Original Article

Morphometric evaluation of middle ear anatomical structures using full volume (12 × 9) CBCT scans: A retrospective study in Navi Mumbai

ABSTRACT

Introduction: The tympanic cavity contains three tiny bones, the malleus, incus, and stapes, which have a fundamental role in the transmission of sound. Recent research emphasizes the use of CBCT for the anatomic study of the temporal bone. The information about middle ear anatomy on CBCT scans is meager; hence, this retrospective study was conducted to identify and determine the various morphometrical parameters of the malleus using CBCT which can be helpful during reconstructive procedures for the otologic surgeon.

Materials and Methods: The retrospective study was performed on 200 subjects (101 M and 99 F) in the Department of Oral and Maxillofacial Radiology. CBCT images of 200 subjects were studied in all planes to identify ossicular chain and the malleus to investigate the morphometric parameters in Indian Subjects.

Result: The average of morphometric parameters shows that the mean length of the malleus is 7.2 mm, the mean width of the head of the malleus is 3.02 mm, length of superior semicircular canal is 4.90 mm, and length of external auditory canal is 19.15 mm in Navi Mumbai population.

Conclusion: The obtained morphometric data of the malleus through our study will help the prosthesis maker in the formation of various implants and grafts required to treat various ear diseases.

Keywords: Anatomy ear, cone-beam-computed tomography, ear ossicles, malleus, stapes, superior semicircular canal

INTRODUCTION

There are a limited number of structures and disease entities in the temporal bone with which one must be familiar to proficiently interpret a cone-beam-computed tomographic image.[1] The three ear ossicles lodged in the middle ear are the malleus, incus, and stapes. The ear ossicles form an articulated chain, connecting the lateral and medial walls of the tympanic cavity. The ear ossicles amplify and transmit the sound vibrations to the cochlear receptors in the inner ear. The malleus is the largest ossicle, shaped like a mallet. It has a head, neck, handle (manubrium), and anterior and lateral processes.[2] The manubrium of the malleus is attached to the tympanic membrane, and the head of the malleus articulates with the body of the incus in the epitympanum forming the incudomalleal joint, which has a characteristic "ice cream cone." The inner ear is situated within the petrous portion and comprises the osseous labyrinth, which includes the cochlea, vestibule, and semicircular canals. The cochlea contains the end organ for hearing, while the vestibule and semicircular canals are responsible for balance and equilibrium. The cochlea is a spiral-shaped structure with 2½ to 2¾ turns, including the basal, middle, and apical turns, which are separated by interscalar septae.[1]

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At the lateral skull base, CBCT is an upcoming and interesting technique in the visualization of the middle and inner ear structures. In comparison to conventional CT especially, higher spatial resolution, lower irradiation, and low cost of CBCT have resulted in its increasing use in pre- and postoperative radiologic diagnostics.[3] With dynamic interactive software, simultaneous possibility of axial, coronal, and sagittal images can be measured by this imaging. The use of the 3D data set (isotropic voxel) realizes an ideal reconstruction of the complex structures of the middle ear and lateral skull base.[3] So precise measurements of ear ossicles are essential in the design of the ear ossicles grafting and electromagnetic implants. The knowledge of variations of these ossicles and its morphometric data will help the otologist during reconstructive surgery and provide necessary information for the prosthesis designer. Successful ossicular repair remains a challenge and depends on precise dimensions of implants.[2] There is presently no study on morphometric evaluation of middle ear anatomy on CBCT in the Indian population. Hence in this radiological study with CBCT images, an attempt is made on morphometrical analysis of middle ear which can help in the treatment middle ear pathologies.

AIMS AND OBJECTIVES

- To study morphometric details of middle ear with cone-beam-computed tomography.
- To determine morphometrical parameters for otologist for ossicular grafting and implants during reconstructive surgery.

MATERIALS AND METHODS

The study was performed after obtaining approval from the institutional ethics committee 168/IRB/YMTDC 22 in accordance with the 1964 Helsinki Declaration and its later amendments. The study was conducted in the Department of Maxillofacial Radiology with 200 retrospective CBCT scans (temporal bone-imaging protocol 40 s, 600 frames, 0.3 mm-pixels, 125 kVp, 50.85 mA, full-volume CBCT scans) on 101 M and 99 F to evaluate the malleus and semicircular canals to investigate the morphometric parameters.

Inclusion criteria

1. CBCT scans of temporal bone showing middle and inner ear clearly
2. Males and females aged between 21 and 80 years

Exclusion criteria

1. CBCT scans with artifacts and positional errors
2. Presence of fractures or other ear pathologies

Technique

CBCT scans of the temporal bone were obtained using Kodak 9600 Carestream with a FOV of 12 × 9 cm, full rotation scan with 120 kVp, 5–10 mA, and voxel size of 70–200 µm. The following parameters were analyzed and measured in millimeters using the software tools.

1. To assess the width of the head of the malleus on a coronal section.
2. To assess the total length of the malleus on a coronal section.
3. To assess the length of external auditory canal on a coronal section.
4. To assess the length of internal auditory canal on a coronal section.
5. To assess mermaids sign to evaluate the length of superior (SCCs) and lateral semicircular canals (LCCs) on a coronal section.
6. To assess the length of apical and basal turns of cochlea on an axial section.

For assessment of the width of the head of the malleus on a coronal section, a horizontal line was drawn (AB), and for assessment of the total length of the malleus on a coronal section, a vertical midline was drawn from AB till a point C [Figure 1]. For assessment of the length of external auditory canal on a coronal section, a horizontal line DE was drawn, the length of the canal was calculated, for assessment of the length of internal auditory canal on a coronal section, a horizontal line FG was drawn [Figure 2], the length of the canal was calculated with the help of the dimensional tool available in the software. In order to assess the Mermaids sign which symbolizes the SCCs and LCCs on a coronal section, a horizontal line IH and KJ was drawn; the length of the SCC and the LCC, respectively, was calculated [Figure 3]. And on an axial section, the length of apical and basal turns of cochlea was calculated by drawing a horizontal line LM and NO, the length of the apical turn and the basal turn, respectively [Figure 4]. Two experienced radiologists evaluated the CBCT scans to avoid any potential source of bias.

Data standardization was done as follows:

1. Both radiologists took five readings of the parameter.
2. The mean of five readings was considered as the final value of the parameter.

Statistical analysis

All the data were entered into a computer by giving a coding system, proofed for entry errors. Data obtained were compiled on an MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, WA, the United States). The data collected were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS v 26.0, IBM).

Descriptive statistics like frequencies and percentage for categorical data, mean, and SD for numerical data were depicted. Intergroup comparison (two groups) was done using *t*-test. For all the statistical tests, $P < 0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

RESULTS

Among the 200 CBCT images analyzed, 101 (50.5%) were males and 99 (49.5%) were females. The mean age of the patients was 47.37 ± 16.126 [Table 1], ranging from 21 to 76 years.

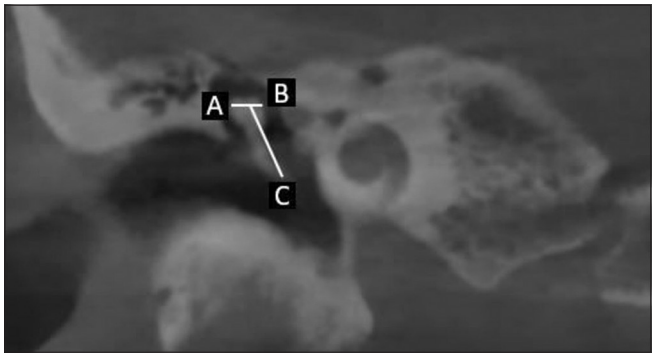


Figure 1: Width and total length of malleus

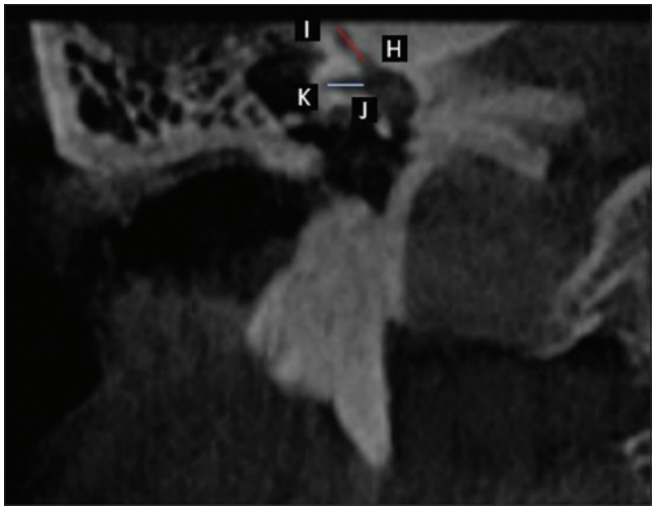
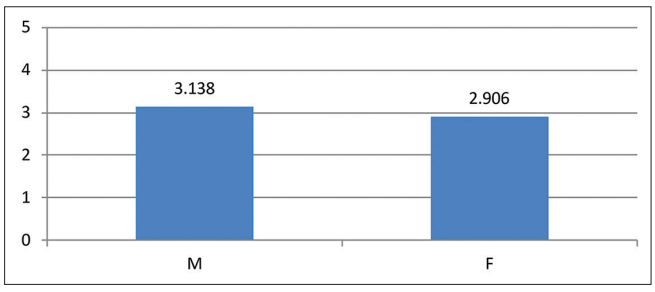


Figure 3: Mermaids sign- Length of superior and lateral semicircular canal



Graph 1: Inter gender comparison for width of head of malleus

In this study, the morphometric data of ear ossicles were recorded gender wise; it included in a coronal section: width of the head of the malleus, the total length of the malleus, the length of external auditory canal, length of internal auditory canal, length of SCCs and LCCs; and in an axial section: the length of apical and basal turns of cochlea.

On a coronal section, in males, the mean total width of the head of the malleus was 3.138 mm and that of females was 2.90 mm, the difference being statistically highly significant ($P < 0.01$) [Graph 1]. The mean total length of the malleus was 7.16 mm and 7.38 mm in males and females, respectively [Table 1]. There was a statistically highly significant difference ($P < 0.01$) [Graph 2] in the mean length of external auditory canal between males and females (18.65 mm and 19.67 mm, respectively). The mean length of internal auditory canal was

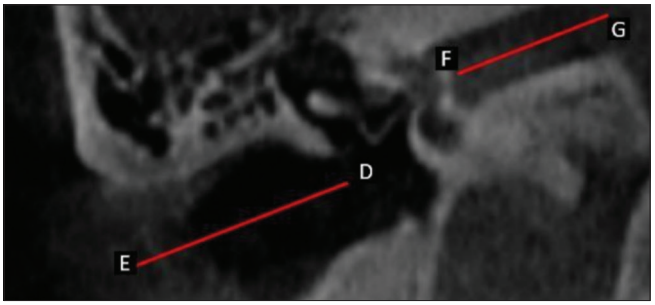


Figure 2: Length of external and internal auditory canal

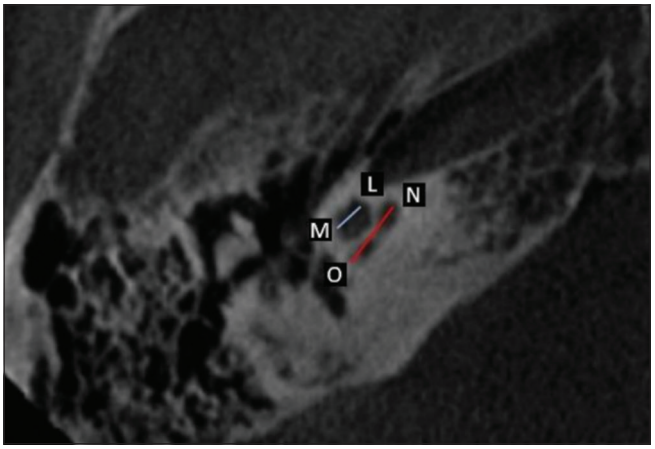
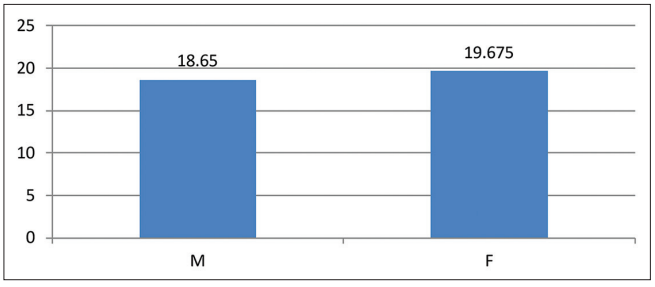


Figure 4: Length of apical and basal turn of cochlea



Graph 2: Inter gender comparison for length of EAC

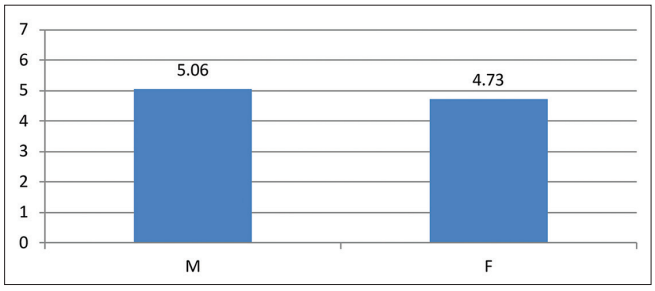
11.99 mm and 12.34 mm in males and females, respectively [Table 2].

A statistically highly significant difference ($P < 0.01$) between males and females was seen in the mean length of SCC [Graph 3] (5.06 mm and 4.73 mm, respectively). The mean length of LCC was found to be 4.48 mm in males and 4.40 mm in females [Table 2].

On axial sections, the mean length of apical turn of cochlea was observed to be 3.04 mm in males and 2.9 mm in females. The mean length of basal turn of cochlea was found to be 5.6 mm in males and 5.7 mm in females.

DISCUSSION

The aim of this study was to evaluate morphometrically the anatomical structures of middle ear with CBCT. Peltonen *et al*.[4] in his study highlighted the advantages of CBCT, greatest being the possibility to restrict the imaged area to the clinically relevant site. In the head and neck region, this technique may be useful in ontological imaging since the area from which the information is needed is often limited and unilateral. They determined the applicability of CBCT in ontological imaging and compared its accuracy with the routinely used multislice helical CT (MSCT) for imaging of the middle and inner ear areas. They observed that structures were viewed equally well from the CBCT and MSCT images. In particular, clinically and surgically important structures such as the auditory ossicular chain were seen equally well. The contrast-to-noise ratio was more than 50% lower in CBCT than in MSCT but still adequate for diagnostic task. Gupta *et al*.[5] have demonstrated the superiority of CBCT in comparison to CT in visualization of the ossicular chain, inner ear structures, and in studies on isolated temporal bones. In a first clinical trial, Dalchow *et al*.[6] reviewed 25 patients with conductive hearing loss and were able to demonstrate the potential of visualization of the detailed bony anatomy and the corresponding pathologies.



Graph 3: Inter gender comparison for length of superior semicircular canal

In the present study, total length of the malleus was 7.1 mm for males and 7.3 mm for females, which is similar to a study conducted by Mogra *et al*.[7] Our results are similar to Mudhol *et al*.[8] and Harneja and Chaturvedi[9] who also found mean length of the malleus to be 7.1 mm. The maximum width of the head of the malleus in our study for females was 2.9 mm and that of males was 3.1 mm, which was slightly more than the values reported by Bast and Anson,[10] who reported it to be 2.13 mm. Zahara Devira *et al*.[11] in his study found that the mean cochlear length was 8.75 mm, the mean cochlear width was 6.53 mm, and the mean cochlear height was 3.26 mm.

Table 1: Mean and SD of numerical variables

	N	Minimum	Maximum	Mean	Std. deviation
Age	200	21	76	47.37	16.126
Coronal section					
Width of head of malleus	200	1.7	4.3	3.023	0.4996
Total length of malleus	200	4.5	9.0	7.273	0.9586
Length of EAC	200	10.5	25.5	19.157	2.5719
Length of IAC	200	7.9	20.1	12.167	1.9913
Length of superior semicircular canal	200	3	7	4.90	0.836
Length of lateral semicircular canal	200	2.9	6.1	4.445	0.6568
Axial section					
Length of apical turn of cochlea	200	2.1	4.2	3.014	0.5017
Length of basal turn of cochlea	200	5	8	5.73	0.563

Table 2: Intergroup comparison of numerical outcomes with gender

	Gender	N	Mean	Std. deviation	Std. error mean	*T* value	*P* value of *t* test
Coronal section							
Width of head of malleus	M	101	3.138	0.4425	0.0440	3.361	0.001**
Length of EAC	M	101	18.650	2.3516	0.2340	-2.869	0.005**
	F	99	19.675	2.6930	0.2707		
Length of superior semicircular canal	M	101	5.06	0.800	0.080	2.921	0.004**

CBCT is an imaging tool which, in comparison to CT, has lower irradiation and higher accuracy due to the primary voxel size of about 0.08 mm. Therefore, it is widely used in pre- and postoperative imaging of diseases of the anterior and lateral skull base. In our study, we have highlighted the normal morphometric measurements of middle ear in Indian subpopulation so as to help diagnose pathology. CBCT is a meaningful tool in radiologic diagnostics of the diseases of the temporal bone and in the majority of cases at least similar to conventional CT.[3]

Assessment of normal morphological anatomy of middle ear helps us to differentiate it from pathology. The following pathologies can be identified: Teacher Collins syndrome[12] which is 2.7 characterized by hypoplasia of the malleus <5 mm and microtia of EAC <6 mm. Cochlear implant measurement[12] ideal length of the malleus is 8 mm and that of width of the malleus is 2.7 mm. Mermaid appearance constitutes to[13] the basal turn of the cochlea with promontory: the tail of the mermaid SCC and LCC: the hands of the mermaid in ballerina pose. Alteration in the headless mermaid appearance on CBCT temporal bone scan in coronal plane gives a clue to the underlying pathological process, pointing the abnormality in the medial wall of the middle ear and involved parts of the bony labyrinth. Our study provides morphometric normal measurements for new prosthetic designs using Teflon material for reconstructive procedures. Cholesteatoma[14] is characterized by erosion of LCC (seen as mermaids sign) and ossicles. Surgeons operating in the middle ear should be aware of the dimensions and the possible variations that can be present in the region to perform the needed and anticipated corrections without causing any instability to the structural integrity in middle ear dynamics. Reckoning this, ossicles are of significant importance in reconstructive efforts and a careful assessment of this region should be carried out during ossiculoplasty.[8] Till date, very few Indian studies have been done on morphometric evaluation of middle ear anatomy on CBCT.

CONCLUSION

High-quality imaging of the middle and inner ear is possible with CBCT; therefore, it is a meaningful tool in radiologic diagnostics of the diseases of the temporal bone. The obtained morphometric data of the malleus through our study will help the prosthesis maker in the formation of various implants and grafts required to treat various ear diseases.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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