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Comparison of the mandibular retromolar space in adults with different sagittal skeletal types and eruption patterns of the mandibular third-molar: a cone-beam computed tomography study

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Abstract

Background The mandibular retromolar space (RMS) has not been extensively studied in relation to various sagittal skeletal classes and patterns of third-molar eruption. The objective of this study was to test the null hypothesis that there is no difference in the mandibular RMS among normodivergent subjects with different skeletal classes and patterns of mandibular third-molar eruption, using cone-beam computed tomography (CBCT).

Method A total of 105 normodivergent patients (20–40 years) were included in this study. Participants were categorized into Class I, II and III groups based on ANB and further impacted and erupted groups based on the eruption patterns of the mandibular third molars. Measurements of the mandibular RMS were taken at four planes parallel to the occlusal plane, along the cusp line. Comparative analyses were conducted among the three sagittal groups and between the impacted and erupted groups.

Results The Class II group exhibited a statistically smaller RMS ($P < 0.05$). RMS was found to be larger in third-molar erupted group ($P < 0.05$). The rates of root contact and third-molar impaction was significantly higher in Class II group. ($P < 0.05$)

Conclusions The null hypothesis was rejected. Patients with Skeletal Class II tend to have a smaller mandibular RMS and a higher prevalence of root contact and third-molar impaction. The presence of impacted mandibular third molars was correlated with a shorter RMS.

Trial registration Retrospectively registered.

Keywords Retromolar space, Sagittal facial pattern, Mandibular third molar, CBCT

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Background

Molar distalization is a widely employed technique for providing space in the treatment of mild to moderate crowding [1]. The identification of the anatomic limit for distalization and the basis of post-treatment stability has been studied [2]. During the process of tooth movement, the risk of fenestration and root resorption is heightened by contact between the root and the cortical bone. [3, 4] The lingual cortex of the mandible has been previously identified as posterior anatomic limit since smaller available distance was at the root level rather than the crown level. [3]

The retromolar space (RMS) is an important consideration when distalizating mandibular molars to address crowding and ensuring the eruption of the third molars. Studies using panoramic radiographs and lateral cephalographs have examined the association between RMS, skeletal classes and eruption status of lower third-molar. Results were surprisingly controversial. Some reports indicate that skeletal Class III subjects have smaller RMS and increased impaction of mandibular third-molar compared with Class I and II patients [5]. Conversely, other study showed RMS was larger in Class III and smaller in Class II, with a higher impaction rate of lower third-molar was found in Class II subjects [6]. The impaction of the third-molar has been attributed to smaller RMS and shorter mandibular length, while other studies have have proposed that mandibular length is not related to impaction [7, 8]. To our knowledge, no study has yet explored the relationship between mandibular third molar eruption patterns and the distances between the mandibular second molar and inner/outer lingual cortex of the mandibular body.

Cone-beam computed tomography (CBCT) provides highly accurate linear measurements [9]. With the finding of lingual cortex as the actual posterior boundary of mandible during molar distalization, the RMS at root level has been correlated with facial skeletal patterns [10]. Zhao reported that hyperdivergent subjects exhibit a smaller RM**S** [11]. Choi only compared the RMS of Class III and I patients, noting a larger RMS in Class III subjects at one of the four planes examined, but did not include Class II patients in the study [12]. Until now, no study has specifically examined the retromolar space in skeletal Class II patients.

In previous studies, the RMS was not thoroughly investigated regarding different skeletal classes and third-molar eruption patterns. Thus, our null hypothesis is that there is no difference in retromolar space among patients with different sagittal facial types and eruption patterns of the mandibular third-molar.

Methods

CBCT scans of 105 subjects, between the ages of 20 and 40 years, were included in this study. These subjects were consecutively selected from a pool of patients who were sequentially admitted for orthodontic treatment from 2014 to 2020 at the Department of Orthodontics, Affiliated Stomatology Hospital of Guangzhou Medical University. The inclusion criteria were as follows: (1) normodivergent vertical facial type (27.3° ≤ S-N/Go-Gn ≤ 37.7°), (2) crowding of less than 4 mm in the mandibular arch, (3) healthy periodontal status without noticeable alveolar bone loss, (4) no prosthesis or missing teeth (except third-molars), (5) no obvious facial asymmetry and deformation, (6) no cleft lip and/or palate, (7) no diagnosed systemic disease and, (8) no history of orthodontic treatment. The study was approved by the Research and Ethics Committee of the Affiliated Stomatology Hospital of Guangzhou Medical University (No. KY2019023). The CBCT scans were obtained using Newtom (VG, Verona, Italy). The imaging parameters were as follows:110 kV, 3.07 mA, scan time of 18 s, with a voxel size of 0.15 mm, FOV of 15×15 cm and focal spot of 0.3 mm. Images were saved as digital imaging and communications in medicine (DICOM) format. The DICOM files were reconstructed into three-dimension images using QR-NNT software (Version 7.2, ImageWork, Elmsford, NY).

Cephalometric analysis was performed on CBCT-derived cephalograms obtained using Dolphin 9.0 Imaging software (Dolphin Imaging & Management Solutions, Chatsworth, Calif). According to ANB value, all subjects were classified into one of the three sagittal groups: Class I (0° ≤ ANB ≤ 4°), Class II (ANB > 4°) and Class III group (ANB < 0°). All of the sides were further divided into subgroups with or without the mandibular third-molar. For those with third molars, data were segmented into impacted and erupted groups, determined by the angle between the intersecting longitudinal axes of the mandibular second and third molars (Fig. 1). A third molar was considered erupted only if it had reached the occlusal plane and the intersection angle was between −10° and 10° [13]. Mandibular length was measured as the distance between Gonion (Go) and Gnathion (Gn).

The mandibular occlusal plane connecting the mesiobuccal cusp tips of the mandibular first molars and the right mandibular central incisor tip was used as the horizontal reference plane. The midsagittal plane was constructed using crista galli, ANS, and opisthion *(*Fig. 2A, *green).* The RMS of the mandible was measured on 4 different planes parallel to the mandibular occlusal plane. The plane passing through the furcation of the mandibular second molar root was named the Plane-0 whereas the other three planes, which were located 2, 4, and 6 mm apical to the Plane-0, were named the Plane-2, Plane-4,

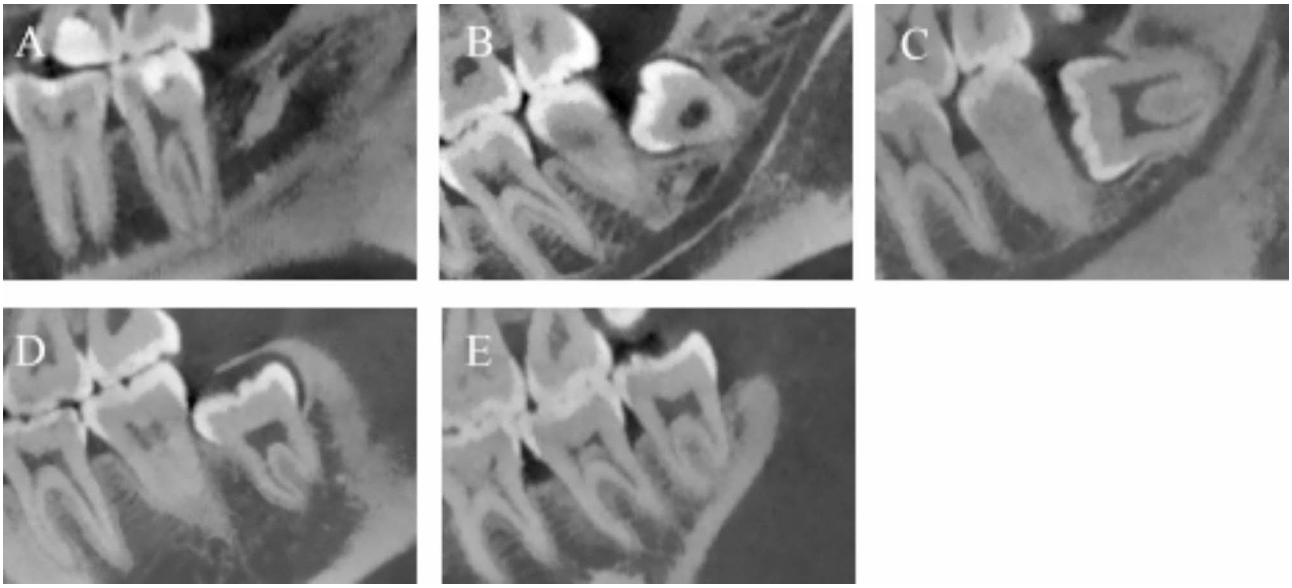

Fig. 1 **(A)** without third-molar group; **(B, C,D)** third-molar impacted group; **(E)** third-molar erupted group

and Plane-6, respectively. *(*Fig. 2B*)* The cuspal line direction was parallel to the projection of the line connecting the mesial-buccal cusps of the mandibular molars on the occlusal plane. *(*Fig. 2C, *Line a).* The sagittal line direction was parallel to the midsagittal plane at the measurement level *(*Fig. 2C, *Line b).* These two reference lines were then projected on Plane-0, 2, 4, and 6 as the reference lines in each plane for linear measurements. The angle formed by these two reference lines was measured. *(*Fig. 2C, *α)* The number of roots that contacted the inner lingual cortex of the mandible were calculated at each measurement plane. The shortest distances between the most lingual point of the distal root of the mandibular second molar and inner *(*Fig. 2C, C-I*)* and outer lingual cortex *(*Fig. 2C, C-O*)* of the mandibular body were measured parallel to both the sagittal line and the cuspal line at "Plane-0,2,4,6". All the measurements in this study were conducted by QR-NNT software. All the measurement was made by 2 senior master's students in Orthodontics.

To assess the reliability of the measurements, 36 randomly selected 3-dimentional(3D) images were re-orientated and re-measured by another investigator (orthodontic resident) and the same investigator at least 2 weeks apart.

Statistical analysis

The minimum sample size was calculated at α=0.05 and power of 90%, with PASS software (PASS 11. NCSS, LLC. Kaysville, Utah, USA). All statistical analysis were performed using SPSS software (version 24.0, IBM Corporation, NY) [11].

The differences among re-measurement by another investigator and the same investigator at least 2 weeks apart were assessed using an independent samples t-test and the methodological errors (MEs) were calculated using Dahlberg's formula: $ME = \sqrt{d^2/2n}$ where d represents the difference between two registrations, and n is the number of duplicate registrations. All data were checked for normal distribution by Shapiro-Wilk test and homogeneity of the variances.

Since the independent t-test showed no statistical difference between the right and left side measurements, the RMS measurements of the 2 sides were pooled in further subsequent analysis. The independent t-test was used to compare the RMS between groups with and without third molars, and groups with impacted and erupted ones. One-way analysis of variance (ANOVA) and Tukey post-hoc test was used to detect differences in baseline information and other variables relevant to the RMS among the 3 sagittal groups at 4 planes. Chi-square tests were applied to compare the number and rate of roots that contacted inner surface of lingual cortex on at least 1 plane. Gender distribution and third-molar impaction rate among three different groups were also tested.

Results

The MEs of measurements of RMS ranged from 0.10 mm for the distance along the cuspal line to the outer cortex at the Plane-0 by intraexaminer, to 0.32 mm along the cuspal line to the outer cortex at the Plane-6 by interexaminer. Independent t-test showed no significant difference between the measurement performed by intra- and inter-examiner at least 2 weeks apart.

No significant difference was found in age or gender distribution among the three groups, except for ANB and Go-Gn. Baseline information were shown in Table 1.

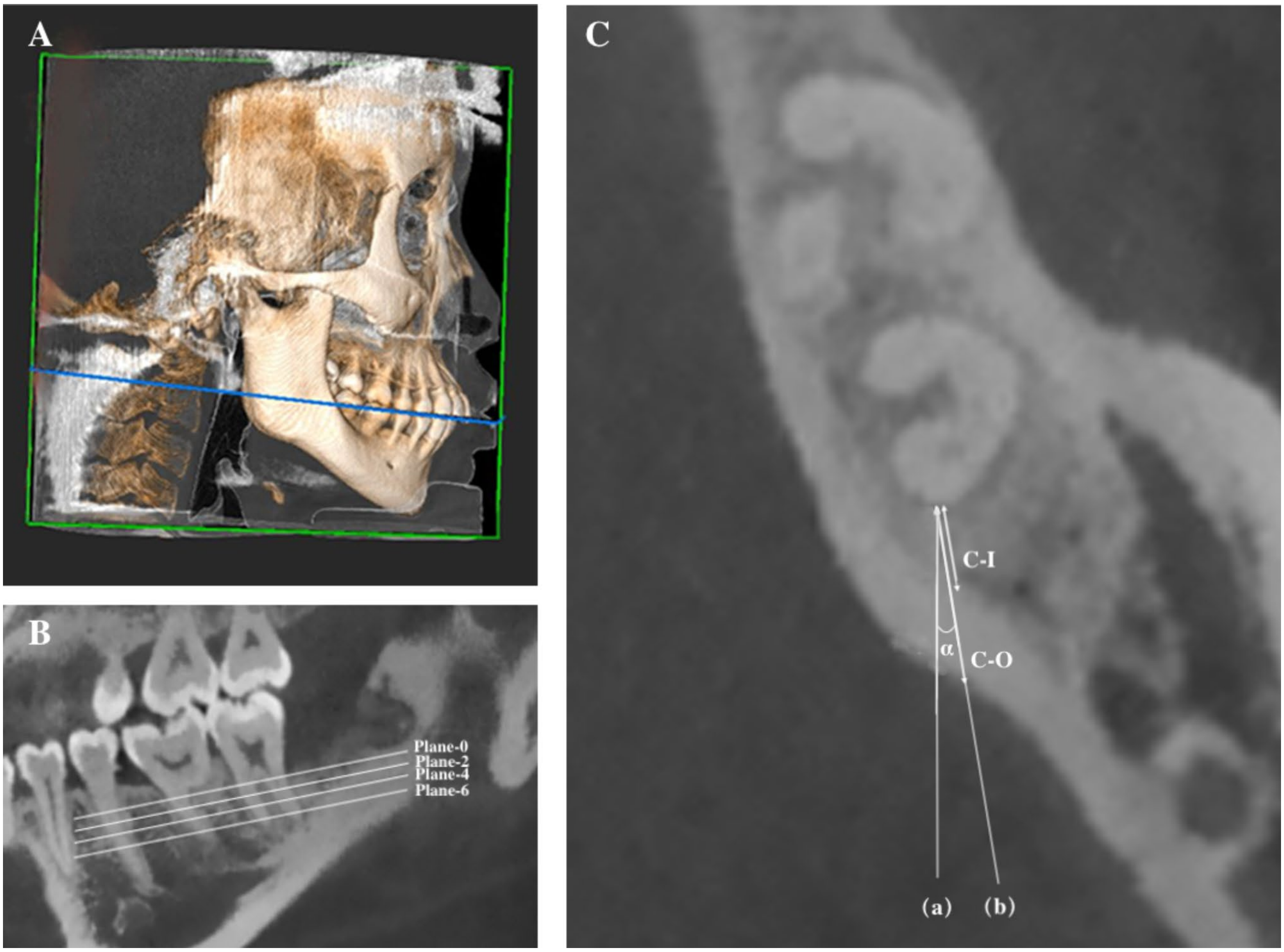

Fig. 2 **(A)** Reference planes. The mandibular occlusal plane: plane connecting the mesiobuccal cuspal tips of the mandibular first molars on both sides and central incisor tip. The midsagittal plane: plane formed by crista galli, ANS, and opisthion. **(B)** Measurement planes. The Plane-0: plane parallel to the mandibular occlusal plane and pass the furcation of the mandibular second-molar. Plane-2, Plane-4 and Plane-6 were parallel to the Plane-0 at 2, 4 and 6 mm below the Plane-0. **(C)** Measurement angle and distances. (**α**) Angle formed by the sagittal and cuspal lines. **(C-I)** The shortest liner distance measured between the most lingual point of the distal root of the mandibular second molar and the inner mandibular cortex **(C-O)** The shortest liner distance measured between the most lingual point of the distal root of the mandibular second molar and the outer mandibular

Table 1 Patient characteristics in the three groups

	Age[a] (Mean ± SD)	ANB[a] (Mean ± SD)	SN-GoGn[a] (Mean ± SD)	Go-Gn[a] (Mean ± SD)	Sex[b] (%)		Numbers (*N*)
					Male	Female	
skeletal class I	24.46 ± 3.95	2.27 ± 1.14	29.51 ± 1.48	81.77 ± 10.54	22.9% (*n* = 8)	77.1%(*n* = 27)	35
skeletal class II	24.77 ± 3.48	5.54 ± 1.27	29.50 ± 1.50	74.84 ± 5.68	20.0% (*n* = 7)	80.0% (*n* = 28)	35
skeletal class III	24.09 ± 3.87	-2.15 ± 1.36	29.05 ± 1.39	84.41 ± 9.78	22.9% (*n* = 8)	77.1%(*n* = 27)	35
***P*-value**	0.535	0.000*	0.104	0.000*	0.946		

SD, Standard deviation;

[a]One-way Anova

[b]Pearson's Chi-square test

*Statistically signifcant at *p* value<0.05

The RMS on both sides showed no significant difference. ($P > 0.05$) The presence of third molar had no significant impact on RMS. ($P > 0.05$).The angle formed between cuspal line and the sagittal line did not show statistical difference among three sagittal groups ($P > 0.05$) (Table 2).

Statistical difference of RMS was found among 3 sagittal groups. ($P < 0.05$) The Tukey post-hoc test revealed the RMS in Class II group was significantly smaller than that in Class III group at all measurement planes and shorter than that in Class I group at several planes. No significant

Table 2 Means and standard deviations of angle between sagittal line and cuspal line direction among group and the *p* value of ANOVA test

	Angle(°)
Skeletal class I (35)	18.76 ± 5.13
Skeletal class II (35)	19.06 ± 4.88
Skeletal class III (35)	18.95 ± 4.45
F	0.074
P	0.928

Statistically signifcant at p value < 0.05

Table 4 Numbers and percentages of root contacts in different skeletal sagittal facial types by the chi-square test of Pearson

		Number	Percentage (%)
Skeletal class I		12	17.1%
Skeletal class II		20[a]	28.6%
Skeletal class III		8	11.4%
Chi-square test	Chi-square	6.918	
	p value	0.031*	

* Statistically significant at p value < 0.05

[a] Significant difference with skeletal class III group

Table 5 Numbers and percentages of different eruption patterns of the mandibular third molar in three groups by the chi-square test of Pearson

		Impacted Molar	Erupted Third Molar	Total
Skeletal Class I *n*(%)		37(67.3%)	18(32.7%)	55
Skeletal Class II *n*(%)		43(86.0%)	7(14.0%)	50
Skeletal Class III *n*(%)		30(60.0%)	20(40.0%) [a]	50
Total *n*(%)		110(71.0%)	45(29.0%)	155
Chi-square test	Chi-square	8.767		
	p value	0.012*		

n Number of sides

* Statistically significant at p value < 0.05

[a] Significant difference with Skeletal Class II group

difference was found in RMS at four measurement planes ($P > 0.05$), and the shortest values were always detected at the Plane-4 for all subjects (Table 3). The number and rate of roots contacting the inner surface of the lingual cortex was statistically higher in Class II group. ($P < 0.05$) (Table 4).

The rate of third-molar impaction was significantly higher in Class II group. ($P < 0.05$) (Table 5) The RMS in the third-molar erupted group was significantly larger than that in impacted group. ($P < 0.05$) (Table 6).

Discussion

Ideal molar relationship is one of the goals of orthodontic treatment. Molar distalization stands out as a compelling strategy for managing crowding or a Class III molar relationship without resorting to extractions. However, it may also lead to compromised periodontal tissue or decreased post-treatment stability [2]. Various studies have identified the mandibular lingual cortex, rather than the anterior border of the ramus, as the definitive anatomical boundary for orthodontic tooth movement [3, 11]. Despite certain correlations were found between the available RMS on the lateral cephalogram and axial CBCT slices, it was necessary to reevaluate the results of previous studies due to the low coefficient of RMS on panoramic radiographs or lateral cephalograms [3]. Thus, the purpose of this study was to clarify the association between the RMS at root level, skeletal classes and the third-molar eruption status.

Previous studies have correlated facial divergence with the RMS. Hyperdivergent subjects tend to have a smaller RMS and higher incidence of lower third-molar

Table 3 Means and standard deviations of retromolar space among three groups and the *p* value of ANOVA test

	Distance Measured by Cuspal Line				Distance Measured by Sagittal Line			
	Skeletal class I (*n* = 35)	Skeletal class II (*n* = 35)	Skeletal class III (*n* = 35)	*p* value	Skeletal class I (*n* = 35)	Skeletal class II (*n* = 35)	Skeletal class III (*n* = 35)	*p* value
Retromolar space to the inner surface of lingual cortex of mandibular body								
Plane-0 (mm)	5.69 ± 2.77	4.38 ± 2.82[a]	6.44 ± 3.33	0.004*	3.31 ± 2.16	2.58 ± 1.72[a]	3.62 ± 2.31	0.010*
Plane-2 (mm)	4.83 ± 2.76	3.88 ± 3.00[a]	5.59 ± 3.04	0.003*	2.85 ± 1.79	2.19 ± 1.77[a]	3.01 ± 1.74	0.016*
Plane-4 (mm)	4.54 ± 2.99	3.38 ± 2.90[a]	5.15 ± 3.30	0.003*	2.66 ± 1.93	1.97 ± 1.84[b]	2.94 ± 1.95	0.010*
Plane-6 (mm)	4.94 ± 3.30	3.56 ± 2.84[b]	5.21 ± 3.60	0.007*	2.91 ± 2.10	2.03 ± 1.74[b]	2.96 ± 2.04	0.008*
***p* value**	1.907/0.129	1.585/0.193	2.246/0.083		0.271	0.172	0.146	
Retromolar space to the outer surface of lingual cortex of mandibular body								
Plane-0 (mm)	9.96 ± 2.63	8.33 ± 3.17[b]	10.41 ± 3.36	0.000*	6.59 ± 2.16	5.25 ± 1.94[b]	6.70 ± 2.57	0.000*
Plane-2 (mm)	9.31 ± 2.86	7.53 ± 3.33[b]	9.98 ± 3.35	0.000*	6.30 ± 1.98	4.96 ± 2.16[b]	6.30 ± 1.96	0.000*
Plane-4 (mm)	9.19 ± 3.43	7.13 ± 3.50[b]	9.72 ± 3.76	0.000*	6.01 ± 2.31	4.75 ± 2.24[b]	6.20 ± 2.23	0.000*
Plane-6 (mm)	9.71 ± 4.17	7.70 ± 3.34[b]	10.19 ± 4.19*	0.000*	5.96 ± 2.56	4.78 ± 2.17[b]	6.10 ± 2.31	0.002*
***p* value**	0.492	0.196	0.719		0.325	0.500	0.574	

*Statistically significant at p value<0.05

[a] Indicate difference with skeletal class III group according to the Tukey post-hoc test

[b] Indicate difference with skeletal class I and class III group according to the Tukey post-hoc test

Table 6 Means and standard deviations of retromolar space between different third-molar eruption status groups and the *p* value of the independent sample t test

	Inner Cortex		*p* value	Outer Cortex		*p* value
	Impacted Third Molar (mm)	Erupted Third Molar (mm)		Impacted Third Molar (mm)	Erupted Third Molar (mm)	
Total sample	*n* = 110	*n* = 45		*n* = 110	*n* = 45	
Plane-0						
Through cuspal line	5.25 ± 3.06	7.24 ± 3.15	0.000*	8.85 ± 3.12	11.42 ± 2.70	0.000*
Through sagittal line	2.80 ± 1.87	4.56 ± 2.49	0.000*	5.65 ± 2.14	7.83 ± 2.28	0.000*
Plane-2						
Through cuspal line	4.25 ± 3.04	6.40 ± 2.75	0.000*	8.23 ± 3.40	10.88 ± 3.04	0.000*
Through sagittal line	2.29 ± 1.72	5.41 ± 2.16	0.000*	5.41 ± 2.16	7.16 ± 1.81	0.000*
Plane-4						
Through cuspal line	3.61 ± 2.97	6.24 ± 3.33	0.000*	7.98 ± 3.71	10.68 ± 3.74	0.000*
Through sagittal line	2.13 ± 1.80	3.60 ± 2.12	0.000*	5.21 ± 2.31	6.94 ± 2.32	0.000*
Plane-6						
Through cuspal line	4.12 ± 3.42	5.83 ± 3.40	0.005*	8.71 ± 4.37	10.57 ± 3.78	0.013*
Through sagittal line	2.34 ± 1.98	3.56 ± 2.13	0.001*	5.32 ± 2.58	6.64 ± 2.33	0.004*

n Number of subject

* Statistically significant at p value<0.05

impaction compared to those with normodivergent and hypodivergent facial types [6, 11]. Therefore, this study exclusively included subjects with a normodivergent facial pattern to mitigate the impact of varying vertical facial morphologies.

The finding that the presence of the third-molar had no significant impact on the RMS agrees with the results of previous studies [5, 11]. The prevalence of the third-molar agenesis varies by ethnicity, with a global rate of 22.63% [14] and a notably lower rate of 8.7% in China [15]. Therefore, the absence of lower third-molar can be mainly ascribed to the extraction rather than agenesis in our study. The angle formed by the cuspal and sagittal lines was constant and in agreement with previous studies [11, 12]. The constancy of this angle suggested that the posterior part of the arch form was independent of the sagittal and vertical skeletal patterns in subjects with minor crowding.

The RMS was significantly smaller in skeletal Class II group compared with other two groups, aligning with a previous study which was conducted using digital orthopantomograms and lateral cephalograms [6] The reduced RMS in Class II group can be attributed to the significantly shorter mandibular body length in our study. It has been reported that Class II subjects had shorter mandibular length and larger dental arch length than Class I subjects, thus it was reasonable to assume that length discrepancy result in a smaller RMS in Class II group [16]. The minimum retromolar distance in the Class II group was 3.38 mm at Plane-4, which was remarkably larger than the 2 mm of lower molar distalization reported in previous studies [17]. Accordingly, lower molar distalization can be accomplished even in Class II subjects to obtain adequate decompensation of the lower incisors in surgical-orthodontic treatment. Meanwhile, no significant difference can be found for RMS between Class I and Class III group. This result was consistent with previous study that indicated Class III subjects had larger RMS only at the molar furcation level [12]. Because of this, distalization of the upper and lower dentition with temporary anchorage devices (TADs) can be employed to alleviate mild to moderate crowding and preserve the molar relationship in Class I patients.

The significantly higher number and percentage of roots contacted with the inner lingual cortex in Class II group was consistent with the smaller RMS observed in this group. The discrepancy in length between mandibular body and lower dentition contributed to decreased RMS, consiquently increasing the incidence of root contact in the Class II group. In addition, the finding that Class II subjects presented more buccally inclined lower molars supports our result [18]. As the lower molar inclined buccally to compensate for transverse discrepancies in Class II group, the root of lower second molar located closer to lingual cortex, leading to the higher number and percentage of root contact.

It has been shown that the time of lower third-molars eruption ranged from 14 to 24 years across different populations, with the most appropriate age for studying the incidence of mandibular third-molar impaction was 20–25 years [19]. The mean age of our sample was 24.76±3.69, aligning with the average age reported in previous studies [6]. Echoing findings from other research, the incidence of lower third-molar impaction in our study was also significantly higher in Class II group [6]. This increased impaction rate may be related to the smaller RMS and shorter mandibular body length. The lack of RMS has long been identified as an important factor in the etiology of lower third-molar impaction [20, 21]. Previous study found the RMS was reduced in 90% of the cases with third molar impaction [22]. Interestingly, a study conducted among the Jordanian population reported that Class III subjects presented increased third-molar impaction with reduced RMS [5]. This discrepancy may be caused by different racial and genetic backgrounds between studies, attributable to varied patterns of facial growth, jaw development, and tooth size [21]. Apart from RMS, the mandibular body length was correlated with the impaction rate of mandibular third-molars. A shorter mandibular length has been associated with third molar impaction, a finding that was also evident in our study [7, 22]. However, some studies found no significant differences in mandibular lengths between subjects with impacted and erupted third-molars, [8, 21] possibly due to different landmarks and radiology methods across studies.

The RMS measured at four planes were all significantly larger in subjects with erupted third-molars compared with those with impacted third-molars. These results suggest that the fully erupted third molar was associated with adequate space not only at the crown level but also at the root level [3, 19]. Therefore, the full eruption of the third molar can serve as an indicator of successful distalization of lower dentition, as at least 5 mm RMS can be obtained after extraction of these teeth.

Our study has some limitations. Firstly, the potential influence of gender on the retromolar space (RMS) could not be assessed due to the limited number of male participants in the sample. [3, 23] Secondly, soft tissue distal to the mandibular second molar was not taken into consideration in the study. Clinically, the soft tissue in the retromolar pad area would cover the distal part of the second molar after the substantial distalization of lower molar, with poor periodontal health and oral hygiene potentially leading to pericoronitis in this area [24]. Thus, the limitation of bony structure and soft tissue should be evaluated carefully before lower molar distalization. Finally, data of individuals who had mandibular third molar agenesis or having prior extractions was not included in this study, so the result could not address the question of whether mandibular third molar status impacts RMS.

Conclusions

1. The null hypothesis was rejected. Skeletal Class II subjects tend to present with significantly smaller mandibular retromolar space, a higher number of roots in contact with the inner lingual cortex of mandible, and increased impaction of third molars when compared with Class I and III subjects.
2. Subjects with impacted third molars showed significantly decreased mandibular retromolar space when compared with subjects with erupted third molars.

Abbreviations

RMS	Retromolar space
M3M	Mandibular third molar
TADs	Temporary anchorage devices
Go	Gonion
Gn	Gnathion
CBCT	Cone-beam computed tomography
C- I	retromolar space measured along the cuspal line from the most lingual point of the distal root of the mandibular second molar to the mandibular body inner cortex
C- O	Retromolar space measured along the cuspal line from the most lingual point of the distal root of the mandibular second molar to the mandibular body outer cortex

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Acknowledgements
Not applicable.

Author contributions
Conceptualization and study design was made by C Liu& QY Gao. Material preparation were performed by BY Chen and Min Huang. Data collection were conducted by HY Lin and WQ Guo. The data analysis and writing were performed by QY Gao and XH Zhou. Language improvement was made by ZD Zhao. All authors have read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The participants/patient were not gave written informed consent, which was approved by the Research and Ethics Committee of the Stomatology Hospital of Guangzhou Medical University.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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