Original Article

Anatomical limitations and factors influencing molar distalization

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ABSTRACT

Objectives: To analyze the anatomical limitations and characteristics of maxillary and mandibular retromolar regions affecting molar distalization using cone-beam computed tomography (CBCT).

Materials and Methods: A total of 120 qualifying patients were classified into equal groups of skeletal Class II and Class III and stratified by vertical growth pattern, age, sex, and third molar presence. The available distance along the axis of distalization and cortical bone thickness (CBT) were measured in the maxillary and mandibular retromolar regions of Class II and Class III patients, respectively. One-way analysis of variance was used to examine the effects of the factors on the measured data.

Results: The minimum available distance of the Class II maxilla was observed at a level 3 mm from the cementoenamel junction (CEJ), while that of the Class III mandible was at a level 9 mm from the CEJ. The average available distance at the limit level was 4.06 ± 1.93 mm in the Class II maxilla, and the average corresponding CBT was 1.00 mm. The average available distance at the limit level in the Class III mandible was 2.80 ± 1.96 mm, and the corresponding CBT was 2.24 mm. In both skeletal Class II and Class III patients, hyperdivergent groups had the least available distance for molar distalization.

Conclusions: The limit for available distance in the Class II maxilla is closer to the coronal level, while that of the Class III mandible is closer to the apical level. A hyperdivergent growth pattern in a patient is indicative of less potential for molar distalization. Axial slices of CBCT images provide valuable evaluation for molar distalization regarding limit levels. (*Angle Orthod.* 2022;92:598–605.)

KEY WORDS: Retromolar region; Molar distalization; Vertical growth pattern; CBCT

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INTRODUCTION

Molar distalization can relieve dental crowding when neither arch expansion nor labial inclination can obtain a stable space for nonextraction orthodontic treatment.[1] It involves moving molars into the posterior region of the alveolar bone, yet molars can be distalized only as far as there is an effective bony envelope to house the roots. The success of such treatment depends strongly on the clinician's thorough understanding of the topography of the region, exceeding which will result in periodontal complications such as dehiscence, orthodontically induced root resorption, and tooth mobility.[2,3] Therefore, the boundaries of the posterior alveolar region are an important factor to consider in the treatment planning of molar distalization.

Previous studies on retromolar regions revealed variations in the distance available for molar distalization. Yamada et al.[4] found that the average available distance in the maxilla was 2.8 ± 1.6 mm by using miniscrew implants and Jing et al.[5] reported 4.85 ± 1.78 mm in the mandible. Previous studies on cortical bone thickness (CBT) were done with the intention of providing clinical guidance for temporary anchorage

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Table 1. Eligibility Criteria

Inclusion	Exclusion
Of Chinese ethnicity	History of orthodontic treatment
Between the ages of 18 and 35 years	One or more missing teeth (except third molars)
Healthy periodontal status, no observable alveolar bone loss	Dental prosthetics present
Minimal crowding on both arches	Caries or filling on first and second molars
Occlusal relations in harmony with skeletal relations	Abnormal interdigitation between molars
	Observable facial asymmetry
	Observable dentofacial disease
	Indication for orthognathic surgery or extraction orthodontic treatment

device insertion[6,7] and were limited to temporary anchorage device insertion sites, neglecting the retromolar region. With the application of three-dimensional cone-beam computed tomography (CBCT), an accurate representation of the retromolar region anatomy is possible, down to the interroot distance and CBT.[8]

Recently, a study compared the mandibular retromolar space among skeletal Class I subjects with different vertical divergence.[9] However, the clinical indication for molar distalization is most common in patients presenting with malocclusions caused by mild anteroposterior skeletal discrepancy who need orthodontic compensation to achieve a neutrocclusive molar relationship.[10,11] To date, research on the retromolar regions of mild skeletal Class II and Class III with different vertical growth patterns is lacking.

The purpose of this study was to investigate the available distance and corresponding CBT in the retromolar regions of mild Class II maxilla and Class III mandible and to understand the anatomical limitations and influencing factors of maxillary and mandibular molar distalization in orthodontic treatment.

MATERIALS AND METHODS

The present cross-sectional retrospective study was approved by the ethics committee of the West China Hospital of Stomatology Institutional Review Board. The retromolar regions were studied in all patients who had CBCT taken for orthodontic diagnosis between 2014 and 2019 from the Department of Orthodontics. The inclusion criteria are listed in Table 1. The mean patient age as 25.7 $\pm$ 4.5 and 23.6 $\pm$ 3.9 years in the Class II and Class III groups, respectively. Patients selected for this study consisted of equal numbers of those with mild skeletal Class II ($4° < \text{ANB} < 8°$) and mild skeletal Class III ($0° < \text{ANB} < 2°$).[12] Within both groups, patients were divided by vertical growth pattern into hypodivergent, hyperdivergent, and normodivergent at a ratio of 1:1:1 based on cephalometric analysis: hypodivergent (S-N/Go-Gn $< 27°$, FHI $>$ 69%), normodivergent ($27° <$ S-N/Go-Gn $< 36°$, 61% $<$ FHI $<$ 69%), and hyperdivergent (S-N/Go-Gn $>36°$, FHI $<61\%$).[13] Sex proportion was controlled at a ratio of 1:1 in each subgroup. This selection process resulted in a final sample size of 120.

The CBCT scans were obtained using the 3D Accutomo XYZ Slice View Tomograph (J.Morita MFG Group, Tokyo, Japan) with the following settings: 90 kVp, 5.0 mA, 17.5-second scan time, and 60- $\times$ 60-cm image area. The images were saved as DICOM files, each with a slice thickness of 0.25 mm. The DICOM data were then uploaded into Mimics 16.0 software (Materialise, Leuven, Belgium), and standardized initial orientations of the images were made in the midsagittal, frontal, and occlusal planes (Figure 1A). All measurements were taken on either the left or right side, with the allocation determined by a random-number generator stratifying patients into either group 1 or 0 with a 1:1 distribution ratio. A posterior occlusal line (POL) connecting the buccal cusps of the first and second molars at the occlusal level was drawn.[8] This represented the axis of distalization (AOD) along the dental arch. Further orientations were then made to ensure that the measurements reflected clinical orthodontic tooth movement (first and second molar tooth axis perpendicular to occlusal plane): from the coronal view, the midsagittal plane was made to be parallel to the POL (Figure 1B,D), and from the sagittal view, the normal axis was made to be parallel to the POL (Figure 1C,1E).

An axial plane passing through the distalmost point of the cementoenamal junction of the maxillary second molar and parallel to the POL was set as U_A0 on the sagittal slice. U_A3, U_A6, and U_A9 were then defined as the parallel planes that were translated 3 mm, 6 mm, and 9 mm apically to the U_A0, respectively. The same applied for the four mandibular levels, namely, L_A0, L_A3, L_A6, and L_A9 (Figure 2). The measurements of the available distance were made parallel to the POL on these three levels in both the maxilla and mandible and defined in the maxilla as the distance from the buccalmost point on the distobuccal root of the second molar to the inner buccal cortex of the maxillary tuberosity "a" and, in the mandible, as the distance from the lingualmost point on the distal root of the second mandibular molar to the inner lingual cortex of the mandibular body "b" (Figure 3). The levels with

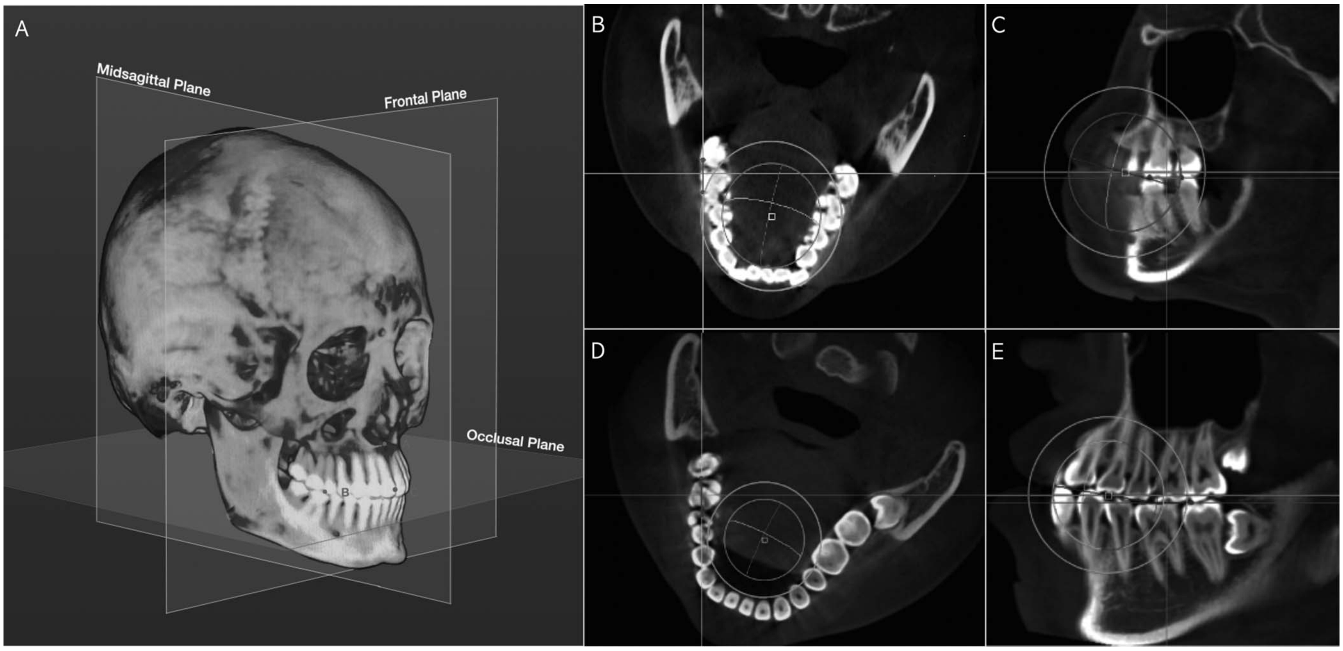

Figure 1. Reference planes used in this study. (A) Reference planes and landmarks for initial orientation: A, anterior nasal spine; B, mesiobuccal cusp of the mandibular first molar; C, midpoint of the two mandibular central incisor tips. Further orientations to mimic clinical orthodontic tooth movement: in the Class II maxilla (B, C), and Class III mandible (D, E).

minimum available distances (ie, "limit levels") were observed.

From the axial slices, U_C0 was set as the coronal level passing through the distalmost point on the distobuccal root of the maxillary second molar and perpendicular to the POL. Six additional levels were then set based on U_C0, each with an increment of 1.5 mm distally, namely, $U_C1.5$, U_C3, $U_C4.5$, U_C6, $U_C7.5$, and U_C9. The same method applied for loci on the mandible, creating L_C0, which passed through the distalmost point on the distal root of the mandibular second molar, $L_C1.5$, L_C3, $L_C4.5$, L_C6, $L_C7.5$, and L_C9. With reference to the planes of the available distance, CBT was measured at $3 \times 7 = 21$ loci both in the maxilla and mandible (Figure 4).[14] CBT at the loci corresponding to the available distances at limit levels were observed. Definitions of abbreviations are provided (Supplemental Table 1).

Statistical Analysis

All measurements were made twice, 2 weeks apart, by the same examiner who was blind to the vertical growth pattern of the patients. SPSS 21.0 software was used to analyze the measured data, and $P < .05$ was considered statistically significant. Paired *t* test ($P < .05$) and interclass correlation coefficient ($>.75$) verified the reproducibility and consistency of both measurements, and the average value was taken. Descriptive statistics were analyzed to establish means

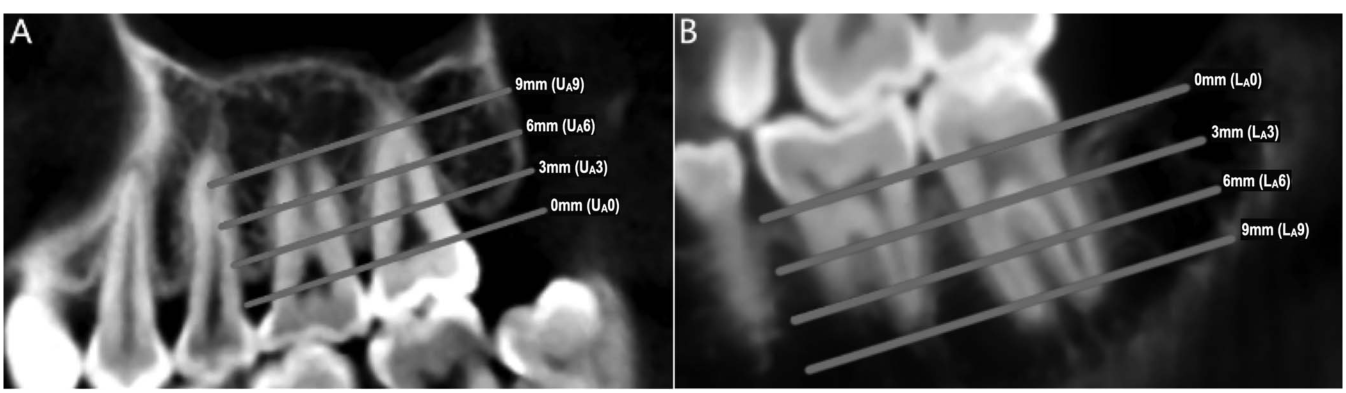

Figure 2. Planes used to assist measurements in the maxillary and mandibular retromolar space. (A) Measurement levels on the maxilla and (B) mandible.

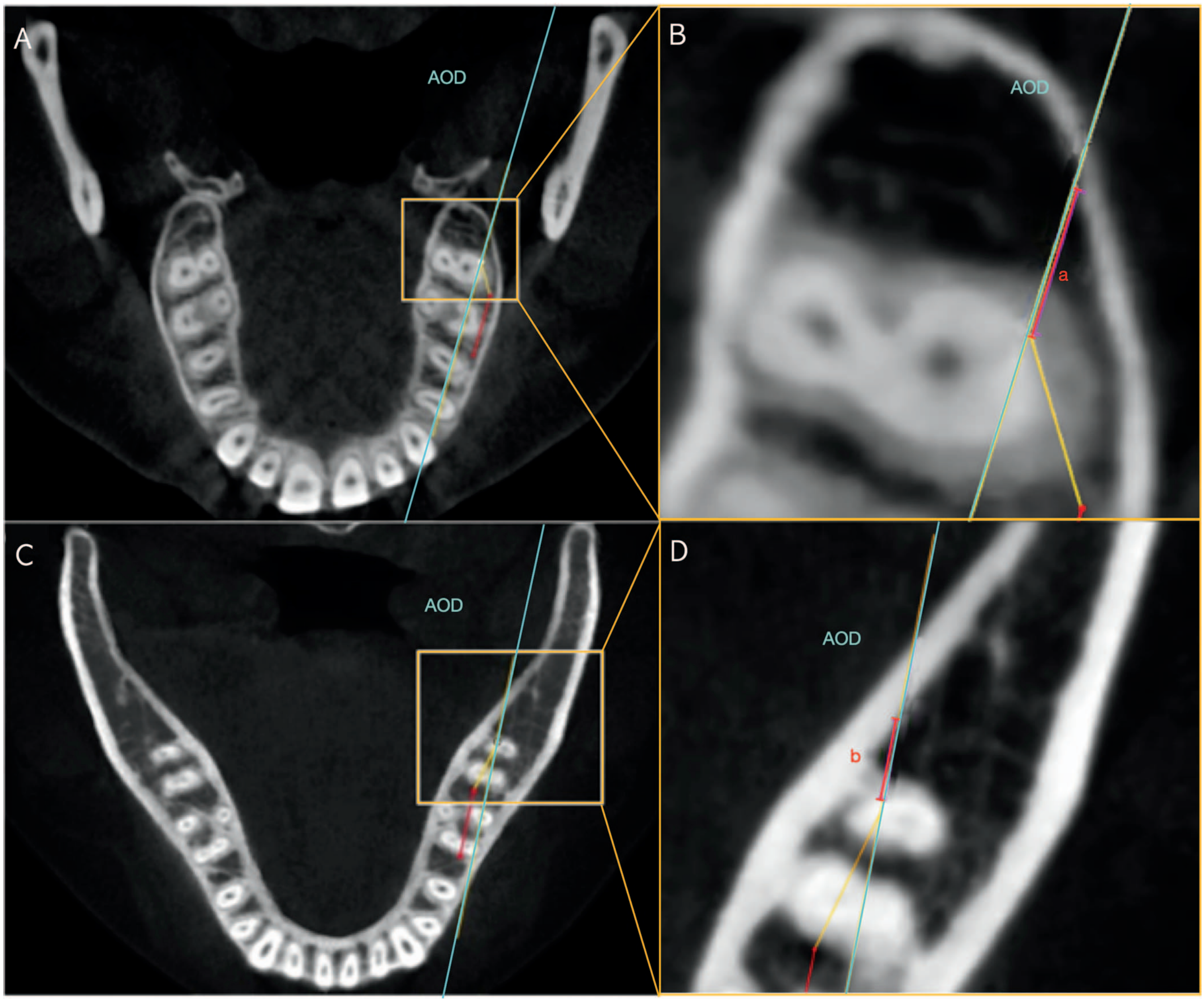

Figure 3. Measurement of available distance in the maxillary and mandibular retromolar region. (A) Axial slice at the maxillary molar root level: red line, posterior occlusal line (POL); cyan line, parallel to POL and extending from the buccalmost point on the distobuccal root of maxillary second molar. (B) Magnified view of the yellow box in A: a, available distance in maxilla. (C) Axial slice at the mandibular root level. (D) Magnified view of the yellow box in C: b, distance along the axis of distalization between the lingualmost point on the distal root of the mandibular second molar and inner lingual cortex of the mandibular body envelope.

and standard deviations. Multivariate analysis of variance (MANOVA) was used to investigate the interactions between vertical growth patterns, levels of measurement, sex, age, and the presence or absence of the third molar. Since the MANOVA showed no statistically significant interaction among these factors on the whole, one-way analysis of variance (ANOVA) was conducted to define the relationships between measured data and examined factors, and the Tukey least significant difference test was used for pairwise comparison between groupings that showed statistically significant differences ($P < .01$).

RESULTS

The values of available distance were normally distributed in age, sex, and presence of third molar groupings, with no significant intragroup differences ($P > .05$; Table 2). Pearson chi-square test demonstrated no statistically significant difference in the constituent ratios of third molar absent/present groups among the three vertical growth patterns in Class II and Class III subjects ($P = .108$, $P = .119$, respectively).

One-way ANOVA and pairwise comparisons of the available distance between levels showed that levels U_A3 in the maxilla and L_A9 in the mandible were significantly smaller than those of U_A9 and L_A3,

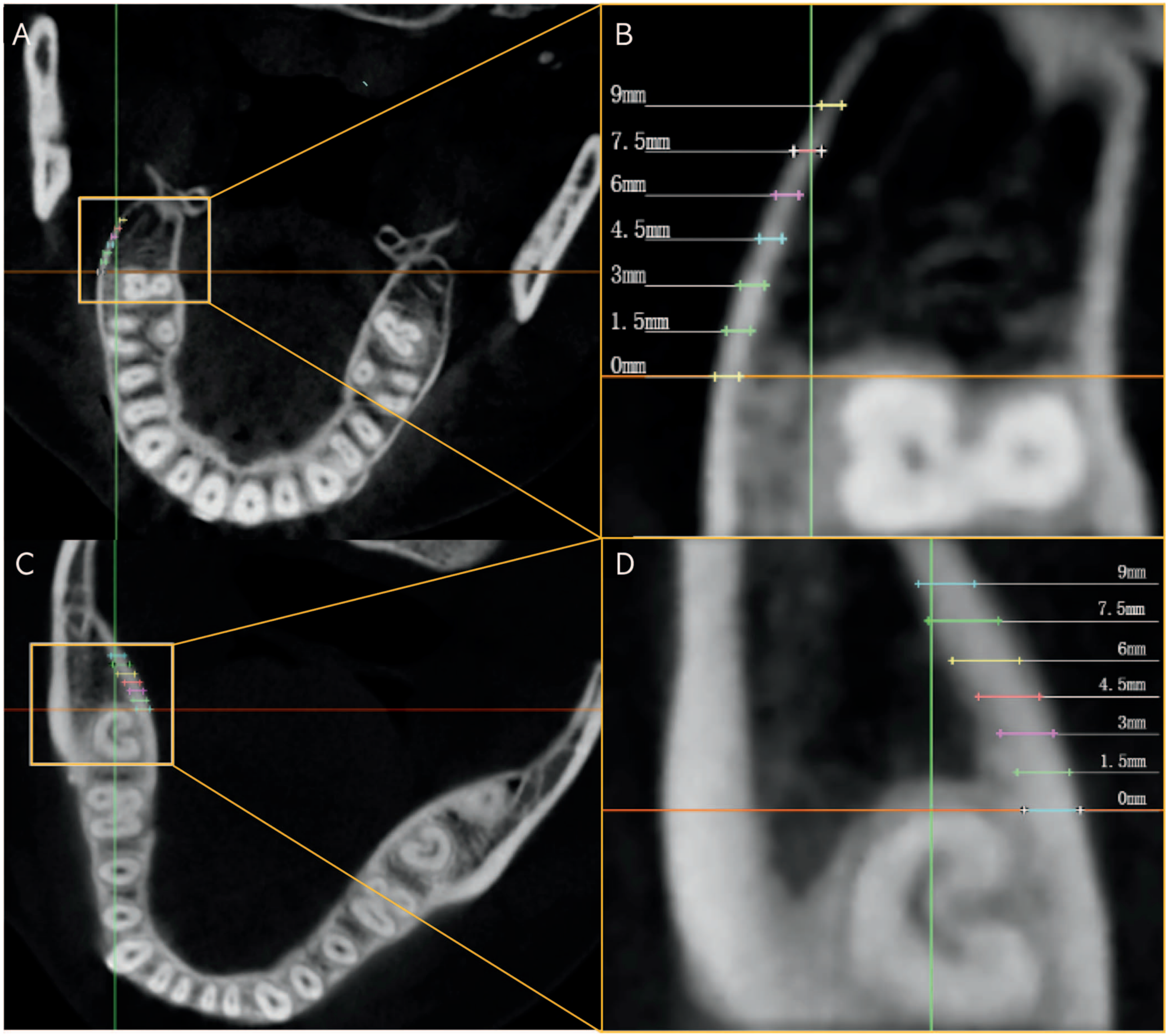

Figure 4. Cortical bone thickness measurement. (A) Axial slice at the maxillary molar root level: green line, parallel to the posterior occlusal line. (B) Magnified view of the white box in A. (C) Axial slice at the mandibular root level. (D) Magnified view of the white box in C.

Table 2. Comparison of Available Distance Among Descriptives of Age, Sex, and Presence of Third Molar

Level	Age, Years			*P*	Sex		*P*	Third Molar		*P*
	18–24	25–30	31–35		Male	Female		Present	Absent	
Class II (Maxilla)	(n = 26)	(n = 22)	(n = 12)		(n = 30)	(n = 30)		(n = 38)	(n = 22)	
U_A3	3.69 ± 1.42	3.92 ± 2.25	3.99 ± 2.40	.595	3.99 ± 1.97	3.58 ± 1.72	.210	3.71 ± 2.06	4.31 ± 1.14	.281
U_A6	5.20 ± 2.23	4.39 ± 2.49	5.22 ± 2.01	.642	4.99 ± 2.07	4.90 ± 2.52	.924	4.85 ± 2.09	5.26 ± 2.57	.581
U_A9	6.02 ± 2.66	4.58 ± 2.09	5.09 ± 1.95	.860	5.25 ± 2.10	5.57 ± 2.81	.602	5.24 ± 2.08	5.63 ± 3.11	.336
Class III (mandible)	(N = 26)	(N = 22)	(N = 12)		(N = 30)	(N = 30)		(N = 44)	(N = 16)	
L_A3	4.84 ± 2.60	4.64 ± 3.03	4.12 ± 2.56	.770	4.04 ± 2.87	5.15 ± 2.52	.138	4.77 ± 2.69	4.29 ± 2.83	.561
L_A6	3.59 ± 2.15	3.38 ± 2.20	3.75 ± 2.01	.880	3.10 ± 1.95	3.94 ± 2.20	.172	3.52 ± 1.99	3.85 ± 2.34	.586
L_A9	2.72 ± 2.21	2.47 ± 1.54	3.49 ± 2.01	.526	2.25 ± 1.60	3.26 ± 2.13	.112	2.18 ± 3.22	2.65 ± 3.27	.294

Table 3. Comparison of Average Available Distance in the Retromolar Regions of Class II Maxilla and Class III Mandible Among Three Levels of Measurement[a]

Growth Pattern	Level of Measurement			E	P
	$U_A3^{§}$	U_A6	U_A9		
Class II maxilla	4.06 ± 1.93$^{¤}$	4.93 ± 2.05	5.75 ± 2.26$^{¤}$	6.717	.002**
	L_A3	L_A6	$L_A9^{§}$		
Class III mandible	4.65 ± 2.70$^{¤}$	3.61 ± 2.07	2.80 ± 1.96$^{¤}$	9.711	.000**

[a] Levels marked with § are presented with the smallest available distances and considered limit levels. Value-pairs marked with ¤ show statistically significant differences ($P < .01$) in pairwise comparisons between the levels of measurement.
* $P < .05$; ** $P < .01$.

respectively ($P < .01$; Table 3), and these levels were considered limit levels. The range of available distance observed at a limit level of the Class II maxilla was 3.89–4.30 mm, averaging at 4.06 mm. That of the Class III mandible ranged from 1.79–3.49 mm and averaged to 2.80 mm. In the Class II maxilla, the retromolar CBT corresponding to the maximum available distances at the limit level (U_A3) averaged to 1.00 mm at locus U_A3U_C3 (Supplemental Table 2). The mandibular CBT at the limit level (L_A9) was observed at loci $L_A9L_C1.5$ and L_A9L_C3, averaging to 2.24 mm.

The distribution patterns of the available distances and CBT of the retromolar region in both jaws are provided in Figure 5, with comparisons among the three vertical growth patterns. In both the Class II maxilla and Class III mandible, the available distance decreased from hypodivergent to normodivergent to hyperdivergent groups successively, with the trends in the Class III mandible showing exceptionally strong correlations according to one-way ANOVA ($P < .001$) and pairwise comparisons between hypodivergent and hyperdivergent groups at all levels ($P < .001$; Table 4). Both groups showed no trend in vertical growth pattern influence on CBT except at three distinct locations ($P < .05$; Supplementary Table 2). All CBT values in the retromolar regions of the Class II maxilla and Class III mandible are provided in the supplementary information.

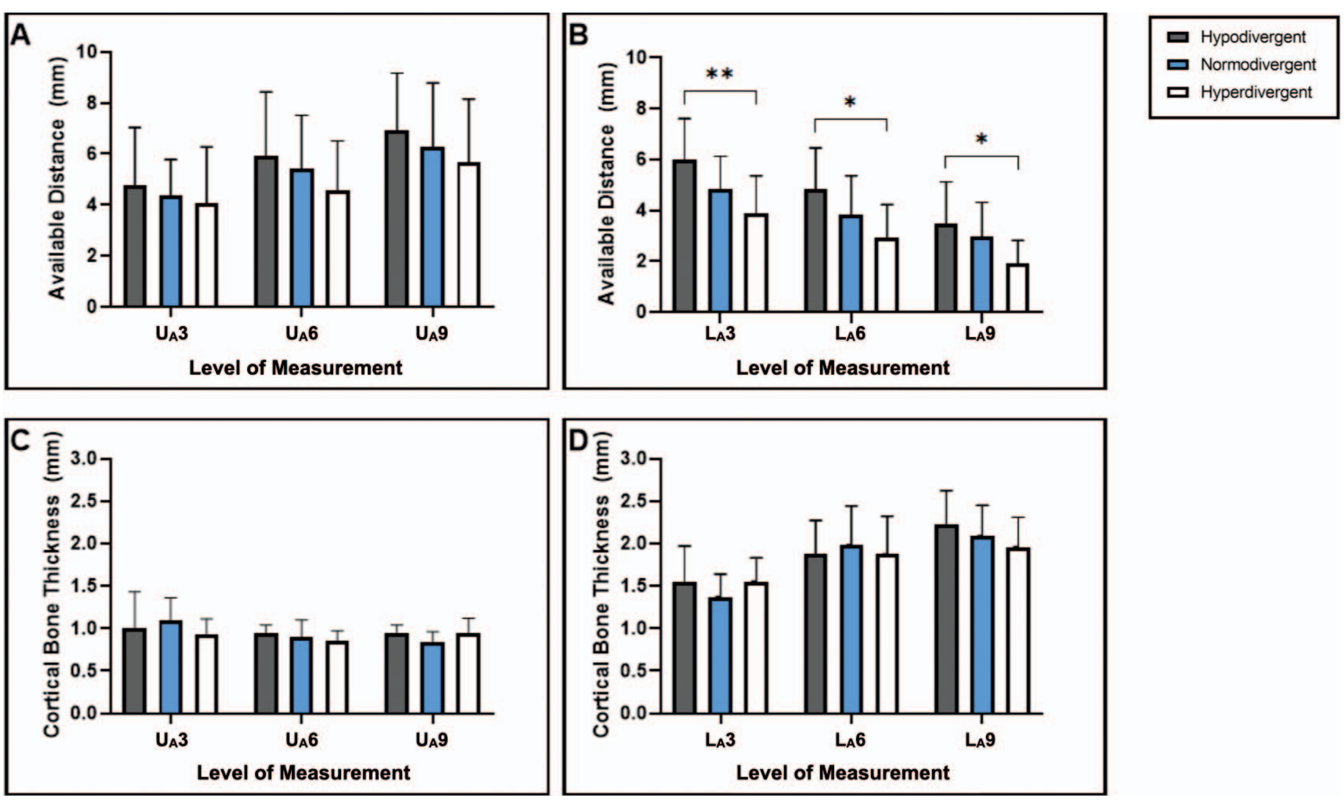

Figure 5. (A, B) Graphs of the available distance along the axis of distalization at each level of measurement in the Class II maxilla and Class III mandible. (C, D) Graphs of the cortical bone thickness at each level of measurement in the Class II maxilla and Class III mandible. *$P < .05$, ** $P < .01$.

Table 4. Comparison of Available Distance in the Retromolar Regions of Class II Maxilla and Class III Mandible Among Three Vertical Growth Patterns[a]

Level	Hypodivergent (n = 20)	Normodivergent (n = 20)	Hyperdivergent (n = 20)	*F*	*P*
Class II (maxilla)					
U_A3	3.82 ± 2.25	4.38 ± 1.40	4.05 ± 2.22	0.171	.843
U_A6	5.41 ± 2.26	5.23 ± 1.82	4.32 ± 2.00	1.465	.241
U_A9	6.10 ± 2.31	5.88 ± 2.31	4.93 ± 1.87	1.578	.215
Class III (mandible)					
L_A3	6.12 ± 2.76$^{\alpha}$	4.23 ± 2.23	3.59 ± 2.57$^{\alpha}$	5.152	.009**
L_A6	4.68 ± 2.33$^{\alpha}$	3.59 ± 1.61	2.54 ± 1.70$^{\alpha}$	6.217	.004**
L_A9	3.42 ± 2.31	3.13 ± 1.84	1.94 ± 1.41	3.455	.038*

[a] Value-pairs marked with $^{\alpha}$ show statistically significant differences ($P < .01$) in pairwise comparisons between growth patterns.
* $P < .05$; ** $P < .01$.

DISCUSSION

The distance between the root of the second molar and inner cortex of the bony envelope directly reflects the available area where the tooth is allowed to move along the AOD within the bony envelope before the root encounters cortical resistance.[8] Attempts to distalize molars into a retromolar region that cannot fully envelope its roots will result in many complications.[2,15] The results suggested that the anatomical limits of molar distalization can be evaluated on the axial slices of CBCT images, along the AOD. The available distance in the retromolar region of the Class II maxilla increased apically and hence should be observed at a "limit level" closest to the occlusal level. Conversely, the available distance in the retromolar region of the Class III mandible decreased apically and should be observed at a level closest to the apical level. The CBT observed at the limit levels represented the loci where the distally moving molars reach the inner cortex of cortical bone, exceeding which will result in periodontal complications.

Previous studies have demonstrated that hyperdivergent patients had thinner alveolar ridges and were more susceptible to periodontal-related iatrogenic complications, because there is less effective space for the teeth to move.[15] It was observed that the available distance along the AOD showed decreasing trends from hypodivergent to normodivergent to hyperdivergent groups successively in both the Class II maxilla and Class III mandible. This trend was especially significant in the Class III mandible ($P < .01$), signaling that mandibular molar distalization is especially risky in the hyperdivergent Class III patient. The influence of vertical growth patterns on the structure of the retromolar region can be explained by Throckmorton's findings that a greater gonial angle produced lesser mechanical advantage for the mandibular elevator muscles.[16] Thus, smaller functional loads produce less strain on the mandible, resulting in decreased bone apposition and increased endosteal resorption and subsequently smaller bone architecture.[17,18] The maxilla could be less influenced by bone adaptations related to the gonial angle because the distribution of masticatory force produces relatively low stress on the maxilla and frontal bone compared with the mandible.[19] The results of age, sex, and the presence of the third molar were consistent with similar studies on the mandibular retromolar regions of Class I patients.[8,9] It is worth noting that sex does not influence measurements because, despite males purportedly having greater maximum bite force than females do, maximum bite force is not a habitual or common function during mastication.[20]

The traditional method for determining the available distance for distalization is to measure the length of the maxillary tuberosity or the distance between the anterior border of the mandibular ramus and the second molar at the coronal level by panoramic and lateral cephalometric techniques.[21–23] However, the pitfalls of this method are that it fails to consider the direction of distalization or the available distance at the apical level. In addition, the reliability of the POL as a reference line was shown by Zhao et al.,[9] who found that the angle between the cuspal lines and lines parallel to the standard midsagittal planes remained constant across vertical growth patterns. By deriving measurements from axial slices of CBCT images and along the AOD, the retromolar region could be examined three-dimensionally to accurately predict anatomic limitations to molar distalization.

The limitation in this study is that the anatomical restrictions of molar distalization in the maxilla also include the maxillary sinus floor. The movement of the teeth through the maxillary sinus floor was reported to be possible but unpredictable.[24,25] In the mandible, the superior border of the inferior alveolar nerve canal may obstruct the distalization of the second molar root at the apical level.[26] Further studies examining these limitations would be beneficial for clinicians attempting molar distalization, and these values, combined with updated visualization technology and artificial intelligence, would result in effective diagnosis and predictable treatment outcomes.

CONCLUSIONS

- The anatomical limit for molar distalization in the Class II maxilla is observed at the coronal level, whereas that of the Class III mandible is at the apical level.
- Patients with hyperdivergent growth pattern have the smallest available distance and the highest risk of cortex contact in molar distalization among the three growth patterns, especially in the mandible.
- Clinicians can obtain much valuable information on the available distance for molar distalization by axial slices of CBCT images, especially regarding limit levels.

SUPPLEMENTAL DATA

Supplemental Tables 1 and 2 are available online.

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