ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 1, January - 2022, Page No. : 116 - 125

Age Estimation by Cone Beam Computed Tomographic Analysis of Articular Eminence Inclination of Temporomandibular Joint in Indian Subpopulation - A Morphometric Study.

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Citation of this Article: Dr. Nikhila B. Shroff, Dr. Ashita Kalaskar, Dr. Lata Balu Gangurde, Dr. Sangeeta Ambhore, "Age Estimation by Cone Beam Computed Tomographic Analysis of Articular Eminence Inclination of Temporomandibular Joint in Indian Subpopulation- A Morphometric Study", IJDSIR- January - 2022, Vol. – 5, Issue - 1, P. No. 116 – 125.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Objective: The present study was planned to predict the age and gender of subjects on the basis of articular eminence inclination of temporomandibular joint by CBCT.

Methods: The study sample constituted of CBCT scans of 186 subjects in the age rangeof 6 to 30 years. Condylar processes were seen with their widest medio-lateral extents on the axial views which were used as reference views for secondary reconstructions. The sagittal slices of the TMJ were performed perpendicular to the long axis of the condylar process. The articular eminence inclination (AEI) measurements were performed on the corrected sagittal slices.

Results: The mean values of AEI by both Best fit line and Top roof line methods showed a gradual increase with increase in the age range. The coefficient of determination (r^2) indicated nearly 21% of variation by both methods determining AEI for both males and females in estimating age. Males showed greater values of AEI as compared to females

Conclusion: The articular eminence inclination increases with age with higher values in males as compared to females. The weak positive co-relation of

AEI with that of age indicates its use as an adjuvant method for age prediction.

Keywords: Age estimation, Articular Eminence Inclination, Best fit line method, Cone-Beam Computed Tomography, Top roof line method.

Introduction

Age is duration or the measure of time of the existence of a person or an object. Commonly, it is expressed as chronological age, which is defined as the measure of time elapsed since a person's birth. Estimation of age is one of the important factors in forensic medicine. From a forensic perspective, sufficiently precise and reliable determination of age isrequired in living person as well as in unidentified cadavers and human remains[1]. Many researchers have proposed different methods for age estimation such as Skeletal, Odontological, Anthropological and Physiological methods. Among all these methods, the ageestimation methods involving the bones and teeth are most commonly used as they show fewer variations as compared to other developmental factors. One such method of age estimation involving bone could be articular eminence inclination (AEI) of temporomandibular joint (TMJ).

The articular eminence inclination (AEI) is defined as the angle formed by the articular eminence (AE) and the Frankfort horizontal (FH) plane or any other horizontal plane such as the occlusal or palatal plane[2]. It can be measured by two methods, the best fit line and the top roof method [2]. The normal range for AEI angle in adults has been reported to be 30°–60°. AEIis considered as flat if it is smaller than 30° and steep if it is greater than 60°[3].

AEI have been studied by different methods like on dry skull, photographs, conventional radiographs, Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT) for either determining its various relationships with other osseous components of TMJ, with or without TMJ disorders or simply to understand the joint mechanism. But evaluation of AEI with regards to its significance in age and gender estimation from a forensic point of view have not been studied much. CBCT, a commonly available 3D imaging modality for facial bones, offers unique advantage of low radiation dose in addition toproviding a high spatial resolution as compared to other 3D imaging like Computed Tomography. Taking into consideration the above mentioned facts, the present study was planned to predict the age and gender of subjects on the basis of articular eminence inclinationby CBCT.

Materials and methods

The study was designed as a cross sectional study and approval was obtained from institutional ethics committee.

Sample

The study sample constituted of CBCT scans of 186 subjects (with alpha error of 5%, and beta error of 20%). The CBCT scans of subjects in the age range 6 to 30 years who had been referred for full volume three dimensional (3D) CBCT scans to the Department of Oral Medicine and Radiology were included in the study. CBCT images of subjects with severe trauma to the craniofacial structures, congenital or hereditary craniofacial abnormalities affecting the TMJ joint, systemic diseases affecting joint morphology such as rheumatoid arthritis, hyperparathyroidism etc. and developmental anomalies/ disorders were excluded from the study. Poor quality CBCT images and those not involving both TMJs were also excluded. With the help of valid official credentials (adhar card, birth certificate, passport, driving license, voting card), the chronological age of the subject was noted and verified.

Theexposure parameters were set according to Planmeca User Manual instruction. (Table 1).

Patient size	kV	mA	mAs	Time	Volume
Adolescent	90	9	325	36s	160x160mm
Small adult	90	10	361	36s	160x160mm
Average-size adult	90	11	433	36s	160x160mm

Measurements

Full volume scans of the subjects were done on the CBCT machine (Planmeca, Promax, 3D Mid, Helsinki, Finland). The 3D images were transferred in DICOM (Digital Imaging and Communications in Medicine) format to the console. Primary reconstructions were performed. TMJs were defined on the axial slices of 0.4mm-thickness.

One of the axial views on which condylar processes were seen with their widest medio-lateral extent were used as reference views for secondary reconstructions (Fig 1a). The sagittal slices of the TMJ were performed perpendicular to the long axis of the condylar process (Fig 1c) and the coronal slices (Fig 1b) were performed parallel to the long axis of the condylar process on the selected axialimage.

The measurements belonging to the AEI were performed on the corrected sagittal slices oriented to Frankfort Horizontal plane. PLANMECA Romexis Viewer, (version 3.2.0R) was used to for measurements of lines and angles used in the study. The articular eminence inclination was measured by two methods: best fit line method and top-roof line method. Best-fit line method is the angle formed by the FH plane and the plane passing through the posteriorsurface of eminence (Fig 2a).

Top-roof line method is the angle between FH plane and the plane passing through the highest point in the roof of glenoid fossa and the lowest point at the crest of the articular eminence (Fig 2b). The screenshots of each section were taken and saved in in Jpeg format in separate files. To blind the observers to the age and sex of the patient, the demographic data was removed from the images. Two experienced Oro-maxillofacial Radiologists performed the Radiographic measurements separately. For determining the intra-observer reliability one radiologist repeated the radiographic measurements after an interval ofone month.

Fig. 1: Axial, Coronal and Sagittal section of condylar process of temporomandibular joint.

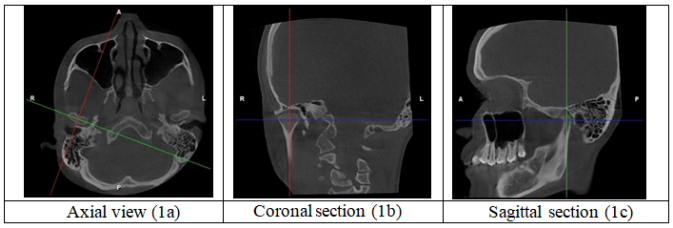
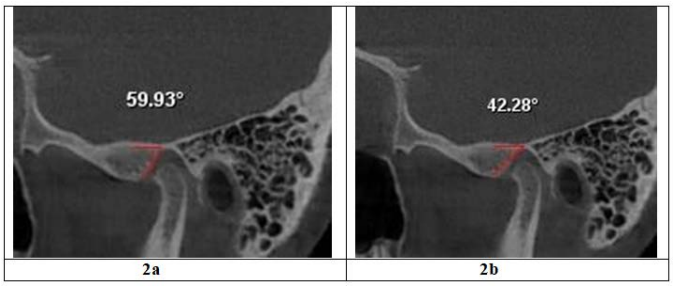


Fig. 2a: Sagittal section showing the measurement of eminence inclination with the best-fit line method. 2b: Sagittal section showing the measurement of eminence inclination with the top-roof line method.



Statistical analysis

The distribution of demographic characteristics such as age and gender was obtained interms of frequencies and percentages. Inter group comparison (2 groups) was done using t test.Inter group comparison (>2 groups) was done using one way ANOVA followed by pair wise comparison using post hoc test. Intra class correlation reliability between 2 observers was carried out. Linear regression analysis for age estimation was performed. The analysis was performed independently for males and females, as well as overall. The goodness of fit of the model was evaluated in terms of coefficient of determination i.e. r^2 also, the intra-class correlation (ICC) coefficient assesses the reliability of ratings by

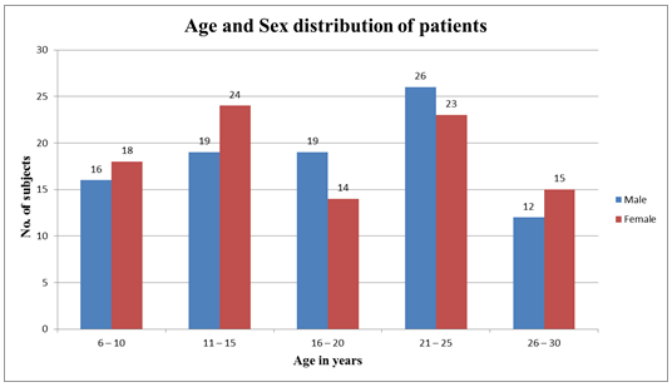
comparing the variability of different ratings of the same subject to the total variation across all ratings and all subjects. Theratings are quantitative.

All the analysis was performed using SPSS software (version 21.0, IBM) and statistical significance was tested at a 5% level.

Result

The study consisted of CBCT scans of total 186 subjects with age range of 6 to 30 years, out of which there were 92 males (49.5%) and 94 females (50.5%).

Graph 1: Describes the ageand gender distribution of the data.



Intra-class correlation (ICC) coefficient was used considering appropriate model, measurement type and definition i.e. absolute agreement to quantify the biases. Intra-class correlation coefficient was obtained considering two-way mixed model, as the selected raters were only of interest. Referring to single measurement and absolute agreement, the coefficient value was >0.7 indicating a strong relation between variables.

Inter-observer assessment, showed a strong reliability between observer 1 and 2 ($p<0.001$).

There was a statistically non-significant difference between the right and left AEI values ($p> 0.05$).

Table 2: Comparison of AEI by Top roof line method with age groups

	Age groups	N	Mean	Std. Deviation	Std. Error	Min.	Max.	F value	p value
Top roof line method	6-10	34	30.885735	5.3177532	.9119871	20.3400	41.1600		
	11-15	43	32.404302	4.2487800	.6479329	21.3000	39.1400		
	16-20	33	35.550909	6.5319225	1.1370618	17.1250	44.0750	13.393	.000**
	21-25	49	37.221020	5.7317607	.8188230	22.2900	48.6300		
	26-30	27	39.203889	5.3709243	1.0336349	29.6150	49.4500		
	Total	186	34.940941	6.1411960	.4502943	17.1250	49.4500		

Table 3: Comparison of AE inclination by Best fit line method with age groups

	Age groups	N	Mean	Std. Deviation	Std. Error	Min.	Max.	F value	p value
Best fit line method	6-10	34	43.444118	8.4303202	1.4457880	25.2650	61.8450		
	11-15	43	48.631047	8.3262458	1.2697406	26.3850	61.8450		
	16-20	33	52.239545	11.2717812	1.9621653	23.5600	72.4650	13.087	.000**
	21-25	49	55.329592	10.3998809	1.4856973	24.2950	72.2550		
	26-30	27	58.783704	8.4035271	1.6172596	42.7950	74.2650		

Table 4: Comparison of AEI by Top roof line method and Best fit line method betweenthe Genders.

Gender		N	Mean	Standard Deviation	Standard Error Mean	T value	p value
Top roof line method	M	92	35.889837	5.5834736	.5821174	2.104	.037*
	F	94	34.012234	6.5387927	.6744250		
Best fit line method	M	92	53.114239	9.6409994	1.0051437	1.978	.049*
	F	94	50.041915	11.4450457	1.1804663		

Statistically high significant difference was noted for the values of AEI between the different age groups ($p<0.001$) as shown in tables 2 & 3, whereas comparison of AEI with gender showed statistically significant difference ($p<0.05$) as shown in table 4.

The linear regression analysis is as follows:

Age =3.129 + 0.282 x AEI (Best fit line method) + 0.217 x Gender

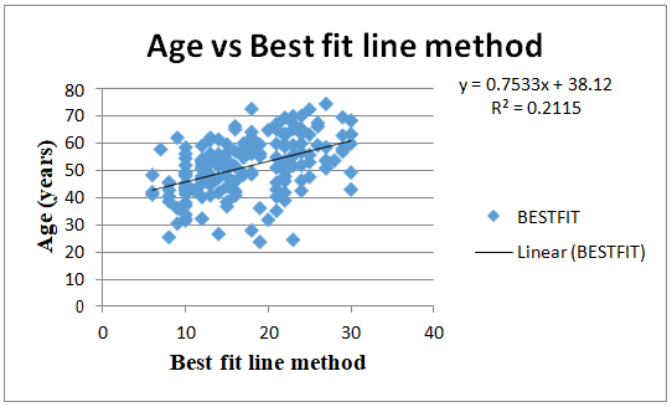
Age = 0.137 + 0.498 x AEI (Top roof line method) + 0.197 x Gender

Age = 0.460 + 0.298 x AEI by Top roof line method + 0.129 x AEI by Best fit line method+ 0.217 x Gender

(Where Male=1and Female =2)

To determine the relationship between articular eminence inclination by best fit line method and the age of individual, a scatter plot was obtained, considering both gender types, as shown in graph 2. It is evident from the plot that as articular eminence inclination increases,the age also increased in almost linear manner. Pearson's correlation coefficient, as an indicatorof linear relationship between two variables, was positive & moderate correlation with r = 0.459 with associated p-value 0.000, indicating statistically significant positive correlation.

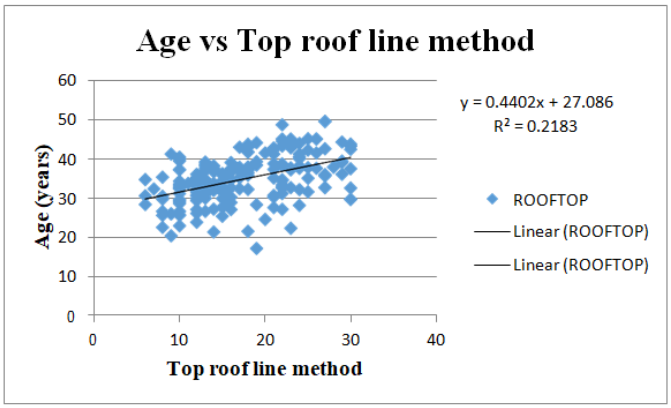
Graph 2: Scatter plot showing relationship of AEI by Best fit line method and age.



Similarly, to determine the relationship between articular eminence inclination by Toproof line method and the

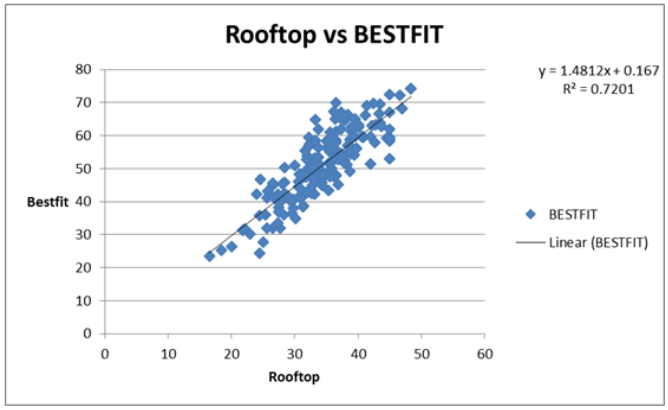
age of individual, a scatter plot was obtained, considering both gender types, as shown in graph 3. It is evident from the plot that as articular eminence inclination increases, the age also increased in almost linear manner. Further, simple linear regression was performed with AE inclination as independent predictor and age as dependent variable. The coefficient of determination (r^2) was 0.211 and 0.218 for best fit line and top roof line methods respectively, indicating that nearly 21% of the variation in data was explained forboth the methods by the model.

Graph 3: Scatter plot showing relationship of AEI by Top roof line method and age.



The analysis for AEI by top roof line method verses best fit line method indicated that there was a positive & high correlation (r = 0.848 with associated p-value 0.000), indicating that as the value of AEI by top roof line method increases, there is also a marked increase of AEI by best fit line method (graph 4).

Graph 4: Scatter plot showing correlation between Top roof line method and Best fit line method.



Discussion

TMJ is a ginglymoarthrodial joint controlling the opening and closing of jaws. The initial opening is associated with rotation of condyle whereas with further wide opening the condyle slides along the postero-inferior slope of AE to glide anteriorly. This movement of condyle along AE mainly depends on the AE morphology which in turn could be affected by factors like age, gender and masticatory functions. **Katsavrias EG et al** [2] showed that the inclination of the articular eminence attained 50% of its adult value by the age of 2, 70-72% bythe age of 10 years and 90-92% by the age of 20 years. It then continues to grow, although ata reduced rate, until the age of 30 years. This justifies the reason for restricting the age of the present study sample to 30years.

By using both the morphometric methods of AEI measurement (best fit line method and top roof line method), **Sumbullu MA et al** observed lower AEI values in 16-20 years age group and highest AEI values in 21-30 years age group[4]. **Chaurasia A et al** also found an increase in articular eminence inclination with increase in age. They found the mean value of eminence inclination in best fit line method to be 50.69±13.75° in 10-20 years age group which gradually increased to 52.31±16.08° in 31-40 years age group and lowered to 49.02±9.06° in 41-50 years aged persons. In top roof line method mean value of eminence inclination was

32.96±9.06° in10-20 years aged persons which increased up to 33.16±8.66° in 21-30 years and lowered to 31.58±8.92° in 41-50 years of age group[5]. Similarly in the present study, the mean value of AEI according to best fit line method was 43.44±8.43° in the age group 6-10 years, which gradually increased to 48.63±8.32° in 11-15 years, 52.24±11.27° in 16-20 years, 55.33±10.39° in 21-25 years and 58.78±8.40° in the age group 26-30 years (Table 2). While according to toproof line method, the mean value of AEI was 30.88±5.31° in the age group 6-10 years, gradually increasing to 32.40±4.24° in 11-15 years, 35.55±6.53° in 16-20 years, 37.22±5.73° in 21-25 years and 39.20±5.37° in the age group 26-30 years (Table 3). The increase noted in AEI values till the age of 30 years co-relates with the full attainment of AE inclination by 30 years as a result of stimulation by growth hormone [6]. Whereas the lowered AEI values in later ages could be co-related with the remodeling of AE along with other osseous structures of TMJ due to continuous masticatory functions associated with different masticatory forces.

In the present study, linear regression analysis was performed and r^2 value wascomputed. The r^2 value is the measure of how well the proposed regression model data fits thereal data. Its value ranges from 0-1. Higher the r^2 values, better is the possibility of estimating age. An r^2 value closer to 1 means the model was better able to catch the variation in the data and hence the predicted age will be more close to reality. In this study according to best fit line method and top roof line method the r^2 value was 0.211 and 0.218, indicating that the nearly 21% of the variation in the data was explained by the model. This variation indicates that the models of fitness were weakly positive for both males and females in estimating age. Thus it could be interpreted that AE inclination could be used as an adjuvant method for estimating age. The weak positive co-relation between the AE inclination and age could be due to variousfactors such as the shape of dental arches, skeletal relationships of jaws, loss of teeth, presence of para-functional habits and variations in diet leading to different masticatory forces. A study by **Verner FS et al[7]** showed changes in AE inclination between different dental arch shapes with angle being greater in ovoid arch and smaller in square arch. **Lobo F et al[8]** found that AE inclinations were significantly lower in class III as compared to class I & II. It has been shown that the AE is completely flat at birth followed by a very rapid growth later. This would have been actually meant to develop TMJ to withstand the future masticatory forces indicating that the AE development could be more affected by masticatory function than any other factors[9, 10].This observation could be backed up by the evidence that congenital absence of condyle is associated with AE underdevelopment indicating a strong functional dependence[2].

There are studies showing difference in eminence inclination according to gender. **Ilguy D et al[11]** performed measurements on 105 CBCT scans retrospectively by both best fit line method and top roof line method and showed that eminence inclination and height values of males were higher compared to females. **Chaurasia A et al [5]** evaluated AEI by both methods on CBCT scans of 206 patients and suggested increase in inclination of articular eminence in males as compared to females. Similar results were observed in the **present study** with the value of articular eminence inclination greater in males as compared to females. Mean values of eminence inclination in males and females by best fit line method were 53.11±9.64° and 50.04±11.4° respectively and by top roof line method were 35.88±5.58° and 34.01±6.53° in males and females

respectively. On the contrary, **Paknahad M et al [12]** used top roof line method to measure AEI of bilateral TMJs of 40 patients on CBCT scans and found that AEI was higher in females as compared to males. Whereas **Jasinevicius TR et al [13]** found that there were no differences in eminence inclination by gender. Wider age group subjects demonstrating degenerative changes and improper gender distribution could be the reasons for above mentioned controversial results.

The literature gives evidence of different methods to measure the inclination of posterior slope of articular eminence for different purposes. These methods include impressions done on dry skull with modeling clay [14], direct measurements on dry skull [15], arthrograms [16], panoramic radiographs [17], tomographic radiographs (both corrected and uncorrected) [18], cephalometric radiographs [19], scaled photographs [10], cephalometry using intensifying screens [20], protrusive condylar path, and wax [19, 21], MRI [22], CT [23], and CBCT [4, 5,]

CBCT imaging has been used in the present study. It has several advantages as compared to allthe above methods which are as follows:

- CBCT images can be stored and verified anytime unlike the modeling clay and wax which were vulnerable to distortion and shrinkage [14,21].
- The strong intra and inter observer reliability indicate that morphometric measurements of AEI by CBCT are reproducible as against the measurements on dry skull, photography and conventional radiography[10,15,17,19,20,21]. Additionally conventional radiograph being a 2D imaging there are superimpositions of anatomical structures thus interfering with clear visualization of AE.
- CBCT offers clear visualization of all the osseous structures of TMJ as compared to other advanced imaging like MRI which has limited value in visualization of bony changes [22].
- Compared to multi-detector CT, which is considered to be the best modality for imagingosseous structures of TMJ, CBCT provides equally accurate visualization of AE and has added advantage of being economical with less radiation dose[23].

Limitations of Study

- The present study was conducted in 186 individuals. This sample size is limited to represent the entire Central India population.
- Factors affecting the AE inclination like shape of arches, skeletal relationships, and absence of teeth, para-functional habits and diet variations were not taken into consideration in the present study as they were out of the scope of the present research.

Future Scope

A multi-centric larger population study could be conducted giving due considerations to the factors affecting the AE inclination. This would also help in achieving an equal and larger number of subjects in each sub groups which would further enable to give a valid statistical evidence.

Conclusion

Within the limitations of the present study it could be concluded that articular eminence inclination increases with age with higher values in males as compared to females. The weak positive co relation of AEI with that of age indicates its use as an adjuvant method for age prediction. Future studies with larger sample size and consideration of major confounding factors would help in further effective validation.

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