Original Article

A comparative study of the effect of the intrusion arch and straight wire mechanics on incisor root resorption: *A randomized, controlled trial*

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ABSTRACT

Objective: To analyze and compare external apical root resorption (EARR) of maxillary incisors treated by intrusion arch or continuous archwire mechanics.

Materials and Methods: This cone-beam computed tomography (CBCT) study analyzed 28 deep bite patients in the permanent dentition who were randomly divided into two groups: Group 1, 12 patients with initial mean age of 15.1 $\pm$ 1.6 years and mean overbite of 4.6 $\pm$ 1.2 mm treated with the Connecticut intrusion arch (CIA) in the upper arch (Ortho Organizers, Carlsbad, Calif) for a mean period of 5.8 $\pm$ 1.27 months. Group 2, 16 patients with initial mean age of 22.1 $\pm$ 5.7 years and mean overbite of 4.1 $\pm$ 1.1 mm treated with conventional leveling and alignment using continuous archwire mechanics for 6.1 $\pm$ 0.81 months. The degree of EARR was detected in 112 maxillary incisors by using CBCT scans and a three-dimensional program (Dolphin 11.7, Dolphin Imaging & Management Solutions, Chatsworth, Calif). The CBCT scans were obtained before (T1) and 6 months after initiation of treatment (T2). Differences between and within groups were assessed by nonpaired and paired *t*-tests, respectively, with a 5% significance level.

Results: Significant differences were found for both groups between T1 and T2 ($P < .05$) indicating that EARR occurred in both groups. However, there were no significant differences when EARR was compared between group 1 (–0.76 mm) and group 2 (–0.59 mm).

Conclusions: The Connecticut intrusion arch did not lead to greater EARR of maxillary incisors when compared with conventional orthodontic mechanics. (*Angle Orthod.* 2018;88:20–26.)

KEY WORDS: Overbite; Intrusion; Biomechanics; Tomography; Root resorption

INTRODUCTION

Deep bite is a common malocclusion characteristic for which treatment depends mainly on its etiology, including mandibular and maxillary growth, altered lip and tongue function, and dentoalveolar development.[1,2] Treatment strategies include extrusion of posterior teeth, intrusion of anterior teeth, or both.[3] Since facial esthetic objectives are a priority in treatment planning, gingival and maxillary incisor exposure at smiling and speech, as well as the relationship between the upper lip and incisors are important considerations in orthodontics.[4] Intrusion of incisors can be achieved by a number of orthodontic archwires, for example, Burstone intrusion arch, Ricketts base arch, and Connecticut intrusion arch (CIA). The CIA is a preformed nickel-titanium arch with a low load/deflection ratio, V-shaped in the posterior region to exert mild intrusion force ranging from 40 to 60 g on the anterior teeth.[5]

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Accepted: August 2017. Submitted: June 2017.
Published Online: October 5, 2017

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 DOI: 10.2319/06417-424R

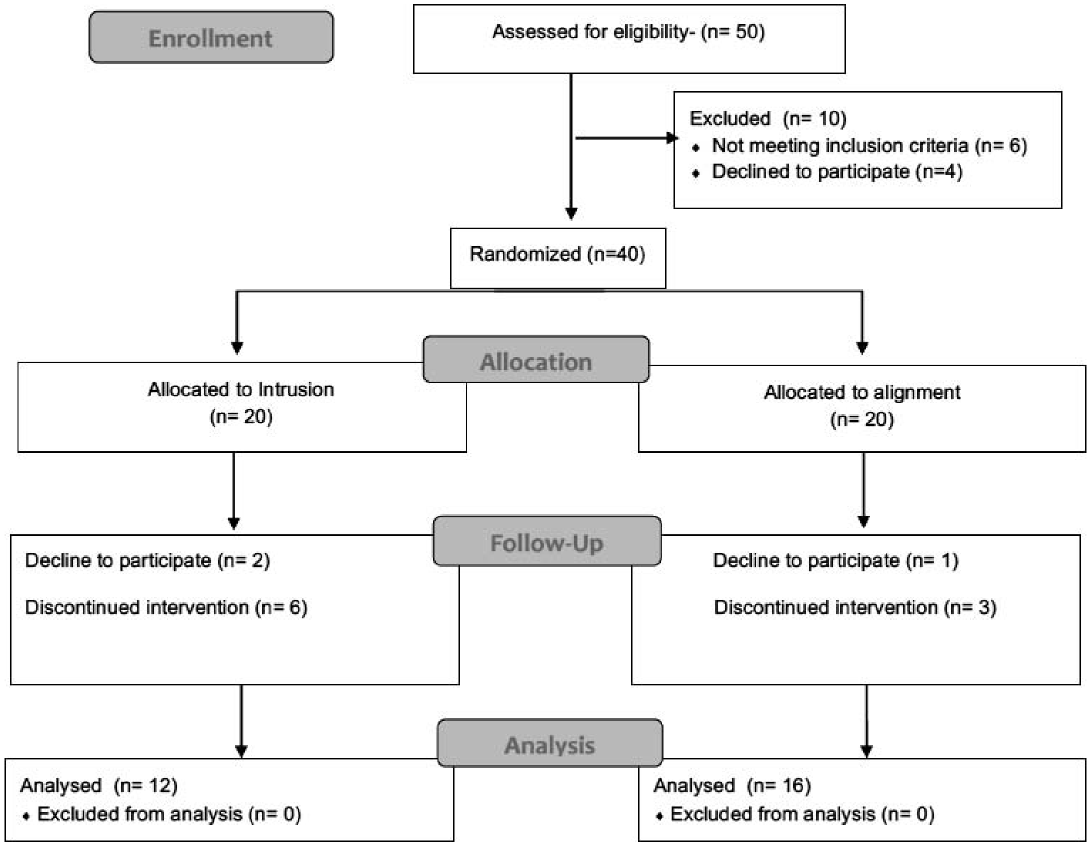

Figure 1. CONSORT flow diagram.

External apical root resorption (EARR) is a frequent, undesirable side effect in orthodontic treatment, and it has a multifactorial etiology.[6] Since one cause of root resorption is orthodontic movement, a correlation may exist between the type of movement and the degree of subsequent root resorption.[6] A previous study assessed EARR caused by mechanical intrusion of the maxillary incisors using intrusion arches by means of periapical radiographs, revealing a mean resorption of 0.6 mm within a 4.3-month period. [7] It is worth highlighting that the degree of force applied and treatment time are seen as factors capable of increasing the likelihood of resorption. A larger amount of EARR was found in teeth subjected to heavy orthodontic force compared with mild forces.[8,9]

The presence of EARR is often diagnosed by means of radiographic examination, which is considered the best means of performing regular follow-up.[10] Nevertheless, standardization of two-dimensional scans is difficult, and a number of factors hinder proper radiographic findings, including anatomical variations.[11] Furthermore, minor incisor angular changes cause significant alterations in linear measurements in the radiographs. Technological innovations have made it possible to evaluate the degree of root resorption three-dimensionally with precision in measuring root shortening. Thus, cone-beam computed tomography (CBCT) is considered the most precise tool to identify external root resorption.[10] However, there has been no study conducted by means of CBCT scans to assess EARR resulting from intrusion of maxillary incisors achieved with the CIA.

The purpose of this prospective study was to assess and compare the magnitude of maxillary incisor apical root resorption by means of CBCT in patients treated with CIA and conventional orthodontic mechanics.

MATERIALS AND METHODS

This study was approved by the local institutional review board. Patients and guardians were fully informed about the study and its implications, with written consent obtained. Sample size estimation was based on a statistical significance level of 5% (alpha) and a beta value of 0.2 to achieve a minimum of 80% probability of detecting a real mean difference of 0.4 mm in EARR between groups with a standard deviation of 0.6.[7] A minimum of 12 patients was required in each group.

As shown by the flow chart (Figure 1), 50 patients with deep bite were initially enrolled. From 50 patients, 10 were excluded because of not meeting the following

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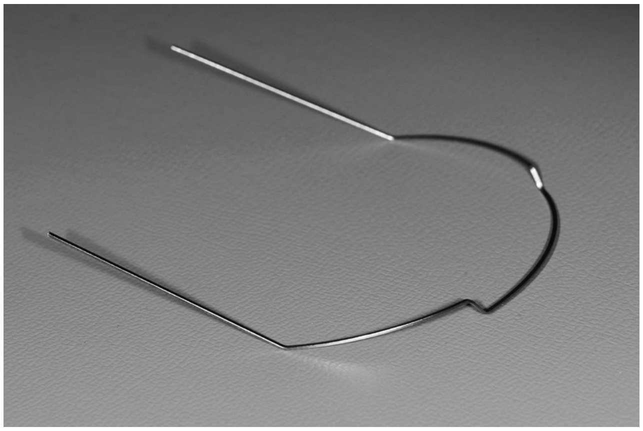

Figure 2. Connecticut intrusion arch.

inclusion criteria: age between 12 and 30 years, no history of previous orthodontic treatment, Class I or II malocclusion (half cusp), permanent dentition present except for third molars, minimal or no anterior crowding (<3 mm) and excessive overbite (>3 mm). Exclusion criteria were: syndromic patients as well as individuals with skeletal asymmetry, history of trauma affecting the maxillary incisors, endodontically treated anterior teeth, need for tooth extraction, crowding >3 mm in the upper arch, agenesis (except for third molars), and any kind of tooth/root shape anomaly. The 40 remaining patients were randomly divided into two equal groups of 20 each: Group 1 (G1) subjects were treated with maxillary incisor intrusion with the CIA, whereas group 2 (G2) subjects were treated with conventional leveling and alignment in the upper arch and reverse curve of Spee mechanics in the lower arch. However, 12 patients were lost during the study to follow-up (3 patients declined to participate and 9 discontinued intervention).

A total of 28 patients remained until the end of the study. Therefore, G1 comprised 12 patients: 8 males and 4 females with an initial mean age of 15.1 $\pm$ 1.6 years, mean overbite of 4.6 $\pm$ 1.2 mm, and mean treatment period of 5.8 $\pm$ 1.27 months. G2 comprised 16 patients: 8 males and 8 females, with an initial mean age of 22.1 $\pm$ 5.7 years, mean overbite of 4.1 $\pm$ 1.1 mm, and mean treatment period of 6.1 $\pm$ 0.81 months. All patients were treated by graduate students and supervised by the same adviser.

All the patients were treated with full fixed appliances having a 0.022 $\times$ 0.030-inch slot (3M Unitek, Monrovia, Calif). Bands were cemented to the maxillary first molars and brackets were bonded according to the central position on the tooth crowns. Patients of G2 were orthodontically treated for leveling and alignment with the same sequence of archwires beginning with 0.013-inch, 0.014-inch, and 0.016-inch nickel-titanium. According to the protocol assigned, each archwire remained in place for 2 months. Patients from G1 followed a protocol with a segmented anterior archwire of 0.014 $\times$ 0.025-inch, heat-activated, nickel-titanium. For the intrusion protocol, a long, preformed nickel-titanium 0.017 $\times$ 0.025-inch intrusion arch (Ortho Organizers, Carlsbad, Calif) was used (Figure 2), activated with a previously calibrated V-bend effecting an intrusive vertical force of 40–60 g.[5,12] The archwire was adapted to an accessory tube attached to the triple tube bonded to the maxillary first molar and cinched back and secured by a metal ligature over the lateral incisors on the same day the maxillary fixed appliances were bonded. Both arches remained until overbite was fully corrected, which occurred in a mean period of 5.8 $\pm$ 1.27 months.

CBCT scans were obtained from all patients at two times: before beginning treatment (T1) and 6 months after treatment began (T2). Intrusion arches were removed for tomographic examination at T2. All CBCT scans were carried out by a single radiologist using the same equipment (i-Cat, Imaging Sciences International, Hatfield, Pa) and acquired with a 22 $\times$ 16-cm FOV, 40 seconds, 120 kVp, 36 mA, and voxel image resolution of 0.3 mm.

Analysis of CBCT scans was blinded in order to have groups allocated in and measured by the 3D software. The examiner remained unaware of which group was being measured. The CBCT scans were assessed by the same researcher to evaluate EARR by using the Dolphin 3D program (Version 11.7, Dolphin Imaging and Management Solutions, Chatsworth, Calif) with a level of sensitivity fixed at 25%.

Sagittal cuts of the upper incisors were selected and a sectional cut was made in the center of the long axis, which coincided with the incisal edge and apex. As a result, the greatest distance from the apex to the incisal edge could be measured (Figure 3). The EARR was calculated by assessing the difference in total tooth length—measured from the incisal edge to the apex—between T1 and T2 (T2–T1), in millimeters. Thus, 112 incisors were blindly evaluated for root resorption.

CBCT scans were also used to obtain cephalograms for measuring incisor vertical movement, in which each subject's head was positioned according to the Frankfort horizontal plane, with the base of the mandible on both the left and right sides being as parallel as possible. To report the amount of vertical incisor movement measured, a method previously published was adopted.[13] The centroid point, located at the center of resistance of each tooth that remains unchanged regardless of tipping,[14] was used. From this point a perpendicular line was traced so as to meet the palatal plane line (ANS-PNS) (Figure 4). The measured distance was compared (T2–T1) to determine

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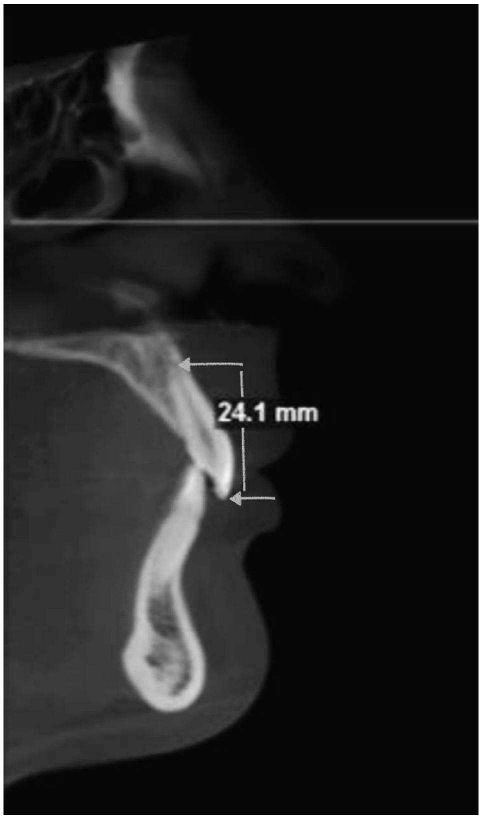

Figure 3. Distance from apex to incisal edge.

vertical movement of maxillary incisors in relation to the maxilla.

Error of Method

Thirty days after the first evaluation, 50% of the CBCT scans were randomly selected, and the respective measurements were repeated to determine intraexaminer errors by means of a paired *t*-test (systematic errors)[15] and the Dahlberg formula (casual errors). Intraexaminer agreement was excellent ($P = .115$, Dahlberg $= 0.33$). Coefficients showed high rates of agreement for the measures with CBCT.

Statistical Analysis

The data were tested regarding the normal distribution by applying the Kolmogorov-Smirnov test. Because the distributions were normal, parametric tests

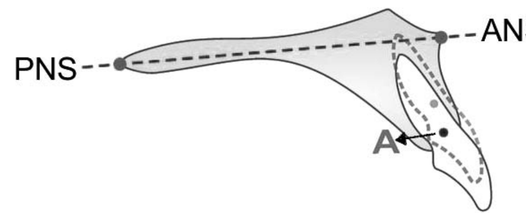

Figure 4. Measurement of incisor vertical movement. A: centroid point; ANS: anterior nasal spine; PNS: posterior nasal spine.

were used. The results were described by parameters of mean and standard deviation of T1 and T2 measurements for both groups. A paired *t*-test was employed to compare the degree of EARR in each group between the T1 and T2 time points, and a nonpaired *t*-test was used for comparison between groups. In all statistical tests, the significance level was set at 5%. Statistical calculations were made with Statistica software (version 7.0, StatSoft Inc, Tulsa, Okla).

RESULTS

The groups were comparable at T1 (Table 1) regarding sex distribution, initial age, and treatment time. A statistically significant difference occurred in all teeth in comparing between T1 and T2 for G1 patients, as shown in Table 2. The same occurred for G2, in which all the teeth had statistically significant root resorption (Table 3). Regarding vertical incisor movement, there was significant intrusion of incisors in G1 (–2.23 mm), whereas a small amount of vertical extrusive movement (0.3 mm) was observed in G2.

No statistically significant difference was found in comparing the degree of root resorption between the two groups (Table 4). Comparing the mean values of root resorption between T1 and T2 within each group revealed statistically significant results: –0.76 mm for G1 and –0.59 mm for G2 (Table 5). No statistically significant difference was found in comparing the mean degree of EARR between the two groups (0.17 mm; Table 6).

DISCUSSION

This is the first randomized prospective study to investigate EARR of the maxillary incisors carried out

Table 1. Results of Intergroup Comparison of the Sex Distribution, Initial Mean Age, and Treatment Time (Student's *T*-Test)

				Age (y)		Treatment Time (mo)	
	Sample	Male	Female	Mean	SD	Mean	SD
G1	12	8 (67 %)	4 (33 %)	15.1	1.6	5.83	1.27
G2	16	8 (50 %)	8 (50 %)	22.1	5.7	6.12	0.81
P			.089 (NS [a])		.060 (NS)		.223 (NS)

[a] NS indicates no statistically significant difference.

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Table 2. Comparison of the Degree of Root Resorption (mm) Between T1 and T2 for the Patients in Group 1 (Intrusion Arch)

Measurements, mm	T1 Mean	T1 SD	T2 Mean	T2 SD	T2−T1	P
Maxillary right central incisor	24.42	2.17	23.51	1.65	−0.91	.025*
Maxillary left central incisor	24.75	2.17	23.93	1.99	−0.82	.007*
Maxillary right lateral incisor	23.24	2.27	22.42	2.10	−0.83	.002*
Maxillary left lateral incisor	23.41	2.21	22.91	2.17	−0.50	<.001*
Incisors mean vertical movement**	19.26	3.42	17.03	3.39	−2.23	<.001*

* Statistically significant difference ($P < .05$).
** Negative values indicate intrusion; positive values indicate extrusion.

with the CIA in deep overbite patients assessed by means of CBCT compared with a group treated with continuous archwires for leveling and alignment.

Although EARR is a major concern in orthodontic treatment, it generally does not exceed 2 mm.[16] Only 2% to 3% of cases exhibit severe EARR greater than or equal to 4 mm.[7,17] Sometimes resorption develops without the influence of orthodontic force, proving it to be a physiological process; however, in orthodontics, it has been shown to be related to the degree, frequency, and type of force applied.[18]

The greater the need for intrusion, the greater the concern, since it is well-known that the degree of root resorption increases with intrusion, especially in single-rooted teeth.[19] The magnitude of force applied is a major concern, since it can affect the degree of EARR observed. Nevertheless, intrusion does not require heavy forces, as revealed in a previous clinical study wherein no difference was observed in the amount of incisor intrusion when forces ranged from 40 to 80 g.[20]

The CIA design is based on Burstone's intrusion arch, which applies a statically determinate force system that can be readily measured, making the potential side effects more predictable.[21] The CIA delivers forces ranging from 40 to 60 g, meaning that, when force is distributed in the anterior region, 10 to 15 g of force is applied to each tooth.[5,12] The objective of the present study was to assess the EARR caused by intrusion of the maxillary incisors carried out by means of the segmented arch technique and an intrusion arch compared with a conventional, continuous archwire.

Conventionally, EARR has been assessed by periapical radiographs. However, resorption is a 3D phenomenon and CBCT has proven to be more accurate, being an important tool not only for scientific research, but also for the diagnosis of alterations revealed by previous examination.[10,11]

A similar study[7] assessed the degree of root resorption during intrusion by means of periapical radiographs using a sample comprising 17 patients treated with a Burstone intrusion arch compared with 17 patients treated with continuous archwires. A mean resorption value of 0.6 mm was found among patients using the intrusion arch, but only 0.2 mm among those with continuous archwires. The mean time between assessments was 4.3 months, and the amount of intrusion assessed using incisor centroid points was 1.9 mm.[7]

Another study[22] assessed Burstone intrusion arch efficiency regarding intruding incisors. The mean intrusion values found in 31 patients was 2.3 mm in the maxilla and 3 mm in the mandible. The mean treatment time was 4.3 months for the maxilla and 5.5 months for the mandible. A previous study[23] assessed 45 patients divided into three groups: G1, no treatment, G2, intrusion of maxillary incisors by means of miniscrews and G3, intrusion of maxillary incisors by means of Connecticut intrusion arch (CIA). Treatment time for both experimental groups was 7 months. The mean amounts of genuine intrusion were 2.20 mm in the CIA group and 2.47 mm in the implant group. No statistically significant differences were found in the

Table 3. Comparison of the Degree of Root Resorption (mm) Between T1 and T2 for the Patients in Group 2 (Continuous Archwire)

Measurements, mm	T1 Mean	T1 SD	T2 Mean	T2 SD	T2−T1	P
Maxillary right central incisor	23.49	1.91	23.01	1.87	−0.48	.001*
Maxillary left central incisor	23.83	1.73	23.11	1.65	−0.72	<.001*
Maxillary right lateral incisor	22.83	2.12	22.24	1.92	−0.59	.001*
Maxillary left lateral incisor	22.42	1.94	21.86	2.04	−0.56	.001*
Incisors mean vertical movement**	18.72	3.09	19.02	3.11	0.30	.213 (NS***)

* Statistically significant difference ($P < .05$).
** Negative values indicate intrusion; positive values indicate extrusion.
*** NS indicates no statistically significant difference.

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Table 4. Comparison of the Difference in Root Resorption Between Groups 1 and 2

	Group 1 (Intrusion Arch), N = 12		Group 2 (Continuous Arch), N = 16			
	Mean	SD	Mean	SD	Diff	*P*
Treatment time (mo)	5.83	1.27	6.13	0.81	0.29	.464 (NS*)
T1 (mm)						
Maxillary right central incisor	24.42	2.17	23.49	1.91	−0.93	.240 (NS)
Maxillary left central incisor	24.75	2.17	23.83	1.73	−0.93	.220 (NS)
Maxillary right lateral incisor	23.24	2.27	22.83	2.12	−0.42	.621 (NS)
Maxillary left lateral incisor	23.41	2.21	22.42	1.94	−0.99	.219 (NS)
T2 (mm)						
Maxillary right central incisor	23.51	1.65	23.01	1.87	−0.50	.467 (NS)
Maxillary left central incisor	23.93	1.99	23.11	1.65	−0.83	.241 (NS)
Maxillary right lateral incisor	22.42	2.10	22.24	1.92	−0.18	.816 (NS)
Maxillary left lateral incisor	22.91	2.17	21.86	2.04	−1.04	.203 (NS)
Root resorption (mm)						
Maxillary right central incisor	−0.91	1.21	−0.48	0.45	0.43	.205 (NS)
Maxillary left central incisor	−0.82	0.86	−0.72	0.50	0.10	.708 (NS)
Maxillary right lateral incisor	−0.83	0.70	−0.59	0.53	0.24	.316 (NS)
Maxillary left lateral incisor	−0.50	0.35	−0.56	0.56	−0.05	.767 (NS)

* NS indicates no statistically significant difference.

extent of maxillary incisor intrusion between the 2 intrusion systems.

In the current study, maxillary incisor intrusion of 2.23 mm was observed in G1, which was similar to that in previous studies (2.3 mm,[22] 2.2 mm,[23] and 1.9 mm[7]). A systematic review[14] highlighted that true maxillary incisor intrusion amounts can be approximately 1.5 mm. As expected, in G2 there was extrusion—rather than intrusion—of the maxillary incisors, since a continuous archwire does not provide intrusive movements.

Another study[24] used CBCT images to compare EARR of maxillary incisors subjected to intrusive forces using mini-screws for anchorage. Thirty-two patients were divided into two groups: one with screws in the anterior region and the other with screws in the posterior region used for attaching a Burstone three-piece arch secured with screws. The mean intrusion value for the anterior group was 0.62 mm monthly, whereas the other group exhibited a mean value of only 0.39 mm during that period. The mean treatment time was 4 months, with mean intrusion values ranging from 1.5 mm to 2.4 mm. EARR found in the group treated with screws in the anterior region ranged from 0.85 mm to 1.19 mm, whereas in the other group it ranged from 0.7 mm to 0.83 mm. The results suggested that the group treated with the Burstone intrusion arch had less EARR as well as less maxillary incisor intrusion.

The EARR found in the present study was 0.76 mm in G1 and 0.59 mm in G2. Similar results have been reported by other studies investigating resorption caused by the CIA (0.7 mm to 0.83 mm[24] and 0.6 mm[7]). Although it occurred in all teeth, this degree of EARR is considered small and clinically irrelevant.[25,26] The difference of 0.17 mm in the mean EARR found between groups corroborates the outcome of a study previously reported.[7]

In summary, the current study found that the amount of EARR resulting from correction of deep overbite using the CIA to intrude maxillary incisors was similar to conventional treatment with continuous archwires during leveling and alignment of the maxillary arch. Moreover, it should be pointed out that the amount of EARR among all patients was within normal limits according to the related literature. However, further long-term clinical studies are necessary to confirm the results observed in this research. Other analyses, such as volumetric evaluation of the impact of root resorption and possible subsequent repair[27] of the maxillary incisors, would broaden the knowledge about EARR severity three-dimensionally.

CONCLUSIONS

- The degree of EARR affecting maxillary incisors following overbite correction by means of the Con-

Table 5. Comparison of the Mean Degree of Root Resorption (mm) Between T1 and T2 for the Patients in Both Groups

Group	T1 (mm)		T2 (mm)			
	Mean	SD	Mean	SD	T2−T1	*P*
G1 (intrusion arch), N = 12	23.95	1.95	23.19	1.77	−0.76	.002*
G2 (continuous arch), N = 16	23.14	1.83	22.55	1.79	−0.59	<.001*

* Statistically significant difference ($P < .05$).

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Table 6. Comparison of the Mean Degree of Root Resorption (mm) Between Both Groups

Group 1 (Intrusion Arch), N = 12		Group 2 (Continuous Archwire), N = 16			
Mean (mm)	SD	Mean (mm)	SD	Diff	*P*
−0.76	0.64	−0.59	0.28	0.17	.335 (NS*)

* NS indicates no statistically significant difference.

necticut intrusion arch (−0.76 mm), was similar to the degree subsequent to conventional orthodontic mechanics (−0.59 mm).

- No significant differences in the degree of maxillary incisor root resorption were found between intrusion with the CIA and alignment mechanics with continuous archwires.

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