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TEMPOROMANDIBULAR JOINT ASYMMETRY IN ASYMPTOMATIC SKELETAL CLASS I PATIENTS

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ABSTRACT

Objectives: Analysis of TMJ asymmetry in a sample of asymptomatic skeletal class I patients.

Methods : This study was performed on one hundred patients requesting CBCT scans. All patients were skeletal class I pattern. They were all free of TMD symptoms, midline deviation of teeth, open bite, cross bite, congenital craniofacial abnormalities or any systemic diseases which may affect joint morphology such as rheumatoid arthritis. TMJ was evaluated through linear and volumetric analysis. Qualitative condyle position was also evaluated. All measures were compared on the right and left sides.

Results: There was relative asymmetry between right and left sides regarding all measured parameters. Condyle height showed the highest asymmetry, while condyle AP dimension was the least. There was absolute asymmetry between right and left sides regarding all measured parameters. fossa roof thickness showed the highest asymmetry, while condyle ML width was the least. On Correlating the R and L measurements, all correlations were positive with medium strength and were statistically highly significant. The highest correlation was shown in condyle volume while fossa roof thickness showed the least. The distributions of cases according to condyle position were almost statistically significantly different between right and left sides with 49 % percentage of agreement.

Conclusion: TMJ shows relative and absolute asymmetry in skeletal class I asymptomatic patients.

Advances in knowledge: TMJ asymmetry has been previously evaluated in different studies in correlation with TMD or craniofacial diseases mostly limited to two-dimensional (2D) imaging. Kambylafkas et al [2005] evaluated the association between unilateral degenerative joint disease and lower facial asymmetry. Yáñez-Vico et al [2012] analyzed and compared mandibular condyle morphology in patients with and without temporomandibular disorder. They concluded that condylar width, height and length asymmetries were a common feature of TMD. Trpkova et al [2000] investigated the amount of craniofacial asymmetry in female orthodontic patients with unilateral or bilateral TMJ internal derangement relative to the amount in female patients without TMJ ID. They found that the amount of asymmetry was not significant between females with normal TMJs and those with TMJ ID.

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On the other hand, the present study is designed to assess the presence of asymmetry of TMJ bony components in asymptomatic adult skeletal class I pattern to assess variations, using three dimensional (3D) CBCT imaging.

KEYWORDS: Temporomandibular joint - Cone Beam Computed Tomography – Asymmetry – Class I jaw relationship - Condyle. The author discloses no potential conflict of interest, financial or other.

INTRODUCTION

The word symmetry is derived from the Greek word '*symmetria'* which means 'of like measure'. Symmetry is defined as correspondence in size, shape and relative position of parts on opposite sides of a dividing line or median plane. Asymmetry is described as a lack or absence of symmetry. When applying this to the human face, it illustrates an imbalance or disproportionality between the right and left sides.[1]

The temporomandibular joint (TMJ) is one of the most important joints in the body, and it has a close relationship with the oral cavity and teeth. The position and function of the mandibular condylar portion of the TMJ is directly controlled by the oral structures, including the associated muscles. [2]

As the primary center of growth in the mandible, the condyle responds to continuous stimuli throughout the remodeling process, and thus plays an important role in the final dimensions of the adult mandible. Its volume and size can be related to the final dimensions of the mandibular as well as to the final relationship between maxillary and mandibular arches. Examination of TMJ structures radiographically is very important for evaluating the abnormalities and bony changes that affect the TMJ. [3]

Many studies have tried to relate temporomandibular disorders (TMD) to structural factors in the anatomy of this joint [4]. Bezuur [5] found that TMJ disorders were influenced by structural factors such as mandibular asymmetry. Habets [4] introduced a method for determining asymmetry between the mandibular condyles, which was based on comparing the vertical heights of the right and left mandibular condyles and the rami. He found that asymmetry of mandibular height correlated significantly for patients with TMJ disorders, compared to those without them. Other authors have corroborated this conclusion, finding asymmetrical height in the condylar process to be a significant relationship in patients with the disorder compared to those who were asymptomatic [6,7]. Other researchers, however, were unable to demonstrate this relationship, and found no statistically significant differences between condylar asymmetry in TMD patients compared to those with no signs or symptoms of TMD [8].

Many studies have investigated the TMJ morphologic parameters using different types of imaging techniques. Conventional X-rays were first used to assess the morphology of mandibular condyle and articular eminence [9]. Moreover, computed tomography (CT) images were widely used for the morphologic detection of TMJ [10, 11, 12]. In recent years, the micro-CT, cone beam computed tomography (CBCT), and magnetic resonance imaging (MRI) are used for research of TMJ morphology [13,14,15].

TMJ asymmetry has been previously evaluated in different studies in correlation with TMD or craniofacial diseases [15,16,17] mostly limited to two-dimensional (2D) imaging. On the other hand, this study assesses the presence of TMJ asymmetry regarding bony components in asymptomatic adult skeletal class I pattern among Egyptian population to assess variations, using three dimensional (3D) CBCT imaging.

Objectives

Analysis of TMJ asymmetry in a sample of asymptomatic skeletal class I patients.

SUBJECTS AND METHODS

Patients' selection

This study was performed on one hundred adult patients requesting CBCT scans as a diagnostic tool for other dental procedures. The study proposal was approved by the Faculty's research ethics committee. A written informed consent was requested.

The age range for all subjects was 30–50 years. All patients were Class I skeletal pattern. This was determined by measuring the ANB angle **(Figure 1)**. The ANB angle indicates the relative position of the maxilla to the mandible [18]. Patients were excluded if TMD was suspected. This was provided through complete patient history for any TMJ pain or sounds and through TMJ complete clinical examination. This was also further confirmed radiographically for any radiographic signs such as condyle flattening, osteophytes or any other morphological changes.

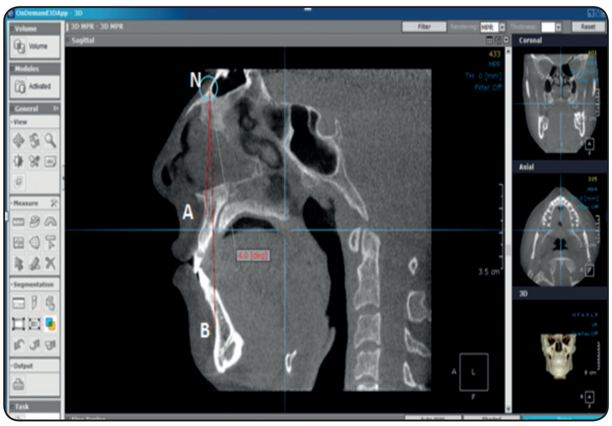

Fig. (1) Sagittal CBCT slice showing ANB angle. A point: position of deepest concavity on anterior profile of maxilla, N point: the nasion point (most anterior point on fronto-nasal suture), B point: position of deepest concavity on anterior profile of mandibular symphysis. {ANB 2-4o=Class I skeletal pattern, ANB > 4o=Class II skeletal pattern, ANB < 2o= Class III skeletal pattern} [18]

Patients were excluded if they had midline deviation of teeth, open bite, cross bite, congenital craniofacial abnormalities or any systemic diseases which may affect joint morphology such as rheumatoid arthritis.

METHODS

I) Data acquisition

CBCT scans were performed using i-CAT imaging system (Imaging Sciences International, Hatfield, PA, USA). Exposure was done at 120 kV and 26.9 s acquisition time. The voxel dimension selected was 0.2 mm. The image detector was a flat panel measuring 20 × 25 cm, and images were acquired at 14 bit in a single 360° rotation. The field of view was adjusted to cover the condyles bilaterally. The patient position was adjusted according to the manufacturer's instructions. CBCT scan data were saved as DICOM files (Digital imaging and communications in medicine) and then transferred to another workstation to view the images using On demand software (On demand 3D™, Cybermed, South Korea). Images were viewed using Dell monitor (22'' Full HD 1920 × 1080 display) in dimmed light room.

II) Image orientation:

On the multiplanar (MPR) screen, coronal, axial and sagittal views were reoriented to view the widest condyle dimension in each plane. The coronal plane was oriented on the axial window to pass through the widest condyle dimension mediolaterally. The sagittal plane was oriented on the axial window to be perpendicular to the coronal plane **(Figure 2)**.

III) Linear TMJ measurements:

Corrected coronal cut:

Condyle mediolateral width was measured on the axial plane passing through the widest condyle dimension using the linear measurement tool on the software **(Figure 3)**.

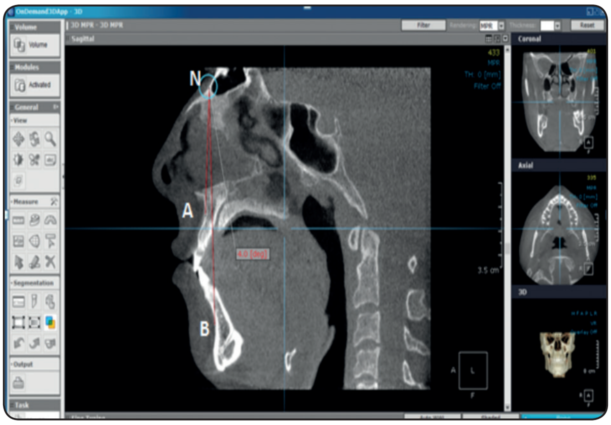

Fig. (2) Standardized orientation of the MPR views. The coronal plane was oriented on the axial window so that it passes through the widest condyle dimension mediolaterally. Sagittal plane was oriented on the axial window so that it runs perpendicular to the coronal plane.

Condyle height was measured on the sagittal plane, perpendicular to the condyle width using the linear measurement tool on the software **(Figure 3)**.

Corrected sagittal cut:

Condyle antero-posterior dimension was measured on a line connecting the most prominent anterior (A) and posterior (P) points of the condylar head **(Figure 4)**.

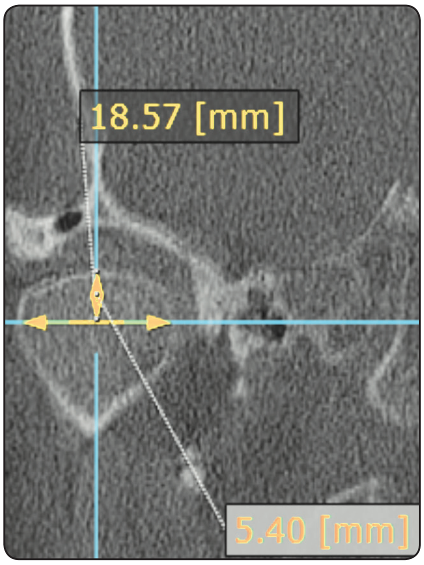

Fig. (3): Corrected coronal view showing measuring of the mediolateral condyle width along the axial plane passing through the condyle and measuring of the condyle height along the sagittal plane as the perpendicular distance from the top of the condyle till the axial plane

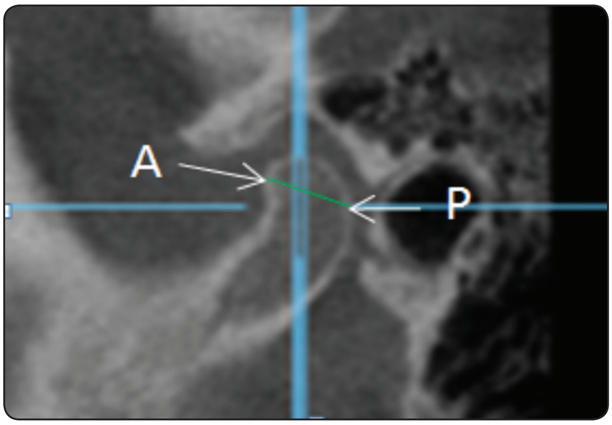

Fig. (4) Corrected sagittal view showing measuring the anteroposterior condyle dimension.

Condyle position.

The Tuberculo-meatal line (TM) [19,20] was drawn as a tangent to the inferior meatal border and inferior border of articular eminence. At its center a perpendicular line was drawn to split it into anterior and posterior parts. Two 90° angles were created between the previous lines. Each angle was divided into two equal (45°) angles by a line extended to the summit of the opposing bone of the fossa. Along this bisecting line, the anterior and posterior joint spaces were measured between the condyle surface and the corresponding fossa slope **(Figure 5)**.

The condyle position was calculated according to Pullinger and Hollender equation [(PJS- AJS /PJS + AJS) × 100]. Between -12 and +12 was considered concentric condyle position, smaller than -12 was considered posterior condyle position and greater than +12 was considered anterior condyle position. [21]

Thickness of the roof of glenoid fossa was measured on the corrected sagittal view from point A to point B, where point A was the most convex point on the superior border and point B was the most concave point on the inferior border of the roof of glenoid fossa [22] **(Figure 6)**.

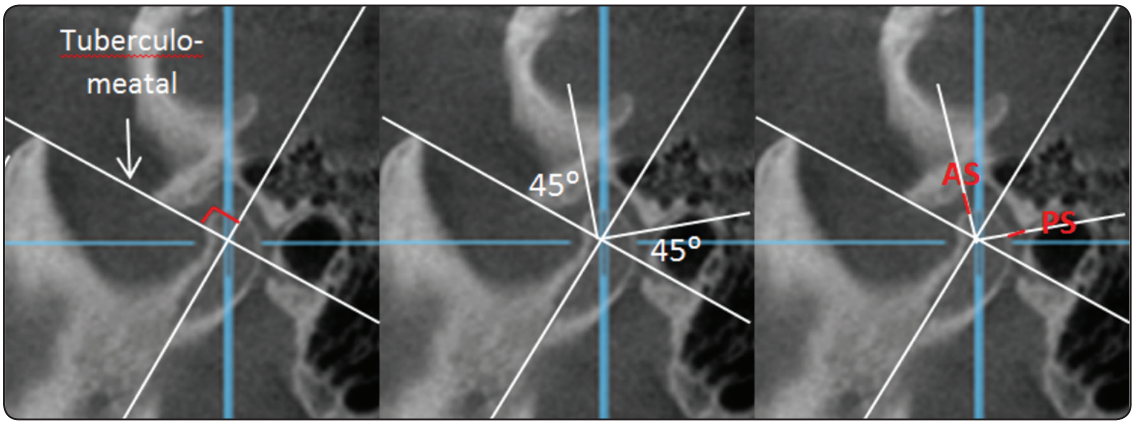

Fig. (5) CBCT sagittal views of the condyle showing measuring the anterior and posterior joint spaces to determine the condyle position.

IV) Volumetric measurement:

3D zooming of the mandibular condyle was performed. All bones surrounding the mandibular condyle were segmented (Fig. 7). The condyle was cropped at the level of the sigmoid notch. Points were picked over the condyle surface, and then the condyle volume was calculated automatically through the volume-measuring tool on the software **(Figure 8)**.

V) Statistical analysis

All data were collected, tabulated and subjected to statistical analysis. Statistical analysis was performed with IBM® SPSS® Statistics Version 17 for Windows.

Data were analyzed through:

1- Asymmetry index formula: [17]

(R - L) / (R + L) ×200

Relative and absolute TMJ asymmetry was evaluated

2- Correlation of the R and L measurements using Pearson correlation coefficient and estimating the P-value.

3- Evaluation of condyle position:

a- Using chi-squared test and estimating P-value.

b- Condyle position cross tabulation for estimating percentage of agreement.

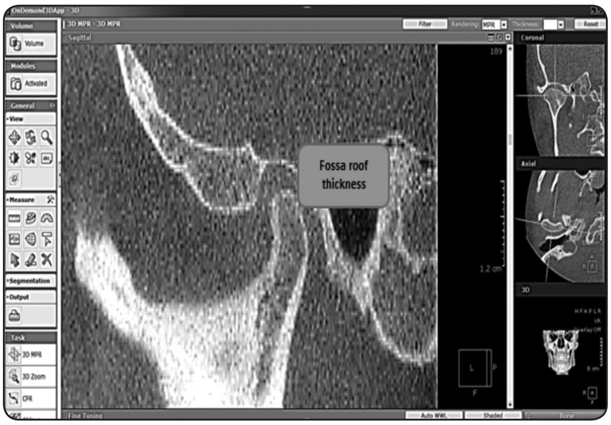

Fig. (6) Thickness of roof of glenoid fossa measurement on the corrected sagittal view. Thickness of roof of glenoid fossa is measured as the distance between point A and point B, where point A is the most convex point on the superior border and point B is the most concave point on the inferior border of the RGF.

• ® IBM Corporation, NY, USA.
• ® SPSS, Inc., an IBM Company.

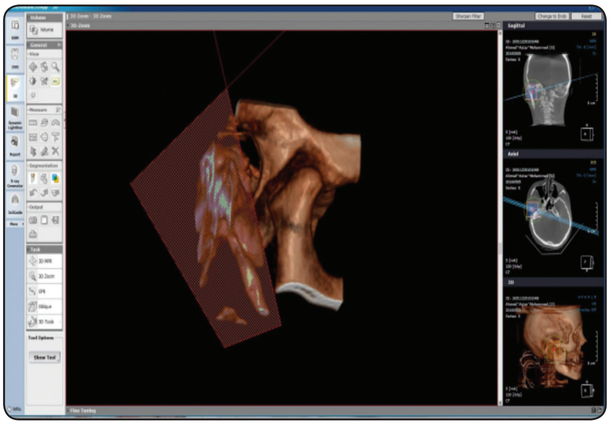

Fig. (7) Cropping of the surrounding bone to segment the condyle.

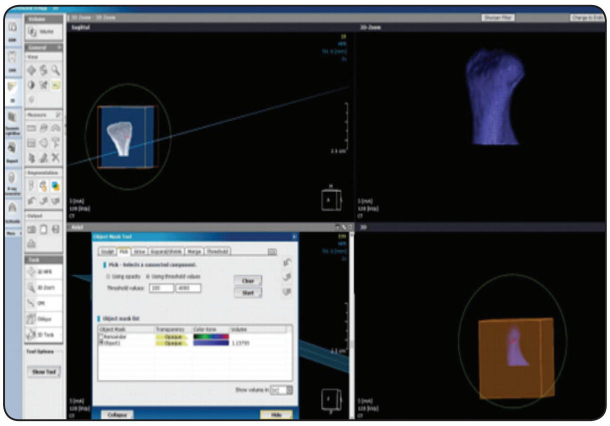

Fig. (8) Calculation of the condyle volume

RESULTS

Asymmetry index

The data were first analyzed using **asymmetry index formula**

$$(R - L) / (R + L) \times 200$$

Relative asymmetry variable was calculated regarding the mean values of all measured parameters. The value and the sign (whether positive or negative) were used to assume the direction of values. There was relative asymmetry between right and left sides regarding all measured parameters. Condyle height showed the highest asymmetry, while condyle AP dimension was the least.

In all parameters, the mean values of the right side exceeded the left side except for the fossa roof thickness **(Table 1).**

Absolute asymmetry variable was calculated regarding the mean values of all measured parameters. The mean values were calculated without considering the negative sign. There was absolute asymmetry between right and left sides regarding all measured parameters. fossa roof thickness showed the highest asymmetry, while condyle ML width was the least **(Table 2) (Figure 9).**

Correlation of R and L measurements using Pearson correlation coefficient:

On Correlating the R and L measurements, all correlations were positive with medium strength and were statistically highly significant ($P < 0.001$). The hi ghest correlation was shown in condyle volume while fossa roof thickness showed the least **(Table 3)**.

Condyle position:

Condyle position as a qualitative variable was evaluated using Chi-squared test. The distributions of cases according to condyle position were almost statistically significantly different between right and left sides **(Table 4)**.

Using cross-tabulations of measurements, 36.1 % of cases had anterior position on both sides, 36.8 % had posterior position and 64.4 % had bilateral concentric position. The total percentage of agreement was 49 % **(Table 5) (Figure 10).**

TABLE (1) Descriptive statistics of Relative asymmetry variables of all measured parameters.

	Mean	SD	95% Confidence Interval for Mean		Median	Minimum	Maximum	Range	Interquartile Range
			Lower Bound	Upper Bound					
condyle height asymmetry variable	6.48	27.70	0.98	11.97	0.32	-55.27	105.82	161.09	34.67
condyle ML width asymmetry variable	2.99	10.90	0.83	5.15	1.34	-21.52	50.09	71.61	11.62
condyle AP dimension asymmetry variable	0.68	15.97	-2.49	3.85	0.37	-53.36	47.39	100.75	18.58
fossa roof thickness asymmetry variable	-7.12	54.32	-17.89	3.66	-0.38	-136.52	130.75	267.27	63.23
condyle volume asymmetry variable	4.24	22.77	-0.28	8.75	3.84	-54.68	72.27	126.95	29.60

TABLE (2) Descriptive statistics of Absolute asymmetry variables of all measured parameters.

	Mean	SD	95% Confidence Interval for Mean		Median	Minimum	Maximum	Range	Interquartile Range
			Lower Bound	Upper Bound					
condyle height absolute asymmetry variable	21.63	17.99	25.28	18.36	18.79	0.00	105.82	105.82	22.23
condyle ML width absolute asymmetry variable	7.96	6.37	9.54	7.99	5.30	0.00	50.09	50.09	9.40
condyle AP dimension absolute asymmetry variable	11.75	9.61	13.88	10.77	8.95	0.00	53.36	53.36	11.76
fossa roof thickness absolute asymmetry variable	41.97	35.03	48.91	34.96	30.29	0.00	136.52	136.52	49.77
condyle volume absolute asymmetry variable	17.48	14.49	20.48	15.09	13.81	0.00	72.27	72.27	16.69

Table (3) Correlation of the right and left measurements

Parameter	Correlation coefficient	Significance
Condyle height	0.55	P < 0.001 HS
Condyle ML width	0.71	P < 0.001 HS
Condyle AP width	0.61	P < 0.001 HS
Fossa roof thickness	0.49	P < 0.001 HS
Condyle volume	0.76	P < 0.001 HS

HS: Highly significant

TABLE (4) Condyle position Chi-squared test

	Right	Left	Chi-squared	P value
anterior	36	23	5.12	0.07737
posterior	19	17		
concentric	45	60		

P ≈ 0.05 Almost S

TABLE (5) Condyle position R and L cross-tabulation

		condyle position left			Total
		anterior	posterior	concentric	
condyle position right	anterior	13	2	21	36
		36.1%	5.6%	58.3%	100.0%
	posterior	2	7	10	19
		10.5%	36.8%	52.6%	100.0%
	concentric	8	8	29	45
		17.8%	17.8%	64.4%	100.0%
Total		23	17	60	100
		23.0%	17.0%	60.0%	100.0%

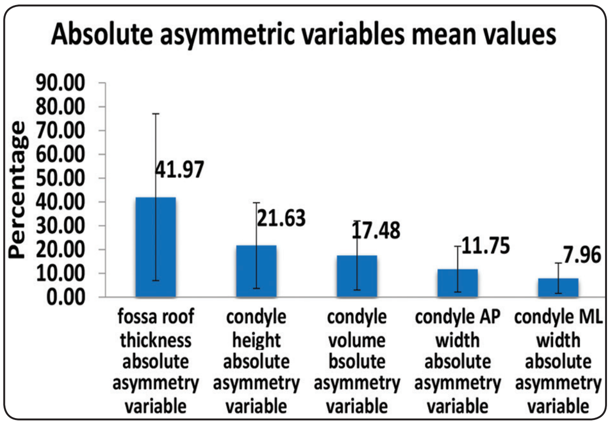

Fig. (8) Calculation of the condyle volume

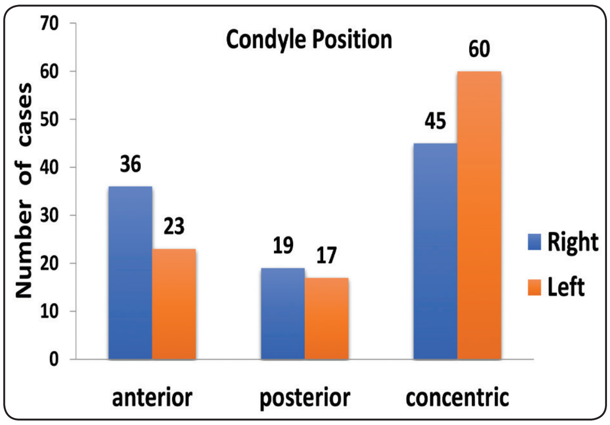

Fig. (8) Calculation of the condyle volume

DISCUSSION

Several studies had previously investigated TMJ or mandibular asymmetry. Several of the causes were obvious by history, physical examination, and plain film radiographic studies such as fractures, tumors, and congenital anomalies. [23]

Many studies have previously suggested that a correlation exists between TMJ-ID and mandibular asymmetry [24]. A potential relationship between TMJ-ID and facial growth aberrations resulting in mandibular asymmetry or retrognathia has been previously suggested. Although the etiology of skeletal asymmetry is not well understood, it has been suggested that advanced joint degeneration may lead to shortening of the condyle with subsequent skeletal asymmetry [25].

Kambylafkas et al [15] evaluated the association between unilateral degenerative joint disease (UDJD) and lower facial asymmetry. They suggested that the UDJD may be associated with lower face asymmetries in certain cases. Yáñez-Vico et al [16] analyzed and compared mandibular condyle morphology in patients with and without temporomandibular disorder (TMD). They concluded that that condylar width, height and length asymmetries were a common feature of TMD. Trpkova et al [17] investigated the amount of craniofacial asymmetry in female orthodontic patients with unilateral or bilateral TMJ internal derangement (TMJ ID) relative to the amount in female patients without TMJ ID. They found that the amount of asymmetry was not significant between females with normal TMJs and those with TMJ ID.

On the other hand, asymptomatic patients with no obvious abnormalities of the TMJ on clinical examination, are supposed to have symmetrical TMJ components. So that, the present study was designed to answer an important question: Is TMJ asymmetry correlated only with symptomatic TMD? or in other words, can we find TMJ asymmetry without any obvious clinical problem despite normal skeletal pattern?

Normal adult patients with skeletal class I pattern were chosen for the study. Full history and clinical examination were performed to exclude any case with symptoms or complaints. To eliminate any influencing factors on the TMJ, we excluded patients with skeletal class II or III, midline deviation, open bite, cross bite, congenital craniofacial abnormalities or any systemic diseases affecting bones and joints.

Patients were imaged by CBCT for other dental problem. Only those patients imaged with FOV covering the TMJ were chosen. CBCT images had to be transferred to another third-party software to facilitate linear, angular and volumetric measurements. Patients were instructed to occlude on their posterior teeth to ensure that the condyles are in the centric position. The multiplanar view was used for TMJ analysis instead of the limited TMJ view as it gives a wide view for the TMJ yielding more accurate and reproducible measurements.

Several linear measurements were done such as condyle height, width, anteroposterior dimensions and thickness of the roof of glenoid fossa. Condyle position was estimated according to Pullinger and Hollender equation [21]. Condyle volume was measured by software after condyle segmentation. Right and left sides were oriented and assessed separately. Results were compared on both sides.

Asymmetry was calculated through the asymmetry index

$$(R - L) / (R + L) \times 200.$$ [17]

Where R is the measurement on the right side, L is the measurement on the left side

The results of this study aimed at analyzing the data in three ways. First, to determine whether it is normal to find asymmetry between right and left TMJ sides in Normal population. Second, to estimate the direction of asymmetry whether the right side exceeds the left one or vice versa or it is variable and don't follow a specific direction. Third, to estimate the degree of asymmetry to determine to which level we can find asymmetry in normal population and still considered clinically accepted?

Absolute asymmetry values of our results showed a degree of asymmetry between the right and left sides. The highest asymmetry was found in fossa roof thickness (41.97) followed by condyle height (21.63), condyle volume (17.48) and condyle AP dimension (11.75) while the condyle ML width showed the least one (7.96). High SD in all parameters indicated the high variability of the measures. The highest variability was found in Fossa roof thickness (35.03).

Relative asymmetry variable was used to estimate the direction of asymmetry. The negative sign suggested that most of the measures was higher on the left side. This was found only in fossa roof thickness (-7.12) while all other variables showed the opposite.

On Correlating the R and L measurements, all correlations were positive. The correlation was statistically significant. The correlation was also with high strength. This positive correlation indicated that the TMJ may show normal remodeling on both sides, this may be different in amount between both sides, but in general the measures either increase or decrease together.

Condyle position correlation was almost statistically significantly different between R and L sides ($P \approx 0.05$). Condyle position was concentric on both sides in 64.4% of cases. The rest of cases varied whether anterior or posterior on one or both sides. The total percentage of agreement was 49%.

The condyle is continuously changing in response to different stimuli in the form of bone remodeling. Bone remodeling effect in the form of bone loss or gain is normal. It may be attributed to many causes such as abnormal chewing habits, loss of teeth or trauma.

TMJ asymmetry can also be caused by Overloading the articular surfaces of the TMJ has been associated with differences between the right and left mandibular condyles [26]. Loads applied to the TMJ could have an influence on its morphology [27,28]. Condylar asymmetry leads to greater muscle hyperactivity, which can overload the surface of the joint [29] and, in turn, affect the soft and hard tissue component [30].

To the best of our knowledge, no previous studies had investigated TMJ asymmetry in normal skeletal class I pattern. Most of studies had correlated this asymmetry with TMD, abnormal skeletal pattern or any other cause. So, from the results of this study, it is normal to find a degree of asymmetry between R and L TMJ sides in normal skeletal class I pattern, without obvious craniofacial asymmetry or TMD symptoms.

CONCLUSION

TMJ shows relative and absolute asymmetry in skeletal class I asymptomatic patients.

List of abbreviations

Temporomandibular joint (TMJ)

Temporomandibular disorders (TMD)

Cone beam computed tomography (CBCT)

Magnetic resonance imaging (MRI)

Two-dimensional (2D)

Three dimensional (3D)

Multiplanar reformation (MPR)

Tuberculo-meatal line (TM)

Temporomandibular joint- internal derangement (TMJ-ID)

Unilateral degenerative joint disease (UDJD)

REFERENCES

1- Chia MS, Naini FB, Gill DS. The aetiology, diagnosis and management of mandibular asymmetry. Orthodontic Update. 2008 May 2;1(2):44-52.

2- Chinea S. The Effect of Cone Beam Computed Tomography (CBCT) Imaging on Orthodontic Diagnosis and Treatment Planning (Doctoral dissertation, University of Southern California).2011

3- Tecco S, Saccucci M, Nucera R, Polimeni A, Pagnoni M, Cordasco G, Festa F, Iannetti G. Condylar volume and surface in Caucasian young adult subjects. BMC medical imaging. 2010 Dec;10(1):28.

4- Habets LL, Bezuur JN, Naeiji M, Hansson TL. The Orthopantomogram®, an aid in diagnosis of temporomandibular joint problems. II. The vertical symmetry. Journal of oral rehabilitation. 1988 Sep;15(5):465-71.

5- Bezuur JN, Habets LL, Hansson TL. The recognition of craniomandibular disorders—a comparison between clinical, tomographical, and dental panoramic radiographical findings in thirty-one subjects. Journal of oral rehabilitation. 1988 Nov;15(6):549-54.

6- Schokker RP, Hansson TL, Ansink BJ, Habets LL. Craniomandibular asymmetry in headache patients. Journal of Craniomandibular Disorders. 1990 Jul 1;4(3).

7- Miller VJ, Zeltser R, Zeltser CH, Yoeli Z. The condylar asymmetry-age relationship in determining myogenous or arthrogenous origin of pain in patients with temporomandibular disorders. Journal of oral rehabilitation. 1996 Jun;23(6):392-4.

8- Saglam AA, Sanli G. Condylar asymmetry measurements in patients with temporomandibular disorders. J Contemp Dent Pract. 2004 Aug 15;5(3):59-65.

9- Kawashima T, Abe S, Okada M, Kawada E, Saitoh C, Ide Y. Internal structure of the temporomandibular joint and the circumferential bone: comparison between dentulous and edentulous specimens. The Bulletin of Tokyo Dental College. 1997 May;38(2):87-93.

10- Dupuy-Bonafé I, Otal P, Montal S, Bonafé A, Maldonado IL. Biometry of the temporomandibular joint using computerized tomography. Surgical and Radiologic Anatomy. 2014 Nov 1;36(9):933-9.

11- Rehman TA, Gibikote S, Ilango N, Thaj J, Sarawagi R, Gupta A. Bifid mandibular condyle with associated temporomandibular joint ankylosis: a computed tomography study of the patterns and morphological variations. Dentomaxillofacial Radiology. 2009 May;38(4):239-44.

12- Minagi S, Sato T, Kishi K, Natsuaki N, Akamatsu Y. Comparative study of the temporomandibular joint space in maximum intercuspation and canine edge-to-edge positions in deep bite and non-deep bite subjects. Journal of oral rehabilitation. 2000 Jun;27(6):517-21.

13- Zhao C, Kurita H, Kurashina K, Hosoya A, Arai Y, Nakamura H. Temporomandibular joint response to mandibular deviation in rabbits detected by 3D micro-CT imaging. Archives of oral biology. 2010 Dec 1;55(12):929-37.

14- Ejima K, Schulze D, Stippig A, Matsumoto K, Rottke D, Honda K. Relationship between the thickness of the roof of glenoid fossa, condyle morphology and remaining teeth in asymptomatic European patients based on cone beam CT data sets. Dentomaxillofacial Radiology. 2013 Mar;42(3):90929410.

15- Kambylafkas P, Kyrkanides S, Tallents RH. Mandibular asymmetry in adult patients with unilateral degenerative joint disease. The Angle orthodontist. 2005 May;75(3):305-10.

16- Yáñez-Vico RM, Iglesias-Linares A, Torres-Lagares D, Gutiérrez-Pérez JL, Solano-Reina E. Association between condylar asymmetry and temporo-mandibular disorders using 3D-CT. Medicina oral, patologia oral y cirugia bucal. 2012 Sep;17(5):e852.

17- Trpkova B, Major P, Nebbe B, Prasad N. Craniofacial asymmetry and temporomandibular joint internal derangement in female adolescents: a posteroanterior cephalometric study. The Angle orthodontist. 2000 Feb;70(1):81-8.

18- Arieta-Miranda JM, Silva-Valencia M, Flores-Mir C, ParedesSampen NA, Arriola-Guillen LE. Spatial analysis of condyle position according to sagittal skeletal relationship, assessed by cone beam computed tomography. Prog Orthod. 2013;14(1):36

19- Pullinger A, Hollender L. Variation in condyle-fossa relationships according to different methods of evaluation in tomograms. Oral surgery, oral medicine, oral pathology. 1986 Dec 1;62(6):719-27.

20- Vitral RW, da Silva Campos MJ, Rodrigues AF, Fraga MR. Temporomandibular joint and normal occlusion: Is there anything singular about it? A computed tomographic evaluation. American journal of orthodontics and dentofacial orthopedics. 2011 Jul 31;140(1):18-24.

21- Vitral RW, de Souza Telles C, Fraga MR, de Oliveira RS, Tanaka OM. Computed tomography evaluation of temporomandibular joint alterations in patients with class II division 1 subdivision malocclusions: condyle-fossa relationship. American journal of orthodontics and dentofacial orthopedics. 2004 Jul 31;126(1):48-52.

22- Durgha.K. Condylar Morphology- A Review. Volume 13, Issue 7 Ver. IV (July. 2014), PP 57-59

23- Hansson TL, Nordstrom B. Thickness of the soft tissue layers and articular disk in temporomandibular joints with deviations in form. Acta Odontol Scand. 1977;35:281-8.

24- Schellhas KP, Piper MA, Omlie MR. Facial skeleton remodeling due to temporomandibular joint degeneration: an imaging study of 100 patients. CRANIO®. 1992 Jul 1;10(3):248-59.

25- Westesson PL, Tallents RH, Katzberg RW, Guay JA. Radiographic assessment of asymmetry of the mandible. American journal of neuroradiology. 1994 May 1;15(5):991-9.

26- Rodrigues AF, Fraga MR, Vitral RW. Computed tomography evaluation of the temporomandibular joint in Class I malocclusion patients: condylar symmetry and condyle-fossa relationship. Am J Orthod Dentofacial Orthop. 2009;136:192-8.

27- Rodrigues AF, Fraga MR, Vitral RW. Computed tomography evaluation of the temporomandibular joint in Class II Division 1 and Class III malocclusion patients: condylar symmetry and condyle-fossa relationship. Am J Orthod Dentofacial Orthop. 2009;136:199-206.

28- Miller VJ. The effect of age on condylar asymmetry in patients with craniomandibular disorders of arthrogenous origin. J Prosthet Dent. 1992;67:845-6.

29- Yáñez-Vico RM, Iglesias-Linares A, Torres-Lagares D, Gutiérrez-Pérez JL, Solano-Reina E. Three-dimensional evaluation of craniofacial asymmetry: an analysis using computed tomography. Clin Oral Investig. 2011; 15:729-36.

30- Kambylafkas P, Kyrkanides S, Tallents RH. Mandibular asymmetry in adult patients with unilateral degenerative joint disease. The Angle orthodontist. 2005 May;75(3):305-10.