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MORPHOMETRIC EVALUATION OF TEMPOROMANDIBULAR JOINT USING CONE BEAM COMPUTED TOMOGRAPHY (CBCT)

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ABSTRACT

Objective to evaluate the morphological and morphometric features of mandibular condyle in a segment of Indian (Asian) population with context to side, sex and age using CBCT scans. Various parameters of temporomandibular joint (TMJ) were determined from CBCT scans (the frontal and the lateral views) of subjects (n=100) in age group of 20-60 years using i-CAT (vision) software (version 1.9.3.14, Imaging Sciences International). The most common shape of the mandibular condyle was convex followed by the round shape. Significant difference was observed in the anteroposterior diameter of the mandibular condyle and the anterior joint space on the right and the left sides as well as in different age groups. Various parameters presented sexual dimorphism. Age associated growth of mandibular condyle was evident along with sexual dimorphism. The values obtained for various parameters from CBCT images could serve as norms for designing the preformed mandibular condyle.

INTRODUCTION

Temporomandibular joint (TMJ) is a unique and complex joint between the condyle of the mandible and the mandibular fossa of the temporal bone. Being the most important component of the masticatory system, TMJ plays a vital role in its harmonious functioning (chewing, deglutition, speech etc.). The mandibular condyle undergoes a remodeling process in response to continuous and varying stimuli from childhood to adulthood and presents as a site of adaptive growth, a requisite for maintaining optimal function of the joint. The remodeling process is vulnerable to various intrinsic and extrinsic factors such as endocrine disorders, radiation therapies, road traffic accidents etc. 'Condylar asymmetry' refers to the disproportion between the vertical condylar heights on the right and the left side [1] and could be the risk factor for mandibulofacial asymmetries.

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However, the structural features differentiating ‘physiological’ from ‘unphysiological’ asymmetry remain to be well defined till date.

In current scenario, temporomandibular disorders (TMD) emerge as one of the important aetiological factors underlying non-dental pain in the orofacial region. TMD are a sequel to diverse conditions such as trauma, arthritis, idiopathic bone resorption, ankylosis etc. For improving the joint form and function, alloplastic replacements are amongst the favored therapeutic options. Accordingly, precise knowledge of parameters pertaining to normal anatomy, morphology and functioning of the TMJ plays an important role in the successful outcomes of various reconstructive procedures.

Amongst various imaging modalities, Cone Beam Computed Tomography (CBCT) scans have been reported to provide more precise information regarding various parameters of TMJ. In order to obtain some baseline data, the current study was designed to determine some of the morphological and morphometric features of TMJ in a segment of North Indian subjects using CBCT images.

MATERIAL AND METHOD

Material

The ethical clearance for this retrospective study was obtained from the Institute Ethics Committee, AIIMS (Ref. No. IESC/T-197/03.05.2013). The CBCT scans of 100 dentulous subjects (Males - 59, Females -41) were procured from the Centre for Dental Education and Research, AIIMS. The age of the subjects ranged from 20 to 60 years and these were divided into four groups: 20-30 years (Group I), 30-40 years (Group II), 40-50 years (Group III) and 50-60 years (Group IV).

The frontal and lateral views of the CBCT scans were viewed and various morphological and morphometric features of TMJ were determined using i-CAT imaging software (version 1.9.3.14 of the Imaging Sciences International).

The following distances between various points (identified on CBCT scans) were considered for measurements of the mandibular condyle:

1. **Anteroposterior diameter (AP)** - Distance between A and P (largest dimension of the condyle on lateral view) (Fig. 1).
2. **Condylar Height (CH)** – Distance between S and I (height of the mandibular condyle on lateral view**)** (Fig. 1).

Asymmetry Index of Condyle [2],

$$\text{Asymmetry index (AI)} = \frac{(\text{Right CH} - \text{Left CH})}{(\text{Right CH} + \text{Left CH})} \times 100$$

3. **Mediolateral diameter (ML)** - Distance between M and L (largest dimension of the condyle on frontal view) (Fig. 2).
4. **Ramus height (RH):** Two horizontal lines from P and R (the most posterior points of the condyle and the ramus) were drawn and the vertical distance between these lines was taken as the ramus height (RH) (Fig. 3).
5. **Joint space (AJS, SJS, PJS):** Anterior joint space (AJS), superior joint space (SJS) and posterior joint space (PJS) were numbered as 1, 2 and 3 and correspond to the distances between the most prominent points on the anterior, superior and posterior aspects of mandibular condyle with the most anterior, deepest and posterior points on mandibular fossa respectively (Fig. 4).
6. Depth of the mandibular fossa (FD): Distance from the deepest point of the mandibular fossa (S') to the point (I') on the plane passing along the most inferior points of the articular tubercle (AT) and the auditory meatus (AM) (Fig. 5).

The data pertaining to sex and side based differences together with the age related data were analysed using paired sample *t*-test, *t*-test for independent samples and ANOVA (followed by a post-hoc test) respectively.

OBSERVATIONS

The superior aspect of the mandibular condyle, observed on frontal views of the CBCT scans, (Fig. 6A) revealed higher incidence of convex shape (71.55 %) followed by round (12.55 %), flat (7.89 %) and angular (7.83 %) shapes. Depressed/deformed areas were observed towards central as well as peripheral parts of the superior aspect of the mandibular condyle (Fig. 6B) and their frequency was higher in age groups III (41-50 years) and IV (51-60 years).

The AP diameter of the mandibular condyle in the total sample size, was significantly (P=0.015) higher on the right side whereas the ML diameters were comparable on the two sides [Table 1(a)]. The AP diameter showed a steady increase from group I to group III on both sides whereas in group IV, AP diameter was significantly lower than in group II. No significant correlation was observed for ML diameter with age [Table 1(b)]. We also observed significantly greater values for AP diameter of the mandibular condyle in males on the left side whereas the values for ML diameter in males were significantly greater on both sides as compared to that in females [Table 1(c)].

The average CH on both the sides was somewhat greater in males. A gradual increase was observed in CH from group I (20-30 years) to group III (41-50 years) on both the sides, however, CH decreased in group IV (51-60 years) on both the sides [Table 1(b)]. The mean value obtained for asymmetry index (AI) for the total sample was 0.31 ± 4.75%, with the mean values in males (0.60 ± 4.67%) being higher than in females (0.12 ± 4.85%). The maximum RH was observed in group II (30-40) with the average height of the ramus (RH) being apparently higher on the right than on the left side [Table 1 (b)]. RH was significantly (P = 0.001) greater in males than in females on both the sides.

A significant difference was observed in AJS on the two sides, AJS being significantly more on the right side [Table 2 (a)]. Significant difference based on sex was evident for SJS on both sides.

For the entire sample size, the values for FD were somewhat higher on the left side than the right side and also in males than in females on both the sides, though the differences were not significant [P = 0.405(R); 0.534(L)]. However, we did not observe any relation between FD and the age.

DISCUSSION

The possibilities of intricate and innovative reconstructive procedures on one hand and the increasing incidence of altered parameters induced by environmental factors, epigenetics and increased vehicular accidents in the orofacial region has rekindled the interest for indepth understanding of this region. Thus more elaborate studies need to be designed and carried out in this direction with the help of available innovative technology, so that base line data covering a wider spectrum is gathered with a focus on higher precision and accuracy in therapeutic as well as cosmetic procedures.

Table 1. Showing the mean values of different parameters of mandibular condyle and ramus height on the right and the left side

Parameters (Mean ±SD) (mm)	AP (mm)		ML(mm)		CH(mm)		RH (mm)	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
Total sample (n=100)	10.94 ± 1.33*	10.75 ± 1.47	19.60 ± 2.23	19.71 ± 2.35	8.27 ± 1.53	8.10 ± 1.39	41.74 ± 4.18	41.61 ± 4.28
I (20-30) (n=30)	10 .74 ±1.22	10.40 ± 1.33	19.53 ± 1.89	19.45 ± 2.28	7.88 ± 1.73	7.87 ± 1.42	41.35 ± 3.80	41.26 ± 4.09
II (31-40) (n=22)	11.21 ± 1.38	11.15 ± 1.57	19.88 ± 2.45	19.46 ± 2.28	8.46 ± 1.44	8.48 ± 1.50	43.32 ± 4.34	43.09 ± 4.42
III(41-50) (n=32)	11.39 ± 1.25	11.24 ± 1.42	19.37 ± 2.46	19.76 ± 2.36	8.76 ± 1.46	8.56 ± 1.34	41.20 ± 4.23	41.12 ± 4.20
IV (51-60) (n=16)	10.06 ± 1.19	9.86 ± 1.21	19.79 ± 2.18	20.04 ± 2.12	7.73 ± 1.04	7.67 ± 1.06	41.35 ± 4.40	41.27 ± 4.54
Male (n=59)	11.06 ± 1.49	11.01 ± 1.62*	20.33 ± 2.22*	20.47 ± 2.13*	8.52 ± 1.64*	8.39 ± 1.52	43.06 ± 4.40*	39.83 ± 2.99*
Female (n=41)	10.78 ± 1.05	10.37 ± 1.14	18.55 ± 1.79	18.62 ± 2.24	7.90 ± 1.29	7.9 ± 1.14	43.05 ± 4.37	39.56 ± 3.22

*P values <0.05 statistically significant.
Paired student t-test applied for side variable. Independent sample test applied for gender variable.
AP – Anteroposterior diameter; ML – Mediolateral diameter; CH – Condylar Height; RH – Ramus height.

Table 2. Showing the mean values of joint spaces on the right and the left side

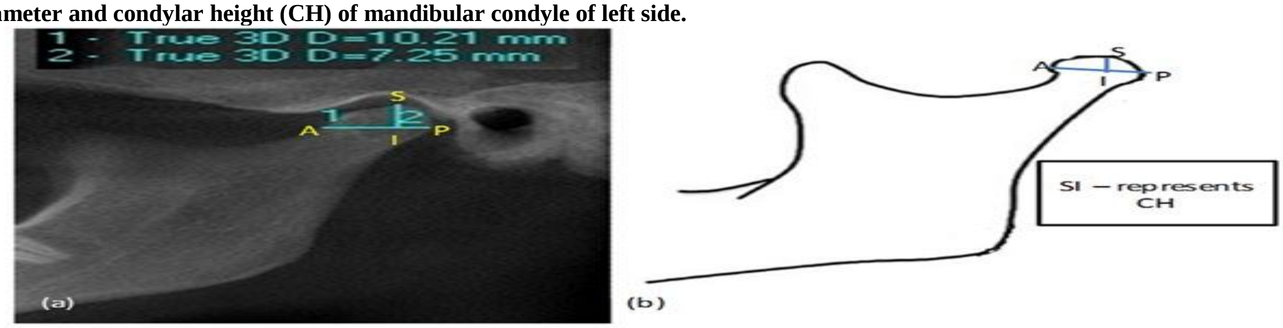
Parameters (Mean ±SD) (in mm)	AJS		SJS		PJS		FD	
	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
Total sample (n=100)	2.02 ± 0.63*	1.96 ± 0.59	2.99 ± 0.89	2.97 ± 0.97	2.55 ± 1.03	2.59 ± 0.92	8.79 ± 1.25	8.81 ± 1.25
I (20-30)	10 .74 ±1.22	10.40 ± 1.33	19.53 ± 1.89	19.45 ± 2.28	7.88 ± 1.73	7.87 ± 1.42	41.35 ± 3.80	41.26 ± 4.09
II (31-40)	11.21 ± 1.38	11.15 ± 1.57	19.88 ± 2.45	19.46 ± 2.28	8.46 ± 1.44	8.48 ± 1.50	43.32 ± 4.34	43.09 ± 4.42
III(41-50)	11.39 ± 1.25	11.24 ± 1.42	19.37 ± 2.46	19.76 ± 2.36	8.76 ± 1.46	8.56 ± 1.34	41.20 ±4.23	41.12 ± 4.20
IV (51-60)	10.06 ± 1.19	9.86 ± 1.21	19.79 ± 2.18	20.04 ± 2.12	7.73 ± 1.04	7.67 ± 1.06	41.35 ± 4.40	41.27 ± 4.54
Male (n=59)	2.07 ± 0.67	2.02 ± 0.59	3.15 ± 0.85*	3.15 ± 0.93*	2.46 ± 0.85	2.50 ± 0.83	8.88 ± 1.32	8.87 ± 1.34
Female (n=41)	1.95 ± 0.56	1.79 ± 0.55	2.77 ± 0.90	2.72 ± 0.97	2.69 ± 1.25	2.71 ± 1.04	8.66 ± 1.14	8.71 ± 1.10

*P values <0.05 statistically significant.
Paired student t-test applied for side variable. Independent sample test applied for gender variable.
AJS – Anterior Joint Space; SJS – Superior Joint Space; PJS – Posterior Joint Space; FD – Fossa Depth

Table 3. Showing the mean values of joint spaces on the right and the left side: Present Study v/s Other Studies

Parameter	Author	N	Age (years)	Right side	Left side	P value
AJS	Present study	100	20-60	2.02 ± 0.63	1.96 ± 0.59	**P < 0.05**
	Rodrigues et al. (2009)	30	13-30	1.29 ± 0.61	1.22 ± 0.51	P > 0.05
	Vitral et al. (2009)	30	15-32	1.22 ± 0.44	1.28 ± 0.53	P > 0.05
	Prabhat et al. (2013)	40	14-25	2.02 ± 0.33	1.95 ± 0.31	P > 0.05
	Dalili et al. (2012)	40	12-59	2.1 ± 0.5	1.9 ± 0.5	**P < 0.05**
SJS	Present study	100	20-60	2.99 ± 0.89	2.97 ± 0.97	P > 0.05
	Rodrigues et al. (2009)	30	13-30	1.57 ± 0.56	1.59 ± 0.54	P > 0.05
	Vitral et al. (2009)	30	15-32	1.67 ± 0.62	1.66 ± 0.69	P > 0.05
	Prabhat et al. (2013)	40	14-25	2.50 ± 0.52	2.42 ± 0.37	P > 0.05
	Dalili et al. (2012)	40	12-59	3.2 ± 0.9	3.4 ± 0.9	**P < 0.05**
PJS	Present study	100	20-60	2.55 ± 1.03	2.59 ± 0.92	P > 0.05
	Rodrigues et al. (2009)	30	13-30	1.87 ± 0.45	1.65 ± 0.45	**P < 0.05**
	Vitral et al. (2009)	30	15-32	1.96 ± 0.69	1.76 ± 0.62	**P < 0.05**
	Prabhat et al. (2013)	40	14-25	2.38 ± 0.29	2.3 ± 0.39	P > 0.05
	Dalili et al. (2012)	40	12-59	2.1 ± 0.7	2.4 ± 0.8	**P < 0.05**

Figure 1.(a) CBCT (lateral view) showing mandibular condyle of left side. (b) Line diagram showing anteroposterior (AP) diameter and condylar height (CH) of mandibular condyle of left side.

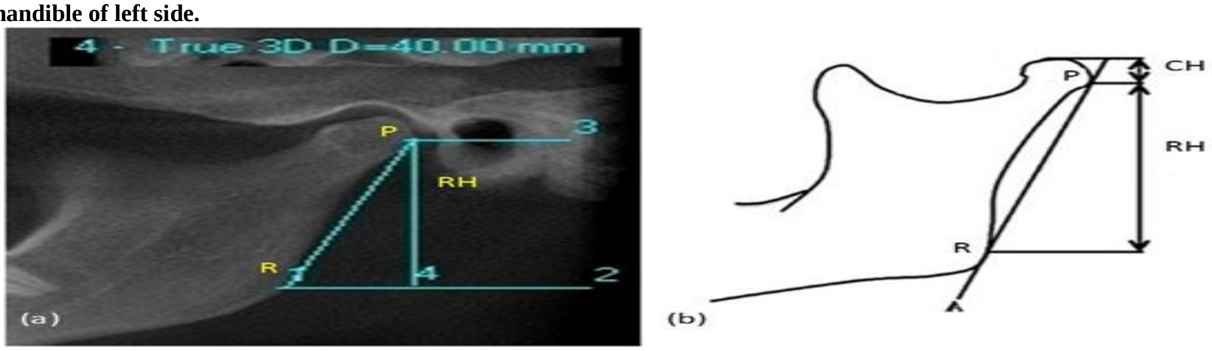


A & P - Most prominent point on the anterior and posterior surfaces of the condyle
S – Most prominent point on the superior surface of the condyle
I – lower end of perpendicular from S on AP

Figure 2.(a) CBCT (frontal view) showing mandibular condyle of left side. (b) Line diagram showing mediolateral (ML) diameter of mandibular condyle of left side.

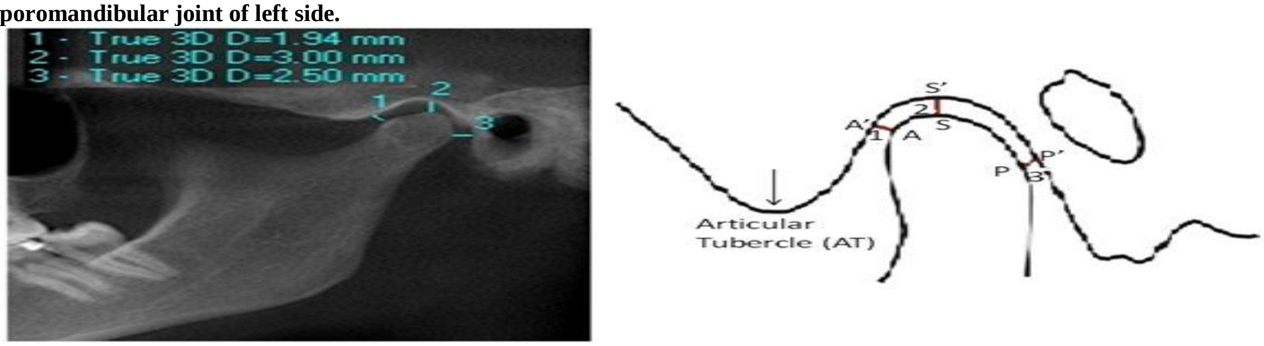
M & L - Most prominent points on the medial and lateral surface of the condyle.

Figure 3.(a) CBCT (lateral view) showing mandibular ramus of left side. (b) Line diagram showing ramus height (RH) of mandible of left side.



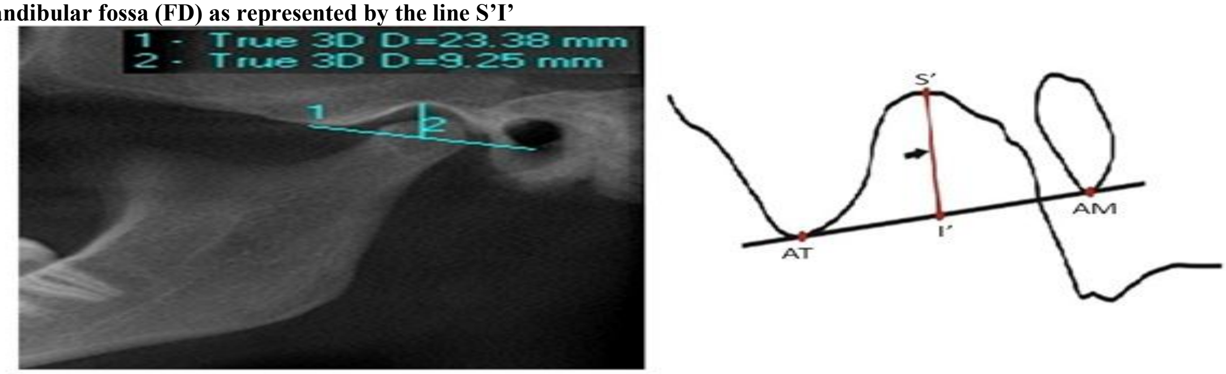
P – Most prominent point on the posterior surface of the condyle
R – Most prominent point on the posterior surface of the ramus
RH – Ramus Height

Figure 4.(a) CBCT (lateral view) showing temporomandibular joint of left side. (b) Line diagram showing three spaces of temporomandibular joint of left side.



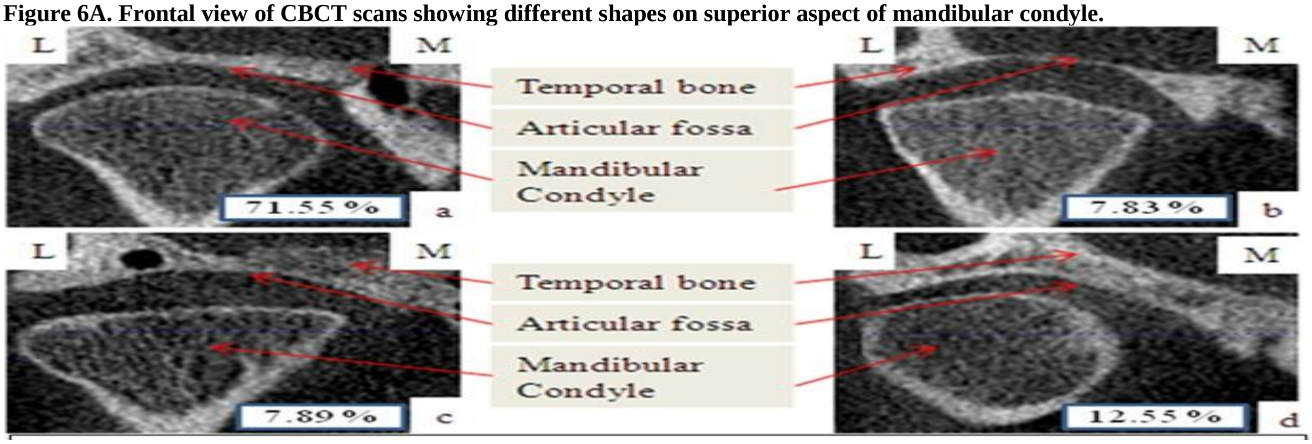
1.AJS 2. SJS 3.PJS AT-Articular Tubercle
A, S, P – Most prominent points on anterior, superior and posterior aspects of condyle
A' S' P' – Most prominent points on anterior, deepest and posterior aspects on mandibular fossa.

Figure 5. (a) CBCT (lateral view) showing temporomandibular joint of left side. (b) Line diagram showing the depth of mandibular fossa (FD) as represented by the line S'I'



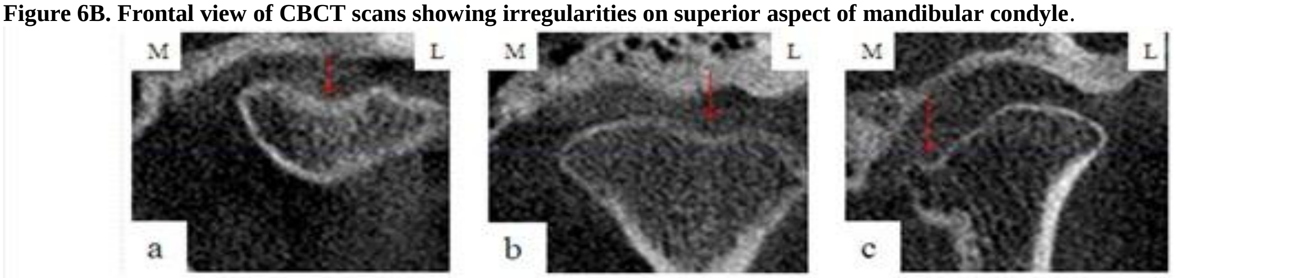
AT – Articular Tubercle, AM – Auditory Meatus, S'- Most deepest point of mandibular fossa, I' –point on plane from AT to AM

Figure 6A. Frontal view of CBCT scans showing different shapes on superior aspect of mandibular condyle.



L – Lateral side, M – Medial side.
a. Convex (71.55%) b. Angled (7.83%) c. Flat (7.89%) d. Round (12.55%)

Figure 6B. Frontal view of CBCT scans showing irregularities on superior aspect of mandibular condyle.



L – Lateral side, M – Medial side, a,b-irregularity in centre; c-eccentric irregularity

According to Kobayashi [3], the images obtained from the CBCT scans are superior to those obtained from other radiographic modalities. Based on their degree of reliability and reproducibility, CBCT scans are reported to provide more accurate measurements of the anatomical structures. In the present study, the morphological and morphometric features of mandibular condyles were determined from CBCT scans of North Indian subjects (age group: 20-60 years) using i-CAT vision software. The observations suggest differential predictability potential of various parameters of TMJ. Parameters like ML, RH and FD could be better indices for sexual dimorphism whereas features like AP and CH could prove better associates for age correlation.

The desired shape and volume of the mandibular condyle in young adults is considered to play an important role in the stability of long term orthodontic and orthognathic therapies. Different imaging modalities such as CT scans [4]; panoramic radiographs [5]; transcranial radiographs [6] etc. have been used for evaluation of mandibular condyle morphology. In the present study, carried out on CBCT scans, the mandibular condyle was observed to be convex in the majority of subjects (71.55%) and this observation is in accordance with the reports put forth by earlier investigations [7-9]. In the present study, the second higher incidence was that of the round form of mandibular condyle whereas the flat type of condyle has been reported as the second highest by various authors [7-9]. The flat shape of the condyle was observed in a smaller percentage (7.89%) of subjects (current study). The discrepancy in the reports especially pertaining to the incidence of round shape could arise because of inclusion of subjects belonging to different ethnic and age groups in various study groups.

The diameters (AP and ML) of the mandibular condyle determined with the help of a number of other imaging modalities have been reported variedly in the literature. The average AP diameter of the mandibular condyle in the present study (10.85 ± 1.40 mm) was half of the average ML diameter (19.66 ± 2.29 mm). This is in accordance with the data provided in the Gray's textbook of Anatomy [10]. The mean values for the AP diameter [10.94 ± 1.33 (R); 10.75 ± 1.47 (L)] of the mandibular condyle in the present study are more or less similar to those reported by Rodrigues et al. and Vitral et al. [4,11]. Somewhat lower values for AP have been reported by other investigators [12-14]. In the present study, right sided AP diameter was significantly higher whereas no significant difference has been reported in AP diameter with context to side by earlier investigators [11,12,15]. Even, the study by Prabhat et al. [13] carried out using axial plane CT images of 40 North Indian subjects (14-25 years) with malocclusion did not reveal any significant difference in the AP diameters on the two sides.

The mean value for ML diameter (current study) was somewhat lower as compared to the values put forth by other investigators [11,15], however, greater ML diameter on the right side in the age matched groups (20-

30 years; 31-40 years) is in agreement with the reports of Vitral et al. [15]. According to Neto et al. [16], the mediolateral (ML) dimension showed a positive correlation with age. Somewhat similar observations of steady increase in ML diameter with age were evident in the present study [Table 1(b)].

Also, the mean values for the AP and the ML diameters of the mandibular condyle were significantly higher in males, thus indicating sexual dimorphism. This observation is substantiated by the reports put forth by other investigators [17,18]. Fabian and Mpembian [19] studied dry mandibles of Tanzanian Bantu population (25 M; 25 F; 20-50 years) and observed higher though statistically non-significant values for AP and ML diameter in males. A number of investigators have associated the higher values for condylar diameter in males with their larger cranial size and intensive dental loading.

The values for the CH, as noted in the present study were higher on both the sides as compared to the values reported by other investigators, this difference could be associated with variation in sample size, age group of subjects, ethnicity as well as the procedural modality used. However, we observed sexual dimorphism in CH on right side only, though there is no mention of sexual dimorphism with context to CH by other investigators [20, 21]. The role of AI in determining the correlation between the condylar asymmetry and the TMD has been suggested by a number of investigators [22,23]. In panoramic radiographs, CH is considered asymmetric if the value of AI is higher than 6% (Habet's method). The condylar asymmetry has been associated with the differential stress borne by the two TMJs [11,24]. Age differences in the subjects under study could be the reason for smaller values (0.31 ± 4.75) of AI as compared to values reported by various other studies [22,23]. Whether evaluation by CBCT is a preferred method for obtaining more precise values as compared to those obtained by other modalities needs to be substantiated by pursuing more extensive studies.

Though we did not observe any significant difference in the RH on the right and the left side, in accordance with the previous studies, yet the overall values for RH in the present study were lower as compared to other reports. These differences could be because of the variation in anatomical landmarks considered for measurement of RH. The sexual dimorphism pertaining to RH as observed in the present study is in agreement with earlier published data [19,21,25].

The values for the anterior joint space (AJS) observed in the present study showed a significant difference on the two sides ($P < 0.05$), with AJS being wider on the right side. This observation is in agreement with the reports put forth by Dalili et al. [26]. On the other hand, no significant difference has been reported for AJS on the two sides by other investigators [11,13,15]. Our observations for SJS and PJS presenting non-significant difference on the two sides are in agreement with the earlier reports [11,13,15]. However, Dalili et al. [26] have reported significant difference ($P<0.05$) in SJS on the two sides.

The fossa depth observed in the present study was somewhat similar on the two sides, being in agreement with the findings of Lee and Lee [6], Rodrigues et al. [11] and Vitral et al. [15]. Prabhat et al. [13] reported non-significant difference for the fossa depth on the two sides. The values for FD in the present study, were not significantly different amongst males and females, though, the greater depth of the mandibular fossa in older age groups (group III and IV) than the younger age (group I and II) could be suggestive of age associated degenerative changes.

Temporomandibular disorders (TMD) are currently the most prevalent cause of non-dental pain in the orofacial region being augmented by wear and tear of the articular surfaces of the TMJ as a result of abnormal forces and autoimmune reactions, trauma, congenital dysmorphism, osteoarthritis, rheumatoid arthritis, neoplasia, idiopathic condylar resorption, ankylosis, previous failed reconstructions etc. Awareness regarding the anatomical features of TMJ plays an important role in treatment planning in orthodontics. For reducing the severity of symptoms of TMD along with its associated psychosocial effects, reshaping of the articular surfaces as well as total joint reconstructions (autogenous and alloplastic) are considered as effective therapeutic measures. Alloplastic replacements have been especially described to reproduce the normal anatomy of the joint, in turn improving the joint form and function with considerable decrease in disability and suffering. Thus, the precise detailing of normal anatomical and morphological features of TMJ could have enormous bearing on outcome of reconstructive surgeries in this region.

The observations of the present study strongly suggest the probability of varied morphology and morphometry of articular components of TMJ. The reported literature stresses upon the importance of accurate knowhow of TMJ parameters in framing the management protocols and designing reconstructive surgeries in the orofacial region with best outcomes. Hence, there is the need for incorporating data gathered from extensive studies focusing on cross ethnic, gender based and age related parameters of TMJ using CBCT scans as the imaging modality for framing uniform details.

CONCLUSION

The most common shape of the mandibular condyle in North Indian Population is the convex shape followed by round shape. Age associated growth of mandibular condyle was evident from AP diameter of the condyle and AJS alongwith sexual dimorphism shown by the ML diameter of the mandibular condyle, RH and SJS. The mandibular condyle is anteriorly inclined in the mandibular fossa. We suggest that the values obtained for various parameters from CBCT images in present study could serve as norms for designing the preformed mandibular condyle.

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CONFLICT OF INTEREST: No conflict of interest.

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