"ANALYSIS OF VOLUME AND DIMENSIONS OF MIDDLE EAR CAVITY USING OTOFORM: A CADAVERIC TEMPORAL BONE STUDY."

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LIST OF ABBREVIATIONS

GLOSSARY	ABBREVIATIONS
ET	Eustachian tube
MEC	Middle Ear Cavity
btwn	between
ER	Epitympanic Recess
EAC	External Auditory Canal
Post.	Posterior
Ant.	Anterior
FN	Facial Nerve
VT	Von Troltsch
RW	Round window
ST	Sinus Tympani
Sa.	Saccus
FR	Facial Recess
MAC	Mastoid Air Cells
TC	Tympanic Cavity
PE	Pyramidal Eminence
Em.	Eminence
TTR	Tubo-tympanic recess
SCC	Semicircular Canal
TBD	Temporal Bone Dissection

ABSTRACT

Title: "ANALYSIS OF VOLUME AND DIMENSIONS OF MIDDLE EAR CAVITY USING OTOFORM: A CADAVERIC TEMPORAL BONE STUDY"

Background and Objectives:

The middle ear cavity is defined as an air-filled hollow irregular space present in the temporal bone with many variations. Very few studies in the recent years, especially in India on the variation of the middle ear cavity has been done. Hence, the study is designed to measure the volume and dimensions of the middle ear cavity along with variations in sinus tympani volume.

The objective of this study is to analyse the volume and dimensions of middle ear cavity and variations in the following parameters of the middle ear in cadaveric temporal bones.

Materials And Methods:

This is a one-year Observational Cross-sectional study conducted between January 2020 to December 2020 in Temporal Bone Dissection Lab of Department of Otorhinolaryngology and Head and Neck Surgery, J. N. Medical College, KAHER, Belgaum. 40 Human temporal bone (both left and right) are dissected. The middle ear cavity was filled carefully with moulding material i.e. Otoform. Once it sets, a 3-dimensional model of the middle ear cavity is made, which is removed carefully without any damage. The volume of the middle ear cavity is calculated. The other contents and parameters was measured using a measuring probe.

Results:

The volume of the middle ear cavity was measured to be 1.17 cubic cm and The volume of the sinus tympani was measured to be 8.77 cubic mm with a range of 6.5 cubic mm to. 10.9 cubic mm hence showing that sinus tympani show a larger variability in terms of size, shape and volume

Conclusion:

The volume of the middle ear cavity was measured to be 1.17 cubic cm and The volume of the sinus tympani was measured to be 8.77 cubic mm with a range of 6.5 cubic mm to. 10.9 cubic mm hence showing that sinus tympani show a larger variability in terms of size, shape and volume

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INTRODUCTION

The temporal bone can show significant anatomic variation in different individuals. The combined volume of the MACs and TC is referred to as the MEV. Mesotympanum is extended posteriorly to form the ST. It is situated lateral to the vestibule and posterior SCC and medial to the FN, stapedius muscle, and PE [6]. ST is of clinical interest to otologists due to its susceptibility to be invaded by cholesteatoma, the difficulties of visualisation, and the absence of a direct operative access channel[1].

Fragmental remnant matrix left behind during the primary surgery leads to residual Cholesteatoma. Under microscopic supervision, it is almost impossible to investigate the ST and other recesses and structures in the retrotympanum[2]. The ST region (where it occurs 37% of the time), the FR, and the underside of scutum are most common locations. Due to its visible complexity and the lack of a straightforward surgical treatment to purge it of any lingering sickness, the ST is significant clinically.[3]

One of the difficulties in ear surgery is clearing the sinus tympani, which is one of the body's most concealed locations and has distinct anatomical variances in its size, shape, and depth. These structural differences demonstrate how challenging it is to perform surgery to address the lesion from the deep region of the ST[4].

Very few studies in the recent years, especially in India on the variation of the MEC and its structures have been done despite high incidence of residual disease of the middle ear pathology due to these anatomical variations. Hence, more anatomical studies are necessary to gives us an insight into the variations in MEC.

OBJECTIVE

The aim of this research is to analyse the volume and dimensions of MEC and variations in the middle ear in the cadaveric temporal bones.

REVIEW OF LITERATURE

Ear Microsurgery in modern times requires detailed study of the MEC as it has lots of cavity and variations which can result in recidivism. To know the variations of the middle ear, knowing the normal anatomical knowledge in detail is necessary starting from the embryology, for managing the middle ear infections.

The development of the tympanomastoid system starts at the third week of intra uterine life which starts from the first pharyngeal pouch as an outpouching known as the TTR. The ET and MEC are derived from the endodermal tissues of the TTR dorsal end. Into four sacci, the tubo tympanic recess buds (Fig. 1)[1,4]:

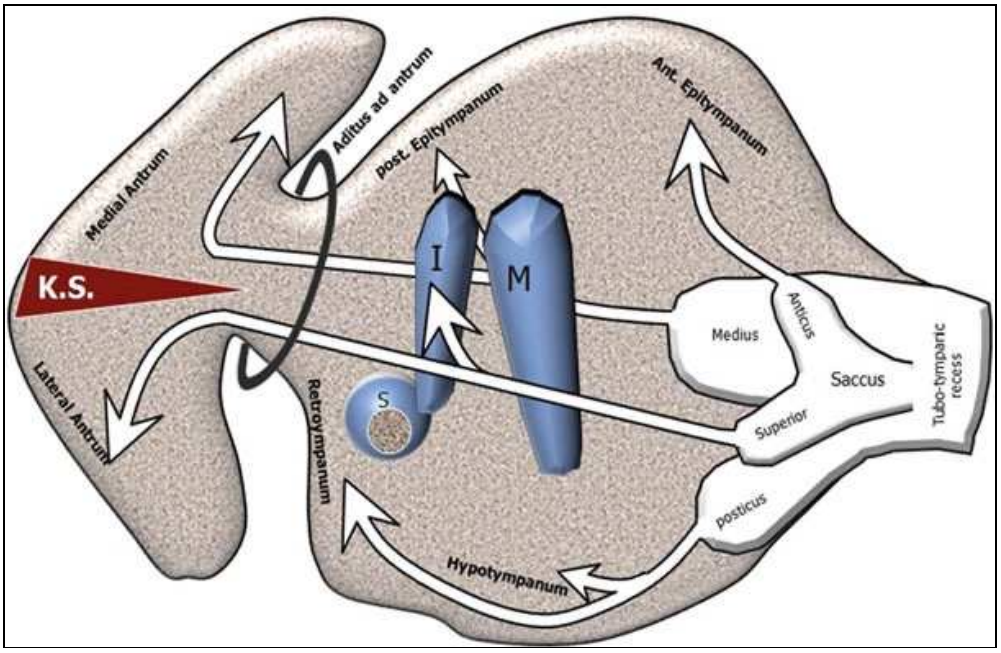


Figure 1: Middle Ear Spaces Embryology; K.S. – Korner Septum, I,M & S stands for Ossicles – Incus, Malleus and Stapes Respectively

1. Saccus anticus :

    - Smallest saccus which extends beyond the tensor tympani anteriorly forming the Ant. ETR and Ant. pouch of VT.

    - The Ant. ETR as well as the supratubal recess are divided by the tensor tympani fold, which is formed when the anterior saccule of the Sa. Medius unites with the Sa. anticus.

2. Saccus Medius:

    - Attic arises from it.

    - It ascends and separates into the anterior saccule, medial saccule, and posterior saccule.

3. Saccus superior

    - • The Post. VT pouch forms when Sa. superior elongates laterally and posteriorly between the malleus head and the incus long process..

    - Posterior saccule of Sa. Medius and Sa. superior fuses and forms MAC system medial part, if bony septum cease to breakdown and persists it is called Korner's septum.

4. Saccus Posticus

    - It forms the RW and oval window niche, ST and the FR.

The MEC, also referred to as the TC, is an irregularly shaped hollow area of the temporal bone that is bounded on the lateral and medial sides by the EAC and the inner ear, respectively. This hollow can be discovered where two significant axes converge

1. The external and internal auditory canals are connected by latero-medial axis,
2. Posteroanterior axes seen between the ET and mastoid antrum.

The MEC is further divided into five different compartments as below:

- In the middle Mesotympanum
- Superiorly Epitympanum
- Inferiorly Hypotympanum
- Anteriorly Protympanum
- Posteriorly Retrotympanum

TC has dimensions of two millimetres in middle, six millimetres in attic and four millimetres in hypotympanum.

MEC is 2 millimetres wide in the middle, 6 millimetres wide in the superior region, or the attic, & 4 millimetres wide in hypotympanum. Horizontal and vertical measurements of the middle ear cleft are 15 millimetres . (Figure 2) [6].

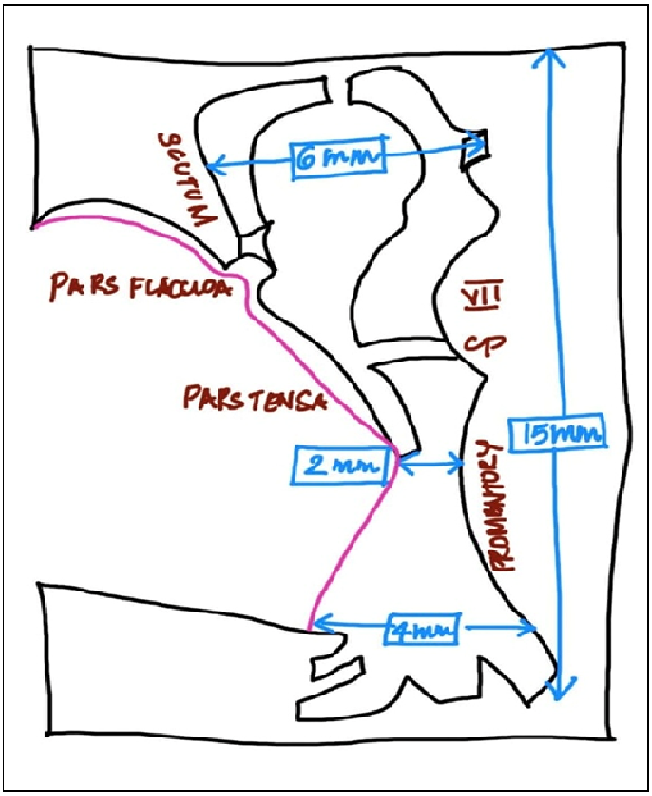


Figure 2: MEC's many dimensions are shown in a schematic diagram. FN- VII and Cochlear process – CP.

The TC has 6 walls i.e. Superior wall, also known as the roof or tegmen, the inferior wall, also known as the jugular wall, lateral wall, medial wall, also known as the cochlear wall, and anterior wall, also known as carotid wall, are six walls that make up the TC[1].

The middle ear, in particular the posterior tympanic chamber and its posterior wall, exhibits a wide range of abnormalities. Hence, Most crucial to the investigation is understanding the posterior TC.

POSTERIOR WALL:

The aditus and the antrum are irregularly shaped openings of wide posterior wall of TC. FN– vertical segment is seen in the posterior wall. The posterior wall has many variations because of its structures. It's 3 eminences is directed anteriorly and contains 4 sinuses and 5 bony ridges[14].

POSTERIOR WALL EMINENCES:

The eminences of the posterior bony wall are

- The chordal eminence
- The pyramidal eminence
- The styloid eminence

All of the above together form the styloid complex, which is derived from the 2nd branchial arch superior portion.

- *The PE*
    - This constitutes the lateral boundary of the ST and is located behind the oval window in its posterior wall. Its height measures roughly two millimetres . The bottom of the PE also contributes to the formation of the FN canal. It is traversed by the stapedial muscular body, and the stapedial tendon emerges from top of PE (Figure 3)[16].
- *The chordal eminence*
    - This eminence, which is lateral to the pyramidal eminence, has a foramen known as the Iter Chordae Posterius, through which enters the chorda tympani.

- *The styloid eminence*
    - An elevation which is smooth and present on the posterior wall which forms the styloid process called the Politzer eminence or styloid eminence.

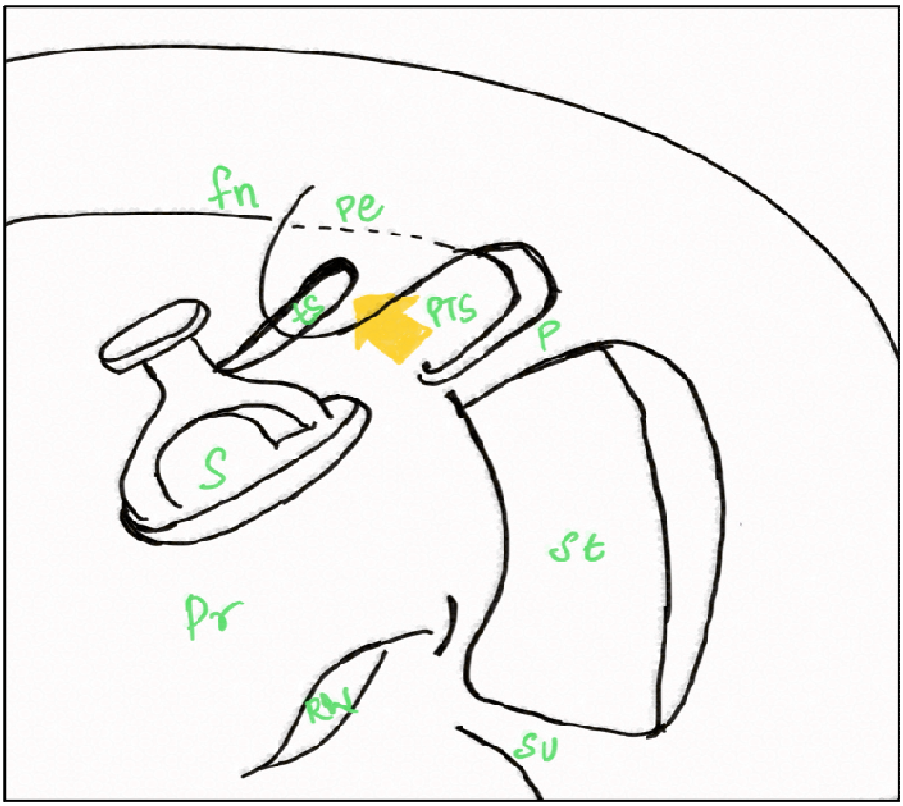


Figure 3 : Sketch of sub pyramidal space (ss).

Posterior Wall Ridges

The 5 bony ridges connect the eminences with the promontory and each other.

The ponticulus and the subiculum, two bony structures, separate the posterior section of the medial tympanic wall into three depressions.[4].

- *The subiculum*
    - It (Figure 3) divides the retrotympanum in to superior and inferior parts[17].
    - It lies between ST superiorly and the RW inferiorly.
- *The ponticulus*
    - This is a bony ridge that runs from the promontory to the pyramidal process of retrotympanum (Figure 3). [13].
    - There are different types of ponticulus as mentioned below
        - Complete ponticulus : When the structure is fully developed from the promontory to the pyramidal process, it is referred to as the complete ponticulus[21]. The complete ponticulus separates the ST from the posterior sinus and creates the lateral border of the sinus tympani. [22-25].
        - Incomplete ponticulus: Unfinished structures are known as incomplete ponticulus, which combine the posterior sinus and ST into a single cavity.[12].

- *The chordal ridge of Proctor*
    - It is a transverse ridge that extends laterally arising from chordal Em. to the PE[9].
- *The pyramidal ridge*
    - This ridge connects the styloid and pyramidal eminences. It could be present or not[10].
- *The styloid ridge*
    - It is a ridge that joins the chordal Em. to styloid eminence[11].

Spaces of Retrotympanum

Retrotympanum has four spaces. The retro tympanum's fulcrum is the PE(Figure 4). The two spaces in the four spaces are medial to the FN and the pyramidal eminence, and the other two are located lateral to them.

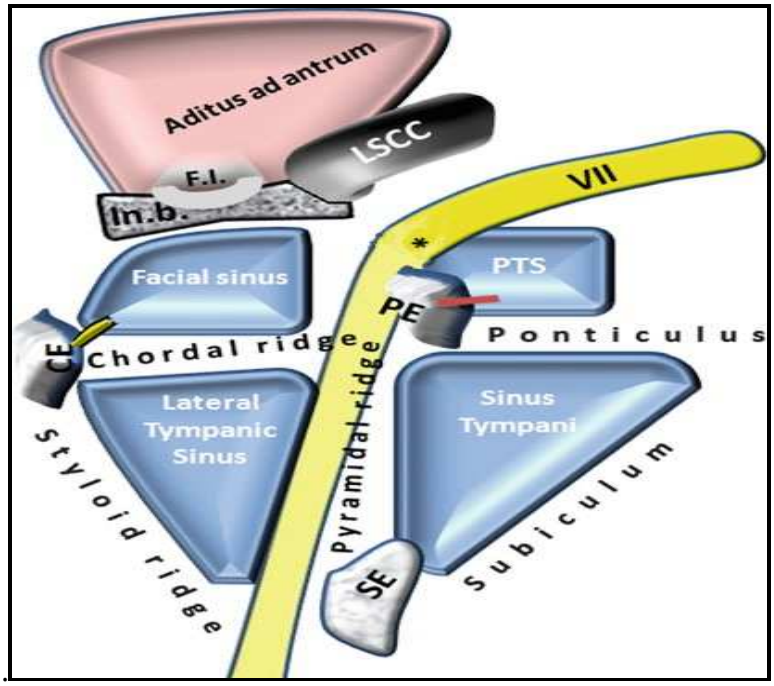


Figure 4: Spaces of Retrotympanum

- **The Lateral Spaces**
    - The chorda tympani, incudal buttress, and the bony portion of the fossa incudis make up the superior border of the FR, which is formed by the lateral spaces that are surrounded by the facial canal and PE on medial side and chorda tympani on the lateral side, respectively[1,10].
    - The FR and incudal buttress separate the aditus and antrum..
    - The chordo-facial angle, can range from eighteen degrees to thirty degrees, creates a FR that is extremely individualistic and measures

around two millimetres at the level of a RW & three millimetres at the point of an oval window[27-29].

- FR is divided by chordal ridge into facial sinus at the sup. part and lateral sinus tympanicus in the inferior part.

- **The Facial Sinus**
  - As mentioned above it is a small pouch in the superior region of FR. It has no connection with the attic air cells or MACs[31].
- **The Lateral Tympanic Sinus**
  - The lower lateral part of the FR is made by the lateral tympanic sinus, which is narrowest sinus in the retrotympanum. It is bounded by chordal Em. medially, by the PE inferolaterally, and superiorly by the styloid eminence.
  - There is no connection with the antrum or the attic and the size varies from 1.5millimetres to 2.5millimetres [32,33].
- **The Medial Spaces**

The retro tympanic medial spaces also known as the tympanic sinus are divided by the ponticulus into two spaces : the ST & posterior tympanic sinus[37].

- **The Sinus Tympani**
  - The ST, biggest sinus of the retrotympanum, is surrounded by medially -the FN-mastoid section, laterally - semicircular canal, superiorly - ponticulus, & inferiorly - subiculum. [5].
  - The ST varies in shape, size and volume greatly and posteriorly it varies between 0.2 to 10millimetres with an average of 2millimetres [38-40].

- **Posterior Tympanic Sinus**
  - It is medially bordered by the PE and FR, and it is located below the ponticulus.
  - When ponticulus is incomplete, it is a single sinus with the sinus tympani[23,42]

ST Types and Surgical Approaches

The ST is classified into 3 types (Figure 5) according to its depth as:

- Type A - shallow ST; it can be accessed trans canal approach since it does not reach the vertical portion of FN posteriorly[14].
- Type B - intermediate depth ST; it stops at the point of the vertical section of FN and lies medial to it. To prevent harm to the high-positioned FN or jugular bulb, blind dissection should be avoided, and endoscope is a better option. [41].
- Type C – deep ST; it goes deep and posteriorly to vertical section of the FN and is mostly only seen in well-pneumatized mastoids. Optimum method for treating such sinus tympani is the trans mastoid retro facial technique[42]

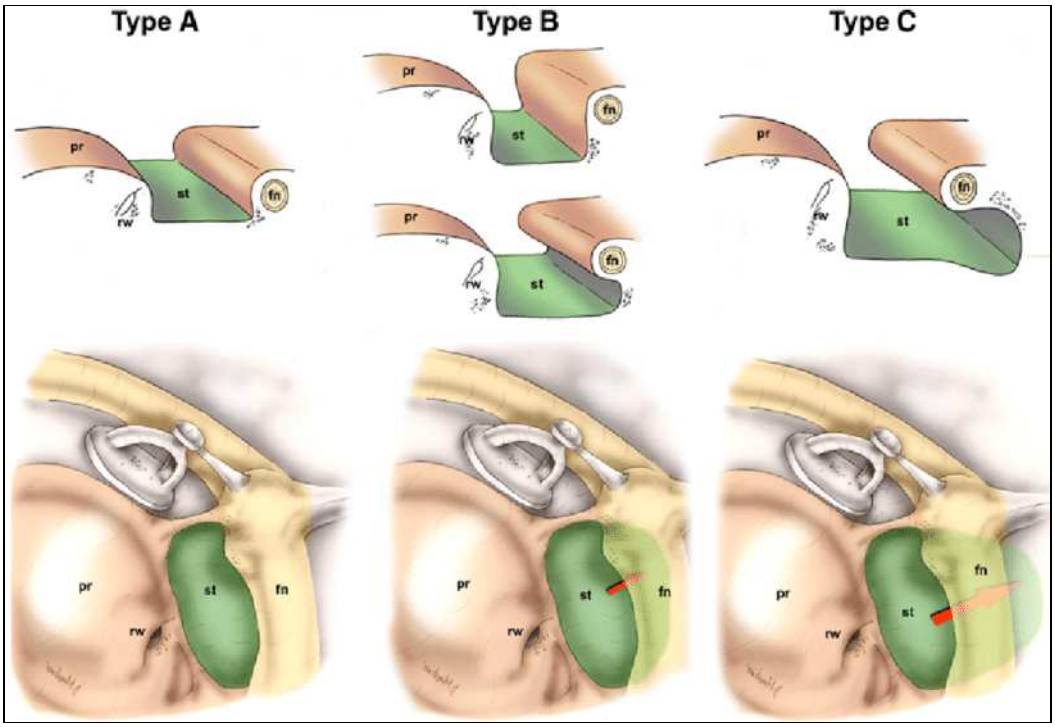


Figure 5 : Types of sinus tympani.

The MEC and its contents must be understood by the otological surgeon as being variable. The earlier research primarily used radiological investigations to measure one parameter. In order to reduce the prevalence of lingering middle ear disorders, this research is intended to analyse the variance of middle ear dimension and middle ear structures by a moulding approach and extrapolating the knowledge in live surgery.

METHODOLOGY

This study was carried out at the cadaveric TBD laboratory from January 2021 to February 2022 in Department of ORL and HNS, JNMC, KAHER, Belgaum. Forty Wet temporal bones were dissected, and the findings were recorded. Photographs of the dissection were taken at various stages.

Cadaveric Temporal Bone Dissection Laboratory:

- The lab contains containers of temporal bones preserved in formalin in storage racks.
- It was equipped with the operating microscope to provide the correct magnification and illumination, TV screen to view the dissection, temporal bone holder, foot-controlled drill, various sizes and types of burrs, irrigation and suction apparatus and ear microsurgery instruments

Cadaveric Temporal Bones:

- 40 temporal ones were harvested from the cadavers in the anatomy hall and were kept preserved in formalin.
- The bones were washed in the running water to get rid of formalin before dissection and fixed over temporal bone holder.
- The dissection was carried out and photographs taken at various stages.
- The soft tissues and external ear were cut and removed after recording the findings i.e., presence of pinna, post and pre auricular region, EAC using a 15. No blade.

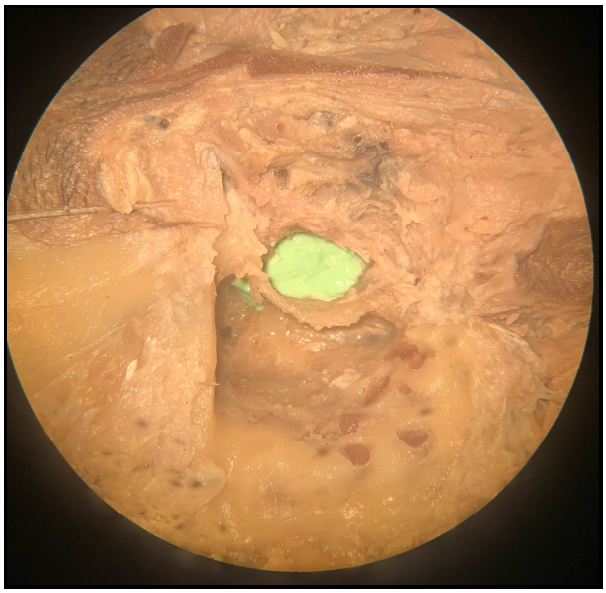
Steps of Dissection:

1. Spine of Henle identified.
2. MacEwen's triangle exposed and drilled.
3. Antrum identified, cortical mastoidectomy completed.

4. Canaloplasty was done to view the incudostapedial joint and ET in one view and measurements were taken.

5. The incus and the malleus were removed.

6. The mold which is OTOFORM was prepared by mixing with hardening agent.
7. The 1ml of Otoform was injected into the MEC through the EAC for 5-7 minutes.



8. The Otoform is carefully removed using the circular knife and ball probe.

9. The ST are marked in the mold using permanent marker.

10. All measurements taken as per set proforma.

Ethical Considerations:

Ethical clearance for this study was obtained from the JNMC Institutional Ethics Committee and the reference number was MDC/DOME/67.

RESULTS

Table 1: Side wise distribution		
Sides affected	**Number of patients**	**Percentage**
Left handed side	21	52.50
Right handed side	19	47.50
Total	40	100.00

Graph 1: Side-wise distribution

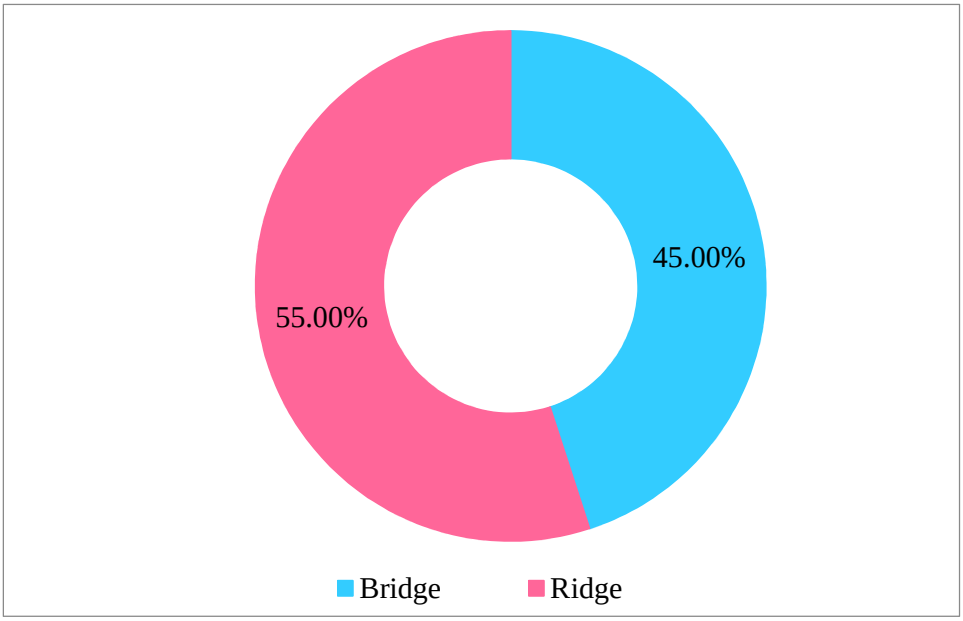
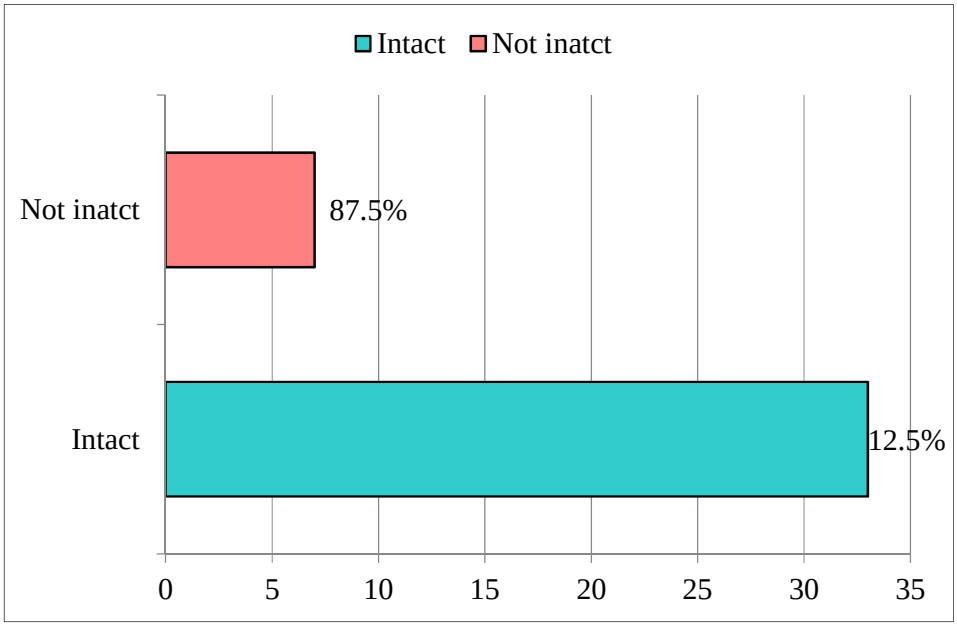


Table 2: Pinna- Present/ Absent		
Pinna	**Number of patients**	**Percentage**
Absent	35	87.5
Present	5	12.5
Total	40	100

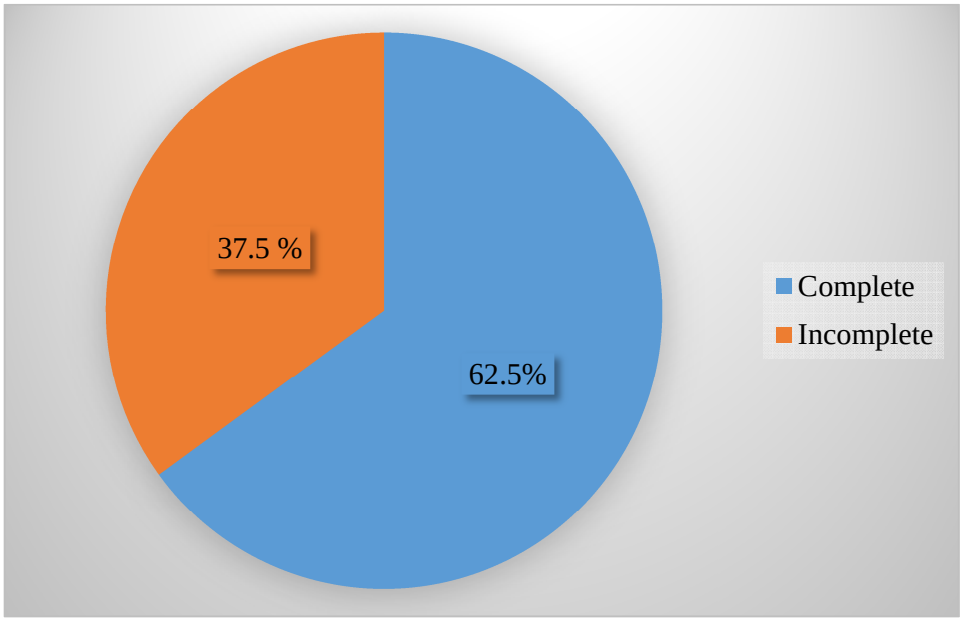
Graph 2: Pinna Present/ Absent



- Out of the 40 bones dissected, there were 21 left side and 19 were right sided.
- Pinna was present and intact in 35 of the bones, whereas in the remaining 5 bones they were removed.

Table 3: Tympanic membrane		
Tympanic membrane	**Number of patients**	**Percentage**
Intact	25	62.5
Not intact	15	37.5
Total	40	100

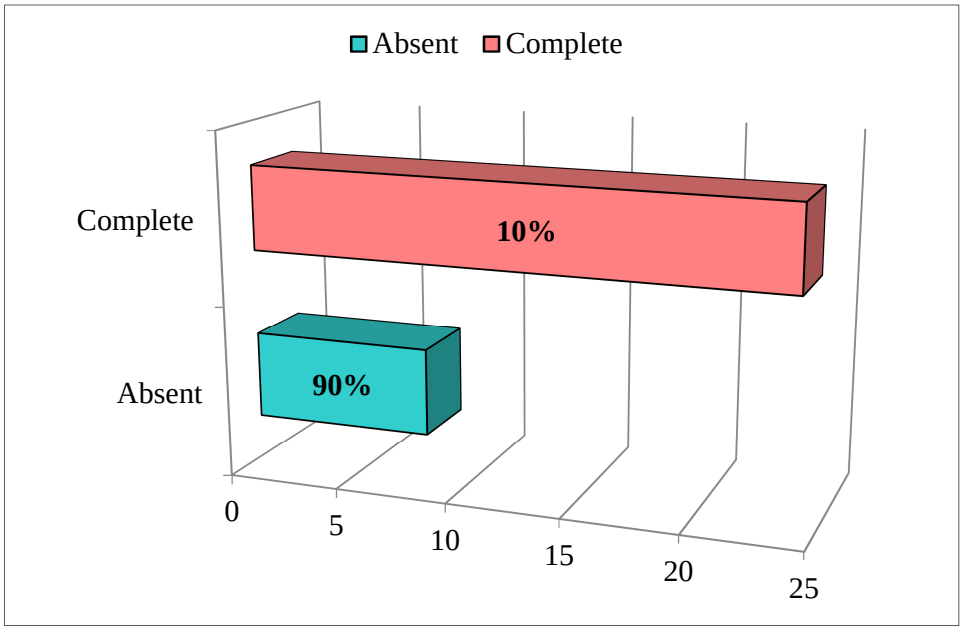
Graph 3: Tympanic membrane



- Tympanic membrane was intact in 62.5 % of the temporal bones and it was partially torn in rest 37.5% of the bones probably due to postmortem handling or preexisting middle ear ante mortem pathology.

Table 4: Mastoid tip prominence		
Mastoid tip	**Number of patients**	**Percentage**
Prominent	36	90.00
Non prominent	4	10.00
Total	40	100.00

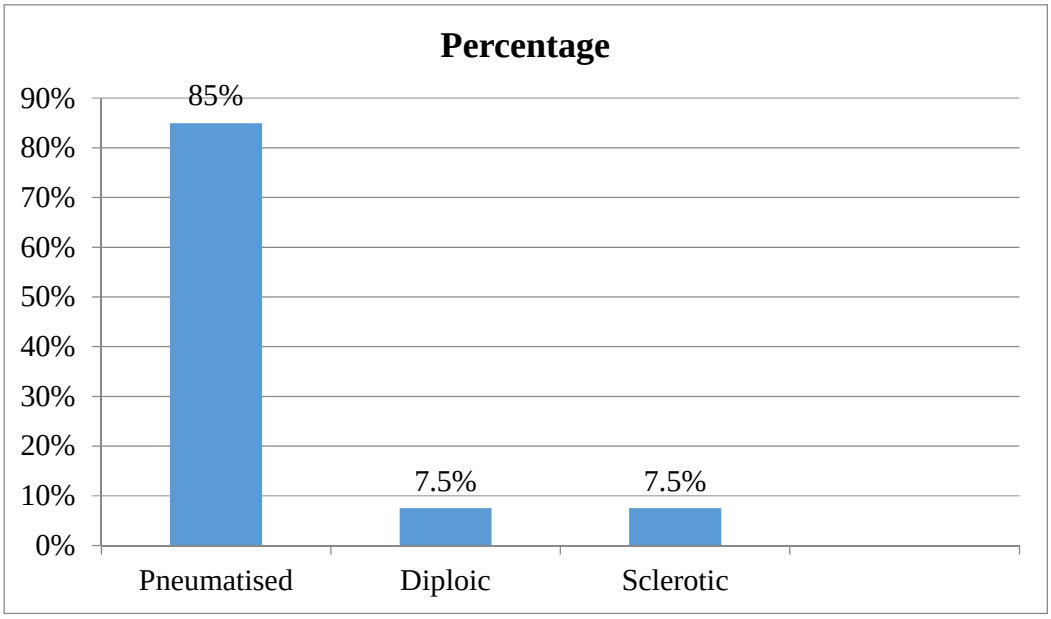
Graph 4: Mastoid tip prominence



- The Mastoid tip was found prominent in 90% of the bones and non- prominent in 10% of the bones (4 bones).

Table 5: Pneumatisation of mastoid		
Pneumatisation	**Number of patients**	**Percentage**
Pneumatised	34	85.0
Diploic	3	7.5
Sclerotic	3	7.5
Total	40	100

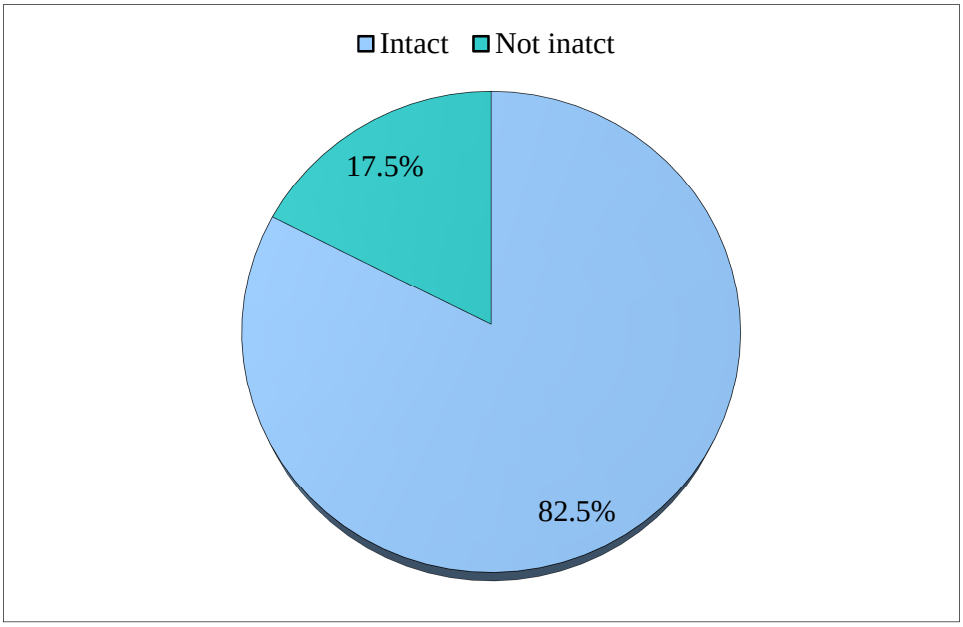
Graph 5: Pneumatisation of Mastoid



- The mastoid cavity of 85% of the samples was found to be Diploic (34 bones), whereas 7.5% were well pneumatized (3) and 7.5% were Sclerotic (3 bones).

Table 6: Ossicular Chain Status		
Ossicular chain status	**Number of patients**	**Percentage**
Not intact	7	17.5
Intact	33	82.5
Total	40	100

Graph 6: Ossicular Chain Status



- The majority of the specimens had a intact Ossicular chain Status (82.50%) whereas the rest of the specimens did not have an intact ossicular chain Status (17.50%).

The mean measurements, its range and standard deviation (SD) of various parameters were as follows:

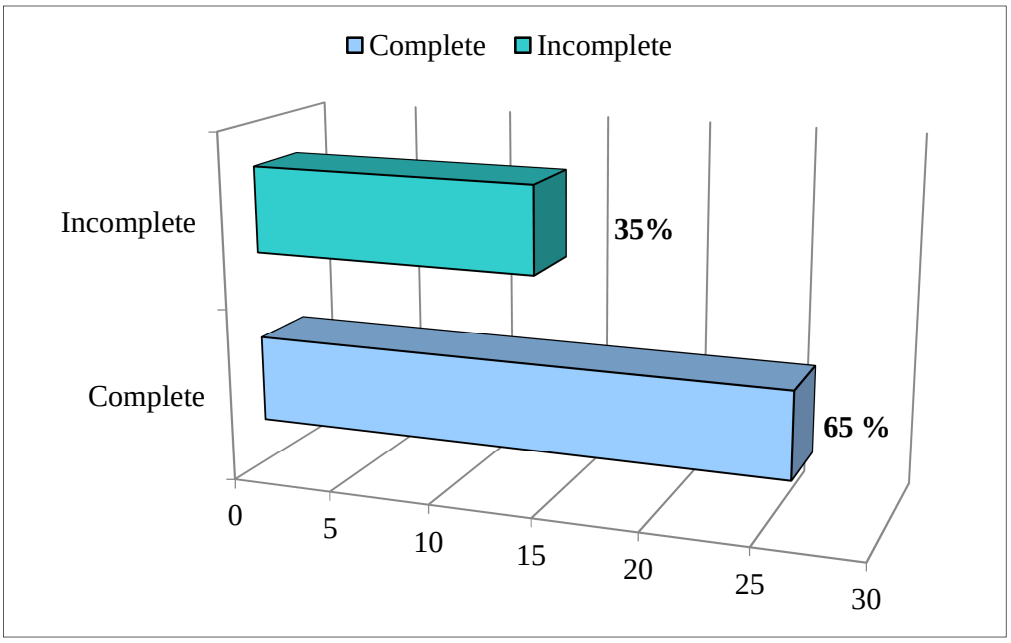
Table 7: Summary or descriptive statistics of parameters related to MEC

Parameters	Min.	Max.	Average	SD
Volume of the MEC (CC)	0.6	1.9	1.17	O.30
Volume of ST(cu. millimetres)	6.5	10.91	8.77	1.25
Volume of Sinus Sub - Tympanicus (cu. millimetres)	123.6	187.9	148.27	14.01
Incudostapedial angle (in degree)	75	90	83.43	3.37
ET diameter (millimetres)	0.21	3.6	2.84	0.57

- The Mean Volume of the cavity of the middle ear was 1.17 $\pm$ 0.30 CC and ranged from 0.6 $\pm$ 0.3CC to 1.9 $\pm$ 0.30 CC.
- The Mean Volume of the cavity of the ST was 8.77 $\pm$ 1.25 Cu millimetres and ranged from 6.5 $\pm$ 1.25 Cu millimetres to 10.91 $\pm$ 1.25 Cu millimetres .
- The Mean Volume of the cavity of the sinus sub tympanicus was 148.27 $\pm$ 14.01 Cu millimetres and ranged from 123.6 $\pm$ 14.01 Cu millimetres to 187.9 $\pm$ 14.01 Cu millimetres which had the maximum variation in the MEC.
- The IS joint Angle was 83.43 degrees as the average with range of 75 degree to 90 degree
- The ET diameter ranged from 0.21 $\pm$ 0.57 to 3 .6 $\pm$ 0.57 and was average of 2.84 $\pm$ 0.5

Table 8: Ponticulus – Complete/Incomplete		
Ponticulus	**Number of patients**	**Percentage**
Complete	26	65.0
Incomplete	14	35.0
Total	40	100

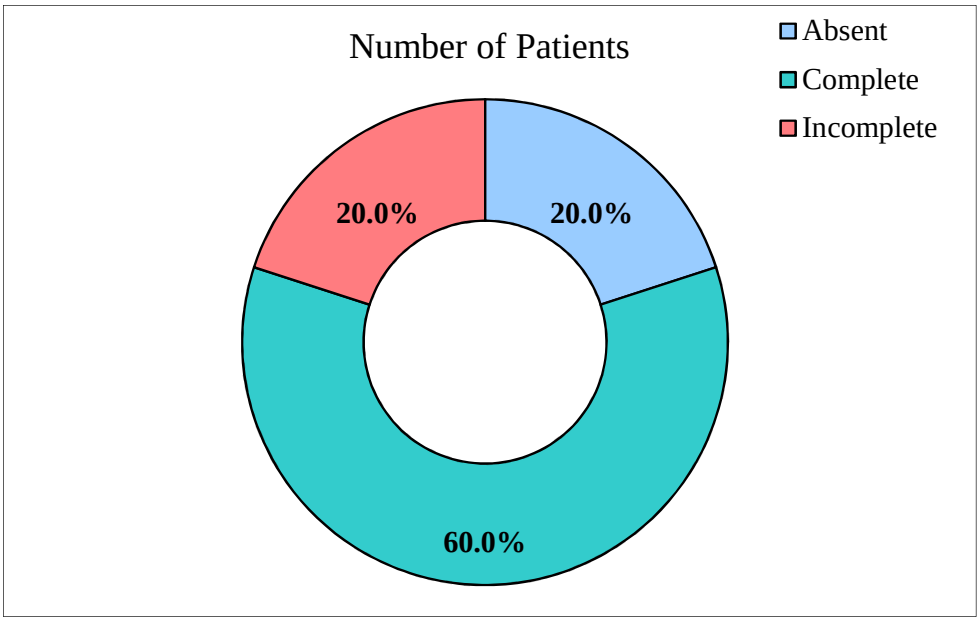
Graph 7: Ponticulus – Complete/Incomplete



- The ponticulus was Complete in 65% of the cases (26 bones) and incomplete in 35% of the cases (14 bones).

Table 9: Subiculum – Absent /Complete/Incomplete		
Subiculum	**Number of patients**	**Percentage**
Absent	8	20.0
Complete	24	60.0
Incomplete	8	20.0
Total	40	100

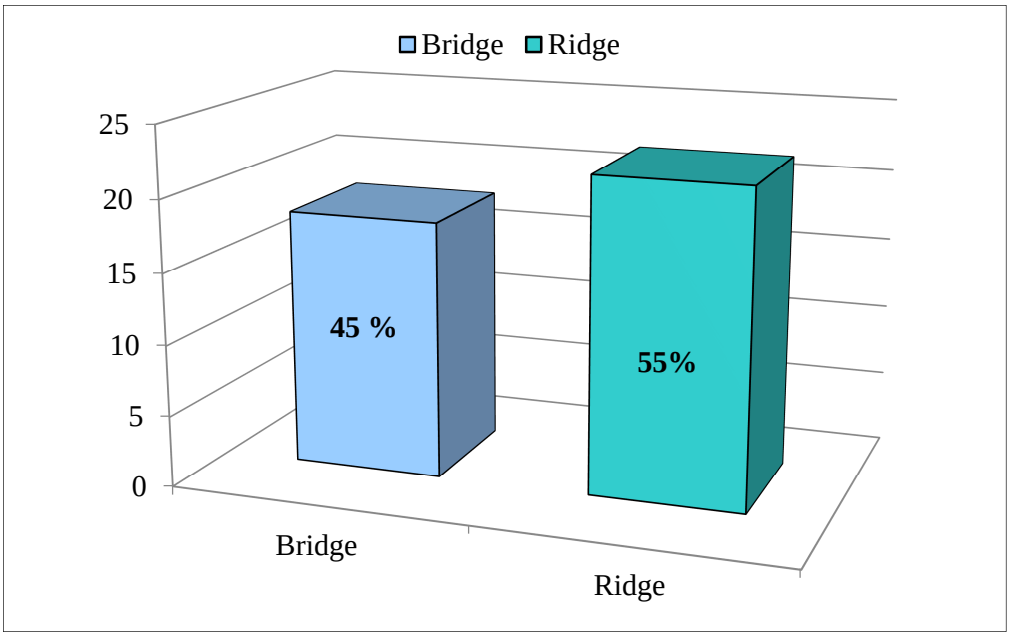
Graph 8: Subiculum – Absent /Complete/Incomplete



- The subiculum is absent in 8 bones (20%) , Complete in 24 bones (60%) and Incomplete in 8 bones (20%).

Table 10: Finniculus – Bridge/ Ridge		
Finniculus	**Number of patients**	**Percentage**
Bridge	18	45.0
Ridge	22	55.0
Total	40	100

Graph 9: Finniculus – Bridge/ Ridge



- The Finniculus can be a bridge or ridge. It is bridge in 45% (18 bones) and ridge in 55%(22 bones).

DISCUSSION

Finding out the amount of MEC and its fluctuations was the aim of the study. Due to the fact that ST was frequently the location of remanent cholesteatoma, its volume and fluctuation are of highest importance.

As the middle ear is an irregular surface, in this study it is measured using a mould of the MEC. The same moulding technique was used by Shakeel M et al in 2015 in Dundee, United Kingdom to measure the RW niche wherein he used the Aquasil putty which is used by dentist, but in this study we have used the Otoform a silicone mould which is generally used by otorhinolaryngolist and audiometrist for external ear cavity mould for hearing aid measurements[15].

Before the mould is taken, the cadaveric temporal bone dissection is carried out. The parameters which are seen and photographed and measured are:

1. **Incudostapedial joint**:

   After elevating the tympanomeatal flap, the canaloplasty is done to visualise the incudostapedial angle clearly and photographed, the angle is then measured with the aid of computer software. It measured the angle to be 83.43 degrees $\pm$ 3.37 with a range of 75 degree to 90 degree.

   Margaret skinner at al in their study in 2003 found that mean Incudostapedial angle was 93 degrees and had also proved the hypothesis that incudostapedial angle is 90 degree was accepted. Here in this study according to the 95 % confidence interval which lies between 83 degrees to 87 degrees,

the hypothesis was rejected and does not confirm the previously reported data probably due to sampling error or measurement error and variability[44].

2. Mastoid cavity

The mastoid tip was prominent in 90% of the samples and not prominent in 10 % of the samples. The mastoid was well pneumatized and sclerotic in equal no of samples that is 7.5% and diploic in 85% of the samples.

Deniz Baklaci et al in 2019 concluded that a mastoid which is well pneumatized was related to deep and posteriorly placed ST. In this study the comparison was not possible as the computerised tomography of the cadaveric bones were not performed, but this study found that well pneumatized mastoid bones had complete ponticulus and subiculum[8].

3. Ponticulus

The ponticulus which is the bone extending from the promontory to the PE was complete in 65 % of the bones in this study which was consistent with the study in 2004 by Holt et al, which stated that ponticulus was present in 66 % of their specimens[13].

4. Subiculum

The subiculum creates the lower boundary of the ST and is a smooth projection that extends from the lower lip of the recess of the RW up to the promontory. It as complete in 60 % of the samples and incomplete or absent in 20%. In this study it is found that subiculum and ponticulus are interrelated and are complete in 60 % of the samples.

After these above observations, the silicone mould is injected and removed carefully and the following parameters are measured.

5. Volume of the ST

The ST which is the largest sinus of retrotympanum is separated by the posterior sinus tympanicus by the ponticulus. The average volume of the ST was found to be 8.77 $\pm$ 1.25 cubic millimetres, which in keeping with the research in 2019 by Hizli et al in which volume of ST was around 8 cubic millimetres in ST with Korner septum and 14 cu millimetres without Korner septum[45].

The study done was based on three dimensional analysis by computed tomography while this present study was done using a moulding technique and the presence of the Korner's septum could not be confirmed in this study.

It was also found in this study that higher range of volume of the ST was seen in 40% of the samples which helps in concluding that the incomplete ponticulus leads to ST to be confluent with the posterior tympanicus sinus giving rise to large volume sinus tympani.

6. Volume of the middle ear

Volume of middle ear in this present study was 1.17 cubic cm $\pm$ 0.30 and ranges between 0.6 cubic cm to 1.9 cubic cm. The previous studies done to measure the volume of the MEC was done using tympanometry studies or computerised tomography studies. Comparison of the study was not possible due to the different parameters used.

The moulding process was useful for determining the ST's volume, but the middle ear's volume was varied. The limitations of this study included the steep learning curving for injecting and removing the mould without damaging or altering the structures as the measurements were made on the mould. Further studies with the moulding techniques with larger sample size may be helpful in learning process.

The analysis of variation in ST and volume compared to variations to other middle ear structures can help in complete removal of cholesteatoma and reduce the recurrence. The temporal done dissection helps in better learning curve for the post graduates. The study of the volume of MEC with accurate measurements and the Otoform mould can also be used in larger scale to get more accurate model of the middle ear implants.

CONCLUSION

1. The volume of the MEC was measured to be 1.17 cubic cm
2. The volume of the ST was measured to be 8.77 cubic millimetres varying between 6.5 cubic millimetres to. 10.9 cubic millimetres hence showing that ST shows a larger variability in terms of size, shape and volume.
3. The ponticulus and subiculum was found to be complete in a well pneumatized mastoid bone.
4. The specimens with incomplete ponticulus had a larger sinus volume concluded that the posterior tympanicus sinus becomes confluent with ST i.e. 10 % of the population as also mentioned in previous studies.

SUMMARY

This study was conducted in KLES Dr Prabhakar Kore Hospital, Belagavi during a period of one year during which forty wet cadaveric temporal bones were dissected and mould taken . The dissections and moulding were done to study and analyse the variation of MEC.

The results obtained were as follows:

- The Mean Volume of the cavity of the middle ear was 1.17 $\pm$ 0.30 CC and ranged from 0.6 $\pm$ 0.3CC to 1.9 $\pm$ 0.30 CC.
- The Mean Volume of the cavity of the ST was 8.77 $\pm$ 1.25 Cu millimetres and ranged from 6.5 $\pm$ 1.25 Cu millimetres to 10.91 $\pm$ 1.25 Cu millimetres .
- The Mean Volume of the cavity of the sinus sub tympanicus was 148.27 $\pm$ 14.01 Cu millimetres and ranged from 123.6 $\pm$ 14.01 Cu millimetres to 187.9 $\pm$ 14.01 Cu millimetres which had the maximum variation in the MEC.
- The IS joint Angle was 83.43 degrees as the average with range of 75 degree to 90 degree
- The ET diameter ranged from 0.21 $\pm$ 0.57 to 3 .6 $\pm$ 0.57 and was average of 2.84 $\pm$ 0.5
- The ponticulus was Complete in 65% of the cases (26 bones) and incomplete in 35% of the cases (14 bones).
- The subiculum is absent in 8 bones (20%) , Complete in 24 bones (60%) and Incomplete in 8 bones (20%).
- The Finniculus can be a bridge or ridge. It is bridge in 45% (18 bones) and ridge in 55%(22 bones).

At the end of study, it was concluded that MEC have many variations and it is different in each and every individual. The surgeons need a complete reconstruction of middle ear in every individual to know the complete picture prior to surgery to avoid complication and reduce residual pathology.

BIBLIOGRAPHY

1. Mansour S, Magnan J, Haidar H, Nicolas K, Louryan S, Et Al. Comprehensive and Clinical Anatomy of The Middle Ear; Springer - Verlag Berlin Heidelberg; 2013; 29-32.
2. Sahin B, Orhan KS, Ashyuksek H, Kara E, Buyuk Y, Guldiken Y; Endoscopic Evaluation of Middle Ear Anatomic Variations in Autopsy Series: Analyses Of 204 Ears. Braz J Otorinolaryngol. 2020; 86:74-82.
3. "Saito R, Igarashi M, Alford BR, Et Al. Anatomical Measurement of The Sinus Tympani." Arch Otolaryngol Head Neck Surg 1971; 94:918-925.
4. Proctor B. Surgical Anatomy of The Posterior Tympanum. Ann Otol Rhinol Laryngol 1969; 78:1026-40.
5. Badr – El-Dine, Mohammed., Surgery of Sinus Tympani Cholesteatoma: An Endoscopic Necessity., Journal of International Advanced Otology; 2009 2:158-165.
6. Carpenter D.J, Tucci D.L Kaylie D.M, Frank – Ito D., Disagreement in Middle Ear Volume Estimation Between Tympanometry and Three- Dimensional Volume Reconstruction in The Context of Tympanic Membrane Perforation; Journal of Otology; 2017.
7. Abdel Baki F, El Dine MB, El Said I, Bakry M. Sinus Tympani Endoscopic Anatomy. Otolaryngol Head Neck Surg 2002; 127:158-62.
8. Baklaci, D., Kuzucu, I., Guler, I. Et Al. Effect of Mastoid Bone Pneumatization on The Conformation and Depth of The Sinus Tympani, A High-Resolution Computed Tomography Study. Surg Radiol Anat. 2019; 41**,** 921–926.

9. Bonali, M., Anschuetz, L., Fermi, M. Et Al. The Variants of The Retro- And Hypotympanum: An Endoscopic Anatomical Study. Eur Arch Otorhinolaryngol. 2017; 274, 2141–2148.
10. Scott Brown's Otolaryngology Eighth Edition : Volume 2. London, England: Hodder Arnold; 2018.
11. Shambaugh GE. Surgery Of The Ear. 4th Ed. London, England: W B Saunders; 2012
12. Marchioni D, Alicandri-Ciufelli M, Piccinini A, Genovese E, Presutti L; Inferior Retrotympanum Revisited: An Endoscopic Anatomic Study. Laryngoscope.2010; 120(9):1880–1886.
13. Holt JJ; The Ponticulus: An Anatomic Study. Otol Neuro-Tol. 2005; 26:1122Y4
14. Donaldson JA, Anson BJ, Warpeha RL, Rensink MJ; The Surgical Anatomy of The Sinus Tympani. Arch Otolarngol. 1970; 91: 219-227.
15. Shakeel M, Spielmann PM, Jones SE, Hussain SSM, Et Al. Direct Measurement of The RW Niche Dimensions Using A 3-Dimensional Moulding Technique - A Human Cadaveric Temporal Bone Study; Clin. Otolaryngol. 2015; 40:657-661.
16. Marchioni D, Alicandri-Ciufelli M, Grammatica A, Mattioli F, Presutti L (2010) Pyramidal Eminence And Sub pyramidal Space: An Endoscopic Anatomical Study. Laryngoscope 120(3):557–564
17. "Marchioni D, Alicandri-Ciufelli M, Pothier DD, Rubini A, Presutti L (2015) The RW Region And Contiguous Areas: Endoscopic Anatomy And Surgical Implications." Eur Arch Otorhinolaryngol 272(5):1103–1112

18. Marchioni D, Alicandri-Ciufelli M, Rubini A, Presutti L (2015) Endoscopic Trans canal Corridors To The Lateral Skull Base: Initial Experiences. Laryngoscope 125(Suppl 5):S1–S13

19. Bennett ML, Zhang D, Labadie RF, Noble JH (2016) Comparison Of Middle Ear Visualization With Endoscopy And Microscopy. Otol Neurotol 37(4):362–366

20. Yong M, Mijovic T, Lea J (2016) Endoscopic Ear Surgery In Canada: A Cross-Sectional Study. ("Endoscopic vs Microscopic Approach in Stapes Surgery: Advantages in the ...") ("Endoscopic vs Microscopic Approach in Stapes Surgery: Advantages in the ...") J Otolaryngol Head Neck Surg 19:45 (1:4)

21. NIEMCZYK K, BRUZGIELEWICZ A, WYSOCKI J, NITEK S, OLESIŃSKI T, *Sinus Tympani In Surgery Of The Middle Ear And Skull Base*, Otolaryngol Pol, 2003, 57(1):65–68.

22. OZTURAN O, BAUER CA, MILLER CC 3rd, JENKINS HA, *Dimensions Of The Sinus tympani And Its Surgical Access Via A Retrofacial Approach*, Ann Otol Rhinol Laryngol, 1996, 105(10):776–783.

23. HOLT JJ, *The Anatomy Of The Sinus Tympani*, Final Program & Abstract Book Of The 26th Politzer Society Meeting, 2007, Oct. 13–16, Cleveland, USA, 55.

24. HOLT JJ, *Posterior Sinus Of The Middle Ear*, Ann Otol Rhinol Laryngol, 2007, 116(6):457–461.

25. MĂRU NICOLETA, *Anatomical Criteria In The Evolution Of The Middle Ear Cholesteatoma*, Phd Thesis, "Iuliu Haţieganu" University Of Medicine And Pharmacy, Cluj-Napoca, 2006, 144–164.

26. Calli C, Pinar E, Oncel S, Tatar B, Tuncbilek MA. Measurements Of The FR Anatomy: Implications For Sparing The Facial nerve and Chorda Tympani During Posterior Tympanotomy. Ear Nose Throat J. 2010;89:490–4.

27. Dahm MC, Shepherd RK, Clark GM. The Postnatal Growth Of The Temporal Bone And Its Implications For Cochlear Implantation In Children. Acta Otolaryngol Suppl. 1993;505:4–27.

28. Eby TL, Nadol JB. Postnatal Growth Of The Human Temporal Bone: Implications For Cochlear Implants In Children. Ann Otol Rhinol Laryngol. 1986; 95:356–64.

29. Eby TL. Development Of The FR: Implications For Cochlear Implantation. Laryngoscope. 1996;106:1–7.

30. Bielamowicz SA, Coker NJ, Jenkins HA, Igarashi M. Surgical Dimensions Of The FR In Adults And Children. Arch Otolaryngol Head Neck Surg. 1988; 114(5):534–7.

31. Dahm M, Seldon HL, Pyman BC, Clark GM. 3D Reconstruction Of The Temporal Bone In Cochlear Implant Surgery. In: Yanagihara N, Suziki J, Editors. Transplants And Implants In Otology II. Amsterdam: Kugler; 1992. P. 271–5.

32. Parlier-Cuau C, Champsaur P, Perrin E, Rabischong P, Lassau JP. High-Resolution Computed Tomographic Study Of The Retrotympanum. Anatomic Correlations. Surg Radiol Anat. 1998;20(3):215–20.

33. Proctor B. Surgical Anatomy Of The Posterior Tympanum. Ann Otol Rhinol Laryngol. 1969;78(5):1026–40.

34. Palva T, Johnsson LG, Ramsay H. Attic Aeration In Temporal Bones From Children With Recurring Otitis Media: Tympanostomy Tubes Did Not Cure Disease In Prussak's Space. Am J Otol. 2000;21:485–93.

35. "Palva T, Ramsey H. Aeration Of Prussak's Space Is Independent Of The Supradiaphragmatic Epitympanic Compartment." ("Anatomical variants of tympanic compartments and their aeration ...") ("Prussak's Space: Anatomy Revisited - Research Posters") Otol Neurotol. 2007;28: 264–8.

36. Von Tröltsch A. Lehrbuch Der Ohrenheilkunde Mit Einschluss Der Anatomie Des Ohres. 7th Ed. Leipzig: FCW Vogel; 1881.

37. Mansour S Et Al. Chronic Inflammatory Otitis Media And The Anterior Epitympanic Recess. J Otolaryngol. 2005;34(3):149–59.

38. "Marchioni D. Lateral Endoscopic Approach To Epitympanic Diaphragm And Prussak's Space: A Dissection Study." ("Middle Ear Compartments | SpringerLink") ("Middle Ear Compartments | SpringerLink") ("Middle Ear Compartments | SpringerLink") Surg Radiol Anat. 2010;32(9):843–52.

39. Ozturan O, Bauer C, Miller C, Et Al. Dimensions of The Sinus Tympani, and Its Surgical Access Via Retrofacial Approach. Ann Otol Rhinol Laryngol. 1996;105: 776–83.

40. Nitek S, Wysocki J, Niemczyk K, Ungier E. The Anatomy Of The Tympanic Sinus. ("Kontakt - niteks.pl") ("Kontakt - niteks.pl") Folia Morphol (Warsz). 2006;65(3):195–9.

41. Amjad AH, Starke JJ, Scheer AA. Tympano-facial Recess In The Human Ear. Arch Otolaryngol. 1968;88(2): 131–7.

42. Thomassin JM, Danvin BJ, Collin M. Endoscopic Anatomy Of The Posterior Tympanum. Rev Laryngol Otol Rhinol (Bord). 2008;129(4–5):239–43.

43. "Marchioni D, Molteni G, Presutti L. Endoscopic Anatomy Of The Middle Ear." (“Endoscopic Anatomy of the Middle Ear | SpringerLink”) (“molteni g - PubMed Result”) Indian J Otolaryngol Head Neck Surg. 2011;63(2):101–13.

44. Skinner M, Honrado C, Prasad M, Kent HN, Selesnick SH. The incudostapedial joint angle: Implications for stapes surgery prosthesis selection and crimping. Laryngoscope [Internet]. 2003;113(4):647–53.

45. Bekci T, Hizli O, Ozturk M, Yildirim G. Quantitative three-dimensional computed tomography analysis of Sinus Tympani volume in temporal bones with petrous apex pneumatization. Auris Nasus Larynx [Internet]. 2020;47(4):587–92.

ANNEXURE - I

ETHICAL CLEARANCE CERTIFICATE

K.L.E. ACADEMY OF HIGHER EDUCATION AND RESEARCH
(Deemed - to-be-University)
Accredited 'A' Grade by NAAC (2nd Cycle) Placed in Category 'A' by MHRD (GoI)
JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA INDIA)
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Principal: 2471701
Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 67 **Date: 25/01/2021**

To,

Dr. Sneha A Sankaran
PG student in Otorhinolaryngology and Head & Neck Surgery,
J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"ANALYSIS OF VOLUME AND DIMENSIONS OF MIDDLE EAR CAVITY USING OTOFORM: A CADAVERIC TEMPORAL BONE STUDY"**, is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Smita Sonoli)
Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Harsha Hegde)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

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ANNEXURE - II

PROFORMA

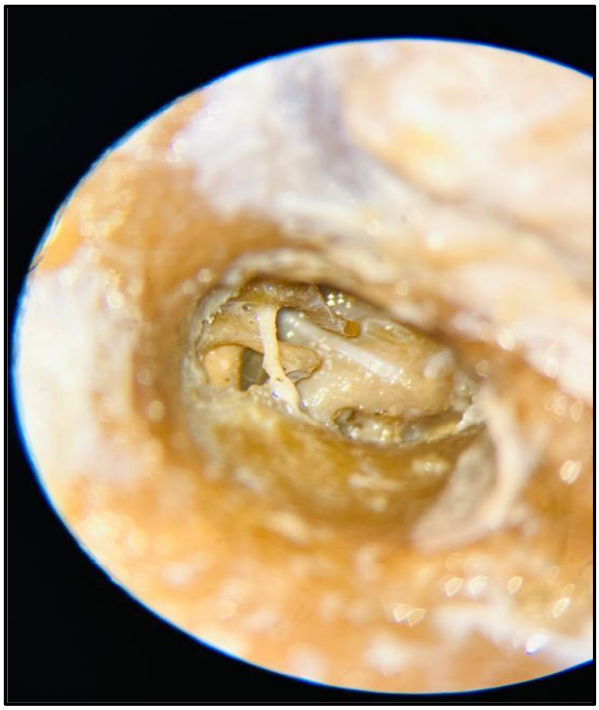
"ANALYSIS OF VOLUME AND DIMENSIONS OF THE MIDDLE EAR CAVITY USING OTOFORM : A CADAVERIC TEMPORAL BONE STUDY"

I.	DATE:		
II.	SPECIMEN NUMBER:		
III.	CHILD/ADULT: AGE(IFKNOWN) :		
IV.	SIDE:	RIGHT (R) / LEFT (L)	
V.	EXTERNAL EAR:	PINNA PRESENT/ABSENT:	P / A
		PREAURICULAR REGION ANOMALIES: (PRESENT/ABSENT)	P / A
		POSTAURICULAR REGION ANOMALIES: (PRESENT/ABSENT)	P / A
		EXTERNAL AUDITORY CANAL: (PATENT/ATRETIC)	P / A
		TYMPANIC MEMBRANE: (INTACT/NOT INTACT)	I / N
5.	MASTOID REGION:	MASTOID TIP:	A. PROMINENT B. NOT- PROMINENT
		PNEUMATIZATION:	A. PNEUMATIC B. SCLEROTIC C. DIPLOIC D. MIXED
6.	MIDDLE EAR CAVITY:	OSSICULAR CHAIN STATUS:	A. INTACT B. NOT INTACT
		INCUDOSTAPEDIAL JOINT ANGLE:	
		DISTANCE OF INCUDOSTAPEDIAL JOINT FROM POSTERIOR BONY WALL:	

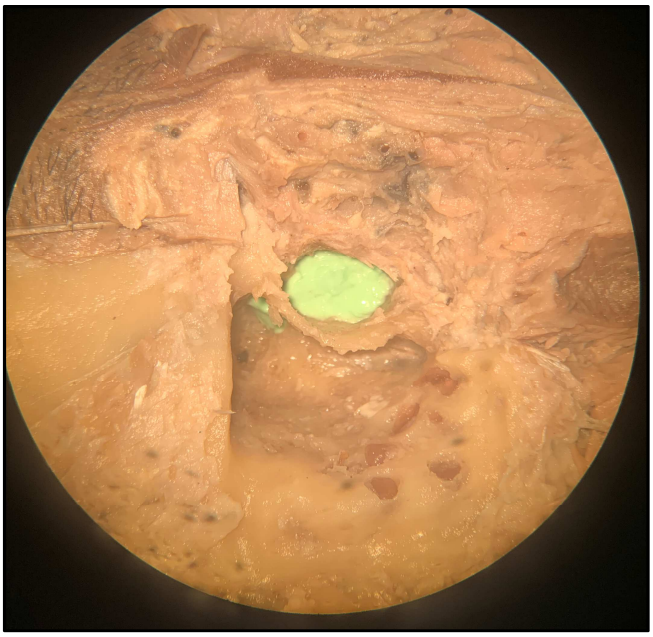
		DISTANCE OF INCUDOSTAPEDIAL JOINT FROM HANDLE OF MALLEUS: VOLUME OF MIDDLE EAR CAVITY: VOLUME OF THE SINUS TYMPANI: VOLUME OF SINUS SUBTYMPANICUS: PONTICULUS: SUBICULUM: FINNICULUS: LENGTH OF THE TENSOR CANAL UPTO COCHLEARIFORM PROCESS: EUSTACHIAN TUBE DIMENSIONS:	A. COMPLETE. B. INCOMPELETE. A. RIDGE. B. BRIDGE. C. ABSENT. A. RIDGE. B. BRIDGE. C. ABSENT.
7.	REMARKS:		

ANNEXURE – III → PHOTOGRAPHS

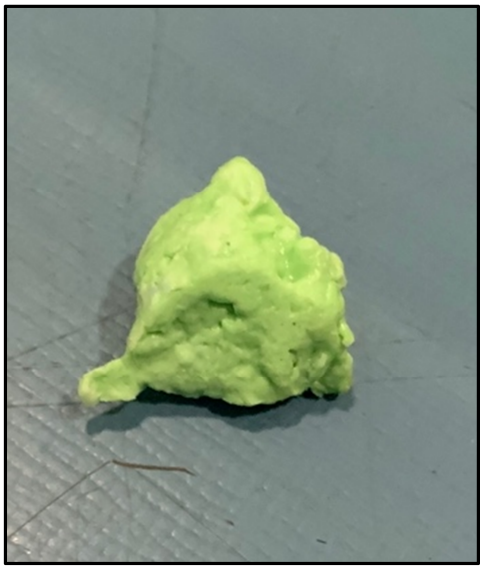
1. Specimen showing Cortical mastoidectomy



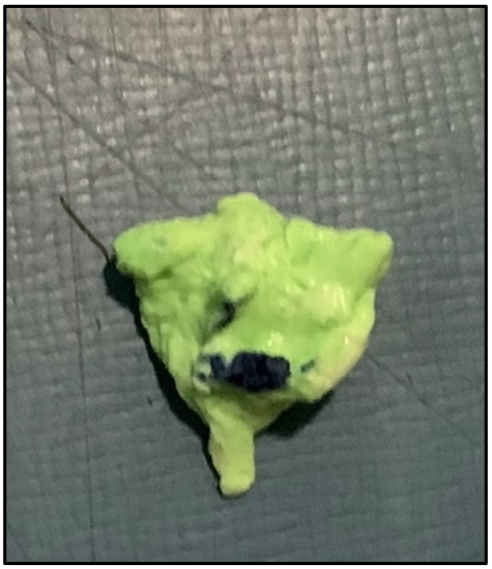
2. Specimen showing incudo-stapedial joint after canaloplasty



3. Middle ear cavity filled with Otoform mould



4. Otoform from the middle ear cavity



5. Mould showing Sinus Tympani marked using permanent marker

ANNEXURE – IV → MASTER CHART

	Master Chart																
S. No	Ear	External Ear					mastoid		Middle Ear Cavity								
		Pinna	Pre Auricular Anamolies	Post auricular Anamolies	External ear canal	Tympanic membrane	Mastoid tip	Pneumatization	Ossicular chain Status	Incudostapedial Angle	Volume of middle ear Cavity (ml)	Volume of sinus tympani (cu. mm)	Volume of sinus sub tympanicus (cu . mm	Ponticulus	Subiculum	Finniculus	ET diameter(mm)
1		present	absent	absent	patent	intact	Prominent	diploic	intact	76	0.9	9.18	154.6	complete	incomplete	bridge	0.21
2		present	absent	absent	patent	intact	Prominent	diploic	intact	82	1	8.4	123.6	complete	complete	ridge	3.1
3		present	absent	absent	patent	intact	Prominent	diploic	intact	84	1	7.08	134.7	complete	Absent	ridge	2
4		present	absent	absent	patent	intact	Prominent	diploic	intact	80	1	9	143.7	incomplete	complete	bridge	2.9
5		present	absent	absent	patent	intact	Prominent	diploic	intact	89	1.1	10.71	156.8	complete	complete	ridge	2.6
6		present	absent	absent	patent	intact	Prominent	diploic	intact	86	1.2	8.9	153.9	incomplete	complete	ridge	2.3
7		present	absent	absent	patent	intact	Prominent	diploic	intact	83	1.3	7.3	133	incomplete	complete	bridge	3
8		present	absent	absent	patent	intact	Prominent	diploic	intact	85	1.5	6.8	132	complete	complete	ridge	3.3
9		present	absent	absent	patent	intact	Prominent	diploic	intact	81	1.6	10.82	165.9	complete	complete	bridge	3.2
10		present	absent	absent	patent	intact	Prominent	diploic	intact	79	1.1	9.16	156.8	complete	complete	ridge	3.1
11		present	absent	absent	patent	intact	Prominent	diploic	intact	75	1.3	7.05	187.9	complete	complete	ridge	2.8
12		present	absent	absent	patent	intact	Prominent	diploic	intact	82	1.1	8.23	165	incomplete	incomplete	ridge	2.5
13		present	absent	absent	patent	intact	Prominent	scleortic	intact	81	1.7	9.23	143	complete	complete	bridge	2.6
14		present	absent	absent	patent	intact	Prominent	diploic	intact	83	1	10.02	176	complete	complete	ridge	3
15		present	absent	absent	patent	intact	Prominent	diploic	intact	84	0.9	10.91	153	complete	Absent	bridge	2.3
16		present	absent	absent	patent	intact	Prominent	pneumatised	intact	85	0.7	9	132	incomplete	complete	ridge	2.7
17		present	absent	absent	patent	intact	Prominent	diploic	intact	88	0.6	7.06	145	incomplete	Absent	ridge	2.8
18		present	absent	absent	patent	intact	Prominent	diploic	intact	89	1	8	134.6	incomplete	complete	bridge	3
19		present	absent	absent	patent	intact	Prominent	diploic	intact	78	0.8	9.1	134.8	complete	Absent	bridge	2.8
20		present	absent	absent	patent	intact	Prominent	diploic	intact	83	0.7	8.2	127.8	complete	complete	ridge	3.1
21		present	absent	absent	patent	intact	Prominent	diploic	intact	85	1.1	9.6	165.8	complete	incomplete	ridge	3.4
22		present	absent	absent	patent	intact	Prominent	sclerotic	intact	82	1.3	9	145.7	incomplete	incomplete	bridge	3.2
23		present	absent	absent	patent	intact	Prominent	diploic	intact	83	1.2	8.54	150.8	complete	complete	ridge	3.1
24		present	absent	absent	patent	intact	Prominent	diploic	intact	81	1.7	7	149.6	complete	complete	ridge	2.9
25		present	absent	absent	patent	intact	Prominent	diploic	intact	87	1.4	6.5	134.8	complete	incomplete	bridge	2.8
26		present	absent	absent	patent	intact	Prominent	diploic	intact	90	1.2	9.1	157.8	complete	complete	ridge	3.5
27		present	absent	absent	patent	intact	Prominent	pneumatised	intact	87	1	10.51	154.9	complete	complete	bridge	3.6
28		present	absent	absent	patent	intact	Prominent	diploic	intact	87	1.1	10.54	143.9	incomplete	Absent	ridge	3.2
29		present	absent	absent	patent	intact	Prominent	diploic	intact	85	1.2	10	175	complete	complete	ridge	3.1
30		present	absent	absent	patent	intact	Prominent	diploic	intact	83	1.4	8.1	154.9	complete	complete	bridge	2
31		present	absent	absent	patent	intact	Prominent	diploic	intact	82	1.2	7.09	145.8	complete	complete	bridge	2.3
32		present	absent	absent	patent	intact	Prominent	diploic	intact	81	1	8.09	134.9	incomplete	Absent	ridge	3.4
33		present	absent	absent	patent	intact	Prominent	diploic	intact	80	0.9	10.15	145.9	incomplete	Absent	ridge	3.1
34		present	absent	absent	patent	intact	Prominent	sclerotic	intact	86	1	9.01	134.7	incomplete	complete	bridge	2.9
35		present	absent	absent	patent	intact	Prominent	diploic	intact	84	1.8	8.01	134.8	complete	incomplete	ridge	3
36		absent	absent	absent	patent	intact	Prominent	diploic	intact	83	1.4	9.1	156.8	incomplete	complete	bridge	3.2
37		absent	absent	absent	patent	intact	Prominent	pneumatised	intact	87	1.9	9	143.5	complete	incomplete	bridge	3.1
38		absent	absent	absent	patent	intact	Prominent	diploic	intact	82	1.2	10.21	145.8	incomplete	complete	ridge	2.8
39		absent	absent	absent	patent	intact	Prominent	diploic	intact	86	1	10	150.8	complete	Absent	bridge	2.7
40		absent	absent	absent	patent	intact	Prominent	diploic	intact	83	1.1	7	150.3	complete	incomplete	bridge	3