A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse

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This prospective study conducted during a period of nearly 15 years initially involved 320 consecutively selected cases. The primary purpose of the investigation was to statistically evaluate the efficacy of the circumferential supracrestal fiberotomy (CSF) procedure in alleviating dental relapse following orthodontic treatment. The "Irregularity Index" method of Little for measuring the malposition of teeth was used to quantitatively record the relapse of the control and CSF cases at approximately 4 to 6 years after active treatment and again at 12 to 14 years after active treatment. The differences between the mean relapses of the control and the CSF cases were highly significant at both time intervals. The surgical procedure appeared to be somewhat more effective in alleviating pure rotational relapse than in labiolingual relapse. On a long-term basis, the CSF procedure was shown to be more successful in reducing relapse in the maxillary anterior segment than in the mandibular anterior segment. Nevertheless, a significant and unpredictable variation in individual tooth movement following orthodontic treatment was observed in both the control and CSF groups. No clinically significant increase in the periodontal sulcus depth nor decrease in the labially attached gingiva of the CSF teeth was observed at 1 and 6 months following the surgical procedure. (AM J ORTHOD DENTOFAC ORTHOP 1988;93:380-7.)

The problem of relapse of orthodontically treated teeth in general and orthodontically rotated teeth in particular has been well recognized for years. Reitan[1] was possibly the first to formulate an explanation for rotational relapse when he demonstrated histologically in dogs the persistence of connective tissue fiber deviations in the supracrestal periodontal (free gingival and transseptal) tissues 7 months after teeth had been orthodontically rotated.

There are two soft-tissue periodontal entities that may influence the stability of the teeth following orthodontic movement: the supraalveolar group of fibers and the principal fibers of the periodontal ligament. The method by which these soft tissues might apply a force capable of moving teeth is not clear since these tissues are composed primarily of nonelastic collagenous fibers. Presumably, the only elastic tissue found in human periodontal ligament exists in the walls of the blood vessels in the interstitial areas of the ligament. There may be some elastic fibers in the supracrestal tissue but these, if present, are sparse.[2] In any case the potential for relapse forces in the fibers of the periodontal ligament and transseptal groups most adjacent to the alveolar crest is certainly minimal because these tissues have been shown to possess a dynamic remodeling mechanism that is quite efficient and histologically complete in only 2 to 3 months after orthodontic rotation of teeth.[1,3-9] The collagen fibers of the free gingiva and higher transseptal groups are similar morphologically to the principal fibers of the periodontal ligament. However, they are apparently more stable. Fiber turnover, as indicated by radioactive precursor incorporation, is relatively slow in these tissues not directly adjacent to the morphologically plastic alveolar bone.[7,10-12]

Nevertheless, an attempt to generalize the relationship of the supraalveolar tissue and the retention-relapse problem is difficult. How does a tissue that is essentially composed of inelastic, noncontractile tissue apply a force? As yet the answer is unknown. One possibility may involve the in vitro observation that the length of a reconstituted collagen fiber can be altered by adjusting the ion concentration of its surrounding medium; thus, a mechanism is proposed by which the contractile collagen could "recoil" following orthodontic tooth movement.[2,13] Another histologic explanation of relapse force may relate to the elastic-like oxytalan fibers that apparently increase in concentration in the supracrestal tissues during the rotational movement of teeth.[5,6,14-19] However, although these oxytalan fibers possess some staining properties similar to elastic fibers, there is no direct evidence that they are physiologically similar to elastic fibers. Fullmer, Sheetz, and Narkates[20] cautioned that oxytalan could actually represent altered collagen fibers. In summary, there is no substantial evidence at the present time to explain the mechanism by which the gingival soft tissues may apply a force capable of moving the teeth.

From a practical and clinical point of view, the supraalveolar soft tissues seemingly do contribute to the relapse of orthodontically treated teeth—specifically, orthodontically rotated teeth.[21-27] In 1970, Edwards[28] reported on a simple and apparently efficacious surgical technique to alleviate the influence that the supracrestal periodontal fibers presumably have on rotational relapse. Campbell, Moore, and Matthews[29] termed the procedure a circumferential supracrestal fiberotomy (CSF) procedure.

Basically, this technique consists of inserting a surgical blade into the gingival sulcus and severing the epithelial attachment surrounding the involved teeth. The blade also transects the transseptal fibers by interdentally entering the periodontal ligament space. Although the transseptal groups adjacent to the alveolar crest, as well as the principal fibers of the periodontal ligament, do show relatively rapid reorganization following tooth rotation[1,3-9] and thus are presumably not of importance in the relapse mechanism, the only clinical method to determine that the more coronal transseptal fibers have been properly transected is to feel the surgical blade enter the enlarged periodontal ligament space.[28] No surgical dressings are indicated and clinical healing usually is complete in 7 to 10 days. The CSF procedure is not recommended during active movement of the teeth or in cases with gingival inflammation because of the unpredictability of regeneration of the epithelial attachment in such situations. To avoid possible gingival recession, the incising of the epithelial attachment is not recommended on the midlabial portion of any tooth with a narrow zone of attached gingiva or clinically apparent thin plate of cortical bone. Rinaldi[30] showed that the average change in sulcus depth as a result of the CSF procedure on 112 teeth was clinically unobservable and reported a maximum range in tissue change of only 0.36 mm. If the surgical blade was not permitted to traumatize the labial or lingual alveolar crest, no bone resorption was reported. Similar postsurgical periodontal findings were reported by Pinson and Strahan.[31] Although the most obvious condition for the use of the supracrestal fiberotomies is that of the rotated tooth, the procedure has also been recommended following labiolingual orthodontic tooth movement.

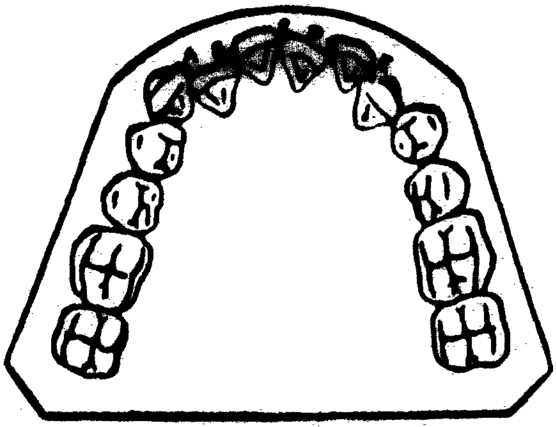
Various modifications of the original CSF technique have been described and numerous retrospective short-term studies reported that tend to support Edwards' initial findings.[21,32-35] The purpose of this prospective investigation is to evaluate the long-term efficacy of the CSF procedure in alleviating dental relapse following orthodontic treatment.

Table I. Prospective study

T_1:	N = 320 consecutively selected cases alternating control and CSF
	$\bar{X}$ age = 12.2 years (range, 10.9 to 14.1 years)
	Control = 96 girls, 64 boys
	CSF = 92 girls, 68 boys
T_2:	N = 299
	$\bar{X}$ treatment = 2.1 years (range, 1.8 to 2.7 years)
	(CSF performed at T_2)
	Control = 90 girls, 61 boys
	CSF = 87 girls, 61 boys
T_3:	N = 194
	4 to 6 years postactive treatment
	(approximately 2 to 3 years out of retainers)
	Control = 51 girls, 42 boys
	CSF = 60 girls, 41 boys
T_4:	N = 48
	12 to 14 years postactive treatment
	(approximately 8 to 11 years out of retainers)
	Control = 11 girls, 11 boys
	CSF = 14 girls, 12 boys

METHODS AND MATERIALS

During 1971 and 1972, orthodontic treatment was initiated on 320 consecutively selected adolescent patients (190 girls, 130 boys) with edgewise appliances. Each patient was alternately designated as a control or a CSF (experimental) case before the initiation of any treatment, thus eliminating the problem of bias in selection. All 320 cases were diagnosed and treated by the same orthodontist. The mean age of the patients was 12.2 years (range, 10.9 to 14.1 years) and mean treatment time was 2.1 years (range, 1.8 to 2.7 years). Ninety of the 320 cases were treated without the extraction of permanent teeth. Two hundred one patients had two maxillary and two mandibular teeth extracted, and 29 had only two maxillary premolar teeth extracted before treatment. The treatment technique of overrotation was not used on any of the patients. The experimental patients underwent a CSF surgical procedure as described by Edwards,[28] with modifications as outlined previously, on both the maxillary and mandibular canine-to-canine teeth, regardless of the initial malalignment of the teeth; the control patients received no CSF intervention. The CSF procedures were done at the time of appliance removal and followed immedi-



A+B+C+D+E = IRREGULARITY INDEX

Fig. 1. Diagram of Irregularity Index.

ately with removable retainer therapy. The duration of retention therapy ranged from 24 to 40 months using removable retainers only during the night; the retention time was approximated from patient history and clinical judgment.

Table I illustrates the parameters of the study; T_1 represents the initiation of active treatment, T_2 the completion of active treatment and the initiation of retention therapy (CSF surgery was performed at T_2), T_3 approximately 4 to 6 years after active treatment and 2 to 3 years after discontinuation of retainers, and T_4 12 to 14 years after active treatment and approximately 8 to 11 years after retention therapy.

The level of the epithelial attachment and the zone of attached gingiva were measured on both the control and experimental teeth before the CSF procedure at T_2 and again at intervals of 1 month and 6 months following T_2. These measurements were made with a Carolina probe (University of North Carolina at Chapel Hill, Department of Periodontics), which measures from a plastic stint located at the incisal edge of the teeth. This method of measurement allows accurate correlation of the level of the attachment apparatus on the tooth, the sulcus pocket depth, and the width of attached gingiva. Periodontal measurements were not made at longer than a 6-month period following the CSF surgery because (1) any deleterious results from this type of surgical procedure should realistically have become apparent in a 6-month period of time and (2) too many uncontrollable factors (patient hygiene, accidental trauma, increase in age) could influence the periodontium and make a correlation with the CSF procedure impossible over a longer observation period.

Although the CSF procedure was originally intended to alleviate rotational relapse, the difficulty inherent in accurately measuring the pretreatment and posttreatment angular changes of the teeth[36,37] necessitated measuring a combination of rotational and labiolingual relationships of the teeth. Therefore, the "Irregularity Index" as described by Little[38] was used to assess the degree of dental malrelationships at intervals T_1 through T_4. The calculation of the Irregularity Index involves measuring the linear displacement of the anatomic contact points (as distinguished from the clinical contact points) of each mandibular or maxillary incisor from the adjacent tooth's anatomic contact point, the sum of these five measurements representing the relative degree of anterior irregularity (Fig. 1). Rather than measuring the contact point to an ideal arch form or to another subjective point, the actual linear distance between adjacent contact points is determined. Such a measure represents the distance that anatomic contact points must be moved to gain anterior alignment. Using dial calipers (with sharpened points) that were calibrated to tenths of a millimeter, three examiners unfamiliar with the purpose of the study measured the "Irregularity Index" of all the cases (T_1 through T_4) directly from stone models on two separate occasions.

The error measurement was determined by randomly selecting three casts and measuring them on 20 different occasions $\left(S_x = \sqrt{\frac{\Sigma D^2}{2N}}\right)$. The measurement error did not exceed ± 0.05 mm. Paired t tests comparing each examiner's quantitative measurements for each group of casts at T_1 through T_4 on the two separate occasions demonstrated no significant difference ($P > 0.05$), thus indicating good consistency between the first and second measurements.

Although there is conflicting data on the usefulness of reproximation ("stripping") of the lower anterior teeth to alleviate orthodontic relapse,[39-43] reproximation was not used in any of the control or CSF cases in order to avoid introducing another variable into the study.

RESULTS

Tables II and III show the treatment results of this prospective study over a period of 15 years for the mandibular anterior teeth. The mean relapse at T_3 or T_4 is calculated by subtracting the Irregularity Index value at T_2 (the termination of active orthodontic correction) from the Irregularity Index value at T_3 or T_4. Thus, in the control group of mandibular anterior teeth, the mean relapse at T_3 (2 to 3 years postretention) was 3.1 mm (note: $3.83^{T_3} - 0.72\ mm^{T_2} = 3.1$ mm). This mean relapse of 3.1 mm represents 42.48% of the initial

Table II. Irregularity Index for mandibular anterior teeth (measurement error = 0.05 mm)

Parameter	Control group				CSF group			
	$\bar{X}$ (mm)	SD	Range	N	$\bar{X}$ (mm)	SD	Range	N
T_1	7.32	2.74	2.1-18.2	160	7.47	3.10	1.7-19.8	160
T_2	0.72	0.10	0.0-1.9	151	0.81	0.14	0.3-1.4	148
T_3	3.83	2.16	0.6-7.8	93	1.84	0.97	0.9-3.6	101
T_4	4.64	3.01	1.9-11.4	22	3.37	1.61	1.2-6.9	26

Table III. Mean relapse for mandibular anterior teeth

Parameter	Control group	CSF group	Difference
T_3	$\frac{3.83\ mm^{T_3} - 0.72\ mm^{T_2}}{7.32\ mm^{T_1}} = 42.48\%$ ($\bar{X}$ relapse of initial problem)	$\frac{1.84\ mm^{T_3} - 0.81\ mm^{T_2}}{7.47\ mm^{T_1}} = 13.78\%$ ($\bar{X}$ relapse of initial problem)	28.70% $\bar{X}$ difference between control and CSF groups
T_4	$\frac{4.64\ mm^{T_4} - 0.72\ mm^{T_2}}{7.32\ mm^{T_1}} = 53.55\%$ ($\bar{X}$ relapse of initial problem)	$\frac{3.37\ mm^{T_4} - 0.81\ mm^{T_2}}{7.32\ mm^{T_1}} = 34.97\%$ ($\bar{X}$ relapse of initial problem)	18.58% $\bar{X}$ difference between control and CSF groups
	11.07% ($\bar{X}$ relapse between T_3 and T_4)	21.19% ($\bar{X}$ relapse between T_3 and T_4)	

Table IV. Irregularity Index for maxillary anterior teeth (measurement error = 0.05 mm)

Parameter	Control group				CSF group			
	$\bar{X}$	SD	Range	N	$\bar{X}$	SD	Range	N
T_1	5.24	2.37	1.1-10.4	160	6.20	2.98	1.6-11.9	160
T_2	0.51	0.11	0.0-1.1	151	0.72	0.09	0.2-1.8	148
T_3	2.80	1.92	0.0-6.2	93	1.60	0.91	0.1-4.1	101
T_4	3.12	2.64	0.1-8.8	22	2.01	1.01	0.2-4.8	26

malalignment or irregularity (note: $\frac{3.1\text{ mm}}{7.3\text{ mm}^{T_1}}$ = 42.48% mean relapse of initial problem). However, in the CSF group of mandibular anterior teeth, the mean relapse was 1.03 mm (note: 1.84 mm^{T_3} − 0.81 mm^{T_2} = 1.03 mm). The mean relapse of 1.03 mm represents only 13.78% (note: $\frac{1.03\text{ mm}}{7.47\text{ mm}^{T_1}}$ = 13.78%) of the initial Irregularity Index for the CSF group of mandibular anterior teeth. At T_4 (between 10 and 13 years postretention), the control group had relapsed 3.92 mm (note: 4.64 mm^{T_4} − 0.72 mm^{T_2} = 3.92 mm) or 53.55% of the original orthodontic irregularity. The CSF group at T_4 had relapsed 2.56 mm (note: 3.37 mm^{T_4} − 0.81 mm^{T_2} = 2.56 mm) or 34.97% relapse from the initial irregularity at T_1. The difference in the mean relapse between the control and the CSF groups at T_3 (3.11 mm − 1.03 mm = 2.08 mm) was significant (t = 21.89, $P < 0.001$). Likewise, the difference in the mean relapse between the control and CSF patients at T_4 (3.92 mm − 2.56 mm = 1.36 mm) was significant (t = 4.28, $P < 0.001$).

It also would appear that the CSF procedure was more effective in alleviating relapse of irregularity in the mandibular anterior teeth in the first 4 to 6 years after inactive treatment than after 13 to 15 years, because the difference in percentage of mean relapse between control and CSF groups at T_3 was 28.7% and only 18.58% at T_4 (Table III). Consequently, the control group experienced 42.48% of its relapse in the first 4 to 6 years after active treatment (T_3) and only 11.07% additional relapse in the next 9 to 11 years. The CSF group showed just the reverse—13.78% relapse at T_3 and an additional 21.19% relapse by T_4.

Table V. Mean relapse for maxillary anterior teeth

Parameter	*Control group*	*CSF group*	*Difference*
T_3	$\frac{2.80\ mm^{T_3} - 0.51\ mm^{T_2}}{5.24\ mm^{T_1}} = 43.70\%$ ($\bar{X}$ relapse of initial problem)	$\frac{1.60\ mm^{T_3} - 0.72\ mm^{T_2}}{6.20\ mm^{T_1}} = 14.19\%$ ($\bar{X}$ relapse of initial problem)	29.51% $\bar{X}$ difference between control and CSF groups
T_4	$\frac{3.12\ mm^{T_4} - 0.51\ mm^{T_2}}{5.24\ mm^{T_1}} = 49.80\%$ ($\bar{X}$ relapse of initial problem)	$\frac{2.01\ mm^{T_4} - 0.72\ mm^{T_2}}{6.20\ mm^{T_1}} = 20.80\%$ ($\bar{X}$ relapse of initial problem)	29.00% $\bar{X}$ difference between control and CSF groups
	6.10% ($\bar{X}$ relapse between T_3 and T_4)	6.61% ($\bar{X}$ relapse between T_3 and T_4)	

Table VI. Change in position of epithelial attachment (mm)

	Control group (N = 191)		*CSF group (N = 148)*		
Interval	$\bar{X}$	*SD*	$\bar{X}$	*SD*	*Significance*
T_2 plus 1 month	0.0	0.23	0.0	0.30	NS
T_2 plus 6 months	0.0	0.31	0.0	0.29	NS

Table VII. Change in zone of keratinized gingiva (mm)

	Control group (N = 19)		*CSF group (N = 148)*		
Interval	$\bar{X}$	*SD*	$\bar{X}$	*SD*	*Significance*
T_2 plus 1 month	0.0	0.18	0.0	0.16	NS
T_2 plus 6 months	0.0	0.23	0.0	0.27	NS

Tables IV and V show the relapse data on the control and CSF groups of the maxillary anterior teeth. The mean relapse in the control group at T_3 was 2.29 mm (2.80 mm^{T_3} − 0.51 mm^{T_2} = 2.29 mm) or 43.70% mean relapse of the initial irregularity $\left(\frac{2.80\ mm^{T_3} - 0.51\ mm^{T_2}}{5.24\ mm^{T_1}} = 43.70\%\right)$. The CSF group relapsed a mean of 0.88 mm at T_3 (1.60 mm^{T_3} − 0.72 mm^{T_2} = 0.88 mm), which is 14.19% of the irregularity at T_1 (Table V). At T_4 the control group relapsed a mean of 2.61 mm (3.12 mm^{T_4} − 0.51 mm^{T_2} = 2.61 mm) or 49.80% of the original irregularity before orthodontic treatment. The CSF group at T_4 relapsed a mean of 1.29 mm (2.01 mm^{T_4} − 0.72 mm^{T_2} = 1.29 mm), which is a mean relapse of 20.80% of the mean irregularity at T_1. The differences between the mean relapses of the maxillary control and CSF groups at T_3 (control 2.29 mm − CSF 0.88 mm = 1.41 mm) and at T_4 (control 2.61 mm − CSF 1.29 mm = 1.32 mm) were highly significant (t = 29.49 and t = 6.67, respectively; $P < 0.001$).

However, in the maxillary arch, the percentage of mean relapse did not show the large increase in the CSF group between T_3 and T_4 as was demonstrated in the mandibular arch because the mean relapse of both the control group and the CSF group increased approximately 6% between T_3 and T_4 (Table V). Consequently, the difference between the mean relapse at T_3 and T_4 of the control and CSF groups remained approximately equal at 29%. Thus, the CSF procedure seemed to alleviate relapse as measured by the Irregularity Index approximately the same amount (28.70% versus 29.51%) in the mandibular and in the maxillary anterior teeth at T_3 (Tables III and V), but became significantly less of a factor in lessening relapse in the mandibular arch over the next 9 to 10 years (T_4, 18.58% mandibular versus 29.00% maxillary).

Of importance is the finding of no significant alteration in the level of the epithelial attachment surrounding the CSF group of teeth or loss of attached gingiva on the labial aspect of these teeth at both the 1-month and 6-months observation intervals following the CSF procedure at T2 (Table VI and VII). These observations closely support the work of Rinaldi.[30]

DISCUSSION

Although the quantitative data of this study definitely demonstrated that the difference between the mean relapse of the control patients and the patients who received the CSF procedure was not equal (that is, the CSF surgery significantly lessened the relapse problem), the actual clinical significance might not be immediately apparent. The mean relapse of the patients who underwent the CSF procedure was approximately 29% less than the control patients at T_3 and T_4 (with the exception of the lower anterior teeth at T_4, which

Fig. 2. Most of the findings of irregularity in this case are the result of labiolingual dental malposition.

Fig. 3. The CSF procedure appeared most effective in alleviating this type of "pure" rotational irregularity.

had only 18.58% less relapse). However, this difference in mean relapse represented a measurement of only 1.32 to 2.08 mm on the Irregularity Index scale. Nevertheless, the large differences between the statistical ranges and variances of the control and CSF groups were extremely meaningful (Tables II through IV). In orthodontic context the CSF surgery seemingly eliminated the relapse categories that Little would have designated as "severe" or "very severe,"[38] whereas the control group did include a number of cases with such large degrees of relapse. The statistical range in the amount of relapse in the individual patients was dramatically less in the CSF cases when compared with the control cases.

In general, the CSF procedure used in this long-term study seems to be more effective in alleviating relapse in cases that initially showed severe irregularity (Irregularity Index of 6 mm or more) than in the cases with mild irregularity (Irregularity Index of 3 mm or less). Although not in the direct scope of this study, it was apparent that the orthodontic cases in which the rotation of teeth contributed more to the pretreatment Irregularity Index than the labiolingual malposition of the teeth definitely appeared to elicit a greater stability from the CSF surgical procedure; the CSF procedure appeared to be more effective in reducing rotational relapse as opposed to labiolingual relapse (Figs. 2 and 3). Perhaps this observation can be partially explained by the realization that the relapse phenomenon in a labiolingual arch position is probably more complex and multifactored (ie, muscle balance, root parallelism, occlusal guidance) than in a strictly rotational relapse. Such a supposition would be supported by the relapse data involving the lower anterior teeth when the importance of the relapse potential in the supracrestal fibers appeared to dissipate in relation to other relapse factors between T_3 and T4. Speculatively, this apparent difference in the efficacy of the CSF procedure in lessening relapse between the mandibular and maxillary anterior teeth at T_4 might be explained by the supposition that the relapse potential in the supracrestal soft tissues is one of the more important factors in relapse during the first 5 to 6 years after active orthodontic treatment and then it gradually diminishes in importance perhaps as the fibers are reoriented or reorganized to the retained position of the teeth. The mandibular anterior teeth would then continue to show more relapse than the maxillary anterior teeth between T_3 and T_4 because of the predominance of relapse factors specific to the mandibular arch—that is, horizontally erupting third molars, continued growth, and overbite and overjet alterations.

From the observation of the individual teeth in this study, it was quite apparent that the amount and even the direction of tooth movement following orthodontic treatment were very unpredictable. In a few instances, teeth that were initially malpositioned labially to adjacent teeth were observed malpositioned lingually to the same adjacent teeth at T_4. Moreover, there were even occasional cases in both the control and CSF groups in which a tooth that was initially rotated in a clockwise direction was actually rotated in a counterclockwise direction 12 to 14 years after orthodontic correction. In fact, is the term "relapse" even appropriate in such situations? These teeth did not move back toward their original malpositions, but rather into an entirely different malposition. Such apparent paradoxes of extreme individual variation present definite problems in a general summary of the relationship of the supraalveolar tissue and the retention-relapse phenomenon.

SUMMARY AND CONCLUSIONS

1. In a long-term prospective study, the difference between the mean relapse (Irregularity Index) in the control cases and the CSF cases was highly significant.

2. The relapse measurements at T_3 and T_4 in the CSF cases would support the assumption that the orthodontic relapse potential presumably inherent in the supracrestal fibers apparently dissipates in relation to other relapse factors approximately 4 to 6 years after orthodontic treatment (possibly by physiologic fiber reorganization?). Thus, the CSF procedure would appear to be most effective in alleviating relapse during the first 4 to 6 years after orthodontic treatment.

3. No clinically significant alteration in the level of the epithelial attachment nor decrease in the labial attached gingiva of the CSF teeth was observed at 1 or 6 months following the surgical procedure. (Note: it was decided that a longer observation period would not be appropriate for this particular periodontal study.)

4. The efficacy of the CSF procedure would appear to be somewhat less in the mandibular anterior segment than in the maxillary anterior segment when observing cases 12 to 14 years after active orthodontic treatment. This observation might be explained by the greater complexity and multifactor potential for relapse inherent in the mandibular anterior arch.

5. The CSF procedure may be more efficient in alleviating pure rotational relapse than in other types of tooth movement.

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