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Three dimensional evaluation of condylar symmetry and condyle-fossa relationship of the temporomandibular joint in Class I malocclusion patients: A CBCT study

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Abstract

Background: To estimate the role of the CBCT imaging technique in the tempormandibular joint morphological characteristics with emphasis on the concentric position of the condyle and its relationship with the glenoid fossa along with the positional symmetry in class I malocclusion patients.

Methods: A simple prospective study was conducted from February 2019 to February 2020 in which 30 patients with class I malocclusion underwent cone beam computed tomography (CBCT) of the temporomandibular joints. The images were assessed in three planes i.e. sagittal, axial, and frontal plane. The data were estimated using paired t test and post hoc comparisons were done using Bonferroni test.

Results: Through the three dimensional measurements, it was revealed that the condyles were non concentrically positioned only in the sagittal plane and medio-laterally-concentrically placed in the frontal plane which was statistically significant (P<0.05).

Conclusion: The condyle can be evaluated for its positional changes and morphological features more accurately in the sagittal as well as in frontal plane with special emphasis on the posterior joint space. And CBCT is a useful assessment modality in assessing the normal position of the TMJ in class I malocclusion patients which might be useful for evaluation the various afflictions of the TMJ.

Keywords: Condyle, Cone beam computed tomography, Glenoid fossa.

Introduction

The ideal spatial relationship of mandibular condyle with the glenoid fossa; when the teeth are in maximum intercuspation, is important to maintain a harmony between the occlusion and masticatory apparatus. Many compelling variables affect the architecture of the TMJ like functional matrix principles, modification in the occlusion, growth and persistent remodelling, and physiological adjustments.[1] Thus, it can be reiterated that the morphology of the condyle and mandibular fossa shows variations in the different malocclusions.

The relationship of mandibular condyle with the glenoid fossa is difficult to investigate radiographically. Conventional radiographic methods show only the 2-dimensional images and it has their own restrictions in order to delineate the anatomic features of the TMJ; because temporomandibular joint is situated in the closed confined space in the maxillofacial region and a composite morphology. Also, it is neighboured by the dense osseous structures which lead to stratification of images, namely, petrous part of the temporal bone, mastoid process, and articular eminence.[2, 3]

The skeletal architecture of the TMJ can be asses 3-dimensionally by using cone beam computed tomography (CBCT) imaging, which provides better images as compared to the traditional radiography methods such as helical CT. It provides images with greater sensitivity and accuracy in the identification of mandibular condyle anatomy and high diagnostic quality imaging with lower patient radiation exposure. Furthermore, the accurate resolution of the angular and linear measurements can be determined by these images.

The effect of the appearance and function on the TMJ and related dental occlusion is not completely understood as both the features go hand in hand. Contemporary literature dictate that there is a remarkable association between the joint morphology and various occlusal factors, [4-7] whereas some studies failed to prove that a correlation exists between occlusal forces and its effect on TMJ. [8-10] Significant number of studies have shown that a positive correlation exists between these variables (Myers et al,[11] Mongini and Schmid,[12] Pullinger et al,[13] Mongini,[14] O'Byrn et al,[15] and Schudy[16]) . However, a study conducted by Cohlmia et al[17] did not find a positive correlation between joint morphology and occlusal factors.

Vitral et.al.[18] and Vitral and Telles,[19] conducted a study in the patients with Class II Division 1 subdivision showed that the condyles were non-concentric, and there was a ample amount of difference was observed among the right and left sides.

In lieu of this, the researchers have designed the study in order to evaluate the ideal condyle-fossa relationship by utilizing the CBCT images. Also, to scrutinize the right and left condyles in terms of dimensional and positional symmetries especially in the Class I malocclusion patients. The researchers have put forwarded the hypothesis that the condyle is placed concentrically in glenoid fossa in all the three planes i.e. sagittal, frontal, and axial in Class I malocclusion patients.

Material and Methods

In order to conduct the study, the researchers planned and actualized a prospective study which was done in the Department of Orthodontics and Dentofacial Orthopedics. The examination was endorsed by the institutional reviewer board and local ethical committee of the Genesis Institute of Dental Sciences. The investigation pursued the benchmark as set by Helsinki.

Prior to the commencement of the study, all the subjects were informed and consent was obtained. Patients with Class I malocclusion aged between 15 and 20 years was enrolled in the study and received CBCT imaging for the right and left TMJs.

The current study comprises of 50 systemically healthy patients with class I malocclusion were incorporated. The assessment criteria were; except third molars, all permanent teeth should be erupt in the oral cavity with class I malocclusion with any functional temporomandibular disorders. Cone beam computed tomography scans were acquired with Kodak CS 9300 CBCT machine (CS9300) manufactured by Carestrem Health, Inc.

In patients with maximum dental intercuspation (centric o cclusion), the CBCT images were obtained and their heads were positioned in such a way that the midsagittal plane was perpendicular to the floor. The scanning conditions were 85 kVp, 10 mA, and 10 seconds with FOV of 17 × 13.5. Software used in Kodak CS 9300 CBCT machine was Trophy DICOM. The measurements were obtained directly by selecting the image structures.

The measurements were taken in the mid-sagittal plane:-

1. The depth of the Mandibular fossa

It is measured from the perpendicular point dropped from the highest point of the mandibular fossa to the plane that j oins the lowest point of the articular tubercle to the auditor y meatus. (Figure 1).

2. Joint space

Anterior, superior and posterior joint space determined by the shortest measured distance between the anterior, superi or and posterior points of the mandibular condyle, and the mandibular fossa (Figure 2).

3. **Anterior to posterior joint space expressed as the percentage (APJS %)**

$$\frac{\text{Anterior joint space} - \text{posterior joint space}}{\text{Anterior joint space} + \text{posterior joint space}} \times 100$$

(The expression of the accurately centered condyle will be count as 0 percent. Posterior positioning of the condyle determines by the positive number

Axial plane measurements

1. The measurement was done in the two planes i.e. in the anteroposterior and medio-lateral direction of the mandibular condyle. (Fig 3) For greater accuracy the two planes were kept perpendicular to each other.
2. The angle of the mandibular condyle: - It is determined by the angle formed between the long axis of the midsagittal plane and mandibular condyle (Fig 4).
3. The distance between the midsagittal plane and geometric centers of the mandibular condyle (Fig 5). For greater accuracy the measurement was done with this plane kept perpendicular to midsagittal plane.
4. Anteroposterior difference of condylar process: - The concentricity of the right and left condyles was measured by using the difference between the geometric center of the right and left condylar processes in the anteroposterior direction as determined on the midsagittal plane (Fig 5).

Frontal plane measurements

1. It is measured by determining the medio-lateral diameter of the mandibular condyle in its greatest dimension. (Fig 6).
2. Joint space (Medial, lateral, and superior): - It is calculated by the shortest distance measured between the

extreme superior, lateral, and medial point on the glenoid fossa and the condyle (Fig 6).

The concentricity of the mandibular condyle in the glenoid fossa was measured in the sagittal as well as in the frontal plane in the CBCT.

Statistical Analysis

The data was assessed by using computer program statistics (SPSS Version 21.0; SPS Inc., Chicago, IL). The statistics was normally distributed as tested using the Paired Student t test (p value was less than 0.05). Level of statistical significance was set at p value less than 0.05. The Bonferroni test was used to do the multiple post hoc comparisons in order to calculate the significance among the groups in the axial plane.

To lessen down the error in recording the measurements at the different points and reference structures, all the CBCT images were assessed by the same assessor second time within the two week time period among the recorded dimensions. The mean value of the two measurements was taken as the final value.

Results

The following results were obtained for the measurements done in the sagittal plane:-

The mean mandibular fossa depth was 8.40 mm and 8.44 mm for the right and left side, with P = 0.436 (P>0.05) statistically non-significant. While evaluating the results for the joint space; the mean of the anterior joint space was 1.94mm and 1.92 mm for the right and left side, with P = 0.599 (P>0.05) which was not statistically significant. The mean superior joint space was 3.47 mm and 3.40mm for the right and left side respectively, with P = 0.678 ; statistically non-significant. The mean posterior joint space was 2.38 mm and 2.16mm for the right and left side respectively, with P = 0.049 (P<0.05); statistically significant. Anterior to posterior joint space expressed as percentage (APJS %) was -8.36 and -8.43 for right and left sides (P=0.984; P>0.05 statistically non -significant).

The following results were obtained for the measurements done in the axial plane:-The mean anteroposterior diameter of the condylar process on the right and left side were 8.44 mm and 8.48 mm, with P = 0.451 (p>0.05) which was statistically non-significant. The mean medio-lateral diameter of the condylar process was 18.43 mm and 18.47 mm for the right and left side, with P = 0.463 which was also not significant statistically.

The angular measurements between the long axis of the mandibular condyle and the midsagittal plane were 72.33° and 67.93° for the right and left side, with P = 0.999 (P>0.05). The average anteroposterior position of the condylar process as reflected on the mid-sagittal plane was -0.88 mm for the right and left side with P = 0.184 (p>0.05). The mean measurements evaluated for the distance from the geometric centre of the condyle to the midsagittal plane were 54.81 mm and 54.67 mm for the right and left side respectively with P = 0.604 which was also not significant statistically.

The following results were obtained for the measurements done in the frontal plane:-The mean of the mediolateral diameter of the condylar process in the frontal plane was 17.61 mm and 17.41 mm for the right and left side, respectively (P = 0.643).

While evaluating the results for the joint space; the mean medial joint space was 2.54 and 2.41 mm for the right and left side, respectively (P = 0.889). The mean superior joint space was 3.02 mm and 3.07 mm for the right and left side, respectively (P = 0.349). The mean lateral joint space was 2.73 mm and 2.71 mm for the right and left side, respectively (P = 0.554). From the calculated p-values it can be seen that the results were not statistically significant. (Table 1)

The concentric position of the condyle in sagittal plane was assessed and it was found that the mean values of the anterior and posterior joint spaces on the right side were 1.94 and 2.38 mm i.e. P=0.001; statistically significant. Similarly, on the left side, the mean values were 1.92 and 2.16 mm for (P = 0.003; P<0.05 statistically significant). However, in the frontal plane, the mean values were found to be 2.54 and2.73 mm for the medial and lateral joint spaces on the right side i.e. P = 0.559. Likewise, the mean values were 2.41 and 2.71 mm for the medial and lateral joint spaces on the left side i.e. P = 0.343. Table 2

Discussion

The principal motivation behind this examination was to appraise the spatial relationship of the condyle and glenoid fossa in three planes namely, sagittal, frontal, and axial plane. The results of this research confirmed the hypothesis that the condyle is non-concentrically positioned only in the sagittal plane (P<0.05) in class I malocclusion. Similarly, the condyle is positioned concentrically medio-laterally in the frontal plane in class I malocclusion.

The TMJ is a troublesome zone to examine radiographically. Various imaging modalities, for example, MRI and CT have been created throughout the years for giving an enhanced perception of TMJ.

Amid the mid-1980's, computed tomography picked up prominence for acquiring imaging of bony structures and these images permitted exact calculation of linear and angular estimations. But the main drawback of the CT imaging is the high radiation dose and that it provides images of the bony components only.[20]

With the introduction of surface-coil-assisted Magnetic resonance imaging, the utilization of CT has decreased significantly. Magnetic resonance imaging is considered as a hallmark for the soft tissue representation and for the exact positioning of the TMJ articular disc, which helps in providing information about the position, form and function of the articular disc, muscle tissues and ligaments.[21]

The latest development in radiographic imaging of TMJ is the introduction of cone beam computed tomography (CBCT).

CBCT is a versatile technology which produces reconstructed pictures of high diagnostic value with low radiation dose as compared to conventional methods. Furthermore, CBCT allows simultaneous visualization of both right and left TMJs on the same image, therefore, allowing a comparison of the right and the left sides on the same image. Due to the complex anatomy and relatively small space of the TMJ; it cannot be viewed correctly in two-dimensional images which require an assessment in the various dimensions. CBCT allows visualization of the joint in different planes (sagittal, frontal and axial), possible, depending on areas of interest.

The sagittal plane is considered as the most appropriate plane for the assessment of the condyle-fossa relationship. Furthermore, concentricity of the condyle can be analyzed by comparing the anterior and posterior articular spaces. The depth of the glenoid fossa depth can be estimated in this plane. Our analysis while evaluating the joint space, showed that there is a significant differences exists among the right and left sides for the posterior joint space (P = 0.049) while this was not the case for anterior and superior joint space (P>0.05). These findings corroborated well with a previous study conducted by Rodrigues AF et.al. [22]

The unsymmetrical position of the posterior joint space is related to the non-identical measurements of the glenoid fossa. On the other hand, this was not the case in the condylar dimension and positioning in the superior and anterior joint space in the sagittal plane. Moreover, both sides had nonconcentric positioning of the condyles. While estimating the concentricity of the condyle it was showed that there was non-concentricity in the position of the condyles among both sides.

A few examinations were directed to decide condyle position in the mandibular fossa. Introductory investigations detailed centralization of the condylar processes.[23,24] Weinberg[25] assessed a data of 61 asymptomatic patients and found that just 23% had bilateral condylar concentricity. Blaschke and Blaschke[26] expressed that non-identical condylar position is rarely observed in asymptomatic subjects. Pullinger et.al.[14] demonstrated that anterior positioning of the condyles is normal for a Class II Division 1 malocclusion. Cohlmia et.al, [17] demonstrated in a survey of Class II Division 1 patients, watched a similar non-concentricity, with the left condyle more anteriorly set than the right. Vitral et.al,[18] with a similar strategy utilized in this examination, found an increasingly anterior condylar position respectively in subjects with Class II Division 1 subdivision malocclusion. In any case, this can be affirmed simply after investigations on TMJ features in a typical normal population. The morphologic features related to a specific pathologic condition can be compared with the normal CBCT images of the TMJ of a population which can act as a reference point amid the assessment and perhaps significant in treatment planning.

The axial plane is considered as the most suitable plane to survey the condylar symmetry as it demonstrates the two condyles in a similar fashion and as the midsagittal plane can be estimated on this plane, further comparative assessments among right and left condyle should be possible. This also allows the real dimensional anteroposterior and mediolateral measurements of the condyles and their angulations with the midsagittal plane. Our results demonstrate there were no significant differences were noticed among the right and left condyles. Vitral and Telles[19] utilized a similar technique and comparable outcomes were found in Class II Division 1 subdivision population. These outcomes very much teamed up with the proclamation of Ben-Bassat et.al.[27] that expressed that the occlusal morphology and relationship may be related to TMJ structure remodelling in order to make different symmetrical connections.

In the mid-sagittal plane, the angulation of the condyles demonstrates no statistical difference among both the sides. These results were similar to the findings of a previous study by Rodrigues AF et.al.[22.]

The comparison of the right and left condyle, especially in the frontal plane, permits the evaluation of the condyle and glenoid fossa characteristics in the mediolateral direction of the same image. In neonates, the thickness of the articular disc relatively uniform in medio-lateral direction but, due to functional loading of the disc; it's size decrease laterally with due of time and it results in compressed joint space in the lateral portion when compared to the central and medial part of the joint. Thus it could be inferred that during functional loading of the joint, the variation in the thickness of the articular disc is considered normal and the medio-lateral displacement of the condyle and its surrounding osseous morphology of the joint changes due to the functional disequilibrium resulting from disc displacement.

Results of the present study showed that the condyle was concentrically positioned mediolaterally in the glenoid fossa. Similar results were reported by a study conducted previously by Ikeda K et al[28].

Albeit a few investigations expressed that the condyle and the mandibular fossa differs in shape and position in patients with different malocclusions,[29] and the assessment of the condylar symmetry and the condyle-fossa relationship demonstrated extensive comparability in Class I and Class II Division 1 subdivision samples.[18,19] Also, the position of the condyle in the fossa is additionally impacted by different factors, for example, growth patterns, facial morphology, shape of the condyle, thickness of the disc, and the tissues that line the condyle and articular eminence so further examinations corresponding these elements and their effect on condylar position should be embraced.

Conclusion

The results of this study demonstrated that the condyle is non-concentrically placed in the glenoid fossa in the sagittal plane as well as only posterior joint space could be evaluated in the sagittal plane. However, the condyles were concentrically situated in the medio-lateral direction in the frontal plane. This study can help the clinicians to study the normal variations in the condyle-fossa relationship in the normal Class I malocclusion population which could help them in diagnosis and treatment planning of various afflictions of the TMJ.

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Legend Figures and Tables

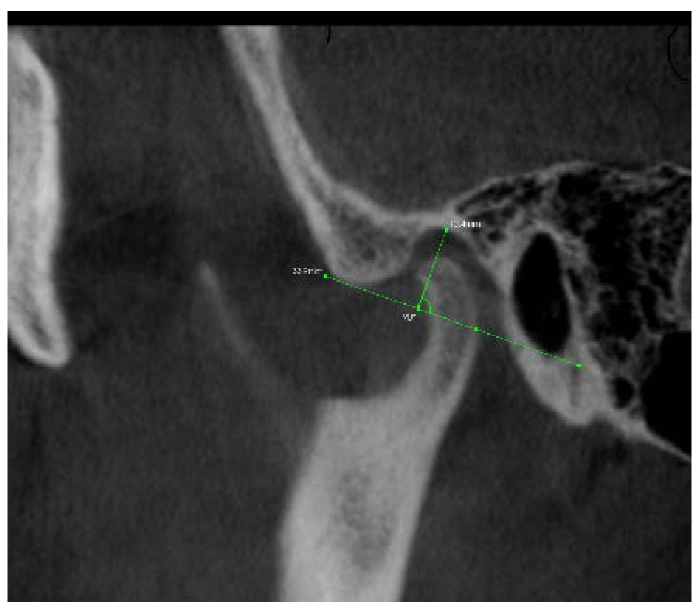

Fig 1: Depth of the mandibular fossa

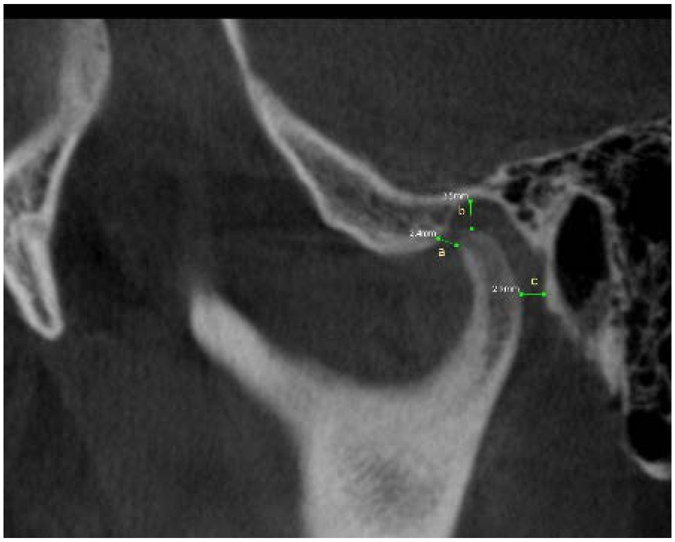

Fig 2: Anterior (a), superior (b) and posterior(c) joint space

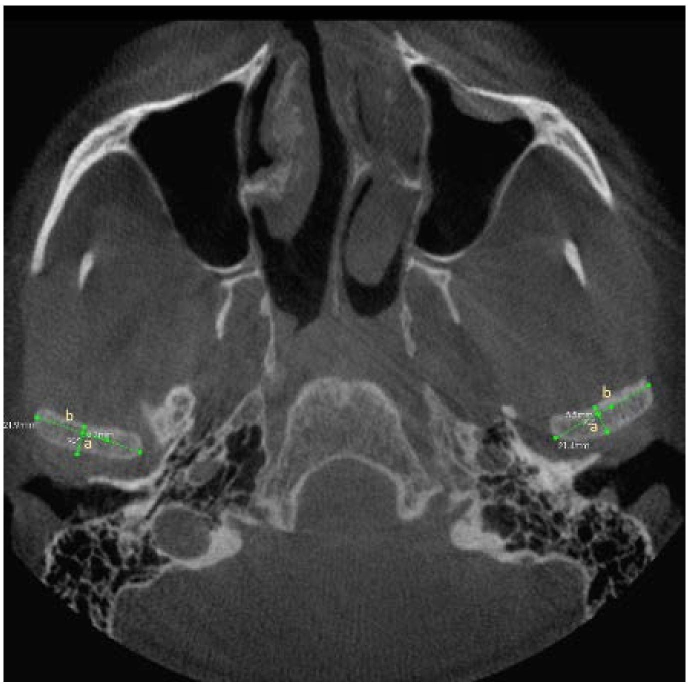

Fig 3: Greatest anteroposterior (a) and Mediolateral(b) diameter of the mandibular condylar processes

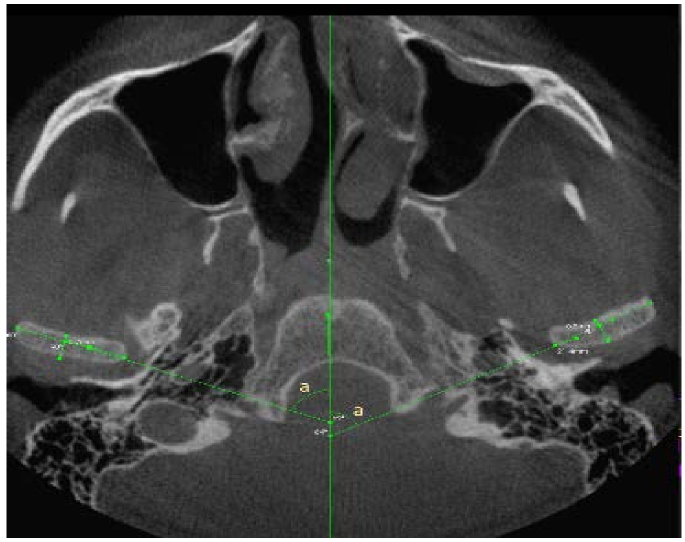

Fig 4: Angle (a) between the long axis of the mandibular condylar process and the midsagittal plane

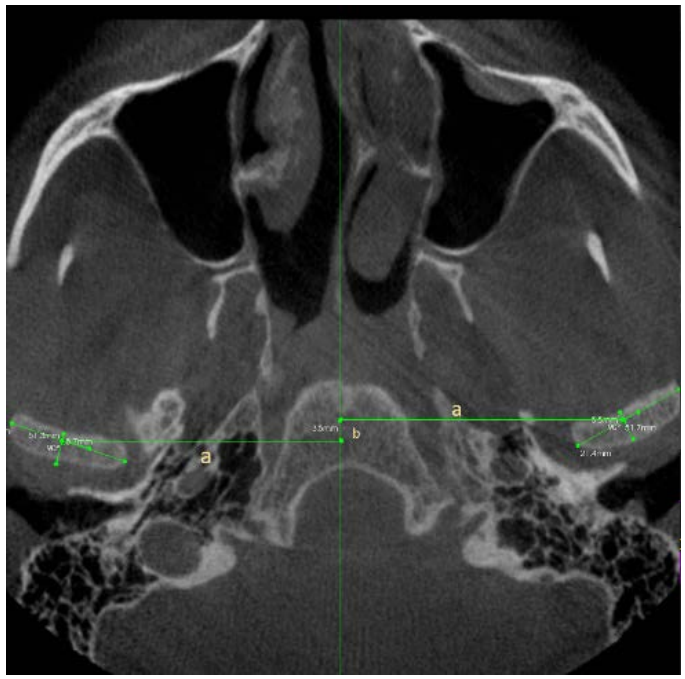

Fig 5: distance between the geometric centers of the condylar processes and the midsagittal plane (a) and anteroposterior difference between the geometric center of the right and left condylar processes as reflected on the midsagittal plane (b)

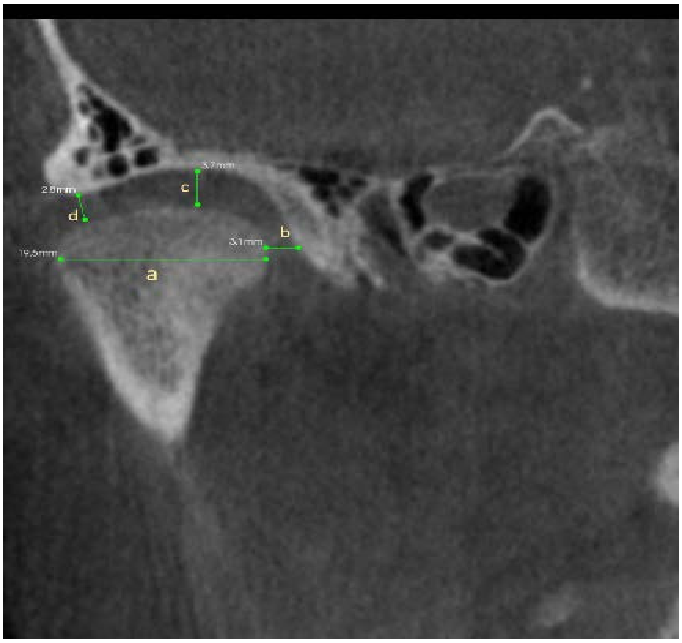

Fig 6: Greatest mediolateral diameter of the mandibular condylar process (a). Medial(b), superior(c) and lateral(d) joint space

Tables

Table 1: Statistical Analysis

	Mean, right side	Mean, left side	SD, right side	SD, left side	P value, paired student t test
In Sagittal plane					
Mandibular fossa depth(mm)	8.40	8.44	1.55	1.36	0.436
Anterior joint space(mm)	1.94	1.92	0.47	0.43	0.599
Superior joint space(mm)	3.47	3.40	0.69	0.70	0.678
Posterior joint space(mm)	2.38	2.16	0.76	0.70	0.049
APJS %	-8.36	-8.43			0.984
In Axial plane	8.44	8.48	1.58	1.78	0.451
Anteroposterior diameter of condylar process(mm)	18.43	18.47	2.32	2.36	0.463
Mediolateral diameter of condylar process(mm)	72.33	67.93	5.11	5.20	0.999
Angle b/w condylar process/midsagittal plane(degree)	54.81	54.67	3.23	2.88	0.604
Distance, condylar process/midsagittal plane(mm)					
In Frontal plane	17.61	17.41	1.85	2.95	0.643
Mediolateral diameter of condylar process(mm)	2.54	2.41	0.83	0.57	0.889
Medial joint space(mm)	3.02	3.07	0.67	0.70	0.349
Superior joint space(mm)	2.73	2.71	0.72	0.79	0.554
Lateral joint space(mm)					

Table II: Statistical analysis: concentric position of condyles

In sagittal plane	Anterior joint space(mm)	Posterior joint space(mm)	P value, paired student t test
Right side (mm)	1.94	2.38	0.001
Left side (mm)	1.92	2.16	0.003
In Frontal plane	Medial joint space(mm)	Lateral joint space(mm)	P value, paired student t test
Right side (mm)	2.54	2.73	0.559
Left side (mm)	2.41	2.71	0.343