A Pilot Study to Assess the Performance of a Partially Threaded Sintered Porous-Surfaced Dental Implant in the Dog Mandible

Eiji Shimada, DDS, PhD[1]/Robert M. Pilliar, BSc, PhD[2]/Douglas A. Deporter, DDS, PhD[3]/
Robert Schroering, DMD[4]/Eshetu Atenafu, MSc[5]

Purpose: *The purpose of this study was to compare patterns of crestal bone remodeling with 2 sintered porous-surfaced dental implant designs during a 14-month functional period.* ***Materials and Methods:*** *Two root-form press-fit dental implants were evaluated in healed extraction sites in dog mandibles. The standard (control) design was a press-fit implant with a 2-mm machined collar; the remainder of the implant had a sintered porous surface. The test or "hybrid" design had 3 coronal machined threads instead of a machined collar; the remainder of the implant had a sintered porous surface.* ***Results:*** *Standardized radiographs indicated significantly less crestal bone loss (0.82 to 0.93 mm versus 1.45 to 1.5 mm) with the hybrid design and a slower approach toward an apparent steady state (12 to 14 months for the hybrid versus 7 months for the standard design). Morphometric assessment of back-scattered scanning electron micrographs confirmed that crestal bone loss was significantly less for the hybrid design on all but the lingual implant aspect.* ***Conclusion:*** *The addition of coronal threads to an implant relying on a sintered porous surface geometry for its long-term osseointegration reduced the extent of crestal bone loss compared to a machined collar region.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:948–954

Key words: *coronal threaded collar, crestal bone loss, implant design, machined smooth collar*

The dental implants most commonly used to replace missing tooth roots are available in 2 basic designs: *(1)* threaded screws or *(2)* press-fit cylinders or press-fit truncated tapered cones.[1] These 2 basic designs offer different clinical advantages and limitations. For example, threaded screws provide good immediate implant fixation (if placed in bone types 1 or 2),[2] but must be used in long lengths (eg, 10 mm in the mandible and 13 mm in the maxilla) to develop and maintain fixation to bone ("osseointegration"), which primarily consists of linear bone-implant contact.[3,4] This is particularly important for implants with a machined finish.[5–7] Modification of threaded implants to provide irregular or roughened surface textures has been shown to improve performance, again provided that they are used in long lengths.[8] Threaded implant designs have been used successfully under the more demanding conditions of immediate implant loading.[9–13] *Immediate loading* is defined as functional loading of an implant within 48 hours of implant placement.[13] Press-fit implants are nonthreaded devices and rely on surface irregularities (eg, undercuts or surface porosity within which bone can form) to achieve osseointegration. Press-fit implants may be more suitable for use in bone of lower density (types 3 and 4)[2] and, in the case of sintered porous-surfaced (SPS) press-fit implants, in shorter lengths.[14,15] They provide less initial stability immediately after implant placement and therefore are not generally considered appropriate for immediate loading.

---

[1] Department of Dentomaxillofacial Radiology, School of Dentistry, Nihon University, Tokyo, Japan.

[2] Professor, Faculty of Dentistry, and Institute of Biomaterials & Biomedical Engineering, University of Toronto, Toronto, Ontario, Canada.

[3] Professor, University of Toronto, Faculty of Dentistry, Toronto, Ontario, Canada.

[4] Private Practice, Louisville, Kentucky.

[5] Biostatistician, Population Health Sciences, Hospital for Sick Children, University of Toronto, Toronto, Ontario, Canada.

Correspondence to: Dr Douglas A. Deporter, Faculty of Dentistry, University of Toronto, 124 Edward Street, Toronto, ON Canada M5G 1G6. Fax: 416 979-4936. E-mail: douglas.deporter@utoronto.ca

Fig 1 The control and hybrid implants; the hybrid implant had 3 coronal threads.

Fig 2 After an initial submerged healing interval, each implant was exposed and connected to a straight-sided abutment with a length of 5 mm and a diameter of 4.1 mm to effect some loading.

The present investigation was intended to determine whether there might be some advantage to adding several coronal threads to an SPS implant. If such a "hybrid" implant performed as well or better than a control SPS implant (ie, one without coronal threads), it might enable SPS implant designs to be used with immediate implant loading. As a first step in this longer-term endeavor, 2 SPS implant designs, a "hybrid" with 3 coronal threads and a control without these threads, were tested in dog mandible using standard submerged implant placement, initial healing for 8 weeks, and subsequent implant function for a 14-month period. Crestal bone remodeling with both implant designs was assessed both with standardized radiographs and with morphometric assessment of back-scattered electron micrographs of histologic sections prepared at the termination of the experiment.

MATERIALS AND METHODS

The 2 implant designs studied are shown in Fig 1. Both were made from titanium alloy (Ti-6Al-4V) with a machined core and sintered porous layer. Both had a tapered, truncated cone shape with an overall length of 5.3 mm for the hybrid and 5.6 mm for the control (nonthreaded) implant, with a maximum diameter at the coronal region of 4.1 to 4.2 mm. The control design had a 2.0-mm-long machined collar segment, while the remaining 3.6 mm of the implant body was covered with a porous layer approximately 0.3 mm thick formed by sintering Ti-6Al-4V powder particles to form a structure with interconnected porosity suitable for fixation by bone ingrowth.[16–19] The hybrid design had 3 machined threads occupying the most coronal 1.8 mm region, coronal to a machined collar region of 0.5 mm. The remaining 3.0 mm of implant length had the same porous surface as the standard (control) implant.

All animal handling and treatment procedures were approved by the University of Toronto Animal Care Committee. Except for regular tooth brushing (3 times weekly), all procedures were done under general anesthesia. The study involved 4 young adult male beagle dogs in which edentulous spaces were created by extracting the mandibular second, third, and fourth premolars and first molars bilaterally. After 3 months of extraction-site healing, 3 implants of each design were placed in each animal. One side of the mandible (determined by the toss of a coin) received 3 hybrid (test) implants, while the contralateral side received 3 standard (control) implants. Implant osteotomy sites were prepared using a motorized handpiece and 2 surgical burs. Each site was prepared initially with an end-cutting pilot bur to create site depth, followed by final preparation with a tapered implant bur made to correspond to the implant shape and dimensions.[17,19] At this point, each control implant was placed in an osteotomy site and tapped into place with a surgical mallet and an implant driver tip.[18] In contrast, each experimental implant, once inserted into its osteotomy site, was seated by means of a hand wrench, allowing the threaded segment to self-thread and engage the crestal bone.

All implants were placed using a 2-stage surgical protocol so as to allow undisturbed initial healing.[18,19] A healing interval of 8 weeks was allowed, after which implants were uncovered surgically and connected to transgingival abutments (Fig 2) to permit functional loading. Standardized periapical radiographs were obtained at this time and at monthly intervals thereafter for the duration of the experiment. The animals were observed for a functional loading interval of 14

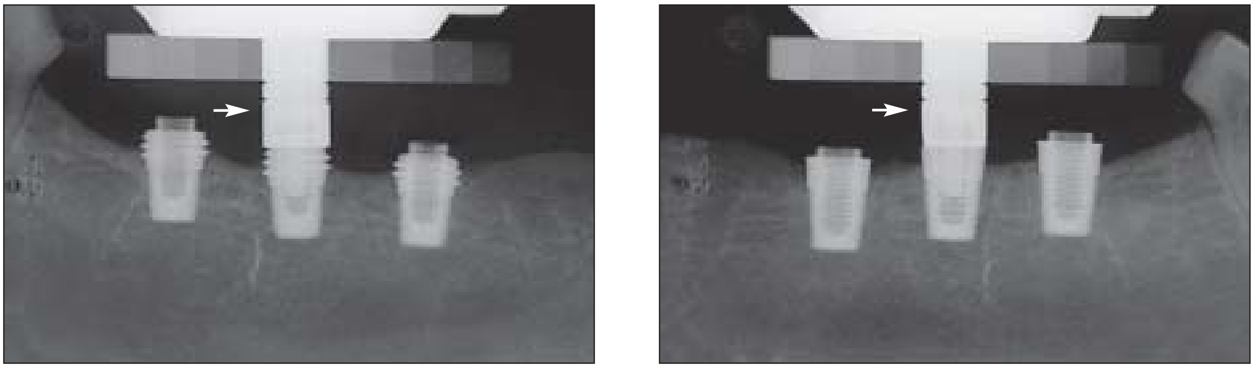


Fig 3 Periapical radiographs. The examples shown are the middle implants from each side of the mandible in 1 animal.

months, after which they were sacrificed by anesthetic overdose. Implant-containing tissue blocks were collected for morphologic assessment. Blocks were fixed by immersion (10% formalin) for 14 days, followed by dehydration in graded ethanols, immersion in xylene overnight, and embedding in methyl methacrylate (Osteo-Bed; Polysciences, Warrington, PA). Nondemineralized sections of each embedded specimen were prepared using routine methods[18] and examined using back-scattered scanning electron microscopy (BSEM; Hitachi S2500 scanning electron microscope, Mito City, Japan, with a Robinson Detector, ETPSEMRA, Sydney, Australia). BSEM images were used to quantify both bone contact with the sintered implant surface (contact length fraction [CLF]) and the extent of peri-implant bone retention (PBR) for each implant. CLF was determined by measuring the length of bone contact with the outermost surface of the sintered surface segment of each implant and converting this number into a fraction by dividing it by the total length of this implant surface available for bone contact. PBR was considered the straight-line distance from the apex of each implant (ie, from the machined implant core at the apex) to the highest point of crestal bone contact with the implant surface. Crestal bone loss was determined by subtracting PBR values from the known overall implant lengths, since implants were initially implanted as near as possible with their superior surface at the level of the crestal bone.

Twelve implants of each design were assessed. Each implant was sectioned to provide 6 to 8 sections,[18] which were measured at mesial, distal, buccal, and lingual aspects. Sigma Scan Pro Image Analysis Version 5 (SPSS, Chicago, IL) was used to collect these measurements.

Radiographic Assessment

Standardized periapical radiographs were obtained at the time of abutment connection and at monthly intervals thereafter during the 14-month functional period. Films were exposed using a customized radiographic stainless steel filmholder,[19] which was connected to each implant individually (Fig 3). Radiographs were subsequently digitized, and measurements were made from these images using Sigma Scan Pro Image Version 5 software (SPSS) to determine the most coronal point of crestal bone contact with the implant surface using the apex of the implant (including its porous surface layer) as the point of reference.

Statistical Analysis

Descriptive methods were used. The analysis of variance (ANOVA) was used. $P < .05$ was considered statistically significant whenever the number of categories being compared was more than 2. The Student *t* test was used where there were only 2 categories; *P* values less than or equal to .05 were considered significant. For the radiographic data with repeated measures from times 1 through 14, mixed model analysis with a first-order autoregressive covariance structure was used to analyze the effects of animal, and implant type over time and to determine the time for both implant types at which the crestal bone levels reached a stable endpoint. SAS for Windows version 9.1 was used for most analyses.

RESULTS

Radiographic Results

Successful implant fixation occurred within the 8-week healing interval. During the 14-month functional period, crestal bone loss with standard implants was limited to the machined collar segment and stopped after reaching the level of the junction between the machined collar and the porous surface (MP-jx). Mean crestal bone loss on the mesial and distal aspects of the standard implants was 1.50 mm and 1.45 mm, respectively (Table 1). A different pattern of crestal bone loss was seen with the hybrid design. While all 3 threads of the hybrid had been submerged in bone at the time of placement, the first 1 to 2 threads became denuded of bone. Mean crestal bone loss values for this design were 0.82 mm (on the mesial side) and 0.93 mm (on the distal side; Table 1). A *t* test performed for the measurements obtained from the last radiographs (ie, those obtained after 14 months in function) for all implants revealed no significant differences (*P* = .34) between the mesial and distal aspects for either implant type. However, there was a significant difference (*P* = .01) between the 2 designs, with the standard implants showing greater loss of crestal bone.

Average bone loss versus time in function with standard and hybrid implants is shown in Figs 4a and 4b, respectively. There was a significant change (*P* < .001) in crestal bone levels with time in function for both designs. Crestal bone levels reached a stable value at around 7 months for standard implants but not until 10 (distal aspect) to 12 (mesial aspect) months for hybrid implants. Time to achieve this stable level was significantly different (*P* = .0289). In both Figs 4a and 4b, MP-jx is shown as a reference point relative to the curve depicting bone loss. For both designs, bone loss was limited to machined segments of the implants and did not involve the sintered surface.

Morphometric Results

Examples of BSEM images for the 2 implant types are shown in Figs 5a and 5b. A typical outcome with a standard implant is seen in Fig 5a. While the implant was placed with its machined collar submerged in bone, by the end of the experiment crestal bone had reached the MP-jx. A typical outcome with the hybrid implant is seen in Fig 5b. While the hybrid had been placed with its 3 threads submerged in bone, by the end of the experiment crestal bone loss had exposed all or part of the first 2 threads.

CLF and PBR measurements were made separately for the mesial, distal, buccal, and lingual aspects of all implant sections. Mean CLF data are displayed in Table 2. Using ANOVA, and including ani-

Table 1 Radiographic Data for Mean Bone Loss (Mean ± SD)

	Mesial loss (mm)		Distal loss (mm)	
	Mean	SD	Mean	SD
Hybrid	0.82	0.40	0.93	0.43
Standard	1.50	0.39	1.45	0.32

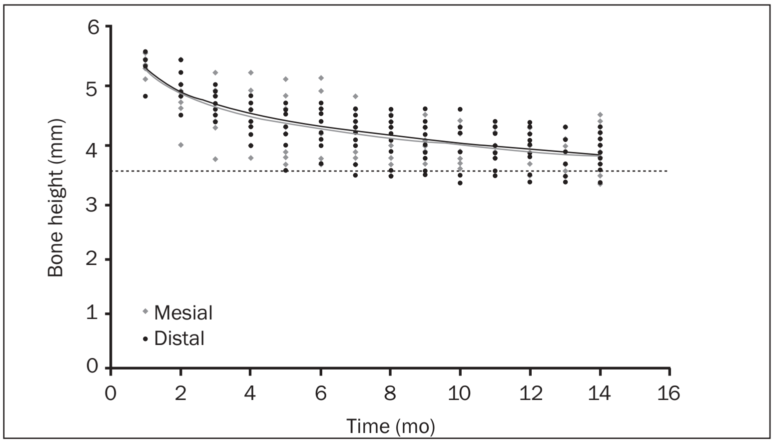


Fig 4a Pattern of crestal bone remodeling for the mesial and distal surfaces of the control (standard) implants. The broken horizontal line represents the MP-jx.

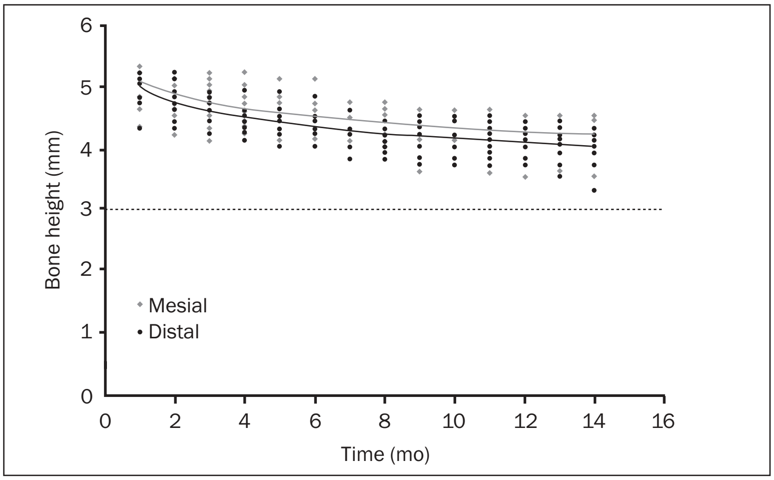
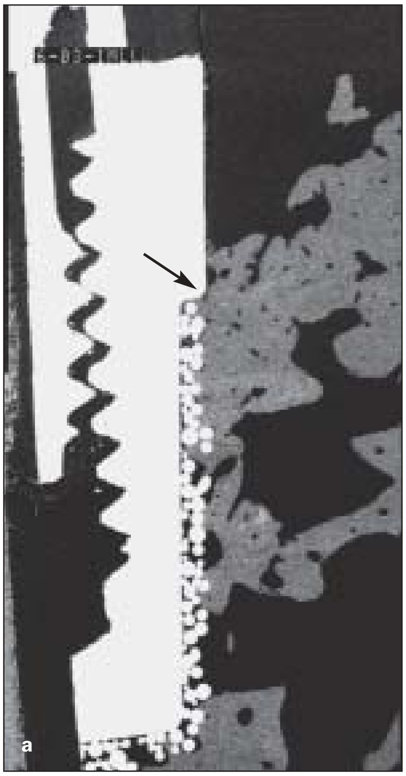


Fig 4b Pattern of crestal bone remodeling for the mesial and distal surfaces of the hybrid implants. The broken horizontal line represents the MP-jx. Crestal bone remained significantly higher in relation to this junction compared to standard implants.



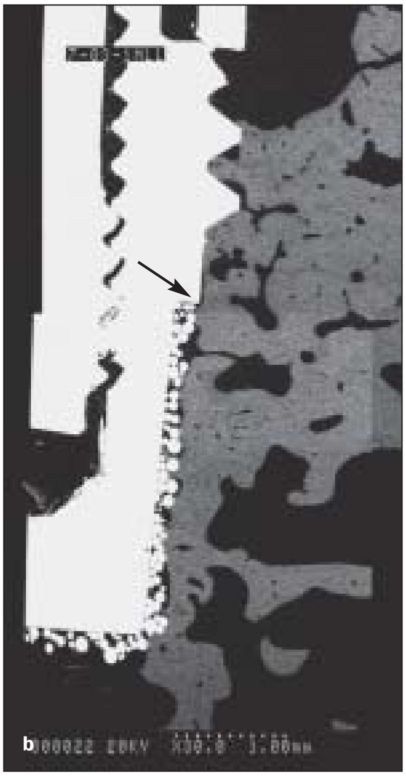


Fig 5a A sample BSEM image of the proximal surface of a control implant. Crestal bone loss was limited to the machined collar segment; it stopped coronal to the junction *(arrow)* of this collar with the sintered surface segment of the implant.

Fig 5b A sample BSEM of the proximal surface of a hybrid implant. Crestal bone loss was limited to the first 2 threads and was at a considerable distance from the junction *(arrow)* with the sintered surface segment of the implant.

Table 2 CLFs (% Contact)

	Buccal		Lingual		Mesial		Distal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hybrid	37.8*	9.9	35.4	9.6	36.7	6.9	39.4	9.5
Standard	24.1*	11.9	35.6	9.5	36.4	8.4	36.4	9.5

Measurements were made from BSEM images. The only significant difference (*) noted was between the buccal measurements for the 2 implant designs (*P* = .0057).

Table 3 PBR and CBL

	Buccal			Lingual			Mesial			Distal		
	Mean PBR	SD	CBL	Mean PBR	SD	CBL	Mean PBR	SD	CBL	Mean PBR	SD	CBL
Hybrid	4.10*	0.62	1.20*	4.41	0.45	0.89	4.61	0.25	0.69†	4.48	0.33	0.82†
Standard	3.59*	0.71	2.01*	4.42	0.45	1.18	4.23	0.39	1.37†	4.19	0.45	1.41†

Measurements were made in BSEM images. CBL = crestal bone loss. *P = .006. †P < .001. There was no significant difference in the lingual aspect.

mal as a variable, a significant difference in CLF between implant types was observed only at the buccal aspect of the implants. There was significantly less bone contact with the porous surface on the buccal aspects of standard implants (*P* = .006).

PBR measurements are shown in Table 3. The only significant difference in PBR between implant types was found with respect to buccal PBR, which was significantly greater for hybrid implants than for standard implants.

Mean crestal bone loss (CBL) values for each aspect of both implant types also are shown in Table 3. These were calculated by subtracting PBR values from known implant lengths (5.6 mm for standard implants versus 5.3 mm for hybrid implants). Crestal bone loss was significantly less for the hybrid implants on all aspects but the lingual aspect.

DISCUSSION

There is an increasing trend for clinicians to utilize immediate or early functional loading following placement of threaded dental implants.[20–25] Patients without sufficient bone height to receive long threaded implants (ie, > 10 mm) generally are not candidates for immediate or early implant loading. These patients commonly are managed with extra grafting procedures and delayed loading after complete site healing and implant integration. Therefore, there is a potential need for a short dental implant design that could be used with immediate loading with such patients.

The present investigation was undertaken to study an implant designed as a hybrid SPS device that might eventually be used under conditions of immediate load. In this first investigation, however, implants were placed using a submerged technique to gather baseline data on implant integration and crestal bone remodeling with delayed loading of hybrid versus standard SPS implants. The objective was to determine whether adding 3 coronal machined threads to an SPS implant would alter the degree of bone-implant contact and/or the extent of crestal bone loss under functional loads compared to standard SPS implants, which have been examined previously.[14,15,18,19] Results showed that the addition of 3 machined coronal threads to an SPS implant had no negative impact on implant integration and that it reduced crestal bone loss during a 14-month functional period in the dog mandible.

BSEM analyses showed significantly less bone-implant contact for the buccal surface of the standard implants than for those of the hybrid implants. This observation may be related to buccal bone thickness and/or density and its lower vascularity. The reasons for this difference in buccal bone-implant contact between the 2 implant designs are uncertain. Operator bias in implant positioning during osteotomy preparation favored retention of a thicker buccal plate with hybrid implants. Since %CLF values were similar for the 2 designs for the other implant aspects (~ 32% to 39%), it appears that initial implant stability, a necessary condition for uninhibited bone ingrowth,[26] was sufficient with both designs. Another factor that might have influenced the extent of bone ingrowth was difference in local peri-implant bone stress field during healing, since this can influence osteogenesis.[27–29] However, it is unlikely that differences in peri-implant bone stresses occurred between implants since, again, similar %CLF values were determined for all but the buccal aspects of the 2 designs.

The morphometric measurements indicated lower values for bone loss compared to those determined from radiographs. This difference between the 2 methods of assessment was believed to be due to the use of different reference points. Radiographic measurements were done in relation to implant apices, including the porous surface on these apices, while the more accurate morphometric measurements were made from the machined surface at the apex of the implant core structure (ie, excluding the approximately porous layer, which was approximately 0.3 mm thick). Although the radiographic measurements allowed a chronologic recording of crestal bone changes, the morphometric data determined at the end of the study are considered more accurate.

Both radiographic and morphometric data showed less crestal bone loss with the hybrid design. This might be explained via differences in stress transfer in the coronal regions of the 2 designs.[30,31] Another possible contributing factor leading to lower crestal bone loss with the hybrid may have been the effect of design differences on re-establishment of "biologic width."[32,33] Biologic width with fully threaded implants constitutes a zone of fibrous connective tissue approximately 1.0 to 1.5 mm thick separating crevicular epithelium from underlying bone. This corresponds closely to the amount of crestal bone loss seen with the standard SPS design. The standard SPS implant had a 2-mm machined collar that was fully submerged in bone at implant placement. Following uncovering of healed standard SPS implants and onset of function, 1.2 to 2.0 mm of machined collar became denuded of bone due to crestal remodeling (with the greatest amount of crestal bone loss on the buccal aspect). In contrast, while the hybrid had a coronal machined threaded segment of 2.3 mm height, only 0.69 to 1.2 mm of this segment was denuded of bone after the 14-month loading period. For the threaded portion of the hybrid, the implant surface/unit implant length was equal to approximately 1.6 times that of the collar segment of the standard SPS implant. Hence, considering levels of crestal bone loss for the hybrid (ie, ~ 0.69 to 1.2 mm), crestal bone loss along the actual length (ie, ×1.6) of the implant surface was equal to 1.1 to 1.8 mm, which is similar to crestal bone loss observed with the standard design (1.2 to 2.0 mm). Crestal loss with the hybrid design also compared well to values attributable by others to biologic width accommodation with fully threaded implants.[32,33]

CONCLUSION

The addition of 3 coronal threads to a short sintered porous-surfaced implant did not significantly alter initial implant integration during an 8-week submerged healing interval in dog mandible. During a

14-month functional period, this hybrid SPS implant showed significantly less crestal bone loss than the standard SPS design with a 2-mm machined collar.

ACKNOWLEDGMENTS

The authors wish to thank Ms Nancy Valiquette, Ms Lynda Woodcock, and Dr Thomas Kauffman for valuable technical and administrative support. The implants were provided by Innova Corporation, Toronto, Ontario, Canada, and partial funding of the study was provided by a grant from the Ontario Research Development Challenge Fund.

REFERENCES

1. Sykaras N, Iacopino AM, Marker VA, Triplett RG, Woody RD. Implant materials, designs, and surface topographies: Their effect on osseointegration. A literature review. Int J Oral Maxillofac Implants 2000;15:675–690.
2. Lekholm U, Zarb G. Patient selection and preparation. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
3. Pilliar RM. An overview of surface variability of metallic endosseous dental implants: Textured and porous-surfaced designs. Implant Dent 1998;7:305–314.
4. Hagi D, Deporter DA, Pilliar RM, Arenovich T. A targeted review of study outcomes with short (≤ 7 mm) endosseous dental implants placed in partially edentulous patients. J Periodontol 2004;75:798–804.
5. Naert I, Koutsikakis G, Duyck J, Quirynen M, Jacobs R, van Steenberghe D. Biologic outcome of implant-supported restorations in the treatment of partial edentulism. Part I: A longitudinal clinical evaluation. Clin Oral Implants Res 2002;13:381–389.
6. Tawil G, Younan R. Clinical evaluation of short machined surface implants followed for 12 to 92 months. Int J Oral Maxillofac Implants 2003;18:894–901.
7. Weng D, Jacobson Z, Tarnow D, et al. A prospective multicenter clinical trial of 3i machined-surface implants: Results after 6 years of follow-up. Int J Oral Maxillofac Implants 2003;18:417–423.
8. Khang W. A multicenter study comparing dual acid-etched and machined-surface implants in various bone qualities. J Periodontol 2001;72:1384–1390.
9. Bogaerde LV, Pedretti G, Dellacasa P, Mozzati M, Rangert B. Early function of splinted implants in maxillas and posterior mandibles using Brånemark system, machined-surface implants: An 18-month prospective clinical multicenter study. Clin Implant Dent Relat Res 2003;5:21–28.
10. Cannizzaro G, Leone M. Restoration of partially edentulous patients using dental implants with a microtextured surface: A prospective comparison of delayed and immediate full occlusal loading. Int J Oral Maxillofac Implants 2003;18:512–522.
11. Ganeles J, Wismeijer D. Early and immediately restored and loaded dental implants for single-tooth and partial-arch applications. Int J Oral Maxillofac Implants 2004;19(suppl):92–102.
12. Morton D, Jaffin R, Weber H-P. Immediate restoration and loading of dental implants: Clinical considerations and protocols. Int J Oral Maxillofac Implants 2004;19(suppl):103–108.
13. Cochran DL, Morton D, Weber H-P. Consensus statements and recommended clinical procedures regarding loading protocols for endosseous dental implants. Int J Oral Maxillofac Implants 2004;19(suppl):109–113.
14. Deporter DA, Pilliar RM, Todescan R, Watson P, Pharoah M. Managing the posterior mandible of partially edentulous patients with short, porous-surfaced dental implants: Early data from a clinical trial. Int J Oral Maxillofac Implants 2001;16:653–658.
15. Deporter DA, Todescan R, Riley N. Porous-surfaced dental implants in the partially edentulous maxilla: Assessment for subclinical mobility. Int J Periodontics Restorative Dent 2002;22:184–192.
16. Simmons C, Valiquette N, Pilliar RM. Osseointegration of sintered porous-surfaced and plasma spray-coated implants: An animal model study of early post-implantation healing response and mechanical stability. J Biomed Mater Res 1999;47:127–138.
17. Pilliar RM. Dental implants: Materials and design. J Can Dent Assoc 1990;56:857–861.
18. Deporter DA, Watson PA, Pilliar RM, Chipman M, Valiquette NA. A histological comparison in the dog of porous-surfaced vs threaded dental implants. J Dent Res 1990;69:1138–1145.
19. Al-Sayyed A, Deporter DA, Pilliar RM, et al. Predictable crestal bone remodeling around two porous-surfaced titanium alloy dental implant designs. A radiographic study in dogs. Clin Oral Implants Res 1994;5:131–141.
20. Bogaerde LV, Pedretti G, Dellacasa P, Mozzati M, Rangert B. Early function of splinted implants in maxillas and posterior mandibles using Brånemark system machined-surface implants: An 18-month prospective clinical multicenter study. Clin Implant Dent Relat Res 2003;5(suppl):21–28.
21. Quinlan P, Nummikoski P, Schenk R, et al. Immediate and early loading of SLA ITI single-tooth implants: An in vivo study. Int J Oral Maxillofac Implants 2005;20:360–371.
22. Rocci A, Martignoni M, Gottlow J. Immediate loading in the maxilla using flapless surgery, implants placed in predetermined positions and prefabricated provisional restorations: A retrospective 3-year clinical study. Clin Implant Dent Rel Res 2003;5(suppl):29–36.
23. Testori T, Meltzer A, Del Fabbro M, et al. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw. A multicenter prospective study. Clin Oral Implants Res 2004;15:278–284.
24. Lekholm U. Immediate/early loading of oral implants in compromised patients. Periodontology 2000 2003;33:194–203.
25. Balshi S, Wolfinger G, Balshi T. A prospective study of immediate functional loading following the Teeth in a Day protocol. A case series of 55 consecutive edentulous maxillae. Clin Implant Dent Relat Res 2005;7:24–31.
26. Carter DR, Beaupré GS, Giori NJ, Helms JA. Mechanobiology of skeletal regeneration. Clin Orthop Relat Res 1998;355(suppl):S41–S55.
27. Goodship AE, Kenwright J. The influence of induced micromovement upon the healing of experimental tibial fractures. J Bone Joint Surg 1095; 67B:650-655.
28. Simmons CA, Meguid SA, Pilliar RM. Differences in osseointegration rate due to implant surface geometry can be explained by local tissue strains. J Orthop Res 2001;19:187–194.
29. Pilliar RM, Lee JM, Maniatopoulos C. Observations on the effect of movement on bone ingrowth into porous-surfaced implants. Clin Orthop Relat Res 1986;208:108–113.
30. Pilliar RM, Deporter DA, Watson PA, Valiquette N. Dental implant design: Effect on bone remodeling. J Biomed Mater Res 1991;25:467–483.
31. Vaillancourt H, Pilliar RM, McCammond D. Finite element analysis of crestal bone loss around porous-coated dental implants, J Appl Biomater 1995;6:267–282.
32. Abrahamsson I. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. Clin Oral Implants Res 1996;7:212–219.
33. Berglundh T, Lindhe J. Dimension of the peri-implant mucosa. Biologic width revisited. J Clin Periodont 1996;23:971–973.