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Volumetric analysis of mandibular condyle for sexual dimorphism using cone beam computed tomography-A cross sectional study

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Abstract

Purpose: Condyle is the important part of mandible that will resist posthumous damage and provide major source of information about sexual dimorphism. This study aims to assess sexual dimorphism of condylar volume using cone beam computed tomography.

Materials and Methods: CBCT scans of 144 males and 144 females above 18 years of age were obtained with details such as age and gender. Acquired CBCT data in DICOM format transferred to a computer for image analysis. After enlargement of the TMJ area the remaining surrounding structures of condyle were removed using software sculpting tools. Next condylar segmentation threshold values was standardized and volumetric measurements made for each condyle through 3D analysis software. Obtained volumetric measurements were subjected to statistical analysis.

Results: The results showed a statistically significant difference in mean condylar volume between males and females. The study showed statistically significant difference in the right and left condylar volume within males and females.

Conclusion: With the above findings it can be concluded that, volumetric analysis of condylar volume offers a valuable tool in sexual dimorphism and it can be used as supplement for the identification of individuals which is useful to the forensic investigations. CBCT is a reliable and accurate technique for taking volumetric

measurements on mandibular condyles in sexual dimorphism

Keywords: Sexual dimorphism, Mandibular condyle, volumetric measurements, CBCT

Introduction

Forensic odontology is a vital and integral part of forensic science that is most widely utilized for identification of the living and deceased persons.[1] Sexual dimorphism is one of its integral aspects as it is one of the initial steps in personal identification of an unknown cadaver thus narrowing down the diagnosis toward a closest possibility.[2] When sexual characteristics of the soft parts are not available, the diagnosis of sex can be based only on the characters displayed by the skeleton. There are several methods for determination of gender using different parameters.[3] CBCT has been shown to be useful in generating intraoral and panoramic images that sufficiently approximate conventional dental radiographs to warrant its use in forensic dental identifications, as well as for the estimation of age. CBCT also provides a method to calculate the volume of the structure.

Condyle, which is a primary center of growth in the mandible, responds to the continuous stimuli through a remodeling process, and thus plays an important role in the final dimension of the mandible. Hence, its volume can be related to the mandibular final dimension as well as to the relationship between maxillary and mandibular bases.[4]

This study is being carried out to determine if there is any difference in condylar volume between males and females and whether this parameter can be used in accessing sexual dimorphism.

Materials and methods

The study titled “volumetric analysis of mandibular condyle for sexual dimorphism using cone beam computed tomography- a cross sectional study” approved by the ethical committee of the institution Dayananda Sagar College of Dental Sciences, Bangalore.

Source of Data

CBCT scans of 288 subjects comprising of 144 males and 144 females was considered for the study. CBCT scans of subjects were collected from CBCT centers which were taken for reasons other than the current study. Total of 288 images of same subjects above 18 years of age were obtained with demographic details such as age and gender.

Method of collection of data

Sample size: 288

Study group: CBCT scans of patients of different demographic data above 18 years of age

Sampling method: Purposive sampling

Study design: Cross sectional study

Inclusion criteria

CBCT scans of subjects above the age of 18 years.

Exclusion criteria

- CBCT scans showing degenerative changes in the TMJ.
- CBCT scans that has be done to assess congenital anomalies of TMJ, trauma, tumors of the TMJ and surgically corrected TMJ.

Study method

Study was carried out on a total of 288 subjects above the age range of 18 years. CBCT scans of subjects were collected from CBCT centers. Scans were taken for reason other than the current study. After obtaining written informed consent the demographic details such as age, gender and date of examination was be recorded.

Acquisition of CBCT images

High resolution CBCT images were obtained using Kodak 9300 CBCT machine. Exposure parameters for CBCT was tube voltage of 90kvp, exposure time 14s,

tube current of 5mA and a cylindrical shaped field of view measuring 14*17 cm with a voxel size of 180 micrometer.

All CBCT images were taken with the subjects sitting in an upright position, with their backs as nearly perpendicular to the floor as possible.

The patients head is positioned with the Frankfort horizontal plane parallel to the floor and stabilized between X ray generator and detector by a head holding apparatus. The subjects was instructed to look straight for obtaining natural head position.

Acquired CBCT data were saved in DICOM format and transferred to a personal computer for further image analysis (Figure no 1)

Analysis of image

Each condyle is visually checked prior to making 3D volumetric measurements. After enlargement of the TMJ area the remaining surrounding structures were progressively removed using various software sculpting tools for the upper, lower and side condylar contours. Segmentation was made on the coronal, superior, inferior and the lateral limits. On the coronal view superior contour of the condyle is defined, when the first radiopaque point viewed in the image.

Lateral contour for each section was identified through clear visualization of the cortical bone. Inferior contour of the condyle was traced where the section passes from an ellipsoidal shape to a more circular shape. The delimited condylar structure was isolated from the rest of the image using the software's cropping tool (Figure no 2).

After condylar segmentation threshold values was standardized and volumetric (cc) measurements (Figure no 3 and Figure no 4**)** were made for each condyle through 3D analysis software.

Results

This study was conducted to evaluate sexual dimorphism in the mandibular condylar volume using cone beam computed tomography. To compare the volume of right and left condyle of each of the subjects, genders in the study group. To compare the mean condylar volume in both genders and also to compare mean condylar volume in right and left sides of mandible

A total of 576 condyles were assessed using CBCT in a total of 288 patients for the evaluation of condyles on the right and left sides. There were 144 male and 144 female patients. With this purpose, CBCT Images of 288 subjects comprising 144 males and 144 females were collected from CBCT centers which were be taken for reason other than the current study. The image of each subject was used to assess the volume of condyle using 3 D analysis software.

Data obtained was compiled systematically in Microsoft Excel spread sheet and the results were analyzed using Statistical Package for Social Sciences software (SPSS version 16). Data comparison was done by applying statistical tests to find out the statistical significance of the obtained results. Level of significance was set at 0.05

Mean condylar volume was higher for left condyle (2.19±0.8) as compared to right condyle (2.15±0.64) among males whereas right condylar volume (1.86±0.61) was higher among females as compared to left condyle (1.79±0.64). (Table 1, Graph 1)

Comparison of the gender wise right and left side of condylar volume in t test showed statistically significant difference between males and females with respect to right (p=0.00) and left(p=0.00) condyle. (Table 2)

Comparison of the sidewise condylar volume based on right and left side in t test showed no statistically significant difference between right and left condylar

volume with respect to males (p=0.27) and females(p=0.14). (Table 3).

Gender wise comparison of condylar volume showed the mean condylar volume of males was 2.17± 0.694 cc and 1.83 ± 0.48 cc for females with a mean difference of 0.34. (Table 4, Graph 2).

Independent sample t test showing statistically significant difference between males and females (p=0.00). The mean right condylar volume among total subjects is 2.00 ± .64 and that of left condylar volume is 1.99 ± .75(Table 5, Graph 3).

Comparison of right and left condylar volume in total subjects using paired sample t test showing no statistically significant difference between males and females (p=0.26). (Table 6)

Discussion

Forensic dentistry is an applied branch of dental anthropology and forensic medicine which deals with the examination and assessment of the dental evidence to identify the victims of crime, accidents, or calamities.[5,6] Sex determination is a key analysis that forensic investigators perform in order to construct biological profile of human remains.[7] Sex determination helps to channelize the investigation by limiting the search to half the population; thus conserves resources and the time required for identification.[8]

When the entire skeleton is available, the gender can be identified with 100% accuracy. Whereas, in the instance of mass disasters when the bodies are mutilated beyond the scope of visual identification, the skull and the teeth often prove to be a valuable source for the identification process.[5, 6] In cases when intact skull is not found, mandible can play an important role in the gender determination because it is considered to be dimorphic, largest, and strongest bone of the body. Mandibular dimorphism varies with the race, age, and the activity of masticatory muscles of the subject.[9, 10]

Various methods have been adopted to identify the gender of the human remains from a crime scene or a site of mass disaster. It has been reported that 100% accuracy can be achieved in gender determination from skeleton, 98.0% from both pelvis and skull, 95.0% from pelvis only or the pelvis and long bones, 90.0–95.0% from both the skull and the long bones, and 80.0–90.0% from the long bones only. [11]

Distinct morphologic and morphometric manifestations of sexual dimorphism have been observed in different populations in most countries of the world.[1] Kharo shah et al [12] used mandibular osteometric measurements on computed tomography (CT) images to determine the sex of a specific population.

Biwas Aka et al[13]. and Angel et al[14]. studied sexual prediction and age using CBCT images in different views of reconstruction. Sahlstrand-Johnson et al[15] measured the dimensions of 120 maxillary sinuses from head CTs and found the volume to be larger in males than in females with a mean value of 15.7 ± 5.3 cm^3

Bones have great importance in identification of a person and they also help in establishing the process of evolution, race and demographic profile. Mandible is the most durable and sexually dimorphic bone of the skull and has the capacity to resist post mortem changes. The mandible bears a curve shaped body with two rami. Each ramus consists of two processes: coronoid and condylar. Coronoid or condylar process of mandible cannot be distinguished in the early stage of mandibular development.[16]

With the advent of CBCT, it is possible for the identification of human because of the presence of diverse geometrical contour allowing a precise superimposition in to an identity.[17]

The present study aims at analyzing the volume of mandibular condyle to assess sexual dimorphism using Cone Beam Computed Tomography. With this purpose, cone beam computed tomographic scans of 288 subjects comprising 144 males and 144 females above 18 years of age were collected.

The CBCT scans in this study have been analyzed using on demand 3 D software. OnDemand3D is a modular design software package combining functionalities for different requirements in different modules.3 D module was used since it helps in the volumetric measurements of bone. One of the main functions of the 3D module is segmentation, create new objects out of a 3D volume. The volume information (either in cubic centimeter or millimeter units) of the segmented object is automatically calculated when the segmentation function is used.

In this study the condylar structure was isolated from the rest of the image using the on-demand software's segmentation tool. The threshold value was set based on the best visualization of the structure. The volume-measuring tool was used to determine the volume of the isolated structure in cubic centimeter.

CBCT has been proved to be an accurate and reliable method for measuring craniofacial structures. Several studies have confirmed its accuracy and reliability by scanning dry skull in order to compare volumetric measurements taken from physical structures and from CBCT images.[18] To assess the method accuracy, it is necessary to use real structure as the gold standard.[19]

Garcia Sanz V et al[20] evaluated the reliability and accuracy of Cone Beam Computed Tomography (CBCT) for taking linear and volumetric measurements of mandibular condyles with the soft tissues intact. For volume calculations, the method was found to be highly accurate, with a mean difference between the methods of 0.010±0.095 cm^3.

Bayram M et al[19] determined the accuracy of volumetric analysis of the mandibular condyle using cone-beam computed tomography (CBCT). Similarly in a study by safi et al[21] conducted among 350 patients they found out that within males group the mean right condylar volume is 2.338 cc and 2.334cc for left condyle, whereas within females the mean right condylar volume was 2.35 cc and 2.13 for left condyle which is statistically significant.

Occlusal forces produced by masticatory muscle are converted in to physiological stress at the condyle in the form of functional strain. As mandibular condylar cartilage is a load bearing musculoskeletal tissue, small changes in the integrity, composition or organization of cellular components of the cartilage will alter the matrix production. Thus, the dimensions of the condyle ought to be affected.[22] This findings can attribute to our study and could be the reason for the differences in the volume of right and left condyles in males and females.

In a study done by Chia hao et al[23] they found that low sella nasion –mandibular plane angle (SN-MP) group had a significantly larger volume of condyles than high sella nasion –mandibular plane angle. This could be due to larger volume and greater cross-sectional area of masticatory muscle which exerts less stress at the condyle in low angle group compared to high angle group.

When the volumetric measurements of right and left sides among total subjects was analysed, it was found that mean condylar volume of right side was 2.00cc and left side 1.99which was not statistically significant. Mendoza L V et al[24], quantified the height of the mandibular condyle and ramus, condylar volume, and the asymmetry index in adult patients of different sex, skeletal class and vertical pattern using Cone- Beam

Computed Tomography, and found out that mean condylar volume of right side was 1.93cc and left side was 1.88 cc. Although there was significant difference among men and women, there were not significant differences between right and left sides.

Comparison of condylar volume among males and females

The present study was carried out among 288 subjects, 144 males and 144 females. The minimum age of the subjects was 18 years and maximum 55 years, both male and female. The mean condylar volume of males was 2.17cc and 1.83cc for females with a mean difference of 0.34. Independent t test showed statistically significant difference between males and females (p=0.00). Bone consists of mineralized matrix in a cortical shell and trabecular network of plate within a marrow cavity. Studies have shown that males have higher bone mineral density compared with females. It is considered that greater the mineral content larger the volume of bone.[25] This could be the reason for the larger condylar volume in males compared to females.

Alessandro Nota et al[26] did a retrospective cross-sectional study on three-dimensional volumetric analysis of mandibular condyle changes in growing subjects. The difference between males and females was statistically significant ($p < 0.05$). The volume found out in the present study is almost close to the study done by Alessandro Nota et al.

Within the males, there were differences in volume of condyle between right and left side which was statistically significant, similarly within females there were differences in the volume of condyle between right and left side which was also statistically significant. Between the right condylar volume of males and right condylar volume of females, although the values were higher in males it was not statistically significant, similarly between the left condylar volume of males and left condylar volume of females although the values were higher in females but it was not statistically significant

Conclusion

According to the results, our study demonstrate that condylar volume is greater in males than in females which indicates there is a definite sexual dimorphism and it could be attributed due to the difference in the size, shape, and masticatory forces exerted on the males and females.[9] Thus sexual dimorphism of the condylar volume measurements can be supplemental for forensic identification.

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growing subjects: A retrospective cross-sectional study. CRANIO .2018; 24:1-7.

Legend Figures

Figure1: On Demand 3D Software for analysis

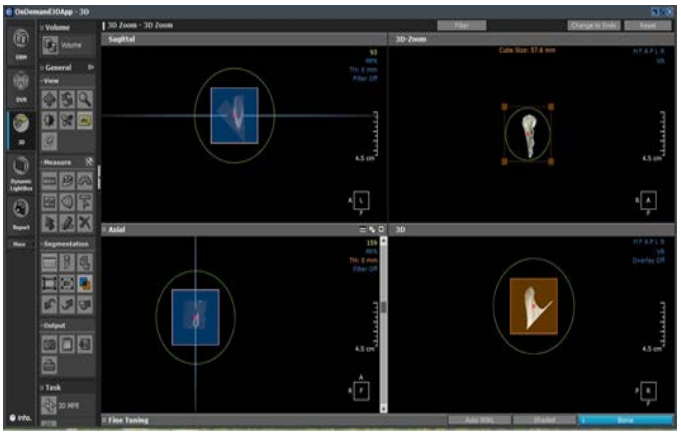

Figure 2: Condylar structure isolated from the rest of the image using the software's cropping tool in 3 planes.

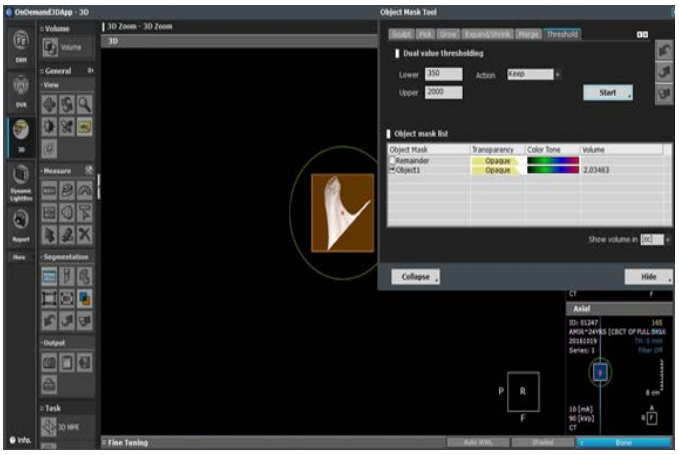

Figure 3: Acquisition of Volumetric measurement (right side).

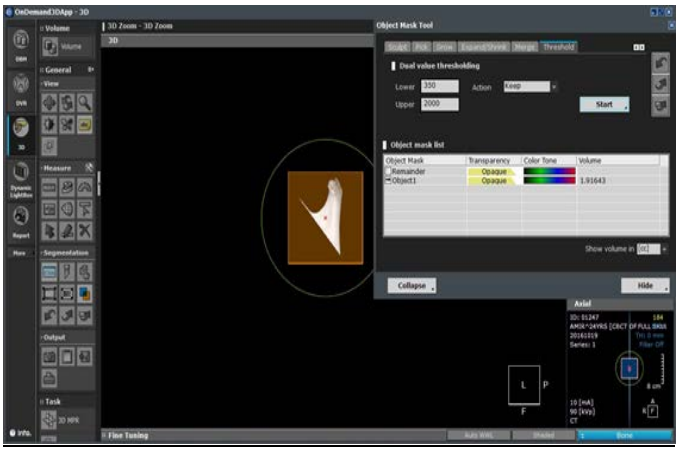

Figure 4: Acquisition of Volumetric measurement (left side).

Table 1: Mean distribution of the condylar volume based on gender and side.

Gender	Condyle	Minimum	Maximum	Mean	Std. Deviation
Males	Right Condyle	1.0800	3.9900	2.15	.64
	Left Condyle	.7000	5.3300	2.19	.80
Females	Right Condyle	1.0000	4.0000	1.86	.61
	Left Condyle	1.0000	3.0000	1.79	.64

Graph 1: Mean distribution of the condylar volume based on gender and side.

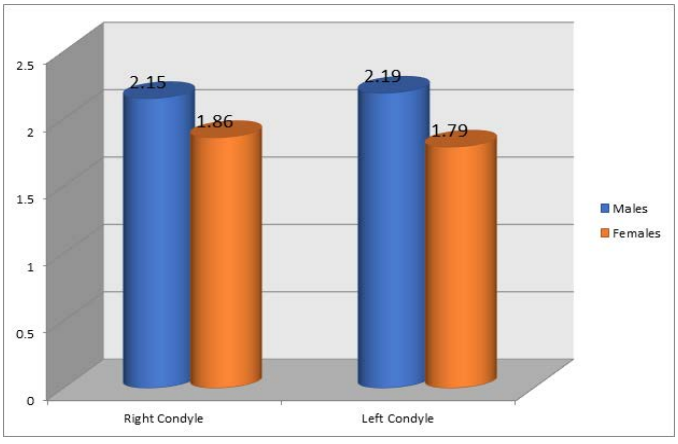

Table 2: comparison of the gender wise right and left side of condylar volume.

Males * females	t test	p value
Right condyle	3.93	0.00*
Left condyle	4.66	0.00*

*Significant

Graph 2: Gender wise comparison of condylar volume.

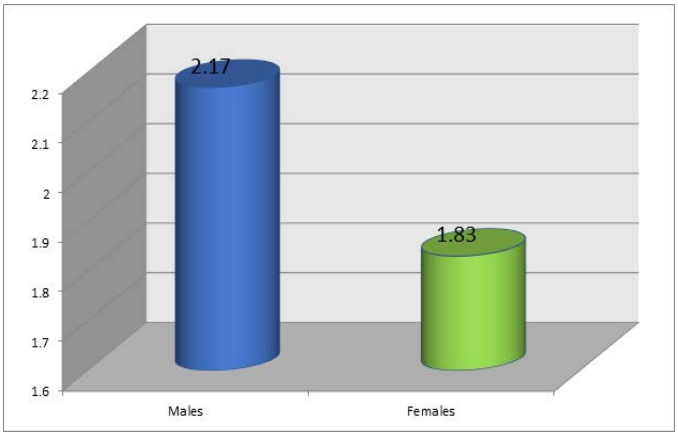

Table 3: comparison of the sidewise condylar volume based on right and left side.

Right * left	t test	p value
Males	-1.1	0.27
Females	1.48	0.14

Graph 3: Mean distribution of the condylar volume in total subjects.

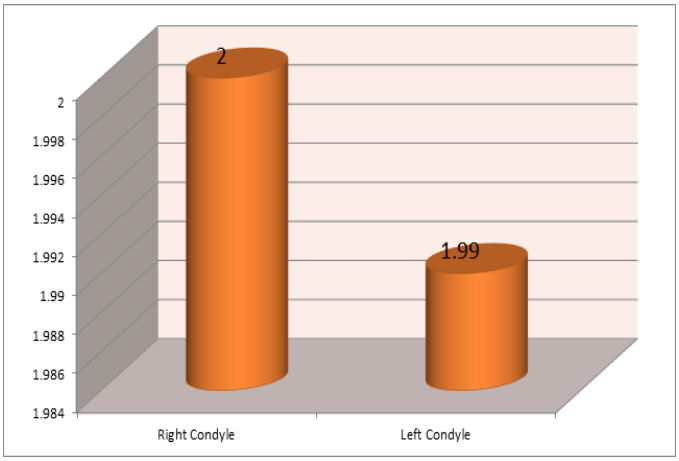

Table 4: gender wise comparison of condylar volume using independent sample t test.

Gender	Minimum	Maximum	Mean	Std. Deviation	Mean difference	t value	p value
Males	.93	4.66	2.17	.694	0.340	4.81	0.00*
Females	1.00	3.20	1.83	.48			

*Significant

Table 5: mean distribution of the condylar volume in total subjects.

	N	Minimum	Maximum	Mean	Std. Deviation
Right Condyle	288	1.00	4.00	2.00	.64
Left Condyle	288	.70	5.33	1.99	.75
Right + left	288	.93	4.66	2.00	.62

Table 7: comparison of right and left condylar volume in total subjects using paired sample t test.

Paired t test	Mean difference	t value	p value
Right Condyle * Left Condyle	-0.02	-1.123	0.26