CONE BEAM COMPUTED TOMOGRAPHY EVALUATION OF CONDYLE POSITION AND JOINT SPACE IN A GROUP OF INTRA-ARTICULAR DISORDERS PATIENTS UNDERGOING STABILIZATION SPLINT TREATMENT

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This cross-sectional study assesses condyle position and joint space using Cone Beam Computed Tomography (CBCT) in patients with intra-articular disorders undergoing stabilization splint treatment. Patients are categorized into three groups based on MRI findings: no disc displacement (no DD), disc displacement with reduction (DDwR), and disc displacement without reduction (DDwoR). The study involves 35 patients, each with at least one DDwR joint. CBCT evaluates joint space and condyle position, revealing wider anterior, posterior, and superior joint spaces in both DDwR (anterior: 2.48 ± 0.98mm; posterior: 1.83 ± 0.71mm; superior: 2.46 ± 0.81mm) and DDwoR groups (anterior: 2.41 ± 1.13mm; posterior: 2.65 ± 1.14mm; superior: 2.74 ± 0.88mm) compared to the no DD group. Posterior condyle position accounts for the highest prevalence, at 60.4%, in DDwR joints. While no significant difference is noted in condyle position and anterior and superior joint space among three groups, a significant difference is observed in posterior joint space between groups ($p < 0.05$). The study suggests that joint space may be greater in joints with disc displacement, and posterior condyle position likely predominates in joints with and without disc displacement. However, further research is needed due to the small sample size.

Keywords: Joint space, condyle position, disc displacement, temporomandibular joint, intra articular disorders.

I. INTRODUCTION

The temporomandibular joint (TMJ) is recognized as one of the most intricate joints within the human body, consists of the mandibular condyle and the articular eminence of temporal bone. According to the American Academy of Orofacial Pain, temporomandibular disorder (TMD) is defined as a group of disorders involving the masticatory muscles, the temporomandibular joint (TMJ), and the associated structures.[1] The most common TMJ conditions are pain-related and intra-articular disorders.[2] Intra-articular disorders pertain to inflammatory or mechanical factors that impact the joint directly, with articular disc displacement being the most prevalent. Additional intraarticular causes encompass trauma, capsular inflammation, osteoarthritis, hypermobility, and inflammatory conditions such as rheumatoid arthritis.[3] The positioning of the mandibular condyle within the articular fossa is subject to variation, holding significant implications for functional disorders of the masticatory system. Extensive research has underscored the importance of condyle position in understanding temporomandibular joint (TMJ) disorders, with suggestions that it may be a contributing factor to their etiopathogenesis, influencing the forces exerted on the condyle

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and disc.[4] However, the precise significance of the relationship between the condyle and fossa in TMJ disorders remains a topic of debate. Several studies have established a connection between aberrant condyle position and temporomandibular disorder (TMD), advocating for corrective interventions in select cases. Conversely, other research endeavors have failed to ascertain a substantial correlation between condyle position and TMD.[7,8] In Vietnam, there have only been a few studies evaluating the position of the condyle and the joint space in patients with temporomandibular disorders (TMD). However, most of these TMD cases are diagnosed clinically based on the DC/TMD or RDC/TMD criteria. Even cases diagnosed with intra-articular TMD involving disc displacement are not definitively diagnosed using MRI.[9,10] Magnetic resonance imaging (MRI) provides a comprehensive depiction of soft tissues in anatomical and semi-functional contexts, facilitating precise assessment of the relationship between the disc and condyle. Conversely, cone-beam computed tomography (CBCT) serves as an effective tool for evaluating the bone structure of the joint, aiding in accurately identifying joint space and condyle position. Therefore, the aim of this study is to measure joint space and assess condyle position using CBCT. This examination will encompass joints without disc displacement, joints with disc displacement with reduction (DDwR), and joints with disc displacement without reduction (DDwoR), as classified in MRI, in patients with intra-articular disorders who are scheduled to undergo treatment with stabilization splints.

II. MATERIALS AND METHODS

1. Subjects

CBCT'temporomandibular joints of patients diagnosed with intra-articular disorders were collected from the National Hospital of Odonto-Stomatology in Hanoi and the School of Dentistry (Hanoi Medical University). These patients are selected for the study upon being diagnosed with intra-articular temporomandibular disorders (TMD), exhibiting disc displacement with reduction (DDwR) in at least one temporomandibular joint (TMJ) on MRI, while the contralateral side could exhibit either no disc displacement (no DD), disc displacement with reduction (DDwR) or disc displacement without reduction (DDwtR). Consequently, the joints were categorized into three groups based on the correlation between the disc and condyle observable on MRI (diagnosed by radiologists.): no disc displacement (no DD), disc displacement with reduction (DDwR), and disc displacement without reduction (DDwtR). In MRI examinations, DDwR was characterized by the posterior band of the disc positioned anterior to the 11:30 position in the maximum intercuspal position, with the intermediate zone of the disc also anterior to the condylar head. Upon full opening, the intermediate zone of the disc was found situated between the condylar head and the articular eminence. DDwoR was characterized by the posterior band of the disc positioned anterior to the 11:30 position in the maximum intercuspal position, with the intermediate zone of the disc also anterior to the condylar head. Upon full opening, intermediate zone of the disc is located anterior to the condylar head.

Exclusion criteria were applied to patients with disorders primarily associated with pain, such as myalgia or myofascial pain, as per the DC/TMD criteria, and those experiencing pain related to other craniofacial structures such as the trigeminal nerve or wisdom teeth. Furthermore, patients with uncontrolled systemic or mental/behavioral disorders, rheumatic diseases, acute infections, or a history of orthopedic, head, and/or facial trauma, including prior TMD treatment involving splint therapy, were excluded.

2. Methods

Study design

This is a retrospective cross sectional study.

Sample size

The sample size is dertermined by using the following formula:[11]

$$n = Z^2_{(1-\alpha/2)} \frac{p(1-p)}{\varepsilon^2}$$

In which:

α: Significance level (chosen as α = 0.05, corresponding to a 95% confidence level, yielding.

$Z_{1-\alpha/2} = 1.96$.

ε: Relative margin of error, ε = 0.15.

p: success rate of treatment for disc displacement with reduction using stabilization splints, p = 0.712 according to the study by Huang et al (2011).[12]

35 patients with a total of 70 joints were recruited for the research.

3. Data collection and analysis

CBCT imaging was performed using the Planmeca Promax® 3D max device (Helsinki, Finland), with settings including maximum output at 46 KVP and 14MA, FOV (field of view) of 13 × 13cm^2, and a voxel size of 200 microns. Multiplanar reconstructions were generated using "Planmeca Romexis 3.8.30" software to acquire coronal, sagittal, and axial images of the TMJ. Patients were positioned upright with their heads in natural head position. Scans were captured in the closed mouth position at maximum intercuspation, following standardized exposure and patient positioning protocols to ensure consistency and standardization across all CBCT scans.

Assessment of condyle position and joint spacein CBCT. On multiple planar reconstruction images, the skull was reoriented to the Frankfort horizontal (FH). Measurement of joint space in sagittal CBCT images was conducted following the method outlined by Ikeda and Kawamura (Fig. 1).[13] The sagittal plane, which divides the longitudinal axis of the condyle in half, served as the section for measurement. The superior joint space (SJS) was defined as the distance from the most superior point of the condyle to the most superior point of the mandibular fossa (with reference to the Frankfort horizontal plane). To determine the SJS, tangents were drawn from the most superior point of the fossa to the condyle, marking two points. From each of these points, an auxiliary straight line was drawn perpendicular to the tangents. The distance between the point of intersection of the posterior auxiliary line and the fossa and the point of intersection of the posterior tangent and the condyle was termed the posterior joint space (PJS), while the anterior joint space (AJS) was determined similarly using the anterior tangent and anterior auxiliary line (Fig. 1).

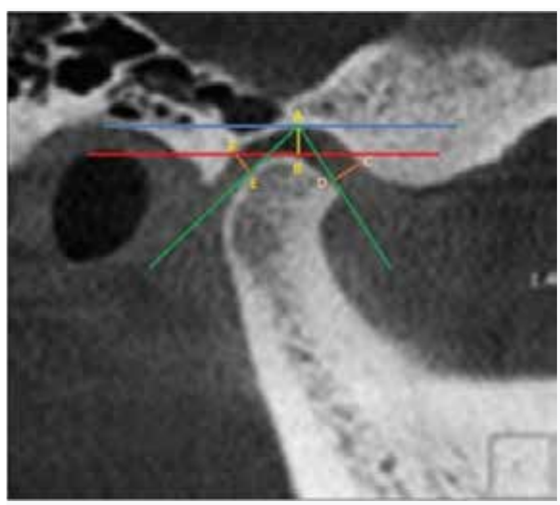

Figure 1. Measurement of joint space in sagittal CBCT images was conducted following the method outlined by Ikeda and Kawamura[13]

Condyle position in sagittal plane was expressed using the Condylar ratio, following the method proposed by Pullinger and Hollender.[14] Condylar ratio: (PJS – AJS) / (PJS + AJS) x 100.

The condyle was considered concentric if the ratio fell within ±12%. A ratio smaller than -12% indicated a posterior condylar position, while a ratio greater than +12% suggested an anterior condylar position.

All measurements in CBCT were performed by the principal investigator, with anonymized patient information and diagnoses.Each image was measured three times on separate days by the same examiner. The mean of these measurements determined the space distance.

To mitigate bias, the principal investigator will engage in discussions with radiologists prior to commencing the study, aiming to establish consensus on the diagnostic criteria for identifying disc displacement with and without reduction on MRI. During the course of the research, there was always close coordination between the radiologists and the clinicians, especially in cases where the radiologists had suspicions about certain features on the MRI images. These would be cross-checked with the clinical symptoms provided by the clinicians. Additionally, before initiating the formal measurements, the principal investigator conducted multiple trial measurements until the intraclass correlation coefficient (ICC) between two trial measurements exceeds 0.75. All patients and research data were encrypted before analysis.

4. Statistical analysis

The software used for the statistical analysis was Statistical Package for the Social Sciences (SPSS) software (version 21.0. Armonk, NY: IBM Corp). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of the variables. One-way ANOVA tests were used to compare the mean of anterior joint space between groups (DDWR, DdwoR, no DD). Kruskal-Wallis tests and Mann-Whitney U tests were used to compare the median superior joint space, and posterior joint space between groups (DDWR, DdwoR, no DD). Chi-square tests were used to compare the distribution of condyle position among the three groups. Intra-class correlation coefficient tests were used to evaluate intra-observer. Results with a p-value less than 0.05 were considered statistically significant.

5. Research ethics

All patients were briefed on the study protocol and provided written consent. The study received approval from the Ethics Council in Biomedical Research of Hanoi Medical University under reference number 662/GCN-HĐĐĐNCYSH-ĐHYHN on May 11, 2022.

III. RESULTS

In this cross-sectional study, CBCT images of 35 patients with a total of 70 joints were evaluated, and these joints were categorized into three groups based on the relationship between the disc, condyle, and eminence.

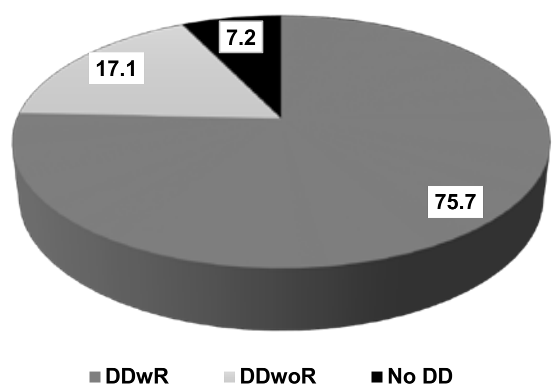

Chart 1. Distribution of joints based on relationship between disc and condyle

In our evaluation of 70 joints from 35 patients with intra-articular disorders, we found that only 7.2% of the joints exhibited a normal relationship between the disc, condyle, and eminence. Additionally, 17.1% of the joints displayed disc displacement without reduction. The majority of cases, comprising 75.7% of the total, exhibited disc displacement with reduction.

Table 1. Joint space measurements in CBCT (n = 70)

		N	Mean	Median	Minimum	Maximum	SD	p
Superior joint space	**DDwR**	53	2.46	2.25	0.70	4.96	0.81	0.68
	DdwoR	12	2.74	2.48	1.8	4.49	0.88	
	No DD	5	2.33	3.14	0.45	3.59	1.36	
Anterior joint space	**DDwR**	53	2.48	2.54	0.79	4.86	0.98	0.56
	DdwoR	12	2.41	2.08	1.27	4.86	1.13	
	No DD	5	2.26	2.54	1.00	3.62	1.10	
Posterior joint space	**DDwR**	53	1.83	1.91	0.5	3.81	0.71	0.03*
	DdwoR	12	2.65	2.4	1.27	5.24	1.14	
	No DD	5	1.73	1.62	1.27	2.25	0.37	

**Kruskal-Wallis test*

The posterior joint space exhibited significant differences among the three groups, being highest in the DDowR group (2.65 ± 1.14mm, median: 2.4mm) and lowest in no DD group (1.73 ± 0.37mm; median: 1.62mm). Conversely, the anterior joint space was highest in the DDwR group (2.48 ± 0.98mm) and lowest in no DD group (2.26 ± 1.10mm), but no significant difference was observed between the groups. Additionally, the comparison of the superior joint space between groups revealed no significant differences ($p > 0.05$), with the shortest measurement recorded in no DD group (2.33 ± 1.36mm) and the longest in the DDowR group (2.74 ± 0.88mm).

The comparisons among subgroups regarding condyle position on sagittal views were presented in Tables 2, 3, and 4. Accordingly, the incidence of posterior condyle position was significantly higher in the DDWR group (60.4%) and the no-DD group (60%), respectively ($p < 0.05$). The incidences of posterior and anterior condylar position were equal at 41.7%, both surpassing the incidence of concentric positioning in the DDwoR group (16.6%). However, the disparities in condylar position between groups did not reach statistical significance, with $p > 0.05$.

Table 2. The difference between sagittal condyle position as depicted in CBCT between no disc displacement group and disc displacement with reduction group

	No DD		DDwR		Total		p
	n	%	n	%	n	%	
Anterior	1	20.0	8	15.1	9	15.6	0.67
Concentric	1	20.0	13	24.5	14	24.1	
Posterior	3	60.0	32	60.4	35	60.3	
Total	5	100	53	100	58	100	

**Chi square test*

Table 3. The difference between sagittal condyle position as depicted in CBCT between no disc displacement group and disc displacement without reduction group

	No DD		DDwoR		Total		p
	n	%	n	%	n	%	
Anterior	1	20.0	5	41.7	6	35.3	0.62
Concentric	1	20.0	2	16.6	3	17.6	
Posterior	3	60.0	5	41.7	8	47.1	
Total	5	100	12	100	17	100	

**Chi square test*

Table 4. The difference between sagittal condyle position between disc displacement with reduction group and disc displacement without reduction group

	DDwR		DDwoR		Total		p
	n	%	n	%	n	%	
Anterior	8	15.1	5	41.7	13	20.0	0.34
Concentric	13	24.5	2	16.6	15	23.1	
Posterior	32	60.4	5	41.7	37	56.9	
Total	53	100	12	100	65	100	

**Chi square test*

IV. DISCUSSION

The temporomandibular joint (TMJ) stands as the singular movable element within the craniomandibular complex. It constitutes a compound joint, comprising three main components: the condylar process of the mandible, the glenoid fossa of the temporal bone, and an avascular fibrocartilage articular disc. During normal physiological function of the TMJ, the articular disc is situated inferiorly between the condylar head and superiorly and anteriorly between the articular eminence when the jaw is closed. However, upon jaw opening, the disc shifts into position between the condylar head and the temporal articular eminence.[15] Several imaging modalities are available for visualizing the temporomandibular joint (TMJ), encompassing magnetic resonance imaging (MRI), computed tomography (CT), cone beam CT, ultrasonography, and conventional radiography. Due to the intricate anatomy of the TMJ, selecting the appropriate imaging modality is crucial. Various techniques have been devised to capture the morphology, position, and degenerative indicators of TMJ disorders.[16] The introduction of cone-beam computed tomography (CBCT) in the 1990s brought about significant advancements in TMJ imaging. CBCT offers several advantages, including lower radiation exposure and the elimination of bony structure superimposition.[17] As a 3D imaging modality, CBCT allows for the acquisition of multiplanar images, facilitating precise evaluation of condyle position within the glenoid fossa and measurement of joint space dimensions. This technique provides images in axial, sagittal, and coronal planes, thereby improving visualization of the TMJ. Studies conducted by Barghan et al., and Larheim et al. have highlighted CBCT's superiority over conventional computed tomography (CT), demonstrating its ability to provide superior resolution and reduced radiation exposure. This enables distortion-free visualization of TMJ anatomy and facilitates comprehensive analysis of joint spaces, including reliable evaluation of linear measurements and assessment of condyle shape and position.[18,19] While CBCT is considered ideal for evaluating the osseous structure of the temporomandibular joint (TMJ), MRI is recognized as the preferred noninvasive modality and is commonly regarded as the gold standard for imaging the soft tissue components of the TMJ, especially the location and morphology of the articular disc. It is crucial to note that MRI is the sole imaging modality capable of providing an accurate assessment of the correlation between the articular disc, condyle, and eminence. Our research employed both MRI and CBCT imaging techniques to achieve a comprehensive understanding of the temporomandibular joint (TMJ) dynamics. By utilizing MRI, we attained precise insights into the relationship between the articular disc and condyle, allowing for detailed examination of their morphology and spatial correlation. Additionally, CBCT enabled accurate evaluation of the condyle position and joint space, providing valuable information on TMJ osseous structures. This dual-modality approach ensured a thorough and precise assessment of TMJ health, enhancing the reliability and completeness of our study findings.

The precise positioning of the mandibular condyle within the glenoid fossa remains a fundamental inquiry in dentistry. While certain authors have suggested a correlation between condylar position and disc displacement, others have observed an association between disc displacement and alterations in joint space dimensions[20]. In our study, the position of the condyle is determined using the condylar ratio method proposed by Pullinger and Hollender. This methodology aligns with the approaches adopted in numerous other studies by authors such as Idan et al. (2019), and Paknahad (2015), Elif Yildizer (2023) among others.[6,20,21]

Our findings indicate that in both groups with disc displacement, the condyle predominantly assumes a posterior position, accounting for 60.4% in the DDwR group and 41.7% in the DdwoR group. This observation aligns with Paknahad et al.'s (2015) study, which similarly reported a higher prevalence of posterior condylar positioning, specifically noting that 38.3% of the symptomatic group exhibited this characteristic.[21] However, our results contrast with those of Yildizer (2023).[6] In Yildizer's research, within the pain DDwR group, condylar positions were predominantly anterior (48%), followed by 33% in centric relationship, and posterior positions accounted for the lowest proportion at only 19%. In the painless DDwR group, centric positions were highest at 50%, while anterior positions were lowest at only 7%. Yildizer's research concluded that patients with painful DDWR exhibited wider lateral joint spaces and anteriorly positioned condyles compared to those without pain and control groups. The correlation between condyle position and pain suggests a relationship between DDwR pain and condyle position.

Measuring the joint space dimension helps determine the optimal positioning of the condyle head within the glenoid fossa. The term "space surrounded joint" refers to the radiolucent area between the condylar and temporal components, typically described radiographically.[22] Regarding joint space measurements, in the DDwR group, the posterior joint space measures 1.83 ± 0.71mm, and the superior joint space measures 2.46 ± 0.81mm, both of which are lower than the corresponding measurements reported for both painful and painless DDwR groups in Yildizer's research (2023). However, the anterior joint space in our study measures 2.48 ± 0.79mm, which is relatively consistent with the measurements observed in both painful and painless DDwR patients in Yildizer's study (2023).[6] Furthermore, our study indicates that the anterior joint space in the disc displacement groups surpasses the measurements reported for TMD joints in the study conducted by Al Rawi et al. (2017) for both male and female participants. Conversely, the superior and posterior joint spaces in our study are smaller than the corresponding measurements when compared with those reported by Al Rawi et al.[23]

From the research findings, we also observed that when assessing the anterior-posterior position of the condyle based on the condylar ratio, the predominant position of the condyle in sagittal plane in the joints with disc displacement is posterior. Anterior joint space, posterior joint space, and superior joint space in the groups with disc displacement are all larger than those in the without displaced disc group. This can be explained by the fact that the position of the condyle within the joint space in joints with disc displacement is lower (in the vertical plane), hence the dimensions of all joint spaces in these joints may be greater than the joints without disc displacement.

Our study was conducted in an effort to determine whether there are changes in the position of the condyle and the joint spaces in the anteroposterior dimension, which can be most accurately assessed on CBCT images, when the position of the disc is abnormal, as confirmed by MRI. These alterations in condylar position on CBCT could potentially serve as indicators to help clinicians predict disc position abnormalities, particularly in situations where MRI are unavailable. The cost associated with MRI imaging for TMJ is significant, and not all patients can undergo such imaging diagnostic technique, especially those with claustrophobia or individuals with various metallic implants like dental braces, crowns, bridges, and implants. Another strength of our study is that the position of the condyle and joint space was evaluated only in a group of patients with intra-articular disorders (those with actual abnormalities in joint structure), rather than all patients with temporomandibular disorders (including those with muscle pain and intra-articular disorders). Additionally, abnormalities in disc position were definitively identified using the gold standard (MRI). However, a notable limitation of our study is the small sample size, which reduces the statistical power to detect significant relationships between changes in condylar position and disc position abnormalities. Another limitation of the study is that all data are derived from measurements obtained from CBCT images. Despite our efforts to minimize bias in the measurement process, the results of our study may still be affected by inaccuracies that occur during the execution of measurements on CBCT.

V. CONCLUSION

The study suggests that joint space may be greater in joints with disc displacement, and posterior condyle positioning likely predominates in joints with and without disc displacement. However, given the small sample size in our study, this finding needs to be confirmed through larger-scale investigations.

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