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Root Surface Biomodification with an Er:YAG Laser for the Treatment of Gingival Recession with Subepithelial Connective Tissue Grafts

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Abstract

Background/Aim: Root surface biomodification has been used to treat gingival recession and periodontitis. The principle for this procedure is that removing the smear layer from the root surfaces exposes collagen fibers, which leads to improved healing. Clinical studies generally have failed to find any improvement in clinical parameters when using such agents. The aim of this study was to evaluate and compare the outcome of gingival recession therapy using the subepithelial connective tissue graft (SCTG) with or without Er:YAG laser application for root surface biomodification. ***Materials and Methods:*** Twenty-four teeth in 12 patients with Miller class I and II recession were treated with SCTG with (test group) or without (control group) the application of an Er:YAG laser (2 Hz, 60 mJ/pulse, 40 s, with air spray). Clinical attachment level (CAL), recession depth (RD), recession width (RW), and probing depth (PD) were measured at baseline and 6 months postsurgery. ***Results:*** There were no significant differences between test and control groups ($p > 0.05$). Postoperatively, significant root coverage, gains in CAL, and highly significant increases in the RW were observed in both groups. For test and control groups, the average root coverage was 80% and 86%, respectively ($p > 0.05$), and complete root coverage was 75% and 67%, respectively. ***Conclusions:*** The present study showed that root surface conditioning with an Er:YAG laser does not enhance the results achieved when SCTG was performed alone.

Introduction

Gingival recession is a most common and undesirable condition, which is characterized by the displacement of the gingival margin apically from the cemento–enamel junction (CEJ) and the exposure of the root surface to the oral environment. The principal objective in the treatment of gingival recession is to cover the exposed root surfaces to improve esthetics and to reduce hypersensitivity. Additional benefits that result from treating areas of gingival recession may include an increase in the width and thickness of keratinized gingiva. Coverage of denuded roots has become one of the most challenging procedures in periodontal mucogingival surgery.[1–4] The search for the appropriate root-coverage technique has taken many different approaches. Various surgical options have been developed to achieve the above goals and include the use of subepithelial connective tissue grafts (SCTG),[5] free gingival grafts,[6] laterally sliding flaps,[7] coronally advanced flaps,[8] double papillae flaps,[9] guided tissue regeneration,[10] and acellular dermal matrix allografts.[11] Among these surgical options, variations of SCTG procedures demonstrated a high percentage of root coverage with high predictability and without significant postsurgical complications.[12–18] Also, the root coverage gained with SCTG procedures was reported to be stable over the long term.[14] Therefore, SCTG procedures have commonly served as the gold standard to evaluate the safety and results of new root-coverage techniques.[1–4]

So far, a concerted effort has been made in the field of root conditioning to improve the outcome of regenerative periodontal therapies by favoring the attachment of the regenerated periodontal structures. Mechanical instrumentation (scaling and root planing) leaves a smear layer, which affects cell reattachment and can serve as a reservoir for microbial growth.[19] Therefore, chemical conditioning of the roots has been performed to remove the smear layer and improve biocompatibility. After smear-layer removal, the dentinal collagens are exposed, and they are supposed to be a chemoattractant for periodontal fibroblasts.[20] Besides these surgical options, various adjunctive agents have been applied to promote healing and further enhance clinical outcomes. These include root conditioners (e.g., citric acid,[20–25] tetracycline HCI,[26] EDTA,[19,27] phosphoric acid,[28] and hydrogen peroxide[3]), enamel matrix proteins,[29] recombinant

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human growth factors, platelet-rich plasma,[30] and dentin bonding conditioner.[31] In addition to chemical conditioning, the applicability of different laser systems, such as the CO_2, Nd:YAG diode, and Er:YAG laser in the removal of the smear layer has been demonstrated.[32–41]

However, until now no published data have been available concerning the clinical outcomes following root-surface biomodification with the Er:YAG laser for the treatment of gingival recession. The aim of the present study was to evaluate and compare the outcome of gingival recession therapy using the SCTG with or without Er:YAG laser application for root-surface biomodification.

Materials and Methods

The research protocol and consent form were initially submitted for consideration by the Ethics Committee, and the Institutional Internal Review and Ethics Board at Atatürk University, Faculty of Dentistry, approved the study. All participants provided written informed consent.

Selection of subjects and test teeth

The study population consisted of 12 patients with esthetic problems due to the exposure of recession-type defects when smiling (6 women and 6 men, 18–42 yr, mean age 27.3 ± 8.4 yr) who visited the periodontology department of Atatürk University, Erzurum, Turkey. Teeth with cracked structure, carious lesions, or restorations or that were nonvital were excluded. All the recession defects (24 teeth) fall into class I or II according to the definitions given by Miller, since no loss of interdental soft and hard tissue height was present.[42] The 24 experimental nonmolar teeth were identified and randomly balanced into two groups (12 test-group teeth, including 4 incisors, 2 canines, and 6 premolars, and 12 control-group teeth, including 6 incisors, 2 canines, and 4 premolars) and were subjected to one treatment modality for each group (Table 1).

All patients were nonsmokers, systemically and periodontally healthy, with no contraindications for periodontal surgery, and not taking medications known to interfere with periodontal tissue health or healing.

Following examination, all teeth received scaling, root planing, and crown polishing, and oral hygiene instructions were given 4 weeks before surgery. All patients demonstrated optimal oral hygiene (plaque score $\leq 15\%$).[43]

Clinical parameters

After baseline clinical measurements [recession depth (RD), recession width (RW), clinical attachment level (CAL), and probing depth (PD)], the teeth were randomly assigned

Table 1. Frequency Distribution of the Two Groups ($n = 12$)

Evaluation group	*Anterior absolute frequency*		*Premolar absolute frequency*	
Gingival recession	*Class 1*	*Class 2*	*Class 1*	*Class 2*
Test group	4	2	2	4
Control group	4	4	2	2

to the test group or control group. All measurements were performed by means of periodontal probe (Williams Periodontal Probe, Hu Friedy, Chicago, IL, USA) and caliper (Castroviejo Calipers 1730-1, Schwert, Germany).

The following clinical measurements were taken at the facial aspect to the experimental teeth 1 week before the surgery and at 6-month follow-up:

- Recession depth (RD), measured from the CEJ to the most apical extension of the gingival margin
- Recession width (RW), measured at the level of the CEJ
- Clinical attachment level (CAL), measured from the CEJ to the bottom of the gingival sulcus
- Probing depth (PD), measured from the gingival margin to the bottom of the gingival sulcus

The percentage of recession coverage was calculated according to the following formula:

$$\text{recession coverage} = (\text{preoperative recession depth} - \text{postoperative recession depth}) / \text{preoperative recession depth} \times 100$$

Examiner calibration

The investigator charged with clinical assessments was calibrated for intraexaminar repeatability prior to the start of the trial. Eleven patients with a total of 21 teeth with gingival recession were enrolled for this purpose. Duplicate measurements of CAL were collected with an interval of 24 h between the first and second recording. The intraclass correlation coefficient, as a measure of intraexaminer reproducibility, was 0.99.

Treatment

The exposed root surfaces were planed with curettes to remove edges, grooves, and dental plaque and to reduce the convexity of the root. The area was gently irrigated with sterilized physiological saline solution. Afterward, relative isolation of the region was carried out with the aid of a cotton roll, drying of the buccal surface with gauze and lasing was performed in the test group, and the exposed root surface was conditioned with the Er:YAG laser.

Lasing was performed using an Er:YAG laser (Doctor Smile erbium&diode, Lambda Scientifica S.r.l., Vicenza, Italy). Root surfaces in the test group were radiated by a laser beam of 2 Hz, 60 mJ/pulse, 40 s, 2094 nm with sweeping motion and air coolants. In addition, the distance between the end of the sapphire tip (diameter 400 μm) mounted on a hand piece (LAEH4012.5) and the tooth surface was adjusted to about 2 mm. (An energy density of 19.51 J/cm^2 with two irradiations of 20 s each was used.) When the lasers were in use, protective eyewear of appropriate optical density was worn by the investigator and patients.

Before surgery, extraoral antisepsis was performed with 10% povidone–iodine solution (Glividon®, Bikar Drug Ltd., Istanbul, Turkey) and intraoral antisepsis with 0.12% chlorhexidine rinse (Kloroben®, Drogsan Drug Ltd., Istanbul, Turkey). All defects were treated by using the Langer and Langer technique.[5] A local anesthetic (Ultracaine DS Forte®, Hoechst Roussel, Frankfurt, Germany) was administered to donor and recipient sites to achieve anesthesia. A partial-thickness flap was created with two vertical incisions placed at least one-half to one tooth wider mesiodistally than the area of gingival recession. The coronal margin of the flap was started with a horizontal sulcular incision to preserve all existing facial gingiva. The proximal papillae were left intact. Care was taken to extend the flap to the mucobuccal fold without perforations that could affect the blood supply. The area was irrigated with a sterile saline solution.

The connective tissue graft was harvested from the palate with the "trap-door" approach described by Harris.[15] A connective tissue graft in an adequate size of 2-mm thickness was harvested, and pressure was applied to the donor area with gauze soaked in saline after the graft was taken. The donor area was closed with silk 4-0 sling sutures.

The graft was trimmed with a sharp surgical blade, if necessary, and the SCTG was introduced to the recipient site, where the flap was pulled over a major portion of the SCTG. The recipient flap was then sutured directly over the graft with silk 5-0 sutures. The overlying flap covered the donor tissue as much as possible to provide more blood supply to the graft. The vertical incisions were also closed with silk 5-0 sutures. A mild compress with gauze soaked in saline was applied for 5 min. Dry foil was applied to the recipient area, and then a noneugenol periodontal dressing (Coe-Pak, GC America, Alsip, IL, USA) was placed over the dry foil to stabilize and protect the donor site for 14 days postsurgery. Techniques were performed with an interval of 6 weeks between surgeries.

Postsurgical care

All patients were instructed to take antibiotic (amoxicillin, Remoxil®, I.E. Ulagay Drug Ltd., Istanbul, Turkey), 500 mg every 8 h for 7 days, and analgesic medication (naproxen, Apranax®, Abdi İbrahim Drug Ltd., Istanbul, Turkey), 550 mg every 12 h for 5 days, and to discontinue tooth brushing around the surgical sites for the first 14 days after surgery. A cold compress extraorally and a bland diet were advised. During this period, plaque control was provided by rinsing with 0.12% chlorhexidine digluconate (Kloroben®, Drogsan Drug Ltd., Istanbul, Turkey) solution twice a day for 1 min. After this period, the sutures were removed. Plaque control in the surgically treated area was maintained by 0.12% chlorhexidine rinsings for an additional 2 weeks, and gentle tooth brushing with a soft-filament toothbrush was permitted twice daily. The patients were instructed to perform a nontraumatic brushing technique (roll technique) using a standardized soft toothbrush and toothpaste during the trial.

All patients were recalled for prophylaxis 1 and 3 weeks after suture removal and then monthly until the end of the study period. All participants completed the study and reported 100% compliance.

The initial therapy, laser application, and surgical treatments were performed by one investigator and the clinical measurements were assessed by another.

Statistical analysis

Descriptive statistics including means and standard deviations were calculated for both groups. The data thus collected were assessed using SPSS 11.0 statistical software (SPSS, Inc., Chicago, IL, USA). The Wilcoxon's signed ranks test was chosen to compare test group and control group differences in RD, RW, CAL, and PD. The differences in mean RD, RW, CAL, and PD values between baseline and 6 months were evaluated using Wilcoxon's signed ranks test. In addition, the Wilcoxon's signed ranks test was used to compare recession coverage (%, mm) between groups.

Results

Following the initial oral hygiene phase and at the post-treatment examinations, all subjects showed low frequencies of plaque-harboring tooth surfaces (PI $< 20\%$) and bleeding gingival units (GI $< 15\%$), indicating a good standard of supragingival plaque control during the study period.

The statistical analyses for the mean $\pm$ SD of clinical parameters at baseline and after 6 months for both groups are presented in Table 2.

No statistically significant differences between groups were observed for any of the clinical parameters at baseline and 6 months ($p > 0.05$). RD values were 3.08 ± 0.57 and 3.00 ± 0.71 mm at baseline and 0.58 ± 1.02 and 0.46 ± 0.75 mm at 6 months in the test and control groups, respectively ($p > 0.05$). RW values were 3.29 ± 1.13 and 3.25 ± 1.07 mm at baseline and 0.75 ± 1.36 and 0.92 ± 1.32 mm at 6 months in the test and control groups, respectively ($p > 0.05$). In addition, CAL values were 4.54 ± 0.90 and 4.67 ± 0.94 mm at baseline and 2.04 ± 0.59 and 2.08 ± 0.49 mm at 6 months in the test and control groups, respectively ($p > 0.05$).

In the test group, statistically significant changes from baseline were found for RD, RW, and CAL. RD decreased from 3.08 ± 0.57 to 0.58 ± 1.02 mm ($p < 0.01$), RW decreased from 3.29 ± 1.13 to 0.75 ± 1 .36 mm ($p < 0.01$), and CAL decreased from 4.54 ± 0.90 to 2.04 ± 0.59 mm ($p < 0.01$).

In the control group, statistically significant changes from baseline were found for RD, RW, and CAL. RD decreased from 3.00 ± 0.71 to 0.46 ± 0.75 mm ($p < 0.01$), RW decreased from 3.25 ± 1.07 to 0.92 ± 1.32 mm ($p < 0.01$), and CAL decreased from 4.67 ± 0.94 to 2.08 ± 0.49 mm ($p < 0.01$).

Probing depths did not show a statistically significant change after treatment in both groups ($p > 0.05$). PD values were 1.46 ± 0.43 and 1.58 ± 0.49 mm at baseline and

TABLE 2. MEAN $\pm$ SD OF CLINICAL PARAMETERS (MM) AT BASELINE AND 6 MONTHS POSTOPERATIVELY ($n = 12$)

Parameters	*Test group*	*Control group*	*p Value*
Recession depth (RD)			
Baseline	3.08 ± 0.57	3.00 ± 0.71	>0.05
6 months	0.58 ± 1.02*	0.46 ± 0.75*	>0.05
Recession width (RW)			
Baseline	3.29 ± 1.13	3.25 ± 1.07	>0.05
6 months	0.75 ± 1.36*	0.92 ± 1.32*	>0.05
Clinical attachment level (CAL)			
Baseline	4.54 ± 0.90	4.67 ± 0.94	>0.05
6 months	2.04 ± 0.59*	2.08 ± 0.49*	>0.05
Probing depth (PD)			
Baseline	1.46 ± 0.43	1.58 ± 0.49	>0.05
6 months	1.46 ± 0.66	1.63 ± 0.68	>0.05

*$p < 0.01$, significant differences between baseline and 6 months.

1.46 ± 0.66 and 1.63 ± 0.68 mm at 6 months in the test and control groups, respectively.

The recession coverages at 6 months postoperatively for the test and the control groups are shown in Table 3.

The mean recession coverage values for the test group were 2.50 ± 1.19 mm and $79.79\% \pm 35.83\%$. Corresponding values for the control group were 2.54 ± 1.14 mm and $85.95\% \pm 22.91\%$. These values were not statistically different ($p > 0.05$).

Complete recession coverage was accomplished in 75% (9 of 12) of the treated cases in the test group and in 66.7% (8 of 12) of the treated cases in the control group (Table 4).

Discussion

The aim of this randomized, controlled, split-mouth, double-blind clinical trial was to evaluate and compare the outcome of gingival recession therapy using the SCTG with or without Er:YAG laser application for root-surface biomodification. The present study showed no clinical benefit of root conditioning with the Er:YAG laser. For test and control groups, the average root coverage was 80% and 86% and the complete root coverage was 75% and 67%, respectively. Both of these results compare well with those of others, who reported an average mean root coverage of 64.7–97.3% and complete root coverage of 18.1–96.1% in studies that was used SCTG to obtain root coverage (Chambrone et al.,[1] Oates et al.,[3] and Roccuzzo et al.[4]).

Patients with gingival recessions who complain of esthetic concerns and hypersensitivity are possible candidates for root-coverage procedures. Before performing periodontal plastic surgery, clinicians should select the most predictable way to achieve successful root coverage. Although the more accepted techniques were the free gingival grafts and various pedicle grafts during the 1960s and 1970s,[6–9] SCTG was used to enhance covering areas of root exposure in the early 1980s.[5] Different flap procedures further modified this technique.[16–18] Longitudinal observations and case studies have shown a high success rate and predictability.[1–4] To accomplish patients' esthetic requirements and obtain successful root coverage, improved surgical techniques with SCTG were used.[11–18] Therefore, in the present study, SCTG was chosen for treatment of gingival recessions.

Complete root coverage is considered the true goal of treatment, because only complete coverage assures recovery from the hypersensitivity and esthetic defects associated with recession areas.[1–4] Previous studies have tried to improve the percentages of complete coverage with root-surface biomodification. Root-surface conditioning has been introduced, using a variety of agents, to detoxify, decontaminate, and demineralize the root surface, thereby removing the smear layer and exposing the collagenous matrix of dentin and cement.[19–28] However, the literature seems controversial with respect to root conditioning. The results of some studies have demonstrated that conditioned root surfaces have a higher percentage of complete root coverage compared with sites not treated with root-conditioning agents.[21–23] Conversely, the results of other studies showed no significant clinical benefit of root conditioning in conjunction with root-coverage procedures.[24,26,27] The present study showed that root-surface conditioning with the Er:YAG laser does not enhance the clinical results achieved when SCTG was performed alone. The results of our study are in agreement with the results of the earlier studies.

Table 3. Mean ± SD of Recession Coverage at 6 Months Postoperatively ($n = 12$)

	Test group	*Control group*	*p Value*
Recession coverage (mm)	2.50 ± 1.19	2.54 ± 1.14	>0.05
Recession coverage (%)	79.79 ± 35.83	85.95 ± 22.91	>0.05

Table 4. Frequency of Recession Coverage with Test and Control Group

Treatment	*100.00%*	*99–50%*	*49–0%*
Test group	9 (75%)	0 (%)	3 (25%)
Control group	8 (66.7%)	3 (25%)	1 (8.3%)

So far, no published data are available concerning the clinical outcomes following root-surface biomodification with the Er:YAG laser for the treatment of gingival recession, whereas the use of lasers has often been proposed for this condition. In previous clinical studies it has been demonstrated that lasers are an effective tool in the field of root conditioning to improve the outcome of regenerative periodontal therapies by favoring the attachment of the regenerated periodontal structures.[32–41] Among the dental lasers, the Er:YAG laser has been considered to be one of the most promising for use in periodontal therapy.[44–48] Previous clinical studies have reported the effectiveness and safety of root-surface debridement using the Er:YAG laser in nonsurgical and surgical periodontal pocket therapies.[49–55]

The changes on the root surface produced by the thermomechanical effect of the Er:YAG laser seem to be composed of both microstructural and thermal changes of the dentin.[38,40,41,56–58] The effect of the microstructure of the lased surface would be advantageous for initial cell and tissue attachment in vivo since the fibrin and blood clot form better on the lased surface[56–58] and would provide a scaffold for the ensuing cell and collagen fiber attachment. Because the emission wavelength is highly absorbed by water, the Er:YAG laser possesses an excellent capacity for ablating dental hard tissues without producing major thermal side effects,[38,44] such as carbonization, melting, and cracking of the root substance, which are usually observed following CO_2 and Nd:YAG laser irradiation.[36–38,59,60] Regarding the biocompatibility of the Er:YAG laser-irradiated root surface, several previous studies reported a faster adhesion and growth of fibroblasts on laser-treated surfaces compared with mechanically debrided surfaces.[41,51,61] Feist and colleagues[41] reported that the root surfaces prepared by Er:YAG laser irradiation at a high energy level delayed early human gingival fibroblast adherence. In addition, Mizutani and colleagues[61] reported that the affected layer on the root surface produced by Er:YAG laser irradiation was generally biocompatible, and most of the lased site with the affected layer was completely resorbed during the wound healing process at the site of connective-tissue attachment. Immunohistochemical characterization of wound healing following nonsurgical periodontal treatment revealed that Er:YAG laser radiation was effective in controling disease progression and may support the formation of a new connective-tissue attachment.[50] However, Maruyama and colleagues[62] reported that the characteristic microstructure of the root cement surface after Er:YAG laser irradiation had a tendency to hinder the early attachment of periodontal ligament cells. The Er:YAG laser parameters used in the present study (2 Hz, 60 mJ/pulse, 40 s, 2940 nm) were based on earlier studies,[41,51] which demonstrated that the Er:YAG laser when used with these parameters did not affect the biocompatibility of the root surface.

In contrast to the favorable effects of Er:YAG laser application described in the above studies, some authors have indicated that root surfaces following Er:YAG laser treatment in vitro exhibit a characteristic feature of micro-irregularities.[63,64] Fujii and colleagues[64] showed that the lased root surface displays a characteristic microstructure with a denaturation of collagen fibers. Regarding studies using other lasers, Trylovich and colleagues[65] reported that Nd:YAG laser irradiation alters the biocompatibility of the root surface, making it unfavorable for fibroblast attachment. Fayad and colleagues[59] reported a total lack of fibroblast attachment to CO_2-lased root surfaces.

The results of recent studies have shown that Er:YAG laser application resulted in significant improvements of some clinical parameters, such as PD and CAL.[51–55] The results of the present study demonstrate that root-surface conditioning with the Er:YAG laser has no additional clinical benefit when compared with root planing alone regarding CAL, RD, and RW. In both the test group and control group, the means of CAL, RD, and RW values showed decreases from baseline to 6 months, and these changes were statistically significant. Caffesse and colleagues[24] and Bouchard and colleagues[25] compared the SCTG in conjunction with citric acid to the SCTG where no root conditioning was performed and reported that root conditioning did not affect the clinical outcome of the surgical technique. Our findings are in accord with these reports.

The laser parameters affecting the amount of energy applied to a given surface include power level (W), exposure time (s), pulsed versus continuous wave energy, energy density (J/cm^2), distance from the surface, and the angle between the target tissue and the fiber tip. As a laser beam strikes a target tissue surface, the light energy can be affected in four ways: it can be reflected, transmitted, absorbed, or scattered, and the changes seen in target tissues are largely due to the absorbed energy.[66] Therefore, the most important issue in laser therapy is to determine the correct parameters to use to achieve satisfactory results, without inducing detrimental thermal effects in the pulp or causing fracturing or carbonization.

Conclusions

The most significant and interesting finding of the present study is that the use of the Er:YAG laser as a root-surface biomodifier did not affect the outcome of root coverage with the SCTG. Further comparative studies are needed to clarify this issue and to evaluate the long-term effects of this type of therapy.

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Author Disclosure Statement

No conflicting financial interests exist.

References

1. Chambrone, L., Chambrone, D., Pustiglioni, F.E., Chambrone, L.A., and Lima, L.A. (2008). Can subepithelial connective tissue grafts be considered the gold standard procedure in the treatment of Miller Class I and II recession-type defects? J. Dent. 36, 659–671.
2. Mariotti, A. (2003). Efficacy of chemical root surface modifiers in the treatment of periodontal disease: a systematic review. Ann. Periodontol. 8, 205–226.
3. Oates, T.W., Robinson, M., and Gunsolley, J.C. (2003). Surgical therapies for the treatment of gingival recession: a systematic review. Ann. Periodontol. 8, 303–320.
4. Roccuzzo, M., Bunino, M., Needleman, I., and Sanz, M. (2002). Periodontal plastic surgery for treatment of localized gingival recessions: a systematic review. J. Clin. Periodontol. 29, 178–194.
5. Langer, B., and Langer, L. (1985). Subepithelial connective tissue graft technique for root coverage. J. Periodontol. 56, 715–720.
6. Miller, P.D., Jr. (1982). Root coverage using a free soft tissue autograft following citric acid application. Part 1: Technique. Int. J. Periodontics Restorative Dent. 2, 5–70.
7. Grupe, H., and Warren, R.J. (1956). Repair of gingival defects by a sliding flap operation. J. Periodontol. 27, 290–295.
8. Bernimoulin, J.P., Luscher, B., and Muhlemann, H.R. (1968). Coronally repositioned periodontal flap. J. Clin. Periodontol. 39, 65–67.
9. Cohen, D.W., and Ross, S.E. (1968). The double papillae repositioned flap in periodontal therapy. J. Periodontol. 39, 65–70.
10. Pini Prato, G., Tinti, C., Vincenzi, G., Magnani, C., Cortellini, P., and Clauser, C. (1992). Guided tissue regeneration versus mucogingival surgery in the treatment of human buccal gingival recession. J. Periodontol. 63, 919–928.
11. Tal, H., Moses, O., Zohar, R., Meir, H., and Nemcovsky, C. (2002). Root coverage of advanced gingival recession: a comparative study between acellular dermal matrix allograft and subepithelial connective tissue grafts. J. Periodontol. 73, 1405–1411.
12. Han, J.S., John, V., Blanchard, S.B., Kowolik, M.J., and Eckert, G.J. (2008). Changes in gingival dimensions following connective tissue grafts for root coverage: comparison of two procedures. J. Periodontol. 79, 1346–1354.
13. Griffin, T.J., Cheung, W.S., Zavras, A.I., Damoulis, P.D. (2006). Postoperative complications following gingival augmentation procedures. J. Periodontol. 77, 2070–2079.
14. Harris, R.J. (2002). Root coverage with connective tissue grafts: an evaluation of short- and long-term results. J. Periodontol. 73, 1054–1059.
15. Harris, R. (1992). The connective tissue and partial thickness double pedicle graft: a predictable method of obtaining root coverage. J. Periodontol. 63, 477–486.
16. Allen, A.L. (1994). Use of the supraperiosteal envelope in soft tissue grafting for root coverage. I. Rationale and technique. Int. J. Periodontics Restorative Dent. 14, 216–227.

17. Raetzke, P.B. (1985). Covering localized areas of root exposure employing the "envelope" technique. J. Periodontol. 56, 397–402.
18. Blanes, R.J., and Allen, E.P. (1999). The bilateral pedicle flap-tunnel technique: a new approach to cover connective tissue grafts. Int. J. Periodontics Restorative Dent. 19, 471–479.
19. Blomlöf, J.P., Blomlöf, L.B., and Lindskog, S.F. (1996). Smear removal and collagen exposure after non-surgical root planing followed by etching with an EDTA gel preparation. J. Periodontol. 67, 841–845.
20. Polson, A.M., Frederick, G.T., Ladenheim, S., and Hanes, P.J. (1984). The production of a root surface smear layer by instrumentation and its removal by citric acid. J. Periodontol. 55, 443–446.
21. Common, J., and McFall, W.T., Jr. (1983). The effects of citric acid on attachment of laterally positioned flaps. J. Periodontol. 54, 9–18.
22. Miller, P.D., Jr. (1985). Root coverage using the free soft tissue autograft following citric acid application. III. A successful and predictable procedure in areas of deep-wide recession. Int. J. Periodontics Restorative Dent. 5, 14–37.
23. Tolmie, P.N., Rubins, R.P., Buck, G.S., Vagianos, V., and Lanz, J.C. (1991). The predictability of root coverage by way of free gingival autografts and citric acid application: an evaluation by multiple clinicians. Int. J. Periodontics Restorative Dent. 11, 261–271.
24. Caffesse, R.G., De LaRosa, M., Garza, M., Munne-Travers, A., Mondragon, J.C., and Weltman, R. (2000). Citric acid demineralization and subepithelial connective tissue grafts. J. Periodontol. 71, 568–572.
25. Bouchard, P., Etienne, D., Ouhayoun, J.P., and Nilvéus, R. (1994). Subepithelial connective tissue grafts in the treatment of gingival recessions: a comparative study of 2 procedures. J. Periodontol. 65, 929–936.
26. Bouchard, P., Nilveus, R., and Etienne, D. (1997). Clinical evaluation of tetracycline HCl conditioning in the treatment of gingival recessions: a comparative study. .J Periodontol. 68, 262–269.
27. Bittencourt, S., Ribeiro, E.P., Sallum, E.A., Sallum, A.W., Nociti, F.H., Jr., and Casati, M.Z. (2007). Root surface biomodification with EDTA for the treatment of gingival recession with a semilunar coronally repositioned flap. J. Periodontol. 78, 1695–1701.
28. Héritier, M. (1984). Effects of phosphoric acid on root dentin surface: a scanning and transmission electron microscopic study. J. Periodontal. Res. 19, 168–176.
29. Sallum, E.A., Casati, M.Z., Caffesse, R.G., Funis, L.P., Nociti, J.F.H., and Sallum, A.W. (2003). Coronally positioned flap with or without enamel matrix protein derivative for the treatment of gingival recessions. Am. J. Dent. 16, 287–291.
30. Lacoste, E., Martineau, I., and Gagnon, G. (2003). Platelet concentrates: effects of calcium and thrombin on endothelial cell proliferation and growth factor release. J. Periodontol. 74, 1498–1507.
31. Abitbol, T., Settembrini, L., Santi, E., and Scherer, W. (1996). Root surface biomodification using a dentin bonding conditioner. Periodontal Clin. Investig. 18, 27–30.
32. Crespi, R., Barone, A., Covani, U., Ciaglia, R.N., and Romanos, G.E. (2002). Effects of CO_2 laser treatment on fibroblast attachment to root surfaces: a scanning electron microscopy analysis. J. Periodontol. 73, 1308–1312.
33. Barone, A., Covani, U., Crespi, R., and Romanos, G.E. (2002). Root surface morphological changes after focused versus defocused CO_2 laser irradiation: a scanning electron microscopy analysis. J. Periodontol. 73, 370–373.
34. Pant, V., Dixit, J., Agrawal, A.K., Seth, P.K., and Pant, A.B. (2004). Behavior of human periodontal ligament cells on CO_2 laser irradiated dentinal root surfaces: an in vitro study. J. Periodontal Res. 39, 373–379.
35. Ito, K., Nishikata, J., and Murai, S. (1993). Effects of Nd:YAG laser radiation on removal of a root surface smear layer after root planing: a scanning electron microscopic study. J. Periodontol. 64, 547–552.
36. Wilder-Smith, P., Arrastia, A.M., Schell, M.J., Liaw, L.H., Grill, G., and Berns, M.W. (1995). Effect of ND:YAG laser irradiation and root planing on the root surface: structural and thermal effects. J. Periodontol. 66, 1032–1039.
37. Tewfik, H.M., Garnick, J.J., Schuster, G.S., and Sharawy, M.M. (1994). Structural and functional changes of cementum surface following exposure to a modified Nd:YAG laser. J. Periodontol. 65, 297–302.
38. Israel, M., Cobb, C.M., Rossmann, J.A., and Spencer, P. (1997). The effects of CO_2, Nd:YAG and Er:YAG lasers with and without surface coolant on tooth root surfaces: an in vitro study. J. Clin. Periodontol. 24, 595–602.
39. Yamaguchi, H., Kobayashi, K., Osada, R., et al. (1997). Effects of irradiation of an erbium:YAG laser on root surfaces. J. Periodontol. 68, 1151–1155.
40. Folwaczny, M., Mehl, A., Haffner, C., Benz, C., and Hickel, R. (2000). Root substance removal with Er:YAG laser radiation at different parameters using a new delivery system. J. Periodontol. 71, 147–155.
41. Feist, I.S., De Micheli, G., Carneiro, S.R., Eduardo, C.P., Miyagi, S., and Marques, M.M. (2003). Adhesion and growth of cultured human gingival fibroblasts on periodontally involved root surfaces treated by Er:YAG laser. J. Periodontol. 74, 1368–1375.
42. Miller, P.D., Jr. (1985). A classification of marginal tissue recession. Int. J. Periodontics Restorative Dent. 5, 8–13.
43. O'Leary, T.J., Drake, R.B., and Naylor, J.E. (1972). The plaque control record. J. Periodontol. 43, 38.
44. Schwarz, F., Aoki, A., Becker, J., and Sculean, A. (2008). Laser application in non-surgical periodontal therapy: a systematic review. J. Clin. Periodontol. 35, 29–44.
45. Cobb, C.M. (2006). Lasers in periodontics: a review of the literature. J. Periodontol. 77, 545–564.
46. Walsh, L.J. (2003). The current status of laser applications in dentistry. Aust. Dent. J. 48, 146–155.
47. Aoki, A., Sasaki, K.M., Watanabe, H., and Ishikawa, I. (2004). Lasers in nonsurgical periodontal therapy. Periodontology. 36, 59–97.
48. Ishikawa, I., Aoki, A., and Takasaki, A.A. (2004). Potential applications of erbium:YAG laser in periodontics. J. Periodontal Res. 39, 275–285.
49. Sculean, A., Schwarz, F., Berakdar, M., Romanos, G.E., Arweiler, N.B., and Becker, J. (2004). Periodontal treatment with an Er:YAG laser compared to ultrasonic instrumentation: a pilot study. J. Periodontol. 75, 966–973.
50. Schwarz, F., Jepsen, S., Herten, M., Aoki, A., Sculean, A., and Becker, J. (2007). Immunohistochemical characterization of periodontal wound healing following nonsurgical treatment with fluorescence controlled Er:YAG laser radiation in dogs. Lasers Surg. Med. 39, 428–440.
51. Schwarz, F., Aoki, A., Sculean, A., Georg, T., Scherbaum, W., and Becker, J. (2003). In vivo effects of an Er:YAG laser, an ultrasonic system and scaling and root planing on the biocompatibility of periodontally diseased root surfaces in

cultures of human PDL fibroblasts. Lasers Surg. Med. 33, 140–147.
52. Schwarz, F., Sculean, A., Berakdar, M., Szathmari, L., Georg, T., and Becker, J. (2003). In vivo and in vitro effects of an Er:YAG laser, a GaAlAs diode laser, and scaling and root planing on periodontally diseased root surfaces: a comparative histologic study. Lasers Surg. Med. 32, 359–366.
53. Schwarz, F., Sculean, A., Berakdar, M., Georg, T., Reich, E., and Becker, J. (2003). Periodontal treatment with an Er:YAG laser or scaling and root planing. A 2-year follow-up split-mouth study. J. Periodontol. 74, 590–596.
54. Schwarz, F., Sculean, A., Berakdar, M., Georg, T., Reich, E., and Becker, J. (2003). Clinical evaluation of an Er:YAG laser combined with scaling and root planing for non-surgical periodontal treatment: a controlled, prospective clinical study. J. Clin. Periodontol. 30, 26–34.
55. Schwarz, F., Sculean, A., Georg, T., and Reich, E. (2001). Periodontal treatment with an Er:YAG laser compared to scaling and root planing: a controlled clinical study. J. Periodontol. 72, 361–367.
56. Sasaki, K.M., Aoki, A., Ichinose, S., and Ishikawa, I. (2002). Morphological analysis of cementum and root dentin after Er:YAG laser irradiation. Lasers Surg. Med. 31, 79–85.
57. Fujii, T., Baehni, P.C., Kawai, O., Kawakami, T., Matsuda, K., and Kowashi, Y. (1998). Scanning electron microscopic study of the effects of Er:YAG laser on root cementum. J. Periodontol. 69, 1283–1290.
58. Theodoro, L.H., Sampaio, J.E., Haypek, P., Bachmann, L., Zezell, D.M., and Garcia, V.G. (2006). Effect of Er:YAG and diode lasers on the adhesion of blood components and on the morphology of irradiated root surfaces. J. Periodontal Res. 41, 381–390.
59. Fayad, M.I., Hawkinson, R., Daniel, J., and Hao, J. (2004). The effect of CO_2 laser irradiation on PDL cell attachment to resected root surfaces. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 97, 518–523.
60. Tucker, D., Cobb, C.M., Rapley, J.W., and Killoy, W.J. Morphologic changes following in vitro CO_2 laser treatment of calculus-ladened root surfaces. Lasers Surg. Med. 18, 150–156.
61. Mizutani, K., Aoki, A., Takasaki, A.A., et al. (2006). Periodontal tissue healing following flap surgery using an Er:YAG laser in dogs. Lasers Surg. Med. 38, 314–324.
62. Maruyama, H., Aoki, A., Sasaki, K.M., et al. (2008). The effect of chemical and/or mechanical conditioning on the Er:YAG laser-treated root cementum: analysis of surface morphology and periodontal ligament fibroblast attachment. Lasers Surg. Med. 40, 211–222.
63. Sasaki, K.M., Aoki, A., Ichinose, S., and Ishikawa, I. (2002). Morphological analysis of cementum and root dentin after Er:YAG laser irradiation. Lasers Surg. Med. 31, 79–85.
64. Fujii, T., Baehni, P.C., Kawai, O., Kawakami, T., Matsuda, K., and Kowashi, Y. (1998). Scanning electron microscopic study of the effects of Er:YAG laser on root cementum. J. Periodontol. 69, 1283–1290.
65. Trylovich, D.J., Cobb, C.M., Pippin, D.J., Spencer, P., and Killoy, W.J. (1992). The effects of the Nd:YAG laser on in vitro fibroblast attachment to endotoxin-treated root surfaces. J. Periodontol. 63, 626–632.
66. Kimura, Y., Wilder-Smith, P., Yonaga, K., and Matsumoto, K. (2000). Treatment of dentine hypersensitivity by lasers: a review. J. Clin. Periodontol. 27, 715–721.

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