Official Dental Journal of Suez Canal University
DENTAL SCIENCE Updates
Print ISSN 2636-3836
Online ISSN 2636-3844
www.dsujournals.ekb.eg
DSU — Vol. 5, No. 2, September (2024) — PP. 267:274

ASSESSMENT OF MANDIBULAR CONDYLAR MORPHOLOGY IN DIFFERENT VERTICAL SKELETAL PATTERNS USING CONE BEAM COMPUTED TOMOGRAPHY: AN IN-VITRO STUDY

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DOI: 10.21608/dsu.2024.220759.1191
Manuscript ID: DSU-2307-1191

KEYWORDS

TMJ , Condyle , Hyperdivergenace

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ABSTRACT

Introduction: The temporomandibular joint (TMJ) has been the topic of many studies because its anatomy and physiology are tightly related to stomatognathic functions. Additionally, the morphology and position of the mandibular condyle, being a primary growth center, is believed to affect the growth rate, and may therefore, affect facial vertical growth patterns. Cone beam computed tomography (CBCT) has recently become the routine imaging modality used by clinicians in different dental specialties **Aim of the study:** To assess the morphology of the mandibular condyle in different vertical skeletal patterns using cone beam computed tomography. **Materials and methods:** Sixty-six cone beam computed tomography (CBCT) scans were selected from the archives of the Oral Radiology Department, Faculty of Dentistry, Suez Canal University. The CBCT scans were divided into three groups based on the vertical skeletal pattern: group I of normal vertical skeletal pattern (norm-divergent), group II of high angle cases (hyperdivergent) and group III of low angle cases (hypodivergent). Specific linear measurements delineating the condylar morphology, namely the anterior, superior and posterior joint space, were measured from the CBCT scans of the three groups and were compared. **Results:** Results of the present study showed significant difference in the mean of most of the measurements related to the condylar morphology between the normal, high, and low vertical skeletal patterns. The hypodivergent group (group III) showed significantly higher values in comparison to the other groups regarding the readings taken from the corrected sagittal plane. **Conclusion:** The morphology of the mandibular condylar process affects the different vertical skeletal patterns.

INTRODUCTION

The temporomandibular joint's (TMJ) anatomy and function are exceptional in many ways. The TMJ is a diarthritic joint, where the mandible is hinged at both ends; therefore, each joint is dependent on the other and unable to move independently. Each articular joint accommodates the condylar process of the mandible within the glenoid fossa of the squamous part of the temporal bone. The anterior wall of the glenoid fossa is formed by the articular eminence, the condylar process' articulating counterpart [(1)]. Due to the complex anatomy of the joint, the well-known limitations of two-dimensional images makes it difficult to analyse the anatomy and morphology of the condyle. As technology has developed over the past few decades, Cone Beam

Computed Tomography (CBCT) has emerged as a widely used and well-liked three-dimensional imaging technique in the field of clinical dentistry. Since conventional cephalograms have always been considered by orthodontists the gold standard radiographs used for analysis of growth and malocclusion, therefore, an in-vitro and in-vivo study was conducted by Kumar et al [2], to compare cephalometric landmarks and analysis between both conventional and CBCT-generated cephalograms. They concluded that cephalometric measures on CBCT-synthesized cephalograms are comparable to standard cephalometric studies.

The types of malocclusions and the vertical distance of the bottom part of the face are related to the shape and position of the TMJ fossa and condyle. Therefore, it is crucial to understand condyle morphology so that if a patient has any abnormalities, the clinician can identify them [3]. Based on how the mandible rotates, several types of facial growth can be identified. In relation to the horizontal plane, the mandible grows excessively vertically when it rotates clockwise, which reduces the vertical overbite resulting in a hyperdivergent profile with a vertical growth. Likewise, a lack of vertical growth (in reference to the horizontal plane) and an increase in vertical overbite occurs when the mandible rotates anticlockwise, which results in a hypodivergent profile and a horizontal growth. [4] Several factors can cause different facial vertical growth patterns, whether 'high angle' which describes patients with an increased mandibular plane angle (MPA), associated usually with increased lower facial height (LFH), 'low angle' which describes patients with a reduced MPA, associated usually with a reduced LFH, or 'normal angle' which describes patients with normal MPA associated with normal LFH. Other factors include the development of the jaws, the dentoalveolar process, tooth emergence, and the function of the tongue and lips. According to the results of previous studies, the mandible rotates backward if vertical growth at the condyles is less than vertical growth at the alveolar processes or facial sutures. The jaw rotates forward, however, if vertical growth at the condyles exceeds the sum of the vertical growth components at the facial sutures and alveolar processes. [5] Therefore, the aim of the present study was to assess the mandibular condyle morphology in different vertical skeletal patterns.

MATERIALS AND METHODS

The current study was designed as a retrospective cross-sectional study. It was conducted on sixty-six Cone Beam Computed Tomography scans that were selected from the archives of the Oral Radiology Department, Faculty of Dentistry, Suez Canal University after the approval of Research Ethics Committee, Faculty of Dentistry, Suez Canal University (no.289\2020)

Sample size was calculated using G power version 3.1 statistical software. A total sample of at least sixty-six CBCT scans (22 each group) were found to be sufficient to detect a power of 80% at a significant level of 5% ($p< 0.05$).

The CBCT scans included in the present study were chosen to fulfil the following eligibility criteria:

a) Inclusion criteria:

- Unidentified full skull CBCT scans.
- Age range of selected patient`s scans were 20-40 years.
- CBCT of high quality and with no artifacts obscuring the region of the condyles.
- No orthodontic appliances seen in the CBCT scans.

- Full set of permanent dentition (no missing teeth except for third molars).
- No radiographic signs of condylar or glenoid fossa pathology.
- Male or female patients were included in the study.

b) Exclusion criteria:

- Skeletal asymmetry
- Temporomandibular joint disorders

I) Study design:

The CBCT scans were divided equally into three groups (22 scans in each group) according to their vertical skeletal pattern. Angles were extracted from the lateral 3D skull view of the Cone Beam Computed Tomography (CBCT) scans.

1. **Group I:** Normal vertical skeletal patterns (Normodivergence).

   The inclusion criteria for this group were to have: [(6,7)]

- SN/ Mandibular plane angle (32+/- 4 degree).
- Y axis to Frankfort plane angle (61+/- 4 degree).
- Frankfort to Mandibular plane angle (25+/-3 degree).

2. **Group II**: High vertical skeletal patterns (Hyperdivergence).

   The inclusion criteria for this group were to have: [(6,7)]

- SN/ Mandibular plane angle is (> 37 degree).
- Y axis to Frankfort plane angle is (> 66 degree).
- Frankfort to Mandibular plane angle is (> 29 degree).

3. **Group III Group III**: Low vertical skeletal patterns (Hypodivergence).

   The inclusion criteria for this group were to have: [(6,7)]

- SN/ Mandibular plane angle is (<27 degree).
- Y axis to Frankfort plane angle is (<57 degree).
- Frankfort to Mandibular plane angle is (<19 degree).

Radiographic evaluation:

All the scans were radiographed using Scanora 3Dx CT Scanner CBCT[1]. The field of view was fixed at 240x 165mm for all images using standard resolution mode, the operating parameters were 90 KVp, 10 MA and effective exposure time 3.2 seconds. The voxel size was 0.5mm using a flat panel detector. All scans were exposed using the same parameters fixed to ensure standardization. After the exposure, the acquired data was transferred into DICOM format, then exported into On Demand 3D software [2]

Radiographic Analysis

The method of radiographic analysis was standardized as follows; on the axial plane the cuts were scrolled back and forth till the head of the condyle was fully visualized mediolaterally. The reference planes were then adjusted on the ROI (head of the condyle). The sagittal plane was realigned to be dividing the head of the condyle into medial and lateral halves, and the coronal plane

1 Scanora 3Dx, Sordex- finland

2 On Demand Cybermed.co., Seoul, Korea

was adjusted to divide the head of the condyle into anterior and posterior halves.(8 The measurement was performed for the right condyle only.

From the corrected sagittal cut, the following measurements were obtained:

1. **Anterior joint space**: was measured as the shortest distance between the most anterior point of the condyle and the posterior wall of the articular tubercle. (Fig.1 A).
2. **Superior joint space:** measured as the shortest distance between the superior point of the condyle and the most superior point of the mandibular fossa. (Fig. 1 B).
3. **Posterior joint space:** measured as the shortest distance between the most posterior point of the condyle and posterior wall of the mandibular fossa. (Fig.1 C).

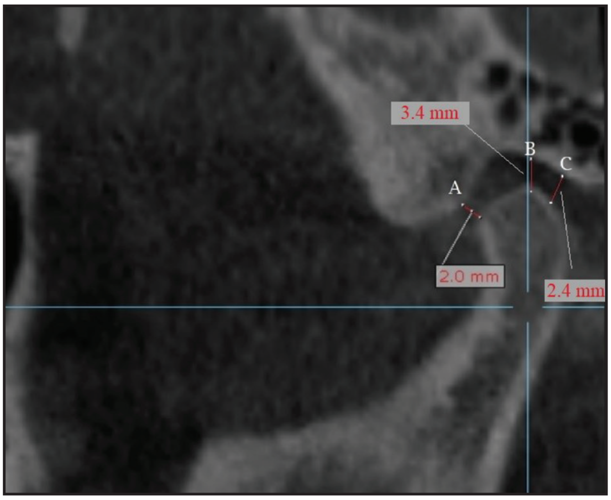

Fig. (1) Corrected sagittal cut showing measurements of the condyle spaces. *(A):* The head of the condyle with anterior joint space measurement (2.0 mm). *(B):* Superior joint space (3.4 mm). *(C):* The posterior joint space (2.4 mm).

Statistical analysis:

Data were fed to the computer and analysed using IBM SPSS software package version 20.0**.** (Armonk, NY: IBM Corp) Qualitative data were described using number and percent. The **Shapiro-Wilk** test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level.

The used tests were

1. **Chi-square test:** For categorical variables, to compare between different groups.
2. **Kruskal Wallis test:** For non-normally distributed quantitative variables, to compare between more than two studied groups, and **Post Hoc (Dunn's multiple comparisons test)** for pairwise comparisons.

RESULTS

The present study was conducted to evaluate the mandibular condylar morphology in different vertical skeletal patterns using cone beam computed tomography.

The comparison between the three studied groups regarding the anterior joint space is illustrated in table (1). From the table it could be seen that there was a statistically significant difference in mean anterior joint space in the three groups ($p=0.037^*$). Group III showed a higher anterior joint space value in comparison to the other groups,

Table (2) Shows the comparison between the three studied groups regarding the superior joint space; there was a statistically significant difference in the mean superior joint space between all three groups ($p<0.001^*$). Group III showed the highest superior joint space value in comparison to the other two groups.

Table (1) *Comparison between the three studied groups regarding the anterior joint space*

Anterior Joint Space					
	Group I (n=22)	**Group II (n=22)**	**Group III (n=22)**	**H**	**P**
Right side (Mean ± SD)	2.15 ± 0.90	1.91 ± 0.69	2.35 ± 0.59	6.600*	0.037*
Sig. bet. grps.	p_1=0.474, p_2=0.075, p_3=0.013*				

SD: *Standard deviation* **H:** *Kruskal Wallis test* **P:** *p value for comparing between the studied groups.*
p_1: *p value for comparing between* **Group I** *and* **Group II** **p_2:** *p value for comparing between* **Group I** *and* **Group III**
p_3: *p value for comparing between* **Group II** *and* **Group III** **: Statistically significant at p ≤ 0.05*

Table (2) *Comparison between the three studied groups regarding the superior joint space*

Superior Joint Space					
	Group I (n=22)	**Group II (n=22)**	**Group III (n=22)**	**H**	**P**
Right side (Mean ± SD)	3.13 ± 0.66	2.54 ± 0.74	3.90 ± 1.09	18.219*	<0.001*
Sig. bet. grps.	p_1=0.023* , p_2=0.046* , p_3<0.001*				

SD: *Standard deviation* **H:** *Kruskal Wallis test* **P:** *p value for comparing between the studied groups.*
p_1: *p value for comparing between* **Group I** *and* **Group II** **p_2:** *p value for comparing between* **Group I** *and* **Group III**
p_3: *p value for comparing between* **Group II** *and* **Group III** **: Statistically significant at p ≤ 0.05*

Table (3) shows the comparison between the three studied groups regarding the posterior joint space. A statistically significant difference in mean posterior joint space was seen between the three groups (p<0.001*). Again, group III showed the highest posterior joint space value between the three studied groups.

Table (3) *Comparison between the three studied groups regarding the posterior joint space*

Posterior Joint Space					
	Group I (n=22)	**Group II (n=22)**	**Group III (n=22)**	**H**	**P**
Right side (Mean ± SD)	2.42 ± SD 0.86	2.0 ± SD 0.63	3.21 ± SD 1.22	15.496*	<0.001*
Sig. bet. grps.	p_1=0.107, p_2=0.021* , p_3<0.001*				

SD: *Standard deviation* **H:** *Kruskal Wallis test* **P:** *p value for comparing between the studied groups.*
p_1: *p value for comparing between* **Group I** *and* **Group II** **p_2:** *p value for comparing between* **Group I** *and* **Group III**
p_3: *p value for comparing between* **Group II** *and* **Group III** **: Statistically significant at p ≤ 0.05*

DISCUSSION

The mandibular condyle plays a great role in the growth of the mandible as it is a primary growth centre that influences the growth rate. It has been currently believed that the morphology and the position of the condyle are correlated to the type of the malocclusion, especially the sagittal and vertical patterns of malocclusion. [(9)] Accordingly, the current study was conducted to evaluate the mandibular condylar bone morphology in different vertical skeletal patterns using cone beam computed tomography.

Sixty-six cone beam computed tomography (CBCT) scans were selected from the archives of Oral Radiology Department, Faculty of Dentistry, Suez Canal University with no sex predilection. The CBCT scans were divided into three groups according to their vertical skeletal pattern: group I of normal vertical skeletal pattern (normodivergent), group II of high angle cases (hyperdivergent) and group III of low angle cases (hypodivergent). Linear measurements delineating the condylar morphology, namely the anterior, superior and posterior joint space, were measured from the CBCT scans of the three groups and were compared.

The sample size for scans used in the current study was similar to that of **Tung et al** [10] and **Girardot** [11]. The sample was taken without any sex prediction as it was reported by **Swasty. *et al.***[12] that there were no statistically significant differences in the cortical bone thickness in the coronal sites of the mandible between males and females. **Yalcin and Ararat.**[13] also found that investigations on condyle morphology have revealed that there is no association between condyle form and gender.

The study of **Watted. *et al.***[14] stated that CBCT technology benefits both patients and practitioners since it offers clinicians with high-resolution 3-D images with short scanning times (10-70 seconds) and low radiation dose. It is very useful in the orthodontic sector since it can capture the anatomy required for orthodontic treatment planning. When used appropriately, the data obtained from CBCT imaging gives more accurate information for treatment planning than other imaging approaches, allowing orthodontists to provide better results. Additionally, according to **Tadinada. *et al***.[15] CBCT imaging was shown to be highly reliable for obtaining linear and volumetric measures, especially for mandibular condyles. **Sonal. *et al.*** [16] and **Arayapisit. *et al.***[17] reported that CBCT scans are more reliable and accurate than panoramic X rays and cephalograms. Furthermore, **Naji. Et al** [18] conducted a study to confirm the accuracy of cephalometric measurements conducted from CBCT scans while other studies like those by **Sam. et al.**[19], **Rodriguez-Cardenas** [20] concluded that the CBCT – synthesized cephalograms can successfully replace the conventional head films. Therefore, it was the imaging modality of choice in the current study.

Regarding results of the current study, there were statistically significant differences in the mean value of the anterior joint space, superior joint space, and posterior joint space between the three study groups, where group III, (hypodivergent group) showed significantly higher values than the other two groups.

Such results were in accordance with those of **Al-Rajeh. *et al.***[21] who compared CBCT images of 68 adult patients, divided into four groups of 17 CBCT images each, made according to ANB and SN-MP angles. They found that the Class II hyperdivergent group had significantly smaller superior joint space compared to class II hypodivergent group. Similarly, **Park. *et al.***[22]stated that the significantly smaller superior joint space in the hyperdivergent group indicates that the hyperdivergent skeletal pattern is associated with more superiorly positioned condyles. Additionally, **Noh. et al.,**[23] found that the superior joint space in the hyperdivergent group was significantly smaller than those in the other two vertical groups.

Such findings however were contrary to **Farinazzo.** ***et al.,***[24] in their study that evaluated the concentric position of the condyle in their respective mandibular fossa between class II subdivisions malocclusion which included normodivergent (group I) and hyperdivergent (group II) cases. Results of their study concluded there is no significant difference in the anterior joint space, superior joint space, posterior joint space between the studied groups.

Moreover, **Ma.** ***et al.,*** [25] stated that no significant difference was found between the groups with normodivergent and hyperdivergent pattern regarding the anterior joint space and superior joint space. Up to our knowledge, no sufficient research was conducted regarding the posterior joint space measurements.

CONCLUSION

Based on the results of the present study the following conclusions could be drawn:

1. The morphology of the mandibular condylar process affects the development of different vertical skeletal patterns.
2. From the morphology of the condyle, the orthodontist could predict the growth pattern of patients at a younger age so the orthodontic treatment could be more useful for growth modification during the growth of the vertical skeletal patterns.

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