ORIGINAL ARTICLE CE AJO-DO

Effectiveness of Er:YAG laser-aided fiberotomy and low-level laser therapy in alleviating relapse of rotated incisors

Arezoo Jahanbin,[a] BaratAli Ramazanzadeh,[b] Farzaneh Ahrari,[c] Ali Forouzanfar,[d] and Mehran Beidokhti[e]
Mashhad, Iran

Introduction: In this study, we compared the effectiveness of laser-aided circumferential supracrestal fiberotomy (CSF) and low-level laser therapy (LLLT) with conventional CSF in reducing relapse of corrected rotations. **Methods:** The study included 24 patients who were at the finishing stage of orthodontic treatment and had at least 1 maxillary incisor with 30° to 70° of rotation before starting therapy. The subjects were divided into 4 groups by treatment: conventional CSF, Er:YAG laser-aided CSF, LLLT, and control. After alginate impressions were taken, the archwire was sectioned from the experimental incisors, and they were allowed to relapse. The second impression was taken 1 month later, and the degree and percentage of relapse were calculated in photographs taken from the dental models. Gingival recession, pocket depth, and pain were also measured in the CSF groups. **Results:** The mean percentages of relapse were 9.7% in the conventional CSF, 12.7% in the Er:YAG laser-aided CSF, 11.7% in the LLLT, and 27.8% in the control groups. Relapse was significantly greater in the control than the experimental groups ($P < 0.05$), which were not statistically different from each other. The changes in sulcus depth and gingival recession were small and not significantly different among the CSF groups ($P > 0.05$), but pain intensity was greater in subjects who underwent conventional CSF ($P = 0.003$). **Conclusions:** Er:YAG laser-aided CSF proved to be an effective alternative to conventional CSF in reducing rotational relapse. LLLT with excessively high energy density was also as effective as the CSF procedures in alleviating relapse, at least in the short term. (Am J Orthod Dentofacial Orthop 2014;146:565-72)

Relapse of corrected tooth rotations is a great challenge frequently facing orthodontists after orthodontic treatment. The slow turnover rate of supracrestal soft tissues is usually blamed for this phenomenon.[1,2] Swanson et al[3] reported an incidence of 48% for rotational relapse in patients 10 years out of retention. It has been demonstrated that the magnitude of relapse is in proportion to the severity of the initial rotation.[3,4] Several strategies have been suggested as adjuncts to minimize relapse tendency of previously rotated teeth—eg, overrotation, early correction, and long-term retention—but the most applicable and efficacious method for this purpose is assumed to be circumferential supracrestal fiberotomy (CSF).

Introduced by Edwards[5] in 1970, CSF consists of transecting the free gingival and transseptal fibers to increase their adaptation to the new tooth position. The effectiveness of the CSF procedure in reduction of periodontal relapse has been demonstrated in previous studies.[6-11] However, some problems can occur during or after the CSF surgery, including bleeding, pain or discomfort, and the possibility of gingival recession and deepening of the gingival sulcus; these have resulted in relatively poor patient acceptability of the procedure. Therefore, alternative approaches such as CSF with electrosurgery[12] or laser[13] have been suggested.

Lasers have various applications in periodontal and orthodontic procedures, including removal of hyperplastic gingiva, exposure of impacted teeth, frenectomy,

[a]Associate professor, Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
[b]Professor, Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
[c]Assistant professor, Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
[d]Assistant professor, Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran.
[e]Private practice, Mashhad, Iran.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Supported by a grant from the Research Council of Mashhad University of Medical Sciences, Mashhad, Iran (grant number 910134). These results have been taken from a postgraduate student thesis by Dr Mehran Beidokhti (number 496).
Address correspondence to: Farzaneh Ahrari, Dental Research Center, School of Dentistry, Mashhad University of Medical Sciences, Vakilabad Blvd, Mashhad, Iran; e-mail, Farzaneh.Aharri@gmail.com.
Submitted, March 2014; revised and accepted, July 2014.
0889-5406/$36.00
Copyright © 2014 by the American Association of Orthodontists.
http://dx.doi.org/10.1016/j.ajodo.2014.07.006

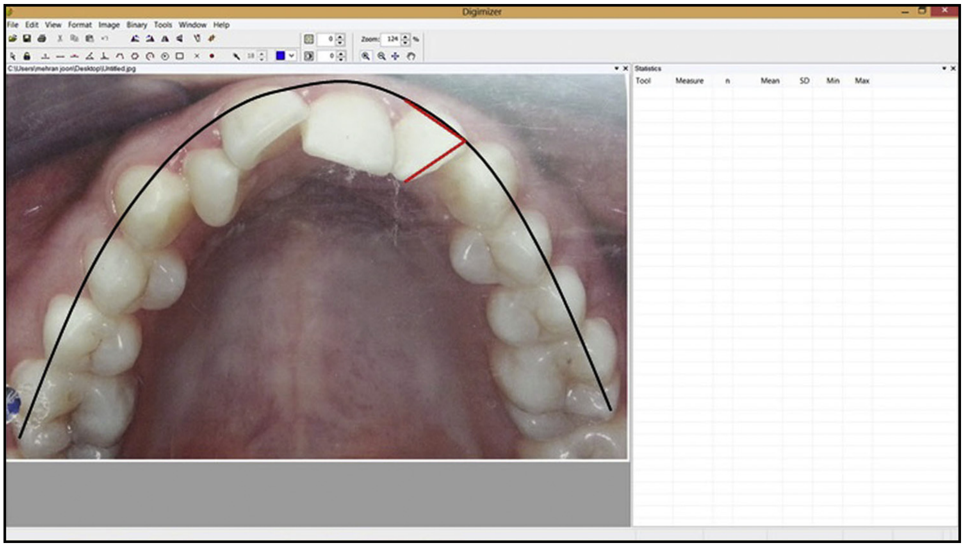

Fig 1. Determining the pretreatment angle of rotation of the maxillary left lateral incisor by measuring the angle formed between the incisal edge and the tangent to the esthetic line of occlusion.

uncovering temporary anchorage devices, and CSF. It is believed that laser-aided CSF has numerous advantages compared with the conventional technique, including minimal pain and swelling, little or no bleeding, and lower probability of postoperative infection because the laser beam sterilizes the irradiated area.

Low-level laser therapy (LLLT) has been used in medicine and dentistry for more than 40 years. This treatment modality can have several biologic effects on cells and tissues, such as enhanced wound healing, reduced pain, and acceleration of the inflammation process. It is believed that the efficacy of LLLT depends on the dose applied. Arndt-Schultz[14] proposed a therapeutic window (between 0.01 and 10 J/cm^2) at which the biostimulatory effects of low-power lasers are presented, whereas the inhibitory effects on physiologic activity can be observed at higher dosages. LLLT has been recently attempted in orthodontics for enhancing the stability of rotational movements, but the results of a previous study in this field were disappointing because significantly more relapse was observed in the LLLT group compared with the control group.[13]

There are few studies regarding the efficacy of LLLT and laser-aided CSF in preventing rotational relapse, and the pathologic sequelae of laser CSF on the periodontium has not been investigated. Therefore, this study was conducted to (1) investigate the efficacy of the Er:YAG laser-aided CSF procedure and LLLT compared with conventional CSF in alleviating relapse of orthodontically corrected rotations, and (2) compare the magnitudes of pain, gingival recession, and pocket depth alteration after conventional and laser-aided CSF procedures.

MATERIAL AND METHODS

The pretreatment maxillary occlusal photographs of patients at the finishing stage of orthodontic treatment were evaluated to find those with at least 1 (up to 4) rotated maxillary incisor(s) with 30° to 70° of rotation before orthodontic therapy. The patients were under treatment at the Department of Orthodontics, School of Dentistry, Mashhad University of Medical Sciences, Mashad, Iran, and at 1 private office in Mashhad, Iran. The participants had no systemic diseases and exhibited good oral hygiene. Patients with gingival inflammation or periodontal problems and those with proximal caries, deep caries extending to the cementoenamel junction, or anatomic abnormalities in the experimental teeth were excluded from the sample. The exclusion criteria also involved patients who consumed medicine that interrupted bone metabolism and those with conditions for which laser therapy could be contraindicated (eg, pregnancy). Twenty-four subjects with 47 rotated maxillary incisors satisfied the inclusion criteria and agreed to participate in the study. The patients (20 females, 4 males) ranged in age from 16 to 32 years (mean age, 24.5 ± 5.1 years). The study protocol was reviewed and approved by the ethics committee of Mashhad University of Medical Sciences, and an informed consent document was obtained from each participant after complete explanation of the treatment process. The subjects were divided into 4 groups by treatment: group 1 (conventional CSF), group 2 (Er:YAG laser-aided CSF), group 3 (LLLT), and group 4 (control).

To measure the initial rotation of the maxillary incisors, the pretreatment (T0) occlusal photograph of the maxillary arch was scanned and imported into the Digimizer image analysis software (version 4.1.1.0; MedCalc Software, Mariakerke, Belgium). The esthetic line of occlusion was then drawn in each photograph, and the steep angle formed between a line passing through the incisal edge of the rotated incisor and the line tangent to the esthetic line of the dentition in the area of the rotated tooth was calculated (Fig 1).

To assign teeth with severe rotations evenly in the study groups, the teeth were divided into 2 groups with 30° to 50° (moderate) or 51° to 70° (severe) rotations, as measured in the pretreatment occlusal photographs. The subjects were then randomly allocated into the 4 groups so that the teeth with moderate (31 teeth) or severe (16 teeth) rotations were evenly distributed among the groups. The mean (± standard deviation) degrees of initial rotation were 43.86° (±10.4°) in group 1, 48.12° (±8.01°) in group 2, 45.67° (±8.48°) in group 3, and 49.23° (±11.21°) in group 4. The procedures performed in the study groups were as follows.

Group 1 (conventional CSF) consisted of 6 patients with 13 rotated incisors who underwent conventional CSF surgery. Before the surgical procedure, the sulcus depth of each tooth was determined by a periodontal probe. The maximum depth of inserting the blade was considered as the sum of the sulcus depth and the biologic width (about 2 mm). Local anesthesia was used with infiltration of 2% lidocaine combined with 1:100,000 epinephrine, and then the CSF was performed by inserting a number 11.0 surgical blade into the gingival sulcus up to the level of the alveolar crest. The blade was moved around the tooth circumference to sever the free gingival and transseptal fibers. A periodontal pack was then placed on the tooth and remained for 24 hours. The patients were asked to maintain good oral hygiene. After the CSF procedure, the archwire was retained for 1 month to allow reattachment of the periodontal fibers in the ideal tooth position.

Group 2 (laser-aided CSF) included 6 subjects with 11 rotated teeth subjected to laser-aided fiberotomy. The device used was an Er:YAG laser (Smart 2940D; Deka Laser, Florence, Italy) emitting a wavelength of 2940 nm. The laser operated with 100 mJ of energy, pulse repetition rate of 10 Hz, and air and water spray. A contact handpiece with a 1.1-mm-diameter sapphire tip was used for tissue incision. The maximum depth of inserting the laser tip was determined similar to that

Fig 2. A digital camera fixed at a 50-cm distance over a cast positioned in a dental surveyor.

in group 1. After local anesthesia, laser-aided CSF was performed by inserting the laser tip intrasulcularly at an angle of 10° to 15° to the radicular surface of the tooth. Since the light is irradiated from the end of the tip, the handpiece was moved in an apicocoronal direction during the CSF surgery. Little or no bleeding was observed, and no periodontal pack was inserted after the procedure. The patients were asked to maintain good oral hygiene. Similar to group 1, the archwire was retained for 1 month after surgery to allow reattachment of the gingival and periodontal fibers in the ideal tooth position.

Group 3 (LLLT) involved 12 rotated incisors in 6 patients who were treated with a low-level gallium-aluminum-arsenide diode laser (DD2 Control Unit; Thor, London, United Kingdom) to alleviate relapse of orthodontically corrected rotations. The laser emitted a wavelength of 810 nm and operated in continuous wave mode with maximum power of 200 mW. The laser probe was positioned in contact with gingival tissue in the coronal third of the root, and the irradiation was performed on 4 points around the tooth, including mesiobuccal, distobuccal, mesiolingual, and distolingual areas. The laser was irradiated for 50 seconds per point, and thus each tooth received 200 seconds of laser irradiation. The energy dose at each area was calculated to be 35.7 J/cm^2, considering the surface area of 0.28 cm^2 for the probe. LLLT was performed twice a week for 4 weeks.

Group 4 (control) included 6 patients with 11 rotated incisors; no intervention to minimize relapse was performed.

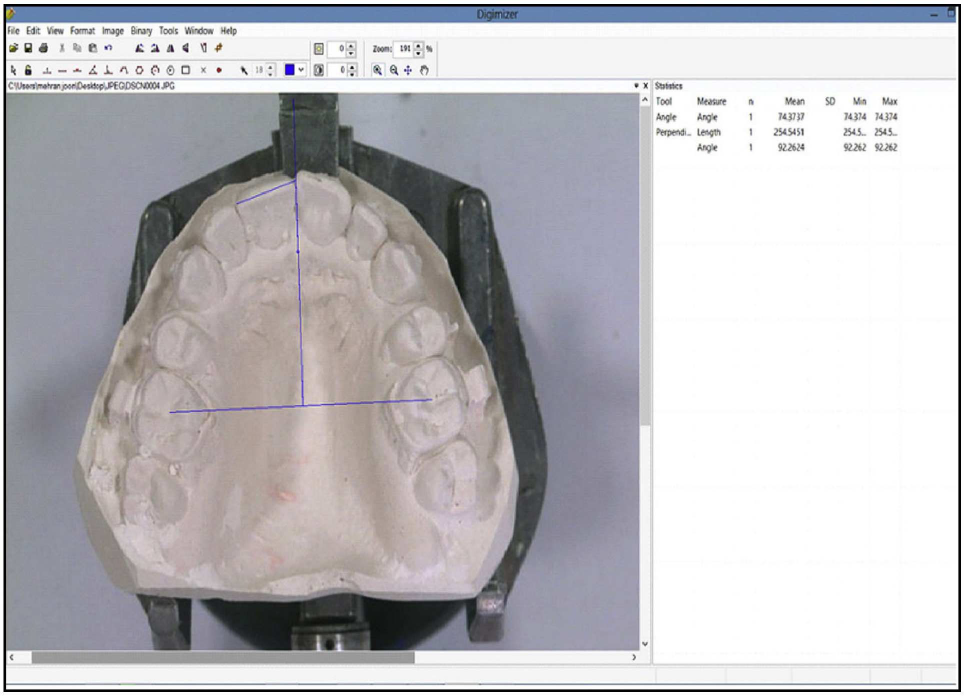

Fig 3. Calculating the angle formed between the incisal edge of the experimental incisor and the reference line (perpendicular to the line passing through the central fossae of first molars).

To determine the amount of relapse, the finishing archwire was removed from the maxilla, and an alginate impression was taken (T1). This initial impression was taken 1 month after performing conventional and laser-aided CSF in order to allow healing of supracrestal soft tissues following the surgical intervention. The impression was poured with orthodontic plaster, and the dental models were positioned on a prosthetic surveyor, so that the occlusal plane of the model was positioned horizontally. The dental models were then photographed at constant magnification with a digital camera (AVerMedia Technologies Inc, New Taipei City, Taiwan) that was fixed at a distance of 50 cm over the casts (Fig 2). The images were then imported into the Digimizer software in which a reference line was drawn that was perpendicular to the line linking the central fossae of the first molars and passing through the midline of the maxillary dentition. The angle formed between the incisal edge line of the experimental incisor and the reference line was then calculated (Fig 3) and rounded to 0.1°.

After taking the first impression, the archwire was sectioned from the experimental incisors, and they were allowed to relapse. The remaining teeth in the arch, however, were ligated to each other, and the archwire was maintained on them to prevent dental movements in other parts of the maxilla.

The second alginate impression was taken 30 days after removing the orthodontic archwire from the previously rotated teeth (T2; 2 months after CSF in groups 1 and 2), and the angle formed between the incisal edge of the tooth and the reference line was measured again. The mean relapse was reported as an absolute value calculated by subtracting the angle obtained at T1 from the corresponding value at T2. The percentage of relapse was also calculated relative to the initial angle of rotation according to the following formula:

$$\text{The percentage of relapse} = \frac{\text{the amount of relapse}}{\text{the initial degree of rotation}} \times 100$$

Pocket depth and gingival recession were assessed preoperatively and 2 months postoperatively (allowing 1 month for healing and 1 month for relapse) in groups 1 and 2 to determine any detrimental effects of the CSF procedure on the periodontium. Pocket depth was recorded at 6 points around the experimental tooth (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual) with a periodontal probe to the nearest 0.5 mm, and the average pocket depth was then determined for the tooth using these measurements. Pocket depth alteration was then calculated for each experimental tooth by subtracting the pocket depth obtained at T1 from the T2 reading.

Table I. Descriptive statistics and the results of statistical analysis for comparison of the amount (degree) and percentage of relapse among the study groups

	Initial angle of rotation (T0)	Amount of relapse (T2−T1)		Percentage of relapse (T2−T1)/T0	
Group	*Mean ± SD (°)*	*Mean ± SD (°)*	*Pairwise comparisons**	*Mean ± SD (%)*	*Pairwise comparisons**
Conventional CSF	43.86 ± 10.40	4.24 ± 1.12	a	9.66 ± 2.27	a
Laser-aided CSF	48.12 ± 8.01	6.12 ± 1.77	a	12.71 ± 3.86	a
Low-level laser therapy	45.67 ± 8.48	5.33 ± 1.91	a	11.67 ± 3.63	a
Control	49.23 ± 11.21	13.67 ± 3.27	b	27.82 ± 6.29	b
Statistical significance (ANOVA)	$P = 0.997$	$P < 0.001$		$P < 0.001$	

*Tukey pairwise comparison test. Different letters indicate statistically significant differences at $P < 0.05$

For determining gingival recession, the height of the buccal crown from the incisal edge of the incisor to the most apical point of the gingiva (gingival zenith) was measured with a gauge to the nearest 0.5 mm. The mean gingival recession was calculated by subtracting the crown height at T1 from that at T2.

The patients were also asked to mark the amount of pain perceived within the first 24 hours after the CSF surgery on a visual analog scale, consisting of a 10-cm horizontal line, with 0 indicating no pain and 10 indicating the most terrible pain.

The clinical and dental cast measurements were performed by 1 investigator (M.B.). Double readings were taken for pretreatment angle of rotation, pocket depth, and buccal crown height variables, and the average was recorded. To determine the measurement error of the dental models, 10 models (with 18 rotated teeth) were randomly selected, and tooth rotation was calculated again. The measurement error was in the range of 0.1° to 1.2°. The Pearson correlation coefficient test showed no statistical difference between the 2 measurements ($r = 0.997$, $P > 0.05$).

Statistical analysis

After we evaluated the normality of the data with the Kolmogorov-Smirnov test, we ran the 1-way analysis of variance (ANOVA) to determine any significant differences in the initial angles of rotation and the degrees and percentages of relapse among the study groups, followed by the Tukey multiple-range test for pairwise comparisons. The Student *t* test was used to determine any significant differences in pocket depth and pain intensity between the conventional and laser-aided CSF groups. Because of the nonnormal distribution of the data regarding gingival recession, the Mann-Whitney U test was used for statistical comparisons among the 2 groups. The statistical calculations were conducted with SPSS software (version 11.0; SPSS, Chicago, Ill), and *P* values less than 0.05 were considered to be significant.

RESULTS

Table I presents descriptive statistics regarding rotation of the experimental incisors before starting orthodontic treatment (initial rotation at T0) and the amounts and percentages of relapse observed between T1 and T2. The mean amounts of relapse 1 month after sectioning the archwire from the experimental tooth were 4.24° ±1.12° in group 1 (conventional CSF), 6.12° ± 1.77° in group 2 (laser-aided CSF), 5.33° ± 1.91° in group 3 (LLLT), and 13.67° ± 3.27° in group 4 (control). As can be observed in Table I, the lowest percentage of relapse occurred in the conventional CSF group (9.66%) followed by the LLLT (11.67%) and Er:YAG laser-aided CSF (12.71%) groups. The highest percentage of relapse (27.82%) was observed in the control group.

ANOVA indicated no significant between-group differences in the pretreatment angle of rotation of the experimental incisors ($P = 0.997$), but there were significant differences in the degrees and percentages of relapse among the study groups ($P < 0.001$). Multiple comparisons with the Tukey test showed no significant differences in the degrees and percentages of relapse among the conventional CSF, laser-aided CSF, and LLLT groups ($P > 0.05$), whereas the control group had a statistically greater relapse than did the other groups ($P < 0.05$).

Table II indicates the average pocket depth in each group before and 2 months after CSF. Both groups showed small increases in sulcus depth 2 months after the surgical procedures. An independent-sample *t* test showed no significant difference in pocket depth alterations between the conventional and laser-aided CSF groups (Table II).

Table III gives the buccal crown height and the amount of gingival recession in the conventional and laser-aided CSF groups. A small amount of gingival recession was observed after surgery in both groups. The Mann-Whitney U test showed no significant

Table II. Comparison of pocket depths before and after surgery between the conventional and laser-aided CSF groups

Group	*Primary sulcus depth* Mean ± SD (mm)	*Sulcus depth after fiberotomy* Mean ± SD (mm)	*Change in sulcus depth* Mean ± SD (mm)
Conventional CSF	1.89 ± 0.32	2.07 ± 0.29	0.18 ± 0.12
Laser-aided CSF	1.68 ± 0.44	2.04 ± 0.50	0.36 ± 0.21
Statistical significance	$P = 0.125$	$P = 0.547$	$P = 0.138$

Table III. Comparison of clinical crown heights and amounts of gingival recession between the conventional and laser-aided CSF groups

Group	*Primary crown height* Mean ± SD (mm)	*Crown height 2 months after fiberotomy* Mean ± SD (mm)	*Gingival recession* Mean ± SD (mm)
Conventional CSF	9.46 ± 1.22	9.69 ± 1.49	0.23 ± 1.31
Laser-aided CSF	9.27 ± 1.49	9.73 ± 1.56	0.46 ± 1.41
Statistical significance	$P = 0.527$	$P = 0.425$	$P = 0.257$

difference between groups 1 and 2 regarding the amount of gingival recession after the CSF procedures (Table III).

Figure 4 indicates pain and discomfort within the first 24 hours after the CSF procedure in the 2 groups. Although pain intensity was not severe in any group, it was about twice as high in the conventional CSF group (4.04 ± 1.12) than in the Er:YAG laser-aided CSF group (1.97 ± 0.72). An independent-sample *t* test showed significantly less pain in patients who underwent laser-aided CSF compared with those treated with the conventional CSF procedure ($P = 0.003$).

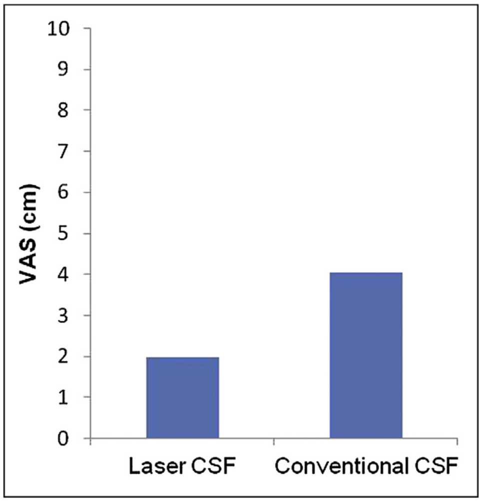

Fig 4. Pain intensity within the first 24 hours after conventional and laser-aided CSF surgeries. *VAS*, Visual analog scale.

DISCUSSION

In this study, we found that both laser-aided CSF and LLLT were as effective as the conventional CSF surgery in alleviating relapse of rotated maxillary incisors within a short observation period (1 month). For ethical reasons, the archwire was retained in place for 1 month after CSF surgery to allow healing of the supracrestal fibers, and then the teeth were allowed to relapse. For determining relapse, we used a reference line that was perpendicular to the line linking the central fossae of the first molars, similar to that used by Kim et al.[13] Some previous studies used Little's irregularity index for measuring rotational relapse. This criterion, however, is influenced not only by the degree of tooth rotation, but also by its anteroposterior position.[6]

In this study, a 9.7% relapse occurred in the CSF group, whereas the control group experienced a 27.8% rotation over 1 month. This means that the percentage of relapse decreased to approximately a third after conventional CSF surgery. Edwards[6] reported that the mean relapse in patients who underwent CSF surgery was approximately 29% lower than the control patients 4 to 6 years after active treatment. The smaller difference between the relapse of the control and CSF patients in this study (18.1%) compared with that of Edwards might be related to the different indexes used for assessing relapse or the different follow-up intervals used in these studies.

In the laser-aided CSF group, the percentage of rotational relapse was 12.7%: ie, about 15.1% lower than the control group. Kim et al[13] induced rotation in the mandibular lateral incisors of beagles by orthodontic elastic chains over 4 weeks and then performed CSF using a gallium-aluminum-arsenide diode laser. Four weeks later without any retainer, they found that the rates of relapse were 14.5% in the laser CSF group and 41.3% in the control group (27% reduction in relapse). In the study of Kim et al, there was a high degree of orthodontically induced rotation at the time of CSF surgery; in our study, the patients were in the finishing stage of orthodontic treatment; thus, the supracrestal fibers of the experimental teeth had a greater chance for remodeling after rotational correction. Furthermore, we retained the experimental teeth for 1 month, but in the study of Kim et al,[13] the teeth were free to relapse immediately after the CSF surgery. These facts might explain the higher efficacy of laser-aided CSF surgery for reducing the relapse of orthodontically rotated teeth in that study compared with our investigation.

In this study, an Er:YAG laser with a sapphire tip 1.1 mm in diameter was used for CSF, with 100 mJ, 10 Hz, and air and water spray. The reason for selecting the Er:YAG laser was its advantages, including high absorption in water and hydroxyapatite, which prevents temperature increases at the root surface and adjacent tissues,[15] although some surface roughness and limited loss of cementum can be observed after Er:YAG laser irradiation, especially at higher energy settings and repetition rates.[16-18] However, using an Er:YAG laser with similar parameters to those in this study, Lee et al[19] reported smooth surface textures and no significant changes in the chemical composition of the cementum. Other possibilities are a diode or a carbon dioxide laser for CSF,[19] but the risk of thermal side effects is higher because of the lack of a cooling system and the lower absorption of these wavelengths in water.

The outcomes of this study showed a relapse rate of 11.7% in the LLLT group; this was 16.1% lower than that observed in the control group. There was no statistical difference in the percentage of relapse between the LLLT and the 2 CSF groups, whereas the control teeth experienced significantly greater relapse than did all the experimental groups. LLLT was performed 2 times a week in this study, and the duration of laser application was about 3 minutes on each tooth. This procedure appeared to be simple and applicable in clinical practice. The coronal third of the root was selected for laser irradiation due to the presence of supracrestal fibers in this area that are believed to be the main cause of rotational relapse. It is possible that the efficacy of LLLT in diminution of relapse would be enhanced by increasing the duration or the frequency of laser applications, but this would be at the expense of reduced simplicity and applicability of the procedure.

Regarding the effect of LLLT on reducing relapse of orthodontically rotated teeth, the only study found in the literature was that of Kim et al,[13] in which a low-power 810-nm diode laser was applied on 8 points around the root with an energy density of 4.63 to 6.47 J/cm^2 per point. Interestingly, the authors reported a relapse rate of 56.8%, which was significantly greater than that of the control group (41.3%). Although Kim et al did not explain the role of LLLT in the increased rate of relapse, the therapeutic effects of low-power lasers mainly depend on the dose applied. We believe that the high rate of relapse reported in that study was related to the acceleration of bone remodeling because of the use of optimum energy densities that promoted tooth movement and the relapse tendency of the orthodontically moved teeth. In contrast, we applied a remarkably high energy density (35.7 J/cm^2) to benefit from the inhibitory effects of LLLT on biostimulation. This might reduce the relapse tendency, at least in the period of laser irradiation, by suppressing the activity of the supracrestal fibers and decreasing bone remodeling in the irradiated areas. The dose-dependent effect of LLLT has also been indicated in previous studies regarding the rate of tooth movement, and it may be the main reason for the controversies observed in this field.[20,21]

Comparison of visual analog scale scores between the 2 CSF groups indicated that the pain experienced within the first 24 hours after conventional CSF was twice as much as that observed with the laser-aided CSF (4.04 vs 1.97). The minimal pain during and after laser-assisted surgical procedures has also been reported by previous authors.[22,23] However, the possibility of the placebo effect because of treatment with a high-quality laser apparatus should also be considered.[24,25]

The increases in sulcus depth were on average 0.18 mm in the conventional CSF group and 0.36 mm in the laser-aided CSF group. A small amount of gingival recession was also observed that was about twice as much in the laser CSF group (0.46 mm) than in the conventional CSF group (0.23 mm). These changes were small and not significantly different between the 2 groups but confirm the finding of Rinaldi[26] that CSF should be performed with caution in the midfacial portions of the anterior teeth with thin and friable tissues. Most orthodontic patients have transient hyperplastic gingivitis at the time of appliance removal that will subside thereafter, a factor that might have contributed to the small amount of gingival recession observed in our investigation. Rinaldi[26] observed a maximum change of 0.36 mm in sulcus depth and concluded that pocket depth was virtually maintained at a physiologic level with no clinically significant deepening at 4 months after the CSF procedure. Kim et al[13] reported no sign of gingival recession but about a 0.67-mm increase in the periodontal pocket depth at 4 weeks after diode laser CSF compared with the initial measurement.

The outcome of this study advocates the use of Er:YAG laser-aided CSF as an alternative to the conventional CSF procedure, because it can be associated with greater patient acceptance and fewer surgical complications such as pain or discomfort and bleeding. Further studies are warranted to elucidate the long-term effectiveness of laser-assisted fiberotomy on improving the stability of corrective tooth rotations and any pathologic sequelae of this procedure on the periodontium. The exact mechanism and the long-term efficacy of LLLT on reducing relapse of rotated teeth also need further investigations.

CONCLUSIONS

Under the conditions used in this study, we concluded the following.

1. Er:YAG laser-aided CSF was as effective as the conventional CSF procedure in diminishing relapse of orthodontically corrected rotations, while causing less pain and discomfort for the patients.
2. LLLT with an excessively high irradiation dosage also proved effective in alleviating the rotational relapse, at least in the short term, compared with the control group.
3. There were a negligible increase in pocket depth and some clinically unobservable recession of the facial gingiva in both the conventional and the laser-aided CSF groups, with no significant difference to each other.

REFERENCES

1. Edwards JG. A study of the periodontium during orthodontic rotation of teeth. Am J Orthod 1968;54:441-61.
2. Reitan K. Tissue rearrangement during retention of orthodontically rotated teeth. Angle Orthod 1959;29:105-13.
3. Swanson WD, Riedel RA, D'Anna JA. Postretention study: incidence and stability of rotated teeth in humans. Angle Orthod 1975;45:198-203.
4. Naraghi S, Andren A, Kjellberg H, Mohlin BO. Relapse tendency after orthodontic correction of upper front teeth retained with a bonded retainer. Angle Orthod 2006;76:570-6.
5. Edwards JG. A surgical procedure to eliminate rotational relapse. Am J Orthod 1970;57:35-46.
6. Edwards JG. A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse. Am J Orthod Dentofacial Orthop 1988;93:380-7.
7. Taner TU, Haydar B, Kavuklu I, Korkmaz A. Short-term effects of fiberotomy on relapse of anterior crowding. Am J Orthod Dentofacial Orthop 2000;118:617-23.
8. Crum RE, Andreasen GF. The effect of gingival fiber surgery on the retention of rotated teeth. Am J Orthod 1974;65:626-37.
9. Ahrens DG, Shapira Y, Kuftinec MM. An approach to rotational relapse. Am J Orthod 1981;80:83-91.
10. How Kau C. Orthodontic retention regimes: will we ever have the answer? Evid Based Dent 2006;7:100.
11. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Orthodontic retention: a systematic review. J Orthod 2006;33:205-12.
12. Fricke LL, Rankine CA. Comparison of electrosurgery with conventional fiberotomies on rotational relapse and gingival tissue in the dog. Am J Orthod Dentofacial Orthop 1990;97:405-12.
13. Kim SJ, Paek JH, Park KH, Kang SG, Park YG. Laser-aided circumferential supracrestal fiberotomy and low-level laser therapy effects on relapse of rotated teeth in beagles. Angle Orthod 2010;80:385-90.
14. Tuner J, Hode L. The laser therapy handbook. Grangesberg: Prima Book AB; 2007.
15. Hakki SS, Berk G, Dundar N, Saglam M, Berk N. Effects of root planing procedures with hand instrument or erbium, chromium: yttrium-scandium-gallium-garnet laser irradiation on the root surfaces: a comparative scanning electron microscopy study. Lasers Med Sci 2010;25:345-53.
16. Fujii T, Baehni PC, Kawai O, Kawakami T, Matsuda K, Kowashi Y. Scanning electron microscopic study of the effects of Er:YAG laser on root cementum. J Periodontol 1998;69:1283-90.
17. Theodoro LH, Haypek P, Bachmann L, Garcia VG, Sampaio JE, Zezell DM, et al. Effect of Er:YAG and diode laser irradiation on the root surface: morphological and thermal analysis. J Periodontol 2003;74:838-43.
18. Gomez C, Bisheimer M, Costela A, Garcia-Moreno I, Garcia A, Garcia JA. Evaluation of the effects of Er:YAG and Nd:YAG lasers and ultrasonic instrumentation on root surfaces. Photomed Laser Surg 2009;27:43-8.
19. Lee JW, Park KH, Chung JH, Kim SJ. Effects of laser-aided circumferential supracrestal fiberotomy on root surfaces. Angle Orthod 2011;81:1021-7.
20. Goulart CS, Nouer PR, Mouramartins L, Garbin IU, de Fatima Zanirato Lizarelli R. Photoradiation and orthodontic movement: experimental study with canines. Photomed Laser Surg 2006;24:192-6.
21. Heravi F, Moradi A, Ahrari F. The effect of low level laser irradiation on the rate of tooth movement and pain perception during canine retraction. Oral Health Dent Manag 2014;13:183-8.
22. White JM, Chaudhry SI, Kudler JJ, Sekandari N, Schoelch ML, Silverman S Jr. Nd:YAG and CO_2 laser therapy of oral mucosal lesions. J Clin Laser Med Surg 1998;16:299-304.
23. Kazancioglu HO, Ezirganli S, Demirtas N. Comparison of the influence of ozone and laser therapies on pain, swelling, and trismus following impacted third-molar surgery. Lasers Med Sci 2014;29:1313-9.
24. Madani A, Ahrari F, Nasiri F, Abtahi M, Tuner J. Low-level laser therapy for management of TMJ osteoarthritis. Cranio 2014;32:38-44.
25. Ahrari F, Madani AS, Ghafouri ZS, Tuner J. The efficacy of low-level laser therapy for the treatment of myogenous temporomandibular joint disorder. Lasers Med Sci 2014;29:551-7.
26. Rinaldi SA. Changes in free gingival level and sulcus depth of the human periodontium following circumferential supracrestal fiberotomy. Am J Orthod 1979;75:46-53.