Original Article

Alveolar bone response to maxillary incisor retraction using stable skeletal structures as a reference

Teerapat Eksriwong[a]; Udom Thongudomporn[b]

ABSTRACT

Objectives: To evaluate alveolar bone change in relation to root position change after maxillary incisor retraction via cone-beam computed tomography (CBCT) using stable skeletal structures as a reference.

Materials and Methods: A total of 17 subjects (age 24.7 ± 4.4 years) who required retraction of the maxillary incisors were included. Labial and palatal alveolar bone changes and root change were assessed from preretraction and 3 months postretraction CBCT images. The reference planes were based on stable skeletal structures. The Kruskal-Wallis test and Wilcoxon signed-rank test were used to compare changes within and between groups, as appropriate. Spearman rank correlations were used to identify the parameters that correlated with alveolar bone change. The significance level was set at .05.

Results: The labial alveolar bone change after maxillary incisor retraction was statistically significant ($P < .05$), and the bone remodeling/tooth movement (B/T) ratio was 1:1. However, the palatal bone remained unchanged ($P > .05$). The change in inclination was significantly related to labial alveolar bone change.

Conclusions: Using stable skeletal structures as a reference, the change in labial alveolar bone followed tooth movement in an almost 1:1 B/T ratio. Palatal alveolar bone did not remodel following maxillary incisor retraction. The change in inclination was associated with alveolar bone change. (*Angle Orthod.* 2021;91:30–35.)

KEY WORDS: Alveolar bone change; Maxillary incisor retraction; Cone-beam computed tomography (CBCT)

INTRODUCTION

Examination of the alveolar bone response to orthodontic force is a topic of interest as the quantity of alveolar bone surrounding a tooth after orthodontic movement is associated with the safety of the treatment. The concept that orthodontic force induces alveolar bone resorption on the pressure side and bone apposition on the tension side is well accepted.[1] However, a histological study in dogs showed alveolar bone remodeling occurred not only on the periodontal ligament side but also on the periosteal side.[2] Clinical studies also revealed cortical bone remodeling occurred following orthodontic tooth movement.[3–6]

Studies conducted in the 1960s reported that when orthodontic tooth movement occurred, the bone around the alveolar socket remodeled at a 1:1 bone remodeling/tooth movement (B/T) ratio.[7,8] More recent cone-beam computed tomography (CBCT) studies demonstrated that the rate of alveolar bone remodeling may not be consistent with maxillary incisor retraction[4,9] or maxillary incisor proclination.[5,6] These CBCT studies also reported significant relationships between alveolar bone change and inclination change,[4,5] the amount of intrusion,[4] and the rate of tooth movement.[4] However, the tooth axis was used as a reference line, which is advantageous in terms of evaluation of the safety of mechanotherapy and the amount of surrounding alveolar bone support after tooth movement.[5] However,

[a] Orthodontic Resident, Orthodontic Section, Department of Preventive Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla, Thailand.

[b] Associate Professor, Orthodontic Section, Department of Preventive Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla, Thailand.

Corresponding author: Dr Udom Thongudomporn, Orthodontic Section, Department of Preventive Dentistry, Faculty of Dentistry, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand
(e-mail udom.t@psu.ac.th)

Accepted: June 2020. Submitted: February 2020.
Published Online: September 9, 2020

DOI: 10.2319/022920-146.1

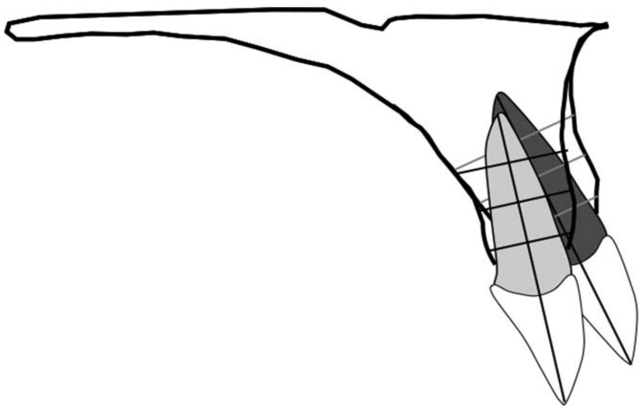

Figure 1. If the tooth axis is used as the reference line, the points of bone being measured also change as the tooth axis changes.

this method cannot be used to explore the actual response of alveolar bone to orthodontic tooth movement because the points of bone being measured also change as the tooth axis changes. In addition, if a tooth is moved vertically, the same points of bone are not measured before and after treatment (Figure 1).

To assess the extent of alveolar bone change after orthodontic tooth movement accurately, external reference lines constructed from stable skeletal structures were used in the current study to define changes in the alveolar bone position and tooth movement. Using this method of measurement, the B/T ratio can be defined at different root levels. Therefore, the aim of this study was to evaluate the alveolar bone change in relation to dental position change after maxillary incisor retraction using stable skeletal structures as a reference. The parameters that correlated with alveolar bone change were also examined. The null hypothesis of the study was that there was no significant change in the alveolar bone position following maxillary incisor retraction and that the B/T ratio was not equal to 1:1.

MATERIALS AND METHODS

This prospective clinical trial was approved by the Ethics Committee on Human Research of the Faculty of Dentistry, Prince of Songkla University (EC6012-42-P-LR). The sample size was calculated by G*Power (version 3.1)[10] using parameters from a previous study of Sarikaya et al. (the difference of means = 0.35 mm, the difference of standard deviations = 0.49, significance level = .05, power = 0.80).[9] A sample size of 16 was required. A total of 17 female patients (18 to 30 years old) were included in the study on the basis of the following inclusion criteria: requiring bilateral extraction of the maxillary first premolars and $\geq$2 mm maxillary incisor retraction, no significant medical history, no long-term use of anti-inflammatory drugs or bisphosphonates for at least 12 months before or during orthodontic treatment, no evidence of periodontal tissue destruction at the beginning of or during orthodontic treatment, and no history of trauma to the maxillary anterior teeth. All of the patients were informed of the purpose of the study and provided signed, written informed consent before participating in the study.

The patients were treated with preadjusted bidimensional edgewise fixed appliances (Roth prescription; 0.018" $\times$ 0.025" brackets on incisors, 0.022" $\times$ 0.028" brackets on canines, and posterior teeth and buccal tubes on second molars). The maxillary teeth were bonded and aligned using sequential 0.012", 0.014", 0.016", and 0.016" $\times$ 0.016" nickel–titanium and 0.016" $\times$ 0.016" stainless-steel archwires, and then the maxillary canines were distalized. Preretraction CBCT images (CT0) were taken after the completion of canine distalization. Incisor retraction was performed using 0.016" $\times$ 0.022" titanium–molybdenum alloy retraction T-loop (8-mm loop length and height) continuous archwires with an accentuated curve. Each loop was activated by 1.5 mm per month until the incisors were completely retracted. The maxillary arch was passively maintained with 0.016" $\times$ 0.022" stainless-steel archwires for 3 months to facilitate completion of the alveolar bone remodeling process.[11] Postretraction CBCT images (CT1) were taken at the end of the 3-month period.

CBCT Imaging

All CBCT images were taken with the same machine (Veraviewepocs 3D F80; J. Morita, Irvine, Calif) with the same patient positioning protocol. CBCT images covering the area of the anterior nasal spine (ANS)–posterior nasal spine (PNS) were taken at 70 kV, 51 mAs, 0.125-mm voxel resolution and 80 $\times$ 80 mm field of view. One Volume Viewer software (version 11.0; J Morita, Chatsworth, CA, USA) was used to measure all parameters in this study. The reference planes of each CBCT image were oriented according to a previous study.[12] The palatal plane (ANS-PNS) on the sagittal section, mid-palatine suture on the axial section, and the most inferior level of the nasal floor on the coronal section were parallel or perpendicular to the image border (Figure 2). Later, two reference lines were constructed on the sagittal image: (1) a horizontal reference line (H-line) connecting the ANS to the PNS and (2) a vertical reference line (V-line) perpendicular to the H-line halfway between ANS and PNS determined by coordinates read from the software (Figure 2A).

The investigator was blinded to the subject's identity in each image. The sagittal slice passing through the center of the mesio-distal width of each tooth was used

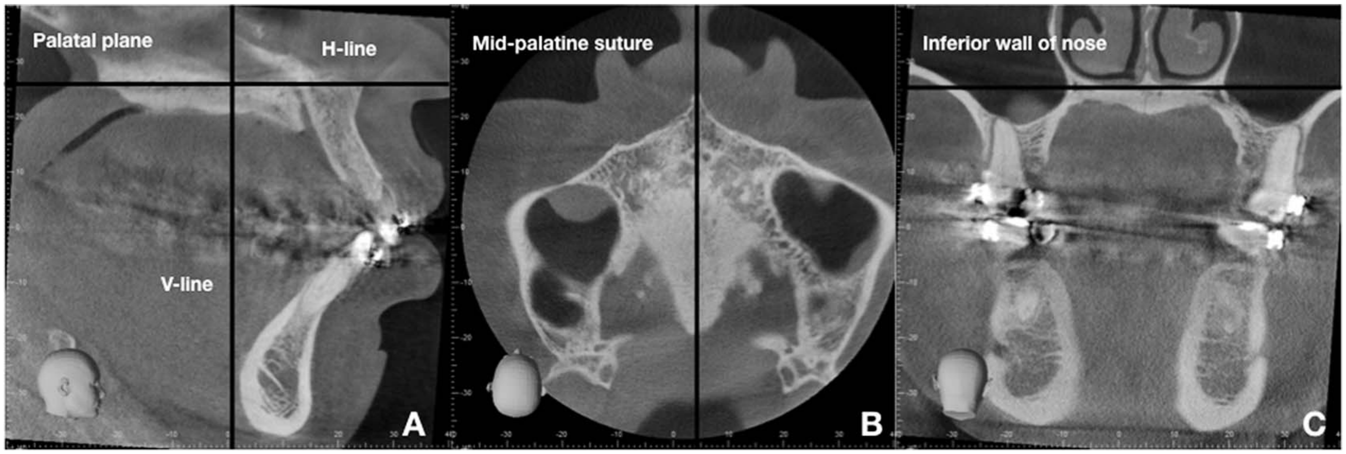

Figure 2. Orientation of the planes in the CBCT images. (A) Sagittal slice. (B) Transverse slice. (C) Coronal slice.

to assess the changes in each tooth and the corresponding bone. The dental crown measurement variables were (1) vertical dental position, the perpendicular distance between the maxillary incisor edge and the H-line; (2) horizontal dental position, the perpendicular distance between the maxillary incisor edge and V-line; and (3) dental inclination, the angle formed between the tooth axis and H-line (Figure 3). The difference in the vertical dental position between CT0 and CT1 was defined as vertical dental change; the difference in the horizontal dental position between CT0 and CT1 was defined as retraction distance. The rate of tooth movement was calculated as the retraction distance divided by the retraction time. All parameters were calculated and averaged for the upper incisors in each individual.

For the measurements of labial (L) and palatal (P) root (R) and bone (B) positions on the CT0 images, each tooth was measured at the crestal (S1), mid-root (S2), and apical (S3) levels apical to the labial cemento-enamel junction every 2 mm along the V-line. The root and bone positions were defined as the distances between each point (LR1-3, PR1-3, LB1-3, PB1-3) and the V-line measured parallel to the H-line (Figure 4).

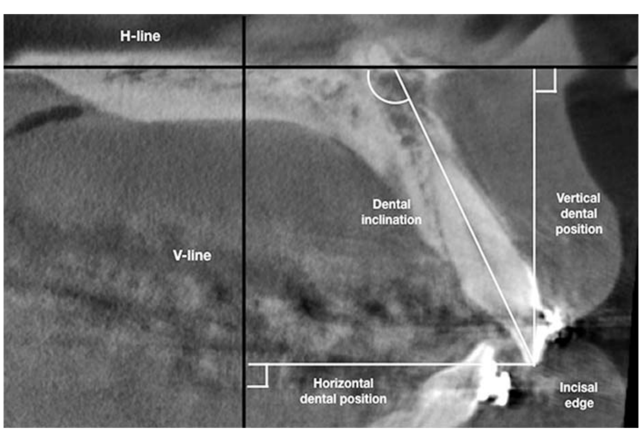

Figure 3. Vertical dental position and dental inclination measurements.

To assess horizontal root and bone changes, H-line, V-line, and horizontal lines parallel to the H-line at the level of S1, S2, and S3 from the sagittal slice of the CT0 image (Figure 4) were transferred to and superimposed on the H-line and V-line of the sagittal slice of the CT1 image. Changes were defined as the horizontal distances between LR1-3, PR1-3, LB1-3, and PB1-3 points of the two images on the S1, S2, and S3 lines.

Statistical Analysis

All CBCT data were measured by one investigator. A total of 10 patients were randomly selected and remeasured after an interval of 4 weeks to assess measurement error and reliability. Dahlberg's formula[13] was used to assess measurement error. Intraobserver reliability was used to assess the reliability of measurement.

Shapiro-Wilk tests showed the data were nonnormally distributed. Consequently, Wilcoxon matched-pairs signed-rank tests were used to evaluate the change in alveolar bone and changes in crown and root positions between CT0 and CT1. The Kruskal-Wallis test was used to compare the intrasubject alveolar bone, crown, and root changes between teeth. The Spearman rank correlation test was used to evaluate the correlations between alveolar bone change, inclination change, and retraction distance. The significance level of all tests was established at .05.

RESULTS

Dahlberg's error for each parameter was less than 0.5 mm for linear variables and less than 0.5° for

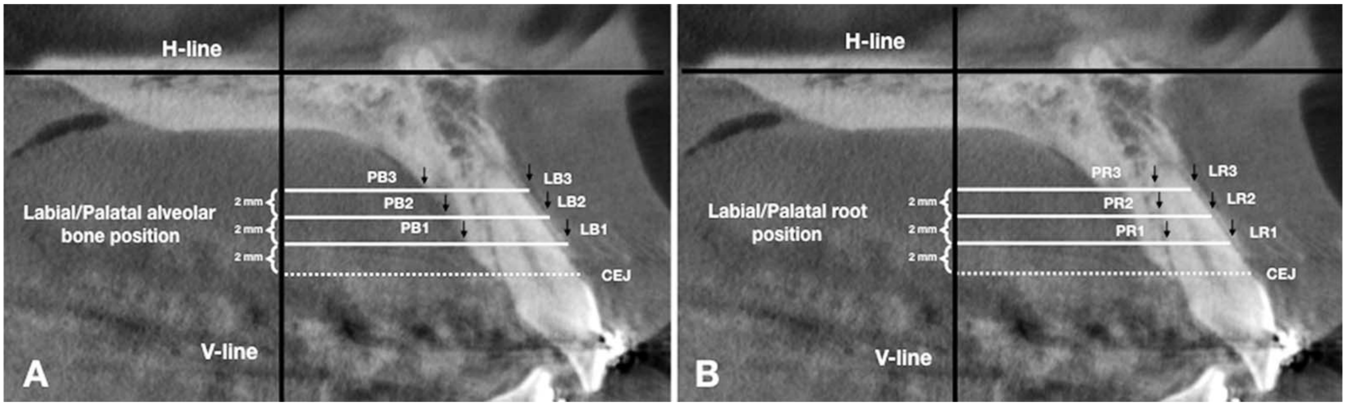

Figure 4. Illustration of (A) the labial/palatal alveolar bone positions and (B) the labial/palatal root positions of the maxillary incisors. L1/P1 indicates labial/palatal alveolar bone and root position at the crestal level; L2/P2, labial/palatal alveolar bone and root position at the mid-root level; and L3/P3, labial/palatal alveolar bone and root position at the apical level.

angular variables. Intraobserver reliability was higher than 0.90 for all measurements.

The mean retraction distance, vertical dental change, inclination change, retraction time, and rate of tooth movement were 3.3 ± 1.1 mm, 0.6 ± 1.2 mm, 6.4 ± 5.2°, 4.2 ± 1.4 months, and 0.8 ± 0.2 mm per month, respectively (Table 1). Wilcoxon matched-pairs signed-rank tests demonstrated the retraction distance and inclination change (both $P < .001$), but not the vertical dental change ($P > .05$) were significantly different between CT0 and CT1.

The Kruskal-Wallis test demonstrated that mean alveolar bone change and root change were not significantly different at any root level between teeth ($P > .05$; Tables 2 and 3). Therefore, the data from all four incisors in each patient were pooled and averaged for further analysis.

Wilcoxon matched-pairs signed-rank tests demonstrated labial alveolar bone significantly decreased between CT0 and CT1 at all root levels ($P < .05$). However, the palatal alveolar bone was not significantly different between CT0 and CT1 at any root level ($P > .05$). The labial and palatal root position relative to the V-line significantly decreased at all root levels ($P < .05$). The B/T ratio was calculated from labial alveolar bone change and dental change. As a result of the noncontinuous characteristics of the ratio data, the medians and interquartile ranges are presented. The labial B/T ratio was nearly 1:1 at all root levels. In contrast, the B/T ratio on the palatal side ranged from 0.2 to 0.4 (Table 4).

Bivariate correlations were examined between the variables that changed significantly between CT0 and CT1. Spearman rank correlation tests demonstrated that the labial alveolar bone changes at the crestal and mid-root level correlated significantly with the inclination change ($r = 0.8$ and 0.6; $P < .05$), but were not significantly related to the retraction distance (Table 5).

DISCUSSION

Using stable skeletal structures as a reference, the present study revealed that alveolar bone on the labial side remodeled concomitantly with root movement during orthodontic retraction. The B/T ratio of nearly 1:1 observed for all root levels was in agreement with previous CBCT studies that used the tooth axis as a reference.[9,14] The small degrees of inclination change may explain why the results were similar between

Table 1. Mean, SD, and Range of Age, Retraction Distance, Vertical Dental Change, Inclination Change, Retraction Time, and Rate of Tooth Movement[a]

Parameter	Mean	SD	Range
Age, y	24.7	4.4	20–31
Retraction distance, mm	3.3	1.1	2.1–5.6
Vertical dental change, mm	0.6	1.2	−0.9 to 3.2
Inclination change, degrees	6.4	5.2	0.1–21.0
Retraction time, mo	4.2	1.4	2.1–6.7
Rate of tooth movement, mm/mo	0.8	0.2	0.4–1.0

[a] SD indicates standard deviation.

Table 2. Alveolar Bone Changes at Different Levels of the Maxillary Incisor Roots

	Alveolar Bone Change (Mean ± SD[a])				
Variable	11	21	12	22	P Value[b]
Labial					
Crestal	1.3 ± 1.0	1.2 ± 1.1	1.4 ± 1.2	1.3 ± 1.2	.971
Mid-root	0.9 ± 1.4	0.8 ± 1.5	0.9 ± 1.7	0.9 ± 1.5	.974
Apical	0.9 ± 0.9	0.7 ± 0.9	0.7 ± 1.1	0.9 ± 1.1	.828
Palatal					
Crestal	0.1 ± 0.6	0.2 ± 0.5	0.0 ± 0.7	0.3 ± 0.4	.681
Mid-root	0.2 ± 0.8	0.0 ± 0.7	0.0 ± 0.8	0.2 ± 0.7	.632
Apical	0.3 ± 0.4	0.1 ± 0.5	0.3 ± 0.6	0.1 ± 0.6	.714

[a] SD indicates standard deviation.
[b] *P* Value of Kruskal-Wallis test.

Table 3. Root Changes at Different Levels of the Maxillary Incisor Roots

Variable	Dental Change (Mean ± SD[a]) 11	21	12	22	*P* Value[b]
Labial					
Crestal	1.2 ± 1.1	1.4 ± 1.3	1.2 ± 1.2	1.5 ± 1.3	.927
Mid-root	1.3 ± 2.3	1.0 ± 1.6	0.8 ± 1.3	1.0 ± 1.4	.931
Apical	0.9 ± 1.0	0.8 ± 1.3	0.8 ± 0.9	1.1 ± 1.2	.768
Palatal					
Crestal	1.1 ± 1.1	1.2 ± 1.2	1.1 ± 1.0	1.3 ± 1.2	.936
Mid-root	0.5 ± 1.6	1.2 ± 1.5	0.9 ± 1.2	1.3 ± 1.4	.479
Apical	1.0 ± 0.8	1.3 ± 1.0	0.9 ± 0.7	1.3 ± 1.0	.674

[a] SD indicates standard deviation.
[b] *P* Value of Kruskal-Wallis test.

studies, regardless of the reference used. The inclination changes in previous studies ranged from 7.8 to 10.4°,[9,14] whereas the average inclination change in this study was 6.4°. Thus, either an external reference or the tooth axis could be used to study the B/T ratio if the inclination change is within the range of 10° or less.

On the contrary, the results disagreed with a previous cephalometric study[15] that found a 1:2 B/T ratio on the labial side after maxillary incisor retraction. The difference in results may be because the amount of inclination change of this previous cephalometric study was about 12.3°, signifying a larger degree of tipping than the present study. Also, the nasion–pogonion line was used as a reference line to measure the positions of the incisor root apex and the bony point A. The inclination of this reference line is not stable throughout the treatment as it could be changed because of mandibular rotation or relocation as a result of orthodontic mechanics.

The nonsignificant change in the palatal alveolar bone position during incisor retraction confirms other investigations that suggested the preretraction palatal bone position represented the boundary for maximal retraction of the maxillary incisors.[9,14,16] Handelman et al.[17] advocated that tooth movement could alter the distance between the alveolar cortical plate and the roots of orthodontically moved teeth, stating "the alveolar cortical plate behaved like the orthodontic wall." Current results for the palatal side, but not the labial side, were in agreement with those of Handelman et al.[17] The stability of the palatal cortical plate, regardless of the amount of maxillary incisor retraction, indicated that caution should be exercised to not overretract the maxillary incisors palatally, especially in cases with thin alveolar bone housing. Uncontrolled mechanics may predispose patients to alveolar bone loss, fenestrations, dehiscence, or root resorption if the amount of tooth retraction required is greater than the pretreatment position of the palatal cortical plate.[3,14,17,18] Previous studies reported that recovery of a well-defined dense cortical plate would not occur if the cortical plate had been penetrated by the root.[19]

Bivariate correlation analysis revealed that the inclination change influenced alveolar bone remodeling, in agreement with previous studies.[4,5] However, the correlation between alveolar bone change at the labio-apical level (LB3) and inclination change was not statistically significant. This may be explained by two factors. First, incisor movement was definitely not bodily, as the apical part of the root moved less than the cervical part. The small amount of movement for the apical part of the root may not be sufficient to signal the corresponding alveolar bone to remodel concomitantly with root movement. Second, type II error may have occurred as the sample size was relatively small.

This study provided a method to evaluate alveolar bone change after maxillary incisor retraction that was not confounded by dental inclination change. The use of CBCT is advantageous as it allows the bone surrounding all four incisors to be investigated. However, because the vertical dental changes were not significant, it may not be possible to extrapolate the results of this study to cases in which the incisors are intruded or extruded during retraction. Using three-dimensional superimposition on stable structures such as the palate may provide more accurate and reliable results. However, specific software is needed to apply

Table 4. Alveolar Bone and Root Positions at CT0 and CT1 and Changes at Different Levels of the Maxillary Incisor Roots and B/T Ratio[a]

Variable	Alveolar Bone Change (Mean ± SD) CT0	CT1	CT0–CT1	*P* Value	Tooth Change (Mean ± SD) CT0	CT1	CT0–CT1	*P* Value	B/T Ratio Median	IQR
Labial										
Crestal	24.9 ± 2.4	23.5 ± 2.7	1.3 ± 1.1	.002[b]	23.8 ± 2.4	22.5 ± 2.7	1.3 ± 1.2	.004[b]	0.9	0.8–1.0
Mid-root	23.3 ± 2.5	22.4 ± 2.6	0.9 ± 1.5	.035[b]	22.4 ± 2.5	21.4 ± 2.8	1.0 ± 1.5	.033[b]	1.0	0.8–1.1
Apical	21.7 ± 2.5	20.9 ± 2.5	0.8 ± 0.9	.013[b]	21.0 ± 2.5	20.2 ± 2.5	0.9 ± 1.0	.011[b]	0.9	0.8–1.0
Palatal										
Crestal	14.8 ± 3.0	14.7 ± 2.9	0.2 ± 0.5	.384	17.8 ± 2.5	16.6 ± 2.7	1.2 ± 1.1	.003[b]	0.2	0.1–0.4
Mid-root	13.4 ± 3.3	13.3 ± 3.1	0.1 ± 0.7	.530	17.2 ± 2.5	16.3 ± 2.6	1.0 ± 1.2	.019[b]	0.4	0.3–0.5
Apical	11.6 ± 3.5	11.4 ± 3.5	0.2 ± 0.4	.058	16.8 ± 2.6	15.7 ± 2.7	1.1 ± 0.7	.001[b]	0.3	0.2–0.4

[a] SD indicates standard deviation; CT0, pre-retraction; CT1, 3-month post-retraction; and IQR, interquartile range.
[b] Significant difference ($P < .05$), Wilcoxon matched-pairs signed-rank tests.

Table 5. Correlations Between Alveolar Bone Change, Inclination Change, and Retraction Distance

	Alveolar Bone Change; *r* Value (*P* Value)		
Parameter	Labial Crestal	Labial Mid-Root	Labial Apical
Inclination change	0.816 (0.000)*	0.586 (0.028)*	0.409 (0.146)
Retraction distance	0.503 (0.067)	0.195 (0.504)	0.144 (0.622)

* Significant at $P < .05$ by Spearman rank correlation.

that methodology. The study of three-dimensional bone volume changes and the changes in cortical bone thickness after incisor retraction could provide additional insight into alveolar bone remodeling attributed to orthodontic force.

The results of this study highlight the importance of assessing the distance between the root surface and palatal cortical plate in cases undergoing maxillary incisor retraction. Excessive retraction beyond this distance may cause the root to hit the cortical plate and possibly lead to several complications such as root resorption and bony defects. Safer treatment options, such as corticotomy with a bone graft or orthognathic surgery, should be considered for cases with a narrow distance between the root and palatal bone.

CONCLUSIONS

Using stable skeletal structures as a reference, after maxillary incisor retraction with T-loop mechanics:

- the labial alveolar bone remodeled in accordance with tooth movement in a 1:1 B/T ratio;
- the palatal alveolar bone remained unchanged, with the distance between the root and palatal cortical plate decreasing; and
- inclination change was the only factor associated with alveolar bone change.

ACKNOWLEDGMENT

The authors thank the graduate school and the Faculty of Dentistry, Prince of Songkla University, for grant support.

REFERENCES

1. Melsen B. Biological reaction of alveolar bone to orthodontic tooth movement. *Angle Orthod*. 1999;69(2):151–158.
2. Kraus CD, Campbell PM, Spears R, Taylor RW, Buschang PH. Bony adaptation after expansion with light-to-moderate continuous forces. *Am J Orthod Dentofacial Orthop*. 2014;145(5):655–666.
3. Vardimon AD, Oren E, Ben-Bassat Y. Cortical bone remodeling/tooth movement ratio during maxillary incisor retraction with tip versus torque movements. *Am J Orthod Dentofacial Orthop*. 1998;114(5):520–529.
4. Yodthong N, Charoemratrote C, Leethanakul C. Factors related to alveolar bone thickness during upper incisor retraction. *Angle Orthod*. 2013;83(3):394–401.
5. Thongudomporn U, Charoemratrote C, Jearapongpakorn S. Changes of anterior maxillary alveolar bone thickness following incisor proclination and extrusion. *Angle Orthod*. 2014;85(4):549–554.
6. Chaimongkol P, Thongudomporn U, Lindauer SJ. Alveolar bone response to light-force tipping and bodily movement in maxillary incisor advancement: a prospective randomized clinical trial. *Angle Orthod*. 2018;88(1):58–66.
7. Reitan K. Effects of force magnitude and direction of tooth movement on different alveolar bone types. *Angle Orthod*. 1964;34(4):244–255.
8. Reitan K. Influence of variation in bone type and character on tooth movement. *Eur Orthod Soc Tr*. 1963;39:137–154.
9. Sarikaya S, Haydar B, Ciğer S, Ariyürek M. Changes in alveolar bone thickness due to retraction of anterior teeth. *Am J Orthod Dentofacial Orthop*. 2002;122(1):15–26.
10. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G* Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. 2009;41(4):1149–1160.
11. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. *Am J Orthod Dentofacial Orthop*. 1973;64(3):278–302.
12. Lin L, Ahn H-W, Kim S-J, Moon S-C, Kim S-H, Nelson G. Tooth-borne vs bone-borne rapid maxillary expanders in late adolescence. *Angle Orthod*. 2014;85(2):253–262.
13. Dahlberg G. *Statistical Methods for Medical and Biological Students*. Br Med J. 1940;2:358–359.
14. Ahn H-W, Moon SC, Baek S-H. Morphometric evaluation of changes in the alveolar bone and roots of the maxillary anterior teeth before and after en masse retraction using cone-beam computed tomography. *Angle Orthod*. 2012;83(2):212–221.
15. Cangialosi TJ, Meistrell ME. A cephalometric evaluation of hard-and soft-tissue changes during the third stage of Begg treatment. *Am J Orthod*. 1982;81(2):124–129.
16. Ten Hoeve AMR. The effect of antero-posterior incisor repositioning on the palatal cortex as studied with laminagraphy. *J Clin Orthod*. 1976;11:804–822.
17. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. *Angle Orthod*. 1996;66(2):95–110.
18. Nahm K, Kang J, Moon S, et al. Alveolar bone loss around incisors in Class I bidentoalveolar protrusion patients: a retrospective three-dimensional cone beam CT study. *Dentomaxillofac Radiol*. 2012;41(6):481–488.
19. Remmelnick H. The effect of anteroposterior incisor repositioning on the root and cortical plate: a follow-up study. *J Clin Orthod*. 1984;18:42–49.