Original Article

Alveolar Bone Loss around Incisors in Surgical Skeletal Class III Patients

A Retrospective 3-D CBCT Study

Yoonji Kim[a]; Je Uk Park[b]; Yoon-Ah Kook[c]

ABSTRACT

Objective: To test the hypothesis that there is no difference in the vertical alveolar bone levels and alveolar bone thickness around the maxillary and mandibular central incisors in surgically treated skeletal Class III malocclusion patients.

Materials and Methods: The study sample comprised 20 Korean patients with skeletal Class III malocclusion with anterior crossbite and openbite (9 male, 11 female, mean ages 24.1). Three-dimensional cone beam computed tomography images were taken at least 1 month before the orthognathic surgery, and sagittal slices chosen at the labio-lingually widest point of the maxillary and mandibular right central incisor were evaluated. Measurement of the amount of vertical alveolar bone levels and alveolar bone thickness of the labial and lingual plate at the root apex was made using the SimPlant Pro 12.0 program.

Results: The mandibular incisors showed reduced vertical alveolar bone levels than the maxillary incisors, especially on the lingual side. The alveolar bone thickness was significantly greater on the lingual side in the maxillary incisors, whereas the mandibular incisors exhibited an opposite result ($P < .05$). The percentage of vertical bone loss to root length showed a statistically significant difference between the upper labial and lower labial alveolar bone and also between the upper lingual and lower lingual alveolar bone, showing more bone loss in the lower incisors ($P < .001$).

Conclusions: The hypothesis is rejected. For the skeletal Class III patients undergoing orthognathic surgery, special care should be taken to prevent or not aggravate preexisting alveolar bone loss in the anterior teeth, especially in the mandible. (*Angle Orthod.* 2009;79:676–682.)

KEY WORDS: Alveolar bone loss; Alveolar bone thickness; Central incisors; 3-D CBCT

INTRODUCTION

Because the advances in surgical technique have improved the predictability of orthognathic surgery, the number of adults electing orthodontic treatment combined with orthognathic surgery has increased over the years. With the improved esthetic facial and dental outcomes after surgery, however, periodontal problems such as bony dehiscence, fenestration, and gingival recession[1] are often encountered, and concerns for the adult periodontal problems must also increase.[2,3] From clinical observation, it appears that the occurrence of alveolar bone loss or fenestration is more common in these patients, especially in the lower anterior teeth.

Wehrbein et al[4] evaluated the alveolar bone/symphysis complex of deceased patients who were undergoing orthodontic treatment and found severe bone loss on the labial and lingual cortical plates. These bony defects were not evident on macroscopic inspection, and this can happen without excessive proclination of teeth in patients with narrow and high alveolar bones.[5] Unfortunately, little information about the alveolar bone loss in adult skeletal Class III patients undergoing orthognathic surgery is available.

Alveolar bone levels have traditionally been evalu-

[a] Clinical Fellow, Department of Orthodontics, Kangnam St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea.

[b] Associate Professor, Department of Craniomaxillofacial Surgery, Kangnam St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea.

[c] Associate Professor, Department of Orthodontics, Kangnam St. Mary's Hospital, The Catholic University of Korea, Seoul, Korea.

Corresponding author: Dr Yoon-Ah Kook, Associate Professor, Department of Orthodontics, Kangnam St. Mary's Hospital, The Catholic University of Korea, 505 Banpo-Dong, Seocho-Gu, Seoul, 137-701, Korea
(e-mail: kook2002@catholic.ac.kr)

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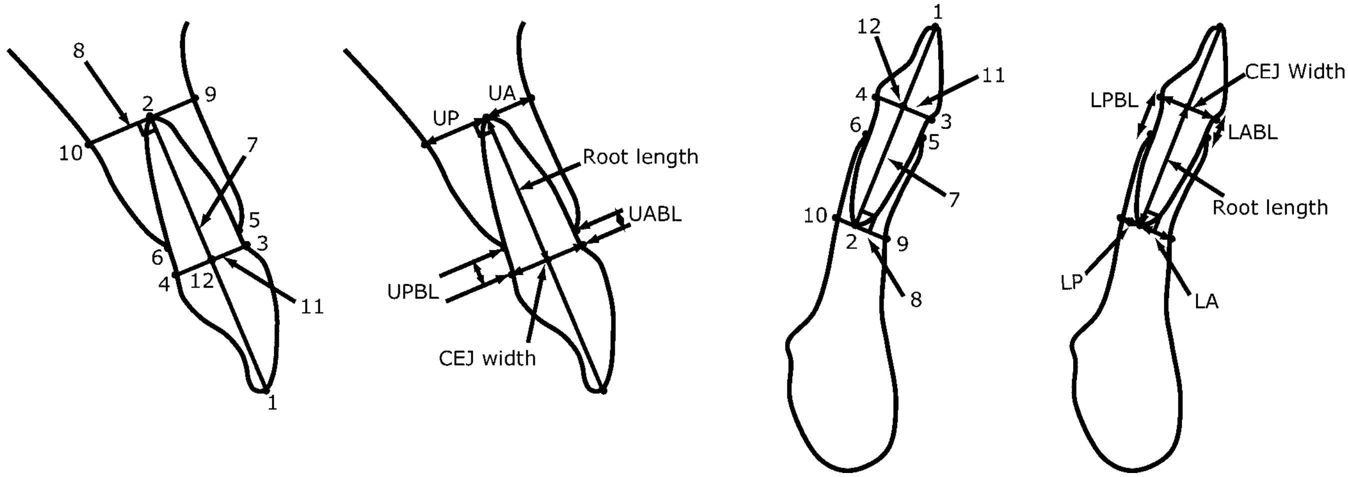

Figure 1. Illustrations of reference points, lines, and measurement variables used in this study.

ated with periapical[6,7] or bite-wing radiographs.[6,8] These standard dental films are difficult to standardize, and image distortion is inevitable due to the varied angulations of the x-ray source. They also do not allow for the evaluation of sites of dehiscence. Lateral cephalograms have also been used for the assessment of the alveolar bone of the anterior palate and symphysis.[9] Since the cortical plates of the palate and symphysis that are traced from cephalometric radiographs present a two-dimensional view of a concave surface, the actual limit of the palate and symphysis at the midline may be narrower than the traced images.[10,11] This may lead to an error of identification and reduced measurement accuracy.[12,13] Three-dimensional (3-D) cone beam computed tomography (CBCT), which was introduced in the late 1990s, has been remarkably useful in its intended craniofacial applications. The advantages of CBCT over conventional CT or dental films include low radiation dose, lower cost, excellent tissue contrast, elimination of blurring and overlapping of adjacent teeth, and high spatial resolution.[14–18]

The goal of this study was to evaluate the vertical alveolar bone levels and thickness around the maxillary and mandibular incisors of adult skeletal Class III patients by using 3-D CBCT images. The hypothesis of this study was that the bone loss is not different in the maxillary and mandibular incisors.

MATERIALS AND METHODS

Twenty patients (9 male, 11 female; mean ages 24.1) with skeletal Class III malocclusion treated at the Department of Maxillofacial Surgery at Kangnam St Mary's Hospital, Seoul, Korea, were recruited for this study. All were patients in whom BSSRO or BSSRO with Le Fort I surgery were indicated. Patients undergoing genioplasty only or with other craniofacial anomalies were excluded. The patients had an anterior crossbite and openbite with no incisor contact at maximum intercuspation before surgery. Because presurgical orthodontic treatment was completed, no crowding was present in the anterior teeth. The experimental protocols were approved by the Institutional Review Board.

Three-dimensional CBCT scans were made 1 month before orthognathic surgery with iCAT (Imaging Sciences International, Hatfield, Pa). The axial thickness was 0.4 mm and the voxels were isotopic. The obtained data were exported from the iCAT software in DICOM format into the SimPlant Pro 12.0 program (Materialise Dental NV, Leuven, Belgium), and 3-D reconstructions were made. Sagittal slices were evaluated where the maxillary or mandibular right central incisor was widest labio-lingually in the axial view. Additional cephalograms and panoramic radiographs were taken to aid surgical planning.

Measurement

Reference points, lines, and measurement variables used are described in Figure 1 and Tables 1 and 2. The measurements used in this study were modified from the report by Handelman[10] and Beckmann et al.[19] The alveolar crest (AC) was defined as the most coronal level of the alveolar bone.[6] The distances between the AC and the CEJ were measured at the labial and lingual surfaces of the maxillary and mandibular right central incisors, parallel to the long axis of the tooth. This represents the amount of vertical alveolar bone loss[20]; a given measurement was designated as UABL, UPBL, LABP, or LPBL according to its anteroposterior and upper-or-lower-arch position. Measurement of alveolar bone thickness at the root apex was made from the root apex to the limit of the alveolar cortex, perpendicular to the long axis of tooth, and these were indicated as UA, UP, LA, and LP, respec-

Table 1. Definitions of Reference Points and Lines Used in This Study

Reference Points and Lines	Definition
1	Incisal edge of upper or lower central incisor
2	Root apex of upper or lower central incisor
3	CEJ at labial side
4	CEJ at lingual side
5	Alveolar crest at labial side
6	Alveolar crest at lingual side
7	Long axis of the upper or lower central incisor
8	A line perpendicular to the long axis drawn at root apex
9	The point of intersection of a line perpendicular to the axis of the incisor, with the labial contour of maxilla or symphysis
10	The point of intersection of a line perpendicular to the axis of the incisor, with the lingual contour of maxilla or symphysis
11	A line connecting 3 and 4
12	The point of intersection of lines 7 and 11

tively. Additionally, the root length and CEJ width were assessed. Measurement was made using the SimPlant Pro 12.0 program, with images generated with maximum zoom according to the size of the incisors. With the measurements, the percentage of bone loss to the root length and percentage of alveolar bone thickness at the apex to CEJ width were calculated.

Statistical Analyses

All measurements were repeated after 2 weeks by the same investigator, and the mean of the two measurements was used in the statistical analysis. The systemic intra-examiner error between the two measurements was determined using a paired *t*-test. Also, the magnitude of the measurement error was assessed by calculating the intraclass correlation coefficient (ICC) based on a two-way mixed analysis of variance (ANOVA). For statistical analyses, Mann-Whitney *U*-test, Wilcoxon signed rank test, paired *t*-test, and repeated-measures ANOVA were used with a standard statistical software package (SAS version 8.02, Cary, NC). The $P < .05$ level of significance was chosen for all tests.

RESULTS

The systemic intra-examiner error was evaluated at $P < .05$ and found to be statistically insignificant. The ICC measurement indicated excellent reliability with a mean ICC of .919 (ICC = .76–.98).

Cephalometric characteristics of the samples are described in Table 3, and no significant difference was found in male versus female subjects (Mann-Whitney test). The mean and standard deviation for all measurement variables are shown in Table 4. No significant difference was found between males and females except for UP and lower CEJ width and, therefore, the combined data of the male and female were used. When comparing data having statistically significant differences between sexes, repeated-measures ANOVA was used to determine interaction due to sex.

Table 2. Definitions of Measurements Used

Measurement Variables	Definition
UABL, LABL	Upper or lower anterior bone loss; distance from 3 to 5 measured parallel to line 7
UPBL, LPBL	Upper or lower posterior bone loss; distance from 4 to 6 measured parallel to line 7
UA, LA	Upper or lower anterior alveolar bone thickness; distance from 2 to 9 measured perpendicular to line 7
UP, LP	Upper or lower posterior alveolar bone thickness; distance from 2 to 10 measured perpendicular to line 7
Root length	Distance from 2 to 12
CEJ width	Distance from 3 to 4
% UABL, % LABL	Percentage of upper or lower anterior bone loss to root length; UABL/root length × 100, LABL/root length × 100
% UPBL, % LPBL	Percentage of upper or lower posterior bone loss to root length; UPBL/root length × 100, LPBL/root length × 100
% UA + UP, % LA + LP	Percentage of alveolar bone thickness at apex to CEJ width; UA + UP/upper CEJ width × 100, LA + LP/lower CEJ width × 100

Vertical Alveolar Bone Level

The mean amount of vertical bone loss at the maxillary central incisor was 2.89 mm at the anterior (labial) and 3.83 mm at the posterior (lingual) side (Table 4). For the mandibular central incisors, the mean amount was 6.87 mm and 8.19 mm, respectively (Table 5). The amount of bone loss was significantly greater in the mandibular incisors than in the maxillary incisors, especially at the lingual alveolar plate (Figure 2A).

Alveolar Bone Thickness at Apex

The mean alveolar bone thickness at the tooth apex showed statistically significant differences between the labial and lingual sides ($P < .05$; Figure 2B; Tables 4 and 5). In the maxillary incisors, the lingual side bone thickness (UP; 5.22 mm) was greater than the labial side (UA; 3.61 mm), whereas the opposite was true in the mandibular incisors (3.45 mm and 2.13 mm for the labial and lingual side, respectively).

Table 3. Cephalometric Characteristics of the Sample

Measurements	Male		Female		Total		P
	Mean	SD	Mean	SD	Mean	SD	
Age	23.3	4.9	24.7	3.6	24.1	4.2	NS[a]
SNA	82.5	4.9	81.3	4.2	81.8	4.4	NS
SNB	86.1	6.9	84.8	4.0	85.4	5.4	NS
ANB difference	−3.6	3.2	−3.5	2.1	−3.6	2.6	NS
Wits	−11.5	6.1	−9.3	7.6	−10.3	6.9	NS
APDI	100.0	10.3	98.6	5.1	99.3	7.7	NS
Facial height ratio	67.6	3.7	64.9	5.7	66.1	4.9	NS
Mandibular plane angle	28.4	3.9	28.8	7.2	28.6	5.8	NS
U1 to FH	117.8	6.6	120.9	8.3	119.5	7.6	NS
IMPA	86.4	9.7	86.8	8.2	86.6	8.7	NS
Interincisal angle	127.4	10.7	123.7	11.0	125.3	10.7	NS

[a] NS indicates no statistical significance between male and female.

Percentage of Alveolar Bone Loss to Root Length

The percentage of alveolar bone loss to the root length was 28.94% (% UABL), 40.39% (% UPBL), 62.88% (% LABL), and 75.94% (% LPBL; Table 4 and 5). Because UP values showed statistically significant differences between males and females (Table 4), a comparison was performed with repeated-measures ANOVA, and no interactions were found between sexes. Therefore, the mean values of the total sample were used for comparison. Figure 3 illustrates significant differences between % UABL and % LABL and between % UPBL and % LPBL, indicating the mandibular incisors had more bone loss than the maxillary incisors relative to their respective root length.

The Percentage of Alveolar Bone Thickness at Apex to CEJ Width

The percentage of alveolar bone thickness at the apex of the incisors to CEJ width was 135.36% in the maxillary incisor and 93.77% in the mandibular incisors, indicating the alveolar bone thickness at the apex was wider than the CEJ width of the maxillary incisors, but narrower than that of the mandibular incisors (Figure 4).

DISCUSSION

The anatomic limits set by the cortical plates of the alveolus at the level of the incisor apices can be regarded as "orthodontic walls,"[10] and challenging these boundaries may accelerate iatrogenic sequelae such as alveolar bone resorption, fenestration, and gingival recession.[11,21] Previous research has shown that in the case of a narrow and high symphysis, pronounced sagittal or anteroposterior incisor movements during routine orthodontic treatment may be critical and lead to progressive bone loss of the lingual and labial cortical plates.[4]

Alveolar bone loss was more difficult to assess with periapical radiographs, especially in the anterior regions.[6] Crowding, rotated teeth, and poor angulation, as well as shortening of the root, made it difficult to determine the position of the CEJ and AC. Other investigations have determined alveolar bone height in relation to either root length or tooth length.[22] Since both methods can be affected by the amount of root

Table 4. Mean Values of the Alveolar Bone Loss of Maxillary Right Central Incisors

Measurements	Male		Female		Total		P
	Mean	SD	Mean	SD	Mean	SD	
UABL	2.36	1.32	3.31	3.60	2.89	2.79	NS[a]
UPBL	3.31	2.38	4.26	3.28	3.83	2.88	NS
UA	3.64	1.10	3.58	1.60	3.61	1.36	NS
UP	6.29	2.16	4.34	1.76	5.22	2.14	.04*
Root length	11.08	1.80	9.57	2.26	10.25	2.16	NS
CEJ width	6.70	0.52	6.32	0.37	6.49	0.47	NS
% UABL	23.86	17.20	33.10	30.32	28.94	25.12	NS
% UPBL	31.93	26.31	47.31	32.96	40.39	30.41	NS
% UA + UP	147.72	15.79	125.25	20.74	135.36	21.51	.01*

[a] NS indicates no statistical difference between male and female.
* $P < .05$.

Table 5. Mean Values of the Alveolar Bone Loss of Mandibular Right Central Incisors

	Male		Female		Total		
Measurements	Mean	SD	Mean	SD	Mean	SD	*P*
LABL	6.74	3.12	6.98	2.78	6.87	2.86	NS[a]
LPBL	8.32	3.16	8.09	1.96	8.19	2.50	NS
LA	3.81	1.70	3.15	1.10	3.45	1.41	NS
LP	2.44	1.88	1.88	0.88	2.13	1.41	NS
Root length	11.20	1.27	10.64	1.35	10.90	1.31	NS
CEJ width	6.15	0.34	5.75	0.48	5.93	0.46	.03*
% LABL	60.00	24.91	65.24	24.62	62.88	24.24	NS
% LPBL	75.76	30.47	76.09	16.55	75.94	23.13	NS
% LA + LP	101.69	32.04	87.29	17.86	93.77	25.57	NS

[a] NS indicates no statistical difference between male and female.
* $P < .05$.

resorption that occurs,[6] absolute and relative methods were used in this study with more accurate images of CBCT. All subjects received presurgical orthodontic treatment, and this may exclude the influence of crowding in the measurements. However, the amount and types of incisor movement during presurgical orthodontic treatment were not measured and could not be related to any differences in bone levels in this study. Further studies with larger samples will be able to address these relationships.

A CEJ-to-AC measurement ≤2 mm is considered normal by the results of earlier studies.[23–25] Considering this, the reduced amount of the vertical bone levels in the present sample is striking, especially the 8.19 mm of bone loss at the mandibular lingual plate. This means 75.94% of the root length is not covered by alveolar bone (Figures 2 and 3; Tables 4 and 5). The maxillary incisors had alveolar bone covering >70% of their root length at both labial and lingual sides, but the mandibular incisors had less than 40% covering their root length. Also, the horizontal bone thickness at the apex was only 2.13 mm at the lingual side of the mandibular incisors. Although the present study did not consider whether the reduced bone levels and thickness were preexisting or worsened during presurgical orthodontic treatment and did not assess the amount of tooth movement before, it is evident that the significantly reduced vertical height and horizontal thickness explains the risks of periodontal problems. Possible reasons for the increased level of bone loss are that the alveolar housing of the anterior palate or the symphysis was originally or developmentally thin-

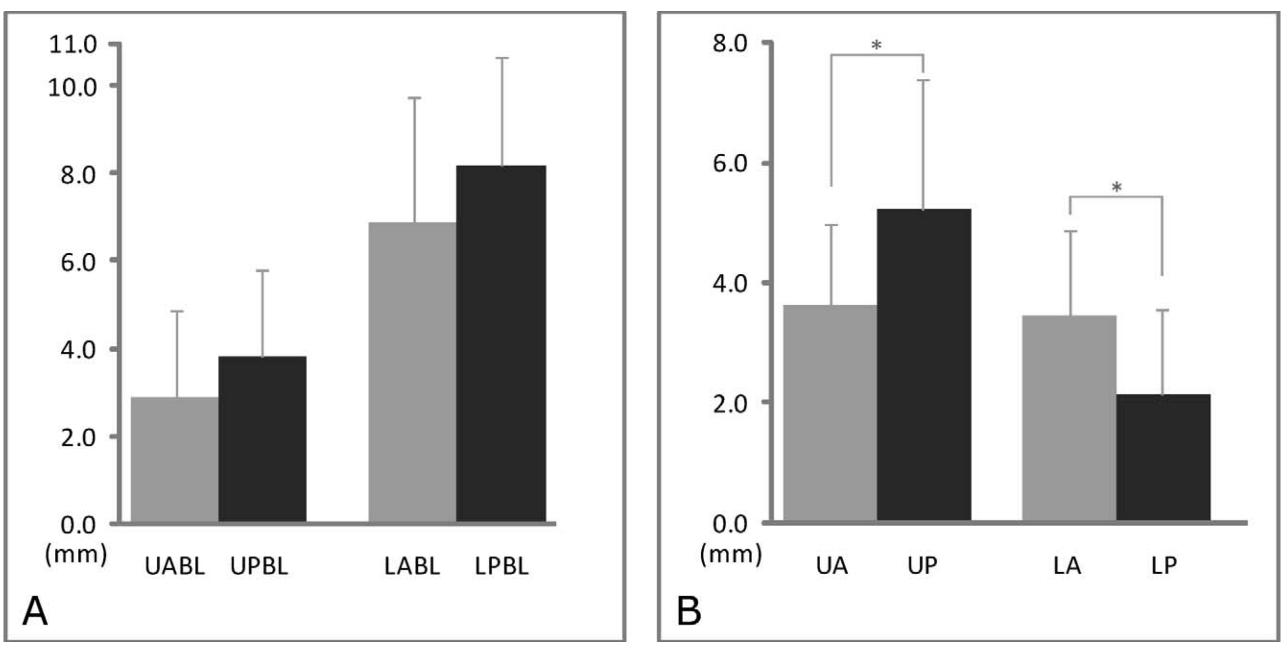

Figure 2. The amount of bone loss was greater in the mandibular incisors, especially in the lingual alveolar bone (A). Alveolar bone thickness at the apex was significantly greater in the lingual (palatal) side in the maxilla, whereas this was opposite in the mandibular incisor (B). The data are described as mean ± standard deviation, and Wilcoxon signed rank test was used. *$P < .05$.

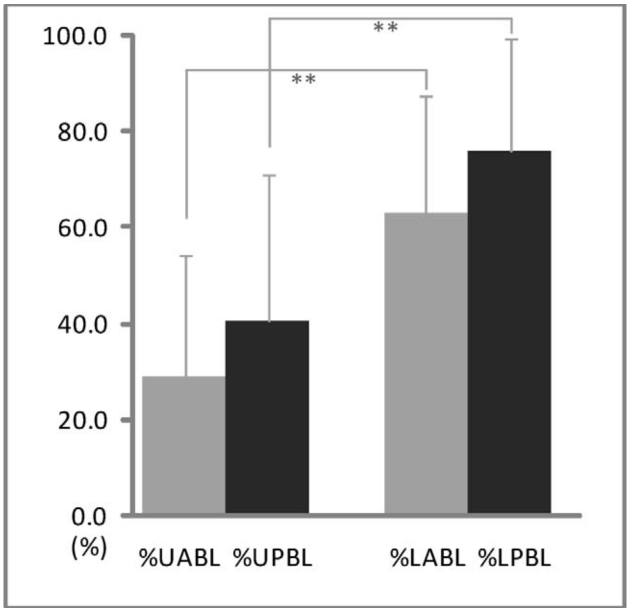

Figure 3. The percentage of alveolar bone loss to the root length was significantly greater in the mandibular labial than in the maxillary labial bone and also greater in the mandibular lingual than in the maxillary lingual bone (**$P < .01$). The data are described as mean ± standard deviation, and repeated-measures ANOVA was used.

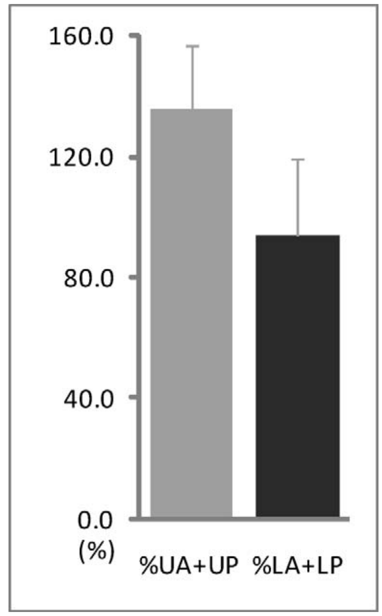

Figure 4. The alveolar bone thickness at tooth apex was greater than the CEJ width of the maxillary incisors, but thinner than that of the mandibular incisors. The data are described as mean ± standard deviation, and Wilcoxon signed rank test was used.

ner than others, and thus presurgical orthodontic treatment may have further exacerbated the problem.

A thin alveolus may be encountered in any skeletal type, but is most frequently encountered in patients with long lower face height and skeletal Class III.[10,19,26] In addition, statistically significant periodontal differences have been demonstrated in patients with crossbite, excessive overjet, and crowding compared with members of a control group.[27] Apparently, as a consequence of facial height increase, the incisors erupt to maintain overbite and the alveolus becomes attenuated, with thinning of the width between the labial and lingual walls. In addition, the anterior openbite with the skeletal Class III malocclusion group had significantly thinner symphyseal morphology when compared with the crossbite or control group in the study by Chung et al,[26] and this may explain the results of this study further. Due to the relatively small sample size, no further subgrouping or statistical tests were conducted to correlate the extent of bone loss with the facial height, mandibular plane, or cephalometric measurements. However, except for four individuals, all had a relatively high SN-MP angle (>27°), and all had anterior openbite.

It is interesting that the labio-lingual thickness at the apex of the lower incisor was narrower than the thickness of its CEJ (Figure 4), and the bone thickness was significantly less at the lingual side ($P < .05$; Figure 2B). Evaluation with 3-D CBCT revealed that the incisor roots were largely without cortical plate covering (data not shown). This may imply that movement at the mandibular incisor apex may result in the movement outside the alveolar housing in these patients, particularly movements like labial tipping. Therefore, greater attention should be paid to the movement of lower incisor in these patients.

The incidence of bone loss and root resorption in adult orthodontic patients is, in general, at a level that is clinically acceptable.[6,28] However, many investigators have suggested that excessive labial or lingual movement of maxillary and mandibular incisors should be avoided to prevent irreversible bone loss, which leaves the tooth with less bone support.[11,29,30] Combined with the results of this study, extreme orthodontic movement should be reconsidered according to the patient's anatomic limits and periodontal health, particularly in skeletal Class III adult patients. Further studies should address the association of reduced bone levels with predisposing factors and mechanical factors. Also, investigation with normal samples or untreated skeletal Class III samples would be required to provide a definitive comparison.

CONCLUSIONS

- The hypothesis is rejected. Vertical alveolar bone loss was more severe in the mandibular incisors than in the maxillary incisors, and the lingual alveolar bone showed increased bone loss.
- Alveolar bone width at the incisal apex was significantly thicker at the maxillary lingual side, but sig-

nificantly thinner at the mandibular lingual side. The bone thickness at the incisor root apex was wider than the maxillary incisor CEJ width, but narrower than the mandibular incisor CEJ width.

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