Articles that will be discussed during The Angle Orthodontist lecture by Dr. Carlos Flores-Mir:

Article #1: http://www.angle.org/doi/pdf/10.2319/085015-571.1

Article #2 http://www.angle.org/doi/pdf/10.2319/031815-170.1

Article #3 http://www.angle.org/doi/pdf/10.2319/072015-491.1

Original Article

Can posterior teeth of patients be translated buccally, and does bone form on the buccal surface in response?

Chad J. Capps[a]; Phillip M. Campbell[b]; Byron Benson[c]; Peter H. Buschang[d]

ABSTRACT

Objective: To produce buccal translation and determine whether buccal bone forms on the cortical surfaces.

Materials and Methods: Eleven patients requiring maxillary first premolar extractions participated in this prospective, randomized, split-mouth study. Pre- and posttreatment records included models, photographs, and small field of view CBCT images. One randomly chosen maxillary first premolar was moved buccally with 50 g of force applied approximately at the tooth's center of resistance. The other premolar served as the control. Forces were re-activated every 3 weeks for approximately 9 weeks, after which the teeth were held in place for 3 weeks. Pre- and posttreatment records were analyzed and superimposed to evaluate changes in the dental-alveolar complex.

Results: There was significant ($P < .05$) movement of the experimental premolar with minimal buccal tipping (2.2°). Changes in maximum bone height were bimodal, with 6 patients showing 0.42 mm and 5 patients showing 8.3 mm of vertical bone loss. Buccal bone thickness 3 mm apical to the CEJ decreased 0.63 mm. Direct measurements and CBCT superimpositions showed that buccal bone over the roots grew 0.46 mm and 0.51 mm, respectively.

Conclusions: It is possible to produce buccal bodily tooth movement with only limited amounts of tipping. Such movements are capable of producing buccal bone apposition, but there are potential limitations. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Tooth translation; CBCT; Patients; Bone formation

INTRODUCTION

A tooth-size-to-arch-length deficiency is one of the most common problems facing clinical orthodontists.[1] To treat such patients, clinicians must either remove tooth structure or increase arch length, usually with expansion. In recent years, the nonextraction approach has become more popular as new techniques and materials for expansion have been developed.

Despite improvements, expansion continues to present problems; one of the most notable is uncontrolled tipping.[2,3] Tipping produces compressive forces concentrated in the cervical and apical thirds of the tooth's root.[4] Strains that exceed 3000 $\mu\varepsilon$ are considered problematic, producing microcracks that accumulate and eventually lead to failure.[5] Excessive strains provide the link between dental tipping and alveolar bone loss.[3,4,6] If the same forces could be distributed over the entire buccal root surface, the adverse effects of orthodontic expansion might be minimized.

Moreover, lower translational forces could stimulate bony apposition along the buccal cortical plate. Cortical bone mass increases when microstrains fall into the range of 1500–3000 $\mu\varepsilon$.[5] New buccal cortical bone apposition with lateral tooth movements has recently been demonstrated experimentally.[3,7] However, apposition was limited to the region extending from the crest to the reversal zone, around which the teeth were tipped. If the expansion forces had been

[a] Private Practice, Dallas, Tex.

[b] Associate Professor and Chairman, Orthodontic Department, Texas A&M University Baylor College of Dentistry, Dallas, Tex.

[c] Regents Professor, Diagnostic Sciences, Baylor College of Dentistry, Texas A&M University Baylor College of Dentistry, Dallas, Tex.

[d] Regents Professor and Director of Orthodontic Research, Orthodontic Department, Texas A&M University Baylor College of Dentistry, Dallas, Tex.

Corresponding author: Dr Peter H. Buschang, Regents Professor and Director of Orthodontic Research, Orthodontic Department, Baylor College of Dentistry, Texas A&M Health Science Center, Dallas, TX 75246
(e-mail: phbuschang@bcd.tamhsc.edu)

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Table 1. Amount of Tooth Movement (mm) Measured on the Models of Patients 9 and 10, Who Were Excluded Due to the Lack of Tooth Movement

	1st Premolar Intercuspal Distance		Intermolar Distance	
ID Number	Buccal Cusps	Palatal Cusps	Central Fossae	Mesiobuccal Cusps
9	0.13	0.25	0.6	0.74
10	0.28	0.57	–0.25	0.43

spread over a larger area, new buccal bone formation might have occurred over the entire root's surface.

The aims of this clinical study were to produce buccal translation of the maxillary first premolars and to determine whether bone forms on the buccal surfaces. A force system was designed to minimize tipping and produce buccal translation with light, continuous forces.

MATERIALS AND METHODS

The project was approved by the Texas A&M University Baylor College of Dentistry IRB (BCD 2012-12) and informed consent was obtained from all patients. Orthodontic patients between 11–17 years of age were selected based on having: (1) previously accepted a treatment plan that included maxillary premolar extractions and (2) fully erupted maxillary first molars. Based on estimates of buccal tooth movement,[8] a power analysis indicated that 12 subjects were necessary to establish a 1.2-mm difference in buccal tooth movement between sides, assuming a power of 0.95, an alpha of 0.05, and a correlation of 0.5. Thirteen typical orthodontic patients were enrolled in the study; two were not included in the analyses because their premolars did not move sufficiently (Table 1).

The remaining 11 patients (5 females and 6 males) were 14.1 years of age. Pre- and posttreatment records included plaster models, limited field of view cone beam computed tomographic (CBCT) images, and digital photographic images. The CS 9000 3D (Carestream Dental, Atlanta, Ga) CBCT unit was chosen based on its small voxel size (0.076 mm, isotropic) and minimal average radiation dose (9.8 μSv). Four images (pre/post and study/control) were taken on each patient. The maxillary first premolar was centered in the field of view (3.75 $\times$ 5.00 cm) to maximize the accuracy of reconstructing the volumetric data.[9] Settings for the CBCT images were 70 kV, with 10mA, at 10.8 seconds.

The premolar on the control side was not banded and did not receive any form of treatment. The appliance was adapted from previous studies[8,10] and fabricated on the study models. It consisted of bands on the maxillary first molars and first premolars. A transpalatal arch (0.036-inch stainless steel wire) was soldered to the molar bands to maintain molar position and provide a framework for a bite plane made with Triad acrylic (Dentsply GAC, Islandia, NY) (Figure 1A). On the facial surface of the premolar band, a 0.040-inch stainless steel wire was soldered to serve as a power arm (Figure 1B). The solder joint was positioned so that the point of attachment was in the cervical third of the premolar.[11] The power arm extended to the premolar's center of resistance, which was estimated to be 40% from the apex, measured between the alveolar crest and the root apex (Figure 1C).[12] The actual power arm distance was 16.7 mm from the buccal cusp tip.

The bands, the cantilever on the premolar, and the transpalatal arch were transferred to the patient and bonded using a dual-cured, resin-modified, glass ionomer cement (Reliance Orthodontics, Itasca, Ill). Triad acrylic was added to or removed from the bite plane so that the first premolar was free of interferences during buccal movements.

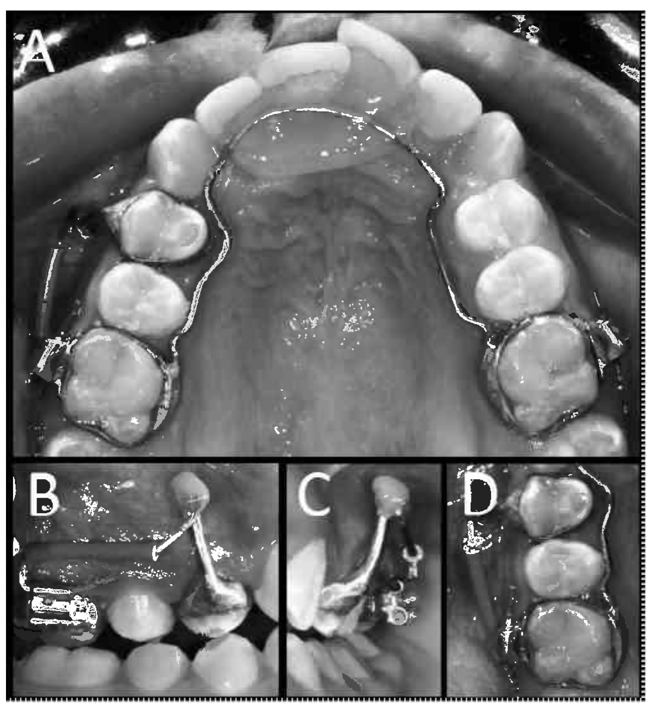

Figure 1. (A) Occlusal view of the transpalatal arch with acrylic bite plane. (B) Buccal view of cantilever arm. (C) Frontal view of the lever arm. (D) Occlusal view of active cantilever arm.

Table 2. Average Duration (Days) Between Appointments

	Delivery and 1st Reactivation	1st and 2nd Reactivation	2nd Reactivation and Maturation	Maturation and Removal
Days	21.3 ± 2.1	20.4 ± 2.0	17.7 ± 4.3	20.5 ± 2.6

A 50-g force was applied to the maxillary first premolar on the experimental side with a β-titanium alloy 0.021 × 0.025-inch sectional wire (3M Unitek, Monrovia, Calif), anchored in the auxiliary slot on the first molar band (Figure 1D). The wire was bent vertically so that its point of attachment was located at the estimated center of resistance (Figure 1B and C) and bent buccally to create a 50-g lateral force (Figure 1D), as verified with a Correx (Haag-Streit, Berne, Switzerland) gram force strain gauge. The activated wire was ligated to the premolar cantilever with a 0.001-inch stainless steel ligature tie (Figure 1B and C).

The buccal force was checked and reactivated to 50 g every 3 weeks (Table 2) for 6–9 weeks, in order to obtain adequate amounts of tooth movement. Forces were reduced for 3 additional weeks to allow the bone to adapt. A 0.021 × 0.025-inch SS wire was bent to apply 10–15 g, closely approximating buccal musculature forces.[13]

Evaluations

All measurements were taken twice by one blinded investigator and averaged. Pre- and posttreatment study models were digitally scanned using an Ortho Insight 3D model scanner (Motion View Systems, Hixson, Tenn) and evaluated using the Motion View Software (Motion View). Width measurements were taken between the buccal and palatal cusp tips of the first premolars, and between the mesiobuccal cusp tips and central fossae of the molars. Replicate analyses of seven randomly selected sets of models showed interclass correlations ranging from 0.98 to 0.94 for the interpalatal cusp and interbuccal cusp measurements, respectively.

Tipping was measured based on the angle formed between the cervical margins on the palatal sides of the control premolar, the cervical of the experimental premolar on the palatal side, and the palatal cusp of the experimental premolar. Based on replicate analysis of five randomly selected sets of digital models, the interclass correlation for the tipping was 0.88.

The CBCT images were oriented as previously described.[14] Three width measurements (Figure 2) were taken at the mesiodistal midpoint of the first premolar. Moving through the coronal slices—from mesial to distal—the operator also measured the maximum and minimum vertical distances from the crestal bone to the CEJ. Replicate analyses using six randomly selected CBCT images produced interclass correlations ranging from 0.92–0.99.

Pre- and post-CBCT images were superimposed using Invivo5 software (Anatomage, San Jose, Calif). A voxel superimposition was performed to measure changes 3 mm apical to the CEJ. Measurements were taken three times by one investigator and averaged. The interclass correlations for root movement and buccal bone thickness were 0.95 and 0.99, respectively. Change in buccal bone thickness was also calculated indirectly using the following formula:

Bone thickness was derived from the CBCT measurements, while root movement was derived from the superimpositions.

Statistical Analysis

SPSS version 22 (SPSS Inc, Chicago, Ill) was used to analyze the data. Skewness and kurtosis statistics indicated that the distributions were not normal. Central tendencies and dispersions were described with medians and interquartile ranges. Wilcoxon

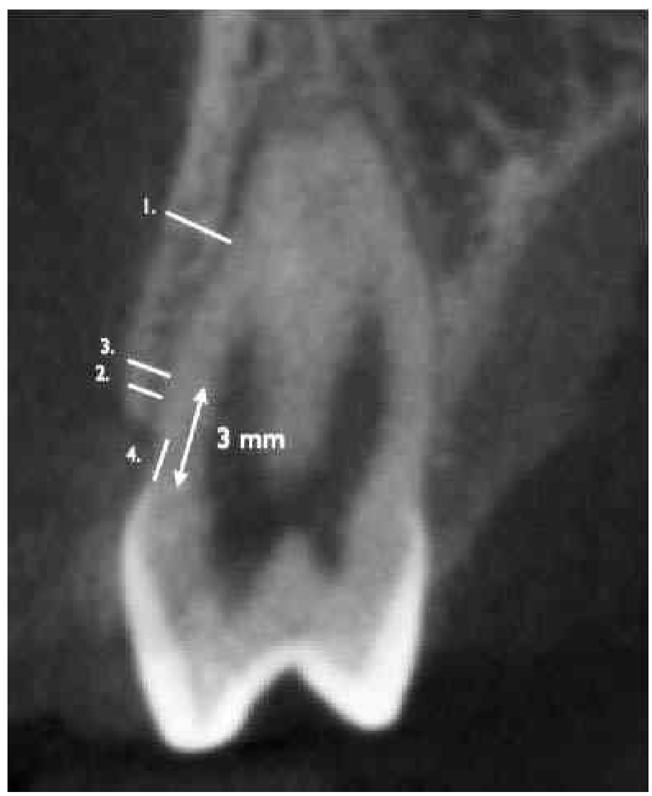

Figure 2. Buccal bone. (A) Maximum width. (B) Minimum width. (C) Width 3 mm apical to the CEJ. (D) Maximum and minimum height from CEJ to crestal bone.

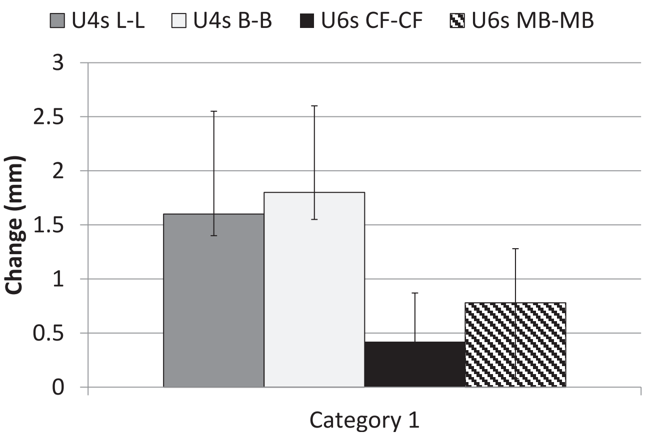

Figure 3. Medians and interquartile ranges for changes in first premolar width (taken between the lingual [U4s L-L] and buccal [U4s B-B] cusps) and first molar width (taken between the central fossae [U6s CF-CF] and the mesiobuccal cusp tips [U6s MB-MB]).

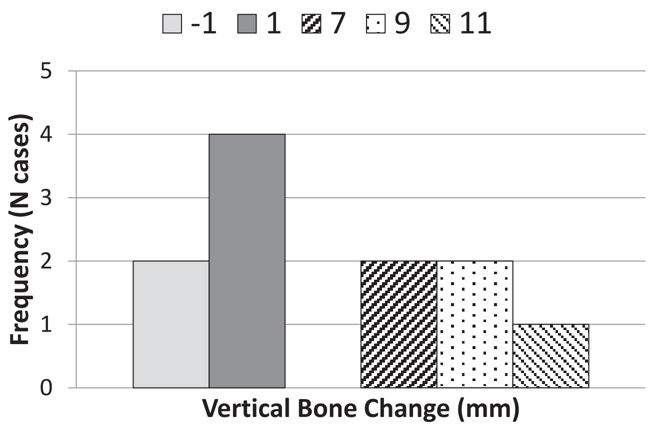

Figure 4. Changes in maximum vertical bone height on the experimental side, with six subjects concentrated around no change and five subjects with vertical height loss greater than 7 mm.

signed rank tests were used to evaluate the changes that occurred over time, compare the control and experimental sides, and compare changes in buccal bone thickness.

RESULTS

After 3 weeks, the active force had dissipated from 50 g to 40.4 ± 4.9 g. After the second and third 3-week time periods, the forces were 41.4 ± 4.6 g and 43.1 ± 4.2 g, respectively.

Model Analyses

The interpremolar distances increased significantly; the lingual and buccal cusp tips increased 1.56 mm and 1.82 mm, respectively (Figure 3). Intermolar widths increased 0.85 mm between the mesiobuccal cusp tips and 0.55 mm between the central fossae. There was slight but significant ($P = .003$) buccal crown tip of the experimental premolars. They tipped approximately 2.2°, with a range of 1.0°–5.4°.

CBCT Radiographic Analysis

Buccal bone thickness decreased significantly on the experimental, but not on the control side (Table 3). Maximum thickness decreased 0.45 mm, minimum thickness decreased 0.35 mm, and bone thickness 3 mm from the CEJ decreased 0.63 mm.

The maximum vertical distance from the CEJ to the crestal bone increased 0.60 mm on the experimental side. The control side showed no significant change. The maximum vertical changes exhibited a bimodal distribution. Six subjects had a median loss of 0.42 mm, while five subjects had a median loss of 8.54 mm (Figure 4). Changes in the minimum distances from the CEJ to the crestal bone showed no statistically significant side difference.

Analysis of 3-D Superimpositions

Movements of the experimental first premolar measured from the superimposed CBCT images were also statistically significant. The root measured 3 mm apical to the CEJ, and moved 0.96 mm on the experimental side (Table 4). Premolar movement on the control side was minimal and not statistically significant.

Direct measurement of buccal bone apposition 3 mm below the cementoenamel junction showed a median increase of 0.46 mm, which was statistically significant. All the patients added bone 3 mm below the CEJ (Figure 5). Bone measured indirectly increased 0.51 mm, which was also statistically significant. The difference between the direct and indirect measurements was not statistically significant.

Table 3. Median Changes (mm) and Interquartile Ranges of Buccal Bone Thickness and Vertical Distances From CEJ

	Experimental			Control			Group Difference
Changes in Buccal Bone	50th	25th	75th	50th	25th	75th	Prob
Thickness 3 mm apical to CEJ	−0.63	−0.79	−0.17	0.00	−0.17	0.10	.016
Maximum thickness	−0.45	−0.60	−0.20	0.05	−0.20	0.15	.011
Minimum thickness	−0.35	−0.43	−0.15	−0.08	−0.29	0.19	.041
Maximum vertical distance from CEJ	0.60	0.40	8.30	−0.05	−0.45	0.15	.003
Minimum vertical distance from CEJ	0.25	0.30	0.55	−0.05	−0.40	0.20	.262

Table 4. Experimental Root Movements (mm) 3 mm Apical to the CEJ, Bone Growth Measured From the Superimpositions 0.3 mm Apical to the CEJ, Along With Bone Growth Calculated From Differences in Bone Thickness and Root Movement

Measure	Units	50th	25th	75th	Prob*
Root movement 3 mm apical to CEJ	mm	0.96	0.29	1.3	.008
Buccal bone growth measured 3 mm apical to CEJ	mm	0.46	0.29	0.94	.005
Buccal bone growth calculated	mm	0.51	−0.40	1.00	.036

* Probability (Prob) indicates statistically significant changes.

There was a negative correlation (-0.674, $P = .033$) between the initial buccal bone thickness measured on the CBCT images and bone apposition measured from the superimpositions. There was no correlation between the initial and final bone thickness (0.202, $P = .551$).

DISCUSSION

After 9 weeks, there was 1.6 mm–1.8 mm of buccal tooth movement at the cusp tips. Another human study, using a similar appliance design with a 50-g buccal force applied at the level of the bracket for 7 weeks, produced 3.7 mm of buccal premolar movement and over 12° of uncontrolled tipping.[10] Mesiodistal tooth movements generally occur at approximately 1 mm/mo.[15] The slightly lower rate observed in the present study could have been due to the buccal cortex, which might be expected to respond differently to forces than would medullary bone.

Lateral translation can be produced with minimal (2.2°) tipping. Similar forces applied at the bracket produce substantially more (9°–14°) tipping.[2,10,16] Most importantly, lateral tooth movements caused buccal cortical bone to form. Since the bone was initially 1.4 mm thick, and the teeth were moved 0.96 mm, final thickness should have been 0.44 mm. However, the final bone thickness was 0.85 mm. This difference (0.51 mm) is consistent with the bone apposition measured on the superimpositions (0.5 mm). In fact, all teeth exhibited measurable amounts of buccal bone apposition (Figures 5 through 8). Bony apposition of cortical bone has been previously reported after lingual tooth movement.[17] Experimental studies have demonstrated osteoblastic activity and new bone formation on the buccal cortex after lateral tooth movement.[3] Cortical bone apposition is probably due to the increased strains associated with tooth movement.[7,17–19]

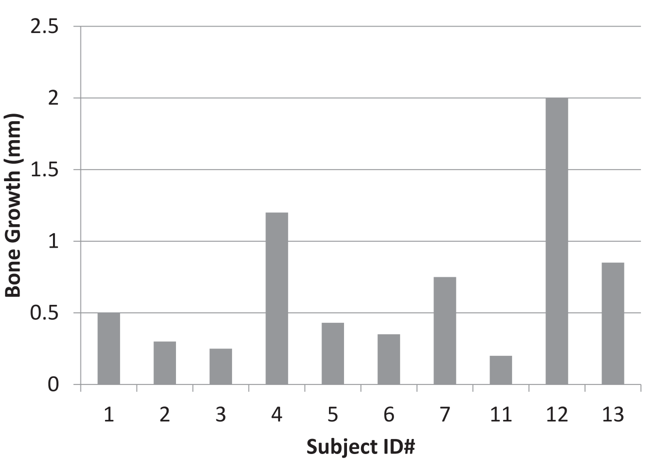

Figure 5. Buccal bone apposition of each subject measured 3 mm below the CEJ.

The roots moved through the medullary bone until they approached the cortical plate, when cortical apposition probably occurred. This explains why the patients who initially had greater amounts of buccal (trabecular and cortical) bone experienced less buccal bone apposition. This also explains why initial and final buccal bone thickness were not correlated. Tooth movements through medullary bone might be expected to have little effect on the alveolar width until the tooth approaches the cortex.[20] Finite element analyses indicate that any given buccal translational force is reduced in the periodontal ligament, and especially in the adjacent alveolar bone.[21] Reduced forces probably affect the cortex only when the tooth root is in close proximity.

While CBCT imaging is reliable for evaluating dentoalveolar changes,[9,22] there are limitations due to voxel size and the partial volume averaging effect.[22,23] When a voxel lies on two objects of different densities, the resulting voxel will reflect their average density, rather than the density of either object. This averaging effect causes bone height and thickness to be underestimated, making it falsely appear as though there is bone loss.[22–24] Accuracy in the present study was maximized by using a voxel size of 0.076 mm, which made it possible to distinguish between tooth movements and new bone formation.

Importantly, the rate of tooth movement can surpass the rate of bony apposition, at least temporarily. Reductions in buccal bone thickness indicated that the premolars had moved through the bone, as well as with the bone. The five subjects who developed significant dehiscences initially had thinner buccal bone than did the other subjects. Since there were no differences in tipping or in the amount of tooth movement, they experienced greater tooth movements through cortical bone. The location of the dehiscences (mesial to the premolar midline) further support the

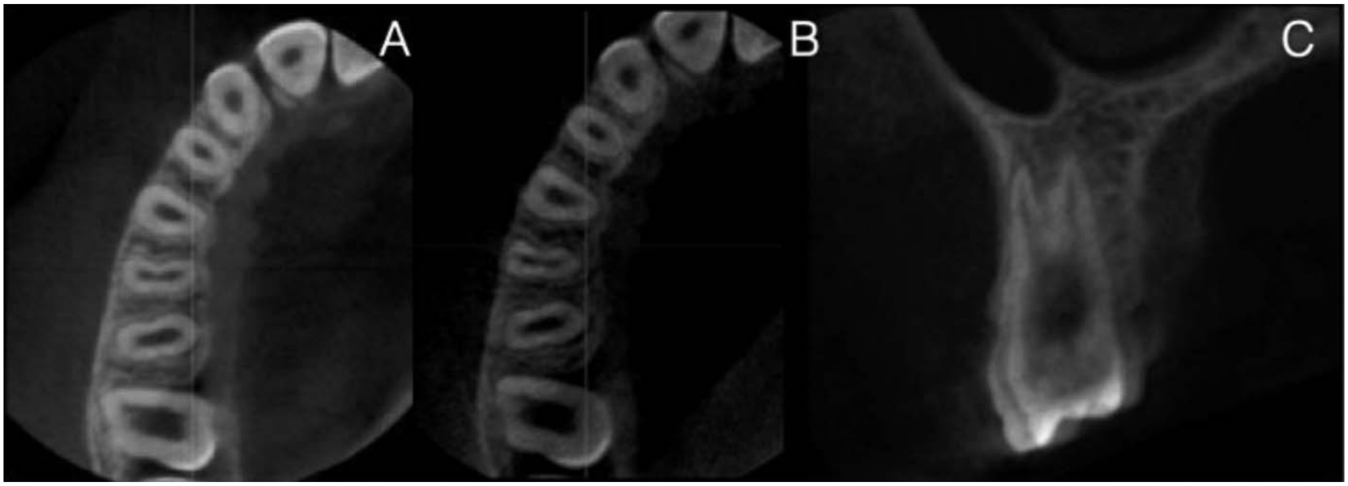

Figure 6. Patient 6, who had a minimal amount of tooth movement. (A) Coronal pretreatment view. (B) Coronal posttreatment view. (C) Frontal view of the superimposed images.

notion that the greater the movements through cortical bone, the greater the risk of dehiscences (Figure 9).

It is also possible that bone was actually present, but not evident on the CBCT images. Due to the partial volume averaging effect previously described, objects must be separated by more than two voxels in order to be discernible.[25] Since the voxel size in the present study was 0.076 mm, buccal bone would not have been evident if it was less than 0.152 mm thick. Moreover, there must be a 40%–60% difference in mineral density between objects in order to be discernable on radiographic images.[26] The new woven bone that formed in the direction of displacement[26] and the loss in mineralization associated with tooth movement[26,27] could have made it difficult to distinguish thin cortical bone.

CONCLUSIONS

- Clinically significant amounts of lateral translation of teeth can be obtained orthodontically with minimal tipping.
- Formation of buccal bone occurs during lateral tooth movements.
- The maximum distance from the CEJ to the crestal bone increases significantly with lateral translating tooth movements.

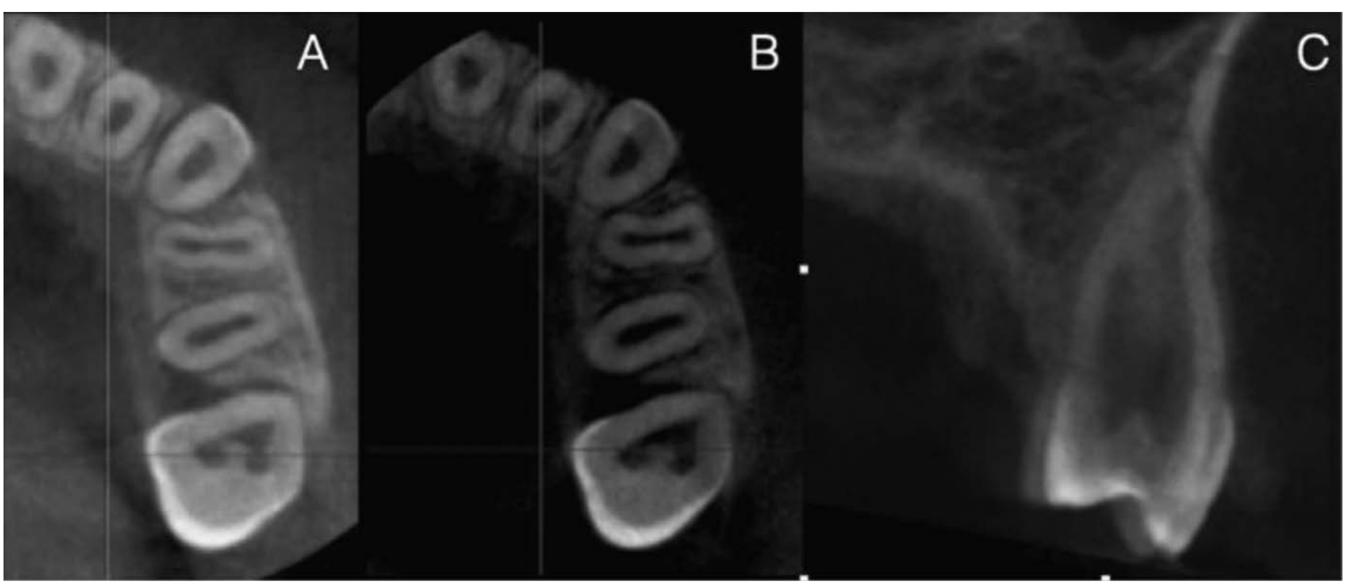

Figure 7. Patient 13, who had a average amount of tooth movement. (A) Coronal pretreatment view. (B) Coronal posttreatment view. (C) Frontal view of the superimposed images.

Figure 8. Patient 12, who had a maximal amount of tooth movement. (A) Coronal and (B) frontal view of the superimposed images.

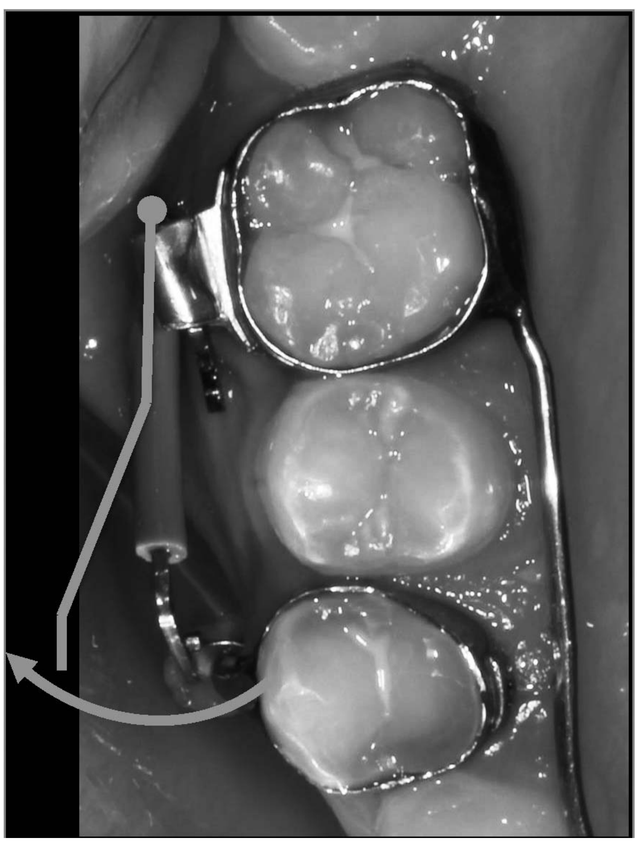

Figure 9. Occlusal photograph displaying rotational movement of the experimental premolars.

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Original Article

Effects of palatal crib and bonded spurs in early treatment of anterior open bite:
A prospective randomized clinical study

Juliana S. Leite[a]; Luciano B. Matiussi[b]; Anne C. Salem[c]; Maria G. A. Provenzano[d]; Adilson L. Ramos[e]

ABSTRACT
Objective: To evaluate the overbite correction of fixed palatal crib (FPC) and bonded lingual spur (BLS) in the early treatment of anterior open bite (AOB) in mixed dentition (primary outcome) as well as its influence on dental and skeletal cephalometric measurements (secondary outcome).
Materials and Methods: The selected patients had AOB and a mean age of 8.23 years. They were divided into the following three groups by casting lots: control (n = 13), palatal crib (n = 13), and spur (n = 13). Data from the lateral teleradiography was obtained at the beginning, at 6 months, and after 1 year. The cephalometric analysis was performed by Cef-X program, recording the values of SNA, SNB, ANB, SnG oGn, 1.PP, IMPA, nasolabial angle, overbite, and overjet. Intergroup and intragroup comparisons were obtained via one-way analysis of variance.
Results: The degree of AOB was similar at baseline ($P > .05$). At 6 months and then after 1 year all groups showed improvement in the overbite. However, only the crib and spur groups showed positive overbite. No cephalometric measurements changed significantly over the period analyzed.
Conclusions: We conclude that the FPC and BLS are simple and effective for the treatment of anterior open bite, with the advantage given to the FPC. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Open bite; Orthodontic appliances

INTRODUCTION

An anterior open bite (AOB), one of the malocclusions with the greatest esthetic and functional impairment, is characterized by the presence of negative overbite between the incisal edges of the upper and lower front teeth when the posterior ones are in occlusion.[1–3] Habits of sucking objects like a pacifier and a finger can cause or worsen AOB in predisposed patients. Most children grow out of the habit, but if they continue with it through mixed dentition they might need orthodontic intervention.[4] Available data have shown that 12.1% of children past the age of 7 years maintain a digit- or pacifier-sucking habit, but general studies show that the prevalence of AOB decreases with age.[5] It was reported that 17.7% of children from 6 to 8 years old, among those with malocclusion evaluated by the Index of Orthodontic Treatment Need, had anterior open bite.[6]

From the age of 5 years, if the habit is interrupted and the patient has a good facial growth pattern, correction of AOB may occur spontaneously.[7] Self-correction of dental AOB may occur in up to 80% of patients when the negative habit is eliminated up until the phase of mixed dentition.[2]

In a systematic review, Borrie et al.[4] showed that orthodontic appliances were beneficial in stopping the sucking habit compared with no treatment, and that the palatal crib was beneficial for occlusion compared with no treatment. The palatal crib works as an obstacle in nonnutritive sucking and maintains the tongue in a more retruded position, preventing its interposition between the incisors.

[a] Postgraduate student, Department of Dentistry, State University of Maringá, Maringá, Brazil.
[b] Private practice, Ubiratã, Brazil.
[c] Private practice, Maringá, Brazil.
[d] Adjunct Professor, Department of Dentistry, State University of Maringá, Maringá, Brazil.
[e] Associate Professor, Departament of Dentistry, State University of Maringá, Maringá, Brazil.
Corresponding author: Dr Juliana S. Leite, Department of Dentistry, State University of Maringá, 1550 Av. Mandacaru, Maringá, Paraná 87080-000, Brazil
(e-mail: jsl.squile@gmail.com)

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Nogueira et al.[8] stated that a palatal crib and spurs are both effective methods for treating AOB in patients with atypical swallowing due to lingual pressing. However, the crib requires consultations to shape and install the device as well as incurring laboratory expenses. The spur, on the other hand, is inexpensive and promotes greater freedom to the tongue due to its small size.

Yang and Kiyak[9] affirm that early treatment of AOB increases the stability of morphologic correction. Huang et al.[10] showed that patients with AOB and who were treated with a palatal crib presented satisfactory stability in the correction of the bite 1 year after the end of treatment. Because the palatal crib acts passively and helps remove etiologic factors, there is evidence of stable correction of the AOB.[1]

No studies were found comparing the use of spurs to a control group[11] or the use of spurs and palatal crib to verify the effectiveness of both treatments. Given this, the primary goal of this study was to evaluate the effects of the fixed palatal crib (FPC) and bonded lingual spur (BLS) for early treatment of AOB in the mixed dentition phase. This study also addressed the cephalometric effects of those appliances, as a secondary outcome.

MATERIALS AND METHODS

The project was approved by the Standing Committee on Ethics in Research Involving Humans of the Universidade Estadual de Maringa (CAAE, 0153.0.09.000-10, 441/2010 on August 12, 2010).

The sample was obtained from the clinical occlusal evaluations of patients at the Integrated Children's Clinic of the Department of Dentistry, State University of Maringá, in the city of Maringá in the state of Paraná. We selected patients with nonnutritive sucking habits and/or tongue thrusting from 5 years to 10 years old, with AOB, at the stage of mixed dentition. Patients who had already undergone prior orthodontic treatment, had deciduous/permanent dentition, were undergoing speech therapy, or had syndromes were all excluded from the study.

The sample size of each group was calculated based on alpha significance level of 0.05 to achieve power of 80% with an error standard deviation of 0.5 for 0.8 mm of difference to be detected; this was drawn from a pilot study. The sample-size calculation showed that nine patients were needed in each group. The initial sample size of this study was 45 patients, and 39 patients completed all study periods. Patients were allocated into the following three groups by drawing lots (numbered envelopes): the control group (n = 13) consisted of 11 girls and 2 boys, the group treated with palatal crib (n = 13) consisted of 10 girls and 3 boys, and the group treated with bonded lingual spur (n = 13) consisted of 12 girls and 1 boy. All patients were instructed to give up the negative habit. At baseline the patients received and signed a consent form that contained explanations about the experiment and action taken for all groups. The initial mean age was 7.79 years for the control group, 8.46 years for the crib group, and 8.44 years for the spur group.

There was blinding during the allocation and during the cephalometric analysis; however, there was no blinding for the treatment process because it was apparent which patient had which treatment. Patients in all groups received instruction to stop the nonnutritive sucking habit and were followed monthly to monitor the progress of treatment and to reinforce the instruction to give up the sucking habit. They also received hygiene supervision and reinforcement every consultation. Lateral radiographs were performed at baseline, at 6 months, and after 1 year.

The control group had its 6-month values set at 1 year, given that, for ethical reasons, it was decided that the treatment would be introduced after 6 months of initial monitoring. For this, the difference between measurements of the overbite and overjet calculated per month from the beginning to the sixth month was projected for the next 6 months. The cephalometric measurements per se were annualized, using the same criteria, based on the *Atlas of Craniofacial Growth* by Riolo et al.[12] considering that there is differential behavior (not progressive) for measurements. Previous studies have demonstrated the validity of this method when records are lacking for the required period.[13] The control group had no interventions for 6 months (teleradiography at the beginning and at 6 months) and then were included as part of the spur group or the crib group.

The overbite measuring technique used in this evaluation measures the distance between the maxillary and mandibular incisor borders perpendicular to the occlusal plane. When AOB occurred this measurement was negative. The overjet measuring technique was obtained by a vertical perpendicular reference to the Frankfurt plane, it was positive when the superior incisive was in front of the inferior incisive. These references were executed by Cef-X software (CDT Software Version 1.04, Bauru, Brazil).

The FPC model included bands on the second deciduous molars or first permanent molars. Bands were transferred to the plaster models for welding a palatal stainless steel arch of 0.9 mm (Morelli, Sorocaba, Brazil). Then, palatal bars were added (three to five arches depending on the space) of 0.7 mm stainless steel, extended up to the height of the cervical lingual aspect of the lower incisors. Before cementing the FPC, prophylaxis was achieved with

Figure 1. Model of palatal crib used in the study.

pumice and water; the region was then isolated. The appliances were cemented with glass ionomer (Vidrion C, SS White, Rio de Janeiro, Brazil). Figure 1 illustrates the FPC used.

The lingual spur (Abzil, 3M, São José do Rio Preto, Brazil) was bonded with composite resin (Transbond-XT, 3M, St Paul, Minn) on the lingual of the upper central incisors after prophylaxis with pumice, relative isolation of the region, etching with 37% phosphoric acid and application of adhesive (Scotchbond, 3M). Figure 2 illustrates the BLSs.

Outcome Measures

The primary outcome measure to be assessed in this study was the overbite, and the secondary outcome measures were SNGoGn, ANB, SNA, SNB, 1.PP, IMPA, nasolabial angle, and overjet. After scanning, the Cef-X program was used to analyze these variables.

Statistical Analysis

All measurements were repeated after 15 days by the same operator to assess method error. For such, we applied the Dahlberg formula and the paired *t*-test. Comparisons were performed by one-way analysis of variance with Bonferroni post test using BioEstat 5.0 software (Mamiraua Institute, Amazonas, Brazil) with a confidence interval of 95%.

RESULTS

Both paired *t*-test and Dahlberg error revealed no significant difference for the method ($P > .05$). Table 1 presents the intergroup and intragroup comparisons, which demonstrated a significant evolution of the overbite as a primary outcome ($P < .05$) and no

Table 1. Intergroup and Intragroup Mean (x) and Standard Deviation (SD) Comparisons Using One-Way Analysis of Variance With Bonferroni Post Test[a]

	Initial						6 mo						12 mo					
	Control (n = 13)		Crib (n = 13)		Spur (n = 13)		Control (n = 13)		Crib (n = 13)		Spur (n = 13)		Control (n = 13)		Crib (n = 13)		Spur (n = 13)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Age (mo)	93.54	17.99	101.55	17.28	101.38	14.25	99.62*	18.16	113.00*	17.47	108.46*	14.40	105.54**	17.99	118.64**	20.05	115.69**	16.96
SNA (°)	81.97	4.08	81.95	4.68	83.84	5.39	80.71	4.00	82.00	4.84	83.55	4.73	80.71	4.00	81.01	4.52	83.36	5.32
SNB (°)	77.13	3.24	77.09	4.84	78.28	5.33	77.13	3.00	77.26	4.65	77.94	5.24	77.13	3.00	78.25	2.75	78.45	6.01
ANB (°)	4.83	2.74	4.86	3.71	5.56	2.15	3.58	3.42	4.75	3.71	5.61	1.97	3.58	3.42	2.76	3.84	4.90	1.90
SnGoGn (°)	34.27	5.45	36.77	4.84	32.22	4.74	34.14	4.07	36.73	4.39	32.38	4.57	34.14	4.07	37.48	5.74	33.82	4.93
IMPA (°)	96.24	6.08	96.25	5.31	96.70	7.79	96.77	6.12	96.12	5.62	98.24	6.29	96.77	6.12	90.74	6.54	94.41	4.83
1PP (°)	116.05	7.68	116.03	5.61	114.13	4.16	116.06	5.97	116.02	6.00	112.50	12.88	116.06	5.97	114.31	6.22	110.03	11.95
Nasolabial angle (°)	105.05	8.35	105.49	9.03	111.44	11.39	107.11	10.09	104.30	8.01	106.76	11.53	107.11	10.09	104.91	8.44	106.54	12.16
Overbite (mm)	−2.69	1.56	−1.45	1.81	−2.38	1.43	−1.46*	1.80	0.23*Δ	1.80	−0.24*	1.90	−0.36*	2.18	2.50**ΔΔ	1.02	0.69**	1.81
Overjet (mm)	5.65	2.86	4.91	1.37	5.19	2.45	4.88	2.41	3.98	1.58	5.02	2.16	3.73	3.04	3.00	2.18	4.62	2.63

[a] Δ indicates statistically different from the control group ($P < .05$) in the intergroup comparison; ΔΔ indicates statistically different from the control group and the spur group ($P < .05$) in the intergroup comparison.

* Statistically different from the initial period ($P < .05$) in the intragroup comparison.

** Statistically different from the initial period and at 6 months ($P < .05$) in the intragroup comparison.

Table 2. Intergroup Mean (x) and Standard Deviation (SD) Comparisons of Initial Overbite (mm), at 6 Months and at 12 Months and Differences Between T3 and T1 for the Control, Crib and Spur Groups[a]

	Initial (T1)		6 mo (T2)		12 mo (T3)		T3-T1	
Groups	x (min-max)	SD	x (min-max)	SD	x (min-max)	SD	x	SD
Control (n=13)	–2.69 (–6 0)	1.56	–1.46 (–5.5 +1)	1.7	–0.36 (–5 +2)	2.17	2.33	1.25
Crib (n=13)	–1.45 (–5.5 0)	2.22	0.23 (–4 +2)Δ	1.67	2.50 (+1.5 +5)ΔΔ	1.01	3.95Δ	1.95
Spur (n=13)	–2.38 (–5 0)	1.43	–0.24 (–3.7 +2)	1.9	0.69 (–3.5 +4)	1.8	3.07	1.82

[a] Δ indicates statistically different from the control group ($P < .05$) in intergroup comparison; ΔΔ indicates statistically different from the control group and the spur group ($P < .05$) in intergroup comparison.

significant change in other measures evaluated as a secondary outcome ($P > .05$), except age, which varied according to the period of the study.

Table 2 presents comparisons between the mean values; the minimum and maximum of initial overbite at study onset (T1), at 6 months, and at 12 months (T2); and the differences between T3 and T1 from the studied groups. The overbite development in the crib group was the largest in the study period (3.95 mm) compared with the spur group (3.07 mm) and the control group (2.33 mm), but there was no statistically significant difference ($P > .05$). Only in the crib group after 12 months was the overlap positive in all patients (minimum value for overbite = 1.5 mm).

DISCUSSION

Correcting AOB remains a challenge for orthodontists when the patient does not receive intervention at an early age, and relapse occurs in up to 38% of patients[14] during treatment at the phase of permanent dentition. Early treatment, up to the mixed dentition phase, executed by a general dentist practitioner or an orthodontist can provide occlusal stability and, consequently, decrease the perpetuation of functional alteration of AOB, favoring occlusal stability in the long term.[1,9,10] The present study shows the effectiveness of two methods of correcting early AOB as well as the influence of simple instruction and motivation for removing the deleterious habit of finger sucking or pacifier use. All groups studied had, on average, improvement of the overbite after 1 year, although only those groups with the intervention of the crib or spur achieved positive values (Tables 1 and 2, Figure 3).

The sample groups had similar degrees of AOB ($P > .05$), and patients had an average age of 8.2 years (98.8 months) which was also similar among the groups ($P > .05$) (Table 1). It has been reported that at this stage intervention for the AOB is necessary, since interrupting the bad habit alone is no longer guaranteed for self-correction, although it may still occur.[7] Spontaneous correction would be more likely if there was interruption of the deleterious habits at the stage of deciduous dentition,[2] which is a chance that patients in this study did not have, considering the age at which treatment was sought. However, even at the stage of mixed dentition three patients showed improvement in the control group, representing 23% of the sample.

Most cephalometric variables analyzed (SNA, SNB, ANB, SnGoGn, IMPA, 1PP, and nasolabial angle) showed no statistical difference in the period studied, corroborating the results of various authors.[1,14–16] Only minor changes were noted in 1PP and IMPA, though there was no statistical significance, as in some patients the overbite correction occurred by extrusion without inclination. Nasolabial angle, ANB, and SNB also presented minor changes without significance, reflecting individual variability in such ages.[12] Pedrin et al.[17] examined patients who underwent treatment with removable palatal crib associated with high pull chin cup and a control group involving untreated patients for a period of 12 months. They noted a reduction of AOB of 1.38 mm in the control group and 5.01 mm in the treated group. They concluded that palatal crib associated with high pull chin cup did not promote significant changes in maxillary and mandibular skeletal components and that treatment effects were dentoalveolar, corroborating the findings of the present study. In the present study the overbite was reduced on average 2.33 mm in the control group and 3.95 mm in the crib group.

Moore[18] conducted a critical analysis on the use of fixed appliances such as palatal crib for the treatment of nonnutritive sucking habits and concluded that it can

Figure 2. Lingual spurs used in the study.

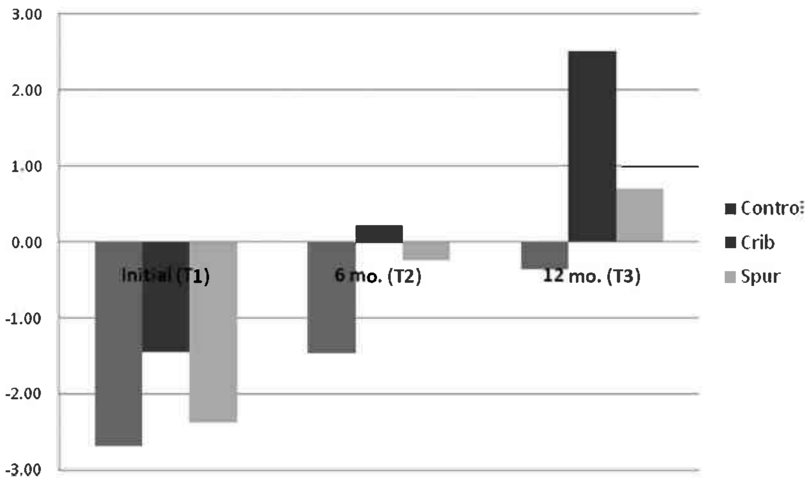

Figure 3. Graph showing overbite comparison between the groups.

cause unnecessary pain and suffering to treat this habit. McRae[11] evaluated the use of bonded lingual spur to see if it would correct lingual malposition or eliminate the habit of nonnutritive sucking and close the AOB. He evaluated 12 patients with nonnutritive sucking habits and/or atypical lingual projection who were treated for 6 months with BLS. Overbite improvement was observed in 11 of 12 patients in the sample, and the average AOB was reduced 1.38 mm in a period of 6 months. In this study the use of the spur reduced the overbite in 12 of the 13 patients studied, altering the average 2.14 mm in the first 6 months.

Cassis et al.[19] conducted a 12-month evaluation of the spur associated with chin cup for treating AOB in patients with mixed dentition. They observed that in the control group there was a spontaneous closure of 1.98 mm of the AOB, which was enough to correct the overbite in 13.3% of patients. The group treated with spur and chin cup had an increase in overbite of 5.23 mm, promoting correction of AOB in 86.7% of patients. In the present study autocorrection occurred in 23% for the control group, with a mean change of 2.33 mm. However, for the spur group, even after 12 months, the vertical correction of 3.07 mm led to a positive overlap in only 53.8% of patients. The final average overbite was +0.69, indicating correction. It is interesting to observe that after a 6-month period, therapy with spurs appears to indicate which patients will succeed, given that the average increase for initial correction was not maintained until the 12th month. In other words, in the first semester of evaluation there was a mean reduction of 2.14 mm, and almost half of those with AOB already had positive overbite, while in the second half there was an additional increase of only 0.93 mm, and 7 of the 13 patients had positive overlap.

Figure 3 illustrates the behavior of the overbite. The crib group showed a significant difference after 6 and 12 months compared with the control group as well as a significant difference at 12 months compared with the spur group. Although clinical improvement was seen, the spur group was not statistically different from the control group at any of the times evaluated. However, only the control group had a negative overbite after 12 months.

In light of our findings, there was still no prospective study in the literature that had compared the effects of crib with those of spur as well as a control group, with no additional appliance. It was clear that, although the lingual spurs can act positively on AOB at this stage of development, it does not have a comparable effect to the classic palatal crib, at least in the period evaluated. Among the advantages of bonded spurs are the simplicity, cost, and easy patient compliance. But besides a lower performance in achieving correction compared with the palatal crib, disadvantages include the possibility that it will come off and be swallowed as well as irritation of the tip of the tongue. As to the palate crib, its efficiency can be considered an advantage (perhaps due to the large blocked area for tongue projection and/or preventing introduction of a finger or pacifier) and the system of fastening bands, which prevents swallowing accidents. The disadvantages include the need for laboratory time and expenses as well as lower initial patient acceptance due to the immediate alteration of speech. A subsequent study can evaluate the long-term stability of the changes observed in this sample.

CONCLUSIONS

- The FPC was effective in the early treatment of AOB in 100% of patients, while the BLS, although it reduced the overbite in all subjects, resulted in positive trespass in only 53.8% of patients after 12 months.

- Instruction and motivation for removing the negative habit during the mixed dentition phase can result in spontaneous correction of the AOB, and this occurred in 23% of the control subjects.
- Treatment of AOB with FPC or BLS did not significantly alter the cephalometric variables within 12 months.

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Original Article

Comparison of anterior and posterior mini-implant-assisted maxillary incisor intrusion:

Root resorption and treatment efficiency

Isil Aras[a]; Ali V. Tuncer[b]

ABSTRACT

Objective: To compare, through cone-beam computed tomography (CBCT), the root resorption and treatment efficiency of two different mini-implant-assisted modalities in intruding the maxillary incisors.

Materials and Methods: Thirty-two adults who had deep bite and elongated maxillary incisors were randomly allocated to two groups: anterior mini-implant group (AMG) and posterior mini-implant group (PMG). In the AMG, approximately 40 g of force was applied per side with elastic chains from mini-implants placed between the lateral incisors and canines and in the PMG, with beta-titanium wires from mini-implants placed between the second premolars and first molars. This study was conducted on CBCT scans taken before intrusion and after 4 months of intrusion. Data were analyzed by means of a paired *t*-test, independent *t*-test, and Pearson's correlation test.

Results: One patient was excluded from the AMG due to mini-implant loosening. While the incisors showed a significant reduction in length and volume, this amount was greater in the AMG, especially in the central incisors ($P < .05$). Together with the mean intrusion rates of 0.62 and 0.39 mm/mo in the AMG and PMG respectively, the center of resistance of the incisors showed distal movement with labial tipping; these changes were greater in the PMG ($P < .001$). Volumetric root resorption was correlated with the amount of intrusion ($P < .05$).

Conclusions: Intrusion anchoring from posterior mini-implants is preferred in cases of upright incisors, as the use of such mechanics directs the roots into the spongiosa where they undergo less root resorption and more labial tipping. (*Angle Orthod.* 0000;00:000–000.)

KEY WORDS: Incisor intrusion; Cone-beam computed tomography; Mini-implant

INTRODUCTION

In recent years, the integration of mini-implants into intrusion mechanics has been proposed as an alternative technique to conventional mechanics, which have side effects on anchorage segments such as narrowing of the buccal segment[1,2] and elongation and distal tipping of the posterior teeth.[3,4]

In published incisor intrusion studies, the mini-implants are located in the anterior region between the central incisors,[5,6] the central and lateral incisors,[7] or the laterals and canines.[3,4,8,9] Though the effectiveness of anteriorly placed mini-implant-assisted intrusion mechanics have been investigated thoroughly, the information on root resorption of the incisors is limited, and no data has been published about incisor intrusion supported by posterior mini-implants.

Researchers have observed severe resorptive root damage from intrusive movements.[10–12] Hence, a precise and unequivocal diagnostic method of imaging is needed to both prevent and monitor resorption, which is possible only by three-dimensional volumetric evaluation. Currently, cone-beam computed tomography (CBCT), as employed in rapid maxillary expansion and molar intrusion, is the leading tool for in vivo dental imaging in the field of root resorption research. However, no study using three-dimensional imaging techniques has been performed on root resorption and treatment efficacy as a consequence of incisor intrusion.

The purpose of this study was to compare, by means of CBCT, the amount of root resorption and

[a] Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Ege University, Izmir, Turkey.

[b] Professor, Department of Orthodontics, Faculty of Dentistry, Ege University, Izmir, Turkey.

Corresponding author: Isil Aras, Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Ege University, Bornova Izmir 35080, Turkey
(e-mail: isilaras@gmail.com)

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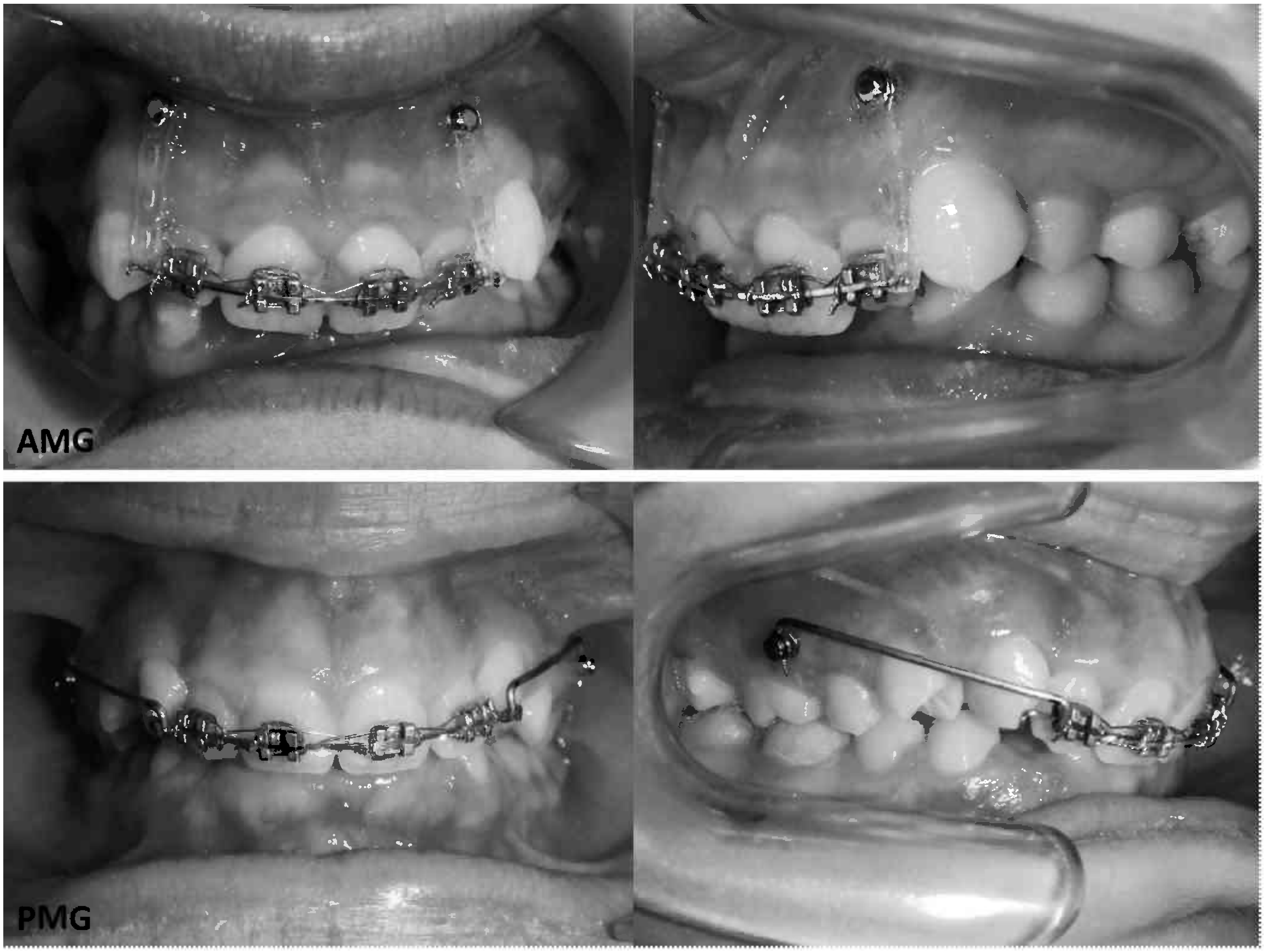

Figure 1. Frontal and lateral views of the intrusive mechanics applied to the AMG and PMG.

treatment efficacy resulting from incisor intrusion supported by anterior vs posterior mini-implants.

MATERIALS AND METHODS

The study protocol was approved (10-5.1/13) by the Ethics Committee of the School of Medicine, Ege University, and written consent was obtained from the patients.

Included in the study were 32 adult subjects (20 female, 12 male) requiring maxillary incisor intrusion according to the following criteria: (a) overbite ≥5 mm, (b) Angle Class I or II discrepancy, (c) maxillary anterior crowding <5 mm, (d) maxillary incisors positioned below the functional occlusal plane, and (e) ≥5 mm of incisor display at rest. Patients were excluded if (a) the maxillary incisors had a history of any trauma or endodontic treatment, (b) the subject had any systemic disease or required periodic medication, or (c) the patient exhibited poor oral hygiene. Patients were allocated to two groups using RandList 1.2 (DatInf GmbH, Tübingen, Germany). The random number generator is based on the algorithm of Park and Miller with Bays-Durham correction at a 1:1 ratio.

Ten female and six male patients with a mean age of 19.31 ± 3.84 constituted the anterior mini-implant group (AMG), while the posterior mini-implant group (PMG) had 10 female and 6 male subjects with a mean age of 19 ± 3.48. An 0.018-inch Roth straight-wire appliance was bonded to the maxillary incisors. After being leveled and aligned, they were consolidated by figure-eight ligature ties of 0.017 × 0.025-inch stainless steel wires.

In the AMG, NeoAnchor Plus (Anchor Plus, Los Angeles, Calif) self-drilling mini-implants were inserted between the maxillary laterals and canines, and mini-implants of 1.4-mm diameter and length of 6 mm were chosen due to the limited interradicular space in the anterior segment. Elastic power chain (3M Unitek/ESPE, St Paul, Minn) was applied from the mini-implants to the archwire. In the PMG, the mini-implants were inserted between the second premolars and first

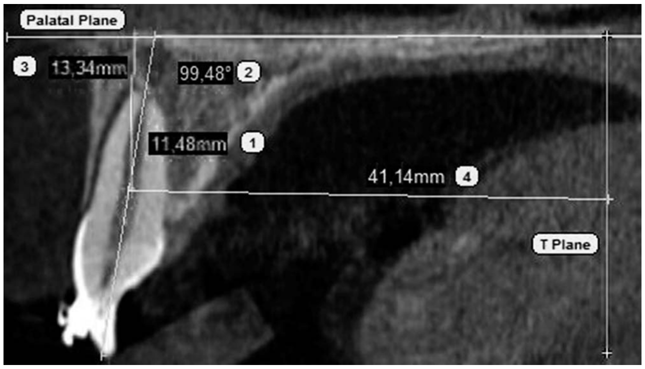

Figure 2. Linear and angular CBCT measurements: (1) 1 length, distance from apex to cementoenamel junction on long axis of the tooth (carried out for all the incisors); (2) 1-PP, angle between long axis of upper central incisor and palatal plane; (3) C_R-PP, perpendicular distance from C_R of the central incisor to palatal plane; (4) C_R-T, perpendicular distance from C_R of the central incisor to T plane (plane passing through posterior nasal spine and perpendicular to the palatal plane).

molars. To minimize the disadvantage of the counterclockwise moment of mini-implant stability on the right side due to the planned intrusion mechanics and relying on the fact that the interradicular space was wider in this area, mini-implants of 1.6-mm diameter and 7-mm length were chosen. Burstone's three-piece intrusion arch was modified, allowing the mini-implants to be integrated into this approach. One end of the 0.032-inch beta-titanium wire (TMA, Ormco, Orange, Calif) was slenderized so that it would fit through the hole in the mini-implant head while the other end was bent to be clinched to the anterior archwire. Force levels were adjusted at 40 g per side with force renewal at monthly intervals (Figure 1).

CBCT scans were performed using Skyview volumetric scanner (Myray, Cefla Dental Group, Imola, Italy) with 10 mA, 90 kVp, and 300 μm of isotropic voxel size. Images were acquired before application of the intrusive force and after 4 months of intrusion.

CBCT data was saved in Digital Imaging and Communications in Medicine format and imported to Simplant 2011 software (Materialise Dental, Leuven, Belgium). To evaluate root resorption, linear and volumetric measurements were made between the cementoenamel junction and apex, followed by calculating percentages of respective root losses. To assess the efficiency of each intrusion modality, one angular and two linear measurements were carried out. The measurements were done in the sagittal slice, comprising the long axis of the tooth running through the incisal edge and apex. Sagittal sections were selected over axial or coronal sections because resorptions were delineated better in sagittal slices.[13,14] The center of resistance (C_R) of the central incisor was used to determine the amount of intrusion.[15] The Cr determined on the preintrusion image was replicated onto the postintrusion image (Figure 2).

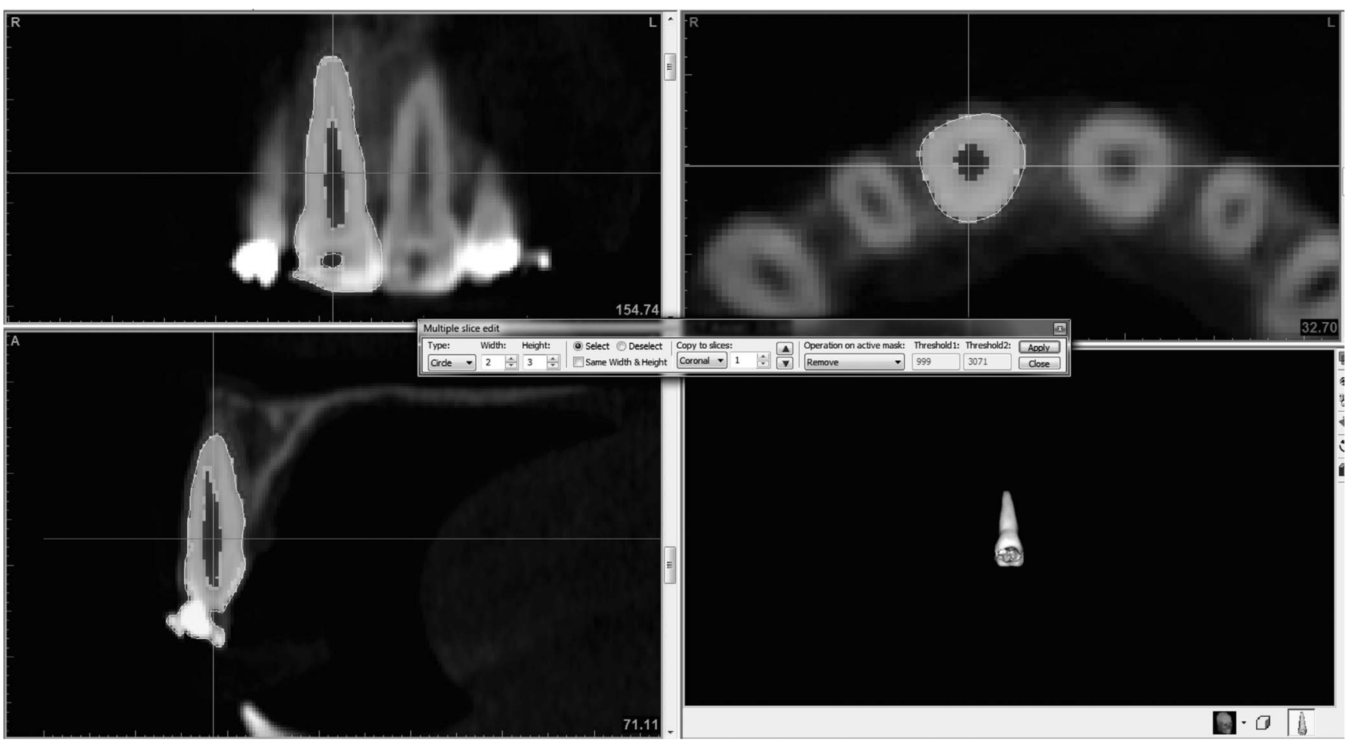

Figure 3. Manual segmentation in axial, coronal, and sagittal slices.

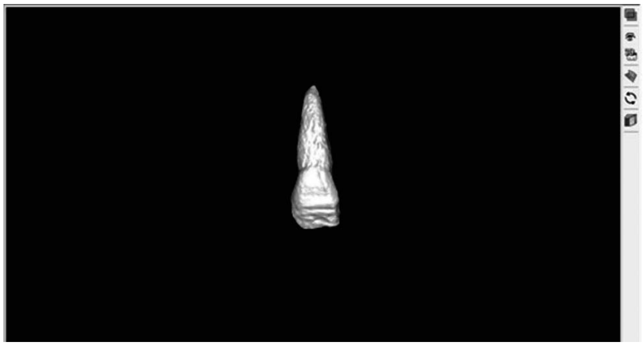

Figure 4. Volumetric reconstruction after manual segmentation.

Because of incomplete tooth contour or teeth fused with the surrounding tissues after the initial automatic segmentation, further manual segmentation was carried out conservatively using the multiple-slice Edit tool for the axial, coronal, and sagittal slices with Add and Remove comments (Figure 3), making sure that only intact tooth morphology was present without surrounding structures (Figure 4). Additional segmentation was carried out to separate the root from the crown at the buccal cementoenamel junction with the incisal edge adjusted parallel to the floor (Figure 5).

According to the power analysis at the 0.05 level and 80% power (based on a 0.56-mm standard deviation and a 0.6-mm detectable group difference regarding intrusion rates[3]), the minimum sample size needed for each group was 14.

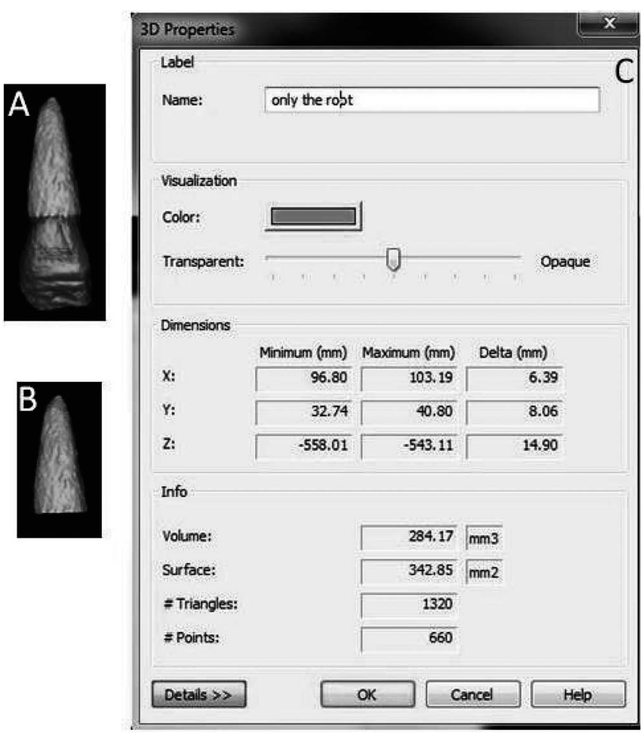

Figure 5. Volumetric measurements: (A) Reconstruction of whole tooth. (B) Separation of root from the crown. (C) Volume calculated.

Statistical Analysis

To test reproducibility after 1 week, 20 images were reexamined using intraclass correlation coefficients. Normal distribution of pre- and postintrusion differences were observed by means of the Shapiro-Wilks test. The paired *t*-test was used for significance of mean changes within groups, and comparisons of mean changes in both groups were performed using an independent *t*-test. Also, to compare resorption between right and left incisors, an independent *t*-test was used. No statistically significant difference in resorption was observed, so the results were pooled. After this, percentages of length and volume losses were compared between the central and lateral incisors. Furthermore, the relationship between the amount of root resorption (124 teeth total) and available intrusion was analyzed with the Pearson correlation test. The data were analyzed using SPSS software (version 16.0, SPSS Inc, Chicago, Ill).

RESULTS

Thirty-one patients were included in the final assessment due to the loss of stability in one anterior mini-implant. High intraclass correlation coefficients were obtained with values of 0.994, 0.992, and 0.928 for angular, linear, and volumetric measurements, respectively.

Preintrusion and postintrusion volumetric, linear, and angular CBCT measurements are depicted in Table 1. Intragroup changes and intergroup differences due to treatment mechanics are presented in Table 2. All the incisors in both groups showed significant reduction in length and volume, with greater decreases in the AMG ($P < .05$), except for the right lateral incisor root volume ($P > .05$). When resorption percentages are considered, the central incisors displayed significantly more linear and volumetric decreases than did the laterals ($P < .05$, Table 3).

The incisors were intruded (decreased C_R-PP), which was significantly greater in the AMG ($P < .05$). Also, the mean rates of intrusion were 0.62 mm/mo and 0.39 mm/mo, respectively, in the AMG and PMG. The C_R of the incisors showed distal movement (decreased C_R-T), with labial tipping (increased 1-PP) in both groups; these changes were greater in the PMG ($P < .001$). Volumetric root resorption exhibited a significant correlation with the amount of intrusion ($P < .05$, $r = .416$).

DISCUSSION

Since mini-implants reduce the need for complicated mechanics and eliminate the side effects of conventional methods, mini-implant-assisted incisor intrusion has gained popularity in recent years. In this context, it

Table 1. Preintrusion (T1) and Postintrusion (T2) CBCT Measurements of the Groups and Results of Statistical Assessment[a]

	Anterior Mini-Implant Group		Posterior Mini-Implant Group	
	T1 (mean ± SD)	T2 (mean ± SD)	T1 (mean ± SD)	T2 (mean ± SD)
LL-RL (mm)	13.15 ± 2.56	12.19 ± 2.74	12.66 ± 2.40	11.99 ± 2.50
RC-RL (mm)	13.56 ± 2.38	12.31 ± 2.51	13.27 ± 2.56	12.37 ± 2.46
RL-RL (mm)	13.00 ± 2.54	11.98 ± 2.68	12.84 ± 2.36	12.12 ± 0.37
LC-RV (mm^3)	292.37 ± 26.25	269.57 ± 28.13	255.46 ± 19.37	241.23 ± 16.53
LL-RV (mm^3)	229.59 ± 23.41	213.61 ± 26.04	204.63 ± 20.01	194.30 ± 17.18
RC-RV (mm^3)	270.77 ± 24.41	246.67 ± 27.15	281.95 ± 21.74	266.86 ± 18.60
RL-RV (mm^3)	213.67 ± 22.52	199.86 ± 25.49	233.82 ± 17.90	222.07 ± 18.01
C_R-PP (mm)	16.34 ± 2.09	13.85 ± 1.98	16.61 ± 2.41	15.06 ± 1.47
C_R-T (mm)	44.31 ± 3.62	43.66 ± 3.18	46.24 ± 3.16	44.70 ± 2.89
1-PP (°)	97.77 ± 6.32	103.96 ± 6.51	97.08 ± 6.27	111.85 ± 6.48

[a] LL indicates left lateral incisor; RL, root length; RC, right central incisor; LC, left central incisor; RV, root volume.

is important to weigh its intrusive ability against its possible side effects, as intrusion increases the chances of root resorption. In previous studies of root resorption occurring during maxillary incisor intrusion obtained with conventional methods and screened with periapical X-rays, resorption varied between 0.6 mm and 2.5 mm.[16–20] Using utility arches, McFadden et al.[18] found 0.84 mm of intrusion but 1.84 mm of resorption after termination of treatment (28.8 ± 7.4 months); Goel et al.[19] observed 1.56 mm of root shortening for 1.60 mm of intrusion during a 4.32-month period. Using a Burstone intrusion arch, Costopoulos and Nanda[16] observed 0.6 mm of resorption after 1.9 mm of apical movement of C_R over 4.6 months with intrusive forces of 15 g per teeth. Also, Goerigk et al.[20] reported similar results with 0.9 mm of resorption after 2.3 mm of intrusion in 4.3 months. However, Dermaut and De Munck[17] reported far more root shortening, with resorptions of 2.8 mm (18%) after a mean C_R intrusion of 3.6 mm after 6.7 months by a slightly modified Burstone technique, using an intrusive force of 25 g per tooth.

Applying intrusive forces of 100 g per side from the mini-implants placed between the laterals and centrals to the continuous archwire including also the buccal segments, Deguchi et al.[7] measured 0.8 mm of root resorption after 6.6 months, with 3.6 mm of intrusion measured from the incisal edge. The present study revealed that loss of root length averaged between 0.85 mm and 1.19 mm in the AMG and between 0.70 mm and 0.83 mm in the PMG. Variations in the type (continuous or transient) and magnitude of force, duration of intrusion, and measuring methods in conventional radiographs can be responsible for the extent of root resorption observed, which at the same time leads to difficulty in comparing the above-mentioned studies with the present one. Furthermore, periapical radiographs to assess root loss present difficulties in landmark determination and standardization.[21–24] Most importantly, since root resorption is a volume loss, three-dimensional quantitative methods would be much more precise in assessing root resorption than would two-dimensional methods.[24–26] Unfortunately, no study has evaluated volumetrically the amount of root resorption occurring during incisor intrusion.

When volumetric measurements of root resorption were considered, root loss of each incisor was found to

Table 2. Preintrusion (T1) and Postintrusion (T2) CBCT Measurement Changes and Intergroup Comparisons[a]

	Anterior Mini-Implant Group			Posterior Mini-Implant Group			Intergroup Difference
	X	SD	*P*	X	SD	*P*	*P*
LC-RL (mm)	−1.30	0.48	<.001**	−0.88	0.35	<.001**	.010*
LL-RL (mm)	−0.96	0.39	<.001**	−0.67	0.28	<.001**	.024*
RC-RL (mm)	−1.25	0.52	<.001**	−0.90	0.37	<.001**	.038*
RL-RL (mm)	−1.02	0.42	<.001**	−0.72	0.32	<.001**	.032*
LC-RV (mm^3)	−22.80	11.34	<.001**	−14.23	9.38	<.001**	.029*
LL-RV (mm^3)	−15.98	7.48	<.001**	−10.33	6.11	<.001**	.028*
RC-RV (mm^3)	−24.10	12.09	<.001**	−15.09	10.20	<.001**	.031*
RL-RV (mm^3)	−13.81	7.11	<.001**	−11.75	7.39	<.001**	.436
C_R-PP (mm)	−2.48	0.51	<.001**	−1.55	0.63	<.001**	<.001**
C_R-T (mm)	−0.65	0.43	<.001**	−1.54	0.39	<.001**	<.001**
1-PP (°)	6.19	0.75	<.001**	14.77	0.88	<.001**	<.001**

[a] X indicates mean change; SD, standard deviation; LC, left central incisor; RL, right lateral incisor; LL, left lateral incisor; RC, right central incisor; RV, root volume.

* $P < .05$; ** $P < .001$.

Table 3. Comparison of Central and Lateral Incisors With Regard to Their Linear and Volumetric Resorption Percentages

	Linear Resorption Percentage			Volumetric Resorption Percentage		
	Central Incisors, %	Lateral Incisors, %	*P*	Central Incisors, %	Lateral Incisors, %	*P*
AMG	9.10	7.19	.028*	7.29	5.61	.042*
PMG	6.76	5.04	.022*	5.10	4.16	.049*

* $P < .05$.

be significant, which held true for both groups. These decreases in volume were more in the AMG. In our opinion, this outcome was due to greater apical movement of the C_R in the AMG, which is a known risk factor for resorption. This concept is reinforced by the significant correlation between the amount of root resorption and achieved intrusion. To our knowledge, only one other study[17] has found a correlation between the amount of root resorption and magnitude of intrusion.

It should be emphasized that, while previous studies evaluated mostly the central incisors, the current study considered root resorption in the laterals as well. In our study, the centrals were subjected to more root resorption than were the lateral incisors in either groups, whereas Dermaut and De Munch[17] found no difference between them. As suggested by De Vincenzo and Winn,[27] close proximity of the roots to the cortical bone could account for greater resorption in the central incisors, because most of the patients in the present study had fairly retrusive incisors.

The literature includes only two studies[3,4] using intrusion systems that incorporated only the four maxillary incisors with identically placed mini-implants as in the AMG. Since intrusion duration varies among those studies, it seems more reasonable to examine intrusion rates to compare treatment efficiency in the present study with previous ones. The rate of genuine intrusion measured from the C_R of the incisors was 0.29 mm/mo in the Polat-Ozsoy et al.[4] study and 0.35 mm/mo in Senisik and Turkkahraman's.[3] Intrusion rates in those studies with an intrusive force of 80 g–90 g were somewhat lower than that of the present study. This difference could be due to loosening of the mini-implant, resulting in lengthening of the intrusion period. While the mini-implant success rate was 90% in Senisik and Turkkahraman's[3] study, there is no information pertaining to this issue in that of Polat-Ozsoy et al.[4] The intrusion rate of 0.39 mm/mo in our PMG could not be compared with any other study since no research was carried out using posteriorly located mini-implants.

More incisor flaring observed in the PMG may be related to the horizontal component of intrusive force, which was greater in this group. This horizontal component may have helped considerably decrease root resorption through further retraction of the incisor roots into the spongiosa, which can be preferable in cases with retrusive incisors. On the other hand, the larger vertical component of intrusive force in the AMG is responsible for greater intrusion rates than in the PMG.

When resorption percentages are considered, volumetric decreases are relatively smaller than length losses. Because of the root's conical shape, volume loss in the apical region accounts for much smaller percentages compared with the whole root.

Although resorption occurred in all teeth, this degree of root resorption might be clinically irrelevant. Nonetheless, it could assume more importance if there had been additional loss of root material during the remaining span of orthodontic treatment, especially in the AMG.

Since we aimed to determine the amount of root resorption (entailing a great risk for root loss) attributable exclusively to intrusion, our observation period was fairly short in terms of treatment duration, which, incidentally, is an important shortcoming of this study.

CONCLUSIONS

- The four maxillary incisors can be effectively intruded on sectional archwires with forces of 40 g per side from anteriorly or posteriorly located mini-implants.
- The rates of both intrusion and root resorption were higher using the anteriorly placed, mini-implant-supported incisor intrusion method compared with intrusion rates resulting from the posteriorly placed mini-implants.
- In patients demonstrating upright incisors, intrusion anchored from posterior mini-implants yielded more labial flaring and less root resorption than that anchored anteriorly.
- Since both incisor intrusion and distalization are possible with mechanics anchoring from posterior mini-implants, usage of mini-implants in this manner presents an alternative to anterior mini-implants in deep-bite cases with premolar extraction. Further studies need to be conducted to observe the pros and cons of this approach.

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