

A CT-Based Comparative Analysis of Mandibular Morphology Across Dentofacial Classification

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ABSTRACT

INTRODUCTION: Anatomical variations of the posterior mandible have been an ongoing dialogue because of the importance of ensuring the safety of a vital structure that has a risk of damage in mandibular surgeries. Hence, this study aims to analyse the morphology of posterior mandibles across different dentofacial relationships. **MATERIAL AND METHODS:** A cross-sectional study was conducted utilizing CT scans of the head and neck. The recruitment of samples adhered to specified criteria, which were then categorised according to their skeletal pattern. The CT measurements include height of ramus (R), distance from lingula to sigmoid notch (LS), distance from lingula to inferior border (LI), vertical position of lingula in relation to occlusal plane (L-OP), ramus thickness at the crestal level (RT-C), and ramus thickness midway between sigmoid notch and lingula (RT-M). **RESULTS:** A total of 60 CT scans were evaluated and classified into Class I, II, and III. The LI and RT-C displayed noteworthy differences ($p < 0.05$) when compared across groups. Other variables showed no significant difference. Nonetheless, a marginal difference was observed in the ramus height ($p = 0.055$). Upon additional post hoc analysis for LI and RT-C, significant differences exist between Class II and III ($p = 0.019$, $p = 0.023$, respectively). **CONCLUSION:** Significant differences exist in the critical landmarks of the posterior mandible of different dentofacial patterns, where Class II mandibles portrayed a thicker ramus at the crestal level and a shorter distance from the lingula to the inferior border. These findings are crucial information in ensuring safe surgical practice involving the posterior mandible.

Keywords

Mandible, Morphology, Dentofacial, CT Scan

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INTRODUCTION

Dentofacial relationship refers to the alignment of the dental and skeletal components of the maxilla and mandible. Different dentofacial relationships can occur due to multiple developmental causes. One of them includes mandibular prognathism and retrognathism caused by overgrowth and undergrowth of the jaw, respectively¹. Patients with these mandibular anatomical variations may present with a different dentofacial relationship commonly categorised into Class I, Class II, and Class III dentofacial relationships.²

These significant anatomical variations in the posterior mandible can hinder various ramus osteotomy procedures, including sagittal split ramus osteotomy, inverted L ramus osteotomy, vertical ramus osteotomy, and ramus graft harvest. These are common orthognathic surgery procedures indicated in patients with deformities in their dentofacial relationship.³ Key anatomical considerations during the surgical procedure encompass the height and thickness of the ramus, the position of the lingula and coronoid notch, as well as the location of the mandibular foramen. This

anatomical information, which was believed to differ in different dentofacial relationships, is crucial in averting complications associated with mandibular osteotomies.⁴ Unfavourable fracture, also known as bad split, is a disastrous intraoperative complication in orthognathic surgery, with reported incidences ranging from 2% to 23%.⁵ These bad splits result in prolonged operation time to fix the unfavourable fractures while ensuring the planned movement for the orthognathic surgery is achieved intraoperatively. Postoperatively, this complication can exacerbate the morbidity with issues such as postoperative neurosensory disturbance, temporomandibular joint dysfunction, and instability.⁶⁻⁸ Previous studies have identified factors associated with bad splits in mandibular osteotomy, including variations in the mandibular anatomy, presence of third molars, age, and surgical technique.⁸ One particular factor that risks bad split complications is the variations in the mandibular anatomy of different dentofacial classes. It was thought that mandibular prognathism is associated with a longer and thinner ramus, while mandibular retrognathism is linked to a shorter and thicker ramus. An anatomical study of Thai cadaveric mandibles reported the variations in the distance between the coronoid and gonion, as well as the position of the lingula in various mandibular classes.⁹ Another retrospective Cone Beam Computed Tomography (CBCT) study found that shorter ramus and thinner mandible increase the susceptibility of bad splits during sagittal osteotomy.¹⁰

For these reasons, various imaging modalities have been employed and have become a prevalent tool for the preoperative evaluation of mandibular anatomy to aid the identification of gross anatomical features in the posterior mandible.¹¹ A panoramic radiograph will give an overview of the mandible, allowing for assessment of some landmarks in two dimensions. Meanwhile, a three-dimensional assessment of the mandibular anatomy would provide a more precise and accurate evaluation of the key landmarks of the mandible.^{12,13}

The current literature debates the mandibular anatomical differences in various dentofacial relationships due to the heterogeneous methodologies used and the diversity of ethnicity.¹⁰ Currently, there is insufficient evidence to confirm that the differences in the posterior mandibular anatomy in three dentofacial relationship classes do exist.

Therefore, the aim of this research was to evaluate the anatomical morphology of the posterior mandible using CT imaging in different dentofacial relationships concerning the key landmarks involved in various posterior mandibular surgeries. Secondly, this study also aims to compare the morphology between different dentofacial relationships. This information would be crucial for surgical decision-making and establishing a safe surgical reference for mandibular osteotomies.

MATERIALS AND METHODS

STUDY DESIGN

A cross-sectional study was conducted using computed tomography (CT) scans of the head and neck region obtained from the database of the radiology department, Sultan Ahmad Shah Medical Centre @IIUM.

STUDY SAMPLE

The sample consisted of CT scans of the head and neck region taken from the years 2016 to 2021, indicated on adult patients aged 18 and above for any clinical reasons. The CT scans were screened for any notable evidence of a history of jaw surgery, mandibular fracture, severe facial asymmetry, edentulous mandible, and presence of pathology in the maxillofacial region that will lead to deformity of the facial skeleton, such as fibrous dysplasia of the maxillofacial region, intra-bony tumour, and soft tissue tumour that is abutting on the mandible, were excluded. The medical records were carefully reviewed to exclude syndromic cases.

The sample was collected via convenience sampling. Sample size was obtained using G*Power analysis for one-way Anova F test (G*Power software version

3.1.9.7), with the alpha error set at 0.05 and the test power set at 80%. A medium effect size ($d = 0.66$) was assumed based on the magnitude of mean differences and the level of variability commonly reported in previous CBCT-based mandibular morphometric studies comparing different skeletal patterns.¹⁴ The minimum total required sample size for this study was 39. However, to improve the statistical analysis, a total of 60 CT scans of the head and neck were recruited and analysed.

IMAGING

The CT imaging of the head and neck was done with patients in the supine position and head placed at the midline, using Siemens Somatom (Siemens Healthcare, Erlangen, Germany) with the following technical specifications; collimation: 16 x 0.6 mm, tube settings: 130 kV, 26 mAs; scan time: 23.8 s. DLP: 110.6 mGy cm; scan length: 342 mm. CTDI vol: 3 mGy; rotation time: 1s. eff. The images were taken to allow multiplanar reconstruction with axial, coronal, and sagittal reformats at a slice thickness of at least 3mm. These DICOM images were then exported and transferred into the Picture Archiving and Communication System (PACS) for viewing and analysis.

DATA COLLECTION

The dependent variables consist of the posterior mandible landmarks on CT, while the independent variable was characterised by the different dentofacial relationships. The measurement and analysis of the CT images were done using PACS.

The CT scans were first evaluated, and skeletal classification was determined based on the ANB angle from lateral cephalometric analysis according to Steiner’s analysis, with 2-4° as Class I, >4° as Class II, and <2° as Class III.¹⁵ This step involved determining the points A, B, and Nasion at the mid-sagittal slice of the CT scan (see Figure 1). Using the ANB angles, the samples were then categorised according to the Angles skeletal classification. This step was analysed and

categorised by 2 researchers (W.N.Z. and I.N.I.) who underwent prior training to measure the landmarks. Secondly, the mandibular morphology was assessed and measured digitally using PACS by 2 researchers (S.A.Y. and N.N.S.). Both researchers also underwent prior training before their analysis. The posterior mandible anatomical landmarks and measurements were selected and measured according to protocol from a previous CT anatomical study.¹³ Table I represents the anatomical parameters and their descriptions. Figure 2 illustrates the method employed for the CT measurement of each individual landmark.

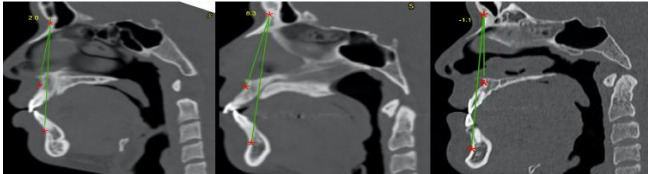


Figure 1. Determination of the $\angle$ ANB

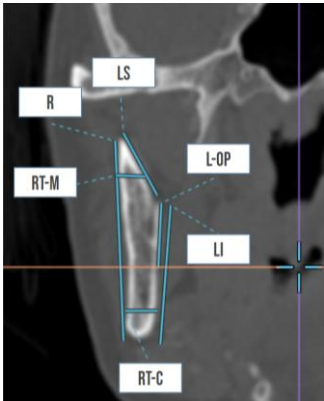


Figure 2. The measurement for the anatomical landmark

Table I. Description of the anatomical parameters

Parameters	Description
Point A	The point of deepest concavity anteriorly on the maxillary alveolus
Point B	The point of deepest concavity anteriorly on the mandibular apical base
Nasion	The most anterior point of the frontonasal suture
ANB	The angle formed by point A, Nasion and point B
R	Ramus height
LS	Lingula to sigmoid notch distance
LI	Lingula to inferior border distance
L-OP	Vertical position of lingula relative to the occlusal plane
RT-C	Ramus thickness at crestal level
RT-M	Ramus thickness midway between sigmoid notch and lingula

OUTCOME MEASURES

The primary outcome of this study was to determine the morphology of the posterior mandible in different dentofacial relationships and compare the morphology of the posterior mandible in different dentofacial relationships. All data collection and relevant statistical analyses were conducted using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). The Intraclass Correlation Coefficient (ICC) test was employed to assess intra-reliability and inter-reliability between two researchers for both CT measurements of the posterior mandible and the different dentofacial classes. Descriptive statistics of the variables were analysed for each category of dentofacial relationships. The normality test was done by using One-Sample Kolmogorov-Smirnov test. The comparison of the posterior mandible anatomical variables between the three groups was done utilizing One-Way ANOVA test for the normally distributed data and Kruskal Wallis test as the non-parametric test. The statistical significance is indicated by a p -value < 0.05 .

RESULTS

A total of 60 CT images were collected and categorised into Class I, Class II, and Class III, with each group consisting of 20 CT images. The mean age of the total sample was 54.5 years (SD: 18.66; range 19 - 84). The gender distribution was generally equally distributed with male and female 43.3% and 56.7%, respectively. The majority of the ethnicity of the CT images belonged to the Malay (N=54/60) with a small Chinese minority. The means for the ANB angle for each dentofacial relationship were in accordance with the Angles definition.

An inter-examiner reliability test was done for the first 10 patients involving every skeletal pattern class. The ICC was used as an inter-examiner reliability test and generally showed good inter-examiner reliability, with ICC ranging from 0.754 to 0.863. Variables LS and L-OP initially showed moderate reliability. However, after additional training and repeat measurements, the

reliability of these measures improved modestly, approaching the good agreement threshold.

Group comparisons were carried out using one-way ANOVA and Kruskal–Wallis tests, as appropriate, to compare the measured parameters across the different dentofacial groups.

PRIMARY OUTCOME

The posterior mandibular landmarks across the three dentofacial groups are summarised in Table II. Group comparisons demonstrated statistically significant differences in certain parameters, particularly LI and RT-C, while the remaining measurements did not differ substantially between the groups.

Table II. Results comparison of mandibular landmarks between different skeletal classes

Mandibular Landmark (mm)	Class I (Mean $\pm$ SD)	Class II (Mean $\pm$ SD)	Class III (Mean $\pm$ SD)	p -value
R ^a	48.8 $\pm$ 6.66	48.7 $\pm$ 4.40	51.3 $\pm$ 4.92	0.055
LS ^b	18.7 $\pm$ 3.04	19.5 $\pm$ 2.97	18.9 $\pm$ 3.76	0.233
LI ^a	32.4 $\pm$ 4.75	31.8 $\pm$ 3.61	34.5 $\pm$ 4.61	*0.017
L-OP ^a	17.2 $\pm$ 5.42	16.2 $\pm$ 6.12	15.7 $\pm$ 4.29	0.446
RT-C ^a	8.7 $\pm$ 1.87	8.8 $\pm$ 1.69	7.9 $\pm$ 1.33	*0.017
RT-M ^b	7.5 $\pm$ 1.36	7.2 $\pm$ 1.37	6.9 $\pm$ 1.58	0.511

^aOne Way ANOVA, ^bKruskal Wallis Test, * p -value <0.05

SECONDARY OUTCOME

Subsequent post hoc analysis was conducted for LI and RT-C to identify significant differences across Class I, Class II, and Class III skeletal patterns, as presented in Table III and Table IV. The results revealed that the statistically significant differences in LI and RT-C were mostly driven by comparisons between Class II and Class III skeletal patterns, while comparisons involving Class I did not demonstrate statistically significant differences for majority of measured parameters.

Table III. Post hoc analysis for LI

Skeletal Pattern	Skeletal Pattern	Mean Difference	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval
(I)	(J)	(I-J)			Lower Bound	Lower Bound
Class I	Class II	0.54	0.973	0.843	-1.76	2.85
Class I	Class III	-2.12	0.973	0.078	-4.43	0.18
Class II	Class III	-2.67	0.973	*0.019	-4.98	-0.36

*Tukey Honestly Significant Difference test with p -value <0.05

Table IV. Results of post hoc analysis for RT-C

Skeletal Pattern	Skeletal Pattern	Mean Difference	Std. Error	Sig.	95% Confidence Interval	95% Confidence Interval
					Lower Bound	Lower Bound
(I)	(J)	(I-J)				
Class I	Class II	-0.14	0.368	0.926	-1.01	0.73
Class I	Class III	0.85	0.368	0.059	-0.02	1.72
Class II	Class III	0.99	0.368	*0.023	0.11	1.86

*Tukey Honestly Significant Difference test with p -value<0.05

DISCUSSION

The key findings of this study revealed notable variations in the measurements of LI and RT-C across three classes of dentofacial deformity. Upon conducting the post hoc test, the comparison between Class II and Class III predominantly drives these significant differences in both parameters. This outcome suggests a discernible distinction in the mean values of the lingula position and ramus thickness, particularly when comparing the Class II and Class III skeletal patterns.

This study first evaluated the morphology of the posterior mandibular landmarks using CT imaging across different dentofacial relationships. The results demonstrated that patients with a class III skeletal pattern had higher LI, indicating a higher lingula level from the inferior border. A significant difference was noted when comparing class III and class II exclusively after conducting the post hoc test. This finding concurred with other recent studies that confirmed a higher position of the mandibular lingula in relation to the inferior border, the occlusal plane, and the internal oblique ridge.^{16–18} However, all the mentioned studies compared between class I and class III while excluding class II skeletal patterns.

The clinical relevance of having knowledge on the variations in the position of the lingula in different dentofacial patterns includes the ability to locate the inferior alveolar nerve that enters the mandibular foramen behind the lingula. This information provides crucial operative planning in various ramus surgeries, including the sagittal split osteotomy, inverted L osteotomy, and ramus graft harvest.^{18,19} Precise

localisation of the lingula allows the osteotomy to be placed higher, thereby reducing the risk of inferior alveolar nerve injury, a known consequence of mandibular osteotomies.^{20,21} Inferior alveolar nerve injury may result in neurosensory disturbances such as numbness, altered sensation, or persistent paraesthesia of the lower lip, chin, and mandibular teeth, which can adversely affect speech, mastication, and overall quality of life. In some cases, these sensory deficits may be permanent, emphasising the importance of comprehensive anatomical assessment prior to surgery.²⁰ Furthermore, when giving an inferior alveolar nerve block for skeletal class III individuals, adjustment needs to be considered, as they have a higher lingula level. Following the standard technique in locating the anatomical landmark for inferior alveolar nerve (IAN) block may lead to ineffective local anaesthesia.

Regardless, there is a limit on the extent to which the osteotomy or the vertical placement of the IAN block needle should be placed more superiorly. This depends on the vertical distance between the lingula and the sigmoid notch and between the lingual and the occlusal plane. Fortunately, this study found no significant difference between the dentofacial classes in the position of the lingula in relation to the sigmoid notch and occlusal plane. Current evidence also indicates that the morphology of the ramus further superior from the lingula becomes slenderer and thinner with minimal cancellous bone between the two cortical walls, thereby further risking complications such as bad splits.^{10,17}

Subsequently, posterior mandibular morphology was compared across Class I, Class II, and Class III dentofacial relationships. This study found a significant variation in the thickness of the mandibular ramus at the crestal level across different skeletal classes ($p=0.017$) with class II and class III having the most significant difference when a post hoc test was analysed ($p=0.023$). This finding is in agreement with other studies, which also found that Class III individuals have a thinner ramus.^{18,22} Similarly, other studies concluded that the class II skeletal pattern has a significantly thicker ramus

near the crestal and occlusal plane level.^{23,24} The clinical significance of this information is that it allows surgeons to determine the depth of the osteotomy, especially where cancellous bone is absent, to ensure a more predictable fracture propagation when the osteotomy is made, thereby preventing the incidence of unfavourable splits and damage to the IAN.^{18, 25}

This study has several methodological considerations that should be acknowledged. The use of convenience sampling may limit the generalisability of the findings to the wider population. However, this approach enabled the inclusion of comparable group sizes across skeletal patterns, thereby supporting balanced statistical comparisons and maintaining adequate analytical power. In addition, the effect size used for sample size calculation was derived from previously published CBCT-based mandibular morphometric studies rather than pilot data from the present population. As anatomical variability may differ according to population characteristics and imaging modalities, the true effect size in this cohort may not be identical to the estimated value. Nevertheless, the final recruited sample exceeded the minimum required number, which strengthens the robustness of the statistical analysis. Furthermore, although the CT scans were collected over a five-year period, all images were acquired using the same scanner and standardised imaging parameters, thereby enhancing reproducibility of the study. Future prospective studies with controlled sampling strategies and standardised imaging timelines may further validate and expand upon these findings.

CONCLUSION

The study highlighted notable distinctions in certain mandibular parameters, namely the lingula position in relation to the inferior border of the mandible and ramus thickness at the crestal level, between Class II and Class III dentofacial deformity. These findings contribute as a surgical reference for clinical applications in maxillofacial surgery, particularly surgeries involving the posterior mandible.

INSTITUTIONAL REVIEW BOARD (ETHICAL COMMITTEE)

Ethical clearance has been granted by the IIUM Research Ethics Committee (IREC 2023-089).

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CONFLICT OF INTEREST

There is no conflict of interest to declare.

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