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Association of temporomandibular joint space and condylar head position with different skeletal patterns among the Malaysian population

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Abstract

During growth and development of the head and neck, some degree of interaction and interdependence between skeletal pattern with temporomandibular joint (TMJ) space and condylar head position occurs. Results from previous studies are varied; some reporting significant difference of TMJ space or condylar head position among the skeletal patterns, whilst others have shown that no such association is present. Considering that previous studies have been conducted in populations outside of Malaysia and the importance of determining the correlation between skeletal and TMJ morphology, this retrospective study was done to evaluate the TMJ space and condylar head position in different skeletal patterns among the Malaysian population using computed tomography (CT) images. A total of 90 CT images of the head and neck were included. Skeletal pattern (class I, II, III) was determined from each CT image based on the ANB angles obtained from reconstruction of these images. The TMJ space measurement and condylar head position were determined from sagittal images based on established landmarks from the reconstructed CT images. Statistical analysis was used to compare the TMJ space and condylar head position across the three skeletal classes and assess its significance. The results of this study demonstrated that there was no significant association between TMJ space or condylar head position in the different skeletal patterns among the Malaysian population. It is recommended that a prospective study with large sample size and standardized measurement techniques be implemented in the future to determine the precise association between TMJ morphology and different skeletal patterns.

Keywords: *condylar head position, skeletal pattern, temporomandibular joint space*

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Introduction

Skeletal patterns are commonly classified according to anteroposterior disproportions as either skeletal class I, II, or III. The determination of skeletal pattern of a patient is essential for orthodontic treatment planning and subsequent management. As referenced to Littlewood *et al.* (2019), a class I skeletal pattern indicates that the upper and lower jaws are growing or have grown at the same rate horizontally (upper jaw lies 2–4 mm in front of the lower). A class II skeletal pattern presents with a prominent maxilla (lower jaw would be greater than 4 mm behind the upper jaw), while a class III skeletal pattern presents with a prominent mandible (lower jaw is less than 2 mm behind the upper).

The temporomandibular joint (TMJ) is a complex joint formed between the condylar head of the mandible and the glenoid fossa of the temporal bone. The other main components of the joint include the articular disc, joint capsule, and associated muscles and ligaments.

During the growth and development of the structures of the head and neck region, some degree of interaction and interdependence between skeletal pattern and TMJ space and condylar head position takes place. Therefore, the determination of association between the TMJ space and condylar head position with the various skeletal patterns has been a topic of interest and intense study over the years.

The findings of these various studies however have proven to be mixed, with some studies showing a significant association between the various skeletal patterns with either TMJ space or condylar head position. However, on the other hand, numerous studies have also shown no significant association between these variables as well.

The morphology of the TMJ is important for treatment outcome in order to ensure long term stability in prosthodontic, orthodontic and orthognathic patients (Noh *et al*., 2020). As stated by Liu *et al.* (2003), the condyle morphology plays an important role in the long-term stability of orthognathic therapies due to its correlation with masseter muscle development. Additionally, as concluded by Ikeda *et al.* (2009), the data provided by determining optimal TMJ space and condyle head position would serve as a point of reference for determining optimal condylar position in assessing joint status and for 3D reconstruction for orthodontic, prosthodontic or other modalities. Furthermore, as described by Chae *et al.* (2020), a concentric condylar position is considered a normal relationship between the condyle and fossa and is seen in asymptomatic individuals, whereas a non-concentric condyle fossa relationship is observed in individuals with abnormal TMJ function. The observation of an adequate TMJ space would also avoid excessive compression of the disc in order to prevent temporomandibular joint dysfunction in patients undergoing surgical procedures related to the TMJ and its associated structures (Chae *et al.*, 2020).

Therefore, considering the points described above, the determination of association between the TMJ space and condylar head position with the various skeletal patterns would prove beneficial in providing clinicians with much needed information in patient treatment planning. Additionally, to the authors knowledge, no such study has been carried out in the Malaysian population prior to this.

Taking these factors into consideration, this study was carried out to evaluate the association of TMJ space and condylar head position in different skeletal patterns among the Malaysian population using computed tomography (CT) images.

Materials and Methods

Study design

This retrospective study was performed on the available CT scans of the head and neck region obtained from the records of the radiographic department of Sultan Ahmad Shah Medical Centre (SASMEC) IIUM, Kuantan, Pahang. Prior to data collection, ethical approval was obtained from the International Islamic University Malaysia Research Ethics Committee (ID No: IREC 2021-088).

Sample size

The required sample size was calculated using G*Power software version 3.1.9.7. An α error of 0.05 was set to achieve a test power of 80%. The calculation indicated that a total of 90 CT scan images were required; 30 for each skeletal pattern (class I, II, III). Purposive sampling was used in this study.

Image selection

A total of 90 CT scans of the head and neck (30 per class I, II and III) in Digital Imaging and Communications Medicine (DICOM) format, were included in this study.

The exclusion criteria for this study were CT images of patients below 20 years of age, patients with history of orthognathic or TMJ surgery, or patients having pathologies such as arthritis involving the TMJ, or tumours involving the facial or TMJ region.

CT reconstruction and measurements

For determination of skeletal pattern, multiplanar reconstructions of the lateral view derived from the axial CT image was first done, followed by determination of landmarks and measurements (Figure 1). The CT scan machine utilized in this study was model CT Somatom Definition AS (Siemens, Germany). The same CT scan machine was used for all patients in this study.

The skeletal pattern I, II and III was determined based on the following landmarks as referenced to Profitt *et al.* (2019):

- Point A: The deepest point in the concavity of the anterior maxilla between the anterior nasal spine and alveolar crest.
- Point B: The deepest point in the concavity of the anterior mandible between the alveolar crest and Pogonion.
- Point N: The junction between the frontal and nasal bones at the frontonasal suture.

The skeletal patterns were determined based on the following ANB angle values (?):

- Class I: 1° to 5°
- Class II: > 5°
- Class III: < 1

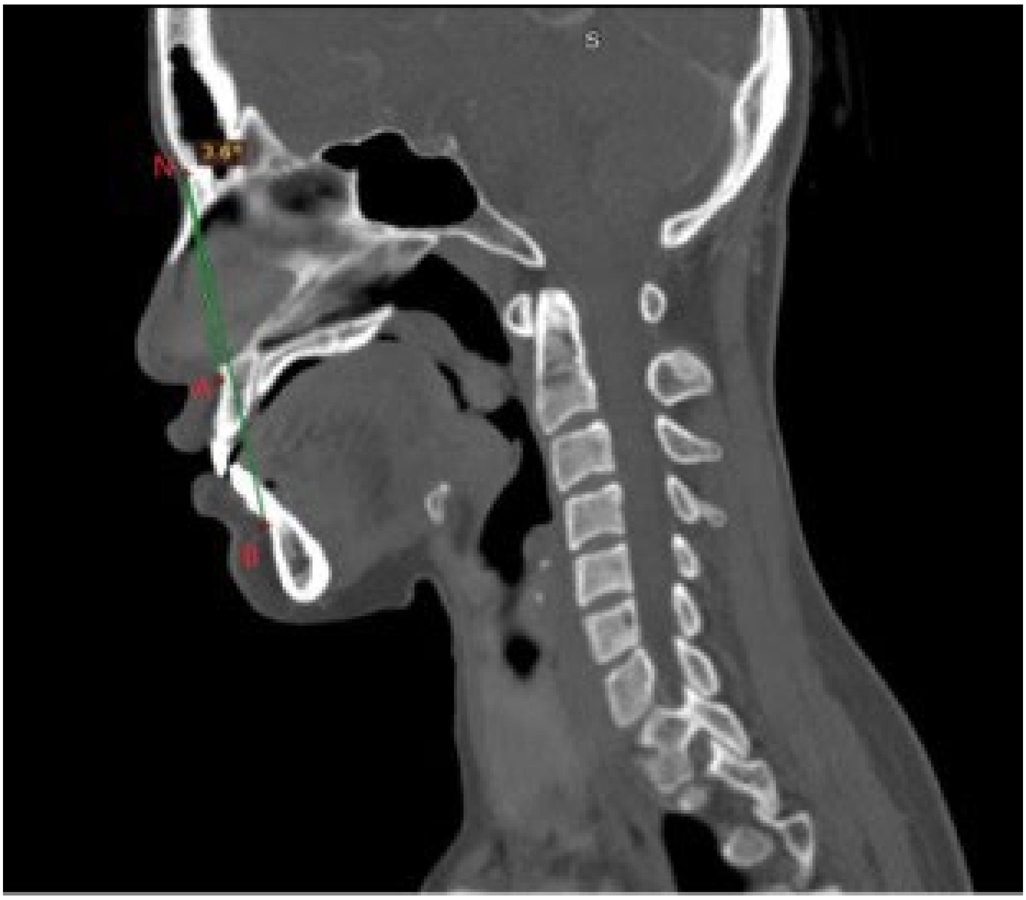

Figure 1. CT image showing ANB angle used for skeletal classification into Class I, II and II.

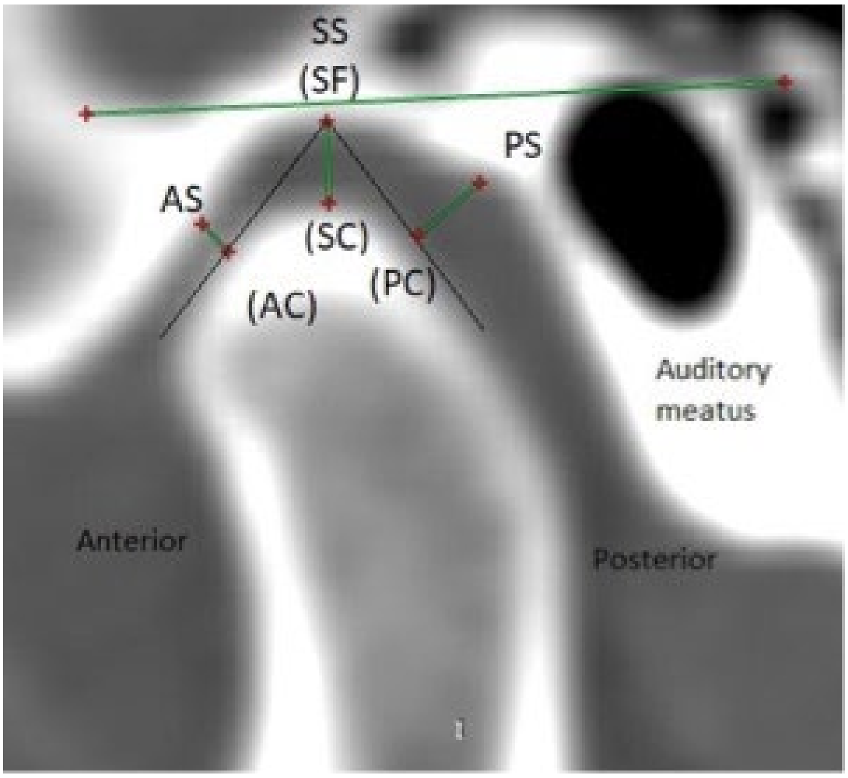

Figure 2. CT image showing landmarks and linear measurements of the TMJ space.

For the purpose of TMJ space measurement, a true central sagittal image with 2 mm thickness and interval distance was chosen from the CT. Following this; anterior, superior and posterior joint spaces were measured on the sagittal image (Figure 2). Initially, a horizontal line from the auditory meatus was drawn (true horizontal line) and the intersection of this line with the glenoid fossa was considered as the superior reference point (SF). Sequentially, this point is then connected to the most prominent points on the anterior (AC) and posterior (PC) aspects of the condyle. Finally, the perpendicular distance from AC and PC tangent points to the glenoid fossa was

measured as the anterior joint space (AS) and posterior joint space (PS). The distance between SF point and superior prominent point of the condylar head (SC) was considered as the superior joint space (SS). This method of measurement was adapted from Ikeda and Kawamura's study (Ikeda & Kawamura, 2009). All radiographic measurements were carried out utilizing RadiAnt DICOM Viewer software version 2022.1.

For the purpose of condylar position measurement, the sagittal plane was assessed with the method first established and used by Pullinger and Hollender; which is measured on the most centered sagittal slice of TMJ. The values of the anterior (AS) and posterior (PS) joint spaces were measured and calculated based on the following formula:

- (PS – AS) / (PS + AS) × 100

An attained value within ± 12% indicates a concentric position of the condyle. A value smaller than – 12 is considered a posterior condyle position, while a value greater than + 12 is considered an anterior condyle position (Pullinger & Hollender, 1986).

Statistical Analysis

Statistical analysis was performed using SPSS version 27.0. Descriptive statistics were performed and reported for mean and standard deviation for all variables in each class. An Anova test was performed to determine significance between skeletal pattern with TMJ space measurements. A chi squared test was performed to determine significance between skeletal pattern with gender and condylar position. Statistical significance was established at $p < 0.05$.

Result

In this study, a total of 90 CT scans were retrieved which were equally divided into 3 separate skeletal patterns (I, II, III). The CT scans were taken from patients within the age range of 20-80 years old (mean:54.84, SD±15.975) with the demographic data as seen in Table 1.
From the results obtained, there were no statistical differences between the skeletal patterns for the various right or left TMJ space measurements (AS, SS, PS) as demonstrated in Table 2.

Similarly, there were also no statistical differences between the skeletal patterns for either the right or left condylar position (anterior, concentric, posterior) as shown in Table 3

Discussion

The morphology of the TMJ varies between individuals, involving an interplay of multiple factors during growth and development of the individual. Over the years, numerous studies have been conducted to ascertain the association between position of the TMJ and skeletal patterns, the overall result of these individual studies have been varied, with mixed results at best.

A number of these studies have shown some degree of association between TMJ space or condylar position and skeletal pattern, such as Song *et al.* (2020); which noted that the superior joint space in class III was the smallest when compared to class I and II, and that the condyle position in class III patients were more anteriorly placed compared with that in class I patients. Similarly, according to Alhammadi *et al.* (2016), class III had the most superiorly positioned condyle with the smallest superior joint space and class II had the most inferiorly positioned condyle with the largest anterior joint space. In a study by Milan *et al.* (2021), the condyle was seen to be concentrically positioned in class I while class III had the most superiorly positioned condyle. However, in a study by Paknahad *et al.* (2016), the condyles were observed to be positioned anteriorly in class II patients, in comparison with class I and III patients and according to Krisjane *et al.* (2009), the condyles were found to be more anteriorly positioned in class II and III patients. Therefore, even among these studies that do manage to find a significant association, there appears to be a variety of mixed findings.

The results obtained from this study however, show no significant association between either TMJ space or condylar position and skeletal patten. These findings are in agreement with Chae *et al.* (2020), whom observed almost no statistical differences in condyle-fossa relationships according to skeletal patterns. These findings are also in accordance with findings by Feres *et al.* (2020), which demonstrate no significant difference between class II and class I patients in relation to the condyle sagittal position. Similarly, in a study by Ma *et al.* (2018), it was shown that although there was some difference in condylar morphology, there was no significant difference in condylar position between the skeletal classes I, II, III. A recent study by Diwakar *et al.* (2023), further demonstrates a lack of significant association between TMJ space with skeletal pattern, with only the anterior joint space showing some significance, while all other measurements were not significant across all 3 skeletal classes.

A systematic review and meta-analysis conducted by Martins *et al.* (2015) with regards to sagittal joint spaces measurements of the TMJ, demonstrated that of the 17 studies examined, it was suggested that the posterior joint space was larger than the anterior joint space.

Table 1. Demographic data for patients.

		Frequency	Percent
Gender	Female	50	55.6
	Male	40	44.4
Skeletal Pattern	I	30	33.3
	II	30	33.3
	III	30	33.3

Table 2. Association between skeletal pattern with TMJ space measurements (N=90).

Factors	Skeletal Pattern	Mean	Std. Deviation	Minimum	Maximum	IQR	F	p
Right AS	I	1.59	0.52	0.90	3.10	0.77	0.37	0.691
	II	1.50	0.49	0.72	2.90	0.74		
	III	1.49	0.42	0.94	2.70	0.52		
Right SS	I	3.15	1.48	1.35	7.00	1.88	2.59	0.081
	II	2.55	0.86	1.42	4.39	1.30		
	III	2.64	0.80	1.30	4.40	1.28		
Right PS	I	1.95	1.33	0.70	6.01	0.77	1.90	0.156
	II	1.83	0.90	1.00	4.72	1.00		
	III	1.48	0.50	0.77	2.70	0.65		
Right condylar position (%)	I	4.78	25.11	-47.62	55.50	32.46	1.10	0.337
	II	7.14	22.36	-31.82	57.45	40.23		
	III	-1.17	19.19	-40.74	35.00	32.12		
Left AS	I	1.54	0.41	0.90	2.80	0.52	0.74	0.480
	II	1.38	0.56	0.70	3.50	0.48		
	III	1.45	0.49	0.90	3.20	0.62		
Left SS	I	3.02	1.46	1.10	7.80	1.53	1.40	0.253
	II	2.71	0.77	1.07	4.29	0.89		
	III	2.58	0.80	1.10	4.40	0.92		
Left PS	I	2.03	1.48	0.50	7.80	0.85	2.75	0.070
	II	1.82	0.90	0.90	4.69	0.97		
	III	1.41	0.42	0.60	2.30	0.73		
Left condylar position (%)	I	5.58	31.18	-62.96	71.43	38.19	1.67	0.194
	II	10.94	26.70	-42.86	58.97	41.89		
	III	-1.25	18.08	-42.86	26.56	25.83		

AS: Anterior joint space, SS: Superior joint space, PS: Posterior joint space

Table 3. Association between skeletal pattern with gender and condylar position (N=90).

Factors	Category	Total	Skeletal Pattern				
			I	II	III		
			n (%)	n (%)	n (%)	χ^2	p
Gender	Female	50	19 (38)	16 (32)	15 (30)	1.18	0.554
	Male	40	11 (27.5)	14 (35)	15 (37.5)		
Right condylar position	anterior	31	10 (32.3)	12 (38.7)	9 (29)	0.85	0.931
	concentric	35	12 (34.3)	10 (28.6)	13 (37.1)		
	posterior	24	8 (33.3)	8 (33.3)	8 (33.3)		
Left condylar position	anterior	35	10 (28.6)	16 (45.7)	9 (25.7)	5.82	0.231
	concentric	32	13 (40.6)	6 (18.8)	13 (40.6)		
	posterior	23	7 (30.4)	8 (34.8)	8 (34.8)		

These findings are echoed here in this study, with the posterior joint space being generally larger than the anterior joint space as well. Additional findings of the study by Martins *et al.* (2015) included the mean anterior joint space measurement was 1.86 mm, the superior joint space was 2.36 mm and the posterior joint space was 2.22 mm.

It is important to note that Martins *et al.* (2015) mentioned that the meta-analysis showed high levels of heterogeneity among the selected studies, with factors such as sample size, sample selection and methods of measurements contributing to this high heterogeneity level. This finding would probably explain the inconsistency and mixed findings of the various studies mentioned in this paper when it came to determine the association between skeletal pattern and TMJ morphology. Furthermore, other contributary factors such as ethnicity, especially in a multiethnic population as in Malaysia may play a role in the growth and development of the TMJ, further resulting in the mixed findings. Therefore, taking into consideration the current available literature and the contributory findings of this study here as well, a much larger study would need to be carried out, with standardized sample selection criteria, as well as standardized measurement techniques to yield significant findings.

Conclusion

The results of this study demonstrate that there is no significant association between TMJ space or condylar head position in the different skeletal patterns (I, II, II) among the Malaysian population. It is recommended that a prospective study with large sample size and with standardized sample selection criteria and measurement techniques be implemented in the future to determine the precise association between TMJ space and condylar head position in these different skeletal patterns. The gathering of such detailed and accurate information on TMJ anatomy would provide an in depth understanding in craniofacial morphology and development.

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