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

Periklis T. Proussaefs, DDS[1]/Dimitris N. Tatakis, DDS, PhD[2]/
Jaime Lozada, DDS[3]/Nicholas Caplanis, DMD, MS[4]/Michael D. Rohrer, DDS, MS[5]

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.

[1]Postdoctoral Student, Center for Prosthodontics and Implant Dentistry, Loma Linda University, Loma Linda, California.
[2]Professor, Department of Periodontics, Loma Linda University, Loma Linda, California.
[3]Professor and Director, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, California.
[4]Assistant Professor, Center for Prosthodontics and Implant Dentistry and Department of Periodontics, Loma Linda University, Loma Linda, California; and Private Practice, Mission Viejo, California.
[5]Presidential Professor and Director, Hard Tissue Research Laboratory, University of Oklahoma College of Dentistry, Oklahoma City, Oklahoma.

Reprint requests: Dr Periklis T. Proussaefs, Center for Prosthodontics and Implant Dentistry, Loma Linda University, Loma Linda, CA 92350. Fax: (909) 558-4803.

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.[15,16]

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.

Fig 1 Periapical radiograph of maxillary right canine implant just before retrieval.

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.

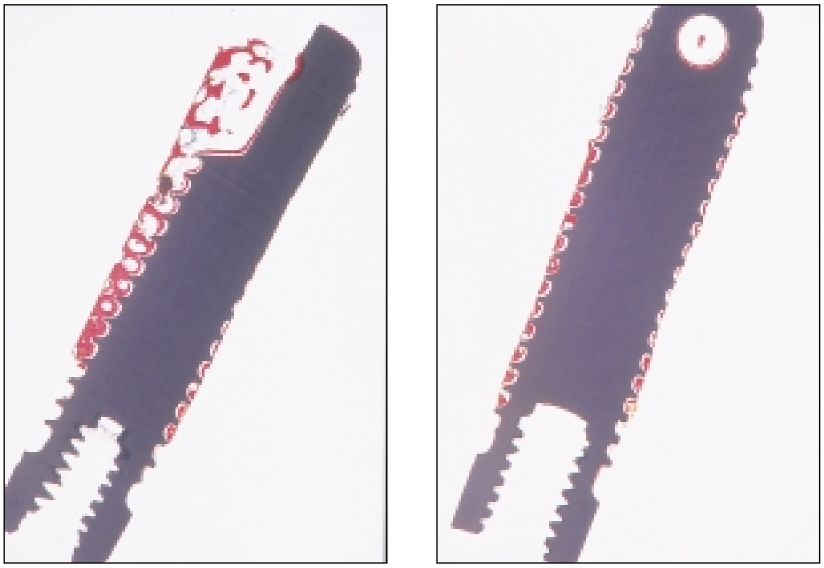
Radiographic Findings

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,



Figs 2a and 2b (*Left*) Histologic overview of maxillary left canine implant and (*right*) right canine implant (original magnification ×1).

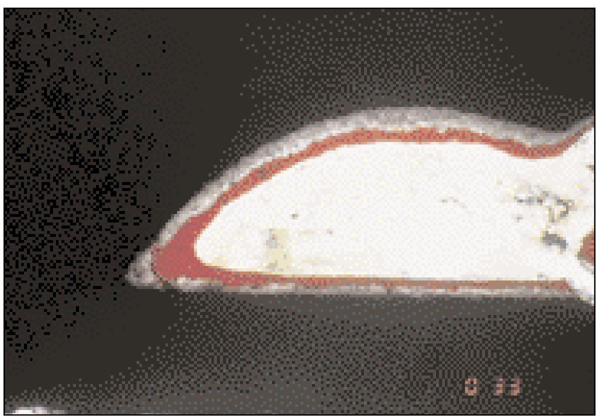


Fig 3 Vent area of maxillary right canine implant. Notice the excellent bone-to-implant adaptation along the entire surface (original magnification ×4).

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.

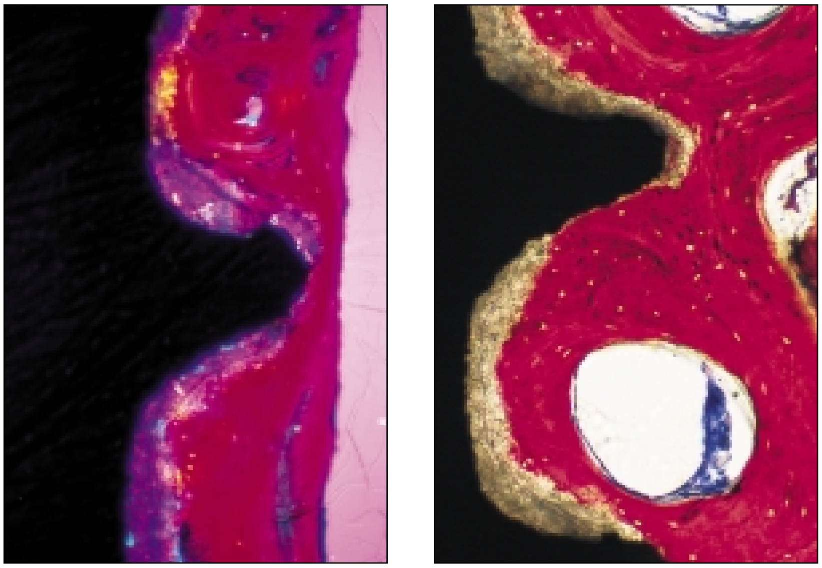
Based on measurements of the distance between the tips of the threads in these specimens and the manufacturer's stated distance of 0.63 mm, it was possible to calculate the thickness of the coating remaining. This was determined to be approximately 50 µm, equal to the original thickness provided by the 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 human[20,21] 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 Trisi[23] 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).

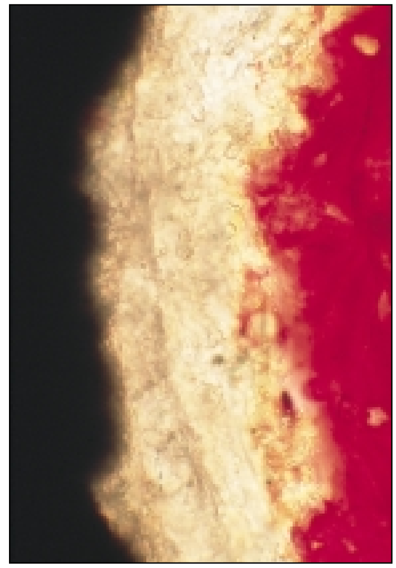


Fig 5 Higher-power view of Fig 4b (maxillary right canine implant). Notice the intimate contact between bone and the hydroxyapatite coating. Fine strands of bone appear to insert into the hydroxyapatite (original magnification ×40).

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

Report	Implant type (n)	Histologic findings	Reason for removal	Location	Time in function
Block and Kent 1993[38]	Cylindric (1)	Osseointegration, no HA degradation	Mandibulectomy	Posterior mandible	2 years
Piattelli et al 1993[28]	Cylindric (2)	Bone-implant contact 70%, no HA degradation	Psychologic	Mandible	1 and 2.5 years
Piattelli and Trisi 1993[23]	Cylindric (1)	Bone-HA contact, no HA degradation	Pain	Mandible (premolar)	1 year
Steflik et al 1994[39]	Threaded (1)	HA coating intact, interfaced by bone	Fracture	Mandible	1 year
Steflik et al 1994[39]	Cylindric (1)	No osseointegration, HA dislodgment	Radiolucency	Not reported	Not loaded
Piattelli and Trisi 1994[40]	Cylindric (4)	Bone-HA contact, no HA degradation	Psychologic, abutment fracture	Not reported	2 to 18 months post-placement
Piattelli et al 1995[41]	Cylindric (1)	No HA degradation	Infection	Posterior maxilla	2.5 years
Rohrer et al 1995[42]	Cylindric (4)	Osseointegration	Postmortem	Mandible	4 months
Piattelli et al 1996[17]	Cylindric (1)	No osseointegration, HA detached	Mobility	Mandible (symphysis)	1 year
Piattelli et al 1996[17]	Cylindric (1)	HA detached, HA degradation	Mobility	Anterior mandible	3 years
Piattelli et al 1996[17]	Cylindric (2)	No osseointegration, no HA degradation	Mobility/pain	Posterior maxilla	3 months
Takeshita et al 1997[18]	Threaded (1)	HA dissolution	Infection	Mandible	Not loaded
Piattelli et al 1998[43]	Cylindric (41)	HA degradation in some cases	Mobility Fracture Other	Variable	2.5 years (mean) 3 years (mean) Not reported
Rosenlicht and Tarnow 1999[26]	Threaded (2)	Osseointegration, tips devoid of HA	Psychologic	Grafted sinus	2.33 years
Piattelli et al 1999[44]	Cylindric (2)	Osseointegration, no HA degradation, some HA detached	Abutment fracture	Posterior mandible	1 year
Current report	Threaded (2)	Bone-implant contact 79% to 84%, tips devoid of HA	Prosthetic	Anterior maxilla	7 years

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

Report	Implant type (n)	Histologic findings	Reason for removal	Location	Years in function
Benjamin and Block 1989[34]	Subperiosteal (1)	Bone-HA contact	Psychologic	Maxilla	1
Bauer et al 1991[24]	Femoral stems (5)	Osseointegration, no HA degradation	Postmortem	Femur	0.5 to 2
Steflik et al 1994[39]	Subperiosteal (1)	Osseointegration	Infection	Mandible	4
Hardy et al 1994[25]	Femoral stems (2)	Osseointegration, no HA degradation, HA resorption (1)	Postmortem	Femur	2

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. Similar results have been reported by others.[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.[36,37] Albrektsson et al[36] observed excellent adaptation between a titanium implant and bone after 7.5 years. Sennerby et al[37] 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.

ACKNOWLEDGMENTS

The authors would like to thank Nobel Biocare for supporting the histologic processing of the specimens. They also acknowledge Hari Prasad, BS, MDT, for his technical support in the laboratory processing of the specimens.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Jemt T, Lekholm U, Adell R. Osseointegration in the treatment of partially edentulous patients. A preliminary study of 876 consecutively installed fixtures. Int J Oral Maxillofac Implants 1989;4:211–217.
3. Adell R, Eriksson B, Lekholm R, Brånemark P-I, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
4. Kent JN, Block MS, Finger IM, Guerra L, Larsen H, Misiek DJ. Biointegrated hydroxyapatite-coated dental implants: 5-year clinical observations. J Am Dent Assoc 1990;121:138–144.
5. Golec TS, Krauser JT. Long-term retrospective studies on hydroxyapatite-coated endosteal and subperiosteal implants. Dent Clin North Am 1992;36:39–65.
6. Saadoun AP, LeGall ML. Clinical results and guidelines on Steri-Oss endosseous implants. Int J Periodontics Restorative Dent 1992;12:486–495.
7. Lozada J, James RA, Roskovic M. HA-coated implants: Warranted or not? Compendium 1993;14(suppl 15):S539–S543.
8. Block MS, Gardiner D, Kent JN, Misiek DJ, Finger IM, Guerra L. Hydroxyapatite-coated cylindrical implants in the posterior mandible: 10-year observations. Int J Oral Maxillofac Implants 1996;11:626–633.
9. Hahn, J, Vassos DM. Long-term efficacy of hydroxyapatite-coated cylindrical implants. Implant Dent 1997;6:111–115.
10. Dhert WJ, Klein CP, Jansen JA, van der Velde EA, Vriesde RC, Rozing PM, de Groot K. A histological and histomorphometrical investigation of fluorapatite, magnesium/whitlockite, and hydroxyapatite plasma-sprayed coatings in goats. J Biomed Mater Res 1993;27:127–138.
11. Whitehead RY, Lucas LC, Lacefield WR. The effect of dissolution of plasma sprayed hydroxyapatite coatings in titanium. Clin Mater 1993;12:31–39.

12. Klein CP, Patka P, Wolke JG, de Blieck-Hogervorst JM, de Groot K. Long-term in vivo study of plasma-sprayed coatings on titanium alloys of tetracalcium phosphate, hydroxyapatite and alfa-tricalcium phosphate. Biomaterials 1994;15: 146–150.
13. Caulier H, van der Waerden JP, Paquay YC, Wolke JG, Kalk W, Naert I, Jansen JA. Effect of calcium phosphate (Ca-P) coatings on trabecular bone response: A histologic study. J Biomed Mater Res 1995;29:1061–1069.
14. Gross KA, Berndt CC, Goldschlag DD, Iacono VJ. In vitro changes of hydroxyapatite coatings. Int J Oral Maxillofac Implants 1997;12:589–597.
15. Donath K, Breuner G. A method for the study of undecalcified bones and teeth with attached soft tissues. The Sage-Schliff (sawing and grinding) technique. J Oral Pathol 1982; 11:318–326.
16. Rohrer MD, Schubert CC. The cutting-grinding technique for histological preparation of undecalcified bone and bone-anchored implants. Improvements in instrumentation and procedures. Oral Surg Oral Med Oral Pathol 1992;74:73–78.
17. Piattelli A, Scarano A, Piattelli M. Microscopical aspects of failure in osseointegrated dental implants: A report of five cases. Biomaterials 1996;17:1235–1241.
18. Takeshita F, Iyama S, Ayukawa Y, Suetsugu T, Oishi M. Abscess formation around a hydroxyapatite-coated implant placed into the extraction socket with autogenous bone graft. A histological study using light microscopy, image processing, and confocal laser scanning microscopy. J Periodontol 1997;68:299–305.
19. Jovanovic SA, Kenney EB, Carranza FA, Donath K. The regenerative potential of plaque-induced peri-implant bone defects treated by a submerged membrane technique: An experimental study. Int J Oral Maxillofac Implants 1993;8: 13–18.
20. Rams TE, Roberts TW, Feik D, Molzan AK, Slots J. Clinical and microbiological findings on newly inserted hydroxyapatite-coated and pure titanium human dental implants. Clin Oral Implants Res 1991;2:121–127.
21. Gatewood RR, Cobb CM, Killoy WJ. Microbial colonization on natural tooth structure compared with smooth and plasma-sprayed dental implant surfaces. Clin Oral Implants Res 1993;4:53–64.
22. Tillmanns HW, Hermann JS, Cagna DR, Burgess AV, Meffert RM. Evaluation of three different dental implants in ligature-induced peri-implantitis in the beagle dog. Part I. Clinical evaluation. In J Oral Maxillofac Implants 1997;12:611–620.
23. Piattelli A, Trisi P. Microscopic and chemical analysis of bone-hydroxyapatite interface in a human retrieved implant. A case report. J Periodontol 1993;64:906–909.
24. Bauer TW, Geesink RC, Zimmerman R, McMahon JT. Hydroxyapatite-coated femoral stems. Histological analysis of components retrieved at autopsy. J Bone Joint Surg [Am] 1991;73:1439–1452.
25. Hardy DC, Frayssinet P, Bonel G, Authom T, Le Naelou SA, Delince PE. Two-year outcome of hydroxyapatite-coated prostheses. Two femoral prostheses retrieved at autopsy. Acta Orthop Scand 1994;65:253–257.
26. Rosenlicht JL, Tarnow DP. Human histologic evidence of functionally loaded hydroxyapatite-coated implants placed simultaneously with sinus augmentation: A case report 2.5 years postplacement. J Oral Implantol 1999;25:7–10.
27. Edmonds RM, Yukna RA, Moses RL. Evaluation of the surface integrity of hydroxyapatite-coated threaded dental implants after insertion. Implant Dent 1996;5:273–278.
28. Piattelli A, Trisi P, Emanuelli M. Bone reactions to hydroxyapatite-coated dental implants in humans: Histologic study using SEM, light microscopy, and laser scanning microscopy. Int J Oral Maxillofac Implants 1993;8:69–74.
29. Hanisch O, Tatakis DN, Boskovic MM, Rohrer MD, Wikesjo UM. Bone formation and reosseointegration in peri-implantitis defects following surgical implantation of rhBMP-2. Int J Oral Maxillofac Implants 1997;12:604–610.
30. Carr AB, Gerald DA, Larsen PE. Quantitative histomorphometric description of implant anchorage for three types of dental implants following 3 months of healing in baboons. Int J Oral Maxillofac Implants 1997;12:777–784.
31. De Lange GL, De Putter C, De Wijs FL. Histological and ultrastructural appearance of the hydroxyapatite-bone interface. J Biomed Mater Res 1990;24:829–845.
32. Weilaender M, Kenney EB, Lekovic V, Beumer JD, Moy PK, Lewis S. Histomorphometry of bone apposition around three types of endosseous dental implants. In J Oral Maxillofac Implants 1992;7:491–496.
33. Tracy BM, Doremus RH. Direct electron microscopy studies of the bone-hydroxyapatite interface. J Biomed Mater Res 1984;18:719–726.
34. Benjamin LS, Block MS. Histologic evaluation of a retrieved human HA-coated subperiosteal implant: Report of a case. Int J Oral Maxillofac Implants 1989;4:63–66.
35. Steflik DE, Corpe RS, Lake FT, Sisk AL, Parr GR, Hanes PJ, Buttle K. Composite morphology of the bone and associated support-tissue interfaces to osseointegrated dental implants: TEM and HVEM analyses. Int J Oral Maxillofac Implants 1997;12:443–453.
36. Albrektsson T, Brånemark P-I, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand 1981;52:155–170.
37. Sennerby L. Ericson LE, Thomsen P, Lekholm U, Astrand P. Structure of the bone-titanium interface in retrieved clinical oral implants. Clin Oral Implants Res 1991;2:103–111.
38. Block MS, Kent JN. Cylindrical HA-coated implants—8-year observations. Compendium 1993;14(suppl 15): S526–S532.
39. Steflik DE, Parr GR, Singh BB, Lake FT, Siks AL, Howell FV, Shelton TW. Light microscopic and scanning electron microscopic analyses of dental implants retrieved from humans. J Oral Implantol 1994;20:8–24.
40. Piattelli A, Trisi P. A light and laser scanning microscopy study of bone/hydroxyapatite-coated titanium implants interface: Histochemical evidence of unmineralized material in humans. J Biomed Mater Res 1994;28:529–536.
41. Piattelli A, Cosci F, Scarano A, Trisi P. Localized chronic suppurative bone infection as a sequel of peri-implantitis in a hydroxyapatite-coated dental implant. Biomaterials 1995;16: 917–920.
42. Rohrer MD, Bulard RA, Patterson MK Jr. Maxillary and mandibular titanium implants one year after surgery: Histologic examination in a cadaver. Int J Oral Maxillofac Implants 1995;10:466–473.
43. Piattelli A, Scarano A, Piattelli M. Histologic observations on 230 retrieved dental implants: 8 years experience (1989–1996). J Periodontol 1998;69:178–184.
44. Piattelli A, Scarano A, Di Alberti L, Piattelli M. Bone-hydroxyapatite interface in retrieved hydroxyapatite-coated titanium implants: A clinical and histological report. Int J Oral Maxillofac Implants 1999;14:233–238.