

Evaluation and Correlation of Condylar Cortication by Cone-Beam Computed Tomography: A Retrospective Study

Abstract

Background: Temporomandibular joint (TMJ) is a ginglymo-diarthroidial joint with fibroelastic cartilage. The chondrogenesis initiates from the 12th week of intrauterine life and the development of condyle is associated with growth. The condylar cortication shows distinct morphological variation for each individual in each stage of their life. The cortical bone around the condyle could be used as a factor for chronological age assessment and it can act as a tool in forensic medicine. **Aim and Objective:** The study was carried out to evaluate the cortical grading in mandibular condyle using two different applications and to correlate their grades with chronological age. **Setting and Design:** Hospital-based retrospective observational cross-sectional study. **Materials and Methods:** The study was carried out in 40 patients and 80 TMJs were assessed for cortication grades in Carestream 3D imaging and Image J applications. These grading from both the applications were correlated with the chronological age. **Statistical Analysis:** SPSS (Statistical Analysis for the Social Science) – Cohen's Kappa inter-examiner reliability and Spearman's correlation coefficient were used. **Results:** The radiological assessment of condylar cortication in individual application showed significant results and the relationship of cortication with chronological age showed a significant correlation. **Conclusion:** The condylar cortication grading is a simple technique and can be used as a factor for chronological age assessment. This is an initial study which used two different applications to view the cortication of the mandibular condyle and to correlate the cortication with chronological age. Hence, a large sample size-based study is required for further research.

Keywords: Age estimation, condyle cortication, cone-beam computed tomography, mandibular condyle

Introduction

Mandibular morphology is associated with the development of age and is sensitive to adolescent growth spurt.^[1] Condyle is a part of the mandible which is considered as the integral component of the temporomandibular joint (TMJ). Mandibular condyle can differentiate the gender based by its morphological appearance and duration in growth/development.^[1] Condylar formations begin in the 9th week of intra-uterine life (IU) and by the 12th week of IU, there is endochondral ossification, which leads to secondary cartilage formation, which results in the elongation of condyle and increase in the height of mandibular ramus.^[1,2] As the condyle initiates to mature, there is the continuous formation of the subchondral bony layer and the endochondral ossification ends

at this stage.^[1] The cortical bone is a homogenous bony and continuous layer seen at the periphery of the mandibular condyle.^[3] This homogenous bony layer starts to appear from the age of 12–14 years and completes its formation by 22 years of age.^[3] The cortication initiation is early in females than in males.^[3] The cortical bone can be detected in radiographs and it could be used for the assessment of developmental changes in condyle. We have used cone-beam computed tomography (CBCT) imaging to investigate the cortical bone in subjects from 12 to 16 years old. Age-related differences in the formation of cortical bone were also assessed using two software platforms. Our study aims to evaluate the cortical level in mandibular condyle from the database using one viewing software and one analyzing software platform. These assessments were correlated with chronological age.

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**K. S. Sethna
Muthlakshmi,
C. L. Krithika,
Kannan Asokan**

*Department of Oral Medicine
and Radiology, SRM Dental
College, Chennai, Tamil Nadu,
India*

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Address for correspondence:
Dr. K. S. Sethna Muthlakshmi,
Department of Oral Medicine
and Radiology, SRM Dental
College, Ramapuram,
Chennai - 600 089, Tamil Nadu,
India. E-mail: korkaisethna@
gmail.com

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Materials and Methods

The study was carried out in the department of Oral Medicine and Radiology, SRM Dental College, Chennai. The study was approved by the Institutional Ethical Committee Review Board (SRMU/MandHS/SRMDC/2019/PG/014). This study was conducted over a period of 2 months from December 2019 to January 2020. It was a cross-sectional observational retrospective study conducted with a sample size of 40 individuals and 80 TMJs. The CBCT scans of mandibular condyle were selected from the database of the radiology center in the Oral Medicine department. Images with appropriate sharpness and contrast to visualize both the condyle was included. Any congenital or developmental craniofacial and skeletal deformities, bone mineral metabolism disorder, arthritic changes, trauma or any pathologic conditions that affect the mandibular condyle was excluded from the study.

Methodology

Forty patients CBCT images with eighty TMJs were acquired. Bilateral TMJ in CBCT was obtained using a Carestream 9300 CBCT machine at 120 kVp, 5 mA and with 17 cm × 13 cm as the field of vision. The image was obtained from the patients in a standing position and the Frankfort horizontal plane was parallel to the floor. The images of the condyles were recorded and saved at the sagittal section, 0.3 mm³ voxel size and zoom at 0.44 [Figure 1]. These images were then independently evaluated by three expert oral radiologists who were

blinded about the subject's age and sex. The condyle was viewed in the sagittal section in 300- μ m slice thickness at zoom 0.44. The spatial resolution of the region of interest was maintained that the condylar cortication was seen with its boundaries from the carestream application. These images [Figure 1a-f] were saved for the evaluation of cortication grading by the examiners using carestream application. In Image J application (1.46r National Institute of Health, USA – Java 1.6.0_20 [32-bit]), the saved images were changed into a standardized 108 × 147 size. The standardized image was transformed into 8-bit grayscale image. Digital images are grids of the pixel which hold the intensities in the numerical range between black and white. Bit image defines the number of intensity values in an image. This image was processed into a binary image, where the image was converted into a black and white image. This binary image was further processed into skeletonized image. The skeletonized image is in a topological skeleton form, where the shape reveals its connectivity, length, width, and shape boundary [Figure 2a-c]. The obtained skeletonized image can be used for reconstruction of the original image. These skeletonized images were saved, and the examiners graded the skeletonized images accordingly. The cortication assessment was done using Table 1.^[3]

The images were assessed by three examiners separately in a 15.6 inch HD LED screen of Lenovo laptop with Intel i3core. The examiners procured a maximum of 2 min for the evaluation of one image. A maximum of 10 images were assessed continuously to avoid any visual fatigue

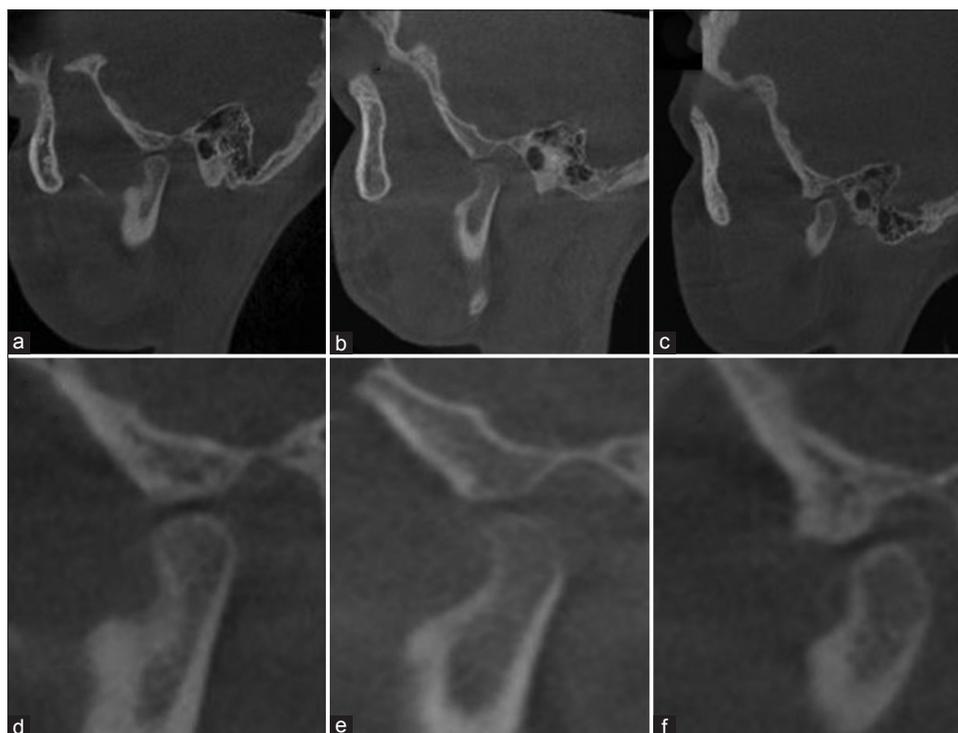


Figure 1: (a and d) Reveals the sagittal section of the condylar region showing cortication grading I. (b and e) Reveals the sagittal section of the condylar region showing cortication grading II. (c and f) Reveals the sagittal section of the condylar region showing cortication grading III

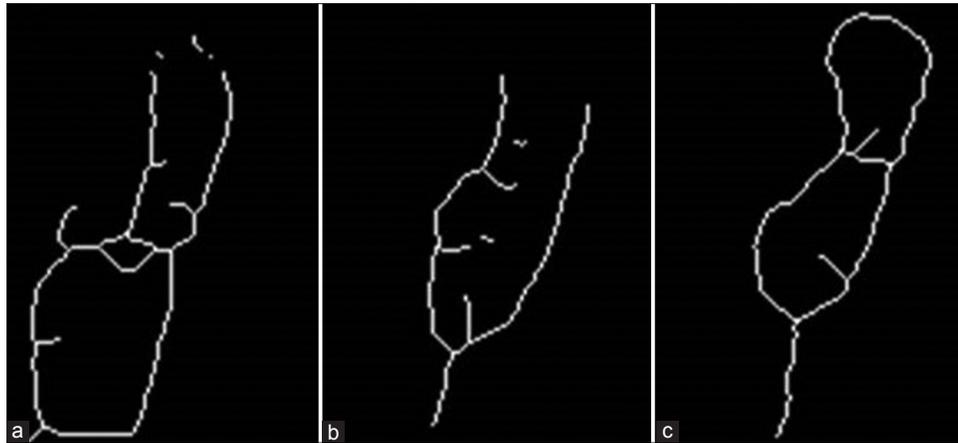


Figure 2: (a,b,c) reveals the skeletonized images of the mandibular condyle – cortical bone with cortication grade I (a), II (b) and III (c)

Table 1: Cortication grade for assessment of mandibular condyle

Types of grading	Features
Type-I	No cortication was observed on the condyle
Type-II	Bone on the condylar surface appears at a lower density than the structures around the condyle
Type-III	The surface of the condyle appears at a higher or similar density than surrounding cortical areas

for the examiners. The examiners were allowed only to adjust the brightness, contrast, and zoom of an image. The demographic age of the patient was retrieved from the CBCT data to correlate the chronological age and condyle cortication grading.

The results were analyzed using SPSS (Statistical Analysis for the Social Science) software version 25.0. Armonk, NY: IBM Corp. The inter-examiner reliability was done using Cohen's kappa measurement of agreement and Spearman's correlation coefficient was done to see the relationship between condyle cortication and chronological age.

Results

Forty patients were recruited for the study in which 17 were female and 23 were male. The mean age of the patients at the time of CBCT acquisition was 18.3 years (range 12–28). All the patients in the study had CBCT of both the condyles and satisfied the inclusion criteria. The cortication grading done by examiners in both the software systems and their Cohen's Kappa inter-examiner reliability is represented in Tables 2 and 3.

The Cohen's Kappa inter-examiner reliability between the three examiners in the Carestream application system revealed $P < 0.001$ [Table 2] which was found to be significant, and the Cohen's Kappa inter-examiner reliability between the three examiners in Image J application revealed a $P < 0.001$ [Table 3] which was found to be significant.

The cortication grading assessed by the three examiners were correlated with the chronological age in both the applications using spearman's correlation coefficient [Tables 4 and 5]. The correlation between examiner's age grading in Carestream application with chronological age by spearman's correlation coefficient was found to be highly significant [Table 4] and the correlation between examiner's age grading in Image J application with chronological age by spearman's correlation coefficient was found to be highly significant [Table 5].

Discussion

Forensic dentistry is an essential part of forensic medicine and it plays a prime role in the identification of human remains through age estimation and sex determination.^[4] The chronological age can be determined with the available data such as height, weight, pubertal, and dental findings. They are evaluated using morphological, radiological, and histological methods.^[4] The morphologic and radiographic techniques are simpler than histological evaluation; the radiographic technique is tranquil and reliable.^[5] Chronological age can be determined with the assessment of skeletal factors such as assessment of skull closure and cervical vertebrae maturity index. Odontological factors such as coronal root index, tooth to pulp ratio, degree of resorption in deciduous and permanent teeth also aid in the age estimation.^[5] Radiological age assessment is a serene technique to evaluate the bone morphology and bone structure with various radiographic modalities such as periapical radiographs, cephalometric radiographs, panoramic radiographs, and advanced three dimensional imaging.^[5] CBCT plays an integral role in diagnosis and treatment planning because of its three-dimensional imaging system of the hard tissues at a considerably low radiation dose and maximal area coverage.^[6] TMJ evaluation has been an enigma for dental professionals. CBCT is a promising modality for imaging of TMJ,^[7] and there are various bone parameters in the developing software systems using CBCT images for its accuracy in

Table 2: Cohen's Kappa inter-examiner reliability between three examiners in the carestream application

Inter-examiner		Cohen's Kappa	P
Examiner 1	Examiner 2	0.887	<0.001
Examiner 2	Examiner 3	0.868	<0.001
Examiner 3	Examiner 1	0.906	<0.001

Table 3: Cohen's Kappa inter-examiner reliability between three examiners in the carestream application

Inter-examiner		Cohen's Kappa	P
Examiner 1	Examiner 2	0.845	<0.001
Examiner 2	Examiner 3	0.903	<0.001
Examiner 3	Examiner 1	0.863	<0.001

Table 4: Spearman's correlation efficient between examiner's age grading and chronological age in Carestream application

Grading	Chronological age		
	ρ	P	Strength of correlation
Examiner 1	0.929	<0.001	Very strong correlation
Examiner 2	0.914	<0.001	
Examiner 3	0.946	<0.001	

Table 5: Spearman's correlation efficient between examiner's age grading and chronological age in Image J application

Grading	Chronological age		
	ρ	P	Strength of correlation
Examiner 1	0.881	<0.001	Very strong correlation
Examiner 2	0.884	<0.001	
Examiner 3	0.886	<0.001	

clinical findings.^[8] There are various software systems for analyzing bone parameters such as bone structure, pattern, and outline of subchondral bone formation.^[9] This study focused on the dynamic part of the joint, the mandibular condyle and its cortication level assessment.

The cortical bone initiates from the periphery around the condyle at the adolescent age and it continues as a homogeneous band of the compact cortical bone till the end stage of adolescence. Morimoto *et al.*^[10] studied the maturation of condyle in children using magnetic resonance imaging with a Double Contour-Like-Structure (DCLS) in 72 subjects, which revealed that the occurrence of DCLS increases with age.^[10] Lei *et al.*^[11] classified the cortical bone formation of condyle with the presence of a cortical bony layer in the periphery of the condyle using CBCT.^[11]

Renders *et al.*^[12] studied the degree of mineralization of bone in the condyle, which revealed that there was a significant difference in the degree of mineralization on the lateral, anterior and superior surface of the condyle with age.^[12] Bayrak *et al.*^[13] studied mandibular condyle superior

surface for cortication grading and speno-occipital synchondrosis in correlation with chronological age using CBCT images of 253 patients. The density of the cortication was assessed and it revealed that the density of cortication increased with age.^[13] Our study results were similar to the results of Bayrak *et al.*^[3,13] Ingevall *et al.*^[14] used TME specimens for condyle cortication using micro radiograms in 22 subjects. Their results reveal that Type I and Type III cortication is seen at the maximum age of 31 years.^[14] Yalcin and Bozan^[15] studied 520 subjects CBCT scans to understand the relationship between mandibular condyle cortication, articular eminence cortication and mandibular cortex index with age and gender. Their results revealed that these cortication had correlated with age and gender and these cortication grades could be used to understand the TMJ disorders and to predict the osteoporotic changes of TMJ.^[15]

The null hypothesis of our study stating no difference in the evaluation of condyle cortication in two different application modalities and there is a significant correlation between chronological age and condyle cortication. In this study, 80 TMJs were assessed for condyle cortication in Carestream and image J application. There was significant level of agreement between the examiners. Hence condyle cortication could be used as a tool in forensic dentistry to evaluate chronological age. The developing software applications could be used as a platform to view condyle and analyze them in future research. The major limitation of the study was sample size and lack of gender analysis from the condyle cortication. This study did not show any significant difference between two applications on condyle cortication assessment. Therefore, the study requires a larger sample size for significant results.

Conclusion

In this study, we evaluated the distribution and deposition of cortical bone in the mandibular condyle. The results of this study highlighted the use of cortical bone around the mandibular condyle. There was a significant relationship between mandibular condyle cortication and chronological age estimation, which could as a forensic tool in forensic dentistry. The study also enlightens the use of developing applications to view and analyze CBCT scans as these applications can be used in future research for analyzing the structures. Hence, these two applications (Carestream imaging and Image J) could be used for mandibular condyle. Further research with a larger sample size is required to analyze the relationship between mandibular condyle cortication and gender.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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