Evaluation of mandibular condyle morphology in Indian ethnics-A cross sectional cone beam computed tomography study

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Abstract

Objective: The present study aims at age and sex related changes in condylar height, condylar width and condylar length and evaluates the correlation between condylar width, condylar height, condylar length with Hounsfield unit(HS). The age prediction and sex determination on the basis of condylar height, condylar width and condylar length is also evaluated.

Materials and Methods: The cone beam images were performed using Carestream 9000cc (USA) CBCT machine. The measurements of study parameters i.e. condylar height, condylar width and condylar length were performed prospectively on CBCT images of 300 temporomandibular joint of 150 study subjects.

Results: The comparison of condylar width and conylar length shows significant ($p<0.05$) difference in the condylar width among the age groups however the difference in condylar length was statistically non-significant ($p>.05$) in both sides (Right and left side). There was statistically significant ($p=0.001$) difference in the condylar width between male and female in both right side and left side. There was significant difference in the condylar height between male and female in both right ($p<0.01$) and left side ($p<0.05$). On the basis of mathematical equations derived from linear regression analysis, age of an individual can be predicted if either of condylar height, condylar width, or condylar length is known.

Conclusion: Age estimation is a sub-discipline of the forensic sciences. This study is first study which has derived mathematical equations for age estimation by linear regression analysis if either of condylar height, condylar width, or condylar length is known.

Keywords: Mandible, Mandibular Condyle, Temporomandibular joint

Introduction

Temporomandibular joint (TMJ) classic radiographic studies such as the plain film radiography and panoramic radiography have insufficient capacity to reveal anything more than gross osseous changes[(1)] within the joint. Radiographic analysis of the TMJ is a vast field and is considered by some to be a separate subset of oral and maxillofacial radiology[(2)] consisting of both two and three-dimensional imaging modalities. Two-dimensional (2D) imaging of the TMJ employs conventional radiology to produce a variety of projections. Three-dimensional evaluations such as computed tomography (CT) and magnetic resonance imaging (MRI), have been utilized to some degree however because of high cost[(3,4)] larger radiation dosage[(5,6)] large space requirements[(3,4)] and the high level of skill required for interpretation leads to minimum use of its. With the introduction of cone-beam technology, such deterrents of CT imaging have been greatly reduced.

With different cone-beam computed tomography (CBCT) scanners now available on the world market, lower radiation dosages,[(7-10)] and lower costs,[(3)] 3D radiography is likely to become more commonly used in dentistry. Demonstrating a broad spectrum of applications and greatly improved accuracy over 2D radiography,[(4,11,12)] CBCT proves to be an invaluable diagnostic tool for the evaluation of the osseous structures of the TMJ like mandibular condyle, coronoid, petrous part of temporal bone. Within the condyle there is variation in bone density and composition. Cortical intertrabecular tissues have varying densities and mechanical properties.[(13-17)] The mandibular condyle (or head), besides joint function, acts as a site of regional adaptive growth even under functional load supported by its cartilage.[(18)] Mandibular condyle morphology is characterized by a rounded bone projection with an upper biconvex and oval surface in axial plane.[(20)] Typically the antero-posterior dimension (or lateral) of condyle is shorter than the medio-lateral (or frontal), whose ends are called medial and lateral poles. A normal variation of the condylar morphology occurs with age,[(19,20)] gender[(20)] and between right and left sides.[(21,22,23)] The most prevalent morphologic changes are detected in the temporomandibular joints (TMJ) of elderly persons[(24)] due to the onset of joint degeneration.

Materials and Methods

Study Participants: This study was carried out in the Department of Oral medicine and Radiology of King George's Medical University, Lucknow. The measurements of study parameters were performed prospectively on CBCT images of 300 temporomandibular joint of 150 study subjects. The study subjects having congenital craniofacial abnormalities and systemic diseases such as rheumatoid arthritis were excluded from study.

Imaging: The cone beam images were performed using Carestream 9000cc (USA) CBCT machine. The study subjects were placed in a position so that the Frankfort horizontal plane was perpendicular to the head to obtain a consistent orientation of sagittal images. The CBCT images were obtained at 90 Kvp, 4 mA for 6.3 seconds at FOV (17x6) voxel size of 200. The temporomandibular joint was defined on 0.5 mm-thick axial slices. One of the axial views on which the condylar processes were seen with their widest mediolateral extent was used as a reference view for secondary reconstruction. The lateral slices of temporomandibular joint were performed perpendicular to the long axis of the condylar process with 1mm thickness and the coronal slices were performed parallel to the long axis of the condylar process with 1mm thickness on the selected axial image. The Trophy Dicom Ink software program was used for all measurements e.g. condylar height, condylar width and condylar length. All the measurements are done as follows-

a. Condylar height is measured as distance between the most superior point on the condyle and perpendicular line drawn along neck of condyle in sagittal section (**Fig. 1**).
b. Condylar width is defined as the linear distance between the most lateral aspect of lateral pole to most medial point on medial pole in axial section (**Fig. 2**).
c. Condylar length is assessed by measuring from most posterior aspect of condyle to most anterior point on condylar head in axial section (**Fig. 3**).

Statistical analysis: Statistical analysis was conducted with the program using Statistical Package for Social Sciences (SPSS) version 21.0. The one-way analysis of variance (ANOVA) and Post hoc tests was used to compare condylar width and conylar length with age. The Unpaired t-test is used to compare condylar width and conylar length with gender. A p-value of 0.05 was considered statistically significant. All the measurements were established by three observers and the mean of the results was used to ensure the reliability of the study.

Results

The study population consists of 150 subjects. The demographic data of study subjects shows about one third of the patients were between 20-30 years (32.7%). More than half of the patients were males (59.3%) (**Table 1**). The comparison of condylar width and conylar length was done in age groups by ANOVA and Post Hoc tests. There was significant ($p<0.05$) difference in the condylar width among the age groups in both right side and left side of temporomandibular joint (**Table 2**) however the difference in condylar length was statistically non-significant in both sides(Right and left side) of temporomandibular joint (**Table 2**). By using Unpaired t-test the sex dependent comparison between condylar width and condylar length was done. There was statistically significant ($p=0.001$) difference in the condylar width between male and female in both right side and left side of temporomandibular joint (**Table 3**). However there was statistically non significant ($p>.05$) difference in the condylar length between male and female in both right side and left side of temporomandibular joint(**Table 3**). The condylar width and length is correlated with Hounsefield unit of CBCT. It is the first study which has tried to standardize the Hounsefield unit of CBCT. There was no correlation noted between Hounsfield unit and condylar width, condylar length in both right side and left side of temporomandibular joint (**Table 4**). The one way ANOVA test is used to compare condylar height in different age group and it was concluded that there is no statistically significant ($p>0.05$) co-relation in the condylar height among the age groups in both right and left side of temporomandibular joint(**Table 5**). The unpaired t-test is used to analyse condylar height in male and female. It was found that there was significant difference in the condylar height between male and female in both right($p<0.01$) and left side ($p<0.05$) of temporomandibular joint(**Table 6**). The co-relation between condylar height and Hounsefield unit of CBCT is also estimated but there was no statistically significant($P>.05$) co-relation noted(**Table 7**). Linear regression analysis is performed to predict the age of a patients if either of condylar height, condylar width, or condylar length is known. Depending on above said parameters, the linear regression analysis have derived mathematical equations. On the basis of these mathematical equations the age of an individual can be predicted (**Table 8**). The comparison between total (right and left side) condylar width and total (right and left side) conylar length was done in age groups by ANOVA and Post Hoc tests. There was significant ($p<0.001$) difference in the total condylar width among the age groups however the difference in total condylar length was statistically non-significant (>.05) (**Table 9**). By using unpaired t-test the sex dependent comparison between total (right and left side) condylar width and total (right and left side) condylar length was done. There was statistically significant ($p=0.001$) difference in total condylar width between male and female (**Table 10**). However there was statistically non significant ($p>.05$) difference in total condylar length between male and female (**Table 10**). The co-relation between total condylar height, condylar length and Hounsefield unit of CBCT is also estimated but there was no statistically significant($P>.05$) co-relation noted(**Table 11**). Linear regression analysis is performed to predict the age of a patients if either of total condylar height, total condylar width, or total condylar length is known. Depending on above said

parameters, the linear regression analysis have derived mathematical equations. On the basis of these mathematical equations the age of an individual can be predicted (**Table 12**).

Table 1: Age and sex distribution of study subjects

Age in years	Male		Female		Total	
	No.	%	No.	%	No.	%
<20	13	65.0	7	35.0	20	13.3
20-30	26	53.1	23	46.9	49	32.7
31-40	27	62.8	16	37.2	43	28.7
41-50	14	56.0	11	44.0	25	16.7
>50	9	69.2	4	30.8	13	8.7
Total	89	59.3	61	40.7	150	100.0

Table 2: Comparison of condylar width and conylar length with age

Age in years	Condylar width		Conylar length	
	Right	Left	Right	Left
<20	17.47±1.94[a]	17.45±2.37[b]	6.76±1.43	6.61±1.18
20-30	18.62±1.86	18.55±2.42	7.52±1.10	7.28±1.16
31-40	19.64±2.06 [a]	19.55±2.16 [b]	7.63±1.46	7.57±1.54
41-50	18.94±2.27	18.82±2.52	7.05±0.92	7.20±1.01
>50	19.35±2.44	19.77±2.41	6.95±1.84	7.35±1.38
p-value[1]	0.003*	0.01*	0.05	0.10

[1]ANOVA test, *Significant, [a]p=0.001, [b]p=0.01 (Post hoc tests)

Table 3: Comparison of condylar width and conylar length with gender

Gender	Condylar width		Conylar length	
	Right	Left	Right	Left
Male	19.49±2.15	19.57±2.40	7.37±1.38	7.32±1.40
Female	17.97±1.77	17.76±2.05	7.25±1.24	7.19±1.14
p-value[1]	0.001*	0.001*	0.59	0.53

[1]Unpaired t-test, *Significant

Table 4: Correlation of condylar width and conylar length with HS

	HS			
	Right		Left	
	Correlation coefficient	p-value	Correlation coefficient	p-value
Condylar width				
Right	-0.16	0.04	-0.12	0.05
Left	0.03	0.64	0.06	0.34
Conylar length				
Right	0.36	0.001	0.16	0.07
Left	-0.07	0.39	-0.04	0.35

Table 5: Comparison of condylar height with age

Age in years	Condylar height	
	Right	Left
<20	8.49±1.28	8.26±1.30
20-30	9.34±1.68	9.38±1.83
±31-40	9.47±1.39	9.33±1.29
41-50	9.32±1.32	9.26±1.73
>50	8.91±1.39	9.42±2.00
p-value[1]	0.13	0.10

[1]ANOVA test

Table 6

Gender	Condylar height	
	Right	Left
Male	9.46±1.53	9.43±1.70
Female	8.88±1.34	8.86±1.50
p-value[1]	0.01*	0.03*

[1]Unpaired t-test, *Significant

Table 7: Correlation of condylar height with HS

Condylar height	HS			
	Right		Left	
	Correlation coefficient	p-value	Correlation coefficient	p-value
Right	0.06	0.43	0.04	0.55
Left	0.15	0.06	0.16	0.03

Table 8: Age prediction

Condylar width	
Right	Age=17.55+0.04Xwidth
Left	Age=17.32+0.04Xwidth
Condylar length	
Right	Age=7.52-0.01Xlength
Left	Age=7.03+0.01Xlength
Condylar height	
Right	Age=8.96-0.01Xheight
Left	Age=8.66+0.01Xheight

Table 9: Comparison of condylar width and conylar length with age

Age in years	Condylar width	Conylar length
<20	17.46±2.06[a]	6.68±1.18
20-30	18.58±2.00	7.40±1.04
31-40	19.59±2.04 [a]	7.59±1.42
41-50	18.87±2.25	7.12±0.89
>50	19.56±2.34	7.14±1.52
p-value[1]	0.003*	0.07

[1]ANOVA test, *Significant, [a]p=0.002 (Post hoc tests)

Table 10: Comparison of condylar width and conylar length with gender

Gender	Condylar width	Conylar length
Male	19.53±2.16	7.34±1.29
Female	17.86±1.82	7.21±1.13
p-value[1]	0.001*	0.53

[1]Unpaired t-test, *Significant

Table 11: Correlation of condylar width and conylar length with HS

	HS	
	Correlation coefficient	**p-value**
Condylar width	-0.12	0.12
Conylar length	0.07	0.37

Table 12: Age prediction

Condylar width	Age=5.69+1.46Xwidth
Condylar length	Age=32.99-0.04Xlength
Condylar height	Age=24.98-0.90Xheight

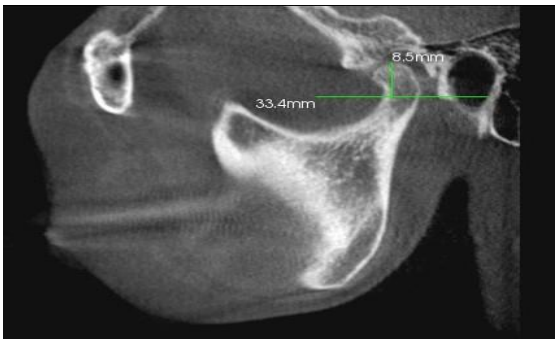

Fig. 1: **Shows condylar height measurement as distance between the most superior point on the condyle and perpendicular line drawn along neck of condyle in sagittal section**

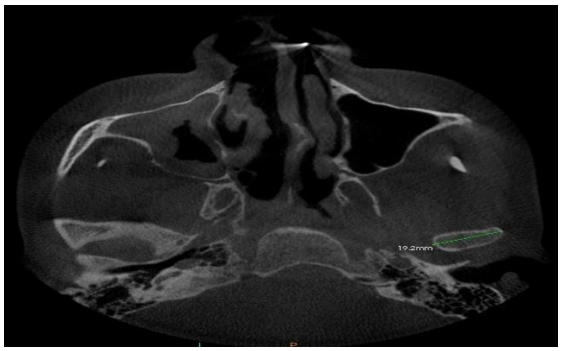

Fig. 2: Shows condylar width as the linear distance between the most lateral aspect of lateral pole to most medial point on medial pole in axial section

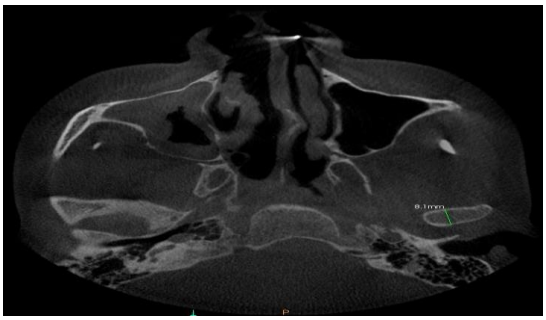

Fig. 3: Condylar length is assessed by measuring from most posterior aspect of condyle to most anterior point on condylar head in axial section

Discussion

The mandibular condyle is one of the main sites of facial growth which is expressed in an upward and backward direction.[25] Age estimation is a sub-discipline of the forensic sciences and should be an important part of every identification process.[26] Estimation of age is important for differentiating the juvenile from the adults in criminal law cases, social benefits and employment and marriage.[27] Determination of chronological age in persons within the range of 15-23 years remains a problem. Skeletal indicators such as diaphysis-epiphysis fusion, hand-wrist examination cervical vertebrae maturation, amino acid racemization, changes in pubic symphysis, fusion of cranial bones, fusion of cranial sutures or changes in the secondary sexual characters are most commonly used for age estimation in this age group.[27] Rodrigues et al[28] investigated the diameter of the right and left condyles in subjects aged 13 to 30 years old. All subjects presented Class I malocclusion and were evaluated by computed tomography. Mean sagittal (lateral) dimensions for right and left condyles were respectively, 9.39 mm and 9.30 mm and for mediolateral (frontal) 20.62 mm and 20.57 mm with no statistically significant differences between right and left condyles.

Valladares N et al[29] investigated the diameter of the right and left condyles in subjects aged 3 to 20 years old and found that mean sagittal (lateral) dimensions for right and left condyles were, respectively, 8.02 mm and 7.43 mm and for mediolateral (frontal). Mathew AL et al[30] stated that the prevalence of changes in the condylar morphology as assessed by orthopantomogram was found to be relatively lower in subjects who were between 20-40years of age as compared to those above 40 years. Where as in our study it is found that condylar width and length is minimum in >20 yrs i.e. in right condyle it is 17.47±1.94 and 6.76±1.43 respectively and in left side of condyle it is 17.45±2.37 and 6.61±1.18 respectively.

Condylar width and length is maximum in 31-40 years. In this condylar width and length in right condyle is 19.64±2.06 and7.63±1.46 respectively and in left side it is 19.55±2.16 and 7.57±1.54 respectively. It is found

that there is significant ($p<0.05$) difference in the condylar width among the age groups in both left and right side. Matsumoto MA et al[31] stated that the linear measurements showing the anteroposterior dimension of the condyle had a mean value of 8.25 for females and 8.42 mm for males. The mediolateral dimension of the condyle showed a mean value of 18.92 mm for females and 18.98 mm for males with no statistically significant differences between sexes for the anteroposterior or mediolateral dimensions of the condyle. Christiansen and Thompson et al[32] also reported that the transverse condylar dimension of normal adult joints was greater for men (19.6 mm) than for women (17.7 mm).

Ishwarkumar S et al[33] recorded that antero-posterior length of the male mandibular condyle as 9.23 mm and 9.57 mm on the right and left side, respectively, while in females a mean length of 8.73 mm and 8.66 mm on the right and left side was recorded, respectively. Whereas in our study we found that antero-posterior length of the male mandibular condyle is 7.37±1.38 mm and 7.32±1.40mm on the right and left side, respectively while in females a mean length of 7.25±1.24 mm and 7.19±1.14mm on the right and left side is recorded respectively and mesiolateral length i.e. condylar width for male mandibular condyle is 19.49±2.15 and 19.57±2.40 on right and left side is recorded and for female it is 17.97±1.77 and 17.76±2.05 for right and left side of condyle. We have found that there was significant ($p=0.001$) difference in the condylar and width between male and female in both left and right side. Nobody ever mention about correlation of condylar height with gender and sex and their comparison between them. On comparing the condylar height with gender, it is seen that condylar height of males is slightly higher than females with significant ($p<0.05$) difference in the condylar height between male and female in both right and left side. On comparing the condylar height with age, it is seen that it is minimum in <20 years and maximum in 31-40 years but There is no significant ($p>0.05$) difference in the condylar height among the age groups in both right and left side.

Conclusion

The mandibular condyle is one of the main sites of facial growth. Age estimation is a sub-discipline of the forensic sciences and it is of utmost importance for differentiating the juvenile from the adults in criminal law cases, social benefits, employment and marriage. This study is first study which have derived mathematical equations for age estimation by linear regression analysis if either of condylar height, condylar width, or condylar length is known.

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