Human Histologic and Histomorphometric Analyses of Hydroxyapatite-Coated Implants After 10 Years of Function: A Case Report

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Purpose: *No consensus exists on the long-term performance of hydroxyapatite (HA) coatings on dental implants. The aim of this study was to evaluate the long-term stability of the HA coating in a human autopsy specimen.* ***Materials and Methods:*** *Two mandibular HA-coated implants were retrieved postmortem from a woman after 10 years of functional loading with an implant/tooth-supported fixed partial denture. After ground sectioning, the specimens were histomorphometrically analyzed.* ***Results:*** *Direct bone-implant contact was found at 78.48% of the implant surface. HA coating disappearance had occurred in a few areas (22.75%), but bone was in direct apposition to the titanium surface. Bone volume measured 27.66%, and expected bone-implant contact was 37.55%. No inflammatory reaction was seen in the supracrestal soft tissues or the bone compartment.* ***Discussion:*** *Most of the HA coating was maintained on the implants, and areas lacking HA were directly apposed by bone. This observation suggests that the underlying titanium surface should have a macro-texture to promote the adaptation of bone to the titanium surface in case of HA disappearance, as well as to decrease failure at the HA-titanium interface.* ***Conclusions:*** *In a patient in whom prosthetic treatment was appropriately performed and proper plaque control was maintained, the HA coating was not damaged and contributed to the success of the implant over 10 years of clinical functioning.* INT J ORAL MAXILLOFAC IMPLANTS 2005;20:124–130

Key words: *autopsies, dental implants, histology, histomorphometry, hydroxyapatite, osseointegration, postmortem*

The bone-implant interface develops according to the host tissue response to the implant surface, which can be bioinert, biotolerant, or bioactive, depending on its chemical composition and topography.[1–4] Roughening the topography of the implant surface by applying a porous coating or through surface treatments may promote osteogenesis by enhancing osteoblast metabolic activity and cellular adhesion, increasing available surface area, and helping to stabilize the fibrin scaffold, with the ultimate goal of increasing bone attachment.[5] At the histologic level, faster bone apposition can be achieved with roughened surfaces compared to machined surfaces.[6] A nearly linear relationship was found between push-out failure load and surface roughness,[6] and higher removal torques for hydroxyapatite (HA) -coated implants in comparison to other implants have been demonstrated experimentally.[7–10]

Although long-term clinical data have indicated high survival rates for HA-coated implants,[11–16] some researchers[17–20] have expressed concerns about the potential for dissolution, resorption, and detachment of the coating and about increased susceptibility to infection, which may promote the loss of osseointegration. Human histologic studies have been published on HA-coated implants removed for various reasons (Table 1),[21–30] with an observation time up to 11 years.[28] In most of the cases, clinical and histologic information was very limited.

This report focuses on the bone response and coating behavior of 2 HA-coated implants after 10

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Table 1 Histomorphometric Studies of HA-Coated Implants in Humans

Study	No. of implants	Location	Loading time (y)	BIC (%)	HA thickness (μm)	HA disappearance (%)	Reason for removal
Piattelli et al[22]	2	Mandible	1 to 2.5	70	—	—	Psychiatric
Block and et al[21]	1	Mandible	9	71.04	67.3 ± 10.8	—	Postmortem
Dominici et al[23]	1	Mandible	1.9	75.3	—	—	Postmortem
Liao and et al[24]	2	Mandible	5	—	50	—	Peri-implantitis
Piattelli et al[25]	41	Maxilla and mandible	2.5 to 3	80 to 90*	—	—	Fracture, mobility, peri-implantitis
Rohrer et al[26]	2	Maxilla	3.3	47 (38 to 56)	—	†	Postmortem
Proussaefs et al[27]	2	Maxilla	7	79 to 84	50‡	—	Prosthodontic
Proussaefs et al[28]	4	Maxilla	11	50 to 75	50‡	—	Implant fracture or bone loss
Proussaefs et al[29]	1	Maxilla	9	45.9	Uniform	—	Prosthodontic
DeLang and Tadjoedin[30]	5	Maxilla	2.5	90.4 to 99.8	63 (51 to 88)	2.7	Psychiatric

*Unloaded implants with mobility or peri-implantitis had lower BIC and HA resorption.
†Detachment in some areas lacking bone contact.
‡Detachment at thread tips.
BIC = bone-implant contact.

years of function by means of histologic and histomorphometric analyses performed on a block section of the human mandible. The present case report adds new information to the literature by describing histologically a clinically well-documented case of long-term HA-coated implants connected to natural teeth and loaded by an overdenture.

MATERIALS AND METHODS

Patient

In 1989, a 63-year-old white woman presented with a complaint of discomfort with her mandibular removable partial denture and dissatisfaction with the esthetics of her maxillary complete denture. She reported a history of right hip joint replacement in 1986, which necessitated antibiotic premedication for all dental procedures, and presented a long history of periodontal disease. In the mandibular arch, the left canine, left first premolar, and right first premolar were still present (Fig 1), and the patient was wearing her second removable partial denture.

The periodontal evaluation revealed advanced periodontitis. The patient wished to save her natural teeth and have a removable partial denture in the mandible. Initial treatment consisted of scaling and root planing of the remaining mandibular teeth. Four months later, definitive periodontal surgery was performed simultaneously with implant surgery. Two cylindric HA-coated implants, 15 mm long and 4 mm in diameter (Integral; Centerpulse Dental, Carlsbad, CA), were placed in the edentulous area extending from the left canine to the right first premolar. Healing was uneventful. Four months postoperatively, second-stage surgery was performed.

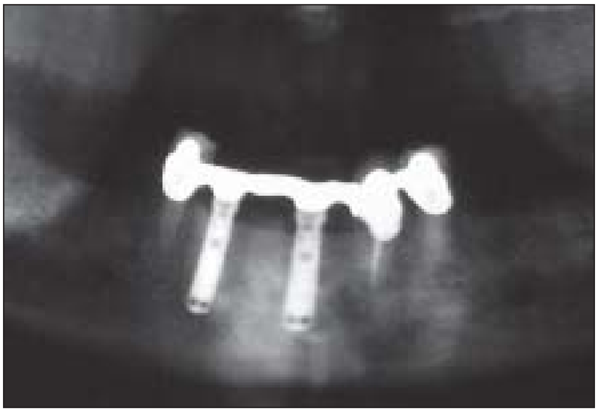


Fig 1 Panoramic radiograph taken after periodontal and surgical treatment.

The implants were splinted to the remaining mandibular teeth by means of a 3-unit, porcelain-fused-to-metal fixed partial denture extended bilaterally to the first premolars. A metal bar supported by 2 implants placed in the anterior region connected the 2 sides of the fixed prostheses with the aim of supporting and retaining the removable partial denture. The prosthodontic treatment was concluded in September 1991. No clinical signs of gingival

Fig 2 Postmortem block section of the anterior mandible. The section included the implants, natural teeth, and fixed prosthesis.

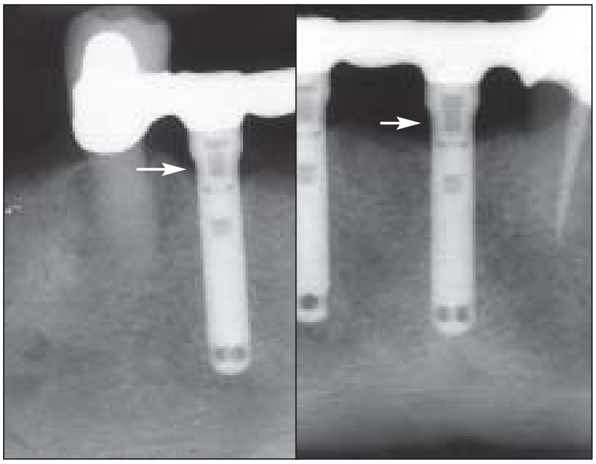


Fig 3 *(Left)* The right implant, which replaced the mandibular right canine. The periapical radiograph shows no signs of radiolucency. The implant-abutment interface *(arrow)* lies below the crestal bone level. *(Right)* The left implant, which replaced the mandibular left lateral incisor. There is no evident difference between the bone level at the 2 sides of the implant. The implant-abutment interface *(arrow)* is localized at the crestal bone level.

inflammation were visible either in the peri-implant or marginal periodontal tissues, and a wide adherent gingiva was visible around the necks of the implants. The follow-up period lasted 10 years. The last panoramic radiograph was taken in 1998. No bone loss was visible around the implants, and the bone level appeared to be well preserved at the natural teeth. The patient developed a disease that progressed rapidly; she died in July 2000 from septicemia resulting from gangrene of her right leg. Before her death she consented to donate her mandible for postmortem examination. The dissection included most of the mandibular body (Fig 2). Postmortem periapical radiographs showed no signs of radiolucency, infrabony pockets, or bone loss around the implants, and bone levels were maintained around the teeth (Fig 3).

Histologic Processing and Histomorphometric Analysis

The retrieved specimens were dehydrated in ethanol and then infiltrated in methacrylate resin. After polymerization the sections were ground to about 40 µm and stained with toluidine blue and basic fuchsin. The morphometric analysis was performed with a video camera (JVC TK C1380; Victor, Yokohama, Japan) and a frame grabber. The digitized images were analyzed using image analysis software (IAS 2000, Delta Sistemi, Rome, Italy) to evaluate bone volume, bone-implant contact (BIC), and HA disappearance. HA disappearance was calculated by measuring the percentage of the implant surface not covered by the HA coating, where the titanium surface was exposed to the surrounding tissues. The expected BIC was calculated using a method, described in a previous publication,[31] that indicates the BIC that would be expected on the day the implant was placed in this particular bone quality. For each implant, the 2 most central sections were analyzed according to 4 parameters (Table 2).

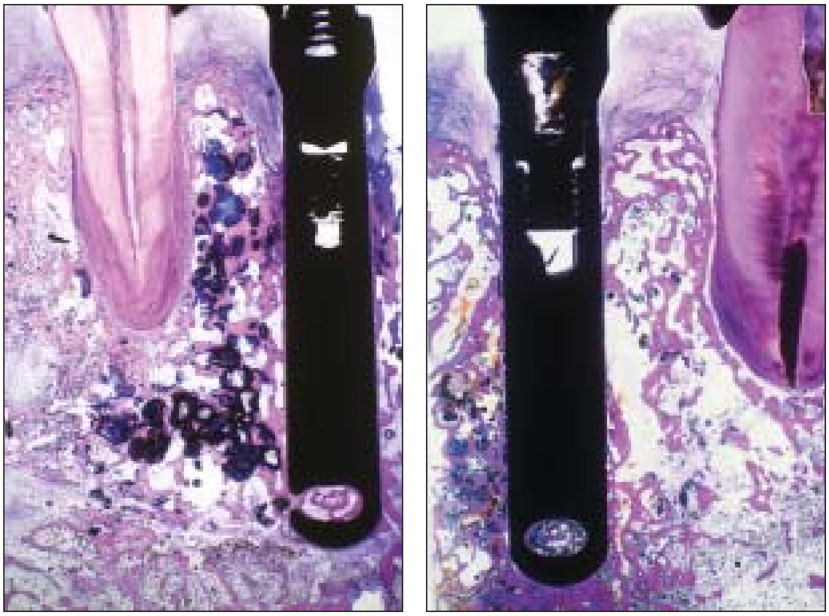
RESULTS

Histologic Evaluation

At low magnification, the implants appeared to be well integrated (Fig 4). In the supracrestal tissues, it was possible to note limited epithelial growth along the implant surface (Fig 5). In the connective tissue, fibers were oriented parallel to the implant surface, and no signs of inflammatory infiltrate were observed. The supracrestal tissue will be described in detail and discussed in another study.

A vertical angular bone defect was visible on the distal surface of the implant replacing the mandibular right canine (Fig 4a). It was possible to observe how different the level of the implant-abutment interface was with respect to the bone crest level: At the implant replacing the left lateral incisor the interface was almost at the crestal level (Fig 4b), while at the implant replacing the canine it was below the bone crest (Fig 4a). At the coronal portion of the

Table 2 HA Surface Analysis Parameters	
Parameter	**Description**
Bone volume (%)	The area occupied by the bone matrix over the entire microscopic field. Measured by outlining the bone surfaces to determine the surface area of bone in the microscopic field.
BIC (%)	The surface of the implant directly contacted by bone matrix. Expressed as the percentage of the implant surface at each side and for each section.
Expected BIC	Determined by the "superimposition technique"[31] and representing the BIC expected on the day of implant placement at a time when the implant surface had not generated any effect on bone growth.
% of HA disappearance	The surface of the implant not covered by HA. Expressed as percentage of the total implant surface.



Figs 4a and 4b *(Left)* Histologic view of the right implant. The crestal bone level is above the implant-abutment interface and higher adjacent to the right first premolar than on the contralateral side. Note a vertical angular bone defect at the distal side. *(Right)* Histologic view of the left implant. Note the implant-abutment location. Bone density appears to be low around the implant body and neck and higher in the periapical region. Bone is clearly visible inside the apical vent (toluidine blue-basic fuchsin; ×2.5).

implants surrounded by marginal soft tissues, HA coating was absent in some limited areas and the connective tissue was in direct apposition with the underlying titanium surface (Fig 6).

Around the canine implant (Fig 4a), bone was uniformly distributed, with trabecules functionally oriented along the implant surface. In the endosseous portion of the lateral incisor implant (Fig 4b), bone appeared denser in the apical portion, and trabecules appeared to be thinner on the middle and coronal portions of the implant.

At higher magnification, a thin continuous layer of lamellar bone was evident on most of the implant surface in tight apposition with the HA coating (Fig 7), which was maintained on most of the surface. BIC was evident also in the apical vent of both the implants examined (Fig 8). Bone appeared especially dense in the apical vent of the canine implant. A neurovascular bundle was visible in close apposition to the apical portion of this implant (Fig 8). In limited areas, HA was absent or reduced in thickness (Fig 9), and the metal implant surface was in direct contact with bone or in contact with bone medullar spaces (Fig 8). In several locations, a sharp passage was evident between areas without coating and areas where the coating was of normal thickness (Figs 6 and 9).

Histomorphometric Analysis

Histomorphometric analysis (Table 3) revealed a high percentage of BIC; values ranged from 67.09% to 92.80% in the different sections examined. The average BIC was 86.23% (SD 9.30) for the lateral incisor and 70.74% (SD 5.20) for the canine implant (Table 3). On the whole, the average BIC was 78.48% (SD 10.85). The expected BIC measured at 150 µm, 500 µm, and 1,000 µm from the implant surface averaged 38.09% for the lateral incisor implant and 37.01% for the canine implant (Table 3). In the sections examined, bone quality was D4,[32] in spite of being in the symphysis region. Bone volume values ranged from 19.91%

Fig 5 Marginal soft tissues around the left implant. The epithelium *(arrow)* ends below the implant-abutment interface. Note the BIC *(arrowhead)* where the HA coating disappeared (toluidine blue-basic fuchsin; ×5).

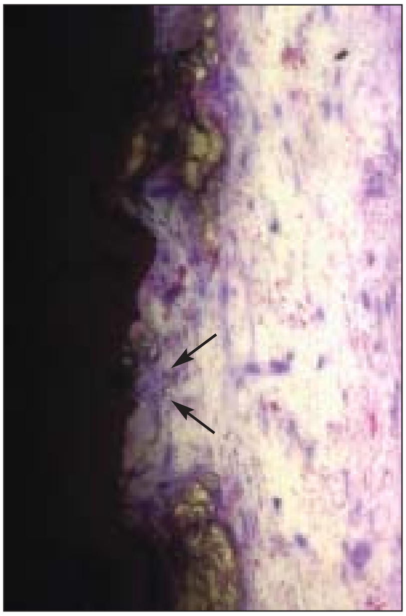


Fig 6 Soft tissue in contact with the coronal portion of the left implant. HA has disappeared in a few areas. A macrophage is visible over the titanium surface, but no inflammatory infiltrate is present *(arrows)* (toluidine blue-basic fuchsin; ×40).

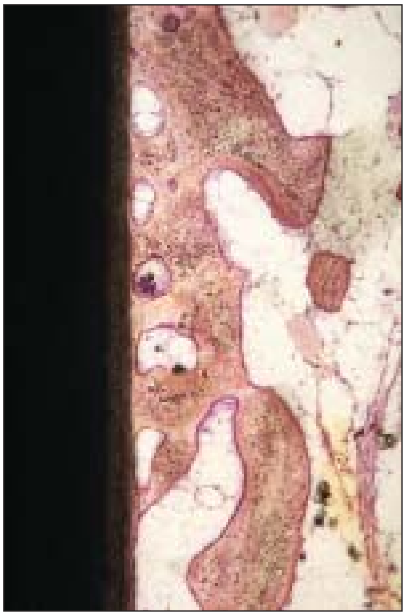
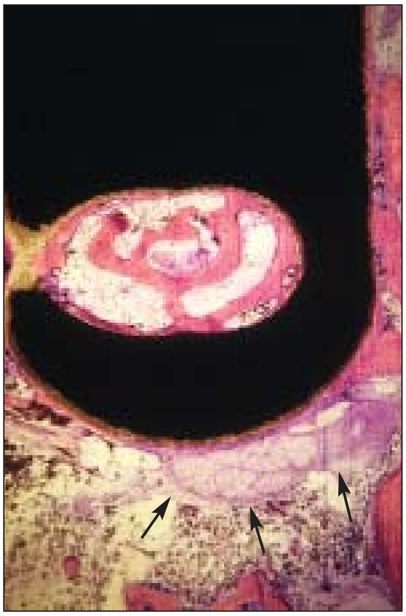


Fig 7 Coating is maintained on most of the surface of the left implant. A continuous layer of bone is visible in direct contact with the HA. Bone trabecules are perpendicularly oriented toward the surface (toluidine blue-basic fuchsin; ×10).

Fig 8 *(Left)* The apical region of the implant replacing the lateral incisor. BIC is almost 100% inside the apical vent. Note the neurovascular bundle *(arrow)* close to the apical portion of the implant (toluidine blue-basic fuchsin; ×2.5).

Fig 9 *(Right)* In limited regions of the implant surface, HA coating is absent. and the bone is in direct contact with the titanium surface (toluidine blue-basic fuchsin; ×2.5).



to 36.58%. The average bone volume values were 27.57% (SD 5.39) for the lateral incisor implant and 27.39% (SD 12.50) for the canine implant. The percentage of implant surface where HA had disappeared ranged from 20.69% to 23.70%, with means for the 2 implants of 23.50% (SD 0.30) and 22.00% (SD 1.90), respectively. The final average HA loss for the 2 implants was 22.75% (SD 1.39). Areas of HA coating disappearance were distributed along the surface and were not specific to the supracrestal portion.

Table 3 Mean (SD) Histomorphometric Values of Study Implants

Implant	BIC (%)	Expected BIC (%)	Bone volume (%)	HA disappearance (%)
Left lateral incisor	86.23 (9.30)	38.09	27.57 (5.39)	23.50 (0.30)
Right canine	70.74 (5.20)	37.01	27.39 (12.50)	22.00 (1.90)

DISCUSSION

In the present study, 2 HA-coated implants were retrieved from the mandibular symphysis after 10 years of functional loading with a fixed partial denture splinted to teeth. Histologic examination revealed a uniform layer of lamellar compact bone in contact with the HA coating on the implant surface, as observed in other studies.[21,22,24–30] Bone volume around the 2 implants examined measured 27.39% and 27.57% around the lateral and canine implants (Table 3), respectively, and was associated with D4 bone quality[32] in spite of being in the anterior region of the mandible. BIC was seen on 70.74% of the surface of the canine implant and on 86.23% of the lateral incisor implant (Table 3). The mean value was 78.48%, which was superior, in most cases, to the BIC values reported in previous histomorphometric studies (Table 1).[21,30] When the reason for implant removal was different from peri-implantitis or severe bone loss, BIC ranged from 45.9%[29] to 99.8%,[30] whereas in cases involving bone loss and suppuration, BIC ranged from 38%[26] to 60%.[28] The BIC reported in the present study appears to be very high when considering the low bone density of the region, which suggests that the HA coating played a role of in achieving good results.

The expected BIC measured at the 2 implants was 38.09% and 37.01% (Table 3), indicating that HA coating was conductive, as BIC was much higher than the expected BIC, and demonstrating that expected BIC reflected the bone quality of the site (bone volume was proportional to expected bone quality).[31]

The coating of the implants examined in the present study was maintained on most of the surface. HA coating disappearance did not exceed 25% of the implant surface after 10 years of functional loading (Table 3) and occurred on both the endosseous portion of the implant and on the coronal portion, which was in contact with epithelium and connective tissue. Instead of evaluating the percentage of surface lacking HA, most other histologic studies in dental literature have reported on HA thickness,[21,22,24,27,28] which is subject to errors related to tangential sectioning.

It is relevant that the loss of the HA coating did not compromise osseointegration. The underlying titanium of the endosseous portion of the implant was in direct contact either with bone or medullary spaces. On the other hand, the absence of BIC was not associated with HA disappearance, as has already been reported.[28,29]

Although some authors[25,26,33–35] claim that contact with soft tissue promotes degradation of the coating, in the present study resorption in the coronal portion of the implant was by no means specific to soft tissue contact. The observed pattern of HA disappearance may have been the result of a localized process of bone remodeling, as a sudden passage was evident between areas with thick HA coating and areas where HA disappeared (Figs 6 and 9). During bone remodeling, osteoclasts, locally activated, form a cavity 50 to 70 μm deep on the bone surface, where osteoblasts produce new bone thereafter. When this occurs at the coated implant surface, some areas of the coating can be resorbed and substituted with new bone. The amount of HA disappearance could be related to the amount of bone remodeling at the implant interface. No signs of HA coating infection, fracture, fatigue, or failure were evident in the present investigation. After 10 years of functional loading, the implants were clinically healthy and osseointegrated, and 80% of the coating had been maintained. The areas of coating disappearance did not appear to compromise bone bonding to the implant surface or clinical success.

CONCLUSION

In the case presented the HA coating performed well in the long term. The 20% absence of HA in a few areas did not compromise the direct contact between bone and the implant surface, since the bone achieved direct apposition to the underlying titanium surface.

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