
**"THE INTRATEMPORAL COURSE VARIATIONS OF FACIAL
NERVE IN WET CADAVERIC TEMPORAL BONES: AN
OBSERVATIONAL STUDY IN KLES DR. PRABHAKAR KORE
HOSPITAL, BELAGAVI."**

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LIST OF ABBREVIATIONS

GLOSSARY	ABBREVIATIONS
<i>a.</i>	artery
b/w	between
CN	Cranial Nerve
DR	Digastric Ridge
EAC	External Auditory Canal
EAM	External Auditory MEatus
ECA	External Carotid Artery
F _l	Labyrinthine segment of facial nerve
F _m	Mastoid Segment of facial nerve
FN	Facial Nerve
F _t	Tympanic Segment of facial nerve
GG	Geniculate Ganglion
GSPN	Greater Superficial Petrosal Nerve
ICA	Internal Carotid Artery
LSCC	Lateral Semicircular Canal
MCF	Middle Cranial Fossa
MMA	Middle Meningeal Artery
PC	Processus Cochleariformis
PCF	Posterior Cranial Fossa
PoE	Point of Emergence
PSCC	Posterior Semicircular Canal
SAN	Spinal Accessory Nerve

SCC	Semicircular Canal
SMF	Stylomastoid Foramen
SoH	Spine of Henle
SPI	Short Process of Incus
SS	Sigmoid Sinus
SSCC	Superior Semicircular Canal
TBD	Temporal Bone Dissection

ABSTRACT:

Title: “The intratemporal course variations of facial nerve in wet cadaveric temporal bones: an observational study in KLES Dr. Prabhakar Kore Hospital, Belagavi.”

Background and Objectives: Facial nerve controls facial expression, and this is an essential component of human social communication. The 7th cranial nerve or the facial nerve, is highly tortuous through its course, and has the longest course through a bony canal out of all the nerves in body. It is divided into various parts as it traverses from its intracranial till it ends into five end branches. The intratemporal part travels in a bony canal, and in case of any pre-existing bony dehiscences, is highly vulnerable to iatrogenic injuries during middle ear and mastoid surgeries (incidence = 0.6%-3.7% in otological procedures). The paralysis of facial nerve is one the most noticeable neuropathy out of all cranial nerves. Iatrogenic injury to this tortuously coursing nerve is one of the otorhinolaryngology surgeon’s greatest fears during ear surgery. Therefore, the surgeon who works in this area needs perfect anatomic knowledge as well as experience, and this is can be achieved by repeated temporal bone dissections. Few studies, especially in India, have been performed on morphometric relations like depth from fixed surgically accessible reference landmarks of facial nerve with other structures of temporal bone. The objective of this study is to acquire a thorough knowledge of intratemporal course of facial nerve and its variations and extrapolating the knowledge of it in a live real surgery, aiming to reduce the risk of facial nerve injuries. The study also aims to understand the surgical anatomy of the facial nerve related structures.

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. The bones were obtained from the anatomy dissection hall of J. N. Medical College, KAHER, Belgaum. Photographs of dissection were taken at various stages. 25 temporal bones were removed and saw cut from the cadavers available in the anatomy dissection hall. The dissection was carried out and various findings and measurements were recorded and appropriate photographs taken.

Results: Out of the 25 bone studies, Spine of Henle was prominent in 84% of bones and in the bones where it was not prominent, it's cribriform appearance can be used to decide the direction of drilling and estimate position of antrum. The average depth of mastoid antrum was 13.2mm. The average length of F_m was found to be 9.80mm and was one of the most variable parameters. The average depth of second genu was 15.2mm and that of lower end of F_m was 11.1mm, and hence F_m showed lateral deviation through its course in mastoid. The average length of F_t was found to be 9.5mm. The average distance between posterior edge of oval window and F_t was 4.21mm. Processus Cochleariformis served as most constant landmark for facial nerve, & was found to lie at an average distance of 1.80mm from geniculate ganglion. F_t was found to be 1.7mm deep to the anterosuperior part of bony annulus, and came to lie more laterally as it approached 2nd genu. Blood vessels served as another indicator of proximity to facial nerve, and were found to be most abundant near 2nd genu. Average length of labyrinthine segment was 3.29mm.

Conclusion: At the end of study, it was inferred that Isolated facial nerve anomalies are rare, and are usually found only in association with other developmental middle ear anomalies. Apart from this, minute morphometric variations form the basis of iatrogenic facial nerve injuries. Although various advanced technological modalities, like pre-operative imaging, can help delineate the course and relation to other middle ear structures, which may vary microscopically from one individual to other; the temporal bone dissection till date holds an indispensable place to prepare an otologist to avoid an iatrogenic injury to FN and also to approach it to address nerve pathologies.

TABLE OF CONTENTS

SL.NO	CONTENTS	PAGE NO.
1	INTRODUCTION	1-3
2	OBJECTIVE	4
3	REVIEW OF LITERATURE	5-26
4	MATERIALS AND METHODS	27-29
5	RESULTS	30-38
6	DISCUSSION	39-50
7	CONCLUSION	51-53
8	SUMMARY	54-55
8	BIBLIOGRAPHY	56-60
9	ANNEXURES	
	Annexure I: Ethical Clearance Letter	61
	Annexure II: Proforma	62-64
	Annexure III: Photographs	65-68
	Annexure IV: Key to Master Chart	69
	Annexure V: Master Chart	70-71

LIST OF FIGURES

SL.NO	FIGURE DESCRIPTION	PAGE.NO
01	Leonardo da Vinci's illustration of brain without brainstem showing various cranial nerves emerging from it	5
02	Vesalius' demonstration of cochleovestibular + facial nerve	6
03	Eustachio's demonstration of facial nerve as a separate entity and its branches	7
04	Diagrammatic representation of embryo at 3-4weeks, with facioacoustic primordium	9
05	Branching and communications with other nerves at 7 th through 13 th weeks	9
06	Intracranial relations of facial nerve	11
07	Relation of Facial nerve and Nervus Intermedius through IAC	13
08	Facial nerve course through Fallopiian Canal	13
09	Relation of facial nerve with cochlea, labyrinth, GSPN and geniculate ganglion	15
10	Course of facial nerve through middle ear and its relations	16
11	7 th cranial nerve and its arterial supply	20
12	Decompression of FN along whole length	23
13	Measurements according to proforma	29

LIST OF TABLES

Sl.No	TABLE	Pg. No.
1	Side wise distribution	30
2	Pinna- Present/ Absent	31
3	Tympanic membrane	31
4	Prominence of Spine of Henle	32
5	Ossicular chain status	32
6	Mastoid tip prominence	33
7	Pneumatisation of mastoid	34
8	Digastric ridge prominence	35
9	Summary or descriptive statistics of parameters related to mastoid segment	36
10	Summary or descriptive statistics of parameters related to tympanic and labyrinthine segments	37
11	Dehiscence in fallopian canal	38
12	Measurements of dehiscence in fallopian canal	39

LIST OF GRAPHS

Sl.No	TABLE	Pg.no
1	Side-wise distribution	30
2	Pinna	30
3	Tympanic membrane	31
4	Spine of Henle	32
5	Status of Ossicular Chain	32
6	Mastoid tip prominence	33
7	Pneumatisation of Mastoid	34
8	Digastric ridge prominence	35
9	Dehiscence in fallopian canal	38

LIST OF PHOTOGRAPHS

SL.NO	FIGURE DESCRIPTION	PAGE.NO
01	Specimen showing SoH, Handle of malleus, chorda tympani	65
02	Specimen showing the chorda tympani arising (black arrow) from the main trunk at SMF.	65
03	Facial recess approach	66
04	F _t relation with oval window.	66
05	Processus Cochleariformis in relation with F _t and adjacent to GG	67
06	Variation in Processus Cochleariformis	67
07	Intratemporal course of facial nerve.	68
08	Facial nerve in anterosuperior quadrant of IAC	68

INTRODUCTION

Facial nerve controls facial expression, and this is an essential component of human social communication. The 7th cranial nerve or the facial nerve, is highly tortuous through its course, and has the longest course through a bony canal out of all the nerves in body. Any middle ear pathologies may affect 7th cranial nerve and these may cause paresis or paralysis of the nerve. The facial nerve involvement incidence increases if associated with an anatomical anomaly of middle ear and its structures, which is usually developmental. The advancement of technology in otological surgeries, especially operating microscopes, has inculcated a new interest in microscopic anatomy of ear and related structures. Now we have a better understanding of development related anatomy, and this in turn has led to various aspects of variations in middle ear structures and its surgical aspects.⁽¹⁾

The facial nerve supplies structures of 2nd pharyngeal arch. The nerve has multiple functions that include general and visceral sensorimotor. General motor function is to supply control of striated facial and neck muscles. Its segment that courses through petrous bone has following branches: GSPN or greater superficial petrosal nerve, nerve to stapedius muscle and chorda tympani.⁽²⁾ This portion again is divided into 2 segments for better understanding: (a) IAC segment (the part that traverses through internal auditory canal) (b) Fallopien canal (the part that traverses in a bony canal with the same name). the first part of facial or fallopien canal is traversed by the labyrinthine segment of nerve, which measures about 3-5mm and is also the narrowest part of the canal. ⁽³⁾⁽⁴⁾ Just superolateral to cochlea, the 7th cranial nerve takes sharp turn forward, approximately at 90 degrees to petrous long axis, to reach geniculate ganglion. Here this nerve forms a hairpin bend and turns towards the

posterior direction. This hairpin turn is known as '1st genu' (genu= turn). The GSPN emerges at geniculate ganglion. Next, the horizontal segment of facial nerve, known as the tympanic segment (since it runs antero-posteriorly through medial bony wall in the middle ear cavity) is about 10-12mm length and extends from 1st genu to the 2nd genu. This lies perpendicular to the petrous long axis. Just before turning vertically to form the second genu, it lies between oval window below & dome of horizontal semicircular canal (LSCC) above. Next is vertical part which is also known as the mastoid segment (it runs in anterior wall of mastoid super-inferiorly extending from 2nd genu to the stylomastoid foramen, where it exits the skull base and continues its extratemporal course) and measures about 13-15 mm in length. The vertical segment (13–15 mm) gives a muscular branch to stapedius near pyramidalis process, and the branch is known as “nerve to stapedius”. Another branch arising from this segment is “chorda tympani”, which is given off approximately 5mm above stylomastoid foramen. ⁽³⁾

The paralysis of facial nerve paralysis is one the most noticeable neuropathy out of all cranial nerves. Iatrogenic injury to this tortuously coursing nerve is one of the otorhinolaryngology surgeon's greatest fears during ear surgery. Leaving aside the potential medico-legal issues that might flow from a palsy that could have been avoided or the risk of acquiring it reduced, it has drastic negative consequences on patient's life quality due to its noticeability as it supplies facial expression muscles. Even with the advent of multiple advanced technologies in this field, the risk of iatrogenic facial nerve injuries stays high (incidence = 0.6%-3.7% in otological procedures). In revision surgeries on middle ear and mastoid, the frequency further increases to almost 10%. ⁽⁵⁾

Therefore, the surgeon who works in this area needs perfect anatomic knowledge as well as experience, and this is can be achieved by repeated temporal bone dissections.

Few studies, especially in India, have been performed on morphometric relations like depth from fixed surgically accessible reference landmarks of facial nerve with other structures of temporal bone. Hence, our study makes an attempt to observe the average morphometric values of 7th CN related to other intratemporal structures and hence address these deficiencies.

OBJECTIVE

- The objective of this study is to acquire a thorough knowledge of intratemporal course of facial nerve and its variations and extrapolating the knowledge of it in a live real surgery, aiming to reduce the risk of facial nerve injuries.
- The study also aims to understand the surgical anatomy of the facial nerve related structures.

REVIEW OF LITERATURE

History of discovery of facial nerve and its anatomy⁽⁶⁾

- **Galen (Greek Physicist):** First description presents from as early as third century. Galen's in his animal descriptions described the present-day 5th, 6th and 7th nerves as single nerve that after entering internal auditory meatus separate into 2 distinct parts- soft part that forms present day auditory nerve "portio mollis" and hard part which is present day facial nerve "portio dura".
- Various mention and description of primitive understanding in following manuals:
 - 1025- "*Canon of Medicine*" (**Avicenna**)
 - 1362- "*Cyrurgia*" (**Guy de Chauliac**)
 - 1491- "*Fasciculus Medicinae*" (**Johannes van Ketham**)
 - 1501- "*Anathomia*" (**Mondino**)
- **Leonardo da Vinci (1452- 1519; Italian polymath):** first illustrations of identifiable cranial nerves in human models. From years 1492 through 1506, his diagrams showed 6 pairs of CN from brain (lacking brainstem). They were marked in a different sign language, but comparing their description to the modern-day knowledge revealed, that his drawings described olfactory, optic, vagus, oculomotor nerves, and 2 nerves from a separate site in brain that supplied face. The functions of these nerves were still unclear at this point.



Figure 1. Leonardo da Vinci's illustration of brain without brainstem showing various cranial nerves

- At this point, a primitive method of dissection was used which included a total craniectomy, followed by release of brain from soft tissues leaving the nerves intact, mobilizing brain to visualize emergence of various nerves from brain and exit of these from cranium fossa via various foramen.

- **Andreas Vesalius (Renaissance physician):**

In his book “*Fabrica*” (1543), he demonstrated that facial nerve was responsible for facial expressions. He said that at IAM, single nerve exists that later gives off “fifth nerve”, and facial and vestibulocochlear nerve existed as a single trunk emerging from single point from brain.

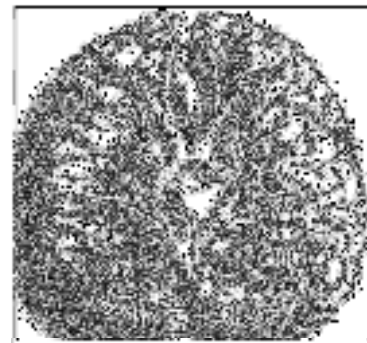


Figure 2. Vesalius' demonstration of cochleaovestibular + facial nerve (CF) (6)

- **Fabrici (De aure, auditus organo; 16th century):** He described a more effective method of dissection which was further used by the following scientists to carry out their studies. Temporal bones were separated from skull using sharp saw, to maintain smooth borders that will help in facilitating an unobscured vision using natural or candle light. The bones after removing their soft tissues, were either held in anatomical positions by hand, or secured using a vise. Chisel or a sharp knife was used to strike an oblique cut over roof of IAC and small fragments of bone were removed using tweezers. The same was done to delineate the full course of facial nerve. This is the closest to the modern day technique, that was described in earlier catalogs.
- **Gabriele Fallopio (Italian anatomist; 1523- 1562):** His account on facial canal (“*Observationes*”) showed intratemporal and peripheral courses of FN/. He

describes geniculate ganglion, genus of facial nerve, its exit from skull base at SMF, supply to the digastric and stylohyoid muscle. His study was limited in understanding the extratemporal course due to difficulty faced in separating the FN branches from parotid gland.

- **Bartolomeo Eustachio (Italian anatomist; 1505- 1574):** His observations were recorded in his books named “*Tabulae anatomicae*” (1538) and “*Opuscula*” (1564) demonstrated 7th and 8th nerve to be distinct nerves, terminal branches of facial nerve to the muscles of expression.



Figure 3. Eustachio's demonstration of facial nerve as a separate entity and its branches (6)

History of facial nerve surgeries:⁽⁷⁾

- **Sir Charles Bells (1829):** Identified FN as nerve of facial expression
- **Schwartz & Eyesell (1873):** Technique of cortical mastoidectomy (done using chisel and mallet without microscope)
- **Drobnik (1879):** Reinnervation in a divided facial nerve, by connecting it to SAN
- **Ballance (1894):** Attempt at direct facial nerve repair
- **Bunnell (1925):** Successful facial nerve repair
- **Alt, Cawthorne, Kettel, Pulec (1908 to 1969):** Facial nerve decompression
- **Conley, Miehle, Svcarrella, Ruben, Harii (1970 to 2000):** Various prognostic, diagnostic and therapeutic developments in relation with facial nerve pathologies

Embryology

Various anomalies of 7th cranial nerve can be understood via a thorough understanding of embryologic development. Facial nerve development occurs in first three months during embryonic life and this is the period during which its course, branching pattern, relationship to the surrounding structures is established. It develops from the second branchial arch closely related in time, to external & middle ear development from first pharyngeal cleft (that gives rise to external auditory meatus and canal- EAM & EAC), pharyngeal arch (incus, malleus), and pharyngeal pouch (that gives rise to middle part of ear & eustachian tube). Hence, any anomalies in external & middle ear should raise a suspicion for associated facial nerve anomalies.⁽⁸⁾

Facial nerve arises from the facio-acoustic primordium which develops during the third week of embryonic development and at this point there are no branches. During 4th week development, nerve divides into two parts- main trunk & chorda tympani. During next few weeks (5th and 6th) chorda tympani courses ventrally to enter mandibular arch, via first pharyngeal pouch and terminates close to what will develop into lingual nerve later, whereas main trunk ends in hyoid arch mesenchyme. Meanwhile, cephalic muscles including that of facial expressions, start developing from four mesenchymal laminae from second arch namely occipital, cervical, mandibular and temporal laminae. These constitute the superficial layer. The deep layer, later during the 6th week develop into posterior digastric complex. During 7th through 9th weeks, facial nerve gives off multiple peripheral branches that supply the muscles of second pharyngeal arch. First during 8th week, stapedius nerve, faciotemporal and faciocervical part becomes apparent, & by end of 8th week, rest of terminal branches form.⁽⁸⁾ The nervus intermedius appears and passes into the

brainstem between auditory nerve (8th CN) and the motor branch of 7th CN. ⁽⁹⁾ During 10th week, extensive communications start with branches of trigeminal nerve. While the nerve is still in middle ear at this point, it now turns vertically to continue its course and forms the second genu. By the end of 12th week, all the branches of facial nerve are well formed, and by 15th week, its relationships to other middle ear structures become fully developed. All communications of facial nerve with other cranial nerves and their branches are fully established by 16th week. From this time until birth, fallopian canal ossification progresses and is closed by bone by 35th week, but 25 percent facial aqueducts show dehiscence, and most commonly so near oval window. ^{(10) (11)}

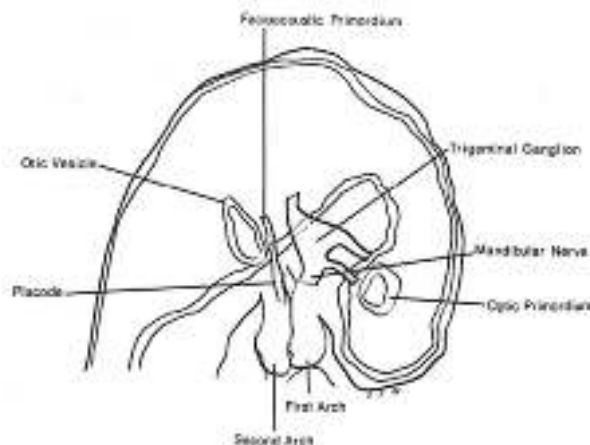


Figure 4. Diagrammatic representation of embryo at 3-4 weeks, with facioacoustic primordium ⁽⁷⁾

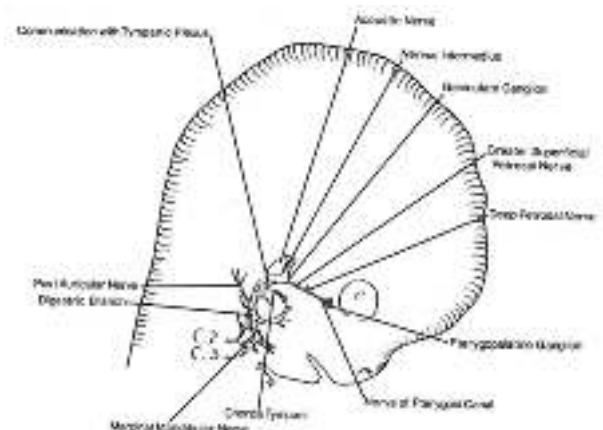


Figure 5. Branching and communications with other nerves at 7th through 13th weeks ⁽⁷⁾

Facial Nerve Connections

- 7th week: Lesser Superficial Petrosal Nerve begins to develop from geniculate and reaches glossopharyngeal ganglia. Also nearing this time, the branch that supplies stapedius appears ⁽¹²⁾.

- 12th & 13th weeks: 2 branches from 7th CN between branch to stapedius & chorda tympani, fuse with each other to reach superior ganglia of 10th CN and glossopharyngeal nerve to give a sensory nerve that supplies posterosuperior aspect of EAC, called Arnold's nerve. This region of supply by Arnold's nerve is also called the Ramsay Hunt Area.
- 17th week: The nerve forms definitive communications with 2nd and 3rd cervical nerves, 5th, 9th and 10th cranial nerves.⁽¹³⁾

Surgical Anatomy

7th CN shows a highly tortuous course, and along with that is the longest nerve to course through a bony canal, making it highly susceptible for iatrogenic injuries while performing otological surgeries.⁽¹⁴⁾ Although the course of nerve does not show much significant variations, the microscopically variable route and bony dehiscences in the fallopian canal make this nerve and its course a subject of constant interest and research.

As described earlier, it is nerve of 2nd pharyngeal arch and has motor and somatosensory components (somatosensory by Nervus Intermedius/ Pars Intermedia of Wrisberg nerve).

Fibres of facial nerve:

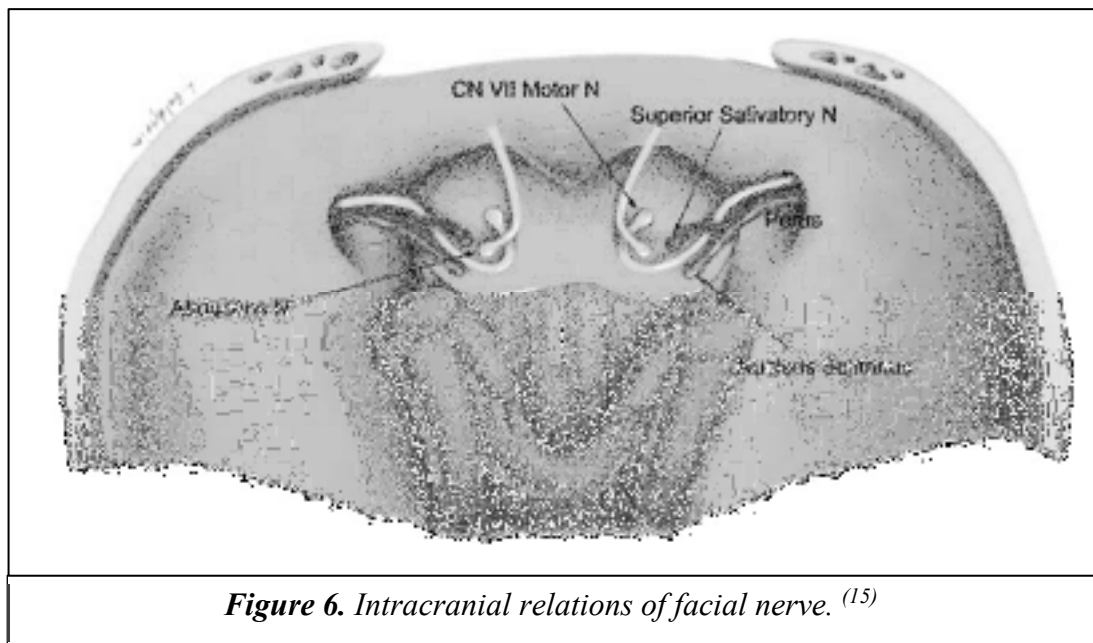
- 10,000 neurons (approximately)
- 7,000 that form motor component (myelinated)
- 3,000 that form nervus intermedius that carries-
 - Afferent fibres for taste from ant. 2/3rd of tongue through chorda tympani
 - Afferent fibres for taste from soft palate through palatine nerve and GSPN

- Secretory innervations (parasympathetic fibres) innervate glands of head and neck (submandibular and sublingual salivary glands, and lacrimal glands).

- Sensory fibres from Ramsay Hunt Area (cutaneous supply).⁽¹³⁾

The facial nerve arises from 3 nuclei in brainstem.

1. Motor nucleus (present in ventrolateral pons)- gives efferent motor fibres. ⁽¹⁵⁾
2. Preganglionic arise from the superior salivatory nucleus.
3. Sensory fibres relay in nucleus tractus solitarius.⁽¹⁶⁾



The nerve makes an exit at the junction between pons and medulla and travels through CPA (cerebellopontine angle), enters internal auditory meatus. It then continues its intratemporal course in fallopian canal to exit through stylomastoid foramen to traverse extra-temporally and later dividing into end branches.⁽¹⁷⁾

1. **The Cerebellopontine Angle (CPA) Segment**

Cortical control is by the inputs from motor face area in precentral and postcentral gyri—internal capsule—midbrain—pons, via corticobulbar tract. These

fibres serving the forehead are bilaterally innervated, rest of the face are unilaterally innervated.

As described earlier, the nerve makes an exit from brainstem at pontomedullary junction, about 1.5mm anteriorly to the VIII cranial nerve.⁽¹⁸⁾ it then traverses in the cerebellopontine angle for 15-17 mm to enter IAM porus. The diameter of the nerve in this segment is 1.8mm, smaller than the diameter of VIII CN (3 mm). nervus intermedius is the smallest nerve seen in this region that emerges between the two abovementioned nerves.

2. Internal Auditory Canal Segment (IAC)

IAC is compartmentalized into 4 quadrants by one horizontal bony crest- crista falciformis and a vertical bony bar- Bill's bar. The 7th CN occupies superior & anterior quadrant during its course in IAC & measures about 8-10mm⁽¹⁹⁾. The cochlear nerve lies below it, i.e., in the anteroinferior quadrant and nervus intermedius passes between the two nerves in the anterior compartment. These relations are shown in Figure 7⁽²⁰⁾. At the end of IAC, i.e., IAC fundus, the nerve starts coursing through facial canal and transition segment between IAC and facial canal is named as "meatal" segment (here the bony canal is the narrowest- 0.65 mm in diameter). Here the facial nerve sheath is formed only by the pia mater. Hence this is most common site of nerve compression in inflammation and related pathologies like Bell's palsy and RHS (Ramsay Hunt Syndrome).⁽¹³⁾

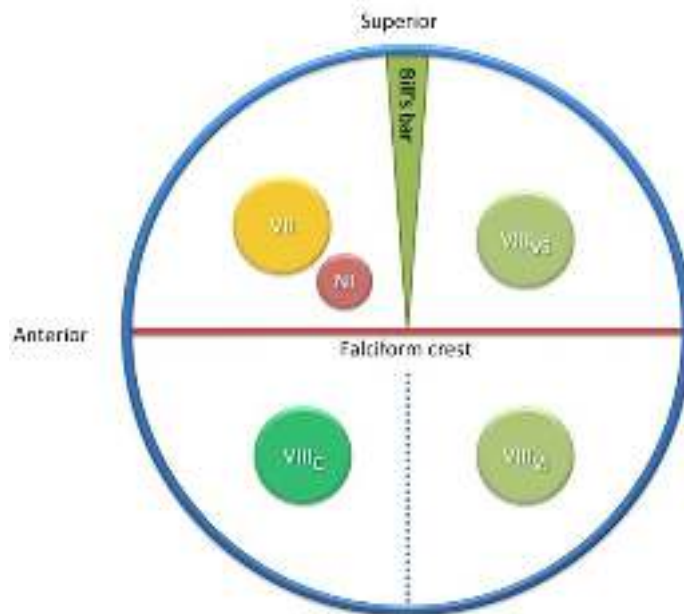


Figure 7. Relation of Facial nerve and Nervus Intermedius through IAC. (VII) Facial nerve, (NI) nervus intermedius, (VIII c) Cochlear nerve, (VIII vs) superior

3. **The Fallopian Canal:** The nerve course through temporal bone in its bony canal, i.e., fallopian canal (named after Gabriel Fallopius), and this length sums up to 25-30mm. The course of nerve through fallopian canal is divided into 3 segments separated by two genus.⁽¹³⁾

1. Meatal segment
2. Tympanic segment
3. Mastoid segment

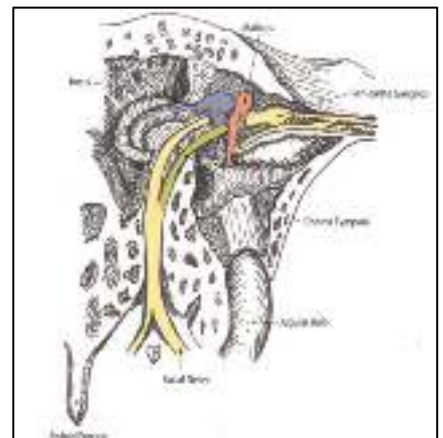


Figure 8. Facial nerve course through Fallopian Canal ⁽²¹⁾

Meatal and tympanic segment are separated by 1st genu, and tympanic and mastoid segment by the 2nd genu, details of which will be discussed further.

The nerve after entering fallopian canal traverses laterally and anteriorly between semicircular canals and cochlea up to the 1st genu where it makes a sharp turn posteriorly. After this it completes its course through tympanic cavity, mastoid

and exits skull base through stylomastoid foramen. This fallopian segment is the most important division of the facial nerve is most important division concerned with the middle-ear and its reconstructive surgery.⁽¹⁷⁾

3.1. Labyrinthine Segment

Extending from the meatal foramen to the geniculate ganglion, it measures about 3-5 mm in length, and forms the narrowest as well as shortest segment of intrafallopian facial nerve. The segment is narrowest at the meatal segment ⁽⁴⁾. It travels anterolaterally, forming an angle of 120° with the IAC portion. Anterior to posterior relations of the nerve include basal turn of cochlea, the facial nerve and anterior part of vestibule in that order. At the point where nerve reaches just superolateral to the cochlea, it angles sharply forward (almost 90° to the petrous bone long axis) to reach geniculate ganglion and forming 1st genu. Through its course in IAC and labyrinthine segment, the main trunk and nervus intermediate travel separately and join to form single nerve just before reaching geniculate ganglion.

3.2. Geniculate Ganglion

Situated at the end of labyrinthine segment, this is where the cutaneous sensory fibres from auricular branch and taste fibres from the chorda tympani synapse with 2nd sensory neurons. Whereas the parasympathetic fibres to lacrimal glands merely pass-through geniculate ganglion without synapsing, and form the greater petrosal nerve that continues antero-superiorly from the ganglion. At geniculate ganglion, the 7th CN takes an abrupt turn posteriorly- FIRST GENU, to continue as second segment (tympanic segment), forming an angle of 48–86° with the first segment.⁽²²⁾ Fallopian canal dehiscence at the geniculate ganglion is found in 15% of individuals making it prone to iatrogenic injury during middle cranial fossa procedures.

Greater Superficial Petrosal Nerve

It is a branch of Nerve of Wrisberg and it carries taste, parasympathetic and sensory fibres of facial nerve. The preganglionic parasympathetic fibers arise from tractus solitarius (superior salivatory nucleus in pons) and continue in Nerve of Wrisberg (Nervus Intermedius) before joining main trunk of facial nerve. The parasympathetic fibers simply relay in geniculate ganglion without actually synapsing, unlike the sensory and taste fibres, and continue anteriorly as Greater Superficial Petrosal Nerve and enters the middle cranial fossa. ⁽²³⁾ Intracranially, the nerve travels deep to Gasserian ganglion and reaches foramen lacerum and enters pterygoid canal where it joins the deep petrosal nerve to form Vidian Nerve (nerve of pterygoid canal). From here the nerve continues to the sphenopalatine ganglion, where the sensory fibres from tongue and soft palate have their cell bodies. The preganglionic fibres (secretory) that arise from superior salivatory nucleus also end in this ganglion and the corresponding postganglionic fibres provide secretomotor innervation to lacrimal gland and mucosa of nasal cavity. Along with the GSPN, its bony canal also carries superficial petrosal artery that supplies geniculate ganglion. ⁽¹³⁾

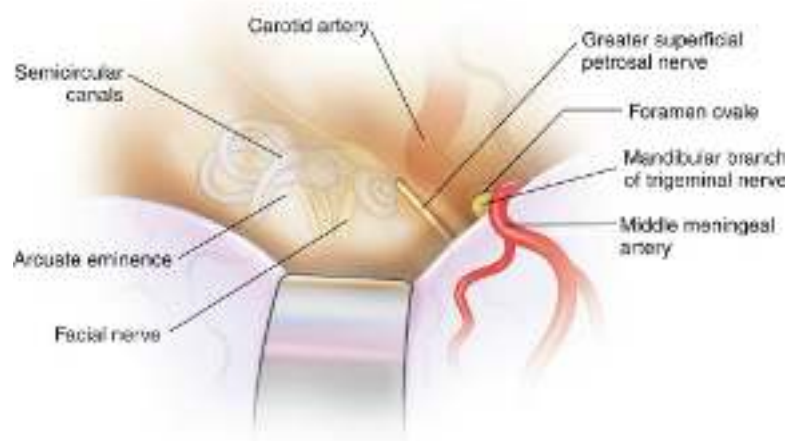


Figure 9. Relation of facial nerve with cochlea, labyrinth, GSPN and geniculate ganglion⁽²⁴⁾

3.3. Horizontal or Tympanic Segment

Extending between 1st genu (GG) and 2nd genu, it travels antero-posteriorly in the medial bony wall of middle ear cavity, in relation to processus cochleariformis below it anteriorly, and oval window below and LSCC above posteriorly. It travels at 90 degrees angle to the petrous bone axis.⁽²²⁾ Length lies between 9 and 12 millimeters (average= 10mm) and width ranges lies between 1.2 and 1.6 millimeters⁽²²⁾. In its anterior part, the horizontal segment courses medial and above the processus cochleariformis, and this is a consistent landmark for facial nerve in its tympanic course. It is observed that this bony process is more resistant than other middle ear structures to erosion in presence of aggressive middle ear pathologies, and hence serves as a steady landmark for 7th CN during middle ear and mastoid procedures.

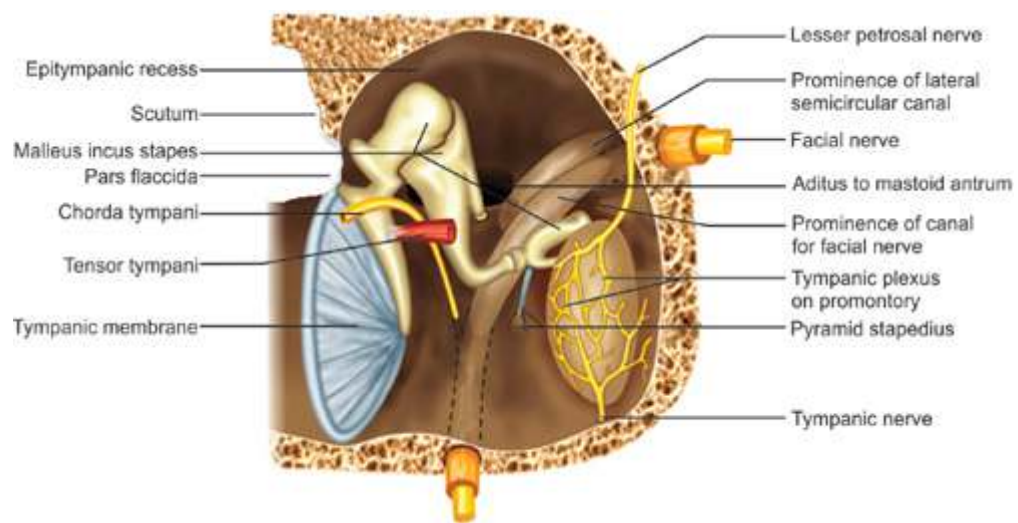


Figure 10. Course of facial nerve through middle ear and its relations. ⁽²⁶⁾

Average distance between the two is found to be around 2 mm. In its posterior part, the horizontal segment lies about 3-4mm above oval window.⁽²²⁾ The nerve here lies in proximity with pyramidalis process⁽¹⁾. Wall of fallopian canal over tympanic segment is usually very thin, and can even be dehiscant, in which case the nerve sheath may be in direct contact with the mucosa of middle ear^{(10) (25)}. As the nerve

courses through fallopian canal, it has defined order in which the fibres are located. With respect to the proximity with oval window, fibres are arranged as oral, ocular and frontal, from closes to farthest in that order.

3.4. Second Genu

The bend between horizontal and vertical segment of facial nerve just posterior to the pyramidal eminence forms the 2nd genu (forming an angulation of about 90-125°). 2nd genu lies between the dome of LSCC superiorly and short process of incus laterally. The latter has a relatively constant distance from 2nd genu of about 2mm.⁽¹³⁾

3.5. Mastoid or Vertical Segment (The Third Segment)

This forms the longest segment of the intratemporal facial nerve, runs between 2nd genu to its exit at the stylomastoid foramen and measures about 15mm ⁽¹⁾. The fallopian canal in this region also is at its widest diameter, with the nerve occupying merely 25-50% of the bony canal lumen. This is the explanation to the observation that the nerve entrapment in this segment is rare during middle ear and mastoid inflammatory diseases ⁽²⁷⁾. This segment descends in the posterior wall of tympanic cavity and anterior wall of the mastoid bone. The depth of nerve at second genu and stylomastoid foramen is not constant as the nerve becomes more lateral as it courses downwards through the mastoid. Sometimes, the nerve around its lower end is found to lie even lateral to the posteroinferior part of tympanic annulus, and in such cases the nerve is more vulnerable to injury during mastoid surgeries.⁽²⁸⁾

Relationship of the Vertical part of FN and other structures of mastoid

- a. During its initial course in mastoid, the nerve lies just below the LSCC.
- b. As the nerve continues through mastoid, it is covered by a bony canal, which may be dehiscent in few individuals making the nerve directly exposed to mastoid cells.

- c. Lower part of vertical segment lies anteromedial to anterior end of digastric ridge which is smooth convex ridge of bone found near the mastoid tip, corresponding to the external insertion of digastric muscle on the mastoid tip. But in individuals with poorly pneumatized mastoid, the digastric ridge itself is difficult to identify and hence not a very persistent landmark.
- d. The nerve's distance from sigmoid plate is variable with an average of 4mm.
- e. The distance of the 7th cranial nerve to the jugular bulb is also highly variable and measures from 0 to 12 mm⁽²²⁾.
- f. While exiting the fallopian canal at the stylomastoid foramen, it lies approximately 13mm deep from the mastoid cortex and here it is invested by a fibrous sheath that contains stylomastoid artery and veins. Just below this point it gives a sensory branch to the posterosuperior part of EAC.
- g. After exiting its intratemporal course, it traverses between stylohyoid and digastric muscles to enter parotid gland.⁽¹⁾

The Nerve to Stapedial Muscle

The fibres of the nerve that supply stapedius arise in brain by few of the neurons that emerge from outside of FN nucleus, & lie just beneath fourth ventricle and here they secondarily join other motor neurons of the 7th CN ⁽²⁹⁾. This small nerve is given off from vertical segment adjacent to pyramidal eminence.

Chorda Tympani

It is terminal branch of intermediate part of Nerve of Wrisberg or Nervus Intermedius. This branch emerges from main trunk of FN at variable levels from vertical segment, with an approximate distance of 5-6mm above its exit from stylomastoid foramen, and enters middle ear cavity via chordal eminence. The chorda tympani forms Plester's chordo-facial angle with the main trunk and it measures 26°

to 35°⁽²²⁾. Through its course in middle ear, it passes between handle of malleus laterally and long process of incus medially and exits it above tensor tympani tendon via canal of Huguier of Gasserian (petrotympanic) fissure. It then passes over mandibular fossa on its medial surface and reaches infratemporal fossa where it joins lingual⁽³⁰⁾.

Chorda Tympani carries following fibres:

- Sensory afferent fibres for taste from anterior 2/3rd of the tongue (cell bodies of these fibres lie in geniculate ganglion)
- Preganglionic efferent fibres (secretomotor) to the submaxillary and sublingual glands (cell bodies in superior salivatory nucleus, synapse in submaxillary ganglion and then supply the above-mentioned glands)

Blood Supply of Facial Nerve

Two arterial systems supply the facial nerve- Vertebrobasilar *a.* and ECA. The various segments are supplied by the aforementioned branches:

- Facial nerve in pons: Anteroinferior Cerebellar Artery (AICA)
- IAC and Meatal segment: The labyrinthine artery (from AICA, that traverses in IAC along with FN)
- Tympanomastoid segments: Superficial petrosal artery, stylomastoid artery (both are branches of external carotid system)

1. Superficial Petrosal Artery (SPA)

One branch of the MMA (branch of 1st part of maxillary artery, which is an end branch of ECA), it enters tympanic cavity with GSPN. This provides arterial supply to nerve around GG and horizontal segment of FN. It forms anastomoses at 2nd genu with “stylomastoid” artery.⁽³¹⁾

2. “Stylomastoid” Artery

It branches from occipital artery (60%) and in few individuals “posterior auricular” artery (40%), which in turn are branches of external carotid artery, enters mastoid cavity through SMF. It provides arterial supply to vertical segment of FN. This along with Superficial Petrosal Artery form the facial arch (arterial arcade) to supply the Tympanomastoid segments of facial nerve. This arch is mainly contributed by SPA⁽³²⁾. In 10% people, the arterial supply from MMA is absent, in which case the stylomastoid foramen alone is responsible for supplying the Tympanomastoid segments of facial nerve⁽³³⁾.

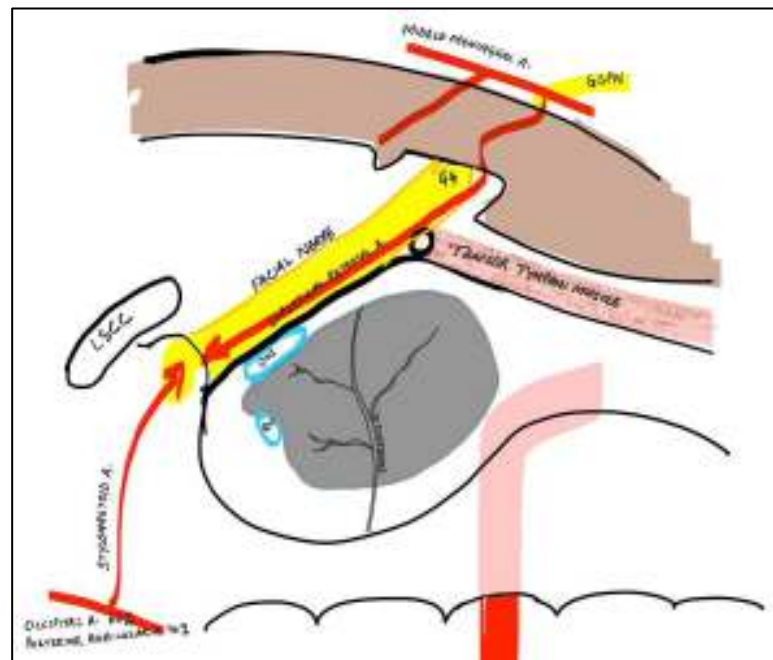


Figure 11. 7th cranial nerve and its arterial supply

Approaches for Facial Nerve

1. “Transmastoid” Approach
2. “Translabyrinthine” Approach
3. “Middle Cranial Fossa” (MCF) Approach
4. “Transcanal” Approach
- 5.

1. Transmastoid Approach

Transmastoid approach to facial nerve can be studied under two headings, i.e., closed tympanoplasty transmastoid approach (canal wall intact), or open tympanoplasty transmastoid approach (canal wall down) depending on the hearing status of the patient.

It provides good exposure to the nerve extending from GG area all the way to its exit from SMF.

1.1. Closed Tympanoplasty Approach

This is preferred when patient does not have significant hearing loss, and hearing has to be preserved.

Steps:

1. Through a postauricular incision, a cortical mastoidectomy is done. Superiorly three landmarks, i.e., LSCC, SPI and fossa incudes are identified and inferiorly the digastric ridge.⁽³⁴⁾
2. Then the drilling is continued using a large cutting burring, with parallel strokes (along vertical segment direction). Once nerve is identified & seen through its whole length, drilling is continued using smaller burr and facial recess can be opened just inferior to fossa incudes.
3. Extended posterior tympanotomy
4. Adequate skeletonization
 - Mastoid segment: 270 degrees of its circumference
 - Second genu: 180 degrees
5. Tympanic segment is approached using the small space between incus body laterally, LSCC (anterior portion), ampullae of LSCC and SSCC medially & dural plate superiorly and nerve is exposed till geniculate ganglion.⁽³⁵⁾

1.2. Open Tympanoplasty Approach

It is preferred in patients where hearing has already been lost because of disease process and hence, preservation of hearing is not a concern. It is easier to perform the facial nerve decompression through this approach because of the ample space provided by taking down the posterior meatal wall.

Steps

1. After earlier described closed tympanoplasty is performed, drilling is continued to lower posterior meatal wall till the level of FN reached. This level is usually indicated by the level of dome of lateral semicircular canal.
2. Facial bridge is completely removed.⁽³⁴⁾
3. Bony wall over mastoid segment is drilled to thin it out for 270 degree skeletonization
4. Drilling is then advanced to skeletonize the 2nd genu(270degrees) & anteriorly horizontal segment, till geniculate ganglion
5. The thin shell of bone remaining after drilling is curetted out with “double-curved hook” or a circular knife or a smaller curette, and perineural sheath of nerve is excised. ⁽³⁵⁾

2. Translabyrinthine Approach

This approach is preferred when the full intratemporal length of nerve is to be decompressed, and hearing is already lost. Labyrinthectomy followed by exposure of IAC allows decompression of horizontal and IAC segments of facial nerve.

Steps

1. Complete mastoidectomy done.
2. Retrofacial cells drilled, jugular bulb identified, bony plate on SS and dura drilled into a thin shell and the removed using a septal raspatory or a curette.

3. Endolymphatic sac identified and cut, labyrinth opened- first lateral semicircular canal, followed by PSCC and SSCC. Vestibule opened. Remaining bone over middle and PCF dura drilled.
4. Dura of posterior cranial fossa is followed and IAC porus is identified. The superior SCC ampulla is landmark for identification of IAC superior limit whereas its inferior border is recognised by excavating the retrofacial mastoid cells b/w the jugular bulb & apparent level of IAC.
5. IAC identified, and bone over it thinned out. Horizontal crest identified, and IAC fully exposed, dura over IAC opened, and the contents exposed. Inferior and superior ampullary nerves detached from the canal, following which FN labyrinthine segment and bills bar can be clearly identified.



Figure 12. Decompression of FN along whole length. (>) Labyrinthine segment, (CT) “Chorda tympani”, (FN(i)) “IAC segment”, (FN(m)) “Mastoid segment”, (FN(t)) “Tympanic segment”, (G) 2nd Genu, (GG) “Geniculate ganglion”, (MFD) “Middle fossa dura”.⁽³⁵⁾

3. Transcanal approach

Steps:

1. Tympanotomy with canaloplasty done for good exposure.
2. Scutum removed, and incudo-stapedial joint exposed, and joint disarticulated.

3. Incus and head of malleus removed, atticotomy done.
4. Bone over the horizontal segment thinned out. In 50% of cases bony canal over horizontal segment is dehiscent.
5. Genuiculate ganglion is present 3-4mm anterior to processus cochleariformis, and is identified by drilling the bone over horizontal segment and tracing it anteriorly.
6. Posterior canal wall drilled to widen the canal, until chorda tympani, followed by vertical segment of facial nerve is identified. The whole of vertical segment is then exposed from second geni up to the stylomastoid process in the same manner.⁽³⁶⁾

Dissection library

Instruments- Few minimums of surgical instruments are required while performing a TBD

- Microscope with adequate illumination
- Bone holder
- A motor & handpiece
- Burrs-round and conical (diamond and cutting)
- Surgical and microsurgical knives- round knife, sickle knife, side knife
- Tissue & micro-surgical scissors
- Tissue dissectors & elevators
- Suction apparatus with tubes- different sizes
- Irrigation

Pointers while drilling

- A low magnification is better to get comprehensive orientation of anatomy and a higher magnification is important for appreciating minute details.
- Largest possible burrs should be used.
- Most of the drilling carried out with cutting burrs. Diamond-burrs should only be used near intricate structures like dural plate, FN, or sigmoid sinus, or for controlling small bleeders from bone.
- Drill should be held like a pen, and the direction of drill strokes should be tangential and not perpendicular to the structures being drilled, such that only the side of burr should be drilling and not the tip. Strokes should always be along the direction of cardinal structures, and only in 1 direction. ⁽³⁵⁾
- Drilling should be started from most treacherous areas & worked towards the easier ones.
- Only minimal pressure should be applied while drilling.
- Usually direction of rotation of the burr is kept clockwise, but near important structures, it should be away from the structure, so the rotation can be changed to anti-clockwise as per the requirement. ⁽³⁷⁾
- Suction & Irrigation- Appropriate suction irrigation is essential as it clears out bony dust that hinders view & clogs burr end, making it blunt. Additionally, it helps in avoiding thermal injury by cooling the surface being drilled. Ample irrigation is essentially required while identifying important structures like facial nerve and blue lining of the lateral semi-circular canal. When working around an important/exposed structure, suction tip can be placed between drill and the structure to avoid hitting the structure.

Preparing Specimen-

Fresh temporal bones are preferred. Older bones show colour change, & vessels are usually clogged by rigid, difficult to remove coagula. Temporal bones are then fixed in a 10 % formalin solution for 2 weeks. High tonicity saline can also be used for preservation, although literature does not exist regarding this. ⁽³⁸⁾ Pre-dissection, these bones are rinsed with running water to remove the unpleasant odor of formalin.

MATERIALS AND METHODS

This present study was conducted between January 2020 to September 2021 in Temporal Bone Dissection Lab of Department of Otorhinolaryngology and Head and Neck Surgery, J. N. Medical College, KAHER, Belgaum. 25 wet temporal bones were dissected and findings were recorded. A time period of average 8 hours per week was allotted during which expert guidance was given by staff members of the Department, The bones were obtained from the anatomy dissection hall of J. N. Medical College, KAHER, Belgaum. Photographs of dissection were taken at various stages.

Temporal Bone Laboratory:

The laboratory contained storage racks for containers of temporal bones preserved in formalin.

The laboratory was equipped with an operating microscope to provide correct illumination and magnification, a screen to project microscopic dissection, temporal bone holder, foot-controlled drill, various dissection burrs, suction apparatus, irrigation apparatus, and microsurgical ear instruments.

Temporal Bones:

25 temporal bones were removed and saw cut from the cadavers available in the anatomy dissection hall. These were kept preserved in containers with diluted formalin.

The bones were kept under running water before dissection to rid of formalin, and then cleared of the soft tissue after recording the external findings such as pinna, pre-auricular region, post-auricular region, cartilaginous external auditory canal, using

periosteal elevator, toothed forceps and 15 no. blade. During dissection, the bone was fixed over “temporal bone holder” (three pronged), in surgical position, which was adjusted during the various stages of dissection. Dissection was carried out and various findings and measurements were recorded and appropriate photographs taken.

Steps of Dissection:

1. Spine of Henle identified.
2. MacEwen’s triangle exposed and drilled.
3. Antrum identified, cortical mastoidectomy completed.
4. Vertical portion of facial nerve identified; measurements taken; facial recess approach performed.
5. Canal wall down mastoidectomy performed; middle ear structures studied; tympanic segment skeletonized and measurements taken.
6. Combined approach (transmastoid + middle cranial fossa approaches) used to delineate the IAC and “labyrinthine” segment of FN.
7. All measurements taken at various levels and proformas filled.

Ethical Considerations:

Ethical clearance for the study was obtained from JNMC Institutional Ethics Committee on Human Subjects Research and the reference number was **MDC/DOME/307**.

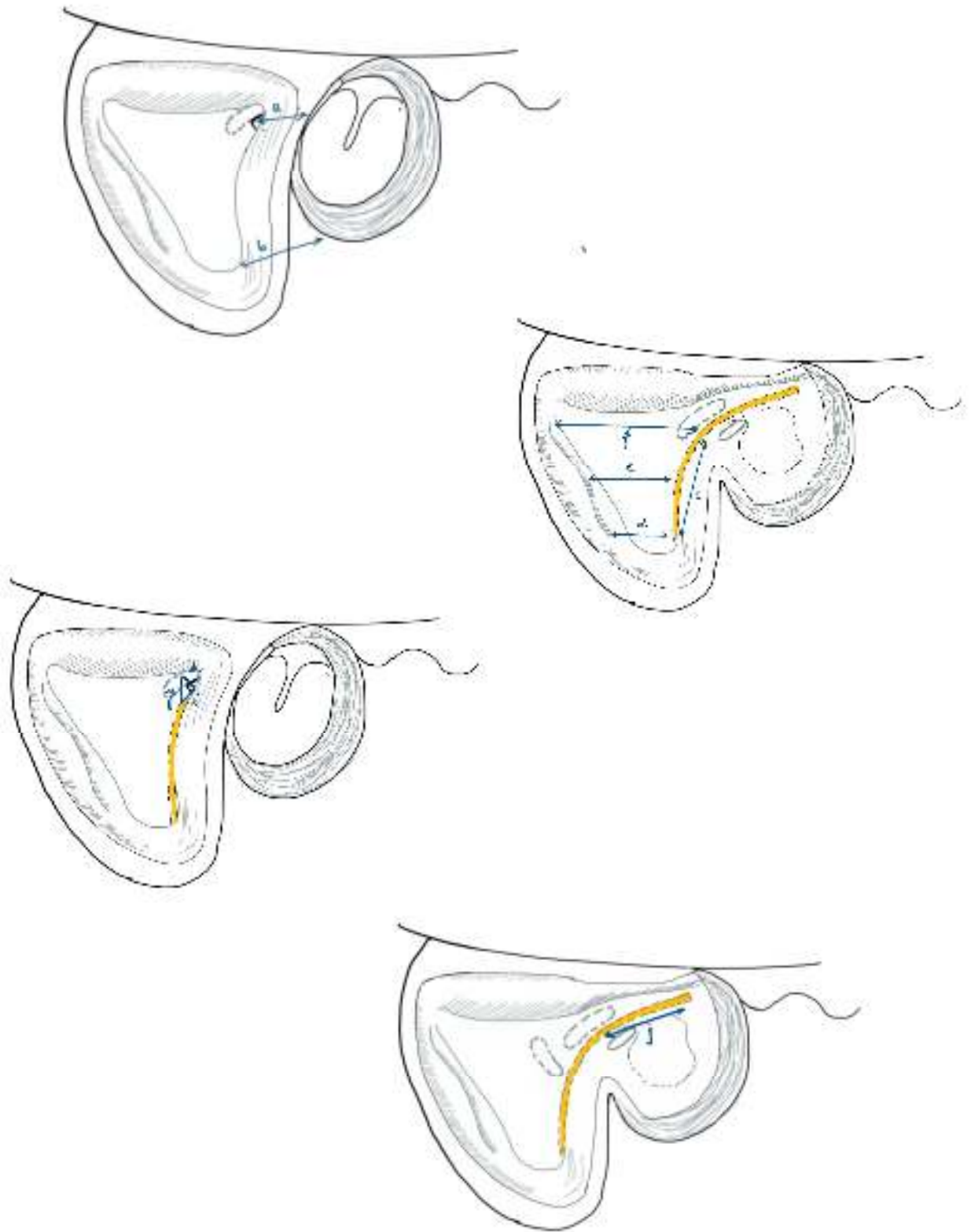


Figure 13: Measurements as per proforma

RESULTS

Table 1: Side wise distribution		
Sides affected	Number of patients	Percentage
Left side	12	48.00
Right side	13	52.00
Total	25	100.00

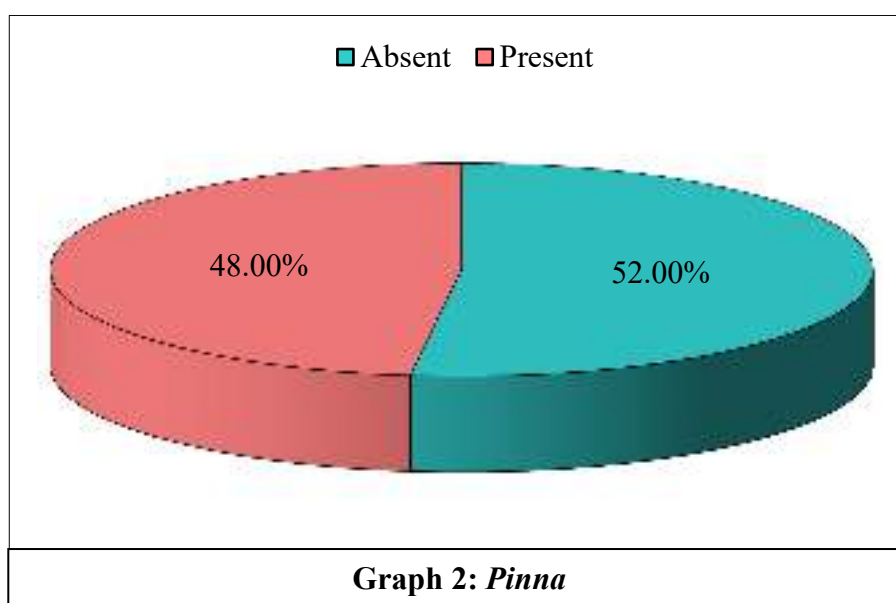
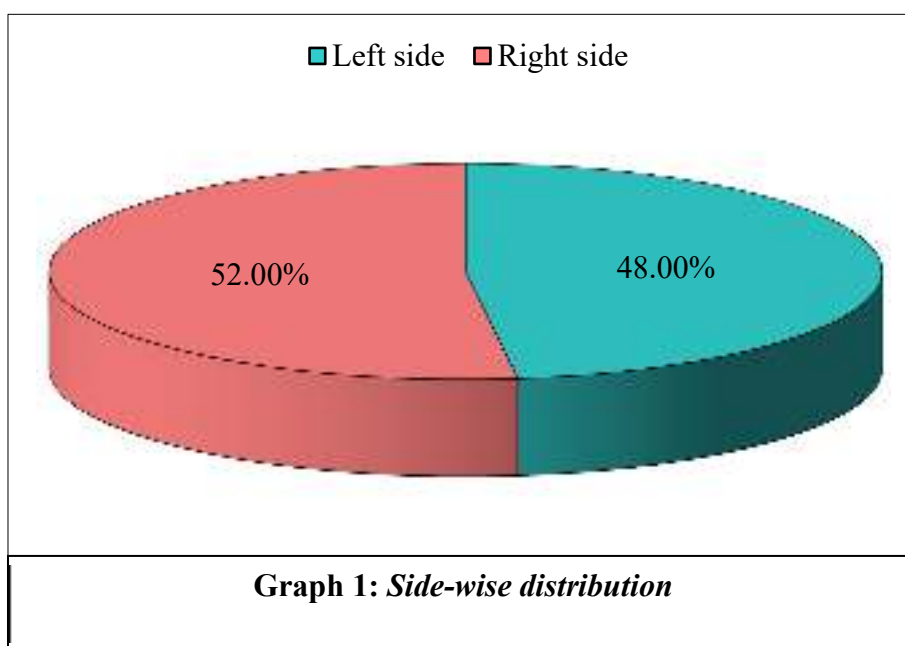
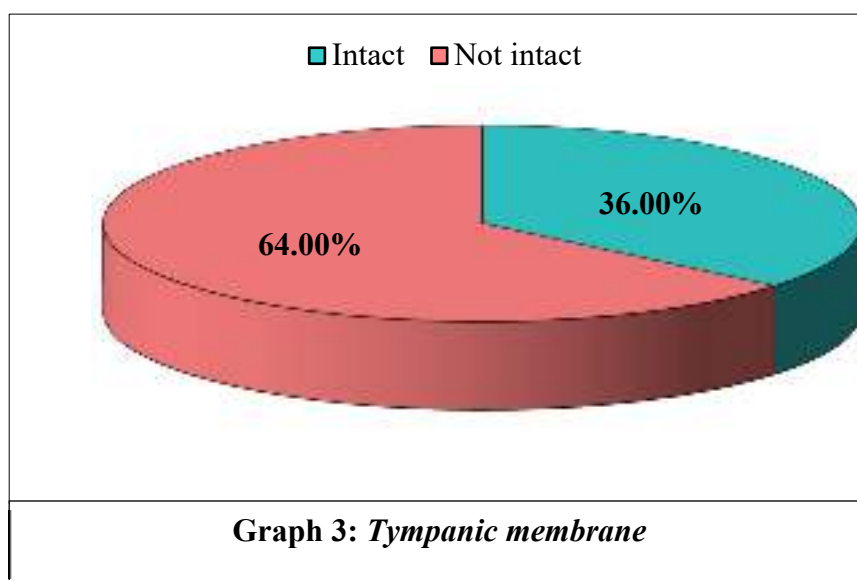


Table 2: Pinna- Present/ Absent		
Pinna	Number of patients	Percentage
Absent	13	52.00
Present	12	48.00
Total	25	100.00

- Out of the 25 bones studied, 12 were left sided and 13 were right sided.
- Pinna was intact and present in 12 of the bones, whereas in others, it had already been removed.

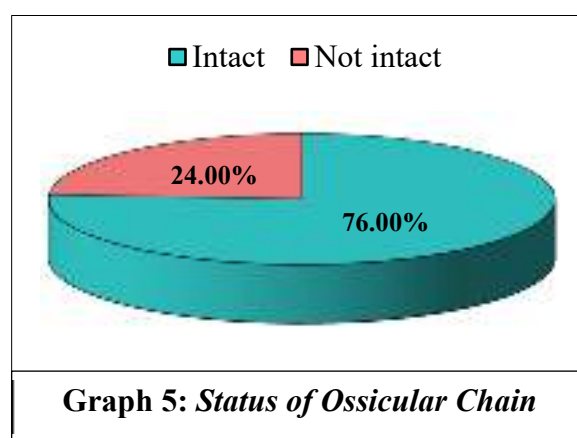
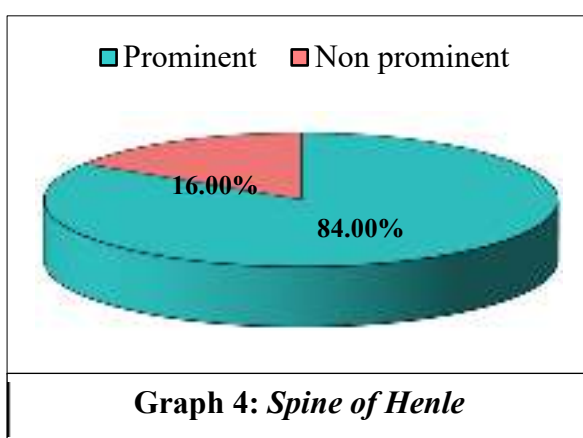
Table 3: Tympanic membrane		
Tympanic membrane	Number of patients	Percentage
Intact	9	36.00
Not intact	16	64.00
Total	25	100.00



- Tympanic membrane was intact in only 36% of the bones, in the rest, it was partially torn, mostly due to postmortem handling, but it was difficult to differentiate this from erosion by pathological process of middle ear. None of the

tympanic membranes showed a characteristic perforation as seen in middle ear pathology.

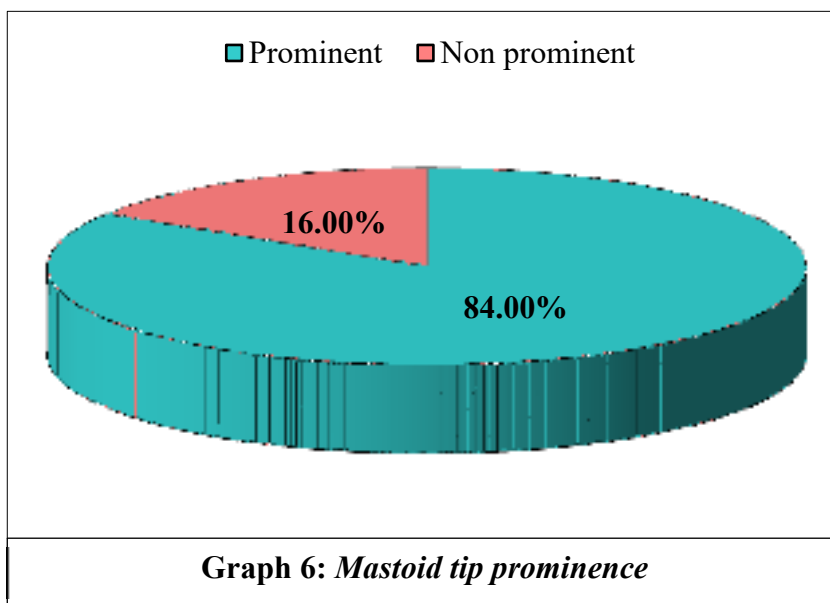
Spine of Henle	Number	Percentage
Prominent	21	84.00
Non prominent	4	16.00
Total	25	100.00



Ossicular chain	Number of patients	Percentage
Intact	19	76.00
Not intact	6	24.00
Total	25	100.00

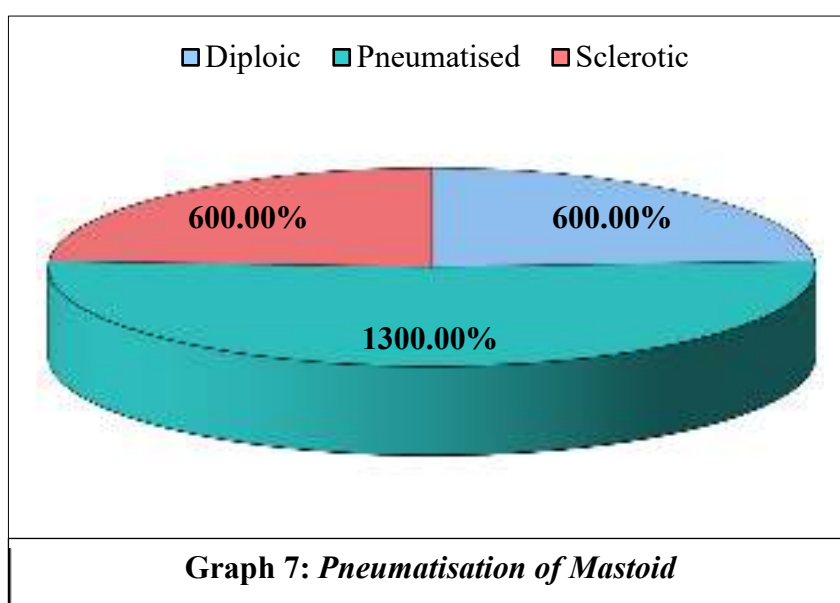
- It was seen that Spine of Henle was prominent in 21 bones, whereas other 4 bones, in which it was not prominent showed cribriform appearance at the location of Spine of Henle.
- The ossicular chain was intact in 19 bones (76%), dislocated in 3 bones (12%) and in the other 3 bones (12%) incus was partially eroded.

Table 6: Mastoid tip prominence		
Mastoid tip	Number of patients	Percentage
Prominent	21	84.00
Non prominent	4	16.00
Total	25	100.00



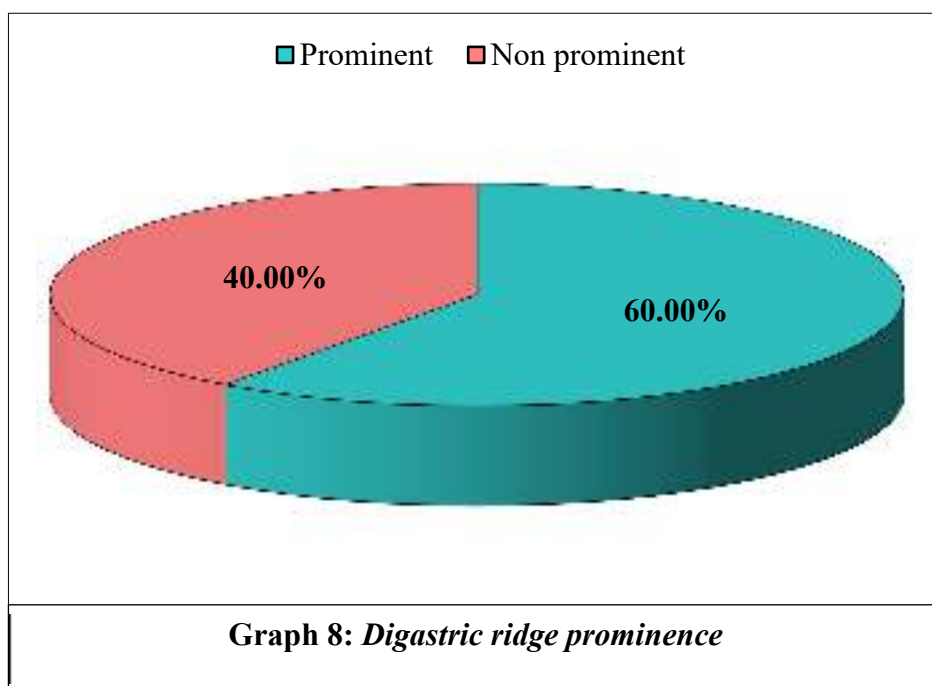
- Mastoid tip was found to be prominent in most of the specimens, whereas it was not prominent in 4 of the bones (16%).

Table 7: <i>Pneumatisation of mastoid</i>		
Pneumatisation	Number of patients	Percentage
Diploic	6	24.00
Pneumatised	13	52.00
Sclerotic	6	24.00
Total	25	100.00



- 52% bones (13) were found to be well pneumatised, whereas 24% (6) were sclerotic, remaining 6 bones (24%) showed diploic pattern of pneumatisation.

Table 8: <i>Digastric ridge prominence</i>		
Digastric ridge	Number of patients	Percentage
Prominent	15	60.00
Non prominent	10	40.00
Total	25	100.00



- There was correlation found between the pattern of pneumatisation and prominence of digastric ridge. Out of the 10 non-prominent digastric ridges, 9 were seen in poorly pneumatised bones (diploic/sclerotic) and only 1 of such bones (with non-prominent mastoid) had well pneumatised mastoid.
- Also 60% of bones showed a prominent digastric ridge, which correlated with the p percentage of bones that were well pneumatised.

Table 9: Summary or descriptive statistics of parameters related to mastoid segment				
Parameters	Min.	Max.	Average	SD
SPI to SoH	11.2	16.0	13.2	1.42
Posterior Canal Wall to anterior end of DR	9.10	12.70	11.1	0.9
F_m length	8.00	13.00	9.80	1.68
Lower End of F_m to Sigmoid Plate	4.20	8.10	6.40	0.89
Mid-point of F_m to Sigmoid Plate	3.80	6.80	5.30	1.02
Upper End of F_m to Sigmoid Plate	5.50	8.90	7.20	0.94
LSCC to 2nd Genu	1.00	2.10	1.51	0.35
LSCC to SPI	1.10	2.30	1.56	0.31
SPI to 2nd Genu	1.40	3.20	2.20	0.55
Chorda tympani origin to SMF	0.1	5.3	2.4	1.2

The average measurements of various parameters along with the range and standard deviations (SD) were as follows:

- The maximum variation between the measurements was seen in depth of 2nd genu that was calculated by adding measurements SPI to SoH and SPI to 2nd Genu, and ranged between 12.6mm (11.2 + 1.4) and 19.2mm (16 + 3.2).

Table 10: Summary or descriptive statistics of parameters related to tympanic and labyrinthine segments				
Parameters	Min.	Max.	Average	SD
F_t length	8.70	10.9	9.5	0.71
F_t to as annulus	4.20	7.50	5.71	0.25
PC to GG	1.10	2.70	1.80	0.53
F_t to oval window	3.00	5.50	4.21	0.64
F_l length	2.70	4.20	3.29	0.42

- The minimum, maximum values of various parameters related to tympanic and labyrinthine segment of facial nerve are mentioned in above table along with the average values and the standard deviation.
- Lengths of the 2 segments was found to be more or less constant.
- Processus Cochleariformis served as a persistent landmark for F_t.

Table 11: Dehiscence in fallopian canal		
Dehiscence	Number of patients	Percentage
Absent	16	64.00
Mastoid segment	2	8.00
Tympanic segment	7	28.00
Total	25	100.00

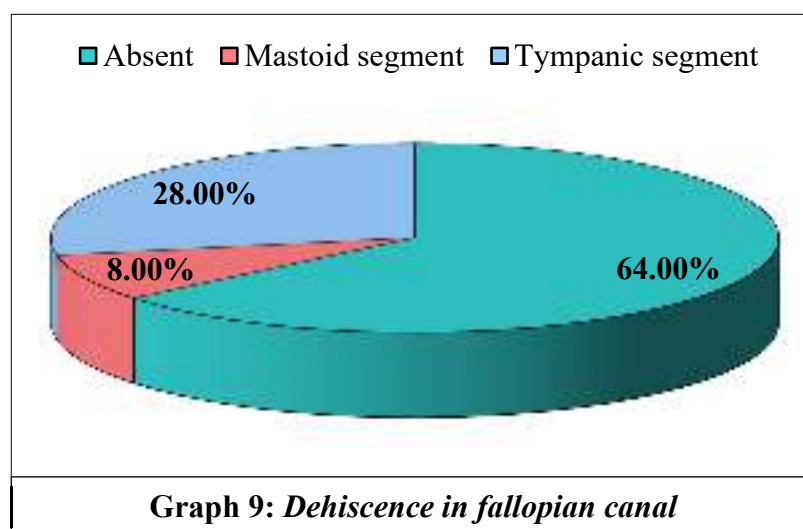


Table 12: Measurements of dehiscence in fallopian canal				
Parameters	Min.	Max.	Mean	SD
Dehiscence dimensions	0.00	0.50	0.09	0.14

Bony canal dehiscence was found most around the 2nd genu, more so in the F_m. Maximum dimension was seen in specimen no. 6, measuring 0.5 x 0.7 mm in posterior part of tympanic segment.

DISCUSSION

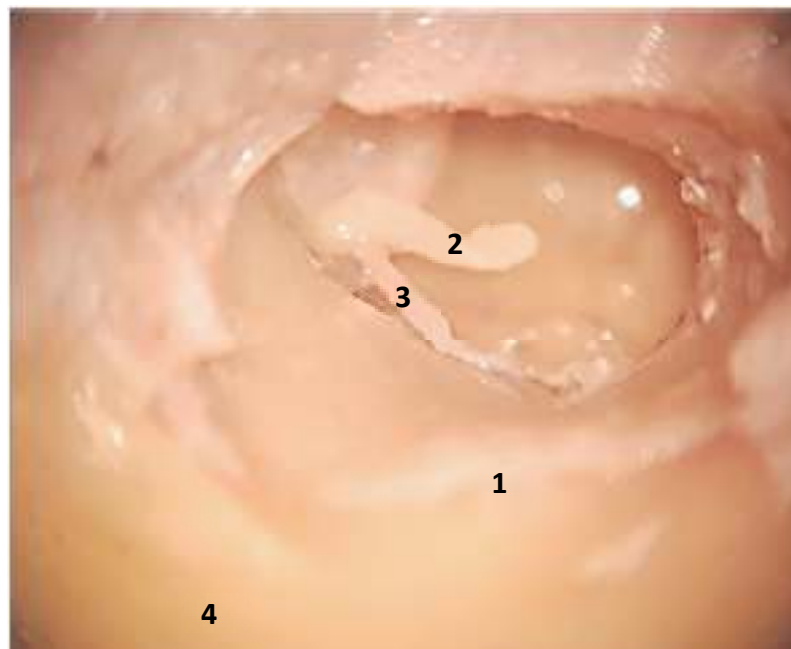
Analysis and Discussion:

As discussed before, there are various ways to approach facial nerve. Majorly used in this study was the transmastoid approach.

The essential surgical landmarks and parameters during this approach are:

1. Spine of Henle and “MacEwen’s triangle”:

The SoH is identified, and “MacEwen’s triangle” delineated, to limit the initial area of drilling, which leads to exposure of mastoid antrum.



Photograph 1: Right temporal bone showing SoH (1); Handle of malleus (2); chorda tympani (3); mastoid cortex (4).

In the 25 temporal bones studied, Spine of Henle was prominent in 21(84%) bones, and not prominent in 4(16%) bones.

2. Mastoid Antrum Exposure:

This is the first step in any transmastoid surgery, because mastoid antrum is constant and there no essential structures lie laterally to it.⁽³⁹⁾ Ease of exposure however depends on two factors:

a. Pneumatization of mastoid: The antrum is localized by appearance of small periantral cells; however, this can only be achieved with ease in a well pneumatized mastoid. Pneumatization is thought to be controlled by hereditary, environmental, nutritional factors, which include infection and Eustachian tube patency, which in turn will affect the ventilation of middle ear and mastoid.

In the study conducted, 52% of temporal bones were well pneumatized, 24% were diploic, and 24% were found to be sclerotic.

b. Koerner's septum: It is a condensed, bony lamina found in mastoid process as a consequence of persistence and further development of the mucosal fold present between saccus superior and saccus medius in the mastoid of the adult. In presence of Koerner's septum and inability to recognize it, deeper cells including mastoid antrum may be left unexplored.⁽⁴⁰⁾

Koerner stated Koerner's septum is hardly recognizable in a well-pneumatized mastoid, whereas Toros et al⁽⁴⁰⁾ in their study found no statistically significant correlation between prevalence of Koerner's segment and the pattern of pneumatization.

In our study, out of 25 temporal bones, Koerner's septum was identified in 4 bones, out of which 3 showed diploic pattern of pneumatization, and 1 bone was well pneumatized.

Mastoid antrum lies approximately 15mm deep to the mastoid cortex. In our study, the depth of antrum was estimated by measuring the distance b/w SoH & SPI, which measured between 11.2mm and 16mm, with an average of 13.2mm.

3. LSCC & SPI: Relationship between facial nerve and lateral semicircular canal is very constant. The nerve lies below and medial to the dome of lateral semicircular canal. In our study, 2nd genu was found to be at a distance from lateral semicircular canal ranging between 1 mm and 2.10 mm, with a mean of 1.51 mm. The tip of short process of incus lies laterally to the tympanic segment of facial nerve as it courses through aditus ad antrum, and usually serves as a good landmark for 2nd genu.

Donaldson et al⁽⁴¹⁾ in their study of 25 temporal bones described a “Triple S” triangle for topographical location of facial nerve(2nd genu), the triangle being formed by short process of incus, lateral semicircular canal and second genu of facial nerve.

Same reference was used in this study to measure these distances. The mean measurement of the distance between SPI and 2nd Genu, SPI and LSCC, 2nd genu and LSCC was found to be 2.20mm, 1.56mm and 1.51mm respectively, forming almost an equilateral triangle. Hence, during surgery, once the SPI and LSCC are identified, an approximate location of the 2nd genu of facial nerve can be anticipated, in turn avoiding facial nerve injury.

4. Digastric Ridge: It is another landmark for identifying the lower end of mastoid segment of facial nerve, where it exits the temporal bone at the stylomastoid foramen. It is a bony ridge near mastoid tip, that corresponds externally with the attachment of posterior belly of digastric muscle over the medial aspect of mastoid

tip. The prominence of digastric ridge is affected by the pneumatization of mastoid. In our study, 15 bones showed prominent digastric ridge, most of which were well pneumatized, or atleast diploic. In the other 10 bones the digastric ridge was not prominent, and this made the identification of lower end of facial nerve difficult.

In a recent cadaveric dissection study done on 93 wet temporal bones, DVK Irugu et al⁽⁴²⁾ came to a similar conclusion that the prominence of digastric ridge is related to how well a mastoid is pneumatized.

In instances where the digastric ridge is not prominent, a line joining the lateral semicircular canal and digastric ridge along the posterior canal wall provides an approximate location of the lower end of the mastoid segment of facial nerve. Once this is done, and the upper end (Short process of Incus, Lateral semicircular canal) and the lower end (anterior end of digastric ridge) of mastoid segment are identified, the whole of the vertical segment can be traced and exposed.

These 2 reference points were also used to estimate the depth of the mastoid segment of facial nerve, which is essential because if misjudged, it may lead to injury to the mastoid segment while performing a transmastoid procedure.

The depth of second genu was measured from Spine of Henle, and ranged from 12.6mm to 18.9mm with a mean value of 15.2mm. The depth of the lower end was calculated by measuring the distance between posterior canal wall at the level of floor of bony annulus to the anterior end of digastric ridge, which ranged between 9.1mm to 12.7mm, with a mean value of 11.1mm.

In a study done by Praveen et al⁽⁴³⁾, the mean depth of second genu was found to be 13.82mm, and that of stylomastoid foramen was 12.75mm. The results were comparable.

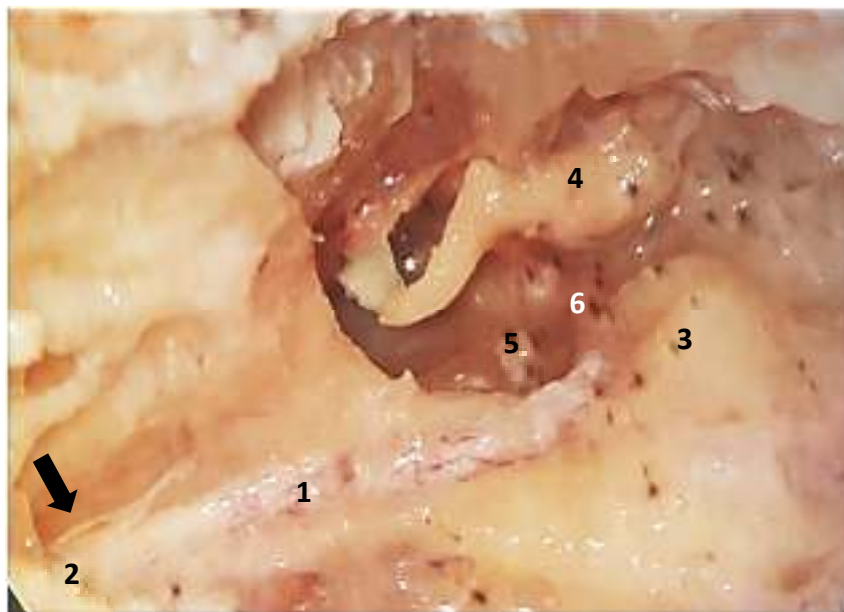
These measurements also bring to our notice, that facial nerve through its vertical segment, courses more laterally as it descends down to exit through the stylomastoid foramen. On contrary, *in specimen no. 15, the depth of second genu and lower end of mastoid segment were 12.6mm and 12.3mm respectively, which were almost equal and the nerve showed minimal lateral deviation through its vertical course.*

5. Sigmoid plate: the horizontal measurements between 2nd genu and upper end of sigmoid plate, the mid-point of vertical segment to sigmoid plate, and the stylomastoid foramen to the lower sigmoid plate were measured. the lower end of facial nerve was found to be at a mean distance of 7.2mm from the sigmoid plate, which was comparable to the CT based study done by Kylen et al, in which 3D reconstruction of Micro-CT images of cadaveric temporal bones revealed lower end of facial nerve- sigmoid sinus distance to be 7.2mm ± 1.8mm.

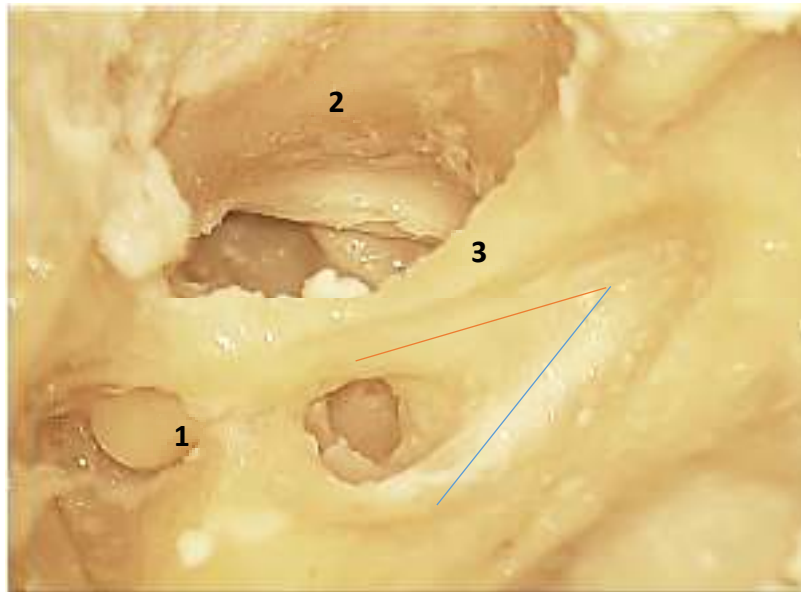
The midpoint of the vertical segment lay at a mean distance of 5.30mm from the sigmoid plate, and second genu at a mean distance of 7.20mm. These differences in the distance between vertical segment and sigmoid plate at various levels reflects the changing contour of sigmoid sinus. In contracted mastoids, these distances are much less.

Parameters	Min.	Max.	Mean	SD
LE of MS to SP	4.20	8.10	6.40	0.89
Mid-point of MS to SP	3.80	6.80	5.30	1.02
UE of MS to SP	5.50	8.90	7.20	0.94

6. Chorda tympani: This forms lateral boundary for dissection during “facial recess” approach. Its point of origin from the main trunk and the course determines the width of facial recess, and this correlation was studied in the study by Shraddha et al⁽⁴⁴⁾ in their study on 35 bones. In their study, variation was found in origin of the Chorda tympani nerve & so, in the length from the point of emergence to SMF, with an average of $4.08 \pm 0.8 \text{ mm}$ & ranging between 2.06 & 5.5 mm. Our study, shows this distance ranging between 1.1mm and 5.3mm with an exception of specimen number 2, in which the chorda tympani was given off just at the stylomastoid foramen. It was also noted, *that the mastoid segment length and the distance b/w SMF and origin of chorda tympani were positively correlated.*



Photograph 2: Left temporal bone showing the chorda tympani arising (black arrow) from the main trunk (1) at SMF (2). In same specimen, horizontal segment (6) length was found to be minimum out of all the specimens studied. Other labelled structures- LSCC (3); head of malleus (4); head of stapes (5).



Photograph 3: Facial recess approach a left temporal bone after identifying chorda tympani (red line) and main trunk of FN (blue line). (1) SPI; (2) EAC; (3) Posterior canal wall

The vertical segment (F_m) length in our study ranged between 8mm and 13mm, with a mean length of 9.80mm. In a similar study done by Raja Kalaiarasi(44) with 50 temporal bones, the average F_m length was 12.8mm (± 1.8 mm). This difference may be attributed to the extreme values in the data collected, such as in specimen no. 2 and 13, in which the mastoid segment lengths were found to be 8.0mm and 8.1mm respectively. However, it may be safe to say at this point, *that F_m length is not a very consistent parameter.*

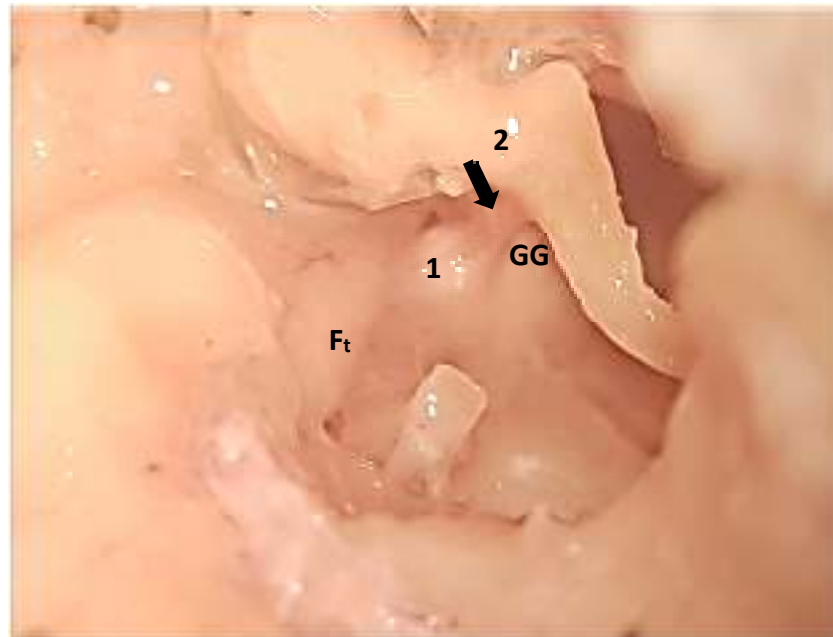
Parameters	Min.	Max.	Average	SD
MS length	8.00	13.00	9.80	1.68

7. Fenestra Ovalis: The F_t (vertical segment) runs right above fenestra ovalis or oval window. In our study, the mean distance between the tympanic segment and the posterior edge of the oval window was found to be $4.21(\pm 0.64\text{mm})$. In a study done by Nicoleta Maru et al this distance was found to be $3\pm 1.15\text{ mm}$.⁽²²⁾ They also found 2 specimens showing the tympanic segment overhanging the footplate, covering almost half of its width. No such overhangs were appreciated in any of the specimens studied in our study.

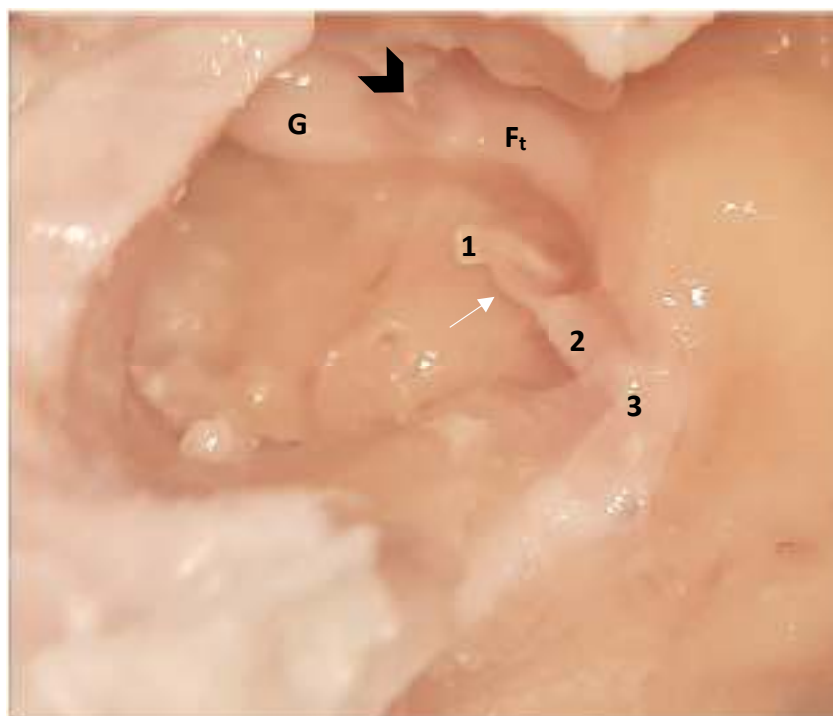


Photograph 4: F_t (1) relation with oval window (2). An air cell (black arrow) is appreciated between the two.

8. Processus Cochleariformis: it serves as a constant landmark for the geniculate ganglion. The study showed the distance between the two was found to be between 1.10 mm to 2.70 mm with a mean of 1.80 mm. this was found to be consistent with the values found in study done by Kalaiarasi et al.(44) In 3 specimens (12%), the tympanic segment of facial nerve was found to run adjacent to the Processus Cochleariformis, whereas in others nerve ran medial and superior to the process.



Photograph 5: *Processus Cochleariformis (1) in relation with Ft and adjacent to GG. Tensor tympani tendon (black arrow) can be appreciated arising from PC (1) to neck of malleus (2).*

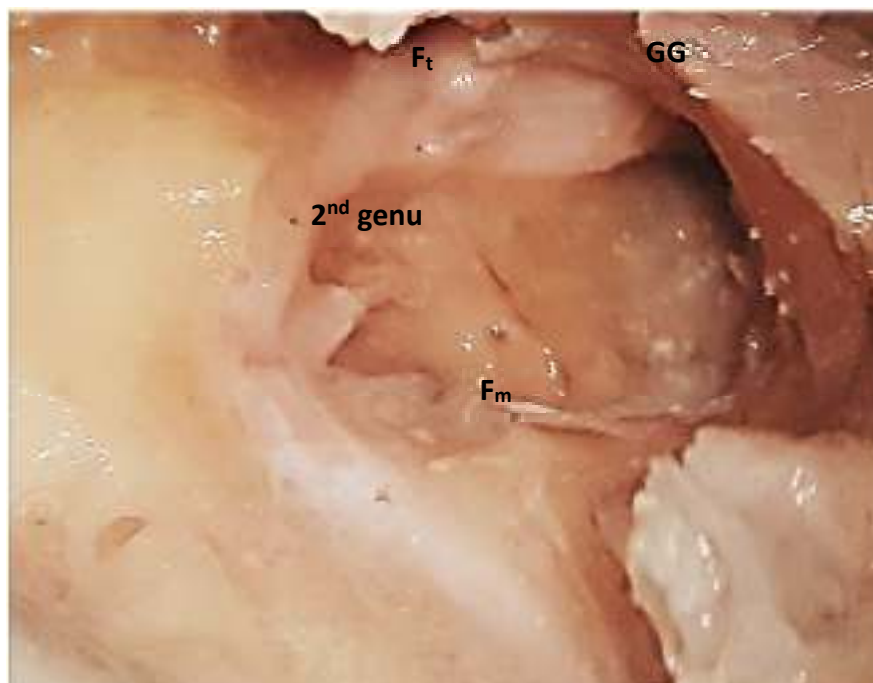


Photograph 6: *Variation in Processus Cochleariformis (black arrow)- not at GG; also, Ft travelling adjacent to it & not superiorly. (1) stapes head; (2) pyramidal process; (3) 2nd genu; (white arrow) stapedius tendon.*

9. Tympanic Annulus: The depth of anterior most part of tympanic segment was estimated by measuring the distance between anterosuperior part of annulus and the beginning of tympanic segment. The mean distance was found to be 1.7mm. This is where the nerve lies most medial, during its tympanic course, the nerve travels more laterally as it approaches 2nd genu.

Length of Tympanic Segment: it ranged between 8.7 mm to 10.9 mm with a mean of 9.5mm. Kalaiarasi et al(44) found this length to be between 8.22- 10.46 mm and Maru et al found a mean value of 10.25mm. (22)

10. Blood vessels: As one approaches close to the facial nerve during dissection, excessive blood vessels can indicate the proximity to the facial nerve. In our study of 25 temporal bones, the abundance of blood vessels was found most near the segment surrounding 2nd genu.

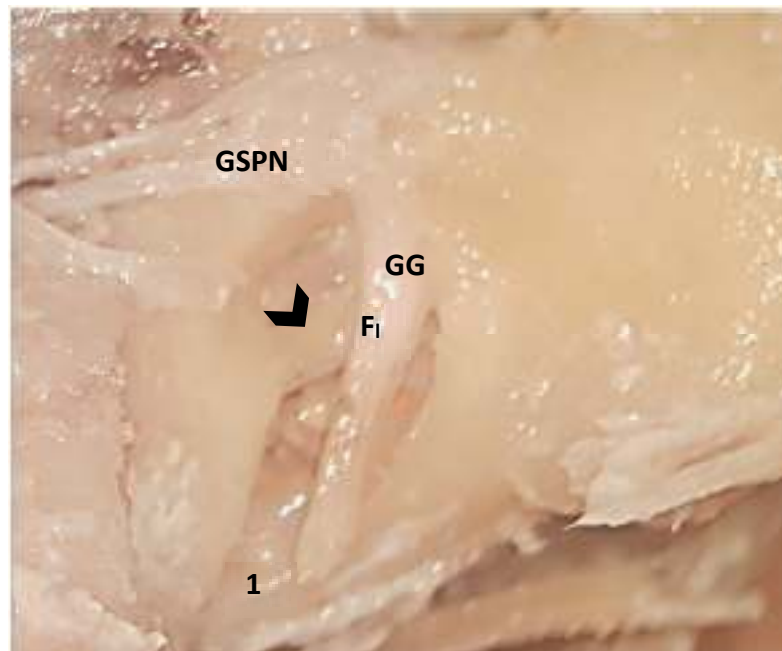


Photograph 7: Intratemporal course of facial nerve.

Labyrinthine segment (F₁)

A combined approach was used to delineate F₁

1. After identifying various middle ear and mastoid landmarks, the attic bone was drilled just medial to superior semicircular canal.
2. Then the middle fossa approach is used- dura elevated and the window created in attic identified.
3. Greater superficial temporal nerve identified by drilling around the window, and followed up to the geniculate ganglion.
4. Labyrinthine segment was identified and roof over the IAC was removed.



Photograph 8: Facial nerve in anterosuperior quadrant of IAM. (1) porus of IAM; (black arrow) falciform crest.

The **length of labyrinthine segment** was found to be between 2.70mm and 4.20mm and an average 3.29mm with standard deviation 0.42 mm. This was consistent with the results of studies by Miguel et al who found the mean length of labyrinthine segment to be 3.09mm.⁽⁴⁵⁾

Parameters	Min.	Max.	Average	SD
LS length	2.70	4.20	3.29	0.42

Dehiscence

Out of the 25 specimens studied, dehiscence in bony canal was observed in 9 bones, of which 7 bones had dehiscence in the F_t (28%) and 2 bones showed dehiscence in F_m (8%).

F_t dehiscence- 1 bone showed near the geniculate ganglion, while others showed dehiscence near the oval window.

In the 2 bones that showed fallopian canal dehiscence in the mastoid segment, both were present in the middle third of the mastoid segment.

Dehiscence dimensions ranged between 0.2mm to 0.7mm, with all showing dehiscence of only the bony canal filled with soft tissue with an intact facial nerve and its sheath.

CONCLUSION

1. Facial nerve is an essential structure in middle ear and mastoid, and its anatomical understanding is of paramount importance for avoiding iatrogenic injury to it and its drastic consequences.
2. Even with multiple attempts at studying anatomy and variations in intratemporal course of 7th CN, the nerve still intrigues otologists because of the never-ending emergence of new parameters and techniques, that may help to localize the nerve better.
3. In our study, most of the bones showed insignificant variation in FN course when considered comprehensively. However, few morphometric parameters in relation with facial nerve and surrounding structures, showed a significant variation from the range mentioned in literature.
4. The most commonly used approach to facial nerve is via “transmastoid” route. Identification of SoH and MacEwen’s triangle is the most important step here to avoid damage to sigmoid sinus and MCF dura. SoH is a constant landmark, and even if not prominent (4 out of 25 bones), it can be identified by a cribriform appearance in the postero-superior wall of bony EAC.
5. Presence of Koerner’s septum (4 out of 25 bones) may obliterate the antrum and diseased air cells, and also hinder with identification of F_m.
6. SPI, LSCC and 2nd Genu form an almost equilateral triangle, hence identification of former 2 can aid in anticipating the position of 2nd genu. These also form the most persistent landmarks for F_m.
7. Poorly pneumatized mastoid poses difficulty in locating facial nerve, because in such bones few landmarks are not well recognised, such as digastric ridge.
8. Once F_m, is identified, apart from its direction and course, following possible

variations should be kept in mind.

- Depth of 2nd genu can show certain variation, but SPI and LSCC serve as good landmark for its identification.
 - As FN courses through mastoid, it shows a lateral deviation as it reaches the SMF. This, if not paid attention to, can lead to iatrogenic injuries in the lower part of F_m.
 - F_m lies in relation to the sigmoid plate and is closest to it near the middle third portion, hence, while approaching facial nerve, care should be taken in this region to avoid injury to sigmoid sinus.
 - Chorda tympani emerges from F_m few millimeters above SMF. This distance is also variable, and in 1 bone, it was found to emerge just at the SMF. Also, mastoid segment length and the distance b/w SMF and origin of chorda tympani were positively correlated.
 - The length of F_m also is not very consistent, but if landmarks are identified prior to approaching the nerve, the iatrogenic injuries can be avoided.
9. Abundance of blood vessels indicate proximity to F_m and was found to be maximum at the peri-genicular segments around 2nd genu.
10. F_t shows fewer variations when compared to F_m, and processus cochleariformis forms a very reliable landmark, due to its tendency to survive through most of the middle ear diseases. It usually lies below F_m and points to the GG, although in 3 bones PC was found adjacent to F_t and in 1 such bone, it did not point the GG but was present at the mid-point of F_t.
11. Oval window serves as a good landmark for posterior part of F_t. In earlier studies by various authors, few bones showed F_t to be overhanging over the oval window and obliterating almost half of its width, however no such findings were observed in our study.

12. Labyrinthine segment shows the least variations in terms of its morphometric parameters as well as relation to surrounding structures. However, a more thorough study focusing on just the labyrinthine segment and its relations would be more appropriate to reinforce such conclusion.
13. Fallopian canal bony dehiscence is not an uncommon finding, even without any middle ear pathology, and poses the highest danger to FN while middle ear and mastoid segments. Segments around 2nd genu showed the highest incidence of such dehiscence, more so F_t but 1 bone showed the same near GG. A pre-operative HRCT can help localize such deficit and therefore, avoid iatrogenic injury to the dehiscent segment.

SUMMARY

This study was conducted in KLES Dr Prabhakar Kore Hospital, Belagavi during a period of one year during which 25 wet cadaveric temporal bones were obtained from the fresh cadavers from Anatomy Dissection Hall at J. N. Medical College, Belagavi. The dissections were carried out with an objective of studying the facial nerve and its course and variations through temporal bone.

After the analysis the following results were obtained:

1. Spine of Henle was prominent in 84% of bones and in the bones where it was not prominent, it's cribriform appearance can be used to decide the direction of drilling and estimate position of antrum.
2. The average depth of mastoid antrum was 13.2mm.
3. The mean measurement of the distance between SPI and 2nd Genu, SPI and LSCC, 2nd genu and LSCC was found to be 2.20mm, 1.56mm and 1.51mm respectively, forming almost an equilateral triangle.
4. The prominence of digastric ridge is affected by the pneumatization of mastoid. In our study, 15 bones showed prominent digastric ridge, most of which were well pneumatized, or atleast diploic. In the other 10 bones the digastric ridge was not prominent, and this made the identification of lower end of facial nerve difficult.
5. The average length of F_m was found to be 9.80mm and was one of the most variable parameters.
6. The average depth of second genu was 15.2mm and that of lower end of F_m was 11.1mm, and hence F_m showed lateral deviation through its course in mastoid.
7. F_m lies in relation to the sigmoid plate, and is at an average distance of 7.20mm, 5.30mm and 6.40mm from it at the 2nd genu, mid-point and the lower end.
8. The average length of F_t was found to be 9.5mm.

9. The average distance between posterior edge of oval window and F_t was 4.21mm.
10. Processus Cochleariformis served as most constant landmark for facial nerve, & was found to lie at an average distance of 1.80mm from geniculate ganglion.
11. F_t was found to be 1.7mm deep to the anterosuperior part of bony annulus, and came to lie more laterally as it approached 2nd genu.
12. Blood vessels served as another indicator of proximity to facial nerve, and were found to be most abundant near 2nd genu.
13. Average length of labyrinthine segment was 3.29mm.

At the end of study, it was inferred that Isolated facial nerve anomalies are rare, and are usually found only in association with other developmental middle ear anomalies. Apart from this, minute morphometric variations form the basis of iatrogenic facial nerve injuries. Although various advanced technological modalities, like pre-operative imaging, can help delineate the course and relation to other middle ear structures, which may vary microscopically from one individual to other; the temporal bone dissection till date holds an indispensable place to prepare an otologist to avoid an iatrogenic injury to FN and also to approach it to address nerve pathologies.

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ANNEXURE I
ETHICAL CLEARANCE.



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 (Govt)

JAWAHARLAL NEHRU MEDICAL COLLEGE,
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Ref: MDC/DOME/907

Date: 24/12/2019


To,

REGISTRATION NO: BE0119011


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
"THE INTRATEMPORAL COURSE AND VARIATION OF FACIAL NERVE IN WET
CADAVERIC TEMPORAL BONES- AN OBSERVATIONAL STUDY IN KLES
DR.PRABHAKAR KORE HOSPITAL BELAGAVI", is ethical and justifiable. The proposed
research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects
Research.


(Dr. Anita Dalal)

Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N Medical College, Belagavi.

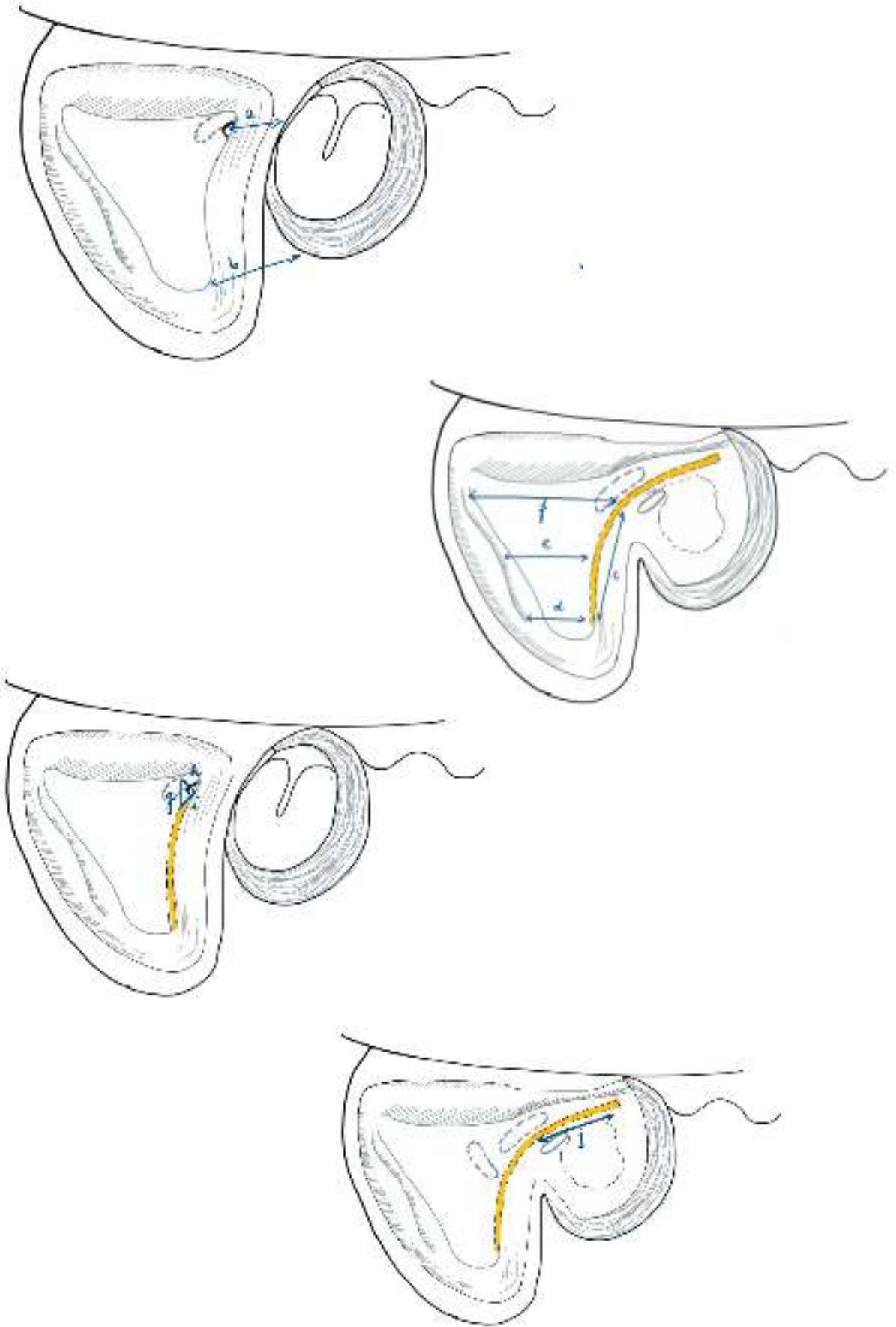

(Dr. Roopa M Bellad)

Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N Medical College, Belagavi.

ANNEXURE II
PROFORMA

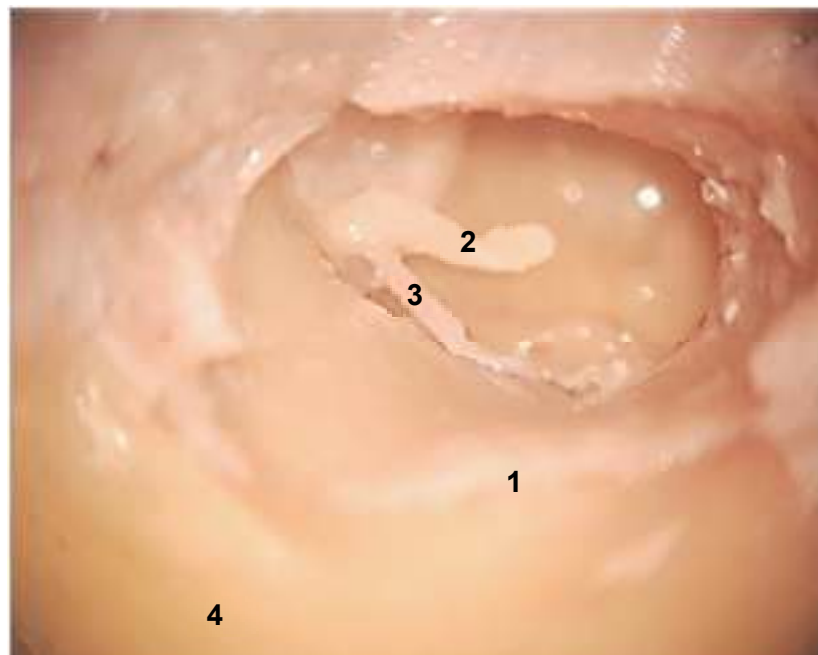
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2.	Specimen Number:	
3.	Side:	Right (R) / Left (L)
4.	External ear:	<p>Pinna Present (P) / Absent (A)</p> <p>Preauricular region anomalies Present (P) / Absent (A)</p> <p>Postauricular region anomalies Present (P) / Absent (A)</p> <p>External auditory canal Patent (Pa) / Atretic (At)</p> <p>Tympanic membrane Intact (I) / Not-Intact (NI)</p>
5.	Mastoid region:	<p>Mastoid tip Prominent (Pr) / Not- Prominent (NPr)</p> <p>Pneumatization Pneumatic (Pnu)/ Sclerotic (Scl)/ Diploic (Dpl)</p> <p>Digastric ridge Prominent (Pr) / Not- Prominent (NPr)</p> <p>Dehiscence Absent</p> <p>-Site Present/ Absent</p> <p>-Dimension Proximal Part/ Distal Part</p> <p>Distance b/w SPI and SOH (a)</p> <p>Distance b/w PCW & ventral end of DR (b)</p> <p>Length of mastoid segment of nerve (c)</p> <p>Distance from:</p>

		<ul style="list-style-type: none"> - Lower end of facial nerve to sinus plate (d) - Junction of upper half and lower half to sinus plate (e) - Distance from second genu to sinus plate (f) <p>Distance b/w LSCC and 2nd genu (g)</p> <p>Distance b/w LSCC & SPI (h)</p> <p>Distance b/w SPI & 2nd genu (i)</p> <p>Distance b/w Chorta tympani origin and SMF</p>	
6.	Middle ear cavity:	<p>Ossicular chain status</p> <p>Dehiscence of facial canal</p> <ul style="list-style-type: none"> - Present/absent: - Site: - Dimensions: <p>Length of horizontal segment of FN (j)</p> <p>Distance b/w facial nerve to anterosuperior aspect of tympanic annulus</p> <p>Distance between cochleariform process and geniculate ganglion</p> <p>Distance b/w FN & oval window (posterior-most margin)</p>	<p>A. Intact</p> <p>B. Not intact</p>
7.	Labyrinthine segment:	Distance from internal auditory fundus to geniculate ganglion	
8.	Remarks:		

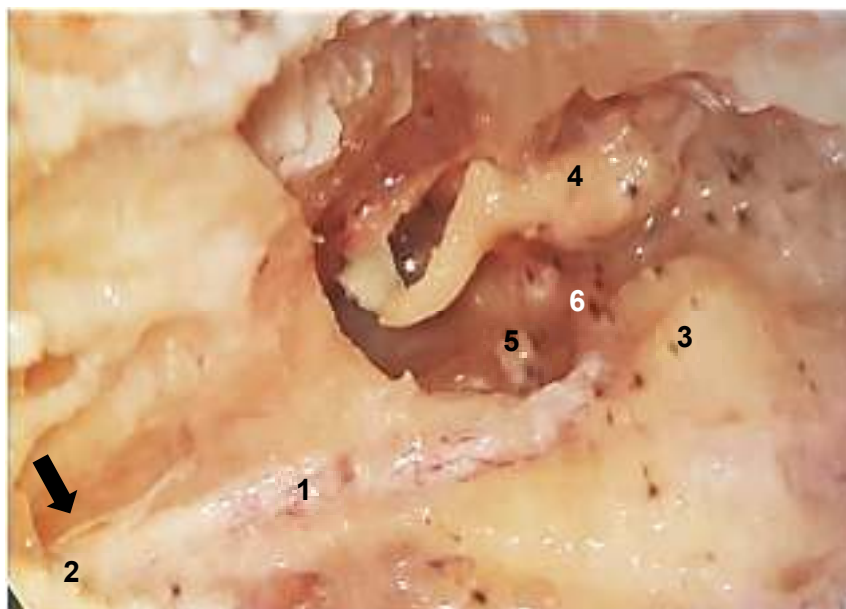


ANNEXURE III

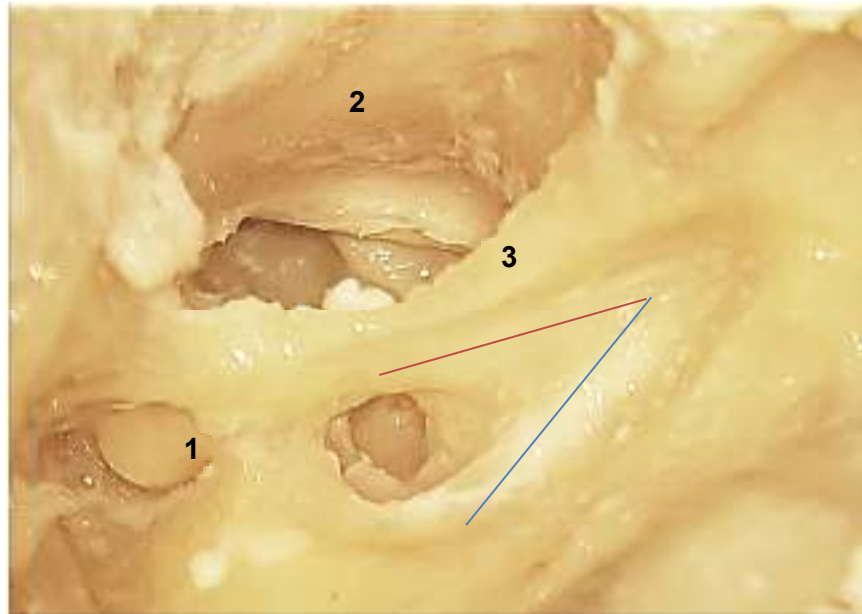
PHOTOGRAPHS



Photograph 1: Right temporal bone showing SoH (1); Handle of malleus (2); chorda tympani (3); mastoid cortex (4).



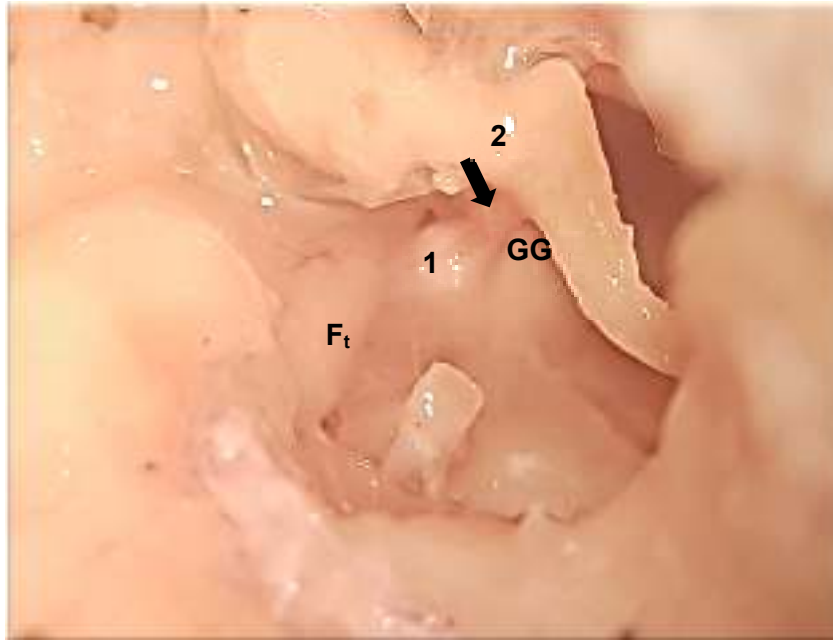
Photograph 2: Left temporal bone showing the chorda tympani arising (black arrow) from the main trunk (1) at SMF (2). In same specimen, horizontal segment (6) length was found to be minimum out of all the specimens studied. Other labelled structures- LSCC (3); head of malleus (4); head of stapes (5).



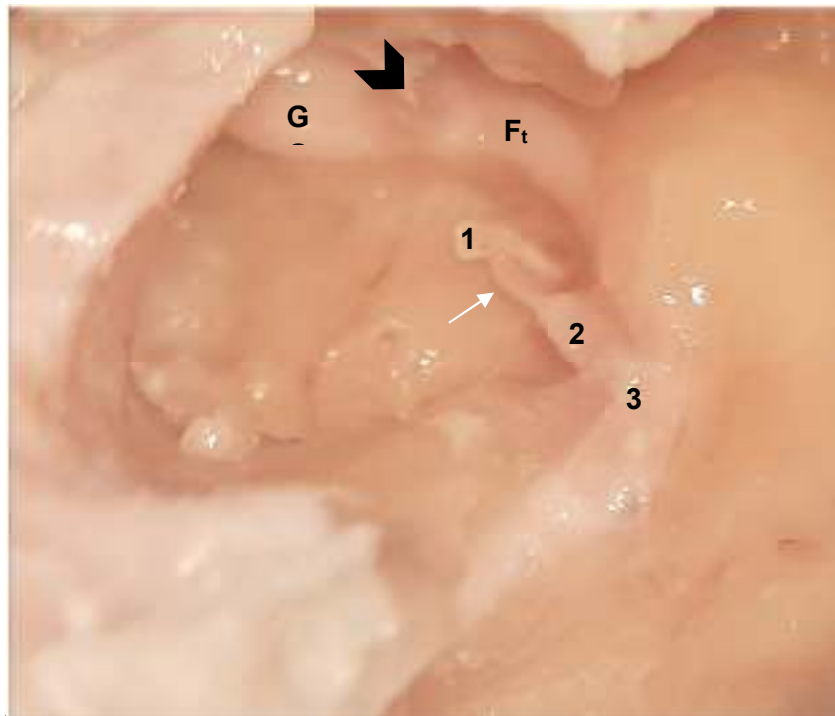
Photograph 3: Facial recess approach a left temporal bone after identifying chorda tympani (red line) and main trunk of FN (blue line). (1) SPI; (2) EAC; (3) Posterior canal wall



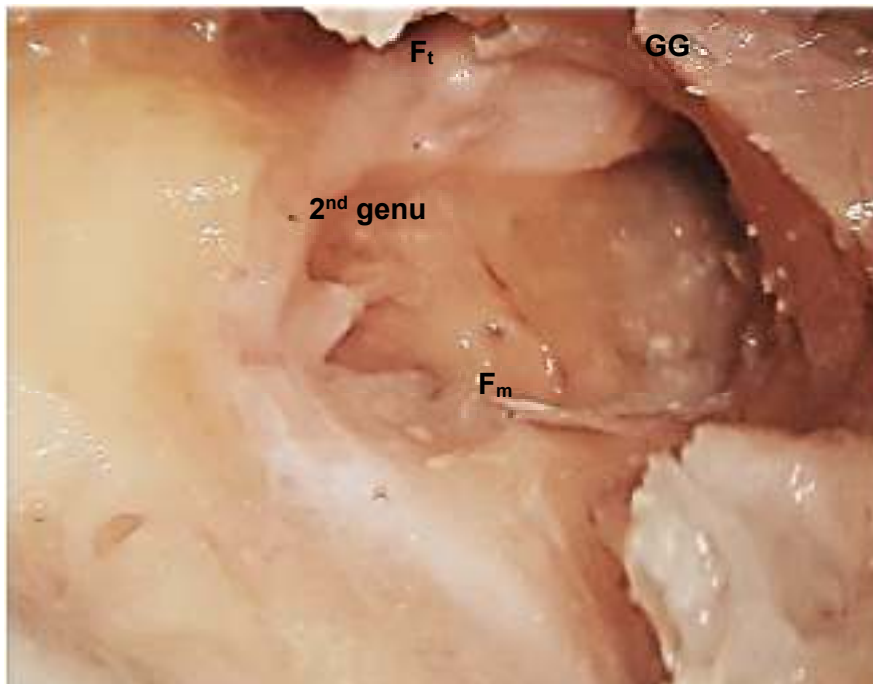
Photograph 4: Ft (1) relation with oval window (2). An air cell (black arrow) is appreciated between the two.



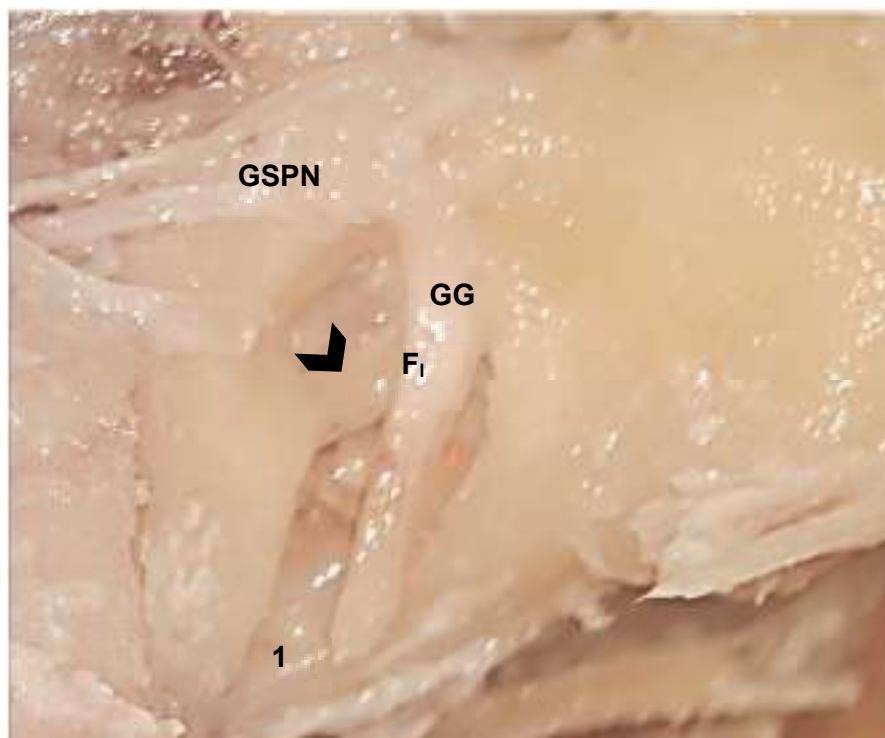
Photograph 5: *Processus Cochleariformis (1) in relation with F_t and adjacent to GG. Tensor tympani tendon (black arrow) can be appreciated arising from PC (1) to neck of malleus (2).*



Photograph 6: *Variation in Processus Cochleariformis (black arrow)- not at GG; also, F_t travelling adjacent to it & not superiorly. (1) stapes head; (2) pyramidal process; (3) 2nd genu; (white arrow) stapedius tendon.*



Photograph 7: Intratemporal course of facial nerve.



Photograph 8: Facial nerve in anterosuperior quadrant of IAC. (1) porus of IAM; (black arrow) falciform crest.

ANNEXURE IV - KEY TO MASTERCHART

GLOSSARY	ABBREVIATIONS
SPI	Short Process of Incus
PCW	Posterior Canal Wall
DR	Digastric Ridge
MS	Mastoid Segment
CT	Chorda Tympani
SMF	Stylomastoid Foramen
LE	Lower End
UE	Upper End
SP	Sigmoid Sinus
LSCC	Lateral Semicircular Canal
G2	Second Genu
TS	Tympanic Segment
AS	Antero-Superior
LS	Labyrinthine Segment
KS	Korner's Septum
FN	Facial Nerve
PC	Processus Cochleariformis
R	Right
L	Left
A	Absent
P	Present
Pa	Patent
At	Atretic
I	Intact
NI	Not-intact
Pr	Prominent
NPr	Non-Prominent
Scl	Sclerotic
Pnu	Pneumatic
Dpl	Diploic

S.NO.	DATE	SIDE	PINNA	PREAURICULAR REGION ANOMALIES	POSTAURICULAR REGION ANOMALIES	EXTERNAL AUDITORY CANAL	TYMPANIC MEMBRANE	SPINE OF HENLE	OSSICULAR CHAIN	MASTOID TIP	PNEUMATISATION	DIGASTRIC RIDGE	SPI TO SOH	PCW TO ANTERIOR END OF DR	MS LENGTH	CT to SMF	LE OF MS TO SP	MID-POINT OF MS TO SP	UE OF MS TO SP	LSCC TO G2	LSCC TO SPI	SPI TO G2	TS LENGTH	TS TO AS ANNULUS	PC TO GG	TS TO OVAL WINDOW	LS LENGTH	DEHISCENCE	DEHISCENCE DIMENSIONS	REMARKS
1	28-02-2020	R	A	A	A	Pa	I	Pr	I	Pr	Scl	Pr	11.2	11.7	9.1	3.5	5.3	4.8	6.9	1.1	2.0	2.9	8.9	1.4	1.3	4.1	3.2	A	0	
2	27-03-2020	R	P	A	A	Pa	NI	NPr	I	NPr	Dpl	NPr	12.2	9.1	8.0	0.1	6.2	5.3	7.1	1.0	1.2	1.9	8.9	1.2	1.9	3.0	3.1	A	0	
3	29-05-2020	L	P	A	A	Pa	NI	Pr	I	Pr	Scl	NPr	11.8	10.7	8.6	2.3	8.1	6.2	8.9	1.6	1.5	1.9	10.9	1.5	1.7	4.2	3.8	A	0	
4	07-07-2020	R	A	A	A	Pa	NI	Pr	I	Pr	Dpl	Pr	14.8	10.9	8.5	2.0	7.2	4.6	8.5	1.0	1.3	2.1	10.2	1.1	1.5	4.9	4.1	A	0	KS, FN adjacent to PC
5	12-07-2020	R	A	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	15.1	11.0	9.6	3.8	6.0	4.0	7.0	1.4	1.7	3.1	9.1	1.4	2.5	3.8	2.9	TS	0.5 X 0.5	
6	17-07-2020	L	P	A	A	Pa	I	Pr	NI	Pr	Dpl	NPr	16.0	11.2	8.6	1.8	7.9	4.5	8.3	1.6	1.5	2.9	9.3	1.2	2.2	3.3	3.8	TS	0.5 X 0.7	
7	24-07-2020	L	P	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	12.5	10.2	8.9	1.4	6.3	3.8	7.9	1.6	1.1	2.8	9.0	1.6	1.4	4.2	3.5	A	0	
8	15-08-2020	L	P	A	A	Pa	NI	NPr	I	NPr	Pnu	NPr	13.6	12.0	10.1	2.9	6.2	6.8	7.7	1.5	1.8	2.0	10.8	1.5	1.2	5.0	3.2	TS	0.5 X 0.3	
9	16-08-2020	L	A	A	A	Pa	I	Pr	I	Pr	Pnu	Pr	14.6	12.2	9.6	1.6	6.1	6.7	7.0	1.8	1.8	2.0	10.1	1.6	1.1	4.0	3.0	A	0.0	
10	25-08-2020	R	P	A	A	Pa	I	Pr	NI	Pr	Scl	NPr	13.2	11.3	8.3	1.2	6.2	6.5	6.1	2.0	1.7	1.6	9.2	1.3	1.5	4.2	2.7	TS	0.5 X 0.5	
11	31-08-2020	L	A	A	A	Pa	I	Pr	I	Pr	Pnu	Pr	12.8	10.8	12.7	3.5	6.4	6.1	6.2	1.8	1.5	1.5	8.7	1.7	2.3	5.0	2.9	A	0.0	KS
12	05-09-2020	L	A	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	14.1	10.6	10.2	2.3	5.2	4.9	6.5	1.2	1.9	2.7	9.1	1.5	1.3	4.2	3.2	A	0.0	
13	20-09-2020	R	P	A	A	Pa	NI	NPr	I	NPr	Scl	NPr	13.1	11.5	8.1	1.1	6.1	5.4	7.1	1.2	1.2	1.8	8.8	1.8	1.5	4.2	3.3	A	0.0	
14	29-09-2020	L	A	A	A	Pa	I	Pr	I	Pr	Pnu	Pr	11.2	12.3	13.0	3.2	6.5	6.2	6.3	1.9	1.4	1.4	10.8	1.9	1.9	5.5	3.0	A	0.0	
15	06-10-2020	R	P	A	A	Pa	NI	Pr	NI	Pr	Pnu	Pr	12.1	10.3	13.0	3.0	6.2	6.5	5.8	1.2	1.8	1.9	9.1	1.4	1.5	4.1	2.8	A	0.0	FN adjacent to PC
16	08-10-2020	L	A	A	A	Pa	I	Pr	I	Pr	Pnu	Pr	12.0	9.8	10.0	2.2	6.2	6.5	7.1	1.9	1.7	1.9	10.2	1.8	2.8	4.2	3.1	A	0.0	
17	21-10-2020	L	A	A	A	Pa	NI	NPr	I	NPr	Dpl	NPr	12.0	10.6	11.2	3.1	4.2	5.2	7.5	1.0	1.2	1.5	9.1	1.9	1.1	5.0	3.0	TS	1 X 0.5	KS
18	02-11-2020	R	P	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	13.2	11.1	8.6	1.4	6.2	3.9	7.2	1.7	1.2	2.7	9.9	2.1	2.7	4.0	3.6	A	0.0	
19	07-11-2020	L	P	A	A	Pa	I	Pr	NI	Pr	Dpl	NPr	14.2	12.5	8.4	1.9	7.8	4.2	8.1	1.5	1.2	2.5	9.3	1.6	1.5	3.2	3.6	A	0.0	

20	15-11-2020	R	A	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	13.5	11.6	9.4	2.4	6.2	4.1	6.8	1.2	1.8	3.2	9.2	1.8	1.3	3.6	3.0	TS	0.2 X 0.5	
21	26-11-2020	R	A	A	A	Pa	NI	Pr	I	Pr	Pnu	Pr	15.1	12.7	9.5	2.1	6.1	4.2	7.1	1.4	1.6	3.0	9.1	1.8	2.4	3.5	2.8	A	0.0	
22	05-12-2020	R	A	A	A	Pa	I	Pr	I	Pr	Dpl	Pr	15.6	10.9	8.2	1.3	7.1	4.2	8.4	1.2	1.3	2.0	8.7	1.9	2.2	4.8	4.2	MS	0.5 X 0.5	KS
23	21-12-2020	L	P	A	A	Pa	NI	Pr	NI	Pr	Scl	NPr	11.4	11.3	8.5	1.4	8.0	6.3	8.8	1.7	1.5	1.9	9.7	1.4	2.7	4.1	3.9	A	0.0	
24	06-01-2021	R	P	A	A	Pa	NI	Pr	NI	Pr	Pnu	Pr	12.8	12.1	11.8	4.2	6.2	5.5	6.2	2.1	1.8	1.9	9.2	1.6	1.6	5.2	3.5	MS	0.3 X 0.3	FN adjacent to PC
25	16-02-2021	R	A	A	A	Pa	NI	Pr	I	Pr	Scl	NPr	11.8	9.9	13.0	5.3	6.1	6.2	5.5	2.1	2.3	1.9	10.6	1.7	1.7	4.0	3.0	TS	0.5 X 0.5	