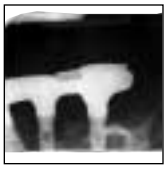
Histologic Evaluation of Threaded HA-Coated Root-Form Implants After 3.5 to 11 Years of Function: A Report of Three Cases



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This article presents a histologic evaluation of three hydroxyapatite (HA)-coated root-form implants retrieved from humans after being in function for 3.5 to 11 years. If the coronal portion, where bone loss was observed clinically and radiographically, is excluded, all implants appeared to be well osseointegrated, with intimate contact between the surrounding bone and the coating. There was no sign of resorption or dissolution of the HA coating. The coating had a uniform thickness (50 µm) equal to the thickness originally provided by the manufacturer. In the few areas where there was no bone contact, the HA coating appeared to line the implant with no sign of dissolution. The few detached particles had tight contact with the bone, demonstrating the biocompatibility of the HA. The observations from the three reported cases suggest that the HA coating of dental implants may not be susceptible to resorption or dissolution under long-term function. (Int J Periodontics Restorative Dent 2001;21:21–29.)

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Titanium or titanium alloy dental implants have become a valid treatment modality for the totally[1,2] or partially[3,4] edentulous patient. Several animal studies have shown that the incorporation of a hydroxyapatite (HA) coating on titanium or titanium alloy implants may offer more rapid osseointegration,[5–9] better maintenance of osseous crest height,[10,11] and increased potential for guided bone regeneration[12] around the implants. Clinical studies have demonstrated good results[13–17] using HA-coated implants.

A controversy exists regarding the condition of the coating after the implant is placed into the bone. In vitro[18] and animal studies[6,19–23] as well as clinical case reports[24,25] have shown that the coating may be susceptible to degradation or dissolution. However, other animal studies[5,10,26,27] and clinical reports regarding dental implants[28–37] and orthopedic prostheses[38,39] that have been retrieved from humans have shown the opposite. The purpose of the current report is to provide a histologic analysis of three HA-coated root-form implants that were

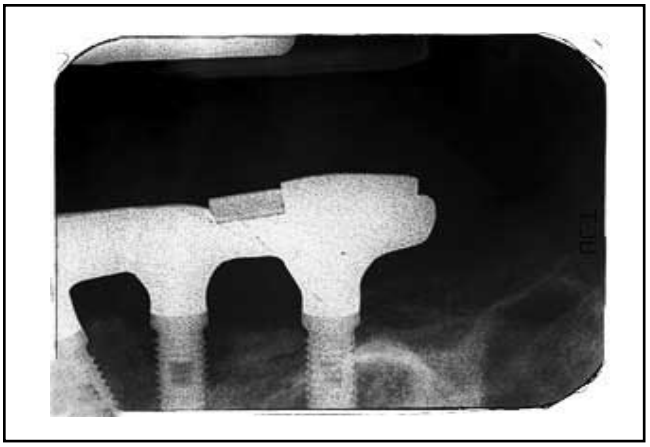


Fig 1 *Case 2, periapical radiograph taken before implant retrieval.*

Fig 2 *Case 1 immediately after retrieval of the implant. The bone is tightly attached to the implant surface.*

retrieved from three human subjects after being in function for 3.5 to 11 years.

Clinical report

All cases were treated at the Center for Prosthodontics and Implant Dentistry, Loma Linda University (LLU). Panoramic and periapical radiographs were taken in each case before the implants were retrieved (Fig 1). Periimplant probing depth and bleeding on probing were also recorded. Mobility was assessed manually (bidigitally using the handles of two instruments). All implants were retrieved under local anesthesia using a 4-mm internal diameter trephine bur (Ace Surgical Supply).

Case 1

A 54-year-old woman presented with pain in the right posterior maxillary area that was intensified upon function. Radiographic examination revealed a fractured implant in the area of the maxillary right second molar. The implant was a 3.8 mm × 12 mm threaded, HA-coated root-form implant (Steri-Oss, Nobel Biocare) that had been placed at LLU in October 1988. The implant was removed in July 1999 (Fig 2).

Case 2

A 42-year-old woman presented with bone loss coronal to an implant in the area of the maxillary right first molar (Fig 1). The implant was placed at LLU in December 1995. It was identified as a Steri-Oss 3.8 mm × 12 mm threaded, HA-coated root-form implant. It was extracted in July 1999.

Case 3

A 45-year-old man presented with bone loss around the implants in the area of the maxillary left lateral incisor and canine. The 2 implants were HA-coated cylindric dental implants (IMZ, Interpore) that had been placed in a private practice in 1988. A decision was made to extract the implants and perform bone grafting before new implants would be considered. The implants were retrieved in August 1999. The implant from

the area of the left canine was histologically analyzed.

Histologic processing

All implants were immediately placed in a 10% buffered formalin solution. The specimens were sectioned in half and immediately dehydrated with a graded series of alcohol for 9 days. Following dehydration, the specimens were infiltrated with a light-curing embedding resin (Technovit 7200 VLC, Kulzer). Following 19 days of infiltration with constant shaking at normal atmospheric pressure, the 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 a previously described cutting/grinding method.[40,41]

The specimens were cut to a thickness of 150 µm on an Exact cutting/grinding system (Exact Apparatebau). Following this, the slides were polished to a thickness of 50 µm using the Exact microgrinding system followed by alumina polishing paste. The slides were stained with Stevenel's blue and Van Gieson's picric fuchsin.

Results

Clinical evaluation

In all cases, there was a 5- to 7-mm probing depth around the implants and bleeding on probing. Pain on percussion was elicited from the fractured implant in case 1. The implants studied in this article exhibited no mobility. In all cases, the surrounding bone was well attached to the implant surface during retrieval (Fig 2). The attached bone appeared to cover the apical 75%, 50%, and 60% of the retrieved implants in cases 1, 2, and 3, respectively.

Radiographic evaluation

In case 1, a fracture of the implant was identified, with a 3-mm crestal bone loss. The implant in case 2 (Fig 1) demonstrated bone loss up to the fourth thread in the mesial aspect and up to the seventh thread in the distal aspect. In case 3, the implant that was retrieved from the area of the maxillary left canine had a 4-mm horizontal bone loss at both the mesial and distal areas.

Histologic evaluation

The retrieved implants appeared well integrated with the surrounding bone, except for the areas where horizontal bone loss had been clinically observed (Fig 3). There was no evidence of dissolution or degradation of the HA coating (Figs 4 to 9). The coating appeared to be continuous along the surface of the implants and in tight contact with the surrounding bone. In some areas the coating was lacking at the tips of the implant threads (Figs 4a and 4b). However, in other areas the coating appeared to be continuous along the threads of the implant (Fig 5). When seen under high magnification, the coating demonstrated intimate contact with the bone (Fig 6). The bone had a saw-like appearance along the implant surface. Thin, fine strands of bone seemed to insert into the irregularities of the coating.

The bone around the implants appeared to be in a remodeling phase, as polarized microscopy revealed (Figs 4a and 4b). In addition, Haversian canals could be frequently observed at a 50- to 80-µm distance from the bone-implant interface, emphasizing the remodeling pattern (Fig 4c).

An interesting observation was made at one side of the implant from case 2, where there was no bone along the coating surface (Fig 7). Despite the lack of bone contact, the HA appeared to have a continuous lining along the implant surface.

In the areas where small particles of the coating had been detached from the implant, a tight contact between the surrounding bone and the majority of the surface of the particles was observed (Fig 8). A similar saw-like interface between the bone and the coating was noticed.

The apical vent of the implant in case 3 was covered continuously by bone (Fig 9). A uniform layer of the coating was observed, and the bone appeared in direct contact with the implant surface in almost 100% of the internal surface of the vent. Fatty tissue was seen in the vent area.

The thickness of the coating was calculated to be approximately 50 µm, equal to the original thickness that the manufacturer provided. This

Fig 3a *Histologic overview of the implant in case 1. (Original magnification × 2.5; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

Fig 3b *Histologic overview of the implant in case 2. (Original magnification × 2.5; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

Fig 3c (right) *Histologic overview of the implant in case 3. (Original magnification × 2; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

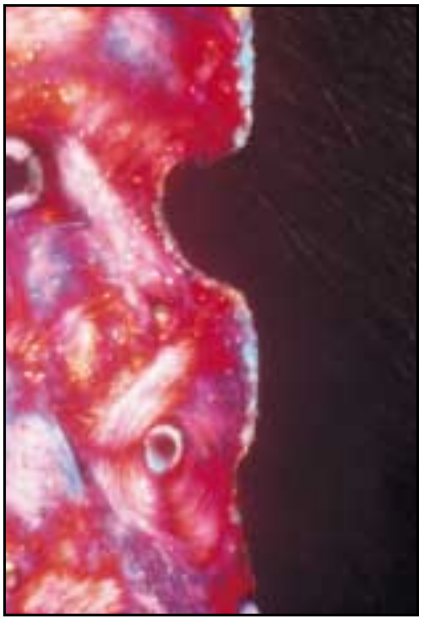


Fig 4a *Case 1. Coating forms a uniform layer along the surface of the implant and appears to be in intimate contact with the surrounding bone. At the tips of the threads, there appears to be a lack of coating, and the exposed titanium surface appears integrated with the surrounding bone. (Original magnification × 10; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

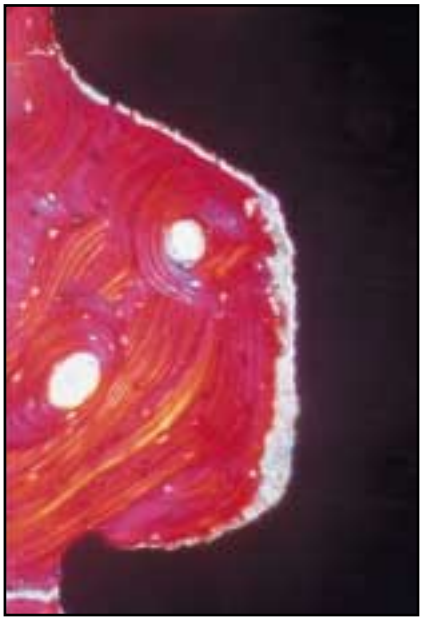


Fig 4b *Polarized microscopy emphasizes the remodeling pattern of the bone around the implant in case 1. (Original magnification × 20; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

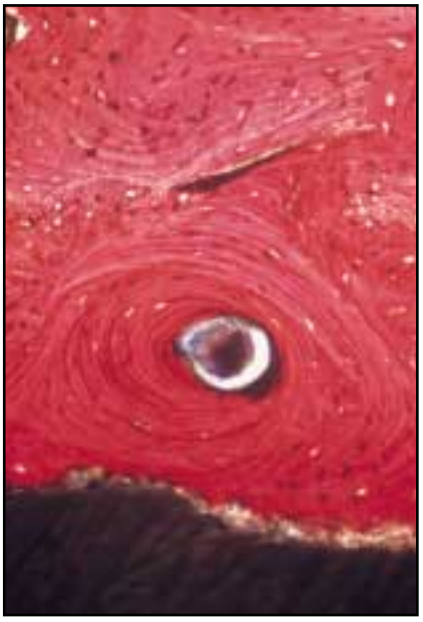
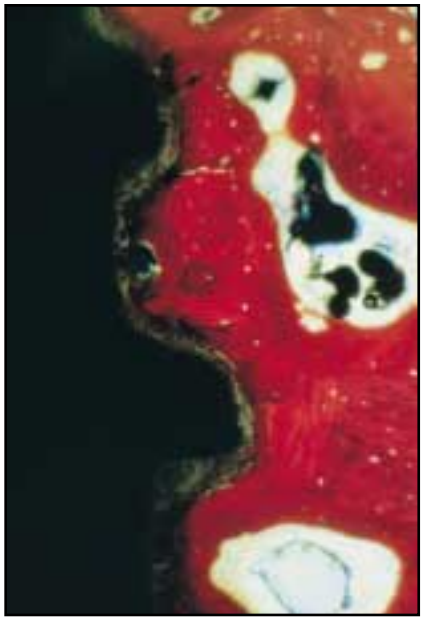


Fig 4c *Haversian canals are identified in close proximity to the implant-bone interface. (Original magnification × 20; Stevenel's blue–Van Gieson's picric fuchsin stain.)*



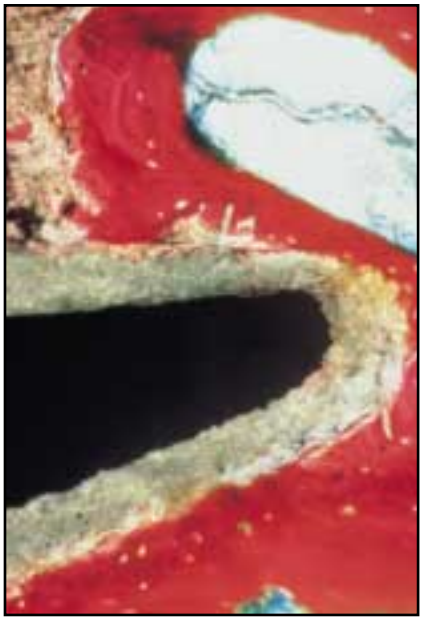
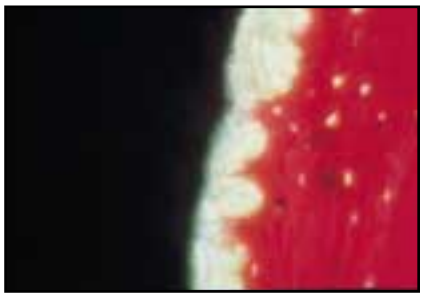


Fig 5a (left) *Case 2. Note the continuous layer of the coating that appears to have uniform thickness and be almost 100% integrated with the surrounding bone. (Original magnification × 10; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

Fig 5b (right) *In contrast with the observations made in case 1, the coating appears continuous along the entire surface of the implant threads, with no disruptions at the tips of the threads. (Original magnification × 20; Stevenel's blue–Van Gieson's picric fuchsin stain.)*



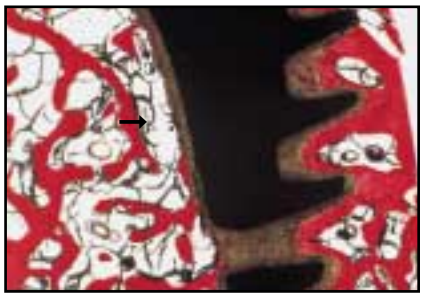
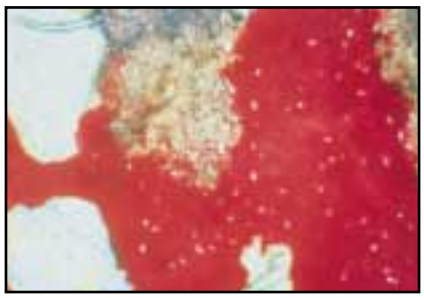


Fig 6 (left) *Case 2. At higher magnification, the bone-coating interface has a saw-like appearance. (Original magnification × 40; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

Fig 7 (right) *Case 2. Part of implant surface appears to not be in contact with bone* (arrow). *Coating appears to have a continuous layer with a uniform thickness, even in areas with no bone contact. (Original magnification × 4; Stevenel's blue–Van Gieson's picric fuchsin stain.)*



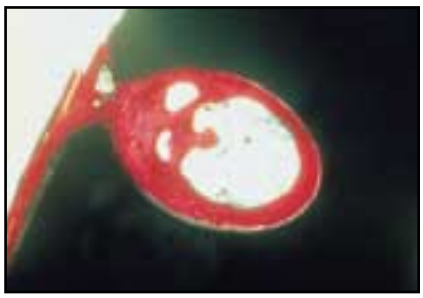


Fig 8 (left) *Case 2. Some HA particles appear detached from the implant surface. They appear to have tight contact with the surrounding bone along the majority of the surface. (Original magnification × 20; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

Fig 9 (right) *Case 3. Area inside vent of the implant is almost 100% integrated with bone. Note coating layer along the internal surface of the vent and intimate bone-HA interface. (Original magnification × 4; Stevenel's blue–Van Gieson's picric fuchsin stain.)*

calculation was made by measuring the distance between the tips of the threads in the retrieved specimens. According to the manufacturer, the distance between the implant threads is 0.63 mm. By using this measurement as a reference, it was possible to demonstrate that after 11 years of implant function, the thickness of the coating had not been reduced.

Discussion

The significance of the current specimens is that they provide some evidence that the HA coating may not be susceptible to degradation or dissolution under long-term function. This has also been shown in other clinical case reports[28–34] in which the implants had been in function for a relatively short period (0.5 to 3 years) before retrieval. Proussaefs et al[37] published a case report in which two HA-coated root-form implants demonstrated 79% and 84% bone-to-implant contact after being in function for 7 years. Case reports demonstrating dissolution of the coating have been associated with infection,[24,25] while animal studies[6,23] have interpreted the presence of macrophages or giant cells at the bone-implant interface as an implication of active HA absorption without providing evidence of actual HA dissolution.

The very tight, saw-like contact between the bone and the HA (Fig 6) suggests a penetration of the bone into the HA coating. It has been reported that a bonding mechanism (biointegration) may exist between the HA-coated implant surface and the surrounding bone.[42,43] The few HA particles that lacked tight contact with the metal surface (Fig 8), probably because of mechanical dislodgment during implant placement,[44] appeared integrated with the bone, as has been previously observed.[36] This observation emphasizes the biocompatibility of the coating.

It has been reported that HA coatings may be susceptible to dissolution when they are not in contact with bone.[45,46] In the specimen from case 2, the coating lacked contact with bone in some areas. However, no dissolution of the HA had occurred. It may be hypothesized that the lack of bony contact could represent only a predisposing factor for coating dissolution and other factors are involved in the dissolution of the HA coating.

Animal studies offer the potential to evaluate specimens histologically at controlled time periods. It has been demonstrated that the HA coating offers a more rapid integration of the implant to the bone as compared to commercially pure titanium or titanium alloy implants.[5–9,23] However, the majority of the studies have demonstrated that the difference in bony integration between HA-coated and noncoated implants tends to diminish over time.[5,7,26,27,47] Additionally, it has been shown that the interface between dental implants and the surrounding bone is dynamic[33,48] and that the degree of osseointegration is a reflection of the applied functional forces.[49–51]

The presence of Haversian canals in close contact with an HA-coated implant surface (Fig 4c) has been demonstrated in both animal[6,10] and human[29,32] studies. This emphasizes the periimplant remodeling activity.[52] On the other hand, titanium[53,54] and titanium plasma-sprayed implants[55] retrieved from humans after long-term function have shown similar results to the current specimens. It is unknown if the tight contact between the implant surface and the bone in the present specimens can be attributed to the properties of the HA or if it is a result of a continuous bone remodeling.

Nevertheless, it should be emphasized that coating properties depend on the manufacturing process used to make them.[18] The biologic behavior of the coating is related to the amount of the amorphous phase along with the crystallinity. The location and distribution of the amorphous phase could also play a role in the longevity of the coating.[18] The observations on these three cases may apply to the coatings of the specific manufacturers only.

It should also be noted that the histologic observations in these clinical reports correspond to the middle and apical third of the implant surface. It is unknown what caused the bone loss at the coronal part of the implants. It could be hypothesized that coating degradation did occur at the coronal level and caused bone loss. Ogiso et al[46] demonstrated that dissolution of the HA coating occurs when the coated surface is in contact with soft tissue. Piatelli et al[45] reported that HA coatings in contact with biologic fluids may initiate resorption of the coating.

Within the limitations of these three case reports, it may be speculated that the HA coating is not susceptible to dissolution in vivo and when it is in contact with bony surfaces. However, further studies are needed to assess the role of the HA in long-term function.

Acknowledgments

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