Histologic Evaluation of Hydroxyapatite-Coated Root-Form Implants Retrieved after 7 Years in Function: A Case Report

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This case report presents a clinical, radiographic, and histologic evaluation of 2 non-adjacent, hydroxyapatite-coated, root-form implants retrieved from the maxillary canine area of a patient after 7 years in function. Clinical examination revealed immobile implants with no sign of pathosis. Radiographic examination indicated close proximity of the bone to the implant surface without evidence of radiolucency. Histologically, the 2 implants appeared to be well integrated with the surrounding bone; 84% of the surface of the first implant and 79% of the surface of the second implant had close bone apposition at the interface. There was no evidence of dissolution of the hydroxyapatite coating. The bone appeared to be in immediate contact with the coating. These observations suggest that a particular hydroxyapatite coating on root-form implants can resist degradation during long-term function. (Int J Oral Maxillofac Implants 2000;15:438–443)

Key words: dental implants, histology, hydroxyapatite, osseointegration, radiography

Commercially pure titanium or titanium-alloy dental implants have become a reliable treatment option for completely and partially edentulous patients.1–3 The quest for enhanced and more rapid osseointegration has led to various implant surface modifications, the most common being the addition of a hydroxyapatite (HA) coating. Clinical studies of HA-coated titanium implants demonstrate a high success rate.4–9 Clinical evaluation, however, provides little information regarding the microscopic hard tissue condition around an implant and no information on the status of the tissue-implant interface. The later is particularly important for HA-coated implants, since there have been reports of dissolution of HA coatings after placement.10–14 The purpose of this histologic case report is to present the results of the evaluation of 2 HA-coated, root-form implants retrieved after having been in function for 7 years.

PATIENT HISTORY AND TREATMENT

A 77-year-old Caucasian female presented at the Center for Prosthodontics and Implant Dentistry, Loma Linda University, in June 1998 with a chief complaint of dissatisfaction with her 1-year-old maxillary implant-retained overdenture. Prior to the current prosthesis, she reported having 4 different implant-retained overdentures after the implants had been uncovered and loaded. Two root-form, HA-coated 3.8 × 16 mm Steri-Oss (Nobel Biocare, Yorba Linda, CA) implants were present in the location of the maxillary canines. They were placed in March 1991 at the Center for Prosthodontics and Implant Dentistry and loaded in September 1991. Clinical and radiographic examination was performed. Two periapical radiographs—one for each implant—were taken with the parallel cone technique.
Because of the extreme labial inclination of both implants, retention of the overdenture was inadequate. Given the patient's history regarding compromised prosthetic rehabilitation of these implants, the decision was made to fabricate a conventional complete denture. Since the implants were considered non-restorable, the decision was made to remove them. The treatment plan was presented to and accepted by the patient, who provided written informed consent.

Surgical removal of the implants was performed in August 1998. The implants were removed using a 4-mm internal diameter trephine bur (ACE Surgical Supply Co, Brockton, MA) and immediately placed in 10% buffered formalin. The implant sockets were filled with bovine bone mineral (Bio-Oss, Osteohealth Co, Shirley, NY), and the surgical sites healed uneventfully.

**Histologic Processing and Analysis**
The 2 implants were sectioned in half and immediately dehydrated with a graded series of alcohols for 9 days. Following dehydration, the specimens were infiltrated with a light-curing embedding resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). Following 19 days of infiltration with constant shaking at normal atmospheric pressure, specimens were embedded and polymerized by 450 nm light, with the temperature of the specimens never exceeding 40°C. The specimens were then prepared by the cutting/grinding method of Donath and Breuner. The specimens were cut to a thickness of 150 µm with the EXAKT cutting/grinding system (EXAKT Apparatebau, Norderstedt, Germany). Following this, the slides were polished to a thickness of 50 µm using the EXAKT microgrinding systems followed by alumina polishing paste. The slides were stained with Stevenel's blue and Van Gieson's picro fuchsin. Two slides per implant were available for analysis.

Osseointegration (%) was measured on digitized images of the most central section of each implant. Analysis was performed on a Macintosh computer using the public domain NIH image program (developed at the U.S. National Institutes of Health and available at http://rsb.info.nih.gov/nih-image/). Portions of the implant surface determined to be damaged during retrieval were excluded from measurements.

**RESULTS**

**Clinical Findings**
Initial clinical examination revealed that both implants were immobile when assessed manually (bidigital using the handles of 2 instruments) and had probing depths of 3 to 4 mm. Soft tissue around the implants appeared healthy, and a well-formed maxillary ridge was evident.

Upon flap reflection (retrieval surgery), no sign of pathosis was seen around the implants. The bone appeared to be well integrated with the implants, and no intrabony defects were noticed. Upon implant removal, the surrounding bone appeared well attached to the implant surface.

**Radiographic Findings**
Radiographic examination (Fig 1) suggested osseointegration with the surrounding bone, with limited bone resorption on the mesial and distal aspects, extending to the second implant thread on the mesial and first thread on the distal. No evidence of peri-implant radiolucency was noted.

**Histologic Findings**
The implants were well integrated with the surrounding bone (Fig 2). Bone-to-implant contact, excluding the part of the implant surface damaged during retrieval, was calculated at 84% and 79% of the implant surface at the left canine and right canine position, respectively.

No evidence of dissolution or degradation of the HA coating was observed. The bone was in close contact with the coating surface (Figs 3 to 5). In the occasional small areas where coating was lacking, typically at the tips of the threads, the bone was in close proximity to the titanium surface. Even under high magnification (Fig 5), the bone was in contact with the coating, with no intervening space. Thin,
fine stands of bone appeared to insert into the coating. Haversian canals were frequently seen in close proximity to the bone-implant interface (Figs 4a and 4b). When observed, the canals were 60 to 80 µm from the bone-implant interface.

The apical area of the implants was covered continuously by bone (Figs 4a and 4b). The apical vent of the implant in the left canine position was lined by a uniform thickness of bone. Fatty tissue was seen in the vent area, with a core of bone in the center. Similar findings were observed at the implant in the right canine location along the apical area.

Based on measurements of the distance between the tips of the threads in these specimens and the manufacturer’s stated distance of 0.63 mm, it was possible to calculate the thickness of the coating remaining. This was determined to be approximately 50 µm, equal to the original thickness provided by the manufacturer.

**DISCUSSION**

The findings from this histologic evaluation indicate that after 7 years of function, HA-coated implants continued to demonstrate adequate bone-to-implant contact. No apparent HA dissolution or resorption was observed. These findings are in agreement with published reports involving root-form (Table 1) or other types (Table 2) of HA-coated implants retrieved from human subjects after much shorter loading periods.

Although there are clinical reports in which retrieved HA-coated implants demonstrated dissolution of the coating,17,18 infection had preceded implant removal in these cases. Reports also suggest that HA-coated implants may be associated with greater peri-implant tissue destruction after infection.19,20 However, the assumption that HA-coated implants may be more prone to infection has not been proven in either human20,21 or animal studies.22

In vitro studies have demonstrated that dissolution of the HA coating can occur.11,14 Nevertheless, implants retrieved from humans have failed to demonstrate any dissolution of the coating in the absence of infection. In the present specimens, thickness of the HA coating after 7 years of loading was similar to the original factory-provided thickness, confirming the lack of HA dissolution. Piattelli and Trisi23 reported similar observations, where HA
Figs 4a and 4b  Detailed views of surface area of (left) maxillary left canine implant and (right) right canine implant. In areas apparently devoid of hydroxyapatite, the bone is in close proximity to the titanium surface. Haversian canals are evident in close proximity to the bone-implant interface (polarized light; original magnification ×10).

Fig 5  Higher-power view of Fig 4b (maxillary right canine implant). Notice the intimate contact between bone and the hydroxyapatite coating. Fine strands of bone appear to insert into the hydroxyapatite (original magnification ×40).

### Table 1  Human Histology Reports of Root-Form Hydroxyapatite-Coated Implants

<table>
<thead>
<tr>
<th>Report</th>
<th>Implant type (n)</th>
<th>Histologic findings</th>
<th>Reason for removal</th>
<th>Location</th>
<th>Time in function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block and Kent 1993</td>
<td>Cylindric (1)</td>
<td>Osseointegration, no HA degradation</td>
<td>Mandibulectomy</td>
<td>Posterior mandible</td>
<td>2 years</td>
</tr>
<tr>
<td>Piattelli et al 1993</td>
<td>Cylindric (2)</td>
<td>Bone-implant contact 70%, no HA degradation</td>
<td>Psychologic, abutment fracture</td>
<td>Not reported</td>
<td>2 to 18 months post-placement</td>
</tr>
<tr>
<td>Piattelli and Trisi 1993</td>
<td>Cylindric (1)</td>
<td>Bone-HA contact, no HA degradation</td>
<td>Pain</td>
<td>Mandible (premolar)</td>
<td>1 year</td>
</tr>
<tr>
<td>Steflik et al 1994</td>
<td>Threaded (1)</td>
<td>HA coating intact, interfaced by bone</td>
<td>Fracture</td>
<td>Mandible</td>
<td>1 year</td>
</tr>
<tr>
<td>Steflik et al 1994</td>
<td>Cylindric (1)</td>
<td>No osseointegration, HA dislodgment</td>
<td>Radiolucency</td>
<td>Not reported</td>
<td>Not loaded</td>
</tr>
<tr>
<td>Piattelli and Trisi 1994</td>
<td>Cylindric (4)</td>
<td>Bone-HA contact, no HA degradation</td>
<td>Psychologic, abutment fracture</td>
<td>Not reported</td>
<td>2 to 18 months post-placement</td>
</tr>
<tr>
<td>Piattelli et al 1995</td>
<td>Cylindric (1)</td>
<td>No HA degradation</td>
<td>Infection</td>
<td>Posterior maxilla</td>
<td>2.5 years</td>
</tr>
<tr>
<td>Rohrer et al 1995</td>
<td>Cylindric (4)</td>
<td>Osseointegration</td>
<td>Postmortem</td>
<td>Mandible</td>
<td>4 months</td>
</tr>
<tr>
<td>Piattelli et al 1996</td>
<td>Cylindric (1)</td>
<td>No osseointegration, HA detached</td>
<td>Mobility</td>
<td>Mandible (symphysis)</td>
<td>1 year</td>
</tr>
<tr>
<td>Piattelli et al 1996</td>
<td>Cylindric (2)</td>
<td>HA detached, HA degradation</td>
<td>Mobility</td>
<td>Anterior mandible</td>
<td>3 years</td>
</tr>
<tr>
<td>Takeshita et al 1997</td>
<td>Threaded (1)</td>
<td>HA dissolution</td>
<td>Infection</td>
<td>Mandible</td>
<td>Not loaded</td>
</tr>
<tr>
<td>Piattelli et al 1998</td>
<td>Cylindric (41)</td>
<td>HA degradation in some cases</td>
<td>Mobility</td>
<td>Variable</td>
<td>2.5 years (mean)</td>
</tr>
<tr>
<td>Rosenlicht and Tarnow 1999</td>
<td>Threaded (2)</td>
<td>Osseointegration, tips devoid of HA</td>
<td>Psychologic</td>
<td>Grafted sinus</td>
<td>2.33 years</td>
</tr>
<tr>
<td>Piattelli et al 1999</td>
<td>Cylindric (2)</td>
<td>Osseointegration, no HA degradation, some HA detached</td>
<td>Abutment fracture</td>
<td>Posterior mandible</td>
<td>1 year</td>
</tr>
<tr>
<td>Current report</td>
<td>Threaded (2)</td>
<td>Bone-implant contact 79% to 84%, tips devoid of HA</td>
<td>Prosthetic</td>
<td>Anterior maxilla</td>
<td>7 years</td>
</tr>
</tbody>
</table>
coating thickness (50 µm) was homogeneous after the implant was loaded for 11 months. Similarly, retrieved orthopedic prostheses have demonstrated close integration of HA-coated titanium implants with the surrounding bone.24,25 Uniform coating thickness was reported, with no signs of resorption after 5 months to 2 years in function.

Areas devoid of HA were limited to the tips of the threads and demonstrated intimate contact between the titanium substructure and bone.25,26 It has been shown that tip denudation may be the result of HA fracture during implant placement because of frictional stress.27

Present findings indicate a high percentage of direct bone-to-implant surface contact (79% to 84%), comparable to reports involving HA-coated implants in jaws of humans,28 non-human primates,29,30 and dogs.31,32 A bonding mechanism has been proposed as an explanation for the tight contact between HA and bone.33 The presence of Haversian canals in close proximity to the implant surface, an observation previously reported by others,25,34 suggests physiologic bone remodeling.31,35

Specimens from human subjects in whom titanium root-form implants had been in function for comparably long periods demonstrate results similar to the present findings.16,37 Albrektsson et al16 observed excellent adaptation between a titanium implant and bone after 7.5 years. Sennery et al17 reported 67% to 86% osseointegration in titanium implants that had been in function for 6 to 16 years. In conjunction with the present findings, these results suggest that there are instances where, under long-term function, there is no discernible difference in osseointegration between HA-coated and non-coated implants.

In summary, this case report indicates that 2 HA-coated implants did not show obvious signs of HA resorption or dissolution after 7 years in function. This report more than doubles the previously reported maximum time in function of HA-coated root-form implants with follow-up histologic evaluation.

Table 2: Human Histology Reports of Non-Root-Form Hydroxyapatite-Coated Implants

<table>
<thead>
<tr>
<th>Report</th>
<th>Implant type (n)</th>
<th>Histologic findings</th>
<th>Reason for removal</th>
<th>Location</th>
<th>Years in function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benjamin and Block 198924</td>
<td>Subperiosteal (1)</td>
<td>Bone-HA contact</td>
<td>Psychologic</td>
<td>Maxilla</td>
<td>1</td>
</tr>
<tr>
<td>Bauer et al 199124</td>
<td>Femoral stems (5)</td>
<td>Osseointegration, no HA degradation</td>
<td>Postmortem</td>
<td>Femur</td>
<td>0.5 to 2</td>
</tr>
<tr>
<td>Steflik et al 199439</td>
<td>Subperiosteal (1)</td>
<td>Osseointegration</td>
<td>Infection</td>
<td>Mandible</td>
<td>4</td>
</tr>
<tr>
<td>Hardy et al 199425</td>
<td>Femoral stems (2)</td>
<td>Osseointegration, no HA degradation, HA resorption (1)</td>
<td>Postmortem</td>
<td>Femur</td>
<td>2</td>
</tr>
</tbody>
</table>

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REFERENCES


