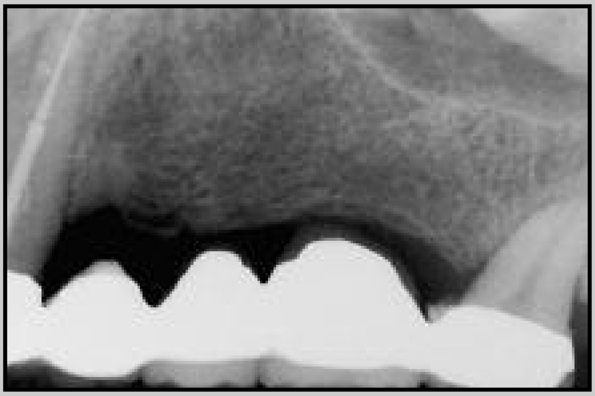
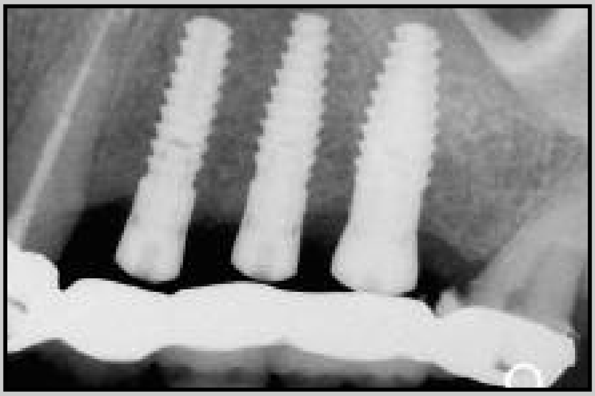
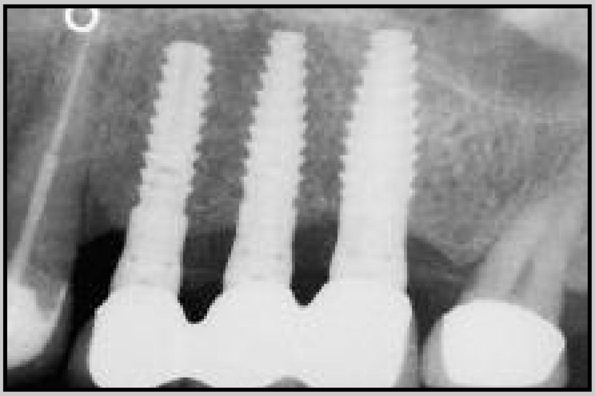


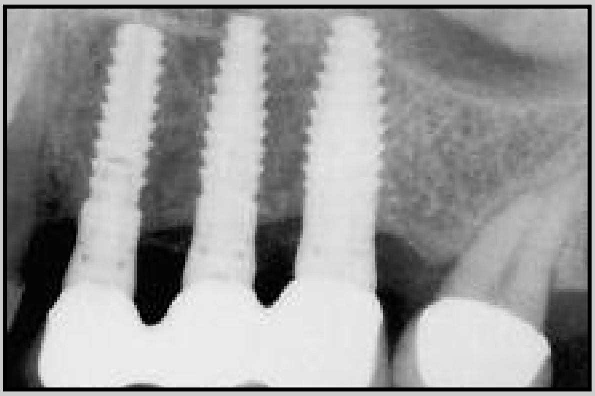
2005 (baseline)



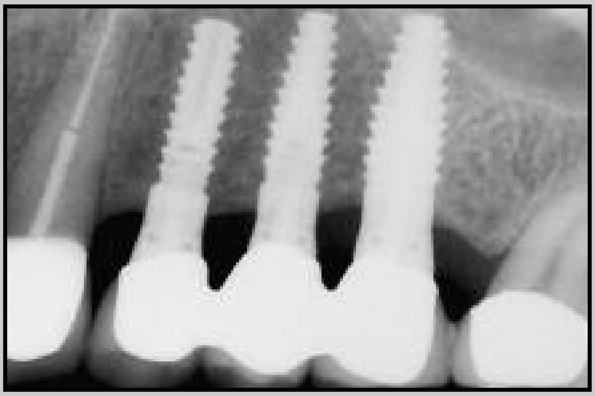
2005



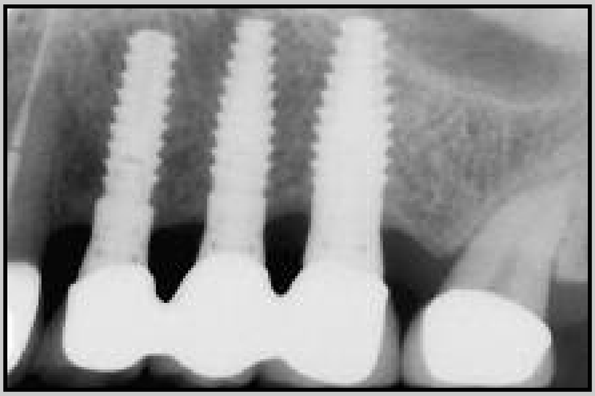
2006



2007

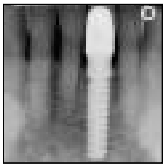


2008



2009

Radiographic Analysis of Crestal Bone Levels Around Laser-Lok Collar Dental Implants



*Cary A. Shapoff, DDS**
*Brent Lahey, DMD, MS**
*Perry A. Wasserlauf, DMD**
*David M. Kim, DDS, DMSc***

This retrospective radiographic study was organized to evaluate the clinical efficacy of implants with Laser-Lok microtexturing (8- and 12-μm grooves). A physical attachment of connective tissue fibers to the Laser-Lok microtexturing on the implant collar has been previously demonstrated using human histology, polarized light microscopy, and scanning electron microscopy. This analysis of 49 implants demonstrated a mean crestal bone loss of 0.44 mm at 2 years postrestoration and 0.46 mm at 3 years. All bone loss was contained within the height of the collar, and no bone loss was evident to the level of the implant threads. The radiographic evaluation of the clinical application of this implant supports previous findings that establishing a biologic seal of connective tissue fibers around a dental implant may be clinically relevant. (Int J Periodontics Restorative Dent 2010;30:129–137.)

Crestal bone resorption (dieback) to the first coronal implant thread of a two-piece dental implant is commonly observed after attachment of the abutment. It is recognized that the functionally loaded dental implant averages approximately 1.0 mm of bone loss in the first year, and at least 0.10 mm per year in function afterward.[1–4] The possible causative factors are speculated to be inadvertent surgical trauma, occlusal overload resulting in high stress at the implant-bone interface, a microgap leading to bacterial infiltration at the implant-abutment junction, and the resulting apical establishment of the biologic width to accommodate the supracrestal connective tissue. The problems associated with continual crestal bone resorption include the formation of an uncleansable peri-implant sulcus with the presence of inflammation, recession leading to loss of interproximal soft tissue, and the potential for bone loss that may compromise the stability of the implant.

The peri-implant connective tissue that is established following implant surgery with a Laser-Lok implant (BioLok International, now manufactured by Biohorizons) acts as

*Private Practice, Fairfield, Connecticut.
**Assistant Professor, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts.

Correspondence to: Dr Cary A. Shapoff, 71 Beach Road, Fairfield, CT 06430; email: cas@shapoff.com.

an effective barrier to the apical migration of epithelial attachment.[5] This translates into the protection of the bone level by 1 mm of connective tissue. In comparison, the natural tooth has connective tissue attached via Sharpey fibers to the cementum surface in a perpendicular plane. Previous observations with osseointegrated implants describe these collagen fibers as being parallel to the implant.[6–14] A physical attachment of the connective tissue fiber to the Laser-Lok microchannels on the implant collar has been clearly demonstrated using human histology, polarized light microscopy, and scanning electron microscopy.[5] The use of Laser-Lok microchannels resulted in a perpendicular, functional physical attachment that helped to stabilize the bone level and diminish the loss of crestal bone.[5,15]

The goal of this retrospective radiographic study was to review the efficacy of the Laser-Lok collar to preserve the crestal bone level in a wide variety of situations encountered in a private practice setting. Radiographic evaluation was deemed to be suitable because crestal bone level changes observed in standardized periapical radiographs are highly accurate when compared to nondecalcified histologies.[16]

Method and materials

This study was conducted in a single private office on 41 consecutively treated patients (mean age, 62 years) who received 50 Laser-Lok dental implants between February 2005 and January 2007. Thirty-seven implants were placed in the maxilla and 13 were placed in the mandible (35 internal-connection and 15 external-hex). The appropriate medical and dental histories were reviewed, clinical and radiographic examinations were conducted, and each patient signed an informed consent form. Patients selected were those typically seen by referral in a periodontal private practice without significant medical history or medications that would preclude them from most periodontal surgical procedures. Patients were prepared for surgery in accordance with accepted dental practice guidelines, and implant surgeries were performed on an outpatient basis. Full-thickness flaps were elevated with a horizontal incision to reveal the bone surface after administration of local anesthetics (2% lidocaine with 1:100,000 epinephrine). Vertical incisions were used as necessary for visibility. Implant osteotomies were prepared according to the manufacturer's guidelines, and the implants were placed. Primary flap closure was obtained with resorbable and nonresorbable sutures. Postoperative digital periapical radiographs were made using a paralleling technique to record the exact bone level at baseline (Gendex Dental Systems, KaVo). Patients were instructed not to brush or floss at the surgical sites until suture removal at 14 days postoperative. They were also instructed to rinse with 0.12% chlorhexidine mouthwash daily for 1 week and were prescribed appropriate antibiotics and analgesics.

Routine postoperative evaluations were conducted until the time of stage-two surgery and abutment connection. Cover screws were replaced with healing abutments using a punch technique if adequate keratinized gingiva was present around the facial aspect of the implant. In sites with an inadequate zone of gingiva, a full-thickness mucoperiosteal flap was elevated, healing abutments were placed, and the flap was repositioned apically to create a wider zone of gingiva. A postoperative digital periapical radiograph was then taken. Mean time from the initial placement surgery to healing abutment connection was 4.8 months.

Postrestoration radiographs were taken shortly after restoration and then at 1 and approximately 2 and 3 years. These digital radiographs were imported into Photoshop CS3 using the Analysis Toolkit (Adobe). Three measurements were obtained for each implant: implant length at midaxis and mesial and distal crestal perpendicular bone lengths to the apical end of the implant (used as a reference point). All measurements were then exported into an Excel (Microsoft 2007) spreadsheet for analysis. Mesial and distal crestal perpendicular bone lengths were standardized with the known midaxis implant length. Mesial and distal crestal bone lengths were then averaged and the mean bone level change was computed. Each implant site was serialized and coded for objective and unbiased measurements.

Results

Fifty implants were placed in a wide variety of clinical situations normally encountered in a periodontal office. Implants were placed in edentulous sites, previously bone-grafted sites,

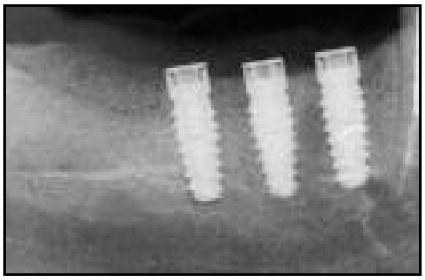


Fig 1a *Initial placement of three Laser-Lok implants in a 75-year-old woman with a strong bruxism habit.*

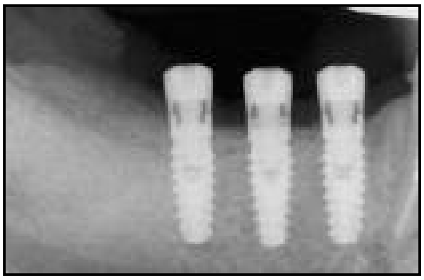


Fig 1b *Healing abutments placed 5 months after surgery.*

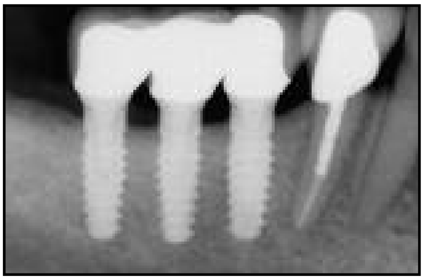


Fig 1c *Radiograph of restored Laser-Lok implants in function for 2 years.*

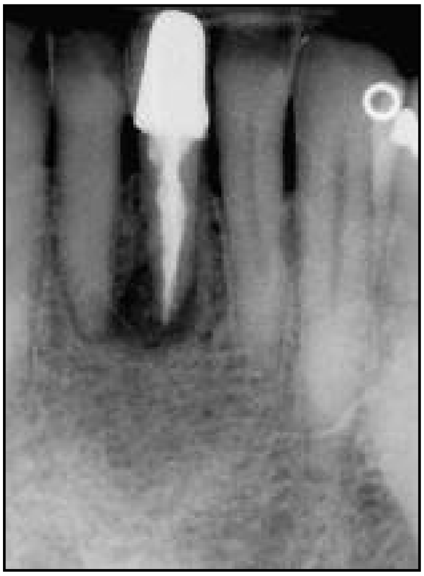


Fig 2a *Initial radiograph of a defect around the mandibular left central incisor. The site showed complete loss of the facial plate and the implant was placed using a bone graft and resorbable barrier membrane.*

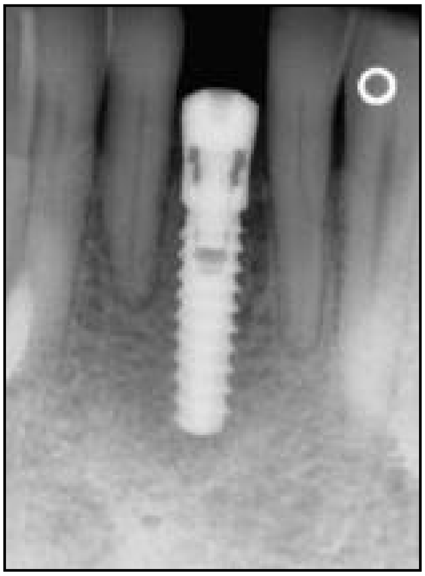
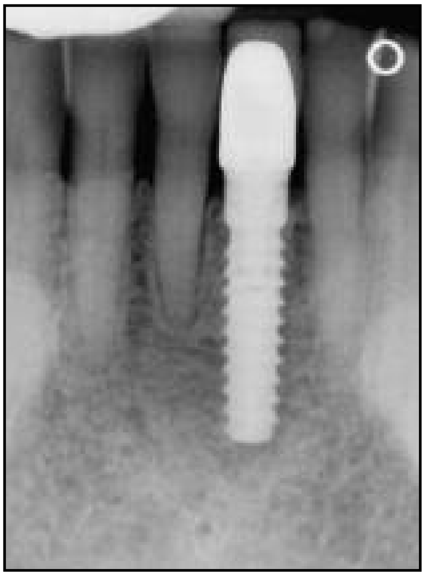


Fig 2b *Healing abutment placed 5 months following implant placement with simultaneous bone grafting.*

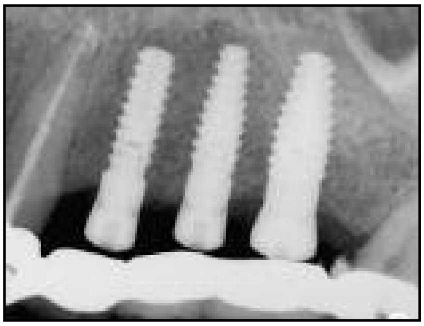


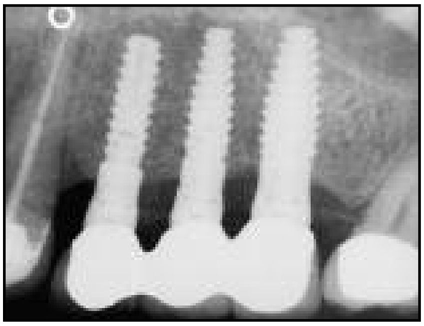
Figs 2c (above) **and 2d** (below) *Two-year* (c) *radiograph and* (d) *clinical photograph of the restored tooth. Note the stable crestal bone levels.*

and immediately after extraction (Figs 1 to 3). Thirty-nine of 50 implants were placed in the anterior region (78%), and the remaining 11 were placed in molar sites (22%) (Figs 4 and 5). One implant failed as a result of an endodontic abscess on an adjacent tooth; thus the total number of implants eligible for radiographic analysis was 49.

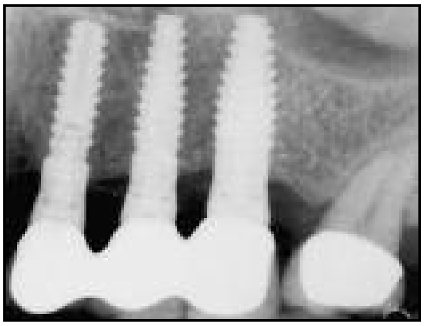
Fig 3a (left) *Initial radiograph of a failed fixed partial denture in the maxillary left posterior region. A computed tomography scan revealed a ridge width of 4 to 5 mm, requiring a ridge-splitting technique at the time of implant placement.*

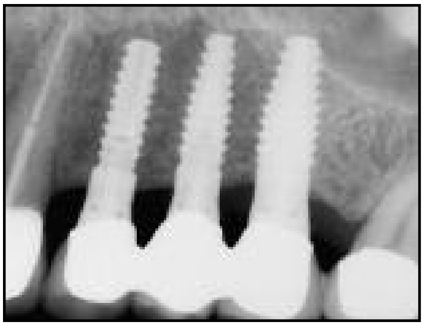
Fig 3b (right) *Healing abutments placed 3.5 months following ridge splitting and implant placement.*

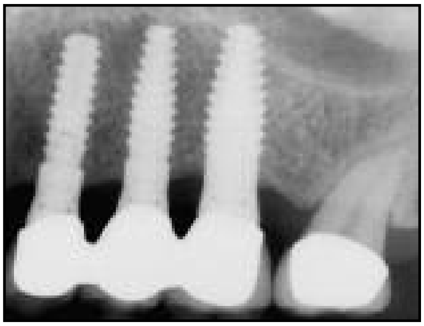




Figs 3c to 3f *Digital radiographs taken at* (top left) *1 year,* (top right) *2 years,* (bottom left) *3 years, and* (bottom right) *4 years postrestoration showing crestal bone stability.*







The radiographic crestal bone levels were expressed in millimeters from the top of the implant platform to the first bone-to-implant contact. Forty-one of the original 49 implants had postrestoration radiographs taken at 2 years (Figs 1, 2, and 4), and 30 of those implants had postrestoration radiographs taken at 3 years (Figs 3 and 5). A small number of implants were able to be followed radiographically for even longer periods of time (Fig 3f). The mean crestal bone level change for the 2-year postrestoration group was –0.44 ± 0.10 mm, while the mean crestal bone level change for the 3-year postrestoration group was –0.46 ± 0.12 mm (Fig 6). There was no statistically significant difference in the mean crestal bone level change between these two groups ($P > .05$). In addition, data from implants placed in edentulous sites, previously grafted sites, or those placed immediately did not show statistically significant differences among them and therefore, all implants were analyzed collectively.

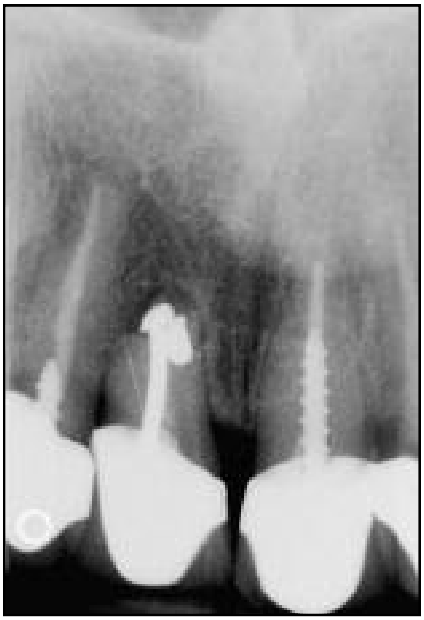


Fig 4a *Initial radiograph of a hopeless maxillary right central incisor.*

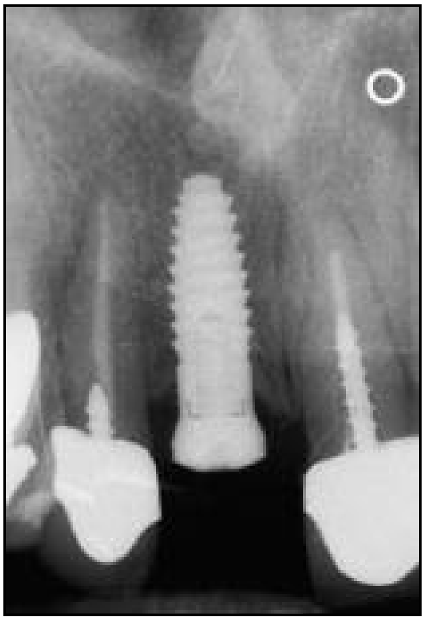


Fig 4b *Healing abutment at 6 months after implant placement and bone grafting of the socket.*

Fig 4c *Digital radiograph of Laser-Lok 5-mm-wide implant at 2 years post-restoration.*

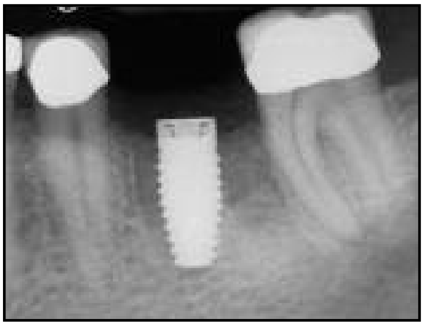


Fig 5a *Initial placement of a 5-mm Laser-Lok implant in site grafted 5 months earlier following extraction of the fractured tooth.*

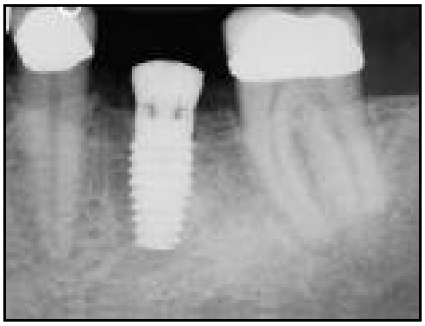


Fig 5b *A healing abutment was placed 3 months after implant placement.*

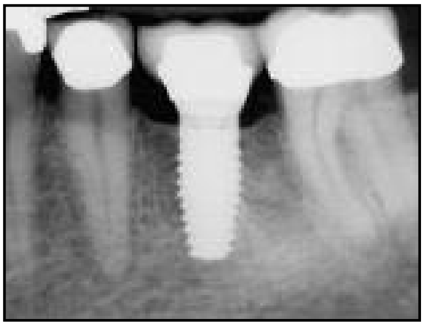


Fig 5c *Three-year follow-up of the Laser-Lok implant. Note the crestal bone stability and increased crestal bone density adjacent to the microtextured collar.*

Discussion

Preservation of the hard and soft tissues adjacent to an implant is partly dependent upon the implant's physical surface characteristics to enhance cell and tissue attachment. Several modifications of surface properties, such as topography, structure, chemistry, surface charge, and wettability, have been investigated in an effort to improve marginal soft and hard tissue integration with different implant surfaces.[15,17–20] Surface microtopography allows different cell types to demonstrate varying degrees of adhesion, proliferation, organization, and differentiation to different topographies.[18,19] Research using human mesenchymal stem cells on roughened titanium surfaces treated to provide surface nanotopography demonstrated marked osteoinduction and osteogenesis of adherent cells.[21] Collectively, these studies demonstrate the need for surfaces with both micro- and nanotopography. Surface microchannels with

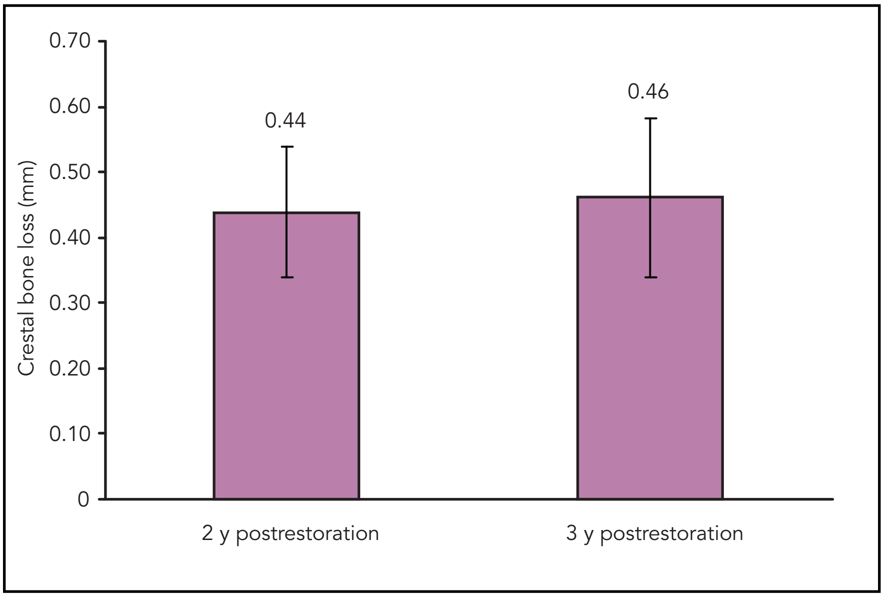


Fig 6 *Mean crestal bone level change during two different time frames.*

a specific shape and depth have demonstrated specific control of osteoblastic and fibroblastic cell function[22–25] since they simultaneously limit epithelial cell downgrowth and proliferation.[5,20]

The relative success of a dental implant can be directly correlated to the level of bone and connective tissue attached to the implant. Implant surface micro- and nanotopography has been identified as a key factor in influencing the attachment and differentiation of many cell types, including gingival fibroblasts, which are responsible for the production of the collagen-rich connective tissue surrounding dental implants. The functional orientation of the connective tissue collagen fibers inserted into the neck of the implant has been reported by some investigators, but the orientation appeared to be influenced by the quality of the mucosa.[7,26,27] The fibers tended to be parallel in alveolar mucosa and organized more perpendicularly in keratinized mucosa.[28] Preclinical and clinical evaluations have routinely demonstrated connective tissue fibers parallel to the implant surface.[6,8,13,14,17] A recently published study compared the histologic orientation of collagen fibers around smooth metal implant necks to that around zirconia-coated surfaces. Regardless of the implant material, collagen fiber orientation was predominantly parallel or parallel-oblique.[29]

Stress concentrations around implants in crestal bone are based on implant design and its ability to attach to the adjacent bone.[30] A recent finite element analysis engineering study revealed that the Laser-Lok design demonstrated reduced crestal bone stress, in particular, the stress associated with off-axis loading that usually occurs in the collar region.[31] An animal study comparing the laser microtextured collar to a machined collar demonstrated that the machined collar experienced greater downgrowth of epithelium and more osteoclastic activity with increased saucerization.[20] In addition, there was a closer adaptation of the bone to the laser microtextured collar as well as evidence of limited epithelial downgrowth and the presence of connective tissue attachment to the laser microtextured collar. Thus, the results of that study supported the hypothesis that a laser microtextured collar can limit epithelial downgrowth, improve the attachment of soft tissue and bone, and simulate the biologic width that is seen in the natural dentition. Nevins et al[5] have also shown, through scanning electron microscopy and human histology analysis, that Laser-Lok can produce a connective tissue attachment around the laser-treated collar portion of the implants. Twelve-micron grooves showed the best potential for inhibition of fibrous tissue growth relative to bone cell growth, and 8-μm grooves showed the most effective inhibition of epithelial cell migration across the grooves.[20,24,25] This is similar to results of an in vitro study conducted by Boyan and Schwartz,[32] suggesting specific surface microstructure spacing and height ranges for optimal cell response. Other dental implant systems have advertised groove-textured surfaces at the coronal aspect of the implant. However, these grooves are substantially larger (200 to 250 μm) and on a cellular level, represent surfaces that do not modulate osteoblastic morphology as effectively as the Laser-Lok 8- and 12-μm microchannels.[33]

In this retrospective radiographic analysis, conducted in a private practice setting, 49 Laser-Lok dental implants were radiographically evaluated for up to 3 years postrestoration to determine the change in crestal bone levels relative to the top of the implant platform. The results demonstrated a mean loss of 0.44 ± 0.10 mm and 0.46 ± 0.12 mm of crestal bone height from the initial surgery to 2 and 3 years postrestoration, respectively. An earlier unpublished pilot study carried out in 2000 by Shapoff in six patients using a Laser-Lok microchannel collar on a 1-mm external-hex BioLok implant demonstrated very stable crestal bone leels, which was maintained for 8 years.

Limitations of the current radiographic study include its retrospective nature and use of nonstandardized radiographs. The results, however, are consistent with a prospective controlled study by Pecora et al.[15] In that study, the Laser-Lok implant reduced crestal bone loss to approximately 0.6 mm at 3 years, compared to a machined-collar implant, which showed 1.9 mm of crestal bone loss. In addition, the Laser-Lok implant was comparable to the machined-collar implant in the safety endpoints of the Plaque Index and Sulcular Bleeding Index.

There have been other attempts to minimize the expected crestal bone loss of 1.5 to 2.0 mm, such as using one-piece implants or a platform-switching concept.[34–38] For example, Cappiello et al[36] evaluated bone loss around 75 two-piece implants that were restored according to the platform-switching protocol. Their 12-month radiographic analysis revealed vertical bone loss between 0.6 and 1.2 mm (mean, 0.95 ± 0.32 mm). A recently published 5-year prospective study on platform-switched implants demonstrated 0.6 mm of crestal bone loss from the apical margin of the smooth metal collar, compared to 0.9 mm for the matching diameter abutment.[39] It should be noted that this study used an external hex implant with a minimal collar dimension, and in many cases the implants were placed 1 mm subcrestally. The results obtained were comparable to the results of this study.

Conclusion

The presence of the Laser-Lok surface resulted in a stable osseous crest without bone loss to the first thread. The Laser-Lok implants showed less crestal bone loss at 3 years postrestoration than the commonly accepted 1.5 to 2.0 mm. This is probably the result of stable bone attachment, fibrous connective tissue attachment, and epithelial attachment to the implant collar, resulting in a stable soft tissue seal that protected the crestal bone.

Acknowledgment

The authors would like to thank Dr Soo Woo Kim for completing the radiographic analysis.

References

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
3. van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. Int J Oral Maxillofac Implants 1990;5:272–281.
4. Quirynen M, Naert I, van Steenberghe D, Nys L. A study of 589 consecutive implants supporting complete fixed prostheses. Part I: Periodontal aspects. J Prosthet Dent 1992;68:655–663.
5. Nevins M, Nevins ML, Camelo M, Boyesen JL, Kim DM. Human histologic evidence of a connective tissue attachment to a dental implant. Int J Periodontics Restorative Dent 2008;28:111–121.
6. Berglundh T, Lindhe J, Ericsson I, Marinello CP, Liljenberg B, Thomsen P. The soft tissue barrier at implants and teeth. Clin Oral Implants Res 1991;2:81–90.
7. Buser D, Weber HP, Donath K, Fiorellini JP, Paquette DW, Williams RC. Soft tissue reactions to non-submerged unloaded titanium implants in beagle dogs. J Periodontol 1992;63:225–235.
8. Listgarten MA, Buser D, Steinemann SG, Donath K, Lang NP, Weber HP. Light and transmission electron microscopy of the intact interfaces between non-submerged titanium-coated epoxy resin implants and bone or gingiva. J Dent Res 1992;71: 364–371 [erratum 1992;71:1267].
9. Chavrier C, Couble ML, Hartmann DJ. Qualitative study of collagenous and non-collagenous glycoproteins of the human healthy keratinized mucosa surrounding implants. Clin Oral Implants Res 1994;5: 117–124.
10. Liljenberg B, Gualini F, Berglundh T, Tonetti M, Lindhe J. Some characteristics of the ridge mucosa before and after implant installation. A prospective study in humans. J Clin Periodontol 1996;23:1008–1013.
11. Liljenberg B, Gualini F, Berglundh T, Tonetti M, Lindhe J. Composition of plaque-associated lesions in the gingiva and the peri-implant mucosa in partially edentulous subjects. J Clin Periodontol 1997;24:119–123.
12. Lindhe J, Berglundh T. The interface between the mucosa and the implant. Periodontol 2000 1998;17:47–54.
13. Moon IS, Berglundh T, Abrahamsson I, Linder E, Lindhe J. The barrier between the keratinized mucosa and the dental implant. An experimental study in the dog. J Clin Periodontol 1999;26:658–663.
14. Piattelli A, Scarano A, Piattelli M, Bertolai R, Panzoni E. Histologic aspects of the bone and soft tissues surrounding three titanium non-submerged plasma-sprayed implants retrieved at autopsy: A case report. J Periodontol 1997;68:694–700.
15. Pecora GE, Ceccarelli R, Bonelli M, Alexander H, Ricci JL. Clinical evaluation of laser microtexturing for soft tissue and bone attachment to dental implants. Implant Dent 2009;18:57–66.
16. Hermann JS, Schoolfield JD, Nummikoski PV, Buser D, Schenk RK, Cochran DL. Crestal bone changes around titanium implants: A methodologic study comparing linear radiographic with histometric measurements. Int J Oral Maxillofac Implants 2001;16:475–485.
17. Schwarz F, Herten M, Sager M, Wieland M, Dard M, Becker J. Histological and immunohistochemical analysis of initial and early osseous integration at chemically modified and conventional SLA titanium implants: Preliminary results of a pilot study in dogs. Clin Oral Implants Res 2007;18: 481–488.
18. Ellingsen JE. Surface configurations of dental implants. Periodontol 2000 1998; 17:36–46.
19. Hamilton DW, Chehroudi B, Brunette DM. Comparative response of epithelial cells and osteoblasts to microfabricated tapered pit topographies in vitro and in vivo. Biomaterials 2007;28:2281–2293.

20. Weiner S, Simon J, Ehrenberg DS, Zweig B, Ricci JL. The effects of laser microtextured collars upon crestal bone levels of dental implants. Implant Dent 2008;17:217–228.
21. Valencia S, Gretzer C, Cooper LF. Surface nanofeature effects on titanium-adherent human mesenchymal stem cells. Int J Oral Maxillofac Implants 2009;24:38–46.
22. Ricci JL, Grew JC, Alexander H. Connective-tissue responses to defined biomaterial surfaces. I. Growth of rat fibroblast and bone marrow cell colonies on microgrooved substrates. J Biomed Mater Res A 2008;85:313–325.
23. Grew JC, Ricci JL, Alexander H. Connective-tissue responses to defined biomaterial surfaces. II. Behavior of rat and mouse fibroblasts cultured on microgrooved substrates. J Biomed Mater Res A 2008;85:326–335.
24. Frenkel SR, Simon J, Alexander H, Dennis M, Ricci JL. Osseointegration on metallic implant surfaces: Effects of microgeometry and growth factor treatment. J Biomed Mater Res 2002;63:706–713.
25. Soboyejo WO, Nemetski B, Allameh S, Marcantonio N, Mercer C, Ricci J. Interactions between MC3T3-E1 cells and textured Ti6Al4V surfaces. J Biomed Mater Res 2002;62:56–72.
26. Schroeder A, van der Zypen E, Stich H, Sutter F. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed surfaces. J Maxillofac Surg 1981;9:15–25.
27. Deporter DA, Watson PA, Pilliar RM, Howley TP, Winslow J. A histological evaluation of a functional endosseous, porous-surfaced, titanium alloy dental implant system in the dog. J Dent Res 1988;67:1190–1195.
28. Rompen E, Domken O, Degidi M, Pontes AE, Piattelli A. The effect of material characteristics, of surface topography and of implant components and connections on soft tissue integration: A literature review. Clin Oral Implants Res 2006;17(suppl 2):55–67.
29. Teté S, Mastrangelo F, Bianchi A, Zizzari V, Scarano A. Collagen fiber orientation around machined titanium and zirconia dental implant necks: An animal study. Int J Oral Maxillofac Implants 2009;24:52–58.
30. Yu W, Jang YJ, Kyung HM. Combined influence of implant diameter and alveolar ridge width on crestal bone stress: A quantitative approach. Int J Oral Maxillofac Implants 2009;24:88–95.
31. Alexander H, Ricci JL, Hrico GJ. Mechanical basis for bone retention around dental implants. J Biomed Mater Res B Appl Biomater 2009;88:306–311.
32. Boyan BD, Schwartz Z. Modulation of osteogenesis via implant surface design. In: Davies JE (ed). Bone Engineering. Toronto: EM^2, 2000:232–239.
33. Zinger O, Zhao G, Schwartz Z, et al. Differential regulation of osteoblasts by substrate microstructural features. Biomaterials 2005;26:1837–1847.
34. Hermann JS, Buser D, Schenk RK, Schoolfield JD, Cochran DL. Biologic width around one- and two-piece titanium implants. Clin Oral Implants Res 2001;12:559–571.
35. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int J Periodontics Restorative Dent 2006;26:9–17.
36. Cappiello M, Luongo R, Di Iorio D, Bugea C, Cocchetto R, Celletti R. Evaluation of peri-implant bone loss around platform-switched implants. Int J Periodontics Restorative Dent 2008;28:347–355.
37. Schrotenboer J, Tsao YP, Kinariwala V, Wang HL. Effect of microthreads and platform switching on crestal bone stress levels: A finite element analysis. J Periodontol 2008;79:2166–2172.
38. Luongo R, Traini T, Guidone PC, Bianco G, Cocchetto R, Celletti R. Hard and soft tissue responses to the platform-switching technique. Int J Periodontics Restorative Dent 2008;28:551–557.
39. Vigolo P, Givani A. Platform-switched restorations on wide-diameter implants: A 5-year clinical prospective study. Int J Oral Maxillofac Implants 2009;24:103–109.