Original Article

Recovery bone formation over radiographic lingual bone dehiscence after mandibular molar distalization with microimplants

Ho-Jin Kim[a]; Hyung-Kyu Noh[b]; Hyo-Sang Park[c]

ABSTRACT

Objectives: To assess mandibular lingual bone thickness changes after molar distalization with microimplants and during retention.

Materials and Methods: Twenty-one patients (10 men, 11 women; mean age: 20.5 ± 4.9 years) who underwent mandibular molar distalization with microimplants were included. Cone-beam computed tomography images at pretreatment (T0), posttreatment (T1), and retention (T2) were used to measure posterior space available and lingual bone thickness distal to the mandibular second molar at 0-, 2-, 4-, and 6-mm levels apical to the root furcation. Repeated measures analysis of variance with Bonferroni correction was applied to compare T0, T1, and T2 measurements. Pearson's correlation analysis assessed the relationship between lingual bone thickness change and other variables.

Results: The mandibular second molar moved distally by 3.0 mm at crown level, and 1.2–1.8 mm at root level, after treatment. Posterior space available decreased significantly with root-cortex contact or radiographic lingual bone dehiscence observed at 6-mm root level. After retention, reduced cortical bone thickness increased significantly; however, T2 lingual bone thickness was less than T0. Although the decrease in lingual bone thickness at 6-mm root level correlated with crown and root distal movement after treatment, the increase in bone thickness during retention was not associated with tooth movement, patient age, or retention duration.

Conclusions: Mandibular lingual bone thickness noticeably decreased after molar distalization with microimplants. After retention, significant bone recovery formation was observed at the thinned lingual cortex or radiographic bone dehiscence. (*Angle Orthod*. 2025;00:000–000.)

KEY WORDS: Mandibular molar distalization; Mandibular lingual cortical plate; Radiographic bone dehiscence; Alveolar bone recovery

INTRODUCTION

The concept of the envelope of discrepancy has been used to indicate the limits of orthodontic tooth movement based on the alveolar bone housing.[1] The cortical plate, which determines the alveolar boundary, has long been considered an anatomical limit for tooth movement.[2] The maxillary sinus floor, the distal end of the maxillary tuberosity, and the palatal or lingual cortex of the incisors are well-known anatomical structures that restrict tooth movement.[3–5] Regarding mandibular posterior space available, previous studies using two-dimensional radiographs mentioned that the anterior border of the ascending ramus was the posterior limit for distal molar movement.[6,7] However, after cone-beam computed tomography (CBCT) became widespread for three-dimensional (3D) analysis, recent studies ascertained that the mandibular lingual cortical plate can limit molar distalization.[8–10] In addition, as mandibular molars can now be distalized effectively and extensively with the aid of microimplants, potential root exposure outside the alveolar bone housing has increased.[8,11] Such considerable tooth movement may raise clinician concerns about bone dehiscence and associated clinical complications. Interestingly, previous CBCT studies on long-term retention checkups after radiographic bone dehiscence caused by extensive incisor retraction revealed noticeable palatal bone

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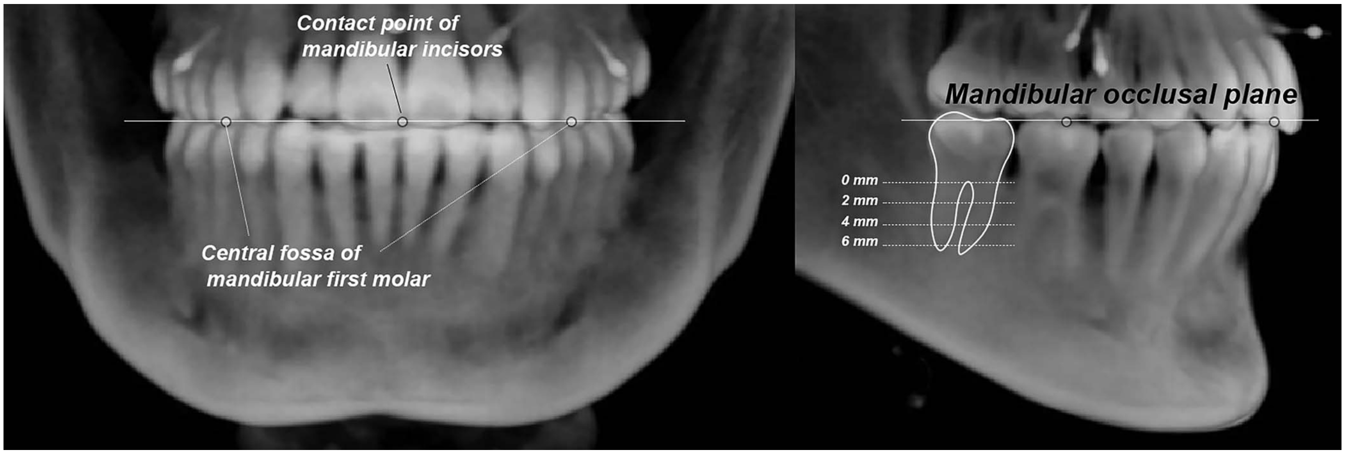

Figure 1. The mandibular occlusal plane and axial planes at the 0-, 2-, 4-, and 6-mm levels apical to the root furcation.

recovery.[12,13] Similarly, a case report using CBCT images observed favorable recovery of mandibular lingual bone dehiscence with protruding molar roots after substantial molar distalization using microimplants, with a newly formed cortical layer.[14] This case suggested the potential for bone regeneration over the lingual bone dehiscence. However, no research has specifically investigated mandibular lingual bone changes during retention after molar distalization-induced bone dehiscence.

Therefore, this study aimed to assess the mandibular lingual bone changes after molar distalization with microimplants and during the retention period. The study compared tooth movement, posterior space available, and alveolar bone thickness at pretreatment (T0), posttreatment (T1), and retention (T2) using CBCT images. The null hypothesis was that there would be no significant difference in mandibular posterior lingual bone thickness between T0, T1, and T2.

MATERIALS AND METHODS

Study Samples

This retrospective study was approved by the institutional review board of Kyungpook National University Dental Hospital (No. KNUDH-2024-12-01-00).

The inclusion criteria were: (1) patients with skeletal Class I or III malocclusions; (2) no congenitally missing teeth or extraction except for third molars; (3) mandibular molar distalization with microimplants after mandibular third molar extraction; (4) mandibular second molar with distal root protrusion into or outside the lingual cortical plate after mandibular molar distalization; and (5) high-quality CBCT images at T0, T1, and T2 ($>$18 months after treatment). Exclusion criteria were: patients with previous orthodontic treatment, craniofacial syndromes, trauma history, orthognathic surgery, or no contact between the second molar distal root and the lingual cortex after treatment.

According to the criteria for this study, 21 patients (10 men, 11 women; mean age: 20.5 $\pm$ 4.9 years; age range: 12.7–30.0 years) were included. After obtaining informed consent, all patients had undergone mandibular molar distalization treatment using 0.022-inch preadjusted brackets and microimplants (AbsoAnchor, Dentos Co. Ltd., Daegu, Korea) placed between the mandibular second premolar and first molar, between the first and second molars, or distal to the second molar. The mandibular molars were distalized using a force of 200–250g from the microimplants to anterior hooks crimped on 0.017 $\times$ 0.025-inch stainless steel archwires.[15] After treatment, lingual fixed retainers were bonded to the incisors, and circumferential retainers were used during the retention period.

CBCT Measurements

CBCT scans (HDX WILL, Seoul, Korea; 85 kVp, 8 mA, voxel size of 0.300 mm) were acquired at T0, T1, and T2. Measurements were performed using 3D imaging software (Invivo 6; Anatomage Inc., San Jose, CA, USA).

The mandibular occlusal plane was established as a horizontal reference plane using the T1 CBCT image (Figure 1). Each T0 or T2 CBCT image was then superimposed onto the T1 image using voxel-based mandibular superimposition.[16,17] Once superimposed, axial planes were set at 0-, 2-, 4-, and 6-mm levels apical to the second molar root furcation, parallel to the mandibular occlusal plane. Next, the posterior space available for the mandibular second molar distalization, lingual bone thickness, and root movement were measured on each axial plane (Figure 2A–C). Linear variables were measured parallel to the posterior occlusal line connecting the contact points of the posterior teeth. Using the sagittal section of the mandibular second molar,

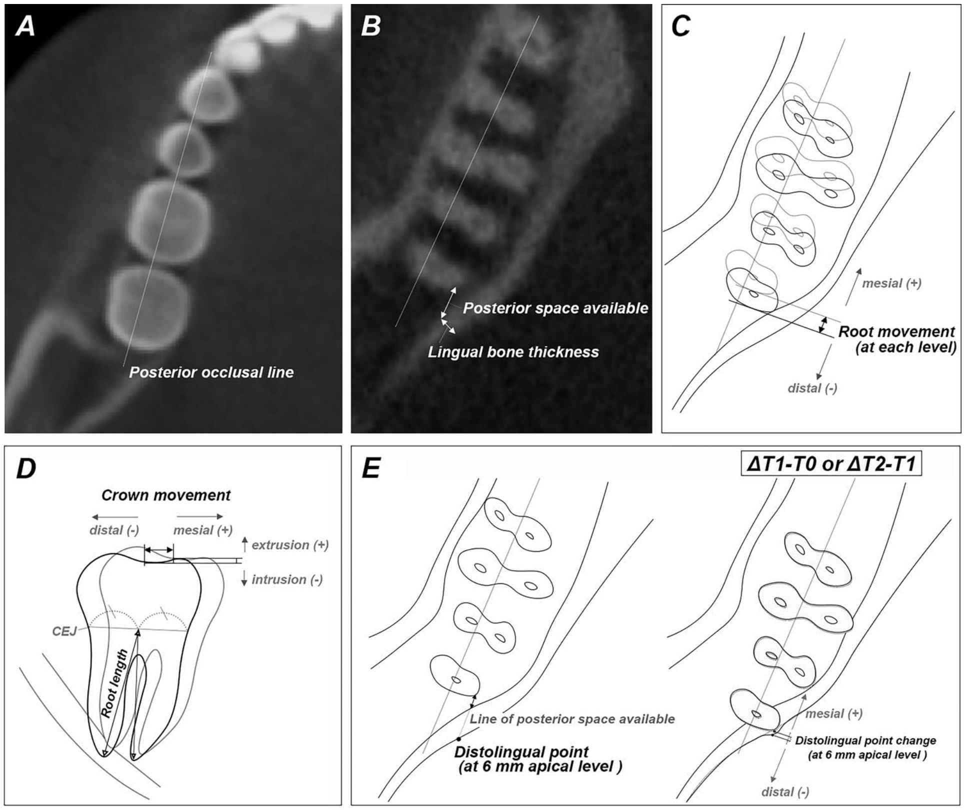

Figure 2. Measurements on axial or sagittal planes. (A) Posterior occlusal line. (B) Posterior space available and lingual bone thickness. (C) Root movement. (D) Crown movement and root length of the mandibular second molar. (E) Distolingual point and positional change at 6-mm root level. CEJ indicates cementoenamel junction; T0, pretreatment; T1, posttreatment; T2, retention.

crown movement and root length change were measured between T0 and T1, or T1 and T2 (Figure 2D). In addition, a distolingual point on the outer lingual cortex or distal root protruding outside the outer cortex was established at the 6-mm root level to investigate the direction of lingual bone remodeling during the treatment and retention periods (Figure 2E). This point was defined as the intersection of the distally extended line from the posterior space measurement and the outer lingual cortex. For samples showing lingual bone dehiscence after distalization, the distolingual point of the exposed distal root was used. The mesiodistal change of distolingual points, parallel to the posterior occlusal line, was only measured in adult patients to exclude mandibular growth effects in growing patients.

Statistical Analysis

All measurements were performed by a single investigator (HJ Kim). To assess the method error and reliability, 10 randomly selected patients were measured again after 2 weeks.

The Kolmogorov–Smirnov test confirmed normal distribution. Repeated measures analysis of variance with Bonferroni correction was performed to compare T0, T1, and T2 variables. Greenhouse–Geisser correction was applied in case of sphericity violation. Pearson's correlation coefficient was calculated to evaluate the correlation between lingual bone thickness changes and tooth movement or clinical variables. Statistical significance was set at $P < .05$, and all analyses were conducted using SPSS statistical software (version 22; IBM, Armonk, NY, USA).

RESULTS

The method error, calculated using Dahlberg's formula, ranged from 0.05 to 0.27 mm. The intraclass correlation coefficients were greater than .90, indicating excellent reliability of the measurements.

The mean treatment duration was 32.3 ± 12.1 months, and the mean retention duration was 41.4 ± 20.7 months (range: 18.0–87.0 months).

During treatment, the mandibular second molar moved distally by 3.0 mm at the crown level and 1.2–1.8 mm at each root level (Table 1). Subsequently, during the retention period, the molar moved mesially by 0.7mm at the crown and 0.07–0.26 mm at each root level. The root length of the second molar decreased slightly by 0.36–0.46 mm after treatment.

Table 1. Tooth Movement and Change in Root Length of the Mandibular Second Molar[a,*]

(mm)	ΔT1–T0	ΔT2–T1
Tooth movement		
Crown (central fossa)		
Mesiodistal [(+), mesial; (−), distal]	−3.04 ± 1.51	0.69 ± 0.48
Vertical [(+), extrusion; (−), intrusion]	−0.29 ± 1.01	0.55 ± 0.35
Root (at root level from furcation)		
0 mm	−1.75 ± 1.49	0.26 ± 0.50
2 mm	−1.56 ± 1.37	0.17 ± 0.46
4 mm	−1.28 ± 1.28	0.11 ± 0.47
6 mm	−1.18 ± 1.30	0.07 ± 0.50
Root length change		
Mesial root	−0.36 ± 0.29	−0.07 ± 0.19
Distal root	−0.46 ± 0.28	−0.01 ± 0.31

[a] T0 indicates pretreatment; T1, posttreatment; T2, retention; ΔT1–T0, difference between T0 and T1 values; ΔT2–T1, difference between T1 and T2 values.

* Values are mean ± standard deviation.

Regarding the posterior space available for mandibular second molar distalization, the measurement significantly decreased at all root levels after treatment. At the 6-mm root level, all samples exhibited contact between the molar distal root and the lingual cortical plate (Table 2). During the retention period, the posterior space available increased but with no statistical significance except at the root furcation level. The lingual bone thickness distal to the mandibular second molar distal root significantly decreased after treatment, suggesting that the distal root moved into the cortical plate. Conversely, after retention, a significant increase in cortical bone thickness was observed, indicating new bone apposition at the previously thinned or penetrated cortical plate. However, the bone thickness at T2 was significantly less than at T0, except at the root furcation level.

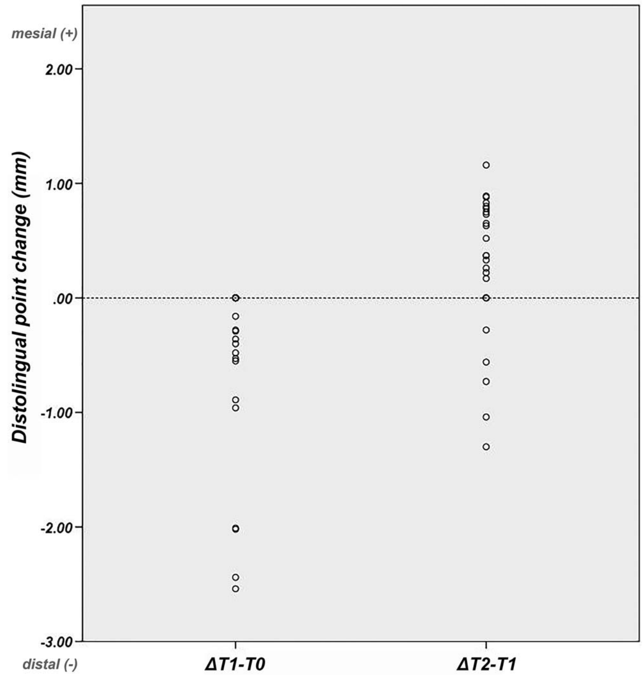

Figure 3. Scattergram of distolingual point changes. T0 indicates pretreatment; T1, posttreatment; T2, retention.

Concerning the positional changes of the distolingual point at the 6-mm root level (Table 2), all points were moved distally by 0.54 mm during treatment. During the retention period, the points moved mesially by 0.25 mm on average, which may indicate new bone apposition following mesial relapse of the molar root. However, when examined individually, distolingual points were observed to have moved distally in five molars from four patients, suggesting bone deposition on the outer surface over the roots protruding outside the cortex (Figure 3).

Table 2. Posterior Space Available, Lingual Bone Thickness, and Distolingual Point Change Distal to the Mandibular Second Molar at Each Root Level[a,*,**]

(mm)	T0	T1	T2	*P* Value	ΔT1–T0	ΔT2–T1
Post space						
0 mm	2.74 ± 1.75[A]	0.55 ± 0.93[B]	0.75 ± 1.10[C]	< .001	−2.20 ± 1.44	0.20 ± 0.43
2 mm	1.99 ± 1.40[A]	0.32 ± 0.71[B]	0.36 ± 1.02[B]	< .001	−1.67 ± 1.28	0.05 ± 0.40
4 mm	1.31 ± 1.25[A]	0.09 ± 0.36[B]	0.21 ± 0.63[B]	< .001	−1.22 ± 1.10	0.12 ± 0.34
6 mm	0.94 ± 1.08[A]	0.00 ± 0.00[B]	0.03 ± 0.17[B]	< .001	−0.94 ± 1.08	0.03 ± 0.17
Lingual bone thickness						
0 mm	1.94 ± 0.49[A]	1.51 ± 0.82[B]	1.93 ± 0.66[A]	.002	−0.44 ± 0.84	0.43 ± 0.48
2 mm	2.14 ± 0.57[A]	1.40 ± 0.90[B]	1.79 ± 0.68[C]	< .001	−0.75 ± 0.78	0.40 ± 0.51
4 mm	2.11 ± 0.78[A]	0.95 ± 0.80[B]	1.36 ± 0.72[C]	< .001	−1.16 ± 0.77	0.41 ± 0.39
6 mm	1.82 ± 0.84[A]	0.60 ± 0.67[B]	1.29 ± 0.57[C]	< .001	−1.21 ± 0.76	0.69 ± 0.48
Distolingual point change (n = 15)						
6 mm	—	—	—		−0.54 ± 0.80	0.25 ± 0.62

[a] T0 indicates pretreatment; T1, posttreatment; T2, retention; ΔT1–T0, difference between T0 and T1 values; ΔT2–T1, difference between T1 and T2 values.

* Values are mean ± standard deviation.

** Values with different superscript letters indicate significant differences at $P < .05$ based on the repeated-measures analysis of variance with Bonferroni correction.

Table 3. Pearson's Correlation Coefficient of the Relationship Between Mandibular Lingual Bone Thickness Changes at 6 mm Root Level, and Mandibular Second Molar Movements and Clinical Variables[a]

	ΔT1-T0								ΔT2-T1									
	Crown Movement (Mesiodistal)		Crown Movement (Vertical)		Root Movement (at 6 mm Level)		Distal Root Length Change		Crown Movement (Mesiodistal)		Crown Movement (Vertical)		Root Movement (at 6 mm level)		Age (T1)		Retention Duration	
	r	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value	*r*	*P* Value
Lingual bone thickness (ΔT1–T0)	.552	.001**	.396	.023*	.417	.016*	.175	.331	—	—	—	—	—	—	—	—	—	—
Lingual bone thickness (ΔT2–T1)	.168	.343	.140	.431	−.239	.180	−.040	.821	.195	.269	.032	.858	.075	.672	.021	.905	−.008	.966

[a] T0 indicates pretreatment; T1, posttreatment; T2, retention; ΔT1–T0, difference between T0 and T1 values; ΔT2–T1, difference between T1 and T2 values.
* $P < .05$; ** $P < .01$.

When evaluating the factors correlated with lingual bone thickness changes at the 6-mm root level (Table 3), the bone thickness decrease was positively correlated with crown and root distal movement after treatment. In contrast, an increase in lingual bone thickness during the retention period was not significantly related to crown and root movement, age at T1, or retention duration.

DISCUSSION

All samples demonstrated that the distal movement of the mandibular second molar root achieved after treatment was significantly greater than the posterior space at T0 at the 6-mm root level, leading to root-cortex contact and a significant decrease in lingual bone thickness (Figure 4). In addition, 11 samples exhibited radiographic bone dehiscence with the root protruding outside the outer cortex. This finding was consistent with previous research, which reported a critical decrease in lingual cortex thickness following considerable mandibular molar distalization with microimplants.[11] Extensive distalization of the entire dentition can result in a counterclockwise rotation of the mandibular occlusal plane, accompanied by molar intrusion.[8,15] Therefore, this simultaneous molar intrusion likely contributed to earlier root-cortex contact and a greater decrease in lingual bone thickness than expected, based on the T0 posterior space available.

At T2, the thinned lingual bone recovered critically with newly formed cortical bone (Figure 4). Intriguingly, the recovered lingual cortex, nevertheless, remained significantly thinner than the T0 cortex. This finding was in agreement with an earlier study on palatal bone changes after incisor retraction which demonstrated that the thickness of the palatal cortex that recovered during retention remained smaller than at pretreatment.[12] Once

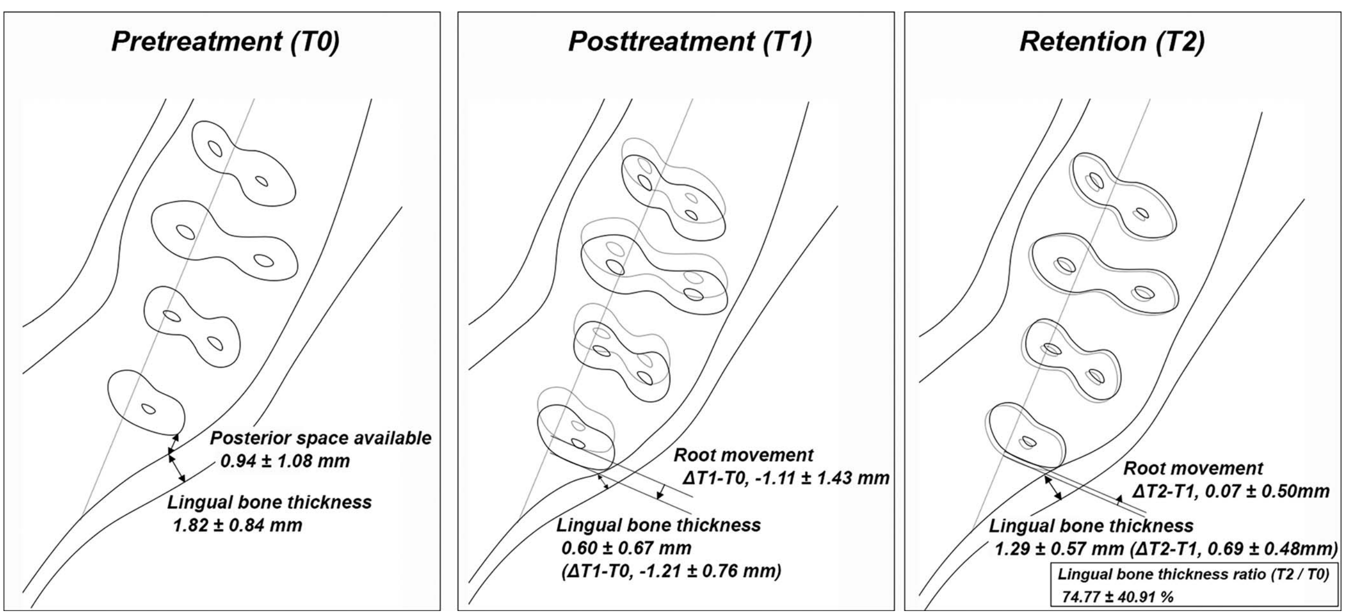

Figure 4. Changes in lingual bone thickness and root movement at 6-mm root level.

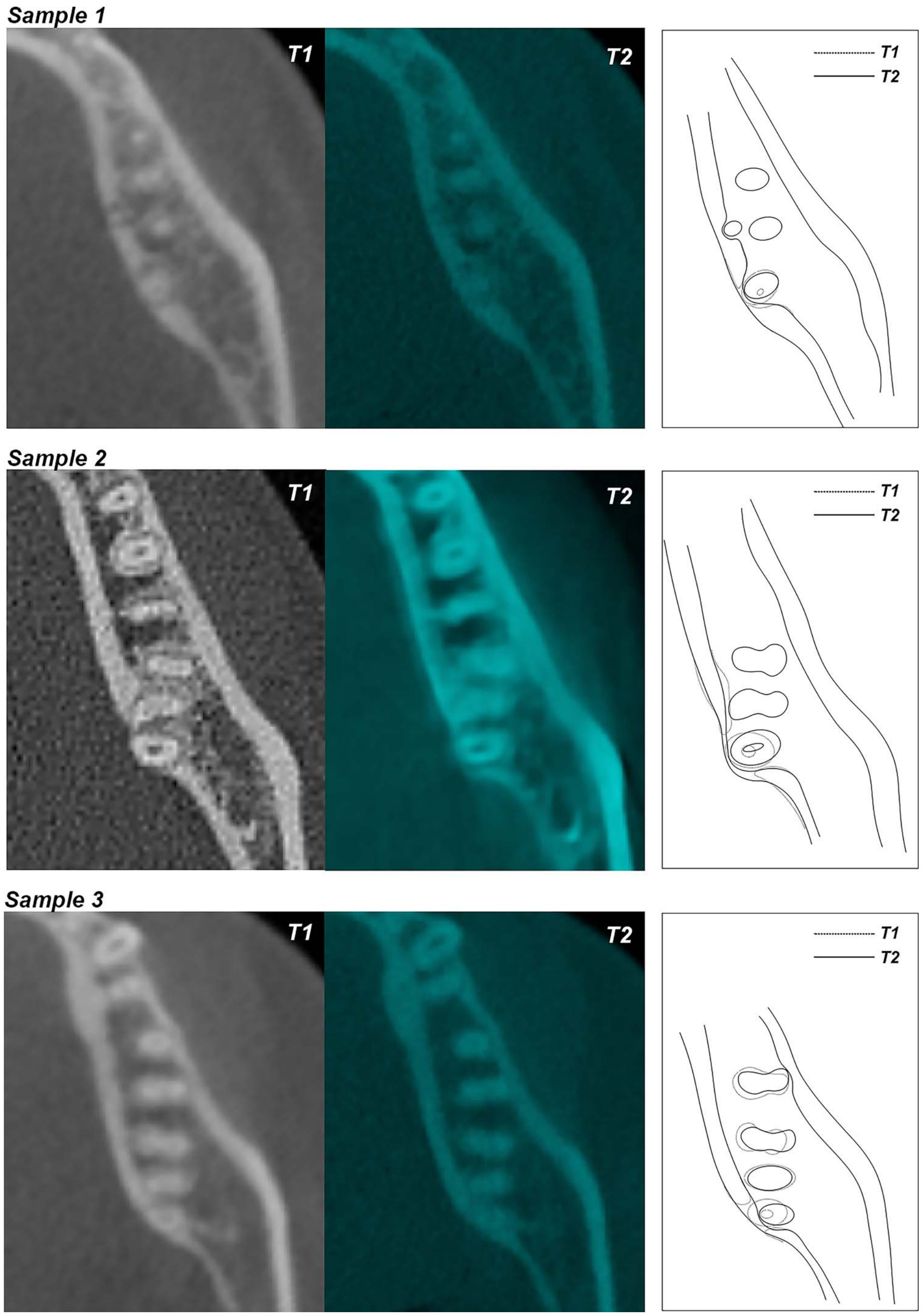

Figure 5. Three samples showing outer surface bone apposition during retention (at 6-mm root level) on lingual bone dehiscence caused by molar distalization. T1 indicates posttreatment; T2, retention.

the cortex is damaged by tooth movement, it is likely that bone tissue tends to maintain its integrity for alveolar bone homeostasis by forming a new cortical layer that reaches an adequate thickness to support the tooth against occlusal forces. This was also consistent with previous research suggesting that occlusal or mechanical forces are key triggers of alveolar bone remodeling.[18] Generally, higher forces are expected to increase cortical bone thickness and density.[19] In addition, the current finding that bone apposition was not correlated with retention duration suggests that lingual bone deposition continues until the bone reaches a minimal thickness sufficient for homeostasis, rather than returning to its original thickness.

During the retention period, the distalized mandibular molars moved forward slightly. This tooth movement back into the alveolar bone housing may have contributed to the thickening of the lingual cortex, as reported in a previous animal study, which showed that complete bone repair occurred once the root moved back into the cortical bone boundary.[20] However, in this study, compared with the amount of relapse tooth movement (ΔT2–T1, 0.07 $\pm$ 0.50 mm; Table 1) at the 6-mm root level, the corresponding increase in lingual bone thickness (ΔT2–T1, 0.69 $\pm$ 0.48 mm) was greater. In other words, the relapse of tooth movement back into the alveolar boundary may not fully explain the extent of new bone formation over the bone dehiscence. Additionally, five molars from four patients exhibited distal movement of the distolingual point during retention (Figure 3). This indicated that there was outer surface bone apposition at the distolingual point of the root that previously had protruded outside the lingual cortex (Figure 5). Accordingly, bone recovery formation might not merely be a repair process returning the bone to its initial state, but rather a homeostatic response to the altered root position, aimed at maintaining tooth position through supporting the bone structure.

None of the samples in this study exhibited any adverse clinical signs, such as gingival recession, root exposure, or severe tooth mobility. An intact periodontal ligament and periosteum can play a crucial role in promoting favorable bone regeneration over a bone dehiscence.[21,22] The posterior lingual gingiva tissue in the mandible is widely keratinized,[23,24] resistant to inflammation and traumatic damage.[25] However, detrimental changes in the lingual gingiva should be monitored, particularly since the molar distalization rate slows down due to root-cortex contact.[14] Although no critical root resorption was observed, possibly because of the mild-to-moderate extent of molar distalization in this study, clinicians should be aware that root-cortex contact during distalization can increase root resorption.[26,27]

This study may enhance the understanding of long-term bone recovery over radiographic dehiscence of the mandibular lingual cortex caused by considerable molar distalization. However, because of limitations of a small sample size and inclusion of growing patients, the current findings need to be interpreted carefully. Future research with larger sample sizes comparing bone recovery formation in adults and growing patients would be worthwhile to generalize these findings.

CONCLUSIONS

- The null hypothesis was rejected since lingual bone thickness changed during molar distalization and after retention.
- A significant decrease in lingual bone thickness was observed after mandibular molar distalization with microimplants.
- Thinned lingual cortical plate or radiographic bone dehiscence recovered with newly formed cortical bone during retention.
- The extent of recovery bone apposition was not correlated with the amount of tooth movement, retention duration, or patient age posttreatment.

REFERENCES

1. Proffit WR, Sarver DM. Combined surgical and orthodontic treatment. In: Proffit WR, Fields HW, Larson BE, Sarver DM, eds. *Contemporary Orthodontics*. 6th ed. St. Louis, Mo: Elsevier; 2019:657–709.
2. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae [published correction appears in *Angle Orthod*. 1996;66(4):246]. *Angle Orthod*. 1996;66:95–110.
3. Ahn NL, Park HS. Differences in distances between maxillary posterior root apices and the sinus floor according to skeletal pattern. *Am J Orthod Dentofacial Orthop*. 2017;152:811–819.
4. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. *Am J Orthod*. 1973;64:278–302.
5. Hung BQ, Hong M, Kyung HM, Kim HJ. Alveolar bone thickness and height changes following incisor retraction treatment with microimplants. *Angle Orthod*. 2022;92:497–504.
6. Begtrup A, Grønastøð HÁ, Christensen IJ, Kjær I. Predicting lower third molar eruption on panoramic radiographs after cephalometric comparison of profile and panoramic radiographs. *Eur J Orthod*. 2013;35:460–466.
7. Sable DL, Woods MG. Growth and treatment changes distal to the mandibular first molar: a lateral cephalometric study. *Angle Orthod*. 2004;74:367–374.
8. Kim HJ, Jang WS, Park HS. Anatomical limits for distalization of lower posterior molars with micro-implant anchorage. *J Clin Orthod*. 2019;53:305–313.
9. Choi YT, Kim YJ, Yang KS, Lee DY. Bone availability for mandibular molar distalization in adults with mandibular prognathism. *Angle Orthod*. 2018;88:52–57.
10. Kim SJ, Choi TH, Baik HS, Park YC, Lee KJ. Mandibular posterior anatomic limit for molar distalization. *Am J Orthod Dentofacial Orthop*. 2014;146:190–197.
11. Sun D, Kim HJ, Noh HK, Park HS. More molar distal movement than pretreatment cone-beam computed tomography posterior space available at the root level in mandibular dentition distalization with microimplants. *Angle Orthod*. 2024;94:623–630.
12. Kim HJ, Noh HK, Park HS. Recovery bone formation on radiographic palatal bone dehiscences after incisor retraction with microimplants. *Angle Orthod*. 2024;94:168–179.
13. Bae SM, Kim HJ, Kyung HM. Long-term changes of the anterior palatal alveolar bone after treatment with bialveolar protrusion, evaluated with computed tomography. *Am J Orthod Dentofacial Orthop*. 2018;153:108–117.
14. Kim HJ, Park HS. The potential for regeneration of mandibular lingual cortical bone after en masse molar distalization. *J Clin Orthod*. 2023;57:512–521.
15. Park HS. Distalization of entire dentitions with microimplants. In: Park HS, ed. *Efficient Use of Microimplants in Orthodontics*. Daegu, Koea: Dentos Co, Ltd; 2015; 75–145.
16. Koerich L, Weissheimer A, de Menezes LM, Lindauer SJ. Rapid 3D mandibular superimposition for growing patients. *Angle Orthod*. 2017;87:473–479.

17. Ruellas AC, Yatabe MS, Souki BQ, et al. 3D Mandibular superimposition: comparison of regions of reference for voxel-based registration. *PLoS One*. 2016;11:e0157625.
18. Naveh GR, Lev-Tov Chattah N, Zaslansky P, Shahar R, Weiner S. Tooth-PDL-bone complex: response to compressive loads encountered during mastication - a review. *Arch Oral Biol*. 2012;57:1575–1584.
19. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. *Am J Orthod Dentofacial Orthop*. 2012;142:170–178.
20. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. *Am J Orthod*. 1973;64:278–302.
21. Hosoya A, Ninomiya T, Hiraga T, et al. Potential of periodontal ligament cells to regenerate alveolar bone. *J Oral Biosci*. 2010;52:72–80.
22. Duong LT, Petit S, Kerner S, et al. Role of periosteum during healing of alveolar critical size bone defects in the mandible: a pilot study. *Clin Oral Investig*. 2023;27:4541–4552.
23. Voigt JP, Goran ML, Flesher RM. The width of lingual mandibular attached gingiva. *J Periodontol*. 1978;49:77–80.
24. Lang NP, Löe H. The relationship between the width of keratinized gingiva and gingival health. *J Periodontol*. 1972;43:623–627.
25. Malpartida-Carrillo V, Tinedo-Lopez PL, Guerrero ME, Amaya-Pajares SP, Özcan M, Rösing CK. Periodontal phenotype: A review of historical and current classifications evaluating different methods and characteristics. *J Esthet Restor Dent*. 2021;33:432–445.
26. Horiuchi A, Hotokezaka H, Kobayashi K. Correlation between cortical plate proximity and apical root resorption. *Am J Orthod Dentofacial Orthop*. 1998;114:311–318.
27. Amuk M, Gul Amuk N, Ozturk T. Effects of root-cortex relationship, root shape, and impaction side on treatment duration and root resorption of impacted canines. *Eur J Orthod*. 2021;43:508–515.