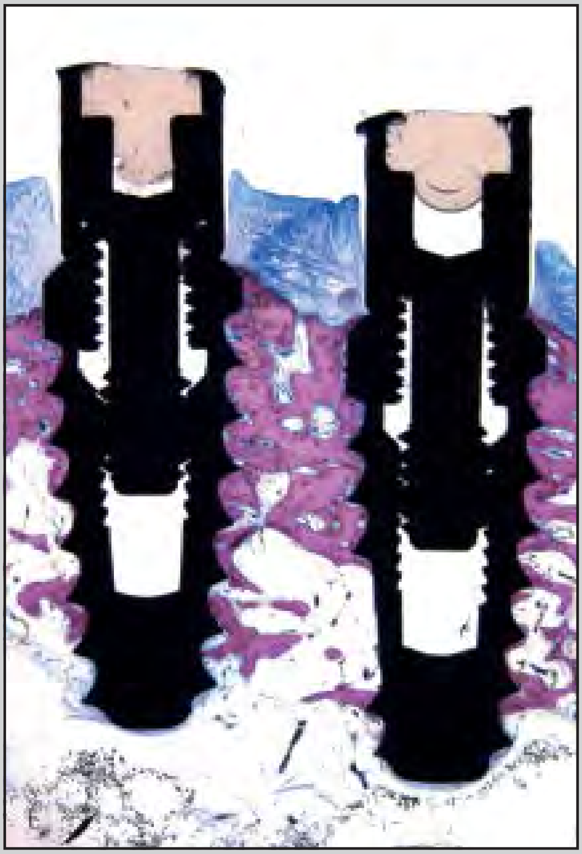
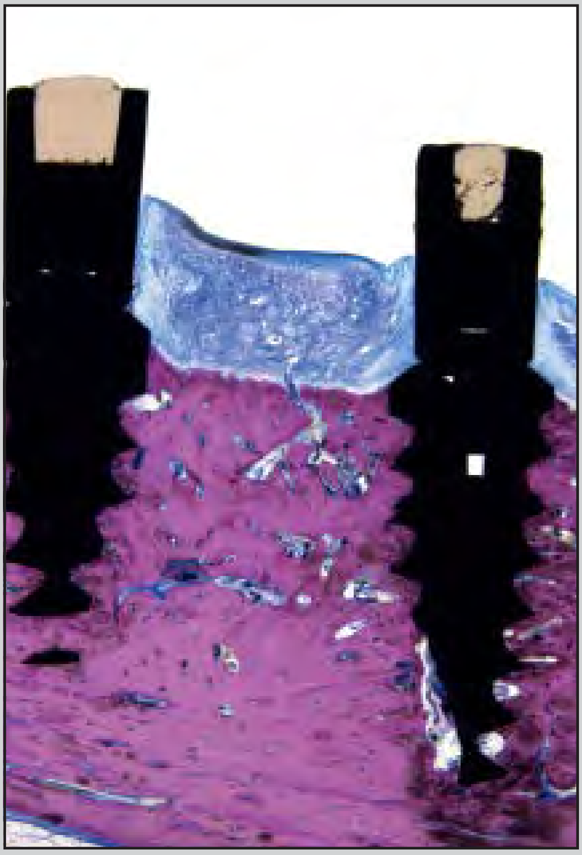
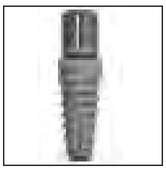




Maintaining Interimplant Crestal Bone Height Via a Combined Platform-Switched, Laser-Lok Implant/Abutment System: A Proof-of-Principle Canine Study



Myron Nevins, DDS[1]
Marc Nevins, DMD, MMSc[2]
Luca Gobbato, DDS, MS[3]
Hyo-Jung Lee, DDS, PhD[4]
Chin-Wei Wang, DDS[5]
David M. Kim, DDS, DMSc[6]

Interimplant papillae are critical for achieving esthetic implant-supported restorations in the maxillary esthetic zone. Stable papillary anatomy, however, depends upon a stable volume of underlying crestal bone for support. Multiple studies have documented a critical interimplant distance of 3 mm under which crestal bone resorption occurs. This preclinical proof-of-principle canine study examines a novel implant-abutment system design, combining platform switching with precisely configured laser-ablated abutment and implant microgrooves to maintain interimplant crestal bone at interimplant distances of 2 and 4 mm. Results of this initial preclinical study suggest that it is possible through precise implant/abutment design modifications to place adjacent implants at distances of 2 to 4 mm without inducing subpapillary crestal bone loss. (Int J Periodontics Restorative Dent 2013;33:261–267. doi: 10.11607/prd.1773)

[1]Associate Clinical Professor, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.
[2]Assistant Clinical Professor, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.
[3]Clinical Instructor, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.
[4]Assistant Professor, Department of Periodontology, Section of Dentistry, Seoul National University Bundang Hospital, Bundang, South Korea.
[5]Postdoctoral Resident, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.
[6]Assistant Professor, Division of Periodontology, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.

Correspondence to: Dr Myron Nevins, Department of Oral Medicine, Infection and Immunity, Harvard School of Dental Medicine, 188 Longwood Avenue, Boston, MA 02115, USA; fax: 617-432-1897; email: nevinsperimp@aol.com.

It is necessary to preserve intact maxillary interdental papillae to achieve esthetically pleasing implant-supported restorations. Maintaining proper papillary morphology, however, is dependent upon a stable volume of crestal bone capable of serving as a viable foundation for overlying interdental soft tissues.[1–3] Achieving and maintaining normal dimensional papillary anatomy is particularly challenging between adjacent implant-supported restorations, where peri-implant crestal bone loss is often seen. Major factors leading to such bone loss include the inflammatory cell infiltrate surrounding the microgap at the implant-abutment junction (IAJ),[4–13] subcrestal placement of the implant platform,[7,14,15] and the distance between adjacent implants.[1,2,16–19] The simultaneous interaction of each of these factors becomes especially evident when implants are placed adjacent to one another.

Multiple studies have demonstrated the critical role interimplant distance plays in determining preservation or loss of crestal bone needed for support of interimplant papillae. When implants are placed less than 3 mm apart, results from these studies suggest an overlap of the horizontal component of bone loss originating from the IAJ microgap of each adjacent implant.[1,2,15–20] The additive effect of overlapping interimplant lateral bone loss components has been shown to lead to an overall decrease in interimplant crestal bone height, resulting in a reduction in interimplant papillary height or loss of interimplant papillae altogether.[1,2,16,17] Additionally, when implant platforms are placed subcrestally, increased interimplant and marginal bone loss tend to occur to provide space for implant-related biologic width, further jeopardizing esthetic interimplant papillary anatomy.[7,14,15]

Platform switching may mitigate some of the interimplant bone loss reported at interimplant distances of 3 mm or less.[15,17,18,21–28] Medializing the implant microgap through platform switching appears to transfer the inflammatory cell infiltrate at the IAJ away from crestal bone, resulting in a reduction of the horizontal component of crestal bone loss. A recent preclinical study examining interimplant distances of 2 or 3 mm suggests that platform switching reduces the amount of interimplant crestal bone loss normally seen at distances less than 3 mm by minimizing the overlapping of horizontal bone loss components between adjacent implants.[17] Similar findings in a prospective human study by Rodriguez-Ciurana et al document significant reduction in interimplant crestal bone loss at interimplant distances of less than 2 mm with platform-switched implants.[18]

Altering implant surface topography through laser-ablated microgrooves adjacent to the IAJ appears to reduce the interimplant crestal bone loss often seen at inter-implant distances of less than 3 mm. Recent proof-of-principle studies confirm a direct connective tissue (CT) attachment to precisely configured laser-ablated microchannels (Laser-Lok, BioHorizons) located in defined regions of the implant collar and abutment.[6,9] By enabling a direct physical CT attachment, a physiologic barrier to the migration of the junctional epithelium occurred and protected against crestal bone resorption. In addition, the sequelae secondary to the IAJ microgap were reduced, further decreasing crestal bone loss.

Given the positive outcomes of maintaining interimplant crestal bone suggested by platform switching and the decreased crestal bone resorption experienced through Laser-Lok configured abutment and implant collar surfaces, further possibilities may be available to improve functional and esthetic outcomes of contiguously placed implants. By combining newly configured Laser-Lok abutment and implant designs with platform switching, the current proof-of-principle study examined the anatomical and histologic outcomes of interimplant crestal bone and soft tissue at implant insertion distances of 2 and 4 mm.

Method and materials

The study protocol was approved by the Institutional Animal Care and Use Committee at PARF in Massachusetts, USA. Six female hounds (aged 2 to 3 years, weighing 20 to 24 kg), which were bred exclusively for biomedical research purposes, were obtained from a licensed vendor.

To examine the outcomes of a newly designed abutment and implant system when placed at two different interimplant distances, bilateral mandibular edentulous defects were created. Under general and local anesthesia, all mandibular premolar and first molar teeth were removed atraumatically and flaps sutured without tension.

After a healing period of 60 days, crestal incisions were made to maximize keratinized tissue on both flap surfaces. Mucoperiosteal flaps were reflected to expose the edentulous ridge for implant placement (Fig 1). Using surgical guides that allowed an interimplant distance of either 2 or 4 mm, two implants were inserted bilaterally into each animal (Fig 2). In group A, a total of eight implants were inserted with an interimplant distance of 2 mm. In group B, the same number of implants were placed but with an interimplant distance of 4 mm. In all instances, the implant platform was placed level with the osseous crest (Fig 2d). All four foxhounds received a soft diet for the duration of the 3-month healing period.

Three months following implant placement, the hounds were euthanized and the mandibles

Fig 1 *Representative edentulous ridge 60 days following removal of mandibular premolars and first molars prior to implant placement.*

Fig 2a *Implant surgical guides at interimplant distances of 2 mm* (top) *and 4 mm* (bottom).

Fig 2b *Surgical guide in place, allowing an exact interimplant distance of 2 mm.*

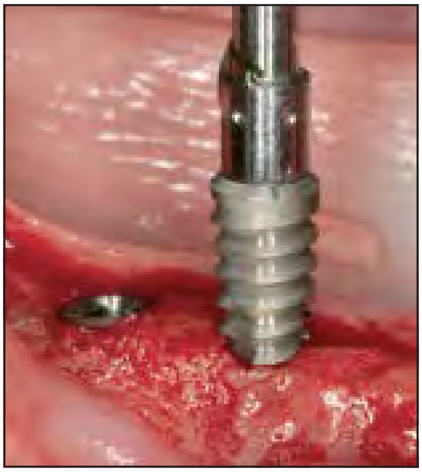
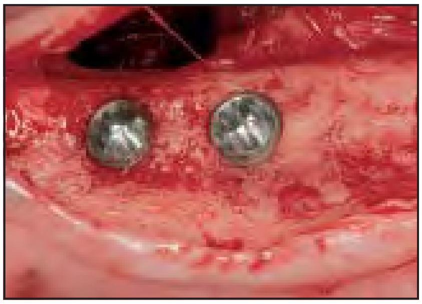


Fig 2c (left) *Test implant placed 2 mm from the posterior adjacent implant.*

Fig 2d (below) *At an interimplant distance of 2 mm, implants are placed even with the ridge crest.*



resected en bloc, followed by immediate fixation for histologic preparation and evaluation.

Test implant and abutment design

Figures 3a and 3b demonstrate the design characteristics of the implants and abutments used in this study. The implant dimensions were 3.8 mm in diameter and 9 mm in length with a beveled platform to allow a platform shift of 0.3 mm per side. Buttress implant threads were designed to increase primary stability. All implant threads, from the apical-most end of the implant body to the implant collar, were Laser-Lok configured with no machined collar. Increased numbers of threads were designed to increase bone-to-implant surface area contact.

The healing abutment, with a reduced diameter at the implant/abutment interface, allowed the implant/abutment system to be platform-switched. There was a 0.7-mm-tall band laser-ablated region with 8-μm Laser-Lok microchannels above the microgap (Figures 3a and 3b).

Light microscopy

Fixed samples were dehydrated in a graded series of ethanol (60%, 80%, 96%, and absolute ethanol) using a dehydration system with agitation and vacuum. The blocks were infiltrated with Technovit 7200 VLC acrylic resin (Kulzer). Infiltrated specimens were placed into embedding molds, and polymerization was performed under blue and white light. Polymerized blocks were sectioned in a mesiodistal direction parallel to the long axis of each implant. The slices were reduced by microgrinding

Fig 3a *Platform-switched abutment/implant system with Laser-Lok microgrooves at a 0.7-mm-tall abutment band and covering the entire implant threaded surface.*

Fig 3b *Abutment and Laser-Lok implant separated with internal hex, platform-switched connection.*

and polishing using an Exakt grinding unit to an even thickness of 30 to 40 µm. Sections were stained with Rapid Bone Stain and counter-stained with acid fuchsin and examined using both a stereo- (MZ16, Leica) and light microscope (6000DRB, Leica).

Results

Clinical observations

Healing proceeded uneventfully for all 16 surgical implant sites during the 2 months following the extraction of all mandibular premolars and first molars, with minimal post-surgical inflammation and no evidence of postoperative infection.

The 3-month post-implant insertion period also proved uneventful, with minimal postoperative swelling or inflammation and no evidence of infection at any time point. All implants and abutments were stable with no implant loss during the postinsertion follow-up period.

Histologic observations: Group A

Figures 4a to 4d show histologies 3 months following implant placement at an interimplant distance of 2 mm.

Soft tissue findings

Peri-implant soft tissues consisted of an epithelial barrier with the sulcular epithelium merging with the junctional epithelium. The junctional epithelium ended abruptly at the coronal-most position of the abutment Laser-Lok microgrooves, where a zone of CT fibers appeared to enter perpendicularly into the microchanneled 0.7-mm-tall band. In addition, CT fibers also appeared to enter into Laser-Lok regions of the implant collar, effectively sealing the IAJ microgap from surrounding tissues (Fig 4). Importantly, no evidence of an inflammatory infiltrate was found in any specimen at the IAJ.

Hard tissue findings

Interimplant crestal bone showed no evidence of bone resorption in any biopsy specimen at the end of 3 months. Significant bone-to-implant contact (BIC) was readily apparent along all aspects of the implant body and collar. In many specimens, regenerated bone was seen immediately proximal to the IAJ microgap. The apposition of both perpendicularly inserting CT fibers and bone onto the laser-ablated microchannels in the region of the IAJ microgap served to anatomically seal the IAJ from surrounding tissues and prevent migration of the junctional epithelium (Fig 4).

Histologic observations: Group B

In group B, Figs 5a to 5c show representative histologies 3 months following implant placement at an interimplant distance of 4 mm.

Soft tissue findings

At a 4-mm interimplant distance, peri-implant soft tissue findings were similar to those at 2 mm. A dense zone of CT fibers appeared to perpendicularly enter into abutment-

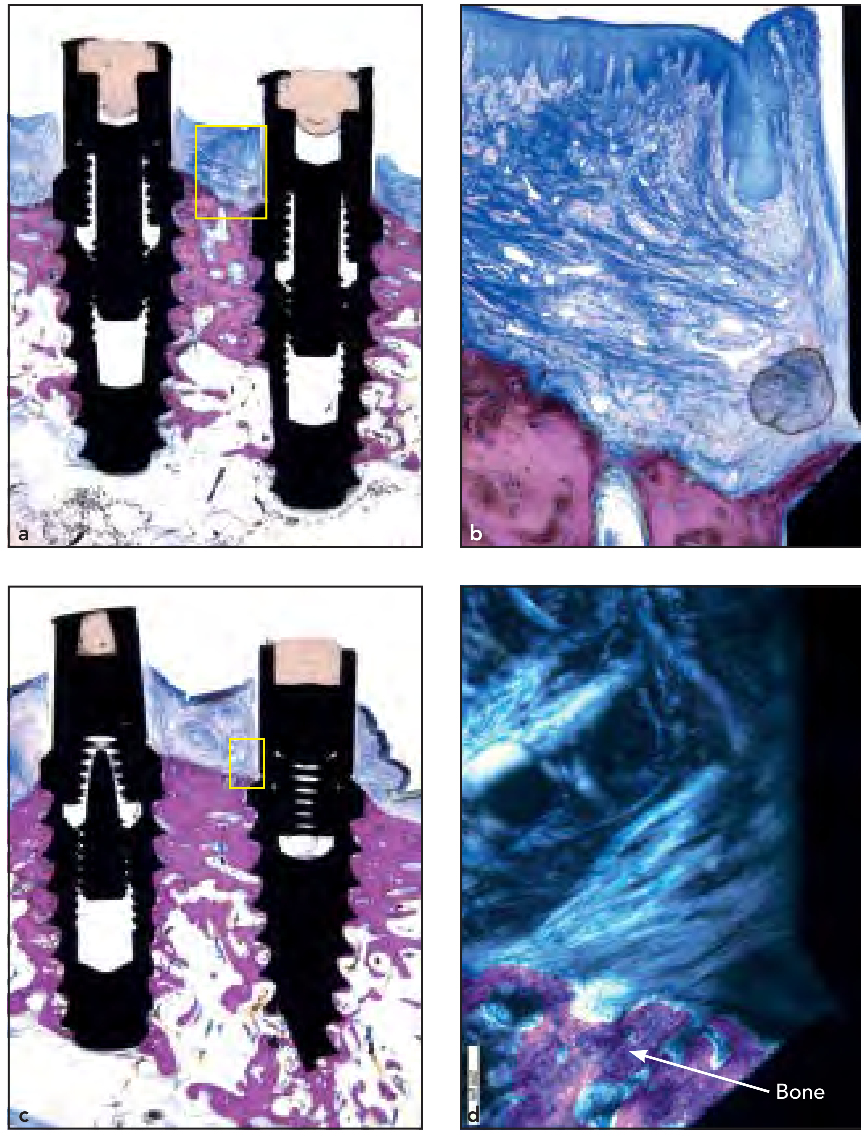


Fig 4 *Group A*

Fig 4a *Low-power view of test implants placed 2 mm apart, with no signs of inter-implant crestal bone loss.*

Fig 4b *High-power view of yellow box area in Fig 4a demonstrates direct CT connection to Laser-Lok grooved abutment and implant collar surfaces. Osseous crest extends onto the laser-ablated implant collar.*

Fig 4c *Implants at 2 mm apart with no crestal bone loss at 3 months post-implant insertion. Note extensive bone-to-implant contact along entire Laser-Lok grooved implant body.*

Fig 4d *Under polarized light, perpendicularly oriented CT fibers enter into the laser-grooved abutment surface (high-power view of yellow box area in Fig 4c). Crestal bone extends onto the Laser-Lok micro-channeled implant collar region.*

positioned Laser-Lok microgrooves as well as into adjacent laser-ablated regions of the implant collar. The direct apposition of these CT fibers onto the laser-ablated microgrooves effectively sealed the IAJ microgap and prevented apical migration of the junctional epithelium. No evidence of an inflammatory cell infiltrate was found in any group B specimen (Fig 5).

Hard tissue findings

At 3 months post-implant placement, interimplant crestal bone remained intact with no evidence of resorption. Crestal bone die-back was not present in any examined specimen. BIC was excellent along the entire implant body and collar surfaces, with dense lamellar bone lining almost all implant surfaces (Fig 5).

Discussion

Intact interimplant papillae are necessary to achieve favorably perceived implant-supported restorations in the esthetic zone of the maxilla. Maintaining intact inter-implant papillae, however, requires stable underlying crestal bone, without which papillary distortion and volume loss occur.[1–3]

Fig 5 *Group B*

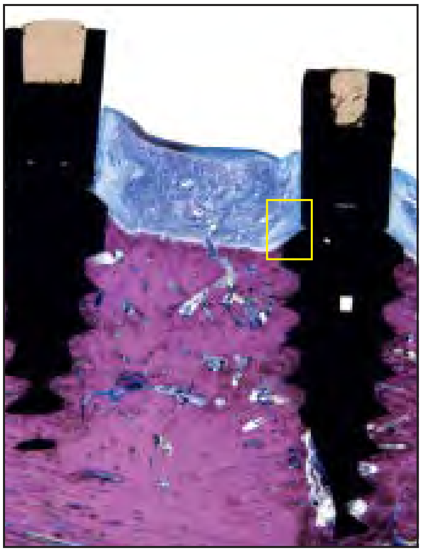


Fig 5a *Implants placed 4 mm apart with no evidence of crestal bone loss and extensive BIC.*

Fig 5b *Magnified view of implant and abutment (yellow box area in Fig 5a) demonstrates dense CT attachment to abutment and implant collar. Note the intimate attachment of crestal bone to Laser-Lok microgrooves of the implant collar.*

Fig 5c *Under polarized light, perpendicularly oriented CT fibers enter directly into the laser-grooved abutment and implant collar in the IAJ region (magnified view of yellow box area in Fig 5a).*

Bone loss is often evident at critical distances between adjacently positioned implants, primarily because of overlapping horizontal components of bone resorption originating from the IAJ microgaps of each adjacent implant.[1,2,15–20] A number of investigations have suggested that interimplant crestal bone loss becomes especially problematic at interimplant distances of less than 3 mm.[1,2,16,17] The current proof-of-principle study, based on positive findings related to laser-ablated microgrooved implant and abutment surfaces[6,9] combined with platform switching,[17,18,21–28] examined interimplant crestal bone responses at interimplant distances of 2 and 4 mm. Several important findings are suggested by this preclinical study.

No evidence of interimplant crestal bone loss occurred in the current investigation, either at 2 or 4 mm. Moreover, new bone formation often occurred on the implant laser-ablated microgrooved collar adjacent to the IAJ microgap. As noted earlier, platform switching appears to medialize the implant-abutment microgap, reducing or eliminating the overlapping of horizontally directed vectors of IAJ-mediated bone loss that normally occurs at interimplant distances under 3 mm. By adding a 0.7-mm-tall band of Laser-Lok microchannels to the abutment and implant collar, the current implant-abutment system appeared to create sustained BIC coronal to the first thread and often to portions of the implant collar.

Unlike previous studies[6,9] examining the effects of laser-ablated microgrooves limited to the implant collar region, the current implant design called for the entire implant surface to be laser grooved with 8-μm microchannels. Unusually high BIC was seen along all surfaces of the microgrooved implant, suggesting that the laser-ablated surfaces have facilitated increased BIC.

In addition to the current platform-switched design, inter-implant crestal bone retention may also have been supported by the consistent CT responses seen at the IAJ microgap. As in prior reported studies, the 8-μm laser-ablated channels on the abutment and implant surfaces allowed perpendicular attachment of dense CT fibers adjacent to the IAJ, effectively eliminating the bacterial and inflammatory cell infiltrate normally present at the IAJ microgap.[6,9] When present, inflammatory cellladened CT adjacent to the IAJ microgap forces apical repositioning of non-inflamed peri-implant CT and crestal bone, resulting in the loss of support for critically important interimplant papillae. By eliminating sequelae normally seen at the IAJ microgap, the laser microgrooved abutment and implant surfaces likely acted synergistically with platform switching to prevent interimplant crestal bone resorption normally seen at inter-implant distances of less than 3 mm. Further prospective human trials are required to confirm the results of this preclinical proof-of-principle study.

Acknowledgment

Special thanks to Dr Stuart Kay, science writer and consultant (Huntington, NY), for his help with the organization and production of this manuscript. The authors reported no conflicts of interest related to this study.

References

1. Tarnow D, Elian N, Fletch P, et al. Vertical distance from the crest of bone to the height of the interproximal papilla between adjacent implants. J Periodontol 2003;74:1785–1788.
2. Gastaldo JF, Cury PR, Sendyk WR. Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. J Periodontol 2004; 75:1242–1246.
3. Choquet V, Hermans M, Adriaenssens P, et al. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. J Periodontol 2001;72:1364–1371.
4. Piataelli A, Vrespa G, Petron G, et al. Role of the microgap between implant and abutment: A retrospective histologic evaluation in monkeys. J Peridontol 2003;74:346–352.
5. Quirynen M, Van Steenberghe D. Bacterial colonization of the internal part of two stage implants. An in vivo study. Clin Oral Implants Res 1993;4:158–161.
6. Nevins M, Nevins ML, Camelo M. Human histologic evidence of a connective tissue attachment to a dental implant. Int J Periodontics Restorative Dent 2008;28: 111–121.
7. Hermann JS, Schoolfield JD, Nummikosi PV, et al. Crestal bone changes around titanium implants: A methodologic study comparing linear radiographic with histometric measurements. Int J Oral Maxillofac Implants 2001;16:475–485.
8. Ericcson I, Persson LG, Berglundh T, et al. Different types of inflammatory reactions in peri-implant soft tissues. J Clin Periodontol 1995;22:255–261.
9. Nevins M, Kim DM, Jun S-H, et al. Histologic evidence of a connective tissue attachment to laser microgrooved abutments: A canine study. Int J Periodontics Restorative Dent 2010;30:245–255.
10. Hermann JS, Schoolfield JD, Schenk RK, et al. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. J Periodontol 2001;72:1372–1383.
11. Broggin N, McManus LM, Hermann JS, et al. Peri-implant inflammation defined by the implant-abutment interface. J Dent Res 2006;85:473–478.
12. King GN, Hermann JS, Schoolfield JD, et al. Influence of the size of the microgap on crestal bone levels in non-sumberged dental implants: A radiographic study in the canine mandible. J Periodontol 2002; 73:1111–1117.
13. Todescan FF, Pustiglioni FE, Imbronito AV, et al. Influence of the microgap in the peri-implant hard and soft tissues: A histometric study in dogs. Int J Oral Maxillofac Implants 2002;17:467–472.
14. Alomrani AN, Hermann JS, Jones AA, et al. The effect of a machined collar on coronal hard tissue around titanium implants: A radiographic study in the canine mandible. Int J Oral Maxillofac Implants 2005;20:677–686.
15. Jung RE, Jones AA, Higginbottom FL, et al. The influence of non-matching implant and abutment diameters on radiographic crestal bone levels in dogs. J Periodontol 2008;79:260–270.
16. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000;71:546–549.
17. Elian N, Bloom M, Dard M. Effect of interimplant distance (2 and 3 mm) on the height of interimplant bone crest: A histomorphometric evaluation. J Periodontol 2011;82:1749–1756.
18. Rodriguez-Ciurana X, Vela-Nebot X, Segala-Torres M, et al. The effect of interimplant distance on the height of the interimplant bone crest when using platform-switched implants. Int J Restorative Dent 2009;29:141–151.
19. Kupershmidt I, Levin L, Schwartz-Arad D. Inter-implant bone height changes in anterior maxillary immediate and non-immediate adjacent dental implants. J Periodontol 2007;78:991–996.
20. Cardaropoli G, Wennstrom JL, Lekholm U. Peri-implant bone alterations in relation to inter-unit distances. A 3-year retrospective study. Clin Oral Implants Res 2003;14:430–436.
21. Vela X, Mendez V, Rodriguez X, et al. Crestal bone changes on platform-switched implants and adjacent teeth when the tooth-implant distance is less than 1.5 mm. Int J Restorative Dent 2012; 32:149–155.
22. Atieh MA, Ibrahim HM, Atieh AH. Platform switching for marginal bone preservation around dental implants: A systematic review and meta-analysis. J Periodontol 2010;81:1350–1366.
23. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postoperative crestal bone levels. Int J Periodontics Restorative Dent 2006;26:9–17.
24. Prosper L, Redaelli S, Pasi M, et al. A randomized prospective multicenter trial evaluating the platform-switching technique for the prevention of postrestorative crestal bone loss. Int J Oral Maxillofac Implants 2009;24:299–308.
25. Canullo L, Fedele GR, Iannello G, et al. Platform switching and marginal bone-level alterations: The results of a randomized-controlled trial. Clin Oral Implants Res 2010;21:151–121.
26. Luongo R, Traini T, Guidone PC, et al. Hard and soft tissue responses to the platform-switching technique. Int J Periodontics Restorative Dent 2008;28:551–557.
27. Wagenberg B, Froum SJ. Prospective study of 94 platform-switched implants observed from 1992 to 2006. Int J Periodontics Restorative Dent 2010;30:9–17.
28. Cappiello M, Luongo R, Di Lorio D, et al. Evaluation of peri-implant bone loss around platform-switched implants. Int J Periodontics Restorative Dent 2008;28: 347–355.