The Effects of Laser Microtexturing of the Dental Implant Collar on Crestal Bone Levels and Peri-implant Health

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Purpose: *Polished and machined collars have been advocated for dental implants to reduce plaque accumulation and crestal bone loss. More recent research has suggested that a roughened titanium surface promotes osseointegration and connective tissue attachment. The purpose of this research was to compare crestal bone height adjacent to implants with laser-microtextured and machined collars from two different implant systems.* ***Materials and Methods:*** *Four implants, two with laser-microtextured collars and two with machined collars, were placed in the anterior mandible to serve as overdenture abutments. They were placed in alternating order, and the distal microtextured- and machined-collar implants were loaded with ball abutments. The mesial implants were left unloaded. The distal implants were immediately loaded with prefabricated dentures. Plaque Index, Bleeding Index, and probing depths (PDs) were measured after 6 and 12 months for the loaded implants. Bone loss for both groups (loaded and unloaded) was evaluated via standardized radiographs.* ***Results:*** *Plaque and bleeding values were similar for both implant types. The microtextured-collar implants showed shallower PDs (0.36 ± 0.5 mm and 0.43 ± 0.51 mm) than those with machined collars (1.14 ± 0.77 mm and 1.64 ± 0.93 mm;* P *< .05 for 6 and 12 months, respectively). At 6 and 12 months, respectively, the microtextured implants showed less crestal bone loss for both loaded (0.19 ± 0.15 mm and 0.42 ± 0.34 mm) and unloaded groups (0.15 ± 0.15 mm and 0.29 ± 0.20 mm) than the machined implants for both the loaded (0.72 ± 0.5 mm and 1.13 ± 0.61 mm) and unloaded groups (0.29 ± 0.28 mm and 0.55 ± 0.32 mm).* ***Conclusion:*** *Application of laser-microtextured grooves to the implant collar resulted in shallower PDs and less peri-implant crestal bone loss than that seen around implants with machined collars.* Int J Oral Maxillofac Implants 2011;26:492–498

Key words: *biologic width, crestal bone, implant collar, tissue engineering*

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Dental implants today are a predictable modality for the replacement of teeth.[1] In addition to the threaded portion of the implant that is embedded in the bone, the coronal portion of the implant has a parallel-walled or flared collar to which the abutment interfaces.[2] This collar has generally been machined to prevent the accumulation of plaque along the edge of the abutment. It has been observed that the collar is surrounded by an organized circular cuff of connective tissue and epithelium, which is supported by the underlying crestal bone that abuts the first thread.[3] This contrasts with the natural-tooth situation, where, in addition to support from the crestal

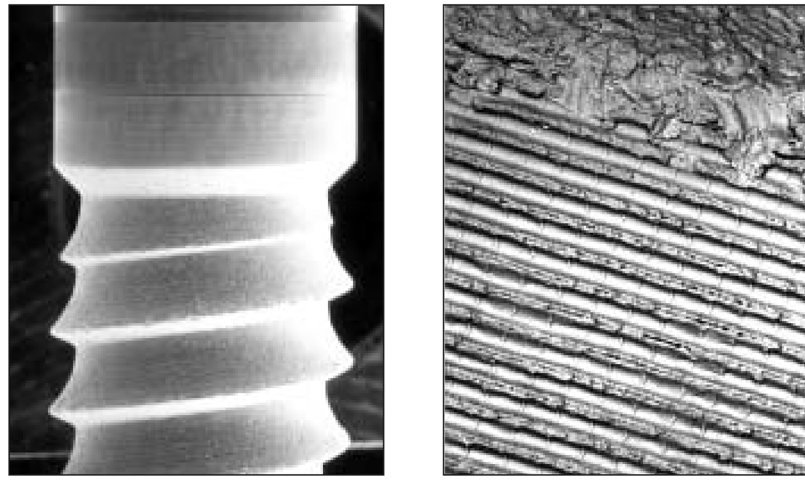


Fig 1 *(Left)* Laser-microtextured surface; *(right)* machined collar, 500X.

bone, the connective tissue and epithelium attach to the cemental root surface. The epithelial attachment occurs by hemidesmisomes, and the connective tissue attachment results from collagen fibers inserting into the cementum that provide additional support for the gingival tissues.[4] Because the implant collar does not provide this support, there are limitations to the height of soft tissue that can surround the implant and thereby resist bacterial invasion of the sulcular epithelium and connective tissue.[5]

Recently, however, several strategies have been proposed, using the principles of tissue engineering, to modify the osseous and soft tissue interfaces with the implant. These strategies promote the attachment of bone and connective tissue to the implant collar surface and, it is claimed, help to transfer stress from the implant to the crestal bone.[4,5] One of these strategies is laser microtexturing the collar surface with 8- and 12-μm grooves. Tissue culture studies have demonstrated cellular attachment by osteoblasts and fibroblasts to laser-microgrooved surfaces.[6] In addition, it has been hypothesized that crestal bone levels adjacent to implants with microtextured collars may achieve more coronal attachment, ie, cover more of the collar, than implants with machined collars.[7]

Accordingly, the purposes of this comparative cohort study were twofold:

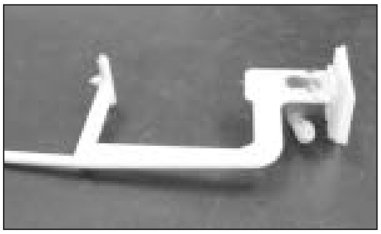
1. To compare the osseous and soft tissue healing adjacent to implants with laser-microtextured collars to that adjacent to implants with machined collars in a group of overdenture patients who received implants to stabilize their dentures, and
2. To observe the success rates following immediate loading of these implants for implant-supported overdentures in this group of patients.

METHODS

This study was approved by the Institutional Review Board, Newark Campus, of the University of Medicine and Dentistry of New Jersey.

Two implant systems were used in this study: an implant with a laser-microtextured collar (Silhouette LaserLok, BioLok International) and an implant with a machined collar (Replace Select, Nobel Biocare) (Fig 1). Four implants were placed interforaminally in each patient. Two of these were microtextured implants and two were machined implants. The positions of these implants were alternated. Thus, one machined and one microtextured implant were placed on each side of the midline. If the distal implant was a machined implant, then on the contralateral side, the distal implant was a microtextured implant. While four implants were placed in each patient, only the distal implants were loaded and used for support of the denture. The two mesial implants were left unloaded for the duration of the study. Subjects for the study required sufficient bone volume in the mandible to allow insertion of four implants of at least 3.45 or 4 mm in diameter and 10 mm in length. Subjects were to be edentulous in both arches and currently wearing functional prostheses. Implants were inserted only in the mandible. Patients with inadequate attached gingiva or who required significant alveoloplasty or extractions were not included in the study. Smokers and individuals with uncontrolled metabolic diseases (eg, diabetes) were also excluded from the study.

A radiographic stent with markers in the canine region was used to obtain a presurgical panoramic film. Surgical implant placement was done with a one-stage, immediate-loading protocol. An incision was made along the crest of the ridge from right to left. The extent of the incision was based upon the correlation between the markers on the radiographic



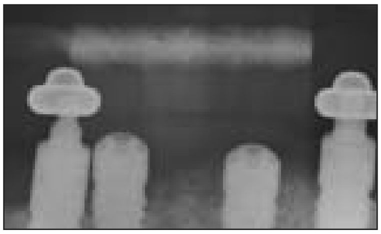


Fig 2 *(Left)* An example of the radiographic holder that fit onto the ball attachments of the distal implants used to obtain standardized radiographs.

Fig 3 *(Right)* An example of a standardized radiograph.

Table 1 Distribution of Implants in the Study

Implant type	Dimensions	No.
Replace Select (machined collar)	4.0 × 10.5 mm 4.0 × 12 mm	16 14
Laser Lok (microtextured collar)	3.45 × 10 mm 3.45 × 11.5 mm 4.0 × 11.5 mm	16 10 4

stent and the images of the mental foramina on the panoramic film. The implants were placed following the manufacturer's protocols. The tops of the implants were placed at the level of the crestal bone. Abutments were placed on the distal implants and the tissue was closed around the abutments, primarily with silk sutures. The dentures were relieved internally, and the retentive elements were placed over the abutments and attached following relief of the intaglio surface of the denture with autopolymerizing acrylic resin (Jet Denture Repair Resin, Lang Dental Manufacturing). After the resin had polymerized completely, the intaglio of the denture around the retentive elements, where acrylic resin had been added, was relieved after identification of pressure areas with the use of Pressure Indicating Paste (Mizzy, National Keystone) to prevent the application of excessive pressure on the peri-implant soft tissues. The patients were dismissed with postoperative instructions. After 1 week, the patients were seen again and an individual standardized radiographic holder was made for each patient (Fig 2). This holder was used for an initial radiograph, a second radiograph at 6 months, and a third at 1 year.

Plaque Index (PI), Sulcus Bleeding Index (SBI), and probing depths (PDs) were evaluated in all patients. All measurements were performed by the same investigator. The periodontal parameters were measured at 6 and 12 months.[8]

The radiographs were then digitized using a dedicated scanner (Hewlett-Packard 3000) with a resolution of 2,048 × 3,072 lines and converted into JPG files. A software package, AutoCAD 2000 (Autodesk), was used to measure crestal bone levels. In the program, a horizontal line was scribed mesiodistally across the implant-abutment interface. Perpendicular lines were drawn from the horizontal line to the top of the crestal bone both mesially and distally. The program then calculated the lengths of the vertical lines, which represented the distance from the top of the implant to the crestal bone. These measurements were made on the baseline radiographs, the 6-month radiographs, and the 12-month radiographs for both the loaded and the unloaded groups (Fig 3).

Measurements were done by one blinded operator trained to read implant radiographs under the same conditions (in a dark room on the same computer screen) and who was evaluated periodically for consistency of the measurements by measuring the same image 10 times. The standard error of the mean (SEM) was required to be less than 10% of the mean value.

Statistical Analysis

PI and SBI values of the loaded microtextured and machined groups were compared at 6 and 12 months using the Wilcoxon nonparametric test. The mean PDs were compared with the paired *t* test.

Crestal bone loss was calculated by subtracting the distance between the top of the implant and the crestal bone level on the most current radiographs from the distance seen on the baseline radiographs. These calculations were done for both mesial and distal surfaces. Means and standard deviations were obtained for all samples in each group. Statistical comparisons were done using the paired *t* test.

RESULTS

Fifteen patients were selected for this prospective study (8 men and 7 women). Their ages ranged from 40 to 74 years (median, 57 years old). Table 1 shows the number and dimensions of implants placed.

Implant Survival

In 14 of the 15 patients, all implants survived. In one patient, one of each type of implant failed to achieve osseointegration (one loaded microtextured and one loaded machined). In this patient, the remaining two implants were therefore loaded. Thus, there were 15 implants in each of the loaded groups and 14 in each of the unloaded groups.

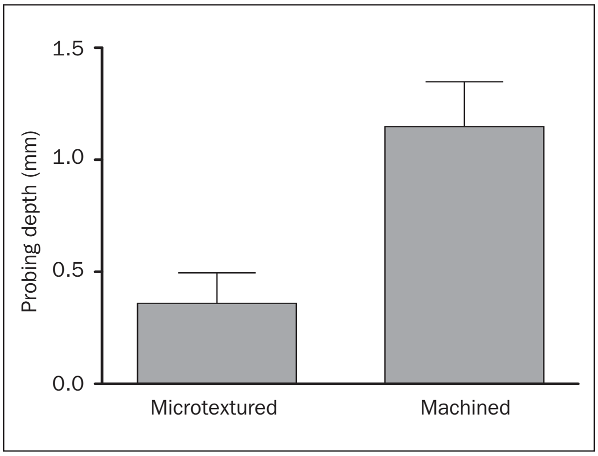


Fig 4a Mean pocket depths of the experimental and control groups at 6 months.

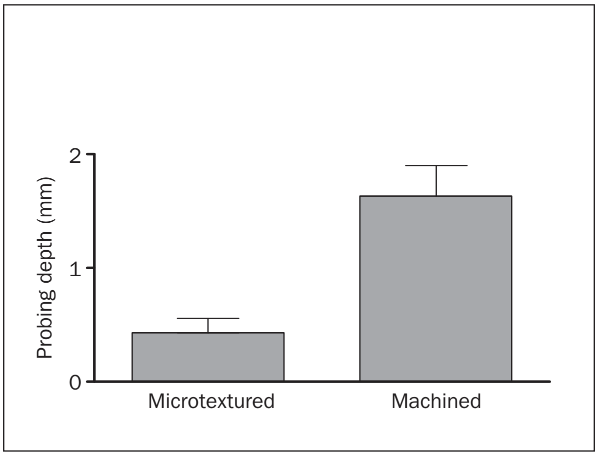


Fig 4b Mean pocket depths of the experimental and control groups at 12 months.

Periodontal Parameters

At the 6-month evaluation, the mean PD for the microtextured loaded group was 0.36 mm (SD 0.5 mm) and for the machined loaded group it was 1.14 mm (SD 0.77 mm). At 12 months, the mean PDs were 0.43 mm (SD 0.51 mm) and 1.64 mm (SD 0.93 mm), respectively. These differences were significant at $P \leq .001$ (Fig 4).

At 6 and 12 months, the mean SBI of the microtextured loaded and the machined loaded groups did not show statistical differences between groups (Wilcoxon nonparametric test).

At both 6 and 12 months, the mean PI values of the microtextured loaded group and the machined loaded groups were compared and did not demonstrate any significant difference (Wilcoxon test).

Crestal Bone Changes

The alveolar crestal bone loss is summarized in Figs 5 and 6. Because there were no statistical differences between the values of the mesial and distal surfaces when compared with the Student *t* test, the mesial and distal sites were combined into one group to expand the number of sites and provide a larger sample size for each group.

In the loaded groups, at 6 months, the microtextured group had a mean crestal loss of 0.19 mm (SD 0.15 mm), compared to 0.72 mm (SD 0.5 mm) for the machined group. The differences between groups were significant ($P \leq .009$) (Fig 5a). In the unloaded groups at 6 months, the microtextured group had a mean crestal bone loss of 0.15 mm (SD 0.15 mm), while the group had 0.29 mm (SD 0.28 mm). The differences between groups were significant ($P \leq .0149$) (Fig 5b).

In the loaded groups at 12 months, the microtextured group had a mean crestal bone loss of 0.42 mm (SD 0.34 mm) compared to 1.13 mm (SD 0.61 mm) for the machined group, a statistically significant difference (paired *t* test; $P \leq .001$) (Fig 6a). In the unloaded groups at 12 months, the microtextured group had a mean crestal bone loss of 0.29 mm (SD 0.2 mm), compared to 0.55 mm (SD 0.32 mm) for the machined group, a statistically significant difference (paired *t* test; $P \leq .01$) (Fig 6b).

DISCUSSION

The results of this study demonstrate that laser microtexturing in the range of 8 to 12 µm on the implant collar results in higher crestal bone attachment adjacent to the implant. This would be reasonable in light of the fact that the mechanical substrate supporting biologic tissues can have a significant influence on cell growth and development.[9] Specifically, the integrins that bridge the cell membrane allow attachment of the cell to the extracellular environment. This in turn significantly influences the internal regions of the cell.[10] In particular, the arginine-glycine-aspartate amino acid complex (also known as the RGD integrin complex) on the external surface of the cell membrane permits transduction of compressive and tensile forces, resulting in modification of cell form.[11] A basic understanding of these processes is clinically relevant, since it explains the mechanism by which occlusal forces and other mechanical strains can influence bone remodeling in the peri-implant region.

Furthermore, tissue culture studies have observed that fibroblasts and osteoblast precursors, when applied to laser-microtextured surfaces, demonstrate

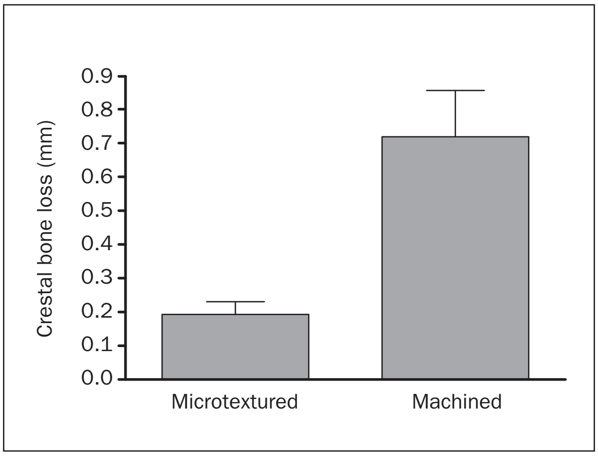


Fig 5a Mean change (loss) in crestal bone height for the loaded group from placement to 6 months.

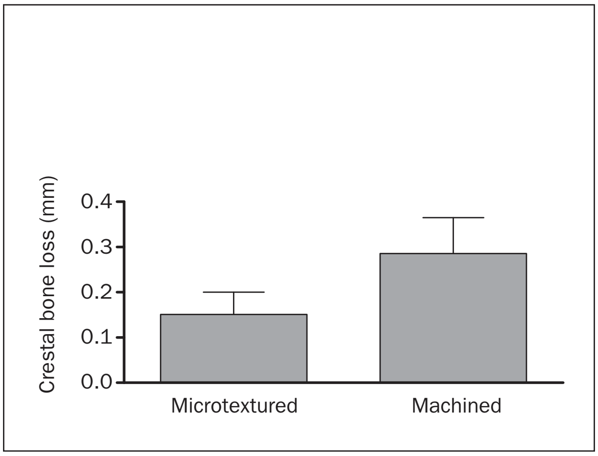


Fig 5b Mean cumulative change (loss) in crestal bone height for the unloaded group from placement to 6 months.

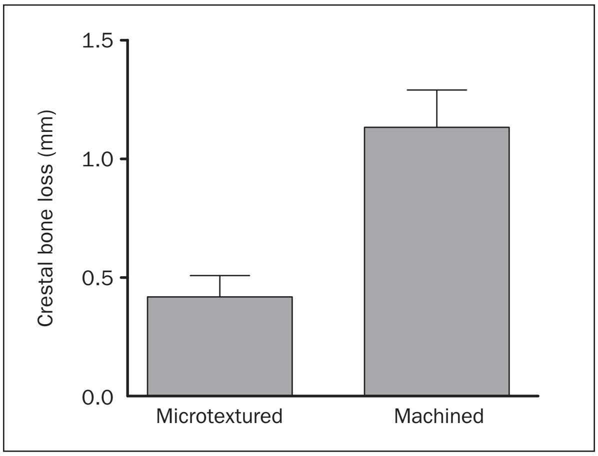


Fig 6a Mean change (loss) in crestal bone height for the loaded group from placement to 12 months.

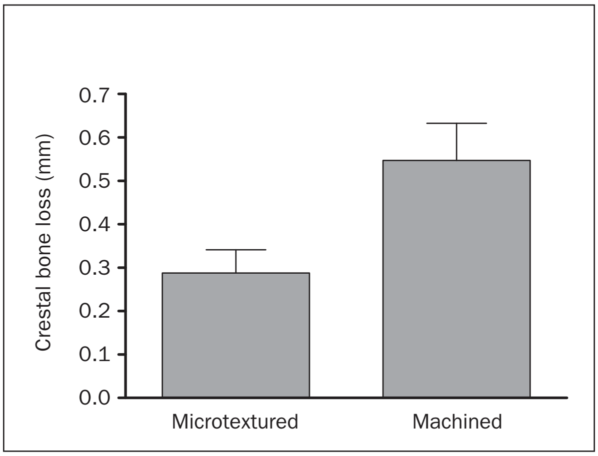


Fig 6b Mean cumulative change (loss) in crestal bone height for the unloaded group from placement to 12 months.

spreading and attachment to the mechanical substrate.[12] Zhu et al[13] reported that modification of substrate topography promotes cell spreading and migration and reduces focal contacts between cells. This results in increased mitosis and cellular proliferation as well as improved attachment to the substrate. Round cells demonstrate greater focal contacts, which suppress the mitotic rate as well as reduce the surface area for attachment. Flattened cells with lamellae and filopodia would appear to improve the quality and quantity of bone adjacent to the implant collar surface.[14] This assumption is supported by the histologic analysis reported by Weiner et al[15] in a canine study of crestal bone adjacent to the implant collar.

The clinical implications of these findings are important. Additional crestal bone height along the implant collar of even 1 mm can provide significant support for the soft tissue along the collar and may significantly improve the esthetic appearance of a restoration in the case of a fixed prosthesis by covering the edge of an abutment.

It should also be recognized that the soft tissues adjacent to the implant collar in this study were located under the denture. The presence of the denture enhances the biofilm present on the soft tissue and the implants. This in turn may result in gingival inflammation and may also influence crestal bone levels.[16] This is particularly true if a patient's home care and plaque removal are not optimal and may provide part of the explanation for the high caries rate and poor survival of natural overdenture abutments.[17] With regard to fixed prostheses with better access for control of the biofilm adjacent to the crowns, Pecora et al[18] and Taylor et al,[19] in prospective studies of adjacent implant-supported crowns, reported higher crestal bone levels adjacent to implant collars with laser-microtextured surfaces.

Studies by Schwartz et al[20] and Al-Sayyed et al[21] in a canine model and Hammerle in a clinical study[22] demonstrated that the crestal bone position was directly correlated with the width of the machined collar. A wider collar resulted in greater bone loss. It has been speculated that machined collars do not provide an effective coupling to the bone, resulting in the application of shear and tensile forces to the crestal bone.[23] The observation that, in the case of implants with machined collars, the crestal bone loss ends at the first thread can be explained by the fact that the thread pattern converts the shear force into a compressive force.[24]

While the implications of the crestal bone level are very significant for the stability of an implant, there are further considerations that relate to the gingival tissues. Typically, the histologic organization of the gingival complex adjacent to an implant collar differs from that adjacent to a natural tooth. In the case of a natural tooth, in addition to circular and interseptal fibers, there are oblique or perpendicular fibers that insert into the cemental surface. This provides both stability for the marginal gingiva as well as resistance to penetration of plaque and associated microbiota.[25] In the case of a dental implant, the machined collar does not permit connective tissue attachment; hence, this stability for the gingival tissue is lacking.[26] However, there is a more recent trend to modify the implant collar with a rough texture, similar to that used along the body of the implant, and the placement of microgrooves along the collar width.[27] However, these grooves are significantly larger than the laser microtexturing on the experimental collars employed in this experiment.[28] The BioLok microgrooves did not accumulate plaque and appeared to stabilize the crestal bone.

In addition, there is histologic evidence of a mechanical attachment of connective tissue fibers to laser-microtextured grooves.[29] The laser-microtextured surface, while not entirely analogous to the cemental surface of the natural tooth, appears to provide more soft tissue support, in addition to that provided by the crestal bone. This type of interface may also resist recession of the gingival soft tissues, which has previously been reported.[30] While the present human study did not demonstrate histologic evidence of a connective tissue attachment to the implant collar, there was a statistically significantly smaller PD associated with the laser-microtextured implant collars. In combination with the higher crestal bone levels, as measured from the top of the implant, these findings support the notion that the laser-microtextured collar provides enhanced support to the adjacent bone and connective tissue.

Finally, in this study in which the implants were immediately loaded with prostheses, the survival rate of the laser-microtextured implants was similar to those seen reports where delayed loading was performed.[31,32] Immediate loading of the implants provided several significant advantages. First, the patients benefited from the stability of the prosthesis. Second, because the denture was supported by the caps embedded in the intaglio surface, there was less pressure on the surgical site and the possibility of displacement of the soft tissue was minimized. This appeared to result in uneventful healing. Three of the dentures required relining during the course of the study, and one of the prostheses fractured and was replaced. These results were similar to those of Cooper et al[33] and others who utilized similar protocols.[34]

CONCLUSIONS

Based on this case control study of 15 overdenture patients with immediately loaded implants designed with laser-microtextured and machined collars, the following can be concluded:

1. The presence of a laser-microtextured implant collar did not increase the plaque or sulcus bleeding indices.
2. The probing depth and the crestal bone loss adjacent to the laser-microtextured collar implants were statistically significantly lower than those observed adjacent to the machined-collar implants.
3. The BioLok implant with a laser-microtextured collar can be successfully immediately loaded and has a clinically acceptable survival rate.

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