Comparison of Er:YAG Laser Flapless Crown Lengthening vs. Open-Flap Bur Approach in Animal Studies

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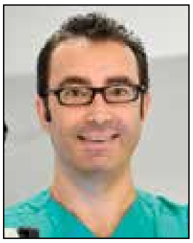

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INTRODUCTION

Crown lengthening (CL) has been used as a preprosthetic surgical method to increase crown retention in fixed partial prosthesis treatment;[1] it was further adopted through the development of esthetic dentistry to become a common procedure in achieving "smile design."[2-4] The aim of CL in esthetic dentistry is to avoid or correct the excessive visible parts of gum tissue below the patient's upper lip line while smiling.[5] Before and during such corrective surgery, care must be taken to preserve the "biologic width" and to measure the distance from the free gingival margin to the bony crest by "sounding" under anesthesia.[6] Sounding is a critical presurgical measurement and must absolutely be performed prior to the surgery, because once incisions are made it is not possible to measure the distance from the free-gingival margin to the crestal bone.[5] With respect to the mucosal tissue band width to be removed, excluding teeth with pockets deeper than 3 mm which are pathologic and need to be eliminated, in healthy periodontal conditions the proportional distance from the new free gingival margin to the bone be retained.[7] Thus, in many cases, collar bone adjacent to the teeth involved must be removed. Conventionally, CL surgery is achieved through an open (raised mucoperiosteal) flap procedure and bone is removed through the use of rotary instruments. Postoperative soft tissue healing and gingival border line stabilization time of such a technique varies from 4 to 6 weeks.[8-9]

To reduce healing time of CL surgery, attempts have been made to introduce new devices such as "piezosurgery," a methodology which uses ultrasonic vibrations with frequencies up to 25,000 Hz to mechanically remove hard tissues by sharp-cutting tips.[10] Piezosurgery is less traumatic compared to rotary instruments; postoperative healing time is also less than with rotary instruments, but is still approximately 4 weeks.[11-12]

ABSTRACT

Background: Conventionally, crown lengthening surgery is achieved through an "open" mucoperiosteal flap access procedure and the use of rotary instruments. The introduction of mid-infrared laser wavelengths, e.g., erbium:YAG (2940 nm), has made possible a "flapless" approach to crown lengthening surgery, which has several advantages such as uneventful healing, less edema, and no sutures. Flapless surgery is a blind approach and the outcome of crevicular bony modeling in such a method is uncertain.

Aim: The aim of this study is to compare the topographic results of both surgical methods in a sheep model.

Material and Methods: Ten fresh sheep mandibles were used. Bilateral crown lengthening was obtained on four molar teeth. Randomly, one side was used as test and the other as control. An Er:YAG laser (15 Hz frequency, 400 mJ energy, 200 µsec pulse duration, 6 W average power) was used on the test sides without raising a mucoperiosteal flap, and buccal crestal bone of 2 mm height was removed around each tooth. After laser application, each alveolar bone site was smoothed with Gracey curettes, and root planing was performed. Control sides underwent conventional open-flap surgery: 2 mm of buccal crestal bone was removed by a round diamond bur, at 800 rpm under saline irrigation, and root planing was performed with Gracey curettes. At the end of the operation, flaps were raised at the test sites. Impressions were taken by high-durometer silicone die material. Impression blocks were rendered uniform in size (10 x 28 mm surface). Stone models were cast and refined to uniform size and then scanned at 15,500 resolution. The data was analyzed using computer software. Macroscopic surface texture was compared by inspection of standardized digital images. Microscopic surface properties were analyzed by "current triangles" and "current vertices."

Results: Both groups revealed similar macroscopic features, but microscopically there were no significant correlations between current triangles and current vertices values of both groups ($r_{\text{current triangles}} = 0.0207$; $r_{\text{current vertices}} = 0.0289$).

Conclusion: Macroscopically, both methods have similar effects on bone surface topography. The Er:YAG laser microscopically creates more rough surface on bone tissue. The results of this study confirm that flapless surgery performed by an Er:YAG laser is as effective in contouring crestal bone as conventional surgery and, taking into consideration the advantages of the flapless surgery, it is suggested as preferable to the conventional crown-lengthening procedure.

KEYWORDS
Laser, erbium, Er:YAG, bur, crown lengthening, gummy smile, smile design, flapless surgery, animal study

Mid-infrared laser wavelengths (2940-nm Er:YAG and 2790-nm Er,Cr:YSGG) with a high absorption rate into water molecules of mucosa and bone, remove such target tissues by a thermo-mechanical ablation mechanism.[13-14] Free-running pulsed emission of such wavelengths and debris dispersal by air and water spray enable cooling of the operating field.[15] Such properties of the erbium family of lasers help ensure atraumatic soft and hard tissue ablation when compared to tissue removal via rotary instruments.[16-17] During the last decade, published reports show how erbium lasers have been used to treat "gummy smile" cases without raising flaps through a closed surgical technique.[18-20] A significant aspect of such techniques is to shorten the healing time period to about 2 weeks.[21]

In such cases, after the chosen level of excess mucosal tissue has been removed either conventionally by scalpel and/or curettes or by use of the laser with soft tissue power settings, the laser tip is inserted perpendicularly to the underlying alveolar crest and parallel to the tooth long axis. Bone is removed to the desired depth, initially point by point and then with circular movements around the root. Thus, mucoperiosteal flaps are not raised and the mucosa remains intact. Critics of this technique cite the "blind" approach to bone surgery and possible damage to adjacent root surface tissue.[22] Thus a study model was designed to investigate bone topography after laser application in CL surgery.

The aim of the present study was to compare topographic results of conventional and laser-assisted surgical methods in a sheep model.

Figure 1: Sample of test group bone topography after flap reflection

Figure 2: Sample of control group bone topography

MATERIALS AND METHODS

Ten freshly harvested sheep mandibles were used. Bilateral crown lengthening was obtained on four molar teeth. Randomly, one side was used as a test and the other as control. Test side procedures were carried out using an Er:YAG (2940 nm) laser (VersaWave, Hoya ConBio, Fremont, Calif., USA). Operating parameters employed were as follows: 200-µsec pulse duration, 400 mJ energy per pulse, 15-Hz frequency, 6 W average power output. No soft tissue flap was raised, as the aim of the study was to investigate collar bone sites. An 80-degree, 600-micron curved laser tip (312-9069, Hoya ConBio), marked to 2 mm and 4 mm depths, was inserted intrasulcularly and buccal collar bone amounting to 2 mm in height was then removed around each tooth. After laser application (an average of 44 seconds duration per tooth), each bone site was smoothed with Gracey curettes and root planing was performed. At the end of the procedure, flaps were raised in the test sides to detect surface alterations (Figure 1).

Control sides underwent a modified conventional open-flap surgery (without establishing a new free gingival margin by a mucoperiosteal incision): 2 mm of buccal crestal bone was removed by a 2-mm diameter round diamond bur. The operator used a 20:1 reduction contra-angle handpiece under saline irrigation at 800 rpm. Subsequent bone smoothing and root planing was carried out using Gracey curettes on about 1 to 2 mm of the beveled collar bone and along the exposed root surface (Figure 2).

In the authors' experience, crown lengthening procedure failure is caused by improper maintenance of the original biological distances of the epithelium-connective tissue to the crestal bone, and the soft tissues tend to revert to their original locations. Connective tissue attaches faster and bonds more strongly to the rough surfaces on bone or root surface, because of the fibrin network attachments to the rough floor within the coagulum and subsequent inflammatory healing process. Thus, to avoid coronal migration of the connective tissue, it is better to smooth collar surfaces both on bone and root surfaces.

The macroscopic surface texture of each sample was photographed with standard settings (Nikon D100 camera, f/22 diaphragm, 1/125 sec exposure, 105-mm macro lens). The presence or absence of a collar osteotomy band of about 2 mm in width was evaluated on the photographs.

Impressions were taken of the exposed operating fields with high-density silicone die material (Quick-Die™, Bisco, Inc., Schaumburg, Ill., USA) (Figure 3). Impression blocks were rendered uniform in size (10 x 28-mm surface) (Figure 4). Stone models were cast and refined in uniform size and then were scanned (Maestro 3D Easy Dental Scanner, AGE Solutions S.r.l., Pisa, Italy) at 15,500 resolution. The data was analyzed by computer software (Maestro Easy Dental Scan, AGE Solutions). Macroscopic surface textures were compared by inspecting standardized digital images (Figures 5-6). Microscopic surface properties were expressed in "current triangles" and "current vertices" and were compared statistically by the Pearson correlation test.

Scanners work by a process called "rasterization" which is "the task of taking an image described in a vector graphics format (shapes) and converting it into a raster image (pixels or dots) for output on a video display or printer, or for storage in a bitmap file format…The most basic rasterization algorithm takes a 3-D scene, described as polygons, and renders it onto a 2-D surface, usually a computer monitor. Polygons are themselves represented as collections of triangles. Triangles are represented by 3 vertices in 3-D space. At a very basic level, rasterizers simply take a stream of vertices, transform them into corresponding 2-dimensional points on the viewer's monitor, and fill in the transformed 2-dimensional triangles as appropriate."[23]

Figure 3: Test and control group mandibles. Impression pastes on operated areas are secured by plastic bases

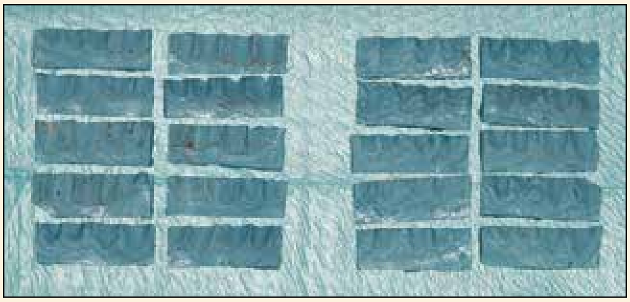

Figure 4: Impressions of control group (left side) and test group (right side)

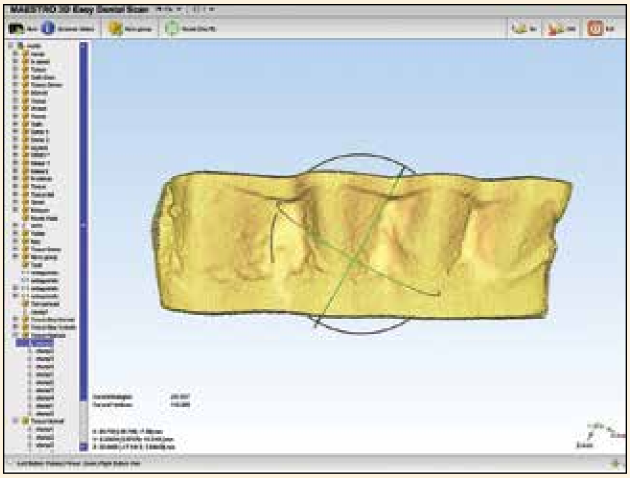

Figure 5: Scanned sample of test group

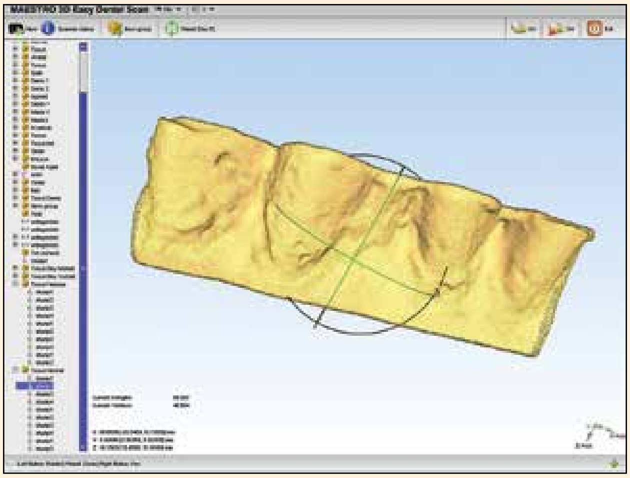

Figure 6: Scanned sample of control group

RESULTS

Macroscopic evaluation of crestal bone topography by evaluation of standard photographs revealed the presence of about a 2-mm width of collar osteotomy band buccally to each tooth in both groups (Table 1). Macroscopically, both methods have similar effects on bone surface topography.

Current triangles and vertices for groups are summarized in Table 2.

Microscopically, there were no significant correlations between current triangles and current vertices values of both groups ($r_{current\ triangles} = 0.0207$; $r_{current\ vertices} = 0.0289$). There was a positive correlation between current triangle and current vertex values of each group as the verification of the rasterization ($r_{test} = 0.9999$; $r_{control} = 0.9999$).

The current triangle and vertex values of the test group are at least three times greater than the control group which show that the Er:YAG laser microscopically creates rougher surfaces on bone tissue (Table 3). Clinically, osseous roughness does not affect the outcome of crown lengthening, because the essential factors are contouring the crevicular bone level and maintenance of the biologic width.

DISCUSSION

Although predictable esthetic results of crown lengthening-related "gummy smile" correction can be achieved, the extended healing time associated with conventional surgical techniques can prove disadvantageous. Thus attempts were made to shorten the healing time by using different surgical devices such as piezosurgery instruments and erbium lasers. Piezosurgery is a less traumatic device compared to rotary instruments.[24-25] However, with such instrumentation, there remains a need to apply open-flap surgery to perform CL. Flap raising lengthens healing time. Once the periosteum is separated from the underlying cortical bone, host inflammatory response pathways are stimulated and initiated.[26] Cortical bone blood supply is interrupted, predisposing to resorption of the outer bony cortex.[27-32] Pain, edema, and inflammation accompany flap surgery.[33-35] Thus, a method to avoid flap raising would avoid these disadvantages.[36-37] Dental hard-tissue lasers have been found to be less traumatic when compared to other surgical devices.[17, 38-40] Dental lasers have been used for crown lengthening procedures during the last two decades.[4, 18-20, 22, 41-42] Techniques to perform closed-flap crown lengthening to promote postoperative comfort and uneventful healing are proposed.[18-19, 22] Appropriate quartz or sapphire delivery tips of erbium lasers can be inserted via the periodontal sulcus to reach cortical bone; by measuring along the laser tip, bone can be decorticated to the desired level. Care must be taken to insert laser tips parallel to the root surface to avoid cementum ablation. The laser tip is placed into the sulcus and the connective tissue at the depth of the sulcus is sectioned vertically. By further ablation in an apical direction, the tip reaches the bony hard tissue level which can be felt through the laser handpiece via tactile feedback. This perpendicular insertion operation is repeated around the entire tooth circumference to enable soft and hard tissue removal through a laser-assisted thermo-mechanical ablation mechanism, without the need to open mucosal flaps. The possible irregularities created on the bone surface by the erbium laser can be smoothed by using hand instruments such as Gracey curettes.

It should be noted that rasterization was performed after surgical intervention. As the sensitivity (resolution) of the rasterization procedure is high, microporosities created by ablation of the hard tissue remained after use of the curette. Gracey curettes mostly served to ensure removal of bony irregularities created during intrasulcular ablation. When the diamond bur was used to remove collar bone, attention was paid to minimizing interaction with the root surface; undesirable grooving on the root surfaces caused by the bur was removed or reduced by subsequent root planing. Irregularities can be seen on macroscopic images (Figures 1-2), but there were no deep grooves or sharp chips.

Table 1: Collar Osteotomy Presence

sample #	test	control
1	+	+
2	+	+
3	+	+
4	+	+
5	+	+
6	+	+
7	+	+
8	+	+
9	+	+
10	+	+

Table 2: Triangles and Vertices in Test and Control Groups

	Test Group – Er:YAG Laser		Control Group – Bur	
sample #	current $triangles_{laser}$	current $vertices_{laser}$	current $triangles_{rotary}$	current $vertices_{rotary}$
1	237817	119268	88321	44442
2	357844	179509	99327	49954
3	360003	180600	92324	46556
4	365576	183417	105184	52938
5	256177	128619	104786	52676
6	356506	178801	99866	50246
7	331478	166277	90831	45753
8	331606	166454	109813	55266
9	374712	188024	103997	52364
10	377480	189329	81639	41204

Table 3: Surface Roughness Values in Test and Control Groups

	Test Group – Er:YAG Laser		Control Group – Bur	
	current $triangles_{laser}$	current $vertices_{laser}$	current $triangles_{rotary}$	current $vertices_{rotary}$
minimum	237817	119268	81639	41204
maximum	377480	189329	109813	55266
median	357175	179155	99596.5	50100
average	334919.9	168029.8	97608.8	49139.9

CONCLUSION

The results of this study, using *in vitro* animal tissue, provide support to the suggestion that flapless surgery performed by Er:YAG lasers can enable crestal bone recontouring to be as effective as conventional surgery. The experimental model of this study considers only the real-time changes on the bone tissue but not the possible clinical consequences of the laser energy on soft and hard tissues. Thus the experiment could be criticized for not including the long-term results of such an approach. For this purpose the research group of the present study would extend the test model on living animals. On the other hand, flapless osseous crown lengthening has been used successfully since the last decade, as published in case reports which are testimonials of the clinical outcomes.[18-20] When one examines the advantages of flapless surgery, the laser-assisted procedure is considered a more advisable technique, compared to a conventional crown lengthening operation.

AUTHOR BIOGRAPHY

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