## **Original Article**

# Bone availability for mandibular molar distalization in adults with mandibular prognathism

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### ABSTRACT

**Objectives:** To investigate the retromolar space available for molar distalization in patients with mandibular prognathism.

**Materials and Methods:** Using cone-beam computed tomography, the posterior mandibular dimensions in 110 consecutive patients with Class I or Class III malocclusion were measured (mean age,  $27.0 \pm 7.1$  years). The shortest linear distances from the distal root of the right mandibular second molar to the inner border of the mandibular cortex were measured at the level of root furcation and 2, 4, and 6 mm apical to the furcation along the sagittal line and the posterior line of occlusion. The retromolar distances were compared between the Class I and Class III malocclusion groups using general linear mixed models.

**Results:** The retromolar space measured through the sagittal line showed no significant intergroup difference. Among the distances measured through the posterior line of occlusion, the space measured at depths 0 and 2 mm to the furcation were significantly greater in the Class III group than in the Class I group.

**Conclusions:** Patients with Class III malocclusion have greater retromolar space for mandibular molar distalization along the posterior line of occlusion only at the level of the second molar furcation. (*Angle Orthod.* 2018;88:52–57.)

**KEY WORDS:** Retromolar space; Molar distalization; Mandibular prognathism; Camouflage treatment

#### INTRODUCTION

The ideal treatment for mandibular prognathism in nongrowing patients involves surgical correction of the skeletal malposition. However, in patients with mild-to-moderate skeletal discrepancies who refuse to undergo orthognathic surgery, camouflage treatment may be used to achieve functional occlusion with a normal incisor overbite and overjet.<sup>1–3</sup>

The use of temporary anchorage devices for Class III camouflage treatment has enabled clinicians to distalize the whole lower dentition without unwanted adverse effects such as upper incisor proclination and extrusion of the maxillary molars. However, the amount of molar distalization is limited by the anatomy of the lingual surface of the posterior mandibular body.4 Although panoramic radiographs and lateral cephalographs have helped determine the amount of available retromolar space,5-8 these imaging approaches lack dimensional accuracy and provide limited views because of overlying anatomical structures.<sup>4,9,10</sup> Therefore, three-dimensional (3D) analysis with cone-beam computed tomography (CBCT) may be a more reliable method with which to analyze a region of interest accurately.11,12

The purpose of this study was to investigate the retromolar space available for molar distalization in patients with mandibular prognathism using CBCT. The null hypothesis was that the retromolar space available for tooth movement would not be different between patients with mandibular prognathism and patients with a normal skeletal relationship.

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#### MATERIALS AND METHODS

This retrospective, multicenter clinical study was approved by the institutional review board of the Korea University Anam Hospital (ED16007), and informed consent was obtained from all patients. The posterior mandibular dimensions were studied in all patients who had undergone CBCT for orthodontic diagnosis at S-Dain Dental Hospital or at Korea University Anam Hospital between September 2014 and August 2015. Patients had been diagnosed with Class I or Class III malocclusion and met the inclusion criteria. The inclusion criteria for the experimental group were the following: (1) age greater than 19 years; (2) mandibular prognathism (Angle Class III molar relationship, ANB angle less than 1°, anteroposterior dysplasia indicator [APDI] greater than 84°, and incisor overjet less than 0 mm); (3) no acute periodontitis, with alveolar bone level above the furcation of the mandibular molars; (4) no missing teeth, except for the third molars; and (5) crowding of less than 5 mm in the lower arch. The control group comprised healthy orthodontic patients who had undergone CBCT and were diagnosed with Class I malocclusion with a normal skeletal pattern, crowding of less than 5 mm, and overbite and overjet of 1-4 mm. The exclusion criteria were (1) a history of orthodontic treatment, (2) facial asymmetry (ie, menton deviation greater than 3 mm assessed by frontal cephalography with a midsagittal reference plane formed by the crista galli and anterior nasal spine [ANS], (3) craniofacial syndromes, and (4) a prosthesis in any of the molars. The study ultimately included 110 patients (49 and 61 patients with Class I and Class III malocclusions, respectively) with a mean age of 27.0 ± 7.1 vears.

The CBCT scans of the patients from S-Dain Dental Hospital were obtained using the Implagraphy scanner (Vatech Co, Hwaseong, Korea) at the following operation settings: tube voltage, 90 kV; tube current, 10 mA: scan time, 24 seconds: voxel size, 0.3 mm; and field of view, 12 cm  $\times$  8.5 cm. The CBCT scans of patients from Korea University Anam Hospital were obtained using the PaX-Uni3D scanner (Vatech Co) at the following settings: tube voltage, 90 kV; tube current. 10 mA: scan time. 13.2 seconds: voxel size. 0.3 mm; and field of view, 12 cm  $\times$  8.5 cm. Both CBCT machines had the same voxel size; therefore, we assumed no significant difference existed in the linear accuracy of the retromolar distances. The images were saved as Digital Imaging and Communications in Medicine files, which were used to reconstruct 3D images as multiplanar reformatted images using EZImplant 3D software (Vatech Co).

The reference plane for the reorientation of the 3D images was the mandibular occlusal plane, which

**Figure 1.** The planes used to measure the retromolar distances to the inner cortex of the posterior mandible. (A) The 0-plane, which is parallel to the lower occlusal plane that passes the furcation of the mandibular second molar root. (B) The 2-plane, (C) 4-plane, and (D) 6-plane, which are parallel to the 0-plane and located 2, 4, and 6 mm, respectively, below the 0-plane.

connected the mesiobuccal cusps of the mandibular first molars and the right mandibular central incisor tip. The plane parallel to the lower occlusal plane, which passed the furcation of the mandibular second molar root, was set as the "0-plane." Three additional planes, which were parallel to the 0-plane and located at 2, 4, and 6 mm apical to the 0-plane, were named the "2plane," "4-plane," and "6-plane," respectively (Figure 1). In each plane, two reference lines were used for measuring the retromolar dimensions: the sagittal line, which was parallel to the midsagittal reference plane (a plane that passes through the ANS, crista galli, and opisthion), and the cuspal line, which was defined as the line connecting the buccal cusps of the mandibular first and second molars (Figure 2). The shortest linear distances from the most lingual point of the distal root of the right second molar to the inner border of the mandibular cortex were measured (Figure 3). Linear distances were measured using EZImplant 3D software (Vatech Co).

To investigate the effects of cephalometric morphology on the retromolar distances, two-dimensional cephalometric images were derived from the CBCT scans by creating an orthogonal projection with parallel rays. The images were imported into cephalometric analysis software (V-ceph version 5.5; Osstem, Seoul, Korea) for conventional lateral cephalometric analysis. Cephalometric landmark identifications and linear measurements of the retromolar space were performed by the same investigator.

The retromolar distances of all patients were remeasured by the same researcher 2 weeks after the first measurements. Intraexaminer reliability analysis was conducted. The intraclass correlation coeffi-

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**Figure 2.** Reference lines used in this study. (A) The sagittal line that is parallel to the midsagittal reference plane (a plane that passes through the crista galli, anterior nasal spine, and opisthion) and (B) the cuspal line connecting the buccal cusps of the first and second molars.

cient was 0.926. To identify potential methodological errors (MEs), Dahlberg's formula was used, as follows:  $ME = \sqrt{d^2}/2n$  (in which *d* is the difference between the repeated measurements and *n* is the number of pairs of measurements). The ME for linear distances from the distal mandibular second molar root to the inner border of the mandibular cortex ranged from 0.21 mm for the distance along the sagittal line at the 4-plane to 0.55 mm for the distance along the cuspal line at the 2-plane.

#### **Statistical Analysis**

After deriving descriptive statistics, general linear mixed model analysis was used to compare the retromolar space between patients with mandibular prognathism and patients with a normal skeletal pattern. Various factors related to the patients' characteristics other than the type of malocclusion may have an influence on the retromolar space. Therefore, a general linear mixed model was applied to identify statistically significant factors that affected the retromolar space. Retromolar distances between the Class I and Class III groups, after controlling for the identified factors that significantly affected the retromolar space, were compared.

In the general linear mixed models, demographic characteristics (eg, age and sex), lateral cephalometric variables (SNA, SNB, ANB, APDI, body length, maxillary length, mandibular length, gonial angle, Frankfort mandibular plane angle [FMA], overbite depth indicator, overbite, overjet, interincisal angle, incisor-mandibular plane angle [IMPA], upper incisor



**Figure 3.** Definition of the retromolar space measured in this study. Distance from the most lingual point of the distal root of the right second molar to the (A) inner border of the mandibular cortex of the lingual bone along the sagittal line (B) the inner border of the mandibular cortex of the lingual bone along the cuspal line.

inclination, and occlusal plane angle), the measurement depth, and the reference lines of measurement as the covariates were considered. The significance of their main effects or interaction effects on the retromolar space was tested. As a result, the general linear mixed model was created with the outcome variable of the retromolar distance. The significance of the covariates was analyzed using the type III tests of the fixed effects.

Tukey-Kramer tests were then used to compare the estimates of the retromolar spaces at different depths between the Class I and Class III groups, with statistical significance set at P < .05. The statistical analyses were performed using SAS software (version 9.4; SAS Institute Inc, Cary, NC).

#### RESULTS

The mean age of the patients in the Class I and Class III groups was  $27.7\pm 9.5$  years and  $26.4\pm 4.4$  years, respectively (Table 1). The proportion of male and female patients was not significantly different between the experimental and control groups, as confirmed by Pearson's Chi-square test (P = .942; Table 1). The cephalometric analyses of the Class I and Class III groups and the independent *t*-test results for the comparison of each variable are shown in Table 2.

In the final models of the retromolar spaces, age, APDI, gonial angle, overbite, overjet, and upper incisor inclination were included as covariates for the retro-

#### Table 1. Patient Characteristics<sup>a</sup>

		Class I Group			Class III Group		
	Male	Female	Total	Male	Female	Total	<i>P</i> *
No. of patients, n Age, y (mean $\pm$ SD)	18 24.8 ± 8.2	31 29.3 ± 9.9	49 27.7 ± 9.5	22 26.8 ± 3.7	39 26.2 ± 4.8	61 26.4 ± 4.4	.942

<sup>a</sup> SD indicates standard deviation.

\* Statistical significance for the difference in sex distribution between the Class I and Class III groups, tested using Pearson's Chi-square test.

molar distance to the inner border of the mandibular cortex (Table 3). Sex was not significant as a single factor, but showed significant interaction effects with measurement depth (P < .001; Table 3) and was thus included in the linear mixed model as a fixed factor.

The means and standard deviations for the retromolar distance to the inner border of the mandibular cortex based on the two reference lines (ie, the sagittal and cuspal lines) and the statistical significance of the intergroup differences derived from the general linear mixed models are displayed in Table 4. No significant differences in the retromolar space measured through the sagittal line were observed between the Class I and Class III groups at all measurement depths (Table 4). Among the distances measured through the cuspal line, the space measured at depths 0 mm and 2 mm to the furcation were significantly greater in the Class III group than in the Class I group by 2.1 mm (P < .001) and 1.3 mm (P = .023), respectively (Table 4).

#### DISCUSSION

Mandibular molar distalization is limited by the proximity of the distal root of the second molar to the lingual cortical plate rather than by the distance from the crown of the second molar to the anterior border of the ramus.<sup>4</sup> Therefore, the retromolar distance at the root level was analyzed, and the distance between patients with mandibular prognathism and patients with a normal skeletal pattern was compared. It was

Table 2. Cephalometric Analyses of the Study Patients<sup>a</sup>

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	Class I Group (n = 49)	Class III Group (n = 61)	Р
SNA, °	$80.5\pm3.2$	$81.1\pm3.4$	.349
SNB, °	$78.3 \pm 3.4$	$81.6 \pm 3.4$	<.001
ANB, °	$2.2\pm1.3$	$-1.9 \pm 1.2$	<.001
APDI, °	$82.4~\pm~1.8$	$91.5\pm4.2$	<.001
Body length, mm	$79.4~\pm~5.5$	$81.2\pm5.5$	.465
Gonial angle, °	$120.4 \pm 6.3$	$122.9 \pm 7.2$	.067
FMA, °	$25.7~\pm~5.5$	$26.8\pm6.1$	.364
Overbite, mm	$1.8 \pm 1.8$	$1.3\pm1.6$	.113
Overjet, mm,	$3.3 \pm 1.6$	$-1.5 \pm 0.8$	<.001
IMPA, °	94.8 ± 7.4	87.7 ± 7.2	<.001
U1-SN, °	$103.8\pm5.9$	$112.0\pm7.6$	<.001

 $^{\rm a}$  APDI indicates anteroposterior dysplasia indicator; IMPA, incisor mandibular plane angle; U1-SN, upper incisor to sella-nasion plane; and FMA, Frankfort mandibular plane angle. All data are presented as the mean  $\pm$  standard deviation.

expected that the retromolar space would be greater in patients with Class III malocclusion than in patients with Class I malocclusion because Class III malocclusion is characterized by a large mandible. However, various factors affect the outcome, such as cephalometric characteristics, age, and sex, and these factors can act as confounders. Using general linear mixed model analysis, it was possible to compare the retromolar distances between patients with mandibular prognathism and patients with normal mandibular growth after adjusting for factors that significantly affected the outcome.

It was assumed that patients who had third molars would undergo extraction prior to molar distalization. Therefore, the retromolar space was measured without considering the presence of the third molars. In patients with impacted third molars, the third molar crowns were often located in the anterior part of the ramus, as there was limited space for eruption, and they were expected to have a minimal effect on retromolar space distal to the second molar root.

For the third molars that had erupted, it was assumed that extraction would not cause significant bony changes in the lingual cortical border of the mandible. According to Kim et al.,<sup>4</sup> the presence of

 $\label{eq:table3.} \begin{tabular}{ll} \begin{tabular}{ll} Table 3. \end{tabular} Type III Tests of Fixed Effects in the General Linear Model with Regard to the Variables That Affect the Retromolar Distance^a \end{tabular}$ 

Effect	Num DF	Den DF	F	Р
Age	1	103	8.94	.004
Sex	1	103	0.86	.356
APDI	1	675	4.17	.042
Gonial angle	1	675	9.80	.002
Overbite	1	675	3.22	.073
Overjet	1	675	5.76	.017
U1-SN	1	675	3.37	.067
Class	1	103	1.79	.184
Depth	3	282	40.08	<.001
Reference line	1	105	335.70	<.001
Class $ imes$ depth	3	282	7.57	<.001
Sex  imes depth	3	282	6.93	<.001
Class $\times$ reference line	1	105	14.18	<.001

<sup>a</sup> "Class" is the type of malocclusion—Class III (ie, the experimental group) or Class I (ie, the control group); "Depth" is the depth at which the retromolar distance was measured. Den DF indicates denominator degrees of freedom; Num DF, numerator degrees of freedom; APDI, anteroposterior dysplasia indicator; and U1-SN, upper incisor to sella-nasion plane.

Table 4. Mean Retromolar Distance Measured Through the Sagittal and Cuspal Lines (Mean  $\pm$  SD, mm)<sup>a</sup>

	D	Distance Measured Through the Sagittal Line				Distance Measured Through the Cuspal Line						
Depth	epth Class I		Class III		Difference*	P **	Class I		Class III		Difference*	P**
0	2.2 ± 1.8	(n = 49)	2.6 ± 1.6	(n = 61)	-0.6	.282	4.0 ± 3.3	(n = 49)	6.0 ± 3.3	(n = 61)	-2.1	<.001
2	$2.0\pm1.6$	(n = 49)	$2.2\pm1.4$	(n = 61)	-0.3	.570	$3.7\pm3.0$	(n = 49)	$4.9\pm2.9$	(n = 61)	-1.3	.023
4	$1.7 \pm 1.5$	(n = 47)	$1.9 \pm 1.5$	(n = 61)	-0.3	.592	$2.8\pm2.4$	(n = 47)	$3.8\pm2.8$	(n = 61)	-1.0	.066
6	$2.1\pm1.7$	(n = 35)	$1.4\pm1.5$	(n = 46)	0.1	.822	$3.4\pm2.6$	(n = 35)	$2.7\pm2.8$	(n = 46)	0.2	.786

<sup>a</sup> All data are presented as the mean  $\pm$  the standard deviation (in millimeters).

"Depth" is the depth at which the retromolar distance was measured; "0" is the depth at the level of the furcation of the mandibular second molar root; "2", "4", and "6" are the depth at the levels 2 mm, 4 mm, and 6 mm apical to the furcation of the mandibular second molar root. \* The estimated difference of the retromolar distances between Class I and Class III, as derived from general linear model analysis; \*\* The data are adjusted using the Tukey-Kramer method for multiple comparisons.

mandibular third molars had no significant effect on the retromolar space measured in patients with Class III malocclusions. For patients whose third molars were missing, it could not be confirmed that the third molars were extracted or whether they were congenitally missing because of the retrospective nature of this study.

Because mandibular prognathism characterizes the anteroposterior relationship of the jaws, the effects of different vertical patterns were controlled for by including the gonial angle and overbite in the final model. In addition, incisor characteristics such as overbite, overjet, and upper incisor inclination were found to have a significant effect on the retromolar space, while IMPA had no significant effect. However, we believe that the effects of the incisor characteristics were the result of dentoalveolar compensation for the different skeletal patterns observed in these patients. Their statistical significance was relatively low, which indicates that they may not have a direct relationship with the retromolar space. Nevertheless, further study is warranted to confirm this speculation.

Two reference lines were used to measure the retromolar space: the sagittal line and the cuspal line. The sagittal reference line was implemented because it is an anatomically stable reference line that can be located with great accuracy and reliability. However, the mandibular second molars would be distalized along the posterior line of occlusion, and the retromolar space along the posterior line of occlusion is the region of interest for clinicians. Therefore, an additional reference line, the cuspal line, was defined to investigate the posterior space that is clinically relevant. At the same measurement depth, the retromolar distances measured using the two reference lines were highly correlated, with Pearson's correlation coefficients ranging from 0.805 (0-mm depth, P < .001) to 0.889 (6-mm depth, P < .001).

The retromolar space was significantly greater in the Class III group only at the furcation level and 2 mm apical to the furcation. This difference was only valid when the space was measured along the posterior line of occlusion. Moreover, although the differences showed high statistical significance, the amount of the difference ranged from 1.3 mm to 2.1 mm, below the clinically significant amount.

The mean distance along the posterior line of occlusion in the Class III group was 6.0  $\pm$  3.3 mm for the furcation level and decreased to 2.7  $\pm$  2.8 mm as the measurement depth increased to 6 mm apical to the furcation. This pattern of space decrease in the Class III group indicates that there was less space for distalizing the root apex. In contrast, the Class I group did not show a significant pattern of space decrease. This may have been related to the mandibular morphology of the patients with Class III malocclusions, in whom the "V" shape of the mandible is more divergent in the apex than in the furcation, with a lingually inclined mandibular body and a more laterally placed ramus. In previous reports<sup>13–16</sup> of clinical cases, the amount of molar distalization performed for the treatment of Class III malocclusion was as much as 6 mm. This amount is similar to the mean retromolar space assessed at the furcation level in the current study, but the patients had relatively high standard deviations for the observed retromolar spaces. Therefore, patients who require substantial amounts of molar distalization may need to have their bone availability evaluated before undergoing treatment. In addition, appropriate mechanics may need to be planned to control molar angulation during retraction. Mandibular molars tip distally to varying degrees when a distalizing force is applied because the force vector is above the center of resistance of the mandibular dentition,<sup>14</sup> which results in greater distalization of the crown than of the root. This type of movement may be favorable in cases in which bone availability decreases at the apical level. However, it should be noted that distal tipping may only be favorable in cases of mesially angulated molars that require distal uprighting to obtain a proper functional occlusion.

The limitations of this study were that it was a retrospective study and that the number of patients was greater in the Class III group (n = 61) than in the

Class I group (n = 49). In addition, the study group had a higher percentage of female patients. Therefore, future studies with a similar number of male and female patients may be warranted to investigate the effect of sex on retromolar distance. Incisor characteristics (overbite, overjet, and upper incisor inclination) were correlated with the retromolar space; therefore, further studies may investigate possible additional factors that affect the retromolar space, such as the amount of crowding, arch dimensions, and molar inclinations.

Another anatomical limit for molar distalization is the inferior alveolar nerve canal, because the superior border of the inferior alveolar nerve canal may restrict the distalization of the second molar root at the apex. Therefore, 3D morphometric analysis of the mandible may provide a better understanding of the mandibular anatomy and its correlations with the posterior mandibular space available for molar distalization.

#### CONCLUSIONS

- The available space for mandibular molar distalization measured from the distal root of the second molars to the inner border of the mandibular cortical bone was affected by age, sex, and skeletal and dental patterns.
- Compared to patients with Class I malocclusions, patients with Class III malocclusions had greater retromolar space for distalization along the posterior line of occlusion only at the level of the second molar furcation.

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