Original Article

Alveolar bone thickness and height changes following incisor retraction treatment with microimplants: *A cone beam computed tomography study*

Bui Quang Hung[a]; Mihee Hong[b]; Hee-Moon Kyung[c]; Ho-Jin Kim[b]

ABSTRACT

Objectives: To evaluate alveolar bone remodeling following incisor retraction treatment with microimplants and to examine the relationship between crown/root distal movement and thickness/height changes of the alveolus.

Materials and Methods: A total of 24 patients (mean age, 19.29 ± 4.64 years) with bialveolar protrusion treated by incisor retraction with microimplants were included. The distances of the crown and root tip movements as well as the thickness (alveolar bone thickness [ABT]; labial, lingual, and total) and vertical level (vertical bone level [VBL]; labial and lingual) of the alveolar bone were assessed using cone-beam computed tomography images obtained before treatment (T1) and after treatment (T2). All T1 and T2 variables were compared, and further comparisons of alveolar bone changes were conducted between the two groups based on the distance of the crown (low-crown-movement and high-crown-movement groups) and root movements (low-root-movement and high-root-movement groups). To determine the correlation of the crown or root movement with the variables of alveolar bone changes, Pearson correlation coefficients were calculated.

Results: Significant differences were found in all VBL and ABT variables after treatment in both jaws but not in total ABT. Based on the crown and root movements, alveolar bone change significantly differed between the root-movement groups, whereas there was no significant difference between the crown-movement groups. In addition, root movement showed significant correlations with the variables.

Conclusions: Remarkable changes in the height and thickness of alveolar bone were found after microimplant-aided incisor retraction treatment in all groups except for total ABT. Root movement was significantly correlated with the alveolar bone changes. (*Angle Orthod.* 2022;92:497–504.)

KEY WORDS: Alveolar bone remodeling; CBCT; Incisor retraction; Microimplant

INTRODUCTION

The use of skeletal anchorage is very advantageous, and it has helped improve outcomes in orthodontic treatment. Increased distance of tooth movement might be one of them by helping to facilitate achieving better clinical esthetic outcomes, particularly in the patients with lip protrusion.[1–4]

Concurrently, the subsequent changes observed in the surrounding alveolar bone are of increasing interest. Previous studies have found that different types of root movement may cause differences in alveolar bone remodeling.[5,6] However, 2-dimensional radiography, which was used in previous studies, was less effective in providing data that demonstrated exact dimensional changes in the alveolar bone.[7–11] In recent years, cone beam computed tomography (CBCT) has

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been used as a valuable tool for evaluating the 3-dimensional structure of alveolar bone.[12,13] Some previous studies that used CBCT showed that the palatal movement of incisors had some effect on the surrounding tissue and caused alveolar bone loss or dehiscence.[14–19] However, the earlier CBCT studies evaluated alveolar bone changes following short-to-moderate amounts of incisor retraction and/or short treatment duration. Thus, these limited conditions might not fully reflect the morphologic changes of the alveolar bone during overall treatment time with a large amount of incisor retraction. In addition, treatment biomechanics with microimplants can effectively enable intrusion and root movement positioning inside the bone, which can particularly affect subsequent alveolar bone remodeling positively.

Therefore, this study attempted to evaluate the effects of incisor retraction treatment using microimplants on the surrounding alveolar bone and investigate the changes in the alveolar bone based on various degrees of crown and root movement. The null hypothesis was that there would be no significant differences in anterior alveolar bone thickness and height before treatment (T1) and after treatment (T2) with microimplant-aided incisor retraction.

MATERIALS AND METHODS

Study Samples

This study was approved by the institutional review board of Kyungpook National University Dental Hospital (institutional review board no. KNUDH-2021-04-03-00).

The sample size was determined using G*power (version 3.1.9.7; Heinrich Heine University of Düsseldorf, Düsseldorf, Germany) based on previous studies of alveolar bone changes during retraction of anterior teeth.[18,19] The power was set at 0.85 with a two-sided significance level of .05, and the effect size was set at 0.65. Thus, a sample of 24 patients was included in this study. The study sample consisted of 24 patients (6 men, 18 women; mean age, 19.29 $\pm$ 4.64 years; range, 11–27 years) treated in the Department of Orthodontics at Kyungpook National University Dental Hospital in Daegu, Korea, from January 2011 to December 2014. The patient records were reviewed with a focus on CBCT images and cephalometric radiographs at T1 and T2. The mean duration of treatment was 29.83 $\pm$ 9.28 months.

The inclusion criteria were the following: patients with normodivergent or hyperdivergent skeletal Class I or II relationships (Björk sum $>$390°; 0°$<$ Angle between the nasion-A point line and nasion-B point line [ANB] $<$ 8°), incisor protrusion (Upper incisor to nasion-A point line [UI to NA] $>$4 mm; Lower incisor to the nasion-B point line [LI to NB] $>$4 mm), normal or large anterior overjet (overjet $\geq$2 mm), and mild anterior crowding (arch length discrepancy $<$3 mm) treated by extraction of four premolars for incisor retraction. Patients with moderate to severe crowding, gingival or periodontal problems, and trauma history or previous root resorption on the incisors were excluded.

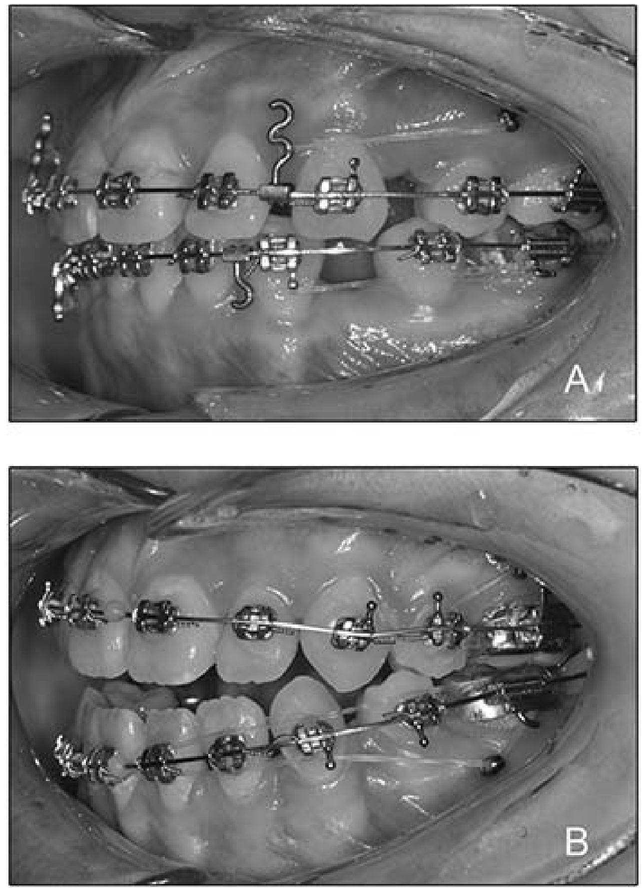

Figure 1. Microimplants used for incisor retraction. (A) Maxillary microimplants. (B) Maxillary and mandibular microimplants.

Preadjusted brackets (0.022 inch) were bonded, and for incisor retraction, super thread (T-45; Rocky Mountain Orthodontics, Denver, Colo) with a force of 150 to 200 g was applied between the anterior hooks crimped on 0.016 $\times$ 0.022-inch or 0.017 $\times$ 0.025-inch stainless steel archwire and microimplants (AbsoAnchor, Dentos Co. Ltd., Daegu, Korea). All of the patients had undergone incisor retraction treatment by sliding mechanics with microimplants in the maxilla, including eight patients who also received microimplants in the mandible (Figure 1).

Variables and Measurements

CBCT scans (CB MercuRay; Hitachi, Osaka, Japan; 120 kVp, 15 mA, 19-cm field of view, 0.377 mm voxel size, 9.6-second scan time) were acquired, and

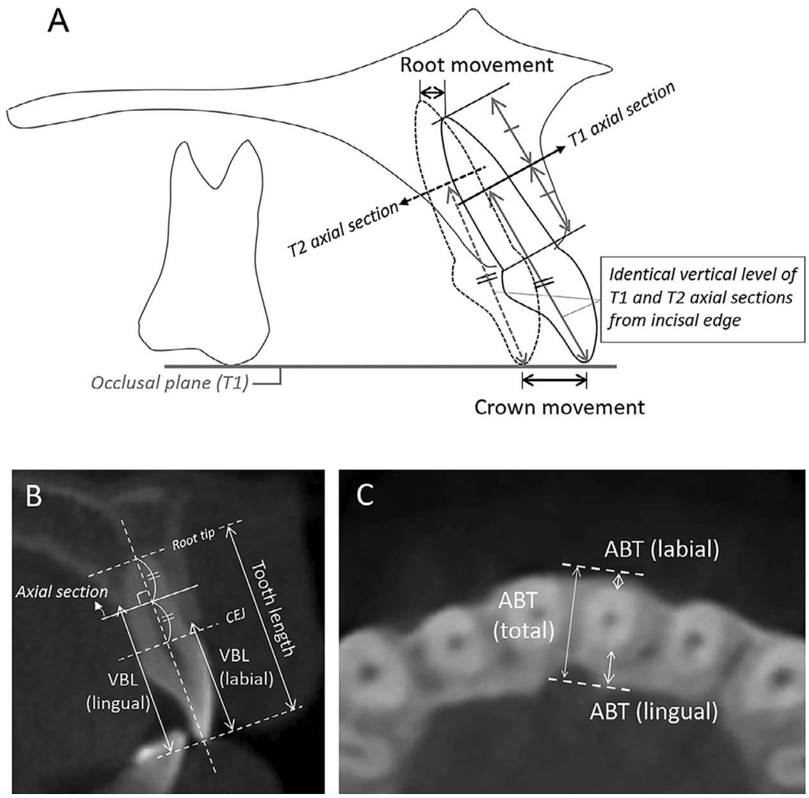

Figure 2. Variables assessed in this study. (A) Distances of the crown (between the incisal edge midpoints) and root movements (between the root tips) between before treatment (T1; solid line) and after treatment (T2; dashed line) with reference to the T1 occlusal plane following cone beam computed tomography superimposition and illustration of the T1 and T2 axial sections. (B) Sagittal section. Tooth length (from the midpoint of the incisal edge to the root tip), vertical level of the alveolar bone (vertical bone level [VBL]; from the uppermost point of the labial/lingual alveolar bone crest to the incisal edge, parallel to the tooth axis), and axial section (solid line) bisecting the root between the cementoenamel junction (CEJ) and the root tip and perpendicular to the tooth axis. (C) Axial section (alveolar bone thickness [ABT] between the labial and lingual surfaces of the labial/lingual alveolar plate or total alveolar bone).

variables were measured using Invivo 5 Anatomy imaging software (Anatomage Inc, San Jose, Calif). All of the measurements of both jaws were executed on a single central incisor of either the right or left side.

Using the sagittally sectioned superimposed CBCT image between T1 and T2, the crown and root movement distances were measured directly on the line parallel to the T1 occlusal plane (Figure 2A). The superimposition was performed via voxel-based registration of the maxilla and the mandible, respectively.[20,21] All measurements were determined by a single investigator (Dr Hung). The variables of tooth length, vertical bone level (VBL; labial and lingual), and alveolar bone thickness (ABT; labial, lingual, and total) were measured on sagittal or axial sections at T1 and T2 (Figures 2B and 2C). For the measurements, a sagittal section passing through the long axis of the incisor and perpendicular to the mesiodistal line of the incisal edge and an axial section bisecting the incisor root and perpendicular to the sagittal plane were used. In addition, when measuring T2 variables, the axial section with the same vertical level of T1 was used with the incisal edge as a reference point.[15]

To investigate the alveolar bone changes depending on the type of tooth movement, the sample was divided into two groups based on the crown or root movement distances: low-crown-movement and high-crown-movement groups (lower or higher than a crown movement of 8.5 mm in the maxilla or 5.0 mm in the mandible) or low-root-movement and high-root-movement groups (lower or higher than a root movement of 3 mm in the maxilla or 2.5 mm in the mandible). The reference values that could be used to divide the sample number into the groups almost evenly were determined with reference to the mean values of the crown/root movement distances.

Statistical Analysis

All of the measurements were repeated by the same investigator (Dr Hung) at an interval of 2 weeks. Reliability of the measurements was assessed with intraclass correlation coefficients $>$0.90. According to

Table 1. Comparison of Cephalometric and Clinical Measurements at T1 and T2[a]

	T1 Mean ± SD	T2 Mean ± SD	*P* Value
Cephalometric measurements			
Skeletal			
SNA (°)	81.39 ± 3.45	81.03 ± 3.62	.218
SNB (°)	76.14 ± 3.57	75.83 ± 3.39	.229
ANB (°)	5.27 ± 2.02	5.12 ± 1.82	.497
FMA (°)	30.07 ± 5.34	28.91 ± 5.62	.028*
Björk sum (°)	400.88 ± 4.92	398.07 ± 6.34	.001*
Dental			
FH/UI (°)	119.48 ± 7.15	109.50 ± 5.54	.000**
IMPA (°)	98.41 ± 6.41	90.07 ± 8.09	.000**
Interincisal angle (°)	112.18 ± 7.58	134.99 ± 8.35	.000**
UI to NA (mm)	7.81 ± 1.98	2.20 ± 1.40	.000**
LI to NB (mm)	10.70 ± 2.14	5.14 ± 1.63	.000**
Soft tissue			
E-line to upper lip (mm)	2.78 ± 2.24	−0.47 ± 1.53	.000**
E-line to lower lip (mm)	5.41 ± 2.63	0.57 ± 1.90	.000**
Clinical measurement			
Anterior overjet (mm)	5.26 ± 1.96	2.83 ± 0.44	.000**

[a] Paired *t*-test was performed to compare the results at T1 and T2. SD indicates standard deviation.
* Significant difference at $P < .05$ between T1 and T2.
** Significant difference at $P < .001$ between T1 and T2.

Dahlberg's formula, the differences in linear measurements ranged from 0.27 to 0.33 mm.

The Shapiro-Wilk test was performed to check the normality of the data. If the group showed normal distribution, a paired or independent *t*-test was performed to compare the variables. If not, Wilcoxon signed rank or Mann-Whitney *U*-test was performed. Pearson's correlation coefficient was calculated to determine the relationship between the crown or root movement and the variables of alveolar bone changes. Significance levels of all values were established at $P < .05$.

RESULTS

Comparison of Cephalometric and Clinical Measurements at T1 and T2

Frankfort-mandibular plane angle and Björk sum were significantly decreased during treatment ($P <$ .05), and the incisors of both jaws exhibited significant distal movement and lingual tipping ($P < .001$; Table 1). Thus, the E line to the upper and lower lips and the anterior overjet significantly decreased ($P < .001$).

Comparison of Incisor Movement and Alveolar Bone at T1 and T2

For the maxillary incisor, the crown and root movement distances were 8.3 and 3.5 mm, respectively, and the tooth length significantly decreased by 1.6 mm during treatment ($P < .001$; Table 2). Lingual VBL significantly increased ($P < .001$); labial and lingual ABT significantly differed ($P < .01$), showing a 0.6-mm increase and 0.9-mm decrease, respectively, whereas no significant difference was found in total ABT (Figure 3).

In the mandible, the crown and root were moved distally by 5.1 mm and 2.7 mm, respectively. The amount of decrease in the tooth length was 0.9 mm (*P*

Table 2. Comparison of Variables With Respect to Tooth Movement and Alveolar Bone at T1 and T2

Variable	T1 Mean ± SD	T2 Mean ± SD	Δ T2 − T1 Mean ± SD	*P* Value
Maxilla				
Crown movement			8.27 ± 2.13	
Root movement			3.52 ± 2.22	
Tooth length	22.55 ± 1.32	20.93 ± 1.65	−1.62 ± 0.92	.000[a,]***
Labial VBL	11.53 ± 3.24	11.75 ± 3.42	0.22 ± 0.63	.172[b]
Lingual VBL	11.89 ± 2.44	14.66 ± 2.92	2.77 ± 2.28	.000[b,]***
Labial ABT	0.82 ± 0.24	1.37 ± 0.91	0.55 ± 0.93	.008[a,]**
Lingual ABT	2.28 ± 0.95	1.34 ± 1.31	−0.94 ± 1.18	.001[a,]**
Total ABT	7.89 ± 1.08	7.62 ± 1.17	−0.27 ± 1.06	.232[a]
Mandible				
Crown movement			5.10 ± 2.29	
Root movement			2.66 ± 1.36	
Tooth length	19.33 ± 1.18	18.44 ± 1.18	−0.89 ± 0.51	.000[a,]***
Labial VBL	10.09 ± 0.58	10.45 ± 0.77	0.36 ± 0.69	.017[a,]*
Lingual VBL	10.74 ± 0.77	13.47 ± 2.32	2.73 ± 2.31	.000[a,]***
Labial ABT	0.61 ± 2.9	1.11 ± 0.91	0.51 ± 0.89	.011[b,]*
Lingual ABT	1.20 ± 0.55	0.42 ± 0.40	−0.79 ± 0.53	.000[b,]***
Total ABT	5.88 ± 0.64	5.85 ± 0.96	−0.04 ± 0.78	.825[a]

[a] Paired *t*-test was performed to compare between T1 and T2.
[b] Wilcoxon signed rank test was performed to compare between T1 and T2.
* Significant difference at $P < .05$ between T1 and T2.
** Significant difference at $P < .01$ between T1 and T2.
*** Significant difference at $P < .001$ between T1 and T2.

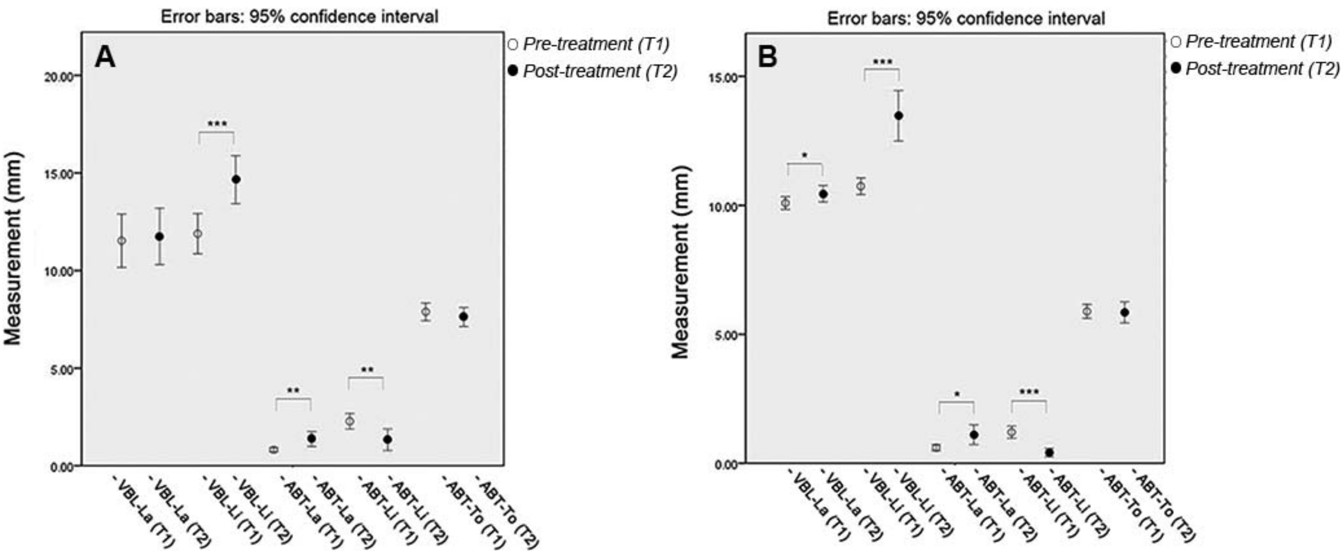

Figure 3. Error bar plot of mean values of the alveolar bone variable. (A) Maxilla. (B) Mandible. $^{*}P < .05$, $^{**}P < .01$, $^{***}P < .001$.

< .001). All measurements of the alveolar bone were significantly different between T1 and T2 except for total ABT (labial VBL, labial ABT, $P < .05$; lingual VBL, lingual ABT, $P < .001$). Labial and lingual VBL and labial ABT showed significant increases, in contrast to a significant decrease of lingual ABT, during treatment.

Comparison of Changes Assessed for the Crown-Movement Groups

In the maxilla, crown movement in the high-crown-movement group (10 mm) was significantly larger than that in the low-crown-movement group (6.6 mm; $P < .001$; Table 3). However, there were no other significant differences in any variables between the groups.

In the mandible, there were significant differences in the distances of the crown ($P < .001$) and root movements ($P < .05$). The reduction in tooth length was significantly greater in the high-crown-movement group than in the low-crown-movement group ($P < .05$). However, there were no significant differences in any of the bone variables between the groups.

Table 3. Comparison of Variables Between the Crown-Movement Groups and the Root-Movement Groups

Variables	Low-Crown Movement Mean ± SD	High-Crown Movement Mean ± SD	*P* Value	Low-Root Movement Mean ± SD	High-Root Movement Mean ± SD	*P* Value
Maxilla, n	12	12		12	12	
Crown movement	6.56 ± 1.27	9.97 ± 1.23	.000[a,***]	7.85 ± 2.11	8.68 ± 2.16	.346[a]
Root movement	2.93 ± 1.18	4.11 ± 2.57	.201[a]	1.79 ± 0.72	5.25 ± 1.80	.000[a,***]
ΔTooth length	−1.38 ± 0.82	−1.78 ± 0.97	.260[a]	−0.65 ± 0.32	−1.13 ± 0.55	.018[b,*]
ΔLabial VBL	0.33 ± 0.73	0.11 ± 0.53	.400[a]	0.19 ± 0.56	0.25 ± 0.72	.819[a]
ΔLingual VBL	2.71 ± 2.77	2.83 ± 1.79	.899[a]	1.66 ± 1.82	3.88 ± 2.21	.014[a,*]
ΔLabial ABT	0.50 ± 0.86	0.60 ± 1.03	.796[a]	−0.08 ± 0.35	1.18 ± 0.73	.000[a,***]
ΔLingual ABT	−0.86 ± 0.97	−1.03 ± 1.39	.728[a]	−0.27 ± 1.18	−1.61 ± 0.73	.003[a,**]
ΔTotal ABT	−0.34 ± 0.98	−0.19 ± 1.17	.748[a]	−0.03 ± 1.11	−0.23 ± 1.05	.867[a]
Mandible, n	11	13		11	13	
Crown movement	3.12 ± 1.43	6.74 ± 1.42	.000[b,***]	4.40 ± 2.04	5.68 ± 2.40	.177[a]
Root movement	2.07 ± 1.03	3.16 ± 1.45	.048[a,*]	1.53 ± 0.57	3.62 ± 1.05	.000[a,***]
ΔTooth length	−0.62 ± 0.33	−1.12 ± 0.53	.013[a]	−0.74 ± 0.55	−1.02 ± 0.45	.184[a]
ΔLabial VBL	0.32 ± 0.81	0.40 ± 0.60	.766[a]	0.82 ± 0.59	−0.02 ± 0.52	.001[a,**]
ΔLingual VBL	2.73 ± 2.80	2.73 ± 1.93	.995[a]	3.93 ± 2.11	1.72 ± 2.03	.016[a,*]
ΔLabial ABT	0.23 ± 0.75	0.34 ± 0.96	.168[a]	0.02 ± 0.52	0.92 ± 0.95	.011[b,*]
ΔLingual ABT	−0.88 ± 0.67	−0.71 ± 0.39	.733[a]	−0.75 ± 0.37	−0.83 ± 0.65	.865[b]
ΔTotal ABT	−0.23 ± 0.54	0.13 ± 0.92	.277[a]	−0.25 ± 0.54	0.14 ± 0.92	.207[b]

[a] Independent *t*-test was performed to compare between the crown-movement groups or the root-movement groups.
[b] Mann-Whitney *U*-test was performed to compare between the crown-movement groups or the root-movement groups.
* Significant difference at $P < .05$ between the crown-movement groups or the root-movement groups.
** Significant difference at $P < .01$ between the crown-movement groups or the root-movement groups.
*** Significant difference at $P < .001$ between the crown-movement groups or the root-movement groups.

Table 4. Pearson Correlation Coefficients Between Variables of Tooth Movement and Alveolar Bone Changes[a]

Tooth Movement	Variables of Alveolar Bone Change		
Maxilla			
Root movement	Δ Lingual VBL 0.584**	Δ Labial ABT 0.773**	Δ Lingual ABT −0.589**
Mandible			
Root movement	Δ Labial VBL −0.491*	Δ Lingual VBL −0.468*	Δ Labial ABT 0.619**

[a] Variables with significant Pearson correlation coefficient are shown.

* $P < .05$, ** $P < .01$.

Comparison of Changes Assessed for the Root-Movement Groups

Root movement was significantly different between the groups in both jaws ($P < .001$); however, no significant difference was found for the crown movement (Table 3).

In the maxilla, there was a greater decrease in the tooth length of the high-root-movement group than in the low-root-movement group ($P < .05$). The difference between T1 and T2 (Δ) in lingual VBL, Δlabial ABT, and Δlingual ABT of the high-root-movement group were significantly different from those of the low-root-movement group (Δlingual VBL, $P < .05$; Δlabial ABT, $P < .001$; Δlingual ABT, $P < .01$).

In the mandible, the vertical-level changes of the alveolar bone were significantly lower in the high-root-movement group than in the low-root-movement group (Δlabial VBL, $P = .001$; Δlingual VBL, $P < .05$). Conversely, the Δlabial ABT of the high-root-movement group was significantly greater than that of the low-root-movement group ($P < .05$). However, there were no significant differences in Δlingual and Δtotal ABT between the groups.

Pearson Correlation Coefficient Between Distance of Crown/Root Movement and Alveolar Bone Changes

Root movement in the maxilla showed significantly positive correlations with Δlingual VBL ($r = 0.584$, $P = .003$) and Δlabial ABT ($r = 0.773$, $P < .001$) and a negative correlation with Δlingual ABT ($r = -0.589$, $P = .002$; Table 4).

In the mandible, root movement showed significantly negative correlations with Δlabial VBL ($r = -0.491$, $P = .015$) and Δlingual VBL ($r = -0.468$, $P = .021$) and a significant positive correlation with Δlabial ABT ($r = 0.619$, $P = .001$).

DISCUSSION

The maxillary incisor demonstrated a large amount of movement (crown, 8.3 mm; root, 3.5 mm), and the variables were evaluated after a longer duration of treatment (29.8 months) compared with those in previous studies.[15,16,18] At the end of treatment, there were significant reductions in vertical height and thickness of the lingual alveolar bone in both jaws (Figures 3 and 4). Particularly, the vertical bone loss on the lingual side in the jaws was approximately 2.7 mm, indicating lingual bone dehiscence to a certain degree. Previous studies using CBCT also showed that the palatal movement of incisors led to narrowing of the alveolar bone on the palatal side.[14–18] On the contrary, the thickness of the labial alveolar bone evidently increased and, thus, we may occasionally encounter bony spicules on the labial gingiva during or after incisor retraction with the use of microimplants.[4] These narrowed or increased alveolar plates may be caused by differences in the rates of teeth movement and bone remodeling.[2,15]

Although in this study there were striking findings about the surrounding bone, these data should be interpreted with caution. Examined carefully, the averaged differences in thickness of the labial (maxilla, 0.6 mm; mandible, 0.5 mm) and lingual alveolar bone (maxilla, −0.9 mm; mandible, −0.8 mm) were rather smaller than even the averaged movement of the root tip (maxilla, 3.5 mm; mandible, 2.7 mm). Hence, this finding suggested that there was simultaneous bone remodeling to a certain degree during or after retraction movement, including labial surface resorption at the labial plate and lingual surface apposition at the lingual plate.

In addition, it is necessary to take into consideration the treatment mechanics of the microimplant to demonstrate the observed alveolar bone changes. With reinforced anchorage, greater distal root or bodily movement is effectively achievable and can cause significant morphologic changes in the covering alveolar bone. In contrast, it may be difficult to perform those movements without microimplants, followed by less bone changes.[5,6] In addition, to decrease root contact to the palatal bone and maintain vertical dimension of the face, the maxillary incisors should be moved postero-superiorly using the microimplants (Figure 4A). Incisor intrusion into the bone, itself, leads to a gradual increase of surrounding bone volume caused by the palatal cortex running through postero-superiorly on the sagittal-sectioned view. However, in the current study, there were no significant differences in total ABT between T1 and T2. This might have been attributed to the slower rate of bone apposition than resorption as teeth were moved.

Because there were no noticeable changes in the incisal edges of teeth in this study, such as attrition or fracture, tooth-length changes could be used as a parameter for root resorption. The maxillary incisor showed a greater decrease in length compared with

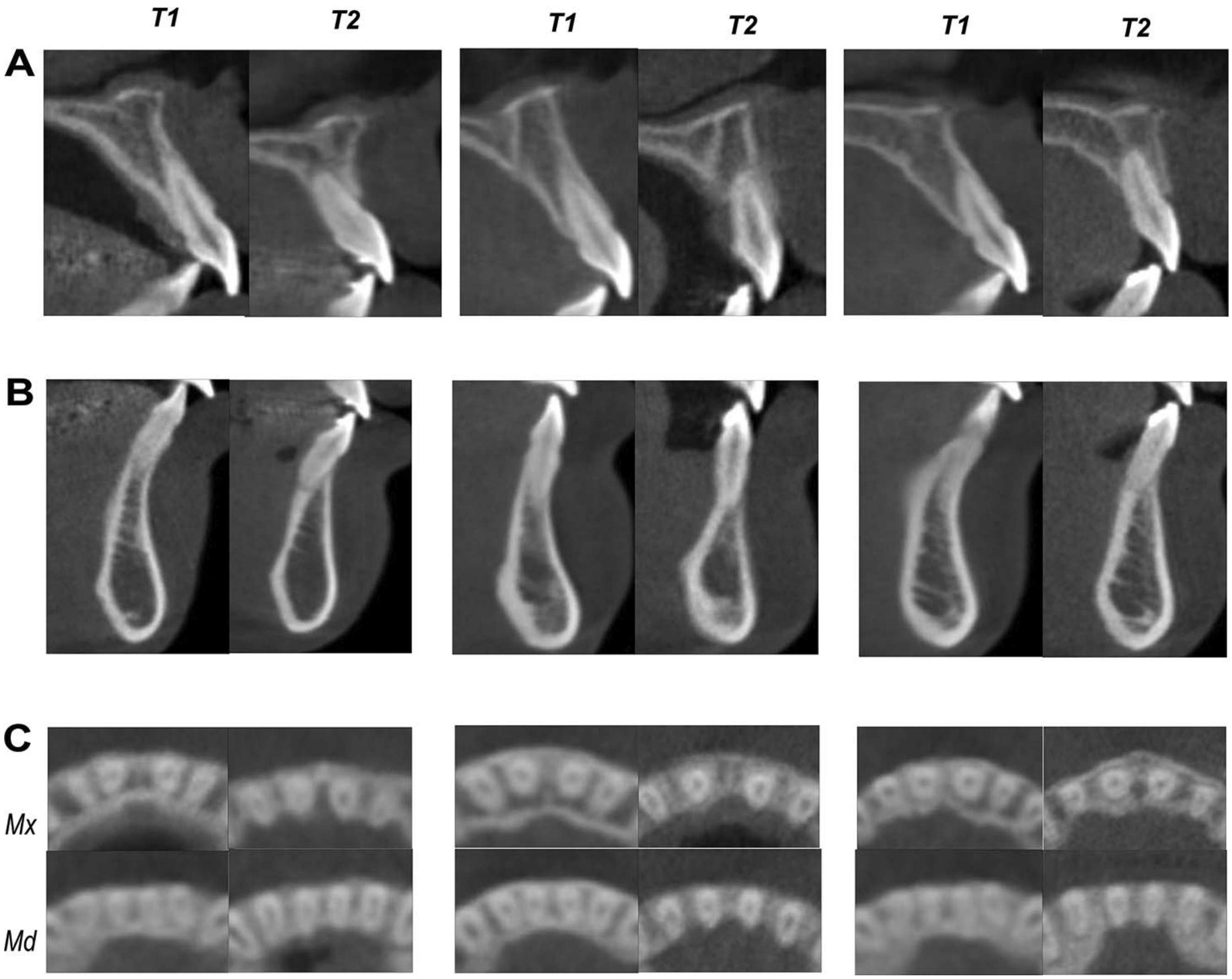

Figure 4. Cone beam computed tomography images of three subjects before treatment (T1) and after treatment (T2). (A) Sagittally sectioned maxillary incisor images. (B) Sagittally sectioned mandibular incisor images. (C) Axially sectioned incisor images. Mx indicates maxilla; Md, mandible.

the mandibular incisor and previous studies, possibly as a result of greater distance of retraction and intrusion and longer treatment time.[16]

Changes in bone relevant to root movement were more enhanced in the high-root-movement group than in the low-root-movement group. The labial bone became thicker and the palatal bone thinner as the root was moved distally. Contrary to what was observed in the maxilla, height loss was lessened on the labial and lingual plates of the mandible even with the increased root movement. This finding may have been caused by intrusion of the mandibular incisors performed to decrease the vertical dimension in high-angle patients who were likely to have been included in the high-root-movement group. The intrusion also seemed to negate the change of lingual ABT in the high-root-movement group. Consequently, bodily or root movement is likely to influence the supporting alveolar bone. Thus, retraction accompanying root movement should be performed cautiously with periodic checks of the root and tooth-supporting apparatus, which would be helpful to achieve subsequent, favorable bone remodeling.

Although this study provided informative findings on alveolar bone remodeling, limitations need to be acknowledged. The mandibular microimplants were only used in eight patients of the patient population studied. Hence, this study may not have been fully reflective of the effects of using microimplants in the mandible. Although the duration of the current observations were significantly longer than those of previous studies, further research regarding long-term changes in the alveolar bone, including during the retention period, is needed.

CONCLUSIONS

- The null hypothesis of this study was rejected.
- CBCT-based evaluation of alveolar bone remodeling following incisor retraction with microimplants showed that the thickness and height of the buccal and lingual plates were significantly different after treatment in both jaws, whereas total bucco-lingual thickness was not.
- Greater distal root movement was significantly associated with greater morphometric changes of the alveolar bone. Retraction of roots should be cautiously performed with periodic checks on the root and tooth-supporting apparatus to observe favorable bone remodeling.

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