MEANDROS MEDICAL AND DENTAL JOURNAL
June 2024 25(2):133-144

Meandros Medical and Dental Journal
doi:10.69601/meandrosmdj.1485120

Research Article

COMPARISON OF TEMPOROMANDIBULAR JOINT SPACE AND ARTICULAR EMINENCE INCLINATION IN VARIOUS SKELETAL ANOMALIES

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ABSTRACT

Objective: This study aims to compare the values of joint spaces and articular eminence inclinations in individuals with various skeletal anomalies.

Materials and Methods: A total of 60 individuals with Class I (n=20), Class II (n=20), and Class III (n=20) anomalies were included in the study, and their cone-beam computed tomography images were utilized. In each individual, the axial sectional joint spaces, including the articular disc, were calculated three-dimensionally using computer software for both the right and left condyles. Additionally, the articular eminence inclinations of both the right and left sides were measured for each individual. The obtained data were statistically compared among groups using one-way analysis of variance and within groups for the right and left values using paired t-tests ($p<0.05$).

Results: No statistically significant differences were observed in terms of the volume values of interclass and intraclass (right-left condylar) joint space. Individuals with Class II malocclusion exhibited a statistically significant difference in articular eminence inclination between the right and left sides ($p=0.032$). Among the groups, it was observed that individuals with Class III malocclusion had a statistically significant difference in articular eminence values compared to the other classes ($p=0.007$).

Conclusion: Individuals with skeletal anomalies were found to have symmetric joint space volume for both right and left sides. Significant differences were detected between the left and right articular inclinations in individuals with Class II malocclusion. These findings provide important insights for the evaluation and treatment planning of temporomandibular joint structures in individuals with various skeletal anomalies.

Keywords: Temporomandibular joint space, articular eminence inclination, skeletal anomaly.

Received: 16 May 2024
Revised: 27 July 2024
Accepted: 09 August 2024
Published: 31 August 2024

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INTRODUCTION

The Temporomandibular Joint (TMJ) is one of the most complex structures in the body, both morphologically and functionally. Over the years, various perspectives on the positioning of the mandibular condyle within the glenoid fossa of the temporal bone have been discussed in the literature (1). Factors such as age, gender, craniofacial growth patterns, pathological/functional changes, variations in muscle activity, occlusal forces, and skeletal malocclusion are thought to influence TMJ morphology and condylar position (2–4). It has been reported that in individuals with skeletal Class I malocclusions, the condyle is typically centrally positioned within the glenoid fossa (5,6), while those with skeletal Class III malocclusions tend to have a more anterior condylar location (6–8). However, there are varying opinions on condylar position when comparing individuals with Class II and Class I malocclusions (5,7–11).

During the initial phase of mandible opening, a rotational motion is observed, followed by a forward and downward translational movement (1). Therefore, the joint space housing the articular disc and the inclination of the articular eminence are critical for the physiological movements of the condyle within the glenoid fossa (12). Ricketts (13) was the first to suggest that joint spaces could be measured to determine condylar position. Changes in joint space volume can occur due to orthodontic, orthognathic, and prosthetic treatments (14,15). It's also important to note that the surfaces making up the joint space undergo continuous remodeling and change. Variations in joint space volume can affect condylar movement, potentially leading to temporomandibular joint disorders or degenerative joint disorders (16,17).

Another factor influencing mandibular condyle movement is the inclination of the articular eminence, a convex bony prominence just in front of the glenoid fossa in the temporal bone of the temporomandibular joint. The posterior surface inclination of the eminence plays a significant role in determining the direction of condylar movement, thus influencing mandible movements (1). Given its role in the direction of condyle-disc complex movement, the articular eminence inclination is thought to be a contributing factor in TMJ dysfunction, similar to joint space (18).

In recent years, the use of Cone-Beam Computed Tomography (CBCT) in dentistry has increased due to its low radiation dose, high resolution, and rapid scanning time (19). The superimposition of TMJ bone structures with the small cranial base makes it necessary to examine them in detail using two-dimensional imaging methods, which can yield different results (20). The use of CBCT allows for monitoring volume changes in the mandibular condyle, providing more accurate results and planning (21). Nicolielo et al. (22) have demonstrated that condyle volume measurements can be evaluated using both CBCT and Multi-Slice Computed Tomography (MSCT) methods. However, one of the drawbacks of CBCT is that it exposes patients to higher doses of radiation compared to two-dimensional imaging. Therefore, it should be kept in mind that no dose of radiation is completely safe, and three-dimensional radiographs should only be preferred in cases where two-dimensional radiographs are insufficient and when there is an appropriate indication (23).

In light of this information, our study aims to compare condylar space and articular eminence inclinations in individuals with different skeletal malocclusions in the sagittal direction. The first null hypothesis (H0) of our study states that "There is no difference in TMJ spaces among individuals with different malocclusions," while the second null hypothesis (H0) states that "There is no difference in articular eminence inclination among individuals with different malocclusions."

MATERIALS AND METHODS

Prior to initiating the research, approval was secured from the Yuzuncu Yil University Non-Interventional Clinical Research Ethics Committee (Approval No: 2023/05-17). To determine the sample size, we utilized the G-Power statistical software package (Version 3.1, Franz Faul, University of Kiel, Germany). Drawing from the effect size identified in a similar previous study, we incorporated a total of 60 participants (12). This retrospective study adhered to the Helsinki Declaration guidelines, and informed consent was obtained from all participants.

The inclusion criteria

Individuals aged 18 to 35; those with complete permanent dentition (excluding third molars); individuals whose mean angle between the anterior cranial base (SN) and the mandibular plane (GoGn) is 31° ± 5°; absence of mandibular asymmetry or dental crossbite; no history of temporomandibular dysfunction, degenerative joint disease, orthodontic or orthognathic treatment; and no craniofacial syndromes or discernible pathologies. Exclusion criteria encompassed: individuals who had previously undergone orthodontic or orthognathic surgery; patients presenting with unilateral condylar hypoplasia, hyperplasia, joint mice, osteophytes, or pronounced condylar flattening; signs of trauma in the condylar region; and CBCT images of subpar quality containing metal artifacts or motion artifacts. Based on the ANB angle (the angle between points Nasion A and B), participants were categorized into three groups. An experienced orthodontist, using NemoCeph NX 2005 software (Nemotec, Madrid, Spain), traced the cephalometric images derived from CBCT scans. The resultant groups were identified as: Skeletal Class I (0° ≤ ANB ≤ 4°), Skeletal Class II (ANB > 4°), and Skeletal Class III (ANB < 0°).

Acquisition of CBCT data

From January 2018 to December 2022, 2000 CBCT images originally taken for diagnostic purposes in the Department of Oral, Dental, and Maxillofacial Radiology of our institution were assessed. Only 60 images that met both the inclusion and exclusion criteria were selected for the study. The KaVo 3D eXam device (Biberach, Germany), regularly serviced in our department, was employed for CBCT measurements. All scans were captured with the following settings: 120 kVp, 5 mAs, 7-second scan duration, 0.4 mm voxel size, and a 130 mm field of view (FOV). The acquired CBCT images, converted into the DICOM format, were analyzed in both axial and sagittal planes. During scanning, patients were seated with the device's Frankfurt plane parallel to the ground. They were instructed to maintain centric occlusion and maximum intercuspation. To minimize movement, specialized chin rests and cephalostats were utilized.

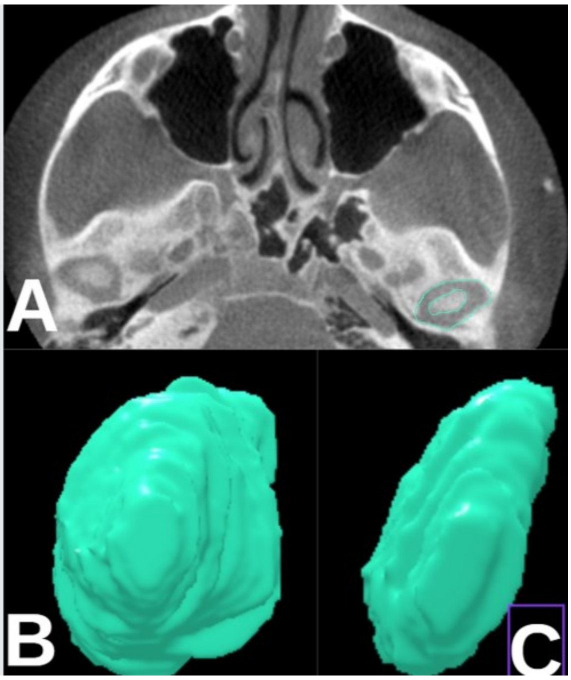

Figure 1. a. Image of the manual segmentation of the temporomandibular joint space and the condyle, **b.** Top and **c.** side views of the three-dimensional reconstruction of the manually segmented temporomandibular joint space.

Examination of condylar cavity volumes

Using 3D-DOCTOR software (Able Software Corp., Lexington, MA, USA), we estimated the volumes of 120 condylar cavities. The Cavalieri principle informed our calculation of temporomandibular joint (TMJ) cavity volumes (24). The combined volumes of the glenoid fossa and mandibular condyle were computed by merging axial sections in accordance with this principle. Volume measurements incorporated the first and last sections where the condylar cavity was visible. After the completion of cavity outlines, the software integrated segmented regions from each section to construct a 3D model (Figure 1).

Table 1. Definition of points, angles and lengths used in the research.

Cu	The highest point of the condylar process.
Po	Porion [the highest point of the meatus acusticus externus (external auditory meatus)].
R	The highest point of the glenoid fossa.
Etr Plane	The plane passing through T and R points.
T	The lowest point of the articular eminence.
F	The Frankfort horizontal plane.

Examination of articular eminence inclinations

Table 1 presents the points and planes used for calculating articular eminence inclinations. Utilizing these planes, we determined the eminence inclinations relative to the Frankfort horizontal plane. In the top-roof method, the inclinations were ascertained by measuring the angle between these planes (Figure 2). We assessed the inclinations of 120 condyles (both right and left) from 60 participants. The average eminence inclination for each participant was computed. All measurements were conducted on the central sagittal section of the TMJ by the same operator using a consistent computer setup and lighting conditions. To evaluate potential measurement inconsistencies, we repeated the measurements for 12 participants from each group four weeks after the initial assessments.

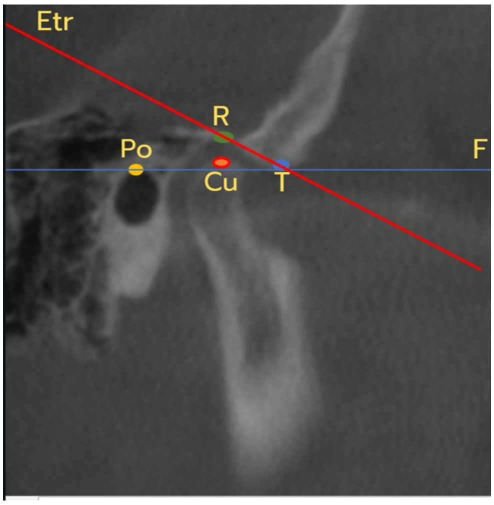

Figure 2. The orange dot represents the Cu point (the highest point of the condylar process), the green dot represents the R point (the highest point of the glenoid fossa), the yellow dot represents the Porion point (the highest point of the external acoustic meatus), blue dot represents T point (the lowest point of the articular eminence) and the blue plane represents the Frankfurt horizontal plane, the red plane represents Etr plane (which passes through the T and R points).

Statistical analysis

Descriptive statistics for the studied variables were presented as means and standard deviations. We performed a one-way analysis of variance to compare means across groups. Additionally, paired t-tests were utilized to contrast the right and left values within each group. We set a significance threshold of $p<0.05$ for all tests. Analyses were conducted using the SPSS software (IBM Corp., Armonk, NY, Version 21).

RESULTS

Table 2 presents the number of participants in the study, their gender distribution, and their average ages with standard deviations. The participants with Skeletal Class I malocclusion had an average age of 22.6 ± 4.7 years. Those with Skeletal Class II malocclusion averaged 22.55 ± 6.5 years, while participants with Skeletal Class III malocclusion had an average age of 22.75 ± 5 years. No significant age differences were observed among these groups.

Table 2. Comparison of age according to classes

Class	n	Gender		Age	*p**
		Female	**Male**	(Mean±SD)	
Class I	20	10	10	22.6±4.7	0.993
Class II	20	10	10	22.55±6.5	
Class III	20	10	10	22.75±5	

*One-way analysis of variance, frequency, M±SD : Mean ± standart deviation, p<0.05

Table 3 presents comparative statistics for the TMJ cavity volume both within and between groups. There were no significant differences in the average TMJ cavity volumes either within the groups or between the right and left sides.

Table 3. Comparison of right and left volume of TMJ and inclination of according to classes.

	Class	Right (Mean±SD)	Left (Mean±SD)	*p***
Volume of TMJ	Class I	1157.0±357.7	1197.3±377.1	0.416
	Class II	1216.3±371.7	1195.34±293.1	0.801
	Class III	1102.5±437.4	1077.6±370.5	0.629
	*p***	0.656	0.467	

*One-way analysis of variance, **Pairwise t test, M±SD : Mean ± standart deviation, p<0.05

Table 4 presents comparative statistics for articular eminence inclinations both within and between groups. A significant difference was observed in the right and left articular eminence inclinations for participants with Skeletal Class II malocclusion (p=0.032). Additionally, individuals with Skeletal Class III malocclusion displayed a significant difference in their articular eminence values when compared to other classes (p=0.007).

The reliability analysis demonstrated good intra-examiner agreement for articular eminence inclinations assessment (intraclass correlation coefficient [ICC]=0.753) and excellent intra-examiner reliability for TMJ volume measurement (ICC=0.902).

Table 4. Comparison of right and left inclination of articular eminence according to classes.

	Class	Right (Mean±SD)	Left (Mean±SD)	*p***
Inclination of Articular Eminence	Class I	29.70±6.8	30.70±7[a]	0.297
	Class II	31.15±5.1	33.10±6[a]	*0.037*
	Class III	28.10±6.4	26.75±5.2[b]	0.325
	*p**	0.297	*0.007*	

*One-way analysis of variance, **Pairwise t test, M±SD : Mean ± standart deviation, p<0.05

DISCUSSION

According to our study results, there were no statistically significant differences observed either within or between groups regarding the right and left TMJ joint spaces. Consequently, we accepted our first null hypothesis (H0). Upon examining the articular eminence inclinations, we noticed that individuals with Skeletal Class II malocclusion exhibited a greater left articular eminence inclination than on the right side (p=0.032). Among the groups, those with Skeletal Class III malocclusion displayed a statistically significant difference in left articular eminence values compared to other classes. As a result, our second null hypothesis was partially rejected.

Three-dimensional assessments of the temporomandibular joint (TMJ) and its surrounding anatomical structures often involve a range of methods for volume calculations. Typically, volume computations use manual segmentation, semi-automatic segmentation, and automatic segmentation methods (22). Sezgin et al. (25) examined the impact of section thickness on the volumes of irregular bone defects using the Cavalieri and Archimedes principles. They discovered that measurements taken with section thicknesses of 0.2 mm, 0.6 mm, and 1 mm closely matched the true volumes. However, using section thicknesses over 1 mm led to radiologically measured volumes being smaller than the actual ones. Meanwhile, Koç et al. (24) explored the consistency among various planimetric methods in volume calculations based on CBCT images. They found negligible differences between the Archimedes method and both manual and semi-automatic segmentation approaches for images with a 0.3 mm section thickness. In our research, we utilized the Cavalieri principle for volume calculations on images with a 0.4 mm section thickness. Based on the literature, the techniques we adopted are well-suited to yield results closely aligned with real volume measurements. Sezgin et al. (25) compared the actual volume measurements of three-dimensional objects obtained through a true volume measurement method with the volume values obtained through the reconstruction of radiographic images taken at appropriate sections. They demonstrated that the radiographic volume measurement method closely approximates the true value. This study indicates that three-dimensional reconstructions obtained from tomographic sections are highly effective in calculating the true values of three-dimensional structures. We believe that this evidence enhances the reliability of our study.

The position of the TMJ is crucial for maintaining a harmonious masticatory system (26). Insights into the position and symmetry of the condyle in individuals are provided by the TMJ cavity, while the articular eminence is fundamental for mandibular movements. Alterations in occlusion, whether from orthodontic or orthognathic interventions, are linked to changes in the condylar position (27). Hidaka et al. (28) observed diverse asymmetry directions in the TMJ positions in 38.7% of individuals before orthodontic treatment. Two studies comparing the TMJ space with malocclusions in the sagittal direction have evaluated it as the linear distance between the condylar head and the articular fossa (29,30). Song et al. (29) evaluated the joint spaces in individuals with Class I, II1, II2, and III malocclusions as anterior, superior, and posterior joint spaces. They found that in individuals with Class III malocclusion, the anterior joint space was statistically larger, while in individuals with Class II2 malocclusion, the posterior joint space was statistically larger compared to other groups. Noh et al. (30), in their study evaluating joint spaces in individuals with sagittal and vertical malocclusion, stated that there was no difference observed among individuals with sagittal malocclusion.

In studies evaluating the joint space in individuals with vertical malocclusion as a linear distance, Noh et al. (30) stated that only in hyperdivergent individuals was the superior joint space smaller, and this difference was significant. Al-hadad et al. (12) also evaluated the joint space volumetrically in individuals with vertical malocclusion in addition to linear measurements. They indicated that besides linear measurements, no difference was observed in volumetric measurements of the joint space between groups. In our study, no difference was observed in the joint space among individuals with sagittal malocclusion. It has been stated that after functional treatments due to mandibular retrognathia or prognathia, changes occur in joint position and joint space (31,32). However, it has been suggested that adaptive changes may occur in the glenoid fossa and condylar surface later on (33). John et al. (34) stated that TMJ in individuals with a vertical growth pattern and Class II malocclusion should be evaluated using magnetic imaging techniques. TMJ space can also be an indicator of degenerative joint diseases like osteoarthritis (16,17).

These degenerative diseases can also affect the articular eminence angle (35). The articular eminence angle can vary between 30° and 60° (36). Kariminasab et al. (37), in their study comparing the right and left articular eminences in individuals with different sagittal anomalies, observed the highest values in Class III individuals and the lowest in Class II individuals. However, they stated that there was no statistical difference observed between any groups. In a similar study by Kuyumcu and Oktay (38), while no difference was observed between Class I and Class II malocclusion individuals, it was stated that the articular eminence angle of Class III individuals was lower and this difference was statistically significant. In our study, it was found that only the left articular eminence value of Class II individuals was significantly higher than the right side. Among the groups, it was observed that in individuals with Class III malocclusion, the value of the left articular eminence was statistically lower and this difference was significant. Furthermore, the articular eminence values related to the classes are consistent with Kuyumcu and Oktay (38) but differ from Kariminasab et al. (37). However, the articular eminence angles in all three studies are within the specified limits. We believe that the differences in the studies may arise from the study groups. Limitations of our study include a limited sample size and the exclusion of individuals with vertical skeletal anomalies.

CONCLUSION

No differences were observed in TMJ cavities according to various sagittal malocclusions. It was found that individuals with Skeletal Class II malocclusion had a statistically significant difference in articular eminence inclination between the left and right sides. Therefore, before orthodontic treatment planning, this issue should be taken into consideration concerning sagittal forces.

Acknowledgments

We thank to Prof. Dr. Sıddık KESKIN due to his contributes in statistical analyses.

Authorship contributions

All authors contributed equally to the writing of this paper.

Data availibity statement

Readers who wish to examine our data may contact the corresponding author, who will facilitate its transfer.

Declaration of competing interest

None of the authors of this article has any relationship, connection or financial interest in the subject matter or material discussed in the article.

Ethics

Approval for this study was obtained from Van Yuzuncu Yil University Non-Interventional Clinical Research Ethics Committee (2023/05-17).

Funding

There is no funding.

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