type of Implant and Surface</th>
<th>Time of Implantation</th>
<th>Cause of Retrieval</th>
<th>Loading (y)</th>
<th>Bone-Implant Contact (%)</th>
<th>Bone-Implant Contact (%) (3 Best Threads)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Root form sandblasted</td>
<td>Submerged 3 mo</td>
<td>Trauma</td>
<td>4</td>
<td>32.2</td>
<td>69.9</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
<td>Root form sandblasted/acid etched</td>
<td>Submerged 3 mo</td>
<td>Overloading</td>
<td>15</td>
<td>49.3</td>
<td>95.1</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>Root form Tioblust</td>
<td>Submerged 3 mo</td>
<td>Abutment fracture</td>
<td>5</td>
<td>77.1</td>
<td>99.2</td>
</tr>
<tr>
<td>4</td>
<td>Maxilla</td>
<td>Blade machined</td>
<td>Immediate loading</td>
<td></td>
<td>15</td>
<td>25.2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>Root form sandblasted and acid etched (Mac System, Milano, Italy)</td>
<td>Submerged 3 mo</td>
<td>Implant fracture</td>
<td>20</td>
<td>74.5</td>
<td>89.4</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Root form acid etched (Osseotic®) (3i, West Palm Beach, FL)</td>
<td>Submerged 3 mo</td>
<td>Bruxism</td>
<td>19</td>
<td>68.1</td>
<td>72.5</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Root form sandblasted and acid etched (SLA) (Straumann, Basel Switzerland)</td>
<td>Submerged 3 mo</td>
<td>Soccer trauma</td>
<td>17</td>
<td>45.2</td>
<td>69.3</td>
</tr>
<tr>
<td>8</td>
<td>Mandible</td>
<td>Root form sandblasted/acid etched (Leone, Florence, Italy)</td>
<td>Submerged 3 mo</td>
<td>Implant fracture</td>
<td>5</td>
<td>65.7</td>
<td>77.8</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Root form acid etched with organic acids (Mac System, Milano, Italy)</td>
<td>Submerged 3 mo</td>
<td>Abutment fracture</td>
<td>12</td>
<td>48.6</td>
<td>99.4</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Root form sandblasted and acid etched</td>
<td>Implant loaded after 9 y. Implant retrieved after a 4-y loading period</td>
<td></td>
<td>13</td>
<td>40.3</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>32</td>
<td>Root form Titanium Plasma Spray (BioHorizons, Birmingham, AL)</td>
<td>Immediate functional loading</td>
<td>Malalignment</td>
<td>14</td>
<td>83.1</td>
<td>99.1</td>
</tr>
<tr>
<td>12</td>
<td>17</td>
<td>Root form sandblasted</td>
<td>Sinus lifting, implant insertion after 5 mo</td>
<td>Abutment fracture</td>
<td>5</td>
<td>70.4</td>
<td>99.3</td>
</tr>
<tr>
<td>13</td>
<td>17</td>
<td>Root form acid etched (Osseotic®) (3i, West Palm Beach, FL)</td>
<td>Submerged 3 mo</td>
<td>Connecting screw fracture</td>
<td>8</td>
<td>50.4</td>
<td>90.1</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Root form Direct Metal Laser Sintering (TIXOS, Leader Italia, Cinisello Balsamo, Milano, Italy)</td>
<td>Overdenture submerged 3 mo</td>
<td>Implant fracture</td>
<td>5</td>
<td>47.6</td>
<td>72</td>
</tr>
<tr>
<td>15</td>
<td>43</td>
<td>Screw sandblasted</td>
<td>Immediate loading</td>
<td>Implant fracture</td>
<td>18</td>
<td>85.1</td>
<td>79.1</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>Root form sandblasted</td>
<td>Submerged 3 mo</td>
<td>Implant fracture</td>
<td>14</td>
<td>56.4</td>
<td>87.3</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>Screw sandblasted</td>
<td>Immediate loading</td>
<td>Implant fracture</td>
<td>14</td>
<td>45.2</td>
<td>51</td>
</tr>
</tbody>
</table>

The specimens included 14 root-form implants, 2 screw implants, and 1 blade implant.
It has also been reported that integration seemed to continue even long after the complete implant osseointegration. Higher levels of bone organization were obtained after longer loading periods; this fact was corroborated by the presence of many remodeling sites within the periimplant lamellar bone. Functional loading seemed to be necessary for bone development and maturation. The BIC values of osseointegrated implants varied, in different studies, between 35% and 95% and between 54% and 87%; this fact could mean that implants may perform with successful clinical function over a large range of osseointegration percentages, and that implants seemed to be able to function in a satisfactory way even when the quantity of mineralized bone at the interface was low.

Understanding the bone response and the biological reactions from the host in clinically successful and functioning implants is certainly extremely important. Osseointegration was introduced as a histological term and can only be diagnosed through a histological analysis. Only limited data were available on implants that have been in situ for many years. Human histologic en bloc evidence remains the ultimate approach to evaluating the soft and hard tissue response around implants. Osteoconductive properties of the implant surfaces, that is, the presence of bone in the thread valleys could also be evaluated.

Bone remodeling is a prerequisite for osseointegrated implants to support functional loading in the long term, and its presence should be relevant to the long-term successful prognosis of dental implants. Long-term osseointegration studies are commonly restricted to a relatively few cases at a time.

Implants retrieved for mechanical reasons not influencing their anchorage, such as autopsy specimens and implants removed for different causes, that is, inadequate patient adaptation, misalignment with a nonrestorable position, presence of pain and dysesthesia, bad implant positioning causing esthetic and hygienic problems, changed prosthetic needs, are reported only rarely in the literature compared with implants that have been retrieved for different kinds of failures, but they present a great opportunity to study osseointegration. Only the biopsy of human-retrieved implants allows a precise evaluation of the events occurring at the interface. Implant stability correlates with the quantity and quality of bone at the implant interface.

The range of bone-to-implant contact that is necessary for an implant to be successfully osseointegrated is, however, still unknown, and differs widely, starting from as low as approximately 20% to 30%. Histological evidence of clinically successfully osseointegrated implants after a period of functional loading of more than 1 year is only rarely found in the literature. Moreover, it could also, perhaps, be...
useful to evaluate the healing events at the interface after different periods.\textsuperscript{12,15,33}

The aim of this study was a histological and histomorphometrical analysis of the periimplant tissues reactions and of the bone-titanium interface in successfully osseointegrated, clinically stable, and immobile human-retrieved titanium dental implants over the long term (up to 20 years).

**MATERIALS AND METHODS**

In the last 30 months (2013–2015), 21 specimens of implants retrieved from individuals for different causes were sent to be evaluated in the Implant Retrieval Center of the Department of Medical, Oral, and Biotechnological Sciences of the University of Chieti-Pescara, Italy.

In 4 cases, almost all the bone had been lost during the retrieval procedure, whereas in the remaining 17 cases, mineralized bone was present at the interface with the implant. All these implants had been retrieved after an insertion time ranging from 4 to 20 years. Only these last 17 implants (14 root-form implants, 2 screw implants, and 1 blade implant) were processed to obtain thin ground section and are reported in this study (Table 1). None of these implants had been previously reported.

**Processing of Specimens**

The implants and the surrounding tissues were immediately stored in 10% buffered formalin and processed to obtain thin ground sections with the Precise 1 Automated System (Assing, Rome, Italy).\textsuperscript{37} 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 implants with a high-precision diamond disc at approximately 150 \( \mu \)m and ground down to approximately 30 \( \mu \)m. Three slides were obtained for each implant. The slides were stained with basic fuchsin and toluidine blue.

Histomorphometry of bone-implant contact percentage was performed using a light microscope (Laborlux S; Leitz, Wetzlar, Germany) connected to a high-resolution video camera (3CCD, JVC KY-F55B) and interfaced to a monitor and PC (Intel Pentium III 1200 MMX; Kraun, Ponte-dera (PI), Italy). This optical system was associated with a digitizing pad (Matrix Vision GmbH) and a histometry software package with image-capturing capabilities (Image-Pro Plus 4.5; Media Cybernetics Inc., Immagini & Computer Snc Milano, Italy).

**RESULTS**

The histological results were similar for all implants and are described together. Around the majority of the implants, mature compact bone with few marrow spaces was found. The trabecular bone, constituted by a few thin bone trabeculae, was found in a perimplant location around only a few implants.

At low-power magnification, a high percentage of bone-implant contact was present at the interface of almost all implants (Fig. 1, A–D). Only in a few specimens, in some areas of the implant perimeter, bone had been removed during the retrieval procedure (Fig. 2, A–D).
Bone to implant contact (BIC) percentage of all implants was comprised between 32% ± 4.1% and 83% ± 2.9%.

In almost all implants, the space within the threads was almost completely filled by compact, lamellar bone, or in a few cases, by a thin layer of bone (Fig. 3). In most implants, many remodeling areas were present in the most coronal portion of the implants, near the line of fracture of titanium, in the cases in which the implant fracture had caused the retrieval of the implant (Fig. 4, A–C). Close and tight contact between bone and implant surface was observed in all specimens, and no gaps or connective, fibrous tissue was found at the bone-implant interface. In a few implants, the perimplant bone had detached from the titanium surface, most probably during the retrieval procedure, but, in these cases, the bone presented a clear mirror image of the implant threads. No inflammatory cell infiltrate was present at the interface or in the marrow spaces. No epithelial cell migration was present in any of the implants. Some primary osteons, characterized by the presence of woven collagen fibers, absence of lamellar bone, and irregularly disposed osteocytes, were observed near the implant surface.

In the perimplant bone around a few implants, a few resorption cones were found. Some hemiosteons were located on the implant surface (Fig. 5). A few marrow spaces abutted on the implant surface. At the tip of some of the threads, it was possible to observe the presence of marrow spaces, lined by newly formed bone. Primary and secondary osteons were present inside the threads.

Around all implants, the periimplant bone had a clear mirror image of the implant threads. No inflammatory cell infiltrate was present at the interface or in the marrow spaces. No epithelial cell migration was present. Some primary osteons, characterized by the presence of woven collagen fibers, absence of lamellar bone, and irregularly disposed osteocytes, were observed near the implant surface. In areas of remodeling bone, it was possible to observe bone-remodeling units with vessels, osteoblasts, and osteoclasts. In most areas, lamellar and woven bones were separated by a well-defined irregular cement line.

**DISCUSSION**

In the histomorphometrical evaluation of the present specimens, the part of the implant damaged during the retrieval procedure was not excluded from the analysis, and the final BIC value was obtained measuring the complete implant perimeter. In all the present specimens, dense compact bone was found in intimate contact with the implant surface. The amount of BIC has been deemed critical for long-term survival and success of the implant. A positive and direct correlation between the healing periods and the BIC has been reported. The degree of bone maturation is an ongoing process and the percentage of BIC increases over time as a result of the remodeling process in response to the functional loading.

The limitations of this study were related mainly to the fact that implants, retrieved after many years of loading history, and sent to the Implant Retrieval Center of our Department by many different clinicians had, in most of the cases, no proper complete records, and it was not easy, after a very long period, to retrieve all the data. Notwithstanding, we strongly believed that the data presented in this study could offer a unique perspective into what happens at the level of the perimplant bone after many years or, in some instances, a few decades of loading history.

Even a heterogenous and not very large body of implants, retrieved from humans, can help, most probably, to answer a few important clinical questions. For example, the lowest amount of BIC required to guarantee implant stability is not known. In the present series, the amount of BIC varied widely, from 32% to 83%, but even the implants with the lowest amount of BIC were clinically stable, healthy, and not mobile, before retrieval. This fact could mean that implants were able to function in a satisfactory way even when the quantity of mineralized bone at the interface was relatively low.

The main results of this study of retrieved human implants, after a long-term loading period, can be summarized as follows:

1. Most of the implants were surrounded by compact mature bone, with few marrow spaces, in close contact with the implant surfaces;
2. As a proof-of-principle concept, it was possible to observe that a high BIC (more than 50%) was present even when the perimplant bone had a trabecular structure;
3. No gaps, foreign body reaction cells, epithelial downgrowth, or connective fibrous tissue was observed at the bone-implant interface or in a perimplant location around any of the retrieved implants;
4. Remodeling areas were observed in the perimplant bone, mostly in the most coronal portion of the implants. This fact could be due to the strains and stresses in the pericoronal/percrestal bone in the fractured implants, before the occurrence of the fracture;
5. In all implants, even in those inserted in the trabecular bone, almost all threads were filled by compact mature bone or, alternatively, by a thin layer of bone. This fact attested to the osteoconductivity of all the surfaces under study;
6. The presence of areas of new bone formation with wide osteocyte lacunae in a perimplant location attested to the fact that, even after a long loading period, bone was still undergoing resorption and formation;
7. In most implants, at the tip of some of the threads, it was possible to observe the presence of marrow spaces, lined by newly formed bone. This fact could, in all probability, be related to the stresses originating in this area;
8. A study of implants retrieved because of mechanical reasons seemed to be extremely important to evaluate the bone response after different periods of healing.
Furthermore, the present histological data demonstrated that different kinds of implant systems with different surface characteristics, inserted in different bone qualities in the mandible or maxilla, could equally establish a successful osseointegration.

A high failure rate has been reported in blade implants because of their nonretentive shape. In the present series, mineralized tissue was found at the interface of a blade implant retrieved after 15 years. Similar results were reported in previous studies from our laboratory,17,19 and also by Linkow et al.14 and Proussaefs and Lozada,20 and they are in agreement with animal and clinical studies that showed that also blade implants were capable of being osseointegrated.28 Very high BIC values were present in both screws in the present series, and this fact could be explained by the large mechanical retention of the screw, and to the possibility of transmitting compressive loads to the periimplant tissues, producing lower shear stresses at the interface. The presence of mineralized tissues at the bone-implant interface has been correlated to the biomechanical stability of the implant and to micromotion.23 High primary implant stability decreases the distortional strains at the interface improving new bone formation.2,3

**CONCLUSION**

All the implants in the present series appeared to be well integrated in the surrounding mineralized bone, and all of them showed adequate bone-to-implant contact percentages. Within the limitation of the present case series, a successful osseointegration had been achieved after a long loading period even in the presence of several implant systems with different surface features, demonstrating a positive periimplant bone response over time.

**DISCLOSURE**

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

**APPROVAL**

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