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EVALUACIÓN TRIDIMENSIONAL DE LAS DISTANCIAS INTRAÓSEAS DE LA ARTICULACIÓN TEMPOROMANDIBULAR SEGÚN LA CLASE ESQUELÉTICA MEDIANTE TOMOGRAFÍA COMPUTARIZADA DE HAZ CÓNICO.

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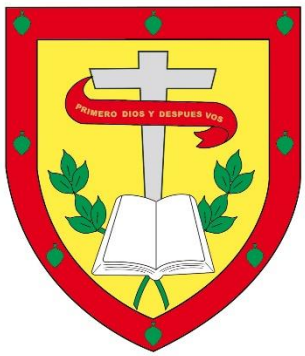
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Clinical, Cosmetic and Investigational Dentistry

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ORIGINAL RESEARCH

Three-Dimensional Evaluation of Temporomandibular Joint Intraosseous Distances According to Skeletal Class Using Cone Beam Computed Tomography

Gissela Maribel Lema-Paguay[1], Magaly Noemí Jiménez-Romero[1,2], Miriam Lima-Illescas[1,2], Fabián Darío Bautista Rojas[1]

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Abstract

Objective: To evaluate the relationship between sagittal temporomandibular joint (TMJ) spaces and skeletal class using cone-beam computed tomography (CBCT).

Materials and methods: Forty-eight CBCT scans were analyzed and equally distributed among skeletal class (I, II, and III) based on the Beta angle. Anterior (AS), superior (SS), and posterior (PS) joint spaces were measured on standardized sagittal reconstructions using an Instrumentarium OP300 unit. Condylar positional patterns were analyzed according to skeletal class.

Results: Significant intergroup differences in joint space measurements were identified ($p < 0.05$), primarily on the right side. Skeletal Class II presented the greatest dimensions (AS: 2.67 ± 1.04 mm; SS: 3.03 ± 0.98 mm; PS: 2.58 ± 0.87 mm), consistent with a more posterior and inferior condylar position. Conversely, Skeletal Class III consistently exhibited the lowest values (AS: 1.85 ± 0.65 mm; SS: 2.12 ± 0.62 mm; PS: 1.74 mm), indicating reduced joint space dimensions.

Conclusion: Sagittal evaluation using CBCT revealed that skeletal class influences joint space dimensions, with larger joint space dimensions observed in Skeletal Class II patients. Bilateral variations may reflect morphological adaptations associated with skeletal patterns.

Keywords: cone-beam computed tomography; mandibular condyle; orthodontics; skeletal class; temporomandibular joint.

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Keywords: orthodontics, cone-beam computed tomography, temporomandibular joint, mandibular condyle, skeletal class

Introduction

Diagnosis, treatment planning, and orthodontic management require comprehensive knowledge of skeletal, dental, and temporomandibular joint (TMJ) components. The TMJ is composed of an articular disc, two osseous structures (the mandibular condyle and temporal bone), an articular capsule, and ligaments. Therefore, understanding its biomechanics, function, and musculoskeletal stability is essential since a functionally stable condylar position is important for maintaining an appropriate condyle–fossa relationship and functional joint stability.[1–4]

This structure has been reported to remodel according to mechanical and functional conditions associated with malocclusions, particularly Skeletal Class II and III.[4,5] This variation may be influenced by racial and population-related factors; Skeletal Class II is more prevalent in American and European populations, whereas Skeletal Class III predominates in Asian populations, whereas both skeletal discrepancies are less prevalent in African populations.[6] In our population, Skeletal Class III was the most prevalent class.[7]

Owing to its anatomical complexity, the TMJ cannot be adequately visualized using conventional two-dimensional radiographs.[8,9] For accurate diagnosis, magnetic resonance imaging (MRI) is considered the gold standard because it

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allows evaluation of soft tissues; however, its routine clinical application remains limited because of limited accessibility and high cost.[10]

Although the joint space is influenced by soft tissue structures such as the articular disc and synovial fluid, which cannot be directly assessed using CBCT, this technique has become an alternative for analyzing the maxillomandibular region because of its high resolution. CBCT enables clinicians to detect changes in condylar position in the sagittal, coronal, and axial planes, facilitating precise evaluation of the osseous condyle–fossa relationship, positional adaptations, and the early identification of degenerative joint diseases.[8]

Ikeda[11] evaluated the condylar position using CBCT on sagittal sections and established reference values for joint spaces in a normal TMJ analyzed in the sagittal plane, reporting mean values of 1.3 mm ± 0.2 for AS, 2.5 mm ± 0.5 for SS, and 2.1 mm ± 0.3 for PS. A greater AS indicates a more posterior condylar position, whereas a greater PS indicates a more anterior condylar position. Variations in these measurements may reflect changes in condylar position within the glenoid fossa and adaptive TMJ remodeling.

In a CBCT study conducted in Skeletal Class III patients, Noh et al[8] reported variations in these spaces, with an SS of 2.9 ± 0.9 mm, an AS of 2.6 ± 0.6 mm, and a PS of 2.5 ± 0.7 mm.

Although these studies provide relevant information regarding sagittal joint spaces and skeletal class, the literature on the specific relationship between sagittal joint spaces and skeletal class in Latin American populations using standardized measurement methods is still limited. This limitation hinders the establishment of clinically applicable parameters for orthodontic and functional TMJ diagnosis, highlighting the need for additional research to clarify this relationship and provide more consistent and clinically applicable evidence.[1,4,12]

The alternative hypothesis was that differences exist in the mean AS, SS, and PS values according to skeletal class (class I, II, and III). Therefore, the aim of this study was to evaluate the relationship between sagittal TMJ space and skeletal class using CBCT.

Materials and Methods

This study had a quantitative, observational, descriptive, and cross-sectional design. A total of 154 CBCT scans from young patients attending a private clinic were analyzed after informed consent was obtained. CBCT images were acquired using an Instrumentarium OP300 multimodal unit (Instrumentarium Dental, Tuusula, Finland). The scanning parameters included 90 kV, 8 mA, a 12-second exposure time, a 16×11 cm field of view (FOV), and a voxel size of 0.2 mm, following a standardized clinical protocol that included natural head position, anatomical plane alignment, and image acquisition by the same operator.

CBCT scans acquired in maximum intercuspation using the multimodal device, with complete dentition excluding third molars, without a history of mandibular trauma, and without previous orthodontic treatment were included. The exclusion criteria included CBCT scans obtained from external databases, image distortions preventing adequate visualization of anatomical structures, incomplete scans limiting TMJ analysis, severe facial asymmetries, previous surgical interventions, articular resorption, degenerative arthritis, joint noise, and intracapsular pathologies.

A nonprobabilistic convenience sample was used. A total of 154 CBCT scans were analyzed using Romexis® Viewer software (Planmeca, Oy, Helsinki, Finland) from patients aged between 18 and 44 years to minimize the effects of ongoing craniofacial growth on condylar position and joint space measurements. Seventy-five CBCT scans were excluded because they lacked complete permanent dentition and were not acquired in maximum intercuspation, two because of image distortions, and 29 because they were incomplete and prevented adequate analysis. Ultimately, 48 CBCT scans met the inclusion criteria. Images obtained between January 2024 and September 2025 were selected.

Joint spaces constituted the primary TMJ study variable assessed through CBCT. For measurement standardization, the CBCT scans were analyzed in a dark room under dim lighting conditions to ensure adequate visualization. To minimize examiner fatigue, no more than 10 CBCT scans were evaluated per day. Images were calibrated with a 2-mm slice interval, and planes were adjusted according to the condyle's long axis in the axial plane and its angulation relative to the midsagittal plane. Subsequently, the sagittal reconstructions were oriented according to the true vertical line. Tangential lines were drawn to the anterior and posterior poles of the condyle, and the distances between these points and the glenoid fossa were defined as AS and PS, respectively. SS was defined as the distance between the deepest point of

the glenoid fossa and the most prominent point on the superior surface of the condyle, enabling assessment of condylar position within the glenoid fossa. These parameters are expressed in millimeters and are based on the method described by Ikeda[11,13] (Figure 1).

The skeletal class was determined using the beta angle (β), as described by Baik and Ververidou.[14] This method was selected because it provides a reliable assessment of sagittal skeletal discrepancies and is less affected by cranial reference planes and mandibular rotations than conventional cephalometric analyses. Skeletal classification was performed on standardized lateral cephalometric reconstructions obtained from the CBCT images. Three skeletal landmarks were analyzed: the subspinale (A), supramentale (B), and center of the condyle (C). Lines connecting C-B and A-B, as well as a perpendicular line from A to C-B, were traced, and the angle formed between this perpendicular line and A-B was measured (Figure 2).

Sixteen CBCT scans were assigned to each skeletal class on the basis of the beta angle measured in degrees on lateral cephalometric CBCT images. Three groups were established: Class I (27–35°), Class II (<27°), and Class III (>35°). Sex was categorized biologically as female or male, and the mean chronological age of the study population was determined.

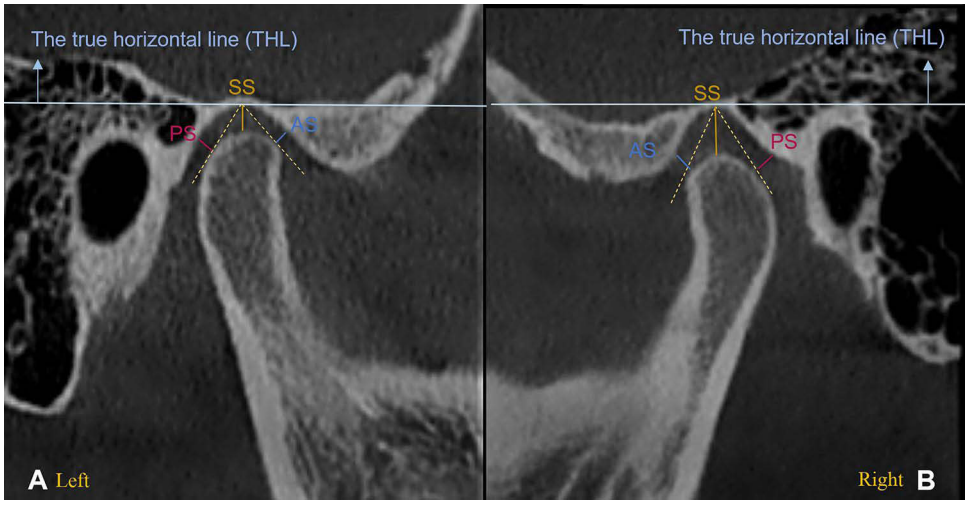


Figure 1 Representative sagital CBCT images of the left (**A**) and right (**B**) temporomandibular joints illustrating the true horizontal line (THL), the highest point of the glenoid fossa (SS), and the anterior (AS) and posterior (PS).

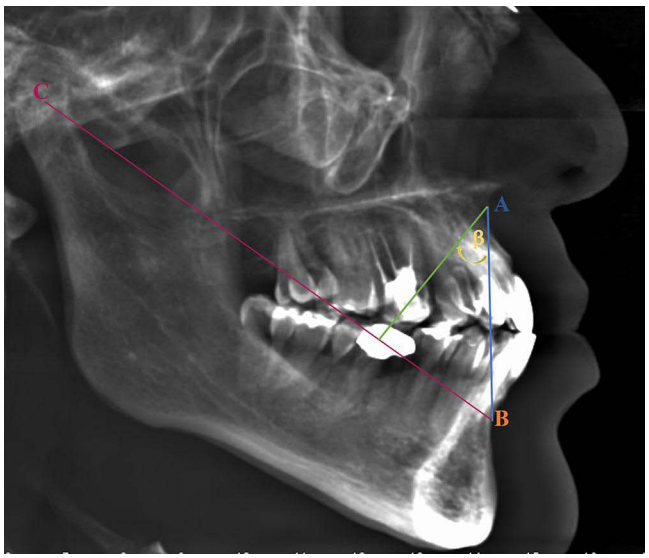


Figure 2 Measuring the beta angle (β) using standardized mandibular reference lines.

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A pilot study was conducted to train the investigator under standardized conditions of image acquisition and analysis, anatomical landmark identification, and examiner calibration using an additional 20% CBCT sample. A second specialized evaluator reviewed the dataset to verify the identification of anatomical structures and landmarks, thereby improving consistency and reducing potential measurement bias. In cases where discrepancies greater than 5% were detected between calibration measurements, a consensus was reached through simultaneous image analysis and discussion of anatomical landmark locations and measurement criteria until agreement was achieved.

Statistical Analysis

To determine measurement error, 20% of the sample was randomly retraced two weeks after the initial tracing. The intraclass correlation coefficient (ICC) showed excellent agreement, with values greater than 0.80 considered indicative of high reproducibility.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 25 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as means, standard deviations, numbers, and frequencies. To evaluate the relationship between skeletal class and joint spaces, data normality was assessed using the Shapiro–Wilk test. Analysis of variance (ANOVA) was used for intergroup comparisons according to skeletal class, and Tukey's honestly significant difference (HSD) post hoc test was applied to identify specific differences in multiple comparisons.

Ethical Considerations

Ethical approval for the study protocol was obtained from the Human Research Ethics Committee of Universidad Católica de Cuenca (CEISH-UCACUE-2024-179) on November 22, 2024, in accordance with the principles established in the Declaration of Helsinki.

Results

The study sample consisted of 48 CBCT scans, including 28 from female patients (58.3%) and 20 from male patients (41.7%). Mean age was comparable between sexes. Participants were distributed according to skeletal class into Class I, Class II, and Class III groups (n = 16 each), as detailed in Table 1.

Table 2 presents the measurements of the joint spaces. With respect to the anterior space (AS), statistically significant differences were observed on the right side ($p = 0.027$). Compared with Skeletal Class III (1.85 ± 0.65 mm), Skeletal Class II had the highest mean value (2.67 ± 1.04 mm), according to the post hoc analysis. Significant differences were also detected on the left side ($p = 0.030$); however, the highest mean values corresponded to Skeletal Class I (2.37 ± 0.88 mm) compared with Skeletal Class III (1.73 ± 0.75 mm).

With respect to the superior space (SS), significant differences were detected exclusively on the right side ($p = 0.025$). Compared with Skeletal Class III (2.12 ± 0.62 mm), Skeletal Class II showed the highest mean value (3.03 ± 0.98 mm), with a statistically significant difference ($p = 0.021$).

For the posterior space (PS), statistically significant differences were also identified exclusively on the right side ($p = 0.002$). Skeletal Class II presented the highest mean values (2.58 ± 0.87 mm), whereas lower measurements were observed in Skeletal Class I (2.03 ± 0.53 mm), with statistically significant differences ($p = 0.047$). Similarly, statistically significant differences were identified between Skeletal Class II and III ($p = 0.002$).

Table 1 Descriptive Measures of Sex and Skeletal Class

Gender	Skeletal Class				
	n (%)	Age ± DE	Class I n (%)	Class II n (%)	Class III n (%)
Male	20 (58.3%)	23.05 ± 5.83	8 (40.0%)	6 (30.0%)	6 (30.0%)
Female	28 (41.7%)	24.57 ± 7.30	8 (28.6%)	10 (35.7%)	10 (35.7%)

Table 2 Skeletal Class and Joint Spaces in CBCT

Joint Spaces											
Skeletal Class		**Right**					**Left**				
		Mean	**SD**	**Minimum**	**Maximum**	**ANOVA**	**Mean**	**SD**	**Minimum**	**Maximum**	**ANOVA**
AS	I	2.37	0.75	I	3.77	0.027*	2.37	0.88	0.85	4	0.030*
	II	2.67	1.04	1.13	4.22		2.31	0.46	1.75	3.16	
	III	1.85	0.65	I	3.77		1.73	0.75	0.63	3.26	
SS	I	2.73	1.11	1.41	5.6	0.025*	2.68	0.89	1.4	4.02	0.346
	II	3.03	0.98	1.2	4.42		2.61	0.86	1.6	4.22	
	III	2.12	0.62	1.2	3.16		2.28	0.74	I	3.74	
PS	I	2.03	0.53	1.13	3.16	0.002*	1.71	0.48	1.13	2.67	0.429
	II	2.58	0.87	0.89	4.33		2	0.83	0.82	4.33	
	III	1.74	0.42	1.02	2.44		1.81	0.55	1.17	3.28	

Multiple Comparisons			
Sagittal Joint Spaces According to Skeletal Class			
Joint Spaces	**Skeletal class**	**Right**	**Left**
		p	**p**
AS	I–II	0.563	0.973
	I–III	0.2	0.043#
	II–III	0.021#	0.071
SS	I–II	0.64	0.97
	I–III	0.159	0.36
	II–III	0.021#	0.49
PS	I–II	0.047#	0.4
	I–III	0.43	0.89
	II–III	0.002#	0.68

Notes: *p<0.05, ANOVA. #p<0.05, Tukey HSD post hoc test.

Overall, Skeletal Class II tended to have larger dimensions of the sagittal joint space, particularly on the right side, whereas Skeletal Class III consistently had the lowest mean values.

The graphical representation of the sagittal joint spaces showed variations according to skeletal class and the side evaluated (Figure 3). In general, Skeletal Class II exhibited higher values for AS (2.67 mm), SS (3.03 mm), and PS (2.58 mm), whereas Skeletal Class III presented the lowest values for AS (1.85 mm), SS (2.12 mm), and PS (1.74 mm), particularly in the right-side measurements. No specific pattern was observed on the left side.

The values shown in Figure 3 correspond to rounded mean values for each joint space.

Discussion

The sample size was relatively small because of the inclusion criteria. During CBCT acquisition, patients were required to be in maximum intercuspation while avoiding the use of a positioning device to prevent alterations in TMJ joint spaces. Consequently, a sample of 48 CBCT scans was obtained, resulting in the evaluation of 96 TMJs (corresponding to the right and left sides). The reliability of the findings is justified because, with a sample size ≥30, the means tend to follow a normal distribution regardless of the shape of the original population distribution.[15]

Among studies reporting sample sizes smaller than 30 individuals are those conducted by Manjula et al[16] and Ikeda and Kawamura,[11] as well as a study with a similar sample size reported by Santillan et al.[17] This supports the use of parametric tests; therefore, an equal number of CBCT scans was assigned to each skeletal class group (n = 16), regardless of factors such as age and sex.

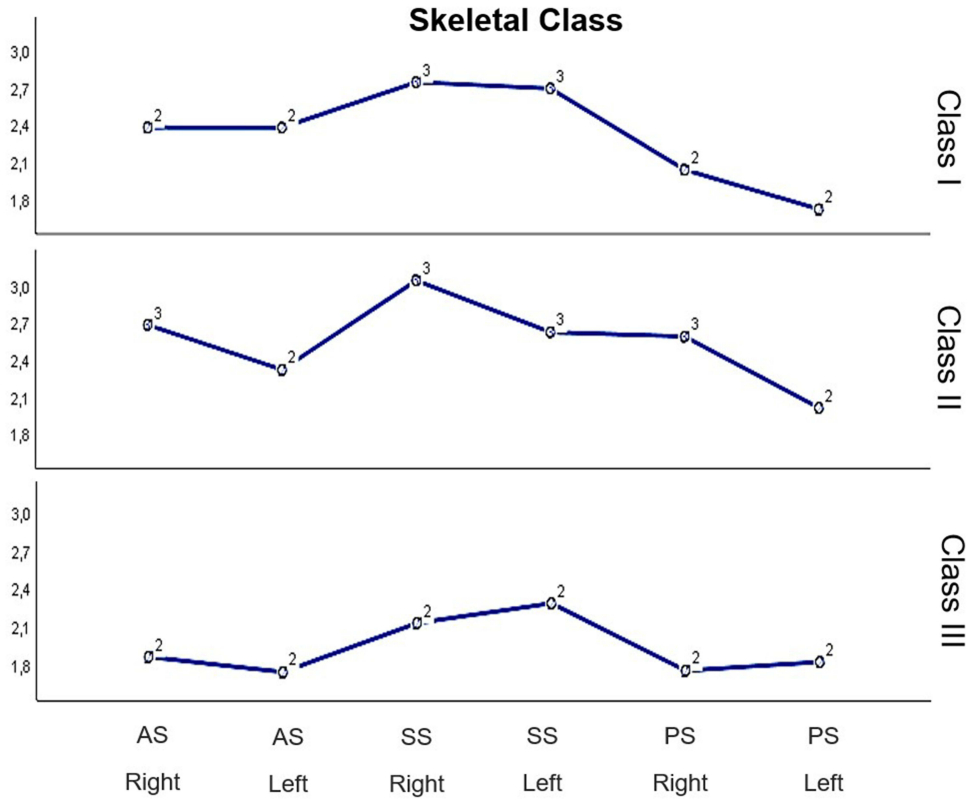


Figure 3 Mean values of the bilateral anterior (AS), superior (SS), and posterior (PS) sagittal temporomandibular joint spaces according to skeletal class. Measurements were obtained from CBCT sagittal sections in subjects with skeletal Class I, II, and III and are expressed in millimeters.

The present investigation revealed differences in TMJ joint space dimensions among the evaluated groups, with a tendency toward larger joint spaces in specific regions and variations according to the side analyzed. These findings are consistent with those of previous studies showing that the condyle–fossa relationship may vary according to skeletal pattern and malocclusion. Das et al[18] reported, through three-dimensional volumetric CBCT analysis, that compared with Class I patients, Class II patients exhibited lower total joint volumes and significant reductions in anterior and medial joint spaces, indicating that the condyle tends to be positioned more anteriorly and medially in patients with mandibular retrognathism. These findings support the hypothesis that skeletal discrepancies may be associated with TMJ adaptations.

Similarly, condylar position in asymptomatic patients with Class I malocclusion using CBCT and reported that a slightly anterior condylar position was the most frequent finding. They also reported mild differences between the right and left sides, with the left condyle being slightly more anteriorly positioned. The authors further reported greater variability in joint measurements than in patients with ideal occlusion, which could explain the differences observed in the present study and suggest that TMJ adaptations may not occur symmetrically.[19]

Sagittal TMJ evaluation using CBCT has proven to be a reliable tool for analyzing the condyle–fossa relationship and measuring joint spaces. Ikeda and Kawamura,[11] established reference values for functionally optimal joints using sagittal CBCT sections, reporting mean values of 1.3 mm for AS, 2.5 mm for SS, and 2.1 mm for PS. The authors emphasized that sagittal analysis enables precise identification of the condylar position within the glenoid fossa, particularly when images are standardized according to the condyle's long axis and true sagittal plane orientation. Furthermore, they reported that compared with conventional radiographic techniques, sagittal reconstructions obtained through CBCT exhibit lower variability and greater precision, allowing more reproducible evaluation of osseous joint relationships.

In the present study, sagittal CBCT evaluation allowed the identification of differences in joint spaces according to skeletal class, revealing a tendency toward larger joint dimensions in Class II patients. These findings suggest that skeletal discrepancies may influence the condyle–fossa relationship and articular morphological adaptations.

The discrepancies observed among studies may be attributed to differences in methodology, sample size, inclusion criteria, patient age, and the parameters used to determine condylar position. Nevertheless, the available scientific evidence collectively suggests that mandibular condyle morphology and position are closely related to skeletal class and that CBCT constitutes a reliable tool for three-dimensional evaluation of TMJ joint relationships.

Another study revealed that Class II patients exhibited larger joint spaces and greater condylar concentricity, which may reflect a more posterior and inferior condylar position within the glenoid fossa. Similarly, the results of the present study revealed larger joint dimensions in Class II patients, particularly in the right PS, which may represent an anatomical adaptation associated with the craniofacial characteristics of this skeletal discrepancy.[20]

Conversely, previous authors reported a significant reduction in anterior and superior joint spaces in Class III patients compared with Class I patients. They also reported that Class III individuals present morphological TMJ modifications, including a more inferior condylar position and changes in glenoid fossa morphology. Collectively, these findings support the existence of articular adaptations associated with skeletal patterns.[21]

The differences observed between the right and left sides may be explained by individual variations, masticatory dominance, or TMJ asymmetries. Previous studies have reported that condylar position and joint spaces do not always exhibit homogeneous bilateral behavior, even in patients without clinical symptoms. Rojas et al[22] reported that complete bilateral facial symmetry is uncommon in the population; therefore, most individuals exhibit some degree of asymmetry, which is considered part of normal anatomical variability. Consequently, the asymmetries observed in the present study should be interpreted with caution and not necessarily regarded as pathological findings.

Sagittal evaluation using CBCT represents a relevant tool for TMJ analysis because it enables three-dimensional assessment of the condyle–fossa relationship and highly accurate detection of morphological variations. Leite-de-Lima et al[23] emphasized that CBCT facilitates the evaluation of osseous morphology, joint spaces, and condylar position without anatomical superimposition, supporting its use as a preferred imaging modality. In this context, the findings of the present study suggest a relationship between skeletal class and increased TMJ joint space dimensions and reinforce the usefulness of sagittal CBCT analysis in orthodontic patients.

The present study has the following limitations: owing to the relatively small sample size, the findings should primarily be interpreted as descriptive evidence of articular morphological variations according to skeletal class. Therefore, future studies with larger samples and standardized protocols are necessary to clarify the relationship between sagittal joint spaces and condylar adaptations in different populations.

Conclusions

Sagittal evaluation of the temporomandibular joint using CBCT revealed differences in joint spaces according to skeletal class. Patients with Skeletal Class II patterns tended to have larger sagittal joint space dimensions, particularly on the right side.

The bilateral variations observed suggest that the condyle–fossa relationship may exhibit bilateral morphological adaptations associated with the skeletal pattern. In this context, CBCT constitutes a useful and reliable tool for the three-dimensional evaluation of TMJ osseous structures and the analysis of sagittal joint spaces in orthodontic patients.

Abbreviations

TMJ, temporomandibular joint; CBCT, Cone beam computed tomography; MRI, magnetic resonance imaging; FOV, field of view; AS, Anterior joint space; SS, Superior joint space; PS, Posterior joint space; A, subspinal; B, supramental; C, center of the condyle; ICC, Intraclass Correlation Coefficient; SPSS, Statistical Package for the Social Sciences; HSD, Tukey's Honestly Significant Difference.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

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