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Using orthodontic intrusion of abraded incisors to facilitate restoration

The technique's effects on alveolar bone level and root length

Lucien J. Bellamy, DMD, MSD; Vincent G. Kokich, DDS, MSD; Jake A. Weissman

ABSTRACT

Background. The authors examined the effects of orthodontic intrusion of abraded incisors in adult patients to facilitate restoration, focusing specifically on changes in alveolar bone level and root length.

Methods. The authors analyzed records of 43 consecutive adult patients (mean age 45.9 years). They identified intrusion by means of cephalometric radiographs and bone level and root length by means of periapical radiographs. They calculated treatment differences from the pretreatment period to the posttreatment period.

Results. In general, bone level followed the tooth during intrusion, but a small amount of bone loss occurred ($P < .0001$). There were no significant associations with age, sex, treatment time, intrusion or pretreatment bone level. All intruded teeth exhibited significant root resorption during treatment (mean = 1.48 millimeters). However, the change was similar to that seen in incisors that were not intruded. There were no associations with age, sex, treatment time or intrusion, but there was a positive relationship between pretreatment root length and root resorption.

Conclusions and Clinical Implications. Incisor intrusion in adults moves the dentogingival complex apically and is a valuable adjunct to restorative treatment. Potential iatrogenic consequences of alveolar bone loss and root resorption are minimal and comparable with the consequences of other orthodontic tooth movements.

Key Words. Orthodontics; incisor abrasion; intrusion; interdisciplinary; restorative; bone level; root resorption.

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The number of adult patients referred for orthodontic treatment has increased through the years. Many of these patients have significant anterior tooth wear caused by parafunction, trauma or both.[1] In most circumstances, the teeth erupt to maintain contact, resulting in short clinical crowns and disproportionate marginal gingivae. The result usually is unesthetic and often presents a dilemma for the restorative dentist. Surgical crown lengthening may be used to address this specific problem. However, in many cases periodontal surgery is undesirable, because it requires greater incisal reduction and often leads to a more extensive final restoration. Orthodontic intrusion offers a valuable alternative as part of the interdisciplinary management of such cases.[2,3] It has the potential added benefit of a more conservative final restoration. In many cases, a bonded veneer restoration is possible, thus precluding the need for full coverage.

An example of maxillary incisor intrusion is shown in Figure 1. One of the authors (V.G.K.) intruded this patient's maxillary central incisors to achieve ideal crown proportions and improve the relation-

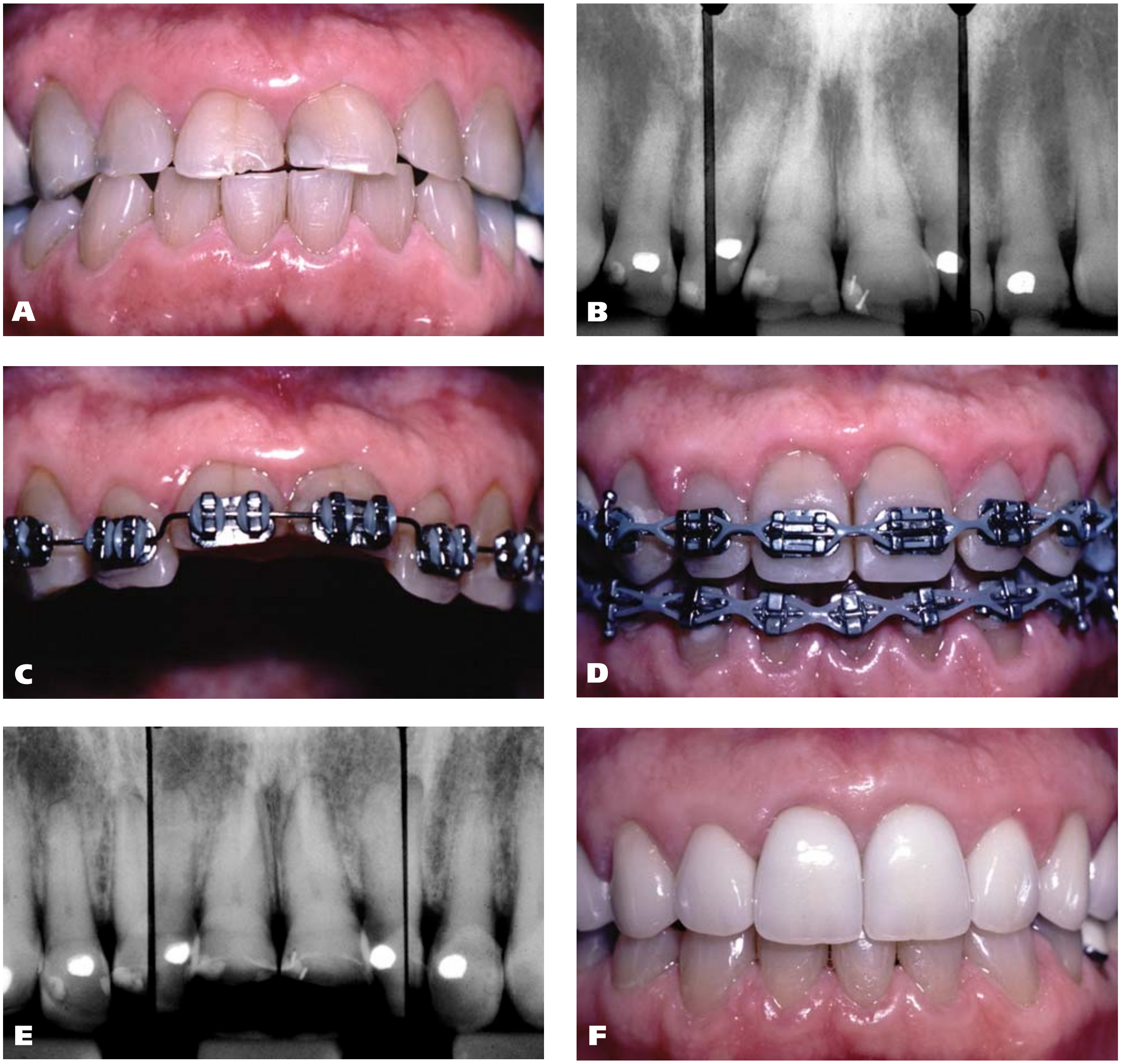

Figure 1. **A.** Adult patient with severe wear of maxillary central incisors resulting in short clinical crowns and disproportionate marginal gingivae. **B.** Pretreatment periapical radiographs demonstrating overeruption. **C.** Central incisors orthodontically intruded to improve gingival levels and create interocclusal space for restorations. **D.** Provisional restoration of these teeth with composite resin and stabilization for six months. **E.** Posttreatment periapical radiographs showing incisors in the intruded position. **F.** Bonded veneer final restorations placed after orthodontic treatment showing marked improvement in anterior esthetics.

ship of the anterior marginal gingiva. Figure 2 shows the intrusion of mandibular incisors performed by the same clinician to create interocclusal space, thus precluding the need for periodontal surgery and facilitating restoration of the abraded teeth to ideal proportion.

Few studies have focused on incisor intrusion in adult patients. What happens to the alveolar bone level as the teeth move apically? Are these teeth more susceptible to root resorption? Some researchers suggest that incisor intrusion actually may improve bone levels and lead to regeneration of lost periodontal attachment[4-9]; however, this has not been confirmed in a large sample of

ABBREVIATION KEY. AC: Alveolar crest. **CEJ:** Cementoenamel junction. **D:** Distal. **M:** Mesial. **T1:** Pretreatment. **T2:** Posttreatment.

Figure 2. A. Study model of abraded mandibular incisor requiring restorations. **B.** Occlusal view of the severe wear. **C.** Subsequent eruption to maintain incisor; restoration of these teeth in this position would require periodontal crown lengthening and possibly endodontic treatment. **D.** Incisors intruded to create interocclusal space. **E.** Provisional restoration of the teeth followed by six-month retention period. **F.** Final restorations placed after orthodontic treatment.

patients. Current thoughts with regard to root resorption are equally controversial. Therefore, the purpose of our study was twofold: to determine the effect of adult incisor intrusion on alveolar bone level and on root length.

MATERIALS AND METHODS

Subjects. We collected the records of 51 consecutively treated adult patients (aged ≥ 19 years) from four Seattle orthodontic practices (one of which belongs to one of the authors [V.G.K.]; the other three used the same radiography laboratory and treated a large number of intrusion cases). The institutional review board at the University of Washington, Seattle, approved the subject recruitment and records analysis. We selected records using the following criteria:

- incisor intrusion attempted to create interocclusal space for restorative treatment, correction of excessive anterior overbite or both;

- pretreatment (T1) and posttreatment (T2) anterior periapical and lateral cephalometric radiographs obtained under identical conditions at a professional imaging center (Northwest Radiography, Seattle);
- treatment completed between 1995 and 2006;
- no incisor extraction or restorative procedures affecting the cementoenamel junction (CEJ) during the treatment period.

We excluded six subjects because their T1 anterior periapical radiographs had been obtained at a different facility, and we excluded two because of incisor extraction. Thus, we obtained a sample of 43 subjects (27 men, 16 women), with a mean age of 45.9 years (range, 19.2-63.6 years) and a mean total treatment time of 28 months (range, 16-40 months).

Among the four clinicians who participated in our study (one of whom is an author [V.G.K.]), intrusion mechanics were similar, involving continuous arch wires with reverse curves, step bends or both. To minimize relapse, the clinicians retained the intruded incisors in their desired positions for at least six months before removing the appliances.

Radiographic measurements. We used cephalometric radiographs to measure incisor intrusion and anterior periapical radiographs for all measurements of alveolar bone level and root length. We imported and analyzed digital images with ImageJ, a public-domain Java image-processing program developed at the U.S. National Institutes of Health and available on the Internet at "http://rsb.info.nih.gov/ij/". We made all measurements to the nearest 0.01 millimeter and made no corrections for magnification.

The authors used the incisor centroid, defined as a point on the longitudinal axis of the tooth that is independent of any change in inclination, to measure intrusion.[10] Incisor proclination, or tooth tipping, is a common side effect of intrusion. Using the incisor centroid eliminated this variable and allowed a true representation of the intrusion achieved during treatment. We estimated the centroid of maxillary and mandibular central incisors to be 33 percent of the distance from the midpoint of a line connecting the mesial and distal alveolar crest (AC) to the root apex.[11] After we identified the centroid on T1 anterior periapical radiographs, we transferred it to T1 and T2 cephalometric radiographs using the labial CEJ as a common reference point. We used a reference plane relative to the centroid to evaluate whether true intrusion had been achieved; we used the palatal plane (anterior nasal spine–posterior nasal spine) for the maxillary incisors and the mandibular plane (gonion-menton) for the mandibular incisors as skeletal reference structures. We used the vertical change of the incisor centroid during treatment relative to the reference planes to measure the amount of intrusion. We assumed that the vertical change of adjacent central incisors would be identical.

We measured alveolar bone level and root length on periapical radiographs. A single examiner (L.J.B.), who was blinded to the record period (T1 or T2), evaluated the position of the CEJs, the level of the ACs and the root apexes of the central incisors. This same examiner measured bone level as the vertical distance from the proximal CEJ to the AC. If a full-coverage restoration was present, he substituted the crown margin for the CEJ. We defined the AC as the most coronal area where the periodontal space retained its normal width.[12] The examiner evaluated the mesial and distal aspects of four teeth—the right maxillary central incisor, the left maxillary central incisor, the right mandibular central incisor and the left mandibular central incisor—for a total of eight sites. He measured root length as the distance from the midpoint on a line connecting the mesial and distal CEJ to the root apex. We evaluated all four central incisors (maxillary and mandibular). To ensure projection similarity, we used the maxillary and mandibular periapical radiographs centered on the midline for analysis. We omitted all nonmeasurable sites from the analysis.

To ensure examiner reliability, the primary author (L.J.B.) repeated and recorded complete T1 and T2 measurements, one month apart, for 10 randomly selected patients.

Data analysis. We calculated the differences between T1 and T2 for all data. We compared alveolar bone levels and root lengths at all sites by using a paired *t* test. For the intrusion versus no-intrusion subgroup analysis, we averaged the data for each person and compared the results with a *t* test for independent samples. For the maxillary versus mandibular subgroup analysis, we averaged the values within each arch and compared them with a *t* test for paired samples.

We used multiple linear regression to determine the associations among variables. In the first model, change in alveolar bone level was the dependent variable, with age, sex, treatment time, magnitude of intrusion and T1 bone level serving as independent variables. In the second model, root resorption was the dependent variable, with age, sex, treatment time, magnitude of intrusion and T1 root length serving as independent variables. We used a significance level of .05 in all analyses.

RESULTS

Method error. We assessed the examiner's reliability by computing intraclass correlation coefficients for repeated measurements. The coefficients ranged from 0.84 to 0.99, indicating high reliability of the measurements. The mean error for intrusion measurements was 0.44 mm for maxillary incisors and 0.69 mm for mandibular incisors. The mean errors for alveolar bone level and root length measurements were 0.19 mm and 0.27 mm, respectively.

Intruded incisors. Within the sample of 43 patients, 79 adjacent central incisor pairs (maxillary and mandibular) were available for study. On the basis of the results of the error study, we defined intrusion as greater than 1.00 mm of vertical movement of the incisor centroid. Combining both maxillary and mandibular incisor pairs, we found that 52 pairs met this criterion with a mean intrusion of 2.29 mm (range, 1.07-4.86 mm).

Relative to the CEJ, alveolar bone level remained relatively constant after intrusion (Table 1 and Figure 3). In other words, the bone followed the tooth during the intrusive movement. All sites exhibited significant bone loss; however, the change was minimal, with a mean loss of 0.32 mm. In general, there was a trend for the mesial sites to lose more bone than the distal sites; however, the difference was not statistically significant ($P = .13$).

All intruded incisors underwent significant root resorption during treatment (Table 2 and Figure 4). There was considerable variation between people as indicated by the high standard deviations within the sample. The mean root resorption was 1.73 mm for maxillary incisors and 1.37 mm for mandibular incisors. Statistically, there was no difference between right and left incisors ($P = .56$) and between opposing arches ($P = .19$).

TABLE 1

Mean (± standard deviation) change in bone level among intruded incisors, in millimeters (mm).

SITE*	PATIENTS ASSESSED (n)	INTRUSION (mm)	BONE LEVEL (mm), BY MEASUREMENT PERIOD		T1-T2 DIFFERENCE§ (mm)	*P* VALUE¶
			T1†	T2‡		
8D	21	2.35 ± 0.91	1.48 ± 0.59	1.77 ± 0.51	–0.19 ± 0.09	.0064
8M	22	2.35 ± 0.91	1.45 ± 0.54	1.82 ± 0.56	–0.37 ± 0.21	< .0001
9M	22	2.35 ± 0.91	1.43 ± 0.52	1.77 ± 0.65	–0.35 ± 0.16	< .0001
9D	22	2.35 ± 0.91	1.54 ± 0.49	1.80 ± 0.46	–0.27 ± 0.11	< .0001
24D	30	2.23 ± 0.85	1.93 ± 0.81	2.22 ± 0.85	–0.29 ± 0.24	< .0001
24M	30	2.23 ± 0.85	2.07 ± 1.16	2.50 ± 1.13	–0.43 ± 0.31	< .0001
25M	30	2.23 ± 0.85	1.95 ± 1.03	2.33 ± 0.80	–0.38 ± 0.17	< .0001
25D	29	2.23 ± 0.85	1.97 ± 0.76	2.22 ± 0.73	–0.26 ± 0.21	< .0001

* Tooth number and aspect. D: Distal. M: Mesial.
† T1: Pretreatment.
‡ T2: Posttreatment.
§ Negative values indicate bone loss relative to the proximal cementoenamel junction.
¶ Paired *t* test.

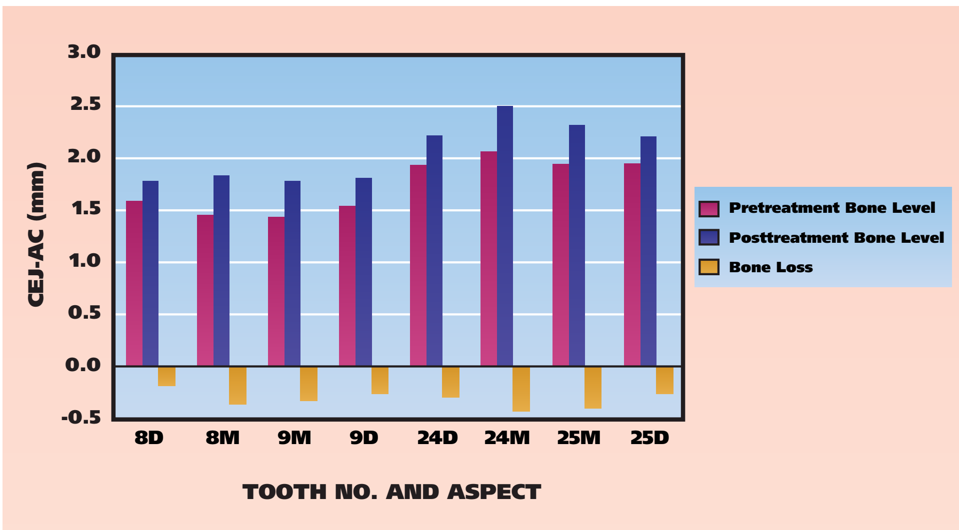

Figure 3. Mean change in bone level among intruded incisors. CEJ: Cementoenamel junction. AC: Alveolar crest. mm: Millimeters. D: Distal. M: Mesial.

TABLE 2

Mean change in root length among intruded incisors.

TOOTH	PATIENTS ASSESSED (n)	INTRUSION (mm)	ROOT LENGTH (mm), BY MEASUREMENT PERIOD		T1-T2 DIFFERENCE (mm)	P VALUE‡
			T1*	T2†		
8	22	2.35 ± 0.91	15.67 ± 1.83	13.83 ± 1.78	1.84 ± 1.54	< .0001
9	21	2.35 ± 0.91	15.57 ± 1.94	13.97 ± 1.79	1.60 ± 1.44	< .0001
24	30	2.23 ± 0.85	13.50 ± 1.42	12.05 ± 1.31	1.45 ± 0.91	< .0001
25	30	2.23 ± 0.85	13.31 ± 1.51	12.03 ± 1.16	1.28 ± 0.98	< .0001

* T1: Pretreatment.
† T2: Posttreatment.
‡ Paired *t* test.

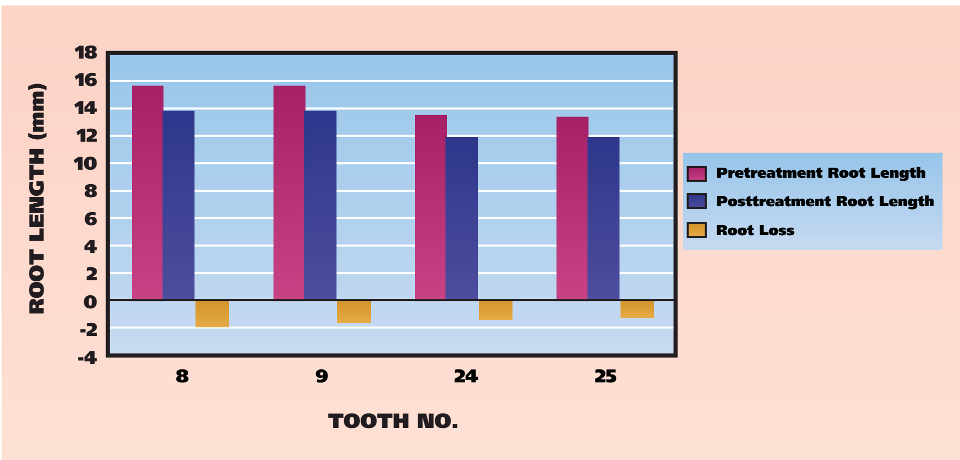

Figure 4. Mean change in root length among intruded incisors. mm: Millimeters.

Intrusion versus no intrusion. Of the 79 adjacent central incisor pairs, 52 were intruded more than 1.00 mm, and 27 were treated orthodontically but not intruded. Within the initial sample of 43 patients, 20 had central incisors in one or both arches that were not intruded. We derived a no intrusion group that excluded the values for any intruded incisors; 23 patients had central incisors in one or both arches that were intruded. We derived an intrusion group that excluded the values for any nonintruded incisors. We averaged both the bone level and root length of all sites within each person and compared them between groups.

The mean intrusion was 2.24 mm (range, 1.07 to 4.86 mm) for the intrusion group and –0.46 mm (range, –1.01 to 0.67 mm) for the no-intrusion group. The groups were well-matched with regard to age, treatment time, T1 bone level and T1 root length (Table 3). There was no statistical difference between the groups for either bone level or root resorption. Considering the entire sample, approximately 10 percent of root length was lost during treatment.

Maxillary versus mandibular central incisors. Within the sample of 43 subjects, 16 patients had both maxillary and mandibular central incisors that were intruded more than 1.00 mm. We averaged the measurements for all sites within each arch and compared the two groups.

The mean intrusion was similar for both groups (Table 4). T1 bone levels and root lengths were significantly different. Mandibular incisors tended to have less bone support, and maxillary roots were longer. There was no statistical difference in bone level change and root resorption between intruded maxillary and mandibular central incisors.

Regression analysis. On the basis of the multiple linear regression model (n = 79), we found no association between the change in bone level and the following variables: age, sex, treatment time, magnitude of intrusion and pretreatment bone level. Similarly, we found no association between root resorption and the following variables: age, sex, treatment time and magnitude of intrusion. However, there was a significant association between root resorption and pretreatment root length ($P < .0001$). The coefficient for this variable was 0.085, indicating approximately 0.085 mm of additional root resorption per millimeter increase in root length.

DISCUSSION

The patients in our sample underwent orthodontic treatment primarily because of esthetic concerns about their anterior teeth. Long-term incisal wear with subsequent overeruption results in short clinical crowns and disproportionate marginal gingivae. Assuming the bony attachment follows the tooth during the eruptive process, there are two ways for clinicians to address these esthetic concerns: surgical crown lengthening and orthodontic intrusion.[1] Crown lengthening exposes cementum and subsequently requires a more invasive, full-coverage restoration. Orthodontic intrusion provides the potential benefit of limiting the restored area to enamel and often results in a more conservative bonded-veneer restoration. Intrusion is beneficial restoratively only if the bone level follows the tooth as it moves apically. In our study, many of the adult patients underwent incisor intrusion of as much as 4.00 mm, thus providing a unique sample for investigation.

The results demonstrate that, in relation to the CEJ, alveolar bone levels remain relatively constant during incisor intrusion. In other words, the bone follows the tooth as it moves apically. Clinically, this finding is beneficial because the primary goal of orthodontic treatment is to move the dentogingival complex apically and restore the missing coronal tooth structure. Our results conflict with those of previous human and animal studies that have shown bone movement toward the CEJ after incisor intrusion.[4-9] The human studies involved only patients with previous periodontal bone loss and, therefore, involved a combined approach in which clinicians performed periodontal surgery to débride the root surface before orthodontic treatment.[5-9] In essence, movement of the bone toward the CEJ constitutes periodontal regeneration. A critical step in regeneration is the population of the root surface by regenerative cells from the periodontal ligament, bone or both, which can be facilitated by surgical débridement.[13] Most of the patients in our sample had minimal periodontal bone loss and had not undergone adjunctive periodontal procedures before having orthodontic procedures. This difference in treatment approach may explain why our results conflict with those of previous clinical studies.[5-9]

Our results are in agreement with those of other studies showing a small amount of bone loss during treatment.[14-18] The loss was similar in both arches and occurred regardless of whether or not the teeth were intruded. Nelson and Artun[18] studied alveolar bone changes in 343 consecutive adult orthodontic patients. They reported a mean bone loss of 0.54 mm among maxillary anterior teeth, which is similar to our finding of 0.32 mm. In adults, bone loss increases with age in the absence of orthodontic treatment. Albandar and colleagues[19] studied bone loss in untreated adult subjects across two years. They found little bone loss in subjects 32 years or younger, but found a loss of 0.20 mm per year in subjects aged 33 to 45 years. Given that the mean patient age in our study was 45.9 years and patients had an average

TABLE 3

Subgroup analysis of bone level change and root resorption comparing intruded incisors with those orthodontically treated but not intruded.

PARAMETER	MEAN ± SD*, ACCORDING TO GROUP		*P* VALUE†
	Intrusion (n = 23)	No Intrusion (n = 20)	
Intrusion (Millimeters)	2.24 ± 0.75	–0.46 ± 0.70	< .0001
Patient's Age (Years)	44.7 ± 8.7	46.0 ± 10.1	.650
Treatment Time (Months)	28.6 ± 7.2	27.8 ± 6.0	.711
Pretreatment Bone Level (mm)	1.59 ± 0.45	1.90 ± 0.80	.130
Pretreatment Root Length (mm)	14.6 ± 3.7	15.2 ± 3.8	.310
Bone Level Change (mm)	–0.38 ± 0.24	–.34 ± 0.32	.614
Root Resorption (mm)	1.48 ± 1.01	1.51 ± 1.17	.938

* SD: Standard deviation.
† Independent *t* test.

TABLE 4

Subgroup analysis of bone level change and root resorption, comparing maxillary and mandibular central incisors.

PARAMETER*	MEAN ± SD† VALUES, ACCORDING TO TYPE OF CENTRAL INCISOR		*P* VALUE‡
	Maxillary (n = 16)	Mandibular (n = 16)	
Intrusion	2.32 ± 0.92	2.25 ± 0.88	.951
Pretreatment Bone Level	1.47 ± 0.45	1.81 ± 0.57	.036
Pretreatment Root Length	15.2 ± 1.87	13.8 ± 1.56	< .0001
Change in Bone Level	–0.29 ± 0.20	–0.32 ± 0.31	.854
Root Resorption	1.56 ± 1.29	1.41 ± 1.05	.552

* All measured in millimeters.
† SD: Standard deviation.
‡ Paired *t* test.

treatment time of 28 months, the patients' bone loss may have occurred independent of orthodontic treatment.

Intrusion as a predictor of root resorption is a controversial topic in the literature. It is commonly believed that high stresses concentrated at the root apex during intrusion place these teeth at higher risk for apical resorption.[20-22] Several studies of adolescents have examined this relationship,[23-27] but assessing intrusion in adolescent patients is difficult because it is complicated by vertical growth of the facial skeleton and alveolus. As McFadden and colleagues[25] demonstrated, intrusion of incisors in a growing patient is "holding against growth" rather than true intrusion. Our study focused specifically on adults, and absolute intrusion was achieved entirely through vertical movement of the teeth within the alveolus. The intruded incisors in our sample exhibited significant root resorption. However, results from our regression analysis were in agreement with results from previous studies and showed no relationship between the magnitude of intrusion and the amount of root resorption. In addition, our results support previous studies with adults that showed intrusion was not a significant predictor of apical resorption.[28,29]

The results of our subgroup analysis showed no difference in the amount of root resorption when we compared intruded incisors to those orthodontically treated but not intruded. This finding supports the hypothesis that the amount of apical resorption may be related more closely to total displacement of the apex rather than direction of movement. As demonstrated in a 2004 meta-analysis,[30] apical displacement correlates highly with mean apical root resorption. The apexes of the nonintruded incisors may have been moved a similar distance but in a different direction, thus explaining our results. We did not assess total apical displacement in this study because of the difficulty in identifying the central incisor apex on cephalometric radiographs.

Our regression analysis showed no significant relationship between root resorption and the following variables: age, sex, treatment time and magnitude of intrusion. Most studies support this lack of association with age; however, a 2001 study of 868 patients showed that adults had significantly more resorption than children only when considering the mandibular teeth.[31] There have been conflicting results regarding the association between sex and root resorption. Results from one study[32] showed a greater prevalence in men, but our results are in agreement with those of other studies that showed no significant association between sex and root resorption.[31,33] Of all treatment variables, treatment duration most often is correlated with resorption. Still, studies in adult patients report no association.[28,29] Prolonged treatment does not coincide necessarily with extended periods of active tooth movement and, thus, may be a poor predictive variable.[30]

As in results from other studies, we found a positive correlation between initial root length and the amount of root resorption.[18,31] The regression coefficient indicated 0.085 mm more resorption per millimeter increase in root length. A possible explanation for this finding is that apical displacement is greater during tipping and torquing of longer teeth. As clinicians, we are more concerned about resorption's occurring in patients with short roots. A more clinically relevant finding may be the loss of approximately 10 percent of total root length within our sample. However, individual susceptibility is likely the greatest factor in determining root resorption, and clinicians should interpret generalizations with caution.

Incisor intrusion as an adjunct to restorative treatment is most applicable to patients with adequate bone support and root length. Dentists should exercise caution when considering this form of treatment for patients with significant periodontal bone loss, short roots or both. Clinicians should expect a further reduction in root length, as shown in this study. In some cases, this may lead to an unfavorable crown-to-root ratio, thus compromising the final restorative result.

Our study has limitations. We did not correct anterior periapical radiographs for differences in projection even though investigators commonly make such corrections according to the method originally developed by Linge and Linge,[34] in which investigators use crown length as a reference to adjust for vertical angulation differences. The subjects in our study were atypical in that most received temporary incisal restorations after intrusion; therefore, the clinician modified crown length during treatment, and correction was not possible. Vertical angulation differences can affect root resorption estimates. However, Hausmann and colleagues[35] showed that angulation deviation of as much as 20 degrees has no significant effect on crestal bone height measurements. Despite our inability to make this correction, the radiographic quality and consistency were excellent because all patients' radiographs were obtained at the same professional imaging center.

CONCLUSION

Orthodontic incisor intrusion in adults is a valuable treatment adjunct to the restorative management of incisal wear. Our findings suggest that the benefits of less tooth preparation and a more conservative final restoration outweigh the minimal iatrogenic effect on alveolar bone level and root length. ■

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