THE HOUSE INSTITUTE
FOUNDATION

Temporal Bone Surgical Dissection Manual

Ralph A. Nelson, M.D.

Third Edition

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Temporal Bone Surgical Dissection Manual

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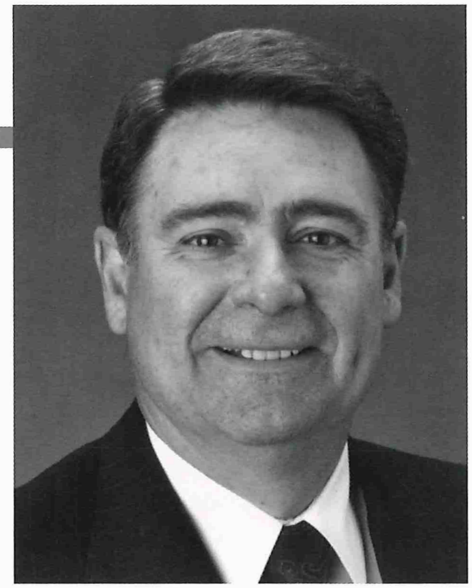
Preface

to the First and Second Editions



This volume is intended as a basic introduction to surgical dissection of the temporal bone. The idea for this project originated with my initial attempts in my residency to dissect a temporal bone. I found no single source that would guide me in setting up a dissection bench and then drilling a bone in such a way that I could learn the anatomy from a surgical approach. I later found that not only was a surgical approach important, but also that an organized approach that would enable me to utilize each and every bone to its fullest extent was just as vital.

Drawings were selected over photographs in order to concentrate on specific details and to obtain the depth of field felt necessary to adequately depict the dissections. In certain areas, actual surgical procedures are used to better illustrate the anatomic detail and its applicability to the dissection. This manual is organized to introduce a student of the temporal bone to basic techniques and basic anatomy in a stepwise fashion, with each dissection building upon a previous one. All of the procedures in this manual can be accomplished in ten drilling sessions with a maximum of two temporal bones.

Each chapter occupies a full two- or three-hour dissection period for the introductory student. Midway through the exercises, time may be taken for review. The volume has been designed for ready reference during drilling in the dissection laboratory. Again let me emphasize that this manual is an introduction to temporal bone dissection and in no way should be construed as a definitive treatise on the subject. I feel that it will aid those who have previously studied the temporal bone to review already acquired skills. The repeated use of these dissections will allow the temporal bone surgeon to become skilled and knowledgeable enough to complete actual surgeries with confidence.

Ralph A. Nelson, M.D.

Preface
to the Third Edition

It is with pleasure that we bring to you this updated 3rd Edition of Dr. Ralph Nelson's Temporal Bone Surgical Dissection Manual. Over the years, his manual has been used by many ear surgeons as an introduction and a guide to learn the complex surgical anatomy of the temporal bone.

Ralph A. Nelson, M.D., intended this manual as a basic introduction to surgical dissection of the temporal bone. He created a source that helps beginners set up a dissection bench and drill a bone in an organized and step-wise fashion that enables them to use the bone to its fullest extent, maximizing the use of every temporal bone and allowing them to practice as many steps as possible.

Schematic drawings of surgical steps and procedures guide the surgeon through the surgical anatomy, bringing to life those essential structures to be identified as part of the surgical exercise before moving on to the next step in learning the three-dimensional anatomy and the relationships between relevant anatomic structures.

The intricate anatomy of the temporal bone can be mastered only by practicing long hours, in a structured and organized way. For the new otologist, this is the first step in becoming well versed in all aspects of temporal bone surgical dissection.

On behalf of all of the Associates of the House Clinic, the House Ear Institute and surgeons around the world who have used this book as their first guide to dissecting the many areas of the temporal bone, we thank Dr. Ralph A. Nelson for this manual, which has made dissection of the temporal bone a well-organized exercise.

Antonio De la Cruz, M.D.
José N. Fayad, M.D.

Foreward

When I began my two-year residency in ear, nose, and throat in 1937 at Los Angeles County Hospital, mastoid surgery was a life-saving procedure. Children with upper respiratory infections frequently developed acute otitis media followed by acute mastoiditis. Without antibiotics, most of these patients required mastoid surgery to prevent disastrous complications, such as lateral sinus thrombosis, meningitis, and, often, death. Subacute and chronic mastoiditis often required modified or radical mastoid surgery.

Temporal bone dissections were performed with mallet, gouge and curettes. The classical modified radical operation was frequently used in an attempt to preserve hearing. In chronic ear disease with a perforated eardrum and infection and cholesteatoma in the middle ear and attic area, the radical mastoidectomy was performed. For radical mastoid surgery, I was instructed to insert a probe into the area of the eustachian tube and to be extremely careful not to go superior to that probe because the fallopian canal and possibly an exposed facial nerve might lie under the cholesteatoma or granulation tissue. The orifice of the eustachian tube was thoroughly curetted and denuded from its mucosa in an attempt to block the tube. In those days of mastoid surgery, it is miraculous that any ears with modified or radical procedures healed and remained dry.

After my residency, I observed Dr. Julius Lempert performing his revolutionary techniques for mastoid surgery, and his techniques were, of course, a result of his temporal bone dissections. To remove bone, he replaced the mallet and gouge with the dental drill and burrs. He introduced the endaural incision, which he used instead of the postauricular approach for all of his ear surgery. With a small ring curette, he demonstrated how to lift the periosteum and thickened mucosa from the posterior portion of the horizontal canal and carefully elevate them anteriorly and then inferiorly to expose the fallopian canal. He emphasized the need to see the fallopian canal rather than to work blindly around it, as I had been taught. He used the split-thickness skin to help epithelize the mastoid cavity. The fenestration operation became the standard surgical treatment for patients with otosclerosis. As a result, thousands of patients with otosclerosis were able to discard their hearing aids and enjoy serviceable hearing.

In 1955, Dr. Fritz Zollner and Dr. Horst Wullstein introduced their concept of myringoplasty and tympanoplasty that was to allow restoration of hearing through reconstruction of ears with chronic disease. Dr. Wullstein's introduction of the Zeiss operating microscope 50 years ago was as important to the development of modern otology.

Shortly after that, my brother, Dr. William House, convinced Mr. Jack Urban to apply his genius to the development of an observer's tube, still and motion picture cameras, and, later, television cameras adaptable to the operating microscope. They made possible the teaching of microscopic surgery to thousands of otologic surgeons throughout the world.

In the area of chronic ear surgery, William House demonstrated the value of the facial recess approach and the intact canal wall technique. His techniques in the removal of acoustic neuromas, his contributions to surgery of the endolymphatic sac in Meniere's disease, and more recently his development of electrical stimulation of the cochlea through the cochlear implant, are well known throughout the world.

Knowledge of the intricacies of the temporal bone anatomy is absolutely essential to the aspiring otologic surgeon. I am sure that this manual of temporal bone dissection will prove valuable in providing you with that knowledge. We are all most grateful to Dr. Ralph A. Nelson for the preparation of this fine treatise.

Howard P. House, M.D., (1908–2003)

Foreward

Temporal bone dissection is the sine qua non for the modern otologist. In the 50 years since Professor Horst Wullstein introduced the Zeiss operating microscope to ear surgeons, areas of the temporal bone formerly considered a surgical no-man's land have become accessible. High-speed diamond-stone drills and continuous suction-irrigation have also aided development of new surgical approaches. Now all areas of the temporal bone can be approached surgically. Indeed, an entire subspecialty called neurotology has evolved.

The temporal bone is one of the most complicated anatomical areas in the human body. Surgical accessibility of all of its structures has vastly increased the number of potential treatments for patients with hearing or balance disorders. For the new otologist, surgical acumen depends entirely on temporal bone dissection. There is absolutely no substitute.

Fortunately, most surgical procedures can be learned by diligent work at the dissection bench. However, it takes hundreds, even thousands of hours dissecting many, many temporal bones to gain the ability to mentally rotate and visualize in complete three-dimensional perspective all of the structures and their many interrelationships. With this knowledge, the surgeon can always visualize what is just beyond the rotating burr and can bring any desired structure into view.

From the postauricular view, the temporal bone must be dissected from the mastoid cortex to the tip of the petrous apex; from the middle fossa view, from the superior semicircular canal to the jugular foramen; and from the inferior view, from the tip of the styloid process to the temporal lobe. This approach must also be carefully studied through dissection. Through removal of the mandibular condyle and the contents of the infratemporal fossa, many new approaches to the temporal bone are now being developed. Let me again emphasize that detailed knowledge of these approaches comes only to those who spend the minimum of several hours weekly for several years dissecting temporal bones. Only dissection, not lectures, will acquaint you with the anatomy, teach you the relationships among structures, and inspire you to devise and practice new approaches.

This manual is merely an introduction to temporal bone dissection. We hope that you will find these dissection sessions fascinating enough to further explore the beautiful and marvelously complicated anatomy of the temporal bone. To become a master temporal bone surgeon is a real challenge -- like graduating from medical school or parenting a child -- and as gratifying. And no one can do it for you.

William F. House, M.D.

Acknowledgments

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Ralph A. Nelson, M.D.

Many thanks to Gail M. Poulson for editorial assistance, Karen I. Berliner, Ph.D. for editing, Linda Morris for updating illustrations and electronic production, and to the House Clinic and House Ear Institute for preparation and publication of this Third Edition.

Antonio De la Cruz, M.D.
Jose N. Fayad, M.D.

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Equipment
Bench (Fig. 1):

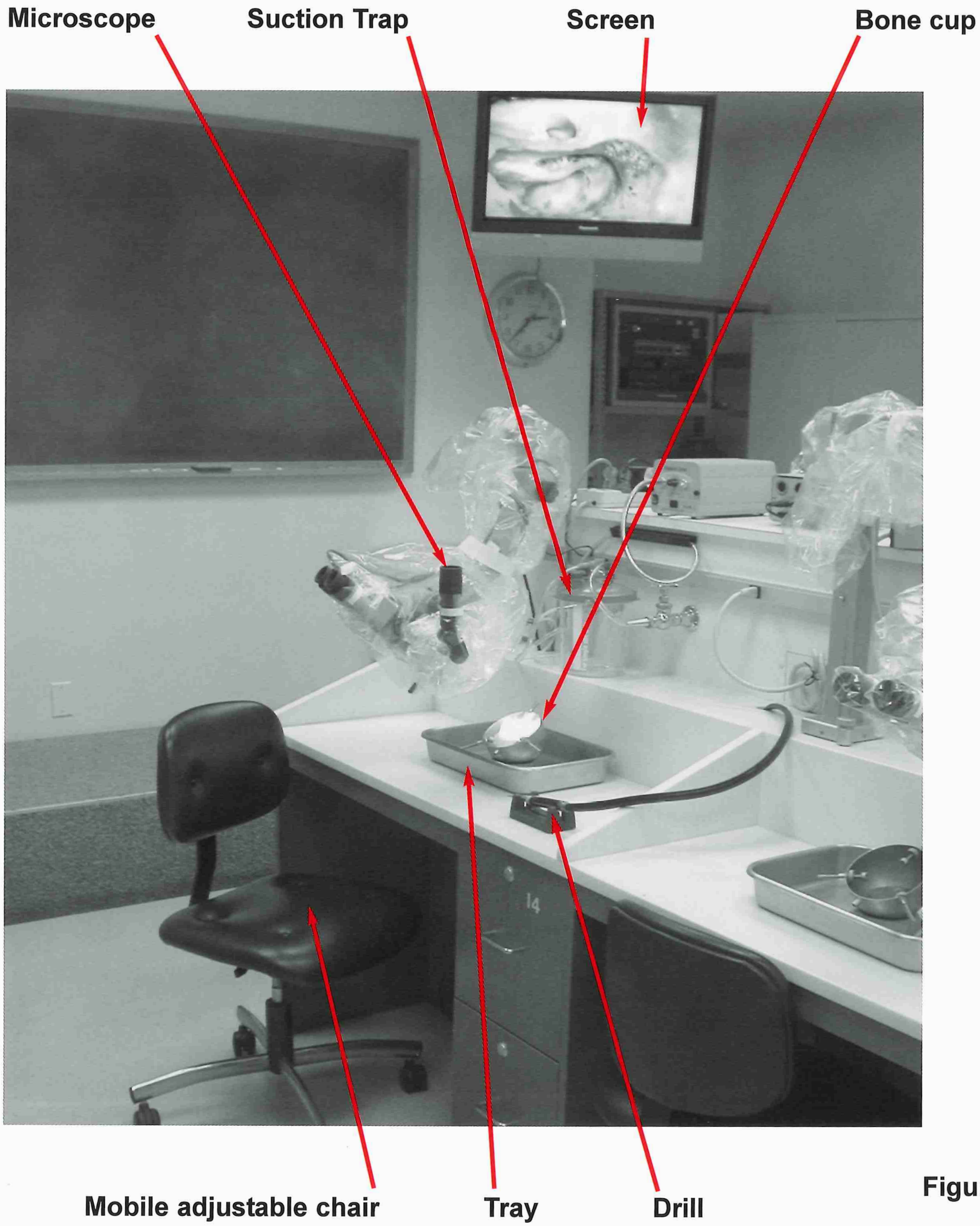

Figure 1

Equipment
Bench (Fig. 1):

The bench is important to a temporal bone dissection laboratory. Although the dissection could be performed on any available table in any available room, a pleasant environment increases the likelihood of repeating the exercises. This is also increased by (1) the ability quickly to set up and break down the equipment, (2) adequate equipment, and (3) use of the same equipment and techniques that will be used in the operating room.

Ideally, the temporal bone dissection bench should: (1) always be available and not be in use for some other purpose, (2) be large and deep enough to allow prolonged sitting without undue discomfort, (3) have a readily accessible power source for either an electrically driven drill or an air-driven drill, (4) have an easily cleaned and serviceably large trap for a suction apparatus so that prolonged dissections can be performed without interruptions for emptying the trap; (5) allow for the installation of an arm capable of supporting a microscope similar to the one used in the operating suite (unfortunately, the large floor stands used in the operating suite are not flexible enough to be easily used around the average bench), and (6) contain enough storage so that the instruments to be used are readily available for anyone to perform a dissection.

Chair

A chair with a backrest, similar to the chair used in the operating suite, should be comfortable and adjustable for height. Choose a chair with wheels for mobility so that the surgeon can move closer or farther away from the bone for proper extension and support of the arms.

Drill

The drill ideally should resemble the equipment in the operating suite. Any drill with a variety of burr sizes will suffice, but reliability should be a consideration. Burr shank support is necessary to prevent whipping; the electrically driven Wullstein-type (geared) drill with that support has been widely and successfully used, but is usually too expensive for laboratory purposes. Whatever system is used should allow enough room for movement of the drill engine on the bench so that both left- and right-handed persons can use the bench. Both diamond and cutting burrs should be available, and cutting burrs should be sharp.

Microscope

The microscope should closely resemble the unit used in the operating room. Again, this is to familiarize the dissection student with instruments to be used in surgery. We have found the Zeiss operating microscope to be durable and satisfactory, but many less expensive models are available.

Equipment

Suction Irrigation

We advise the use of suction-irrigation in both the operating room and the bone dissection laboratory. Adherence to techniques that mimic operating room procedure are important to instill confidence and familiarity in the surgeon and thereby decrease anxiety about actual operating room procedures. In the laboratory, the use of the suction-irrigator is not only to mimic operating room procedure, but also to insure that no bone dust or other debris obscures the field being dissected. A constant flow of cool moisture cools the drill and also keeps the burr free of bone dust, thereby allowing for better cutting edges. Any easily available water source can supply irrigation. It can flow simply by force of gravity, as it does in the operating room or from the top with an appropriate valve to cut pressure. We prefer suction tips of a simple configuration to avoid problems with handling. A straight House suction-irrigator has the least error in transfer from a suction-irrigator to a straight suction. The suction unit should be reliable and attached to a large, easily accessible, and easily cleaned trap.

Bone Holder

Although almost any device that stabilizes the bone for drilling purposes can be used, we have found the House-Urban stainless steel bone holder very satisfactory. It is easily cleaned, stable, and allows three-point fixation of the bone, which enables movement of the bone to any desired position for dissection. The bone cup should always be placed in a larger pan that will contain spilled irrigation fluids and accumulated bone dust. This unit contains three (3) threaded arms which allow easy adjustment. The tips of the threaded arms are fit with ball-joints that swivel. The lock nuts on the arms should be used to stabilize the joints (not the cup wall as is commonly seen), so as to prevent the impaled bone from slipping when being worked on.

Bones

Temporal bones cut from specimens should include all of the mastoid air cells, a small portion of the squamosal part of the bone, the tympanic ring, and the petrous tip. Bones can usually be obtained during postmortem examinations without damage that would interfere with preparation of the body for viewing. Complaints from morticians can be avoided by fixing the facial bones to the cranial vault by wire sutures, as in repair of a facial fracture, and by filling in any defects in the base of the skull with plaster of paris to prevent leakage of embalming fluids. This manner of taking bones leaves no external deformity of the skull.

Equipment
(Fig. 2):

Examination and Orientation of Bones

Before dissection, the temporal bone should be examined thoroughly in an effort to learn the external anatomy. Knowledge of this anatomy will ultimately be useful in identifying external features during surgical exposure and also in gaining three-dimensional orientation. Once the external topography has been reviewed, soft tissue overlying the mastoid area should be removed. All excess tissue that is not to be used in the dissection should be removed from the bone before it is secured in the stainless steel bone cup. The bone is then fixed in the stainless steel bone cup. It is oriented under the microscope for the standard surgical approach: with the postauricular axis of the mastoid tip and the middle fossa floor in the horizontal plane and the temporomandibular joint away from the surgeon.

Temporal Bone Dissection Lab **Figure 2**

General Considerations

The surgeon should be comfortably positioned to prevent strain on extension of the arms or backache due to slouching. The chair should be adjusted to maintain a comfortable position at all times. A waterproof apron is recommended to protect clothing since dissection with copious amounts of irrigating fluid will result in widespread moist bone dust. The microscope should be adjusted to maintain constant focus regardless of the power of magnification used. This is done by setting the proper distance between the eyes before starting and by focusing each eye individually at the highest power of the microscope. You will then find that upon turning to lower powers you remain parfocal. Suction and irrigation should be checked and regulated so that when suction is not used, there is a constant stream of water, and when the thumb is placed upon the suction valve, the stream is directly shunted into the suction apparatus. The flow, when held in the air, differs from that when the tip is on the bone. Adjusting the flow with the suction tip applied to the bone will allow irrigation to escape the tip without prematurely being short-circuited up the suction. The drill should be tested to verify that the burr turns in the proper direction and that its cutting edges are not reversed. With all equipment in proper working order, the surgeon may now proceed with the dissection.

Large-scale bone removal, such as on the cortex, is done with the largest possible cutting burr. The burr should be angled so that the flukes that are largest on the sides of the burr are directly against the surface. Cutting with the smaller flukes at the tip of the burr results in more heat, slower cutting, and often a "chatter." Burring with the tip also obscures the area that is being dissected.

A fundamental principle of temporal bone dissection is no blind dissection. Drilling should never proceed on the sense of touch alone. For better visualization of underlying bone while it is being cut, bone dust and accumulated blood should be removed by adjusting the suction-irrigation. This is done by shifting the suction tip to various positions around the burr so that travel of the burr pushes irrigation fluid and bone dust into the suction tip. This keeps the drill burr cool, the field clear, and the flukes of the burr free of bone dust, which would otherwise interfere with good cutting.

The handpiece of the drill should always be grasped firmly. Torque from the drill, especially if it is air-driven, will commonly cause unwanted movement in the beginning. Once the burr is at its full speed, larger cutting burrs tend to "run" because the burr chews against the bone. This will be accentuated by pressure or placement of the burr against a lip of bone on which the burr flukes can catch. To prevent this difficulty, shift the burr so that the flukes cut perpendicular to the ridge. In particularly tight areas, a diamond burr should be substituted and, preferably, the drill reversed so that it tends to run in the opposite direction.

Temporal bone surgery is based upon landmarks. Landmarks should always be identified before cutting and should always be preserved until other landmarks are located at deeper levels. The most complete exposure assures the best use of available landmarks. A general rule of dissection is to use the largest possible burr for a given area. This is especially true when approaching areas where a burr could plunge through dural plate or into a cavity.

1

Basic Mastoidectomy

Basic Mastoidectomy
Step 1 (Fig. 3):

Landmarks:

External auditory canal
Spine of Henle
Macewen's triangle
Temporal line
Mastoid process

Topography

Surface topography on exposure of the lateral surface of the mastoid bone before dissection is the external acoustic meatus (ear canal) anteriorly, the suprameatal spine (of Henle) at the superior posterior portion of the canal, and the suprameatal triangle (of Macewen) immediately behind the spine of Henle, where subperiosteal abscesses might form secondary to mastoid infection. The temporal line, forming a ridge continuous from the superior border of the zygomatic arch posteriorly onto the mastoid cortex, is the inferior limit of the temporalis muscle insertion and roughly the floor of the middle fossa (tegmen of the temporal bone). The lateral wall of the mastoid process (tip) is the point of insertion of the sternocleidomastoid muscle.

The largest available burr and the largest available suction-irrigator should be used during initial cortical exposure. An absence of important structures in the cortex allows safe and rapid removal of this bone, conserving the surgeon's time and energy for more tedious and delicate dissection elsewhere. A high rate of irrigation is necessary to prevent overheating of the burrs and clogged burr flukes, which decrease cutting ability.

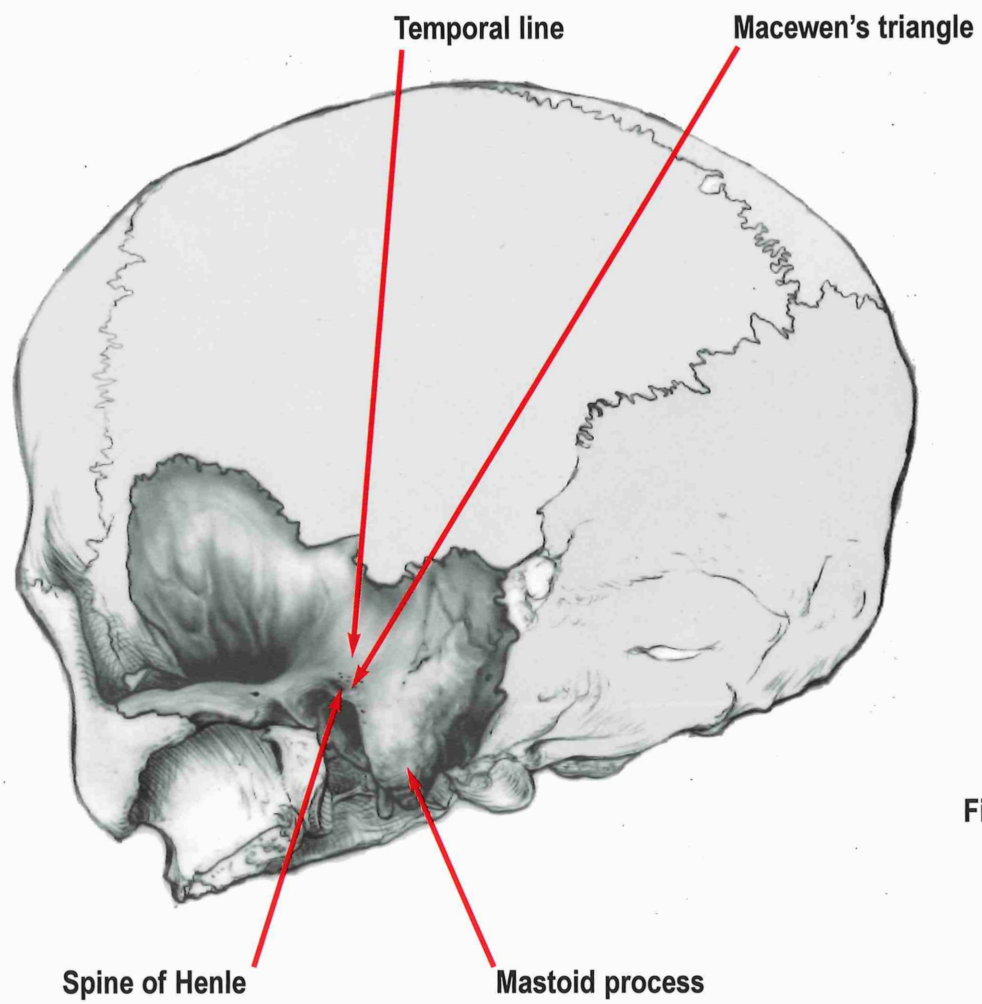

Figure 3

Basic Mastoidectomy

Step 2 (Fig. 4):

Landmarks:

External auditory canal
Spine of Henle
Macewen's triangle
Mastoid tip
Temporal line

Removal of Cortex

The surface of the bone is wet with irrigation fluid from the suction-irrigator, and the drill is applied to the mastoid cortex immediately posterior to the spine of Henle. A straight cut drawn along the temporal line posteriorly into the sinodural angle delineates the upper portion of the dissection. A second cut is made perpendicular to the first and toward the mastoid tip. This cut is immediately posterior to the posterior canal wall. The mastoid cortex is then removed in a systematic fashion of saucerization, with the deepest portion of penetration at the junction between the two perpendicular lines. This area behind the spine of Henle which actually overlies the mastoid antrum is called the suprameatal triangle of Macewen.

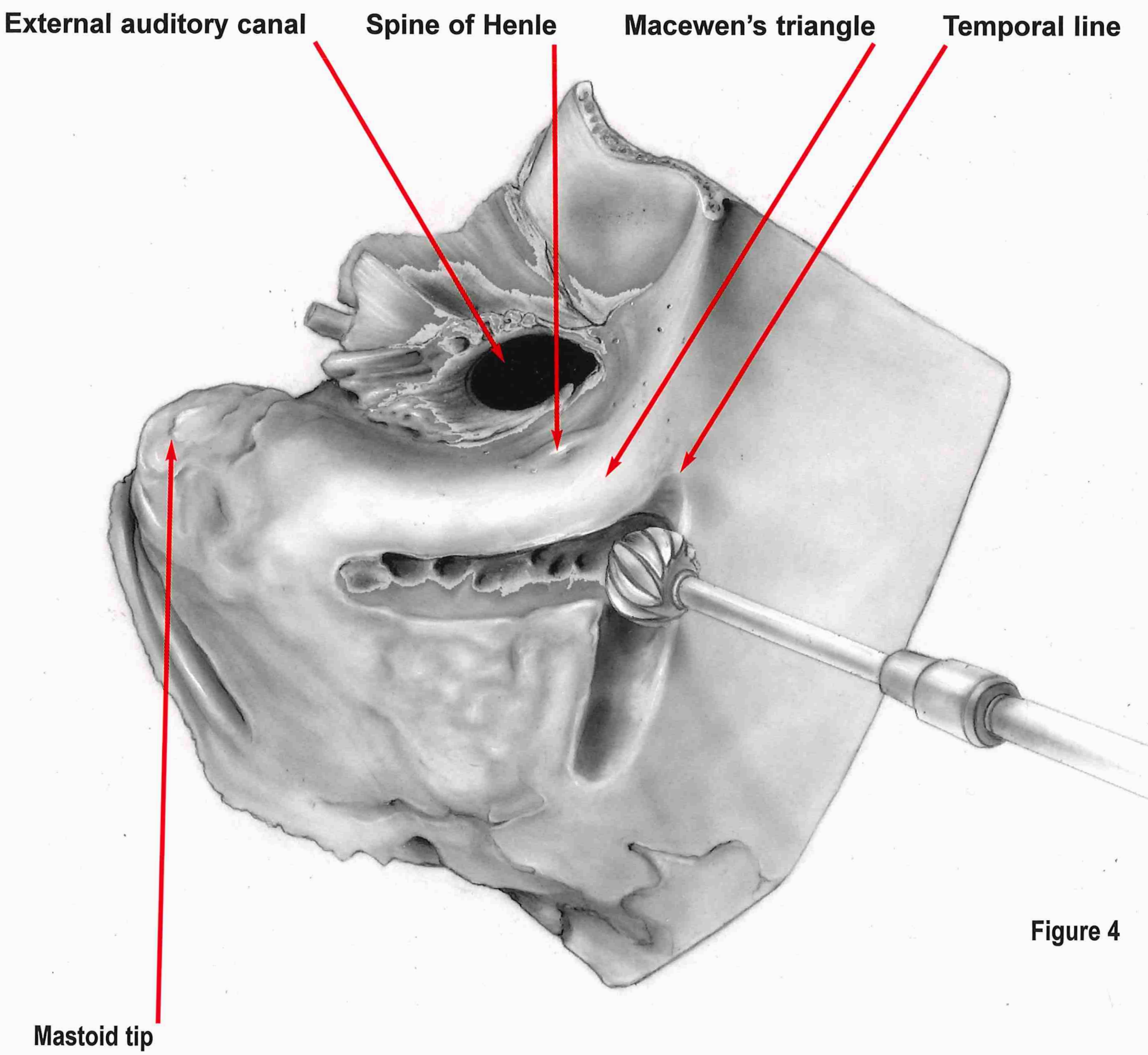

Figure 4

Basic Mastoidectomy

Step 3 (Fig. 5):

Landmarks:

External auditory canal
Posterior canal wall
Tegmen tympani
Mastoid tip

Cavity Saucerization

To avoid a constricted dissection that prevents adequate angular visualization of deeper-lying structures, wide cortical removal should be completed before deeper penetration into the antrum. The mastoid cortex should be unroofed from the posterior canal wall back to and slightly beyond the sigmoid sinus and at an adequate distance into the mastoid tip. The posterior canal wall should be thinned so that the shadow of an instrument can be seen through the bone when the canal skin is elevated. This wide saucerization cannot be emphasized enough. Insufficiently wide saucerization is the single most common reason for inadequate recognition of landmarks and awkward exposure during deeper dissection.

When adequate cortical removal has been accomplished, a kidney bean-shaped cavity will result. The inferior portion of the shape is formed by the mastoid tip below the sigmoid sinus and ear canal. The upper portion is above the sigmoid sinus, extending posteriorly into the sinodural angle and anteriorly into the zygomatic root. Anteriorly, the posterior bony canal wall will constrict the center of the cavity. This type of cortical removal is basic to all posterior approach procedures on the mastoid cavity. Again, be reminded that failure to perform this type of exposure while deepening the dissection toward the antrum can lead to a bothersome constriction of the cavity at more medial levels.

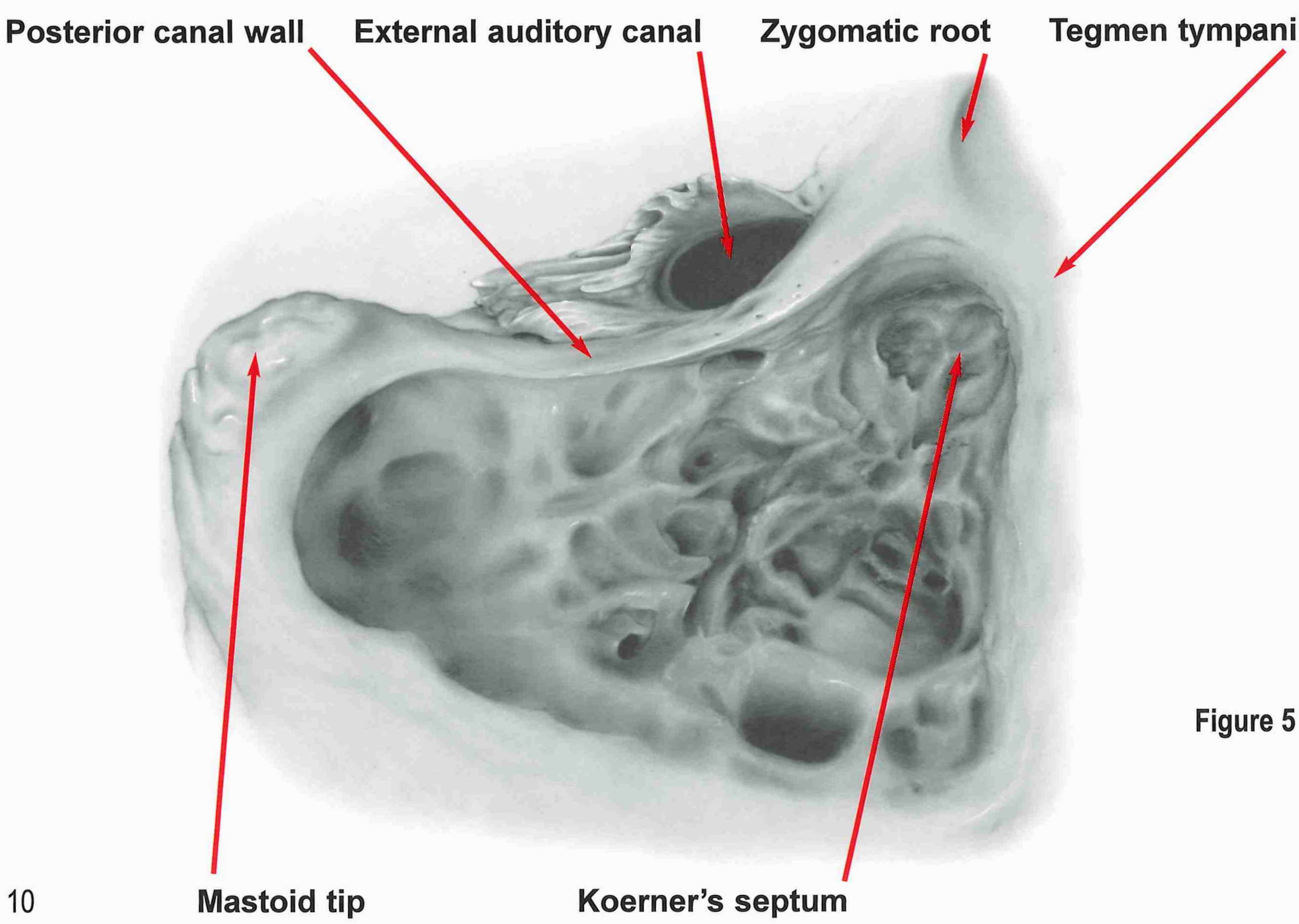

Figure 5

Basic Mastoidectomy
Step 4 (Fig. 6):

Landmarks:

Posterior canal wall
Tegmen tympani
(middle fossa dural plate)

Identification of the Middle Fossa Dural Plate

During mastoidectomy, it is important to expose the middle fossa dural plate (tegmen tympani) for best possible access into the antrum and epitympanic areas. This exposure is critical to a well-dissected sinodural angle, which provides visual access into the internal auditory canal area after labyrinthectomy. Failure to locate the middle fossa plate usually leads to insufficient removal of cells along the superior border and causes compromised exposure and decreased access to the epitympanum and hard angle.

The best way to expose the middle fossa plate is to burr the cortex into the area of the linea temporalis until bone color changes indicate that the middle fossa dura has been reached. The dissection should round off the edge of the superior lip roughly paralleling the curve of the dura. This plate exposure can be followed into the antrum without lacerating the dura. Once the heavier bone is removed, thinning can be performed with a diamond burr, which results in less bleeding.

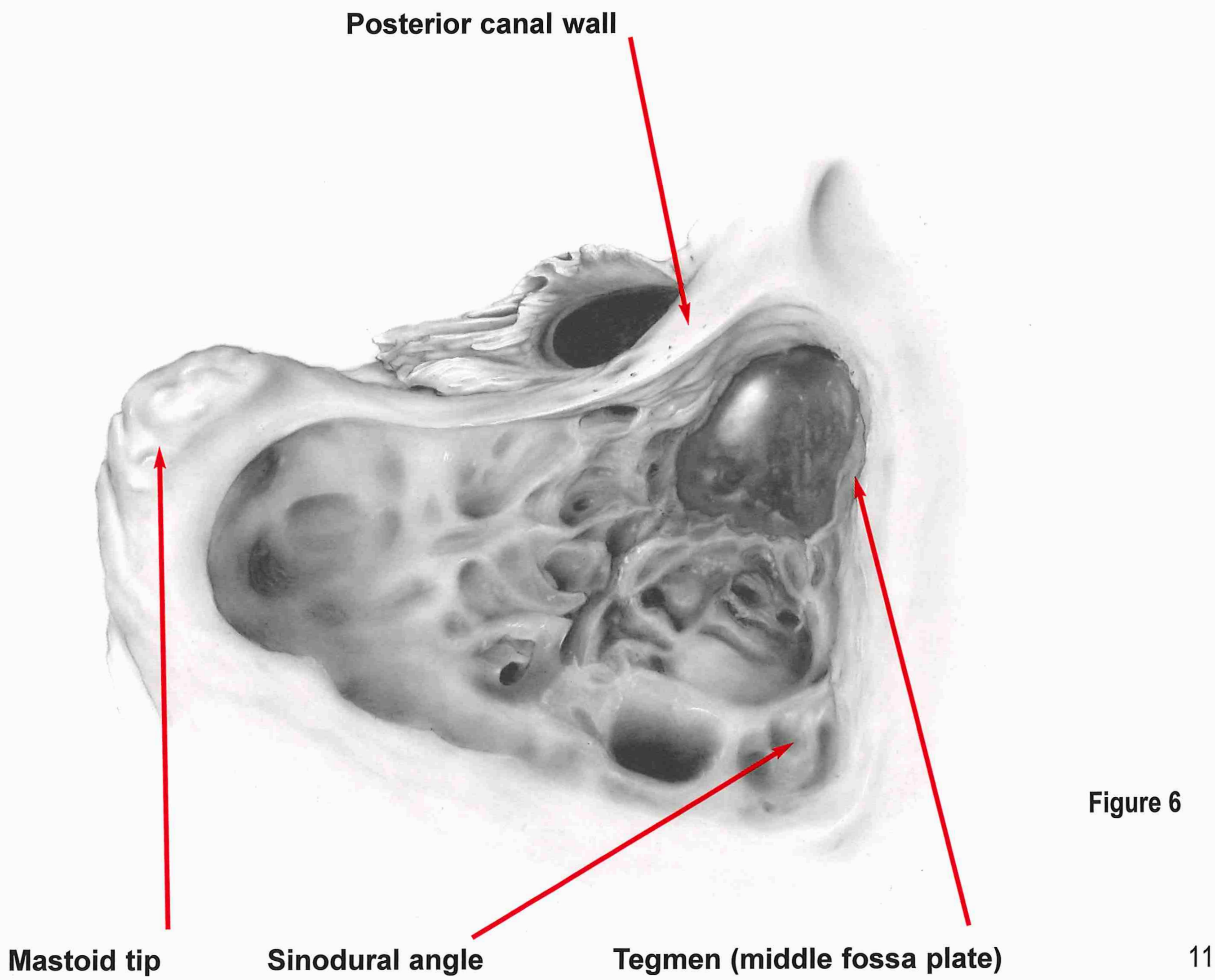

Figure 6

Basic Mastoidectomy
Step 5 (Fig. 7):

Landmarks:

Posterior canal wall
Tegmen tympani
Sinodural angle
Mastoid tip

Identification of the Lateral Sinus

When the middle fossa plate is well established, the surgeon locates the sigmoid sinus by drilling out the posterior portion of the mastoid cavity a sufficient distance from the bony canal wall. Well-aerated mastoid bone is frequently found in neurotologic dissections, and it is possible to continue drilling in the posterior direction until the occiput is exposed. If a sufficient amount of bone has been removed posteriorly, the dissection may proceed deeper into the mastoid cavity in an attempt to find the sigmoid sinus. The sigmoid sinus generally appears in the posterior portion of the dissection as a blue discoloration of smooth dural bony plate. Dural plate of both the middle fossa and the posterior fossa tends to be somewhat uniform and is not cellular. Inspect any area of smooth plate for color changes that indicate an underlying soft structure, such as the sigmoid sinus. Because this plate can be quite thin, proceed with caution. A thinned dural plate can be identified by changes in the sound of the burr vibrating on it. Once the sigmoid sinus has been located under its plate, the area between the sigmoid and the middle fossa plate, the sinodural angle, can be fully evacuated of air cells. In dissection of the sinodural angle, penetration of the plate results in exposure of the superior petrosal sinus. This sinus lies immediately deep to the sinodural angle in its entire extent, and represents the posterior superior lip of the temporal bone where the middle fossa and posterior fossa meet. The sigmoid sinus usually lies a few millimeters deep to the cortex in the mastoid cavity. This structure is the posterior limit of the standard mastoid dissection. It is not more widely exposed unless the posterior fossa is to be entered.

Inferior to the sigmoid sinus lies the largely air-containing mastoid tip. Laterally, there is no danger of entering any vital structures, so the tip may be cleaned of air cells to gain better exposure in the jugular bulb area.

The areas dissected and the structures identified thus become landmarks for deeper penetration into the temporal bone. The cortical landmarks of the external canal, spine of Henle, linea temporalis, and mastoid tip now become the mid-level landmarks of the middle fossa plate, sinodural angle plate, sigmoid sinus plate, mastoid tip air cells, and the thinned posterior external canal bony wall. Knowledgeable and safe penetration deeper in the temporal bone depends upon complete identification of these structures. The principle of temporal bone surgery is to move from one known landmark to the next, guided by the relationships between each.

Basic Mastoidectomy
Step 5 (Fig. 7):

Identification of the Lateral Sinus

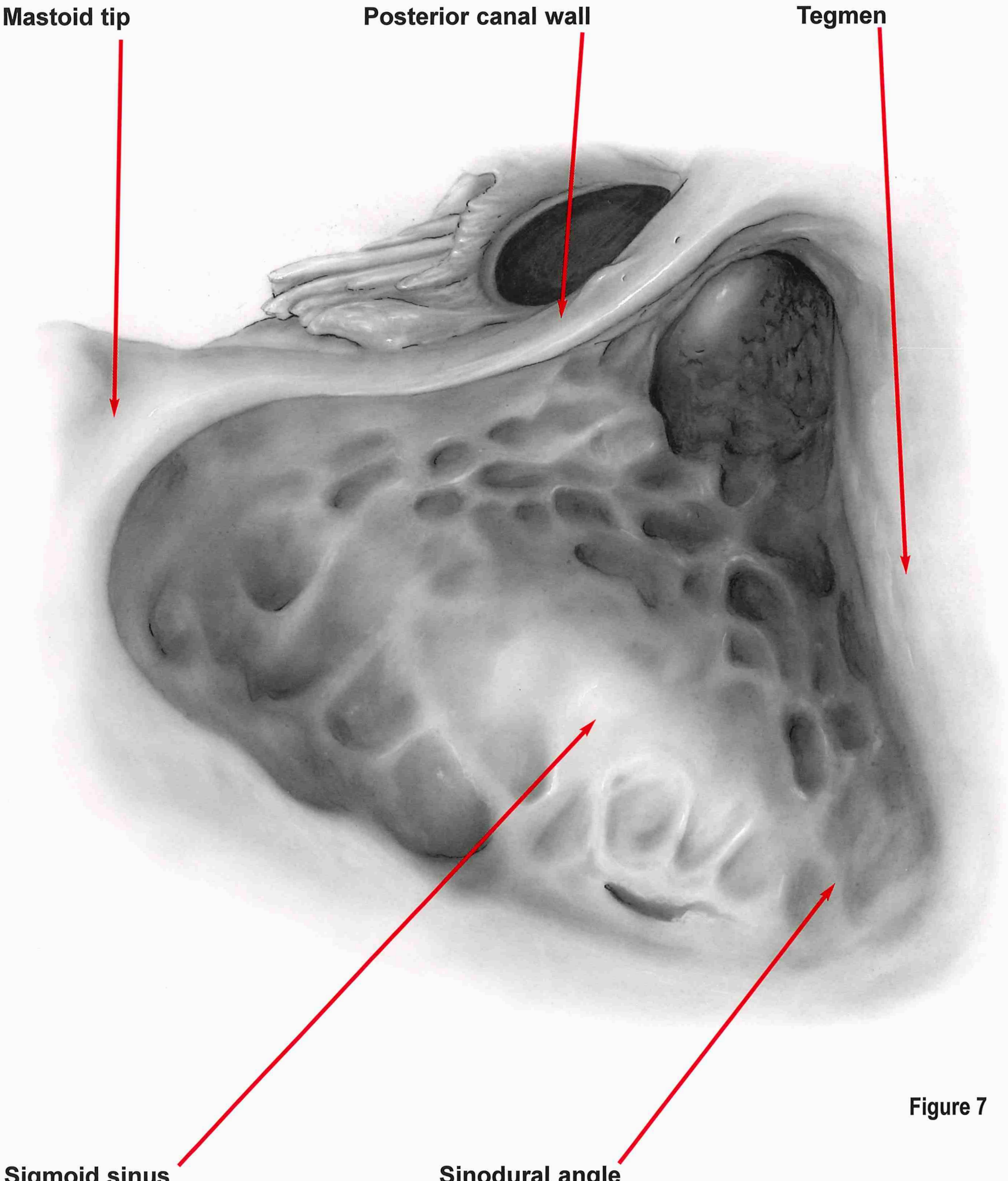

Figure 7

Basic Mastoidectomy
Step 6 (Fig. 8):

Landmarks:

Tegmen tympani
Posterior canal wall
Sinodural angle
Sigmoid sinus
Horizontal semicircular canal

The Mastoid Antrum

The most important landmark at the next level of this dissection is the mastoid antrum. Although the size of this air-containing pocket varies considerably between pneumatized and nonpneumatized bones, one rarely encounters a totally absent antrum. The antrum lies immediately below the deepest point of penetration into the temporal bone posterior to the spine of Henle and the zygomatic root. Koerner's septum (Fig. 5) often lies deep to the mastoid cortex within the air cells of the well-pneumatized temporal bone. It is a segment of the petrosquamous suture line representing the fusion of the squamous and petrous bones. It is usually a solid wall of nonpneumatized bone extending across the entire mastoid cavity separating the more superficial mastoid cortex (squamous) cells from the deeper (petrous) cells and antrum. It extends from the posterior canal wall at the tympanomastoid suture line and blends with the air cells in immediate approximation to the middle fossa plate, sinodural angle, and sigmoid sinus plate. This structure is often initially mistaken for the hard bone of the labyrinth and horizontal semicircular canal. These structures, of course, lie deep to Koerner's septum. After the septum is penetrated in the anterior superior quadrant of dissection, the true antrum will be seen as a very large air-containing cavity. By keeping the canal wall bone thin and avoiding the nearby middle fossa dura, progressively deeper penetration will reveal the antrum. Normally, the antrum can be identified as a larger air-containing space at whose bottom lies the basic landmark of the smoothly contoured, hard, labyrinthine bone of the horizontal semicircular canal.

Identification of the horizontal semicircular canal (lateral canal) allows exposure of the fossa incudis, the epitympanum anteriorly and superiorly, and the mastoid genu of the facial nerve medially and inferiorly. The hard labyrinthine bone extends posteriorly from the horizontal canal to the posterior canal, which lies anterior and medial to the sigmoid sinus. By removing cells between the horizontal canal and the sinodural angle, one encounters the hardest bone of the body, the so-called "hard angle," which is part of the otic capsule. Posterior to the labyrinth there may be some air cells in continuity with the petrous apex.

Inferior to the posterior canal, the posterior fossa dural plate overlies the endolymphatic sac. More inferior to this area, the bone of the mastoid tip may be thinned to expose periosteum of the digastric muscle. Remember the bone is being dissected inside-out, and this digastric ridge represents the flip side of the digastric groove. The digastric ridge runs in a posterior-to-anterior and lateral-to-medial direction, starting inferior to the sigmoid and ending at the stylomastoid foramen where the mastoid segment of the facial nerve exits the temporal bone. The periosteum generally is arranged in a semi-lunar shape and seems to turn superiorly to blend with the facial nerve sheath at the foramen. Finding the digastric is one method of locating the facial nerve in the mastoid cavity. Cells medially lead through the retrofacial area above the jugular bulb. After the mastoid portion of the facial nerve (discussed later) has been definitively identified, the continuity between the jugular bulb and sigmoid sinus can be followed along the smooth dural-type plate.

Basic Mastoidectomy
Step 6 (Fig. 8):

The Mastoid Antrum

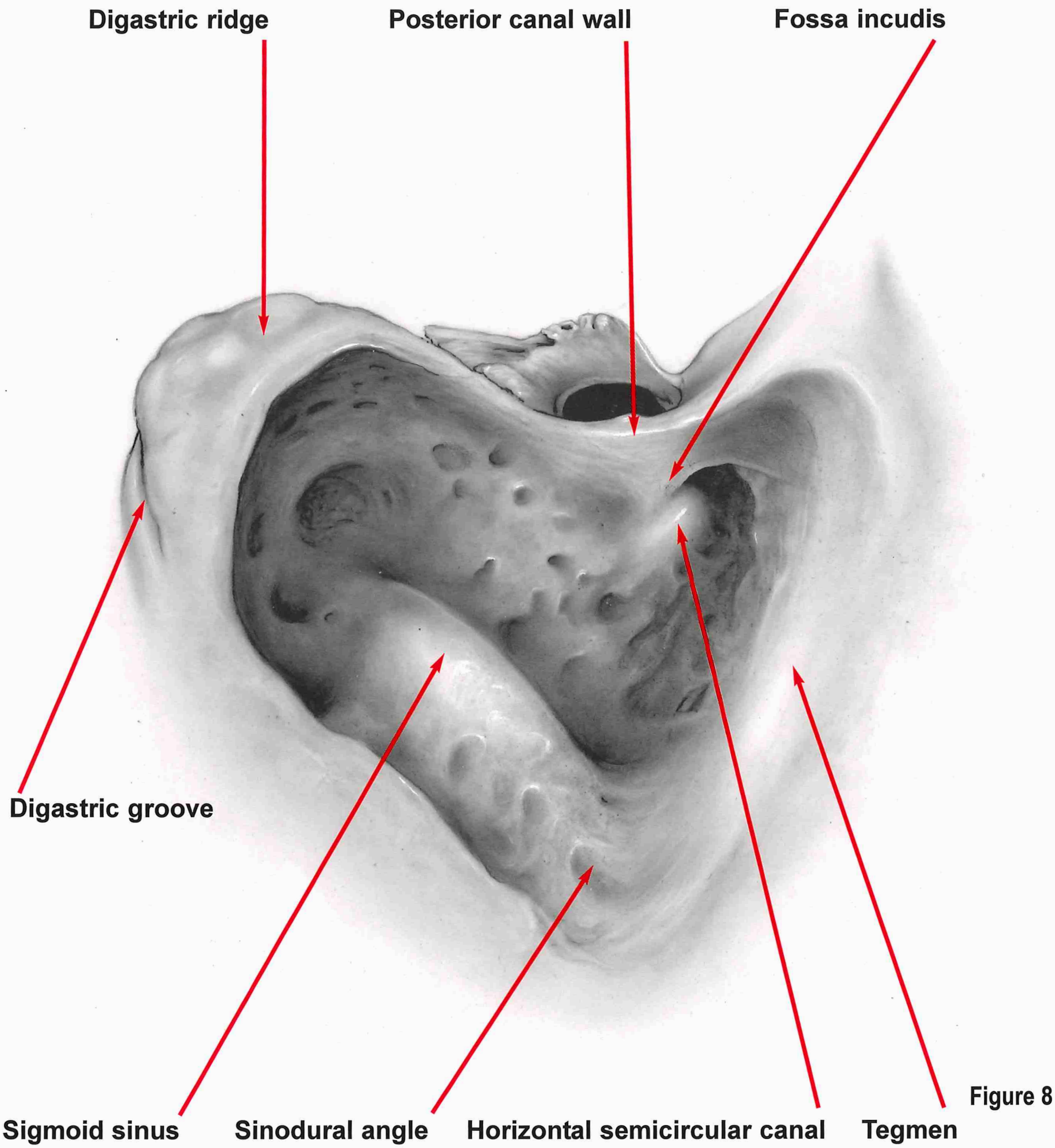

Figure 8

Basic Mastoidectomy
Step 7 (Fig. 9):

Landmarks:

Posterior canal wall
Tegmen tympani
Horizontal semicircular canal
Fossa incudis and incus
Sinodural angle
Digastric ridge
Posterior semicircular canal

Completing the Basic Mastoidectomy

The fossa incudis is most easily identified by removing bone in the zygomatic root overlying the antrum. The incus can normally be seen before actual exposure because of the light-bending refraction of the irrigating fluid (Fig. 9A). As the fluid is removed, the incus appears to disappear. As fluid fills the antrum, the incus once again appears.

The facial nerve is normally located inferior and slightly medial to the horizontal semicircular canal by thinning the posterior canal wall bone and carefully removing bone in the facial recess area. The facial recess is delineated by the fossa incudis, the chorda tympani, and the facial nerve (Fig. 9B). Generally, under increased magnification, a cutting burr is used during irrigation with copious amounts of fluid to remove bone dust and to provide optimal view of underlying bone. In this way, the blood vessels and sheath of the facial nerve will impart discoloration to the bone, normally pink in the living specimen and stark white in the cadaver. Upon location of this discoloration, the sheath of the nerve can be followed inferiorly toward the mastoid tip and superiorly and anteriorly into the facial recess. A prominent vessel on the posterior surface of the mastoid genu is usually encountered before actually unroofing the nerve.

We have now delineated a new set of landmarks that are used for further dissection of the temporal bone. The dissection thus far has created what is commonly called a simple mastoidectomy.

Basic Mastoidectomy

Step 7 (Fig. 9):

Completing the Basic Mastoidectomy

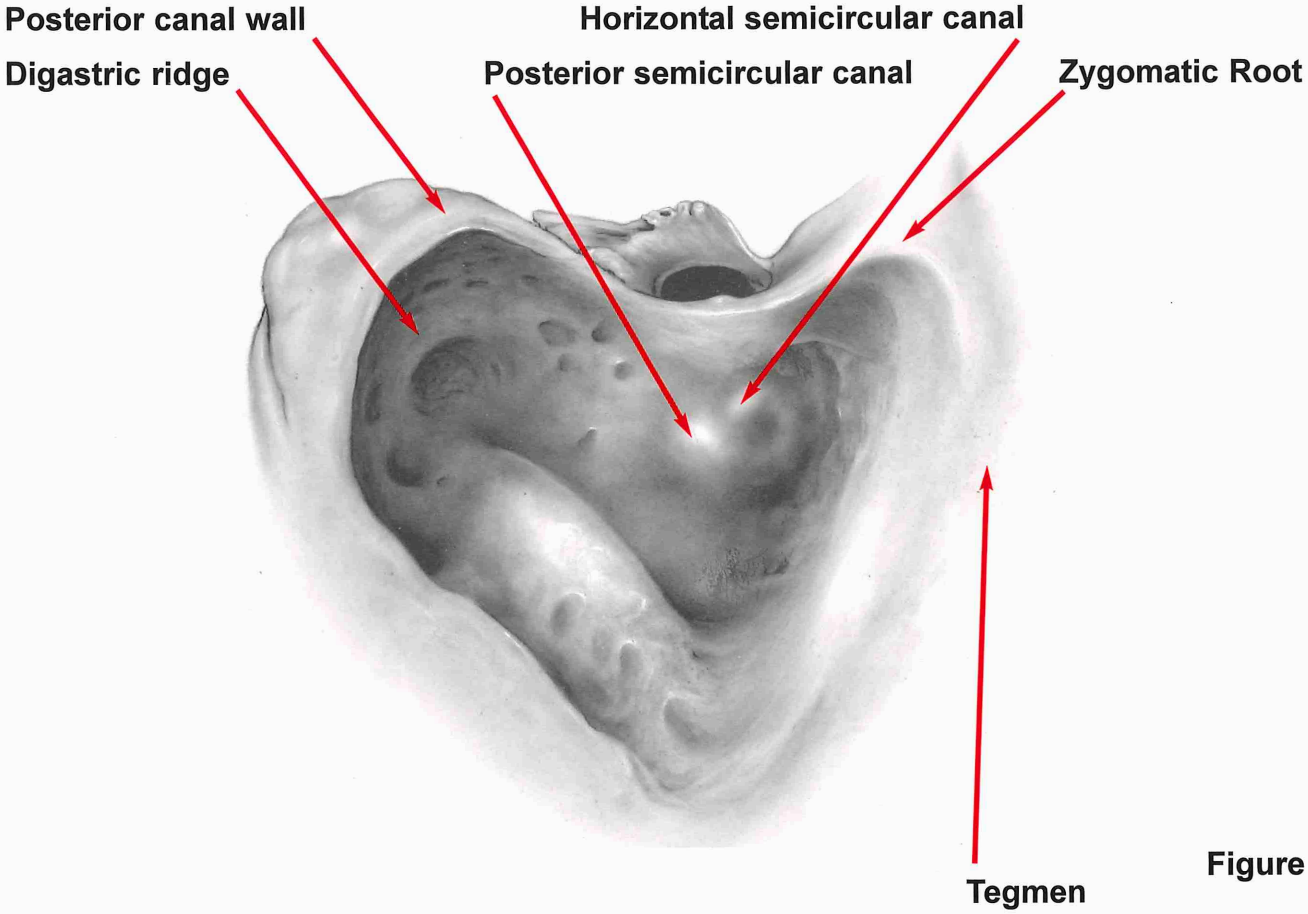

Figure 9

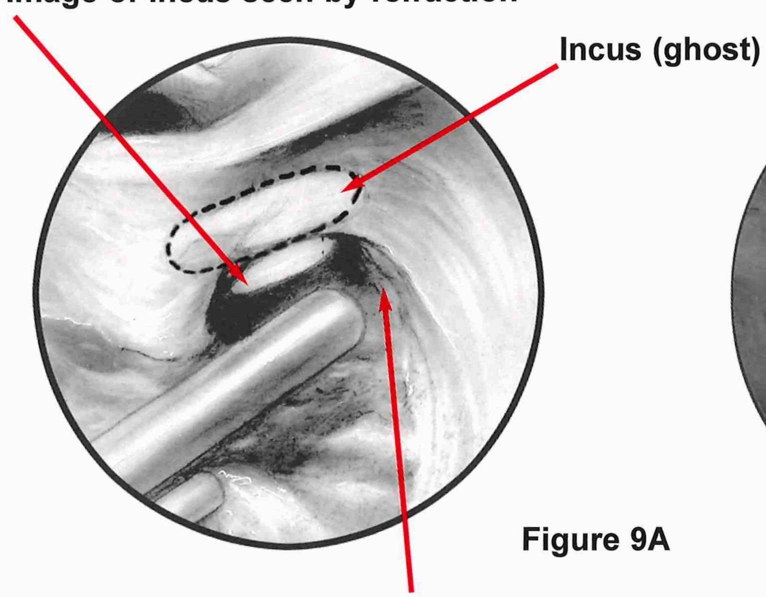

Figure 9A

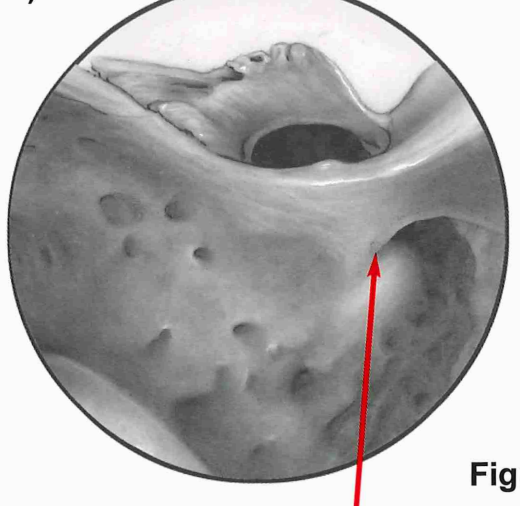

Figure 9B

Notes:

2

Facial Recess, Epitympanum

Facial Recess, Epitympanum

Step 1 (Fig. 10)

Landmarks:

Horizontal canal
Fossa incudis
Posterior canal wall
Mastoid genu of VII

Topography

The facial recess is a tract of air cells lying immediately lateral and parallel to the facial nerve at the mastoid genu. Since the tract follows the facial nerve, it takes an anterior/superior to inferior/posterior course. It occasionally serves as a route for middle ear disease to extend into the mastoid area via cells other than the antrum. Cholesteatoma that frequently invades these cells is difficult to remove with standard transcanal approaches. Opening of the facial recess in a chronically diseased ear is of value in providing an additional avenue of mastoid aeration. This exposure also allows better visualization of the middle ear cavity in chronic ear disease and exposure of the horizontal portion of the facial nerve during facial nerve decompression. It is also the route to the round window for insertion of the cochlear implant electrode. The landmarks used to expose the facial recess are the mastoid genu of the facial nerve medially, the fossa incudis superiorly, the chorda tympani nerve laterally, and the tympanic membrane anteriorly and laterally.

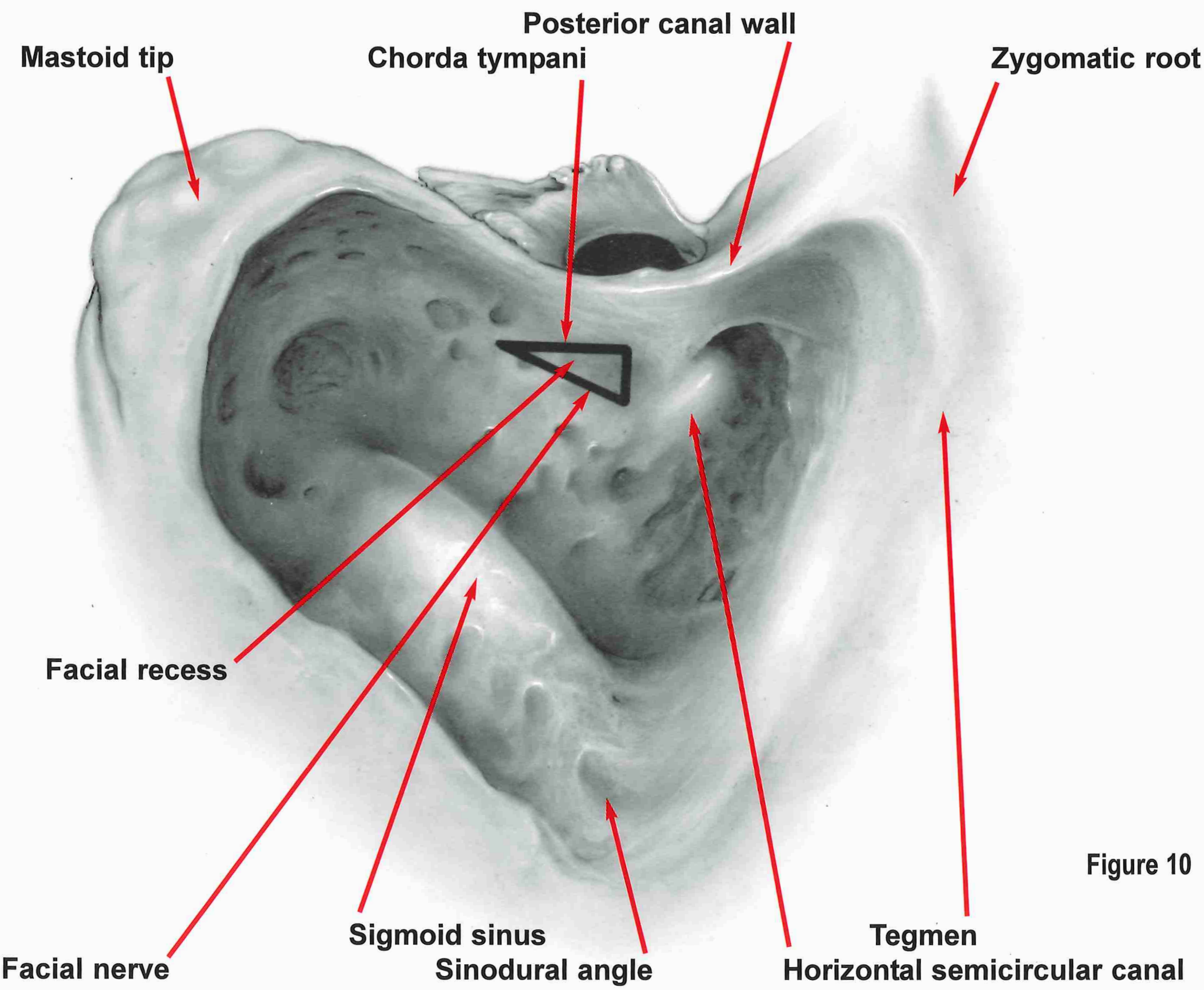

Figure 10

Facial Recess, Epitympanum
Step 2 (Fig. 11)

Landmarks:

Posterior canal wall
Horizontal canal
Fossa incudis
Mastoid genu
Facial Recess cells (if present)

Opening the Facial Recess

One begins dissection of the facial recess by identifying the mastoid genu or the descending portion of the facial nerve in the mastoid cavity. As previously indicated, a free flow of irrigating fluid is used to allow a clear and constant view of the underlying bone so that color variations in it may be easily identified. The microscope is turned to 10 power. The color of the facial nerve is pearly white in the preserved bone and salmon color (from the vascularity of the facial canal and the nerve sheath) in a living specimen. Generally, this dissection is accomplished with a cutting burr until a change in bone character is identified; further dissection is performed with a diamond burr. A thin layer of bone is preserved over the facial nerve and, because color changes in the bone will occur before the facial sheath is uncovered, the soft tissue is not injured.

Identification of a facial recess cell tract is done by thinning the posterior canal wall enough to see the shadow of an instrument through the bone. One must not perforate the canal wall, disrupt the chorda tympani, or transect the annulus. A common error is to penetrate the posterior canal wall lateral to the chorda tympani. This, of course, exposes the external auditory canal lumen since the chorda tympani is immediately beneath the annular ligament.

Figure 11

Facial Recess, Epitympanum

Step 3 (Fig. 12):

Landmarks:

- Facial nerve
- Incus
- Fossa incudis
- Chorda tympani
- Stapes
- Horizontal canal

Completing the Facial Recess

With the new landmark of the facial sheath, the nerve is skeletonized distally along its descending portion in the mastoid and then medially as it follows the wall of the facial recess into the middle ear space. Smaller burrs will be necessary to accomplish most of the dissection in the facial recess since the recess itself rarely exceeds two millimeters. Inferiorly the chorda tympani nerve is detected as it leaves the facial nerve. Dissection does not sacrifice this structure. The chorda tympani nerve joins with the tympanic membrane anteriorly and laterally at the annulus; thus, following the chorda tympani generally prevents disruption of the tympanic membrane. Drilling lateral to the chorda tympani will fenestrate the posterior wall of the external auditory canal and needs to be avoided (cochlear implant surgery).

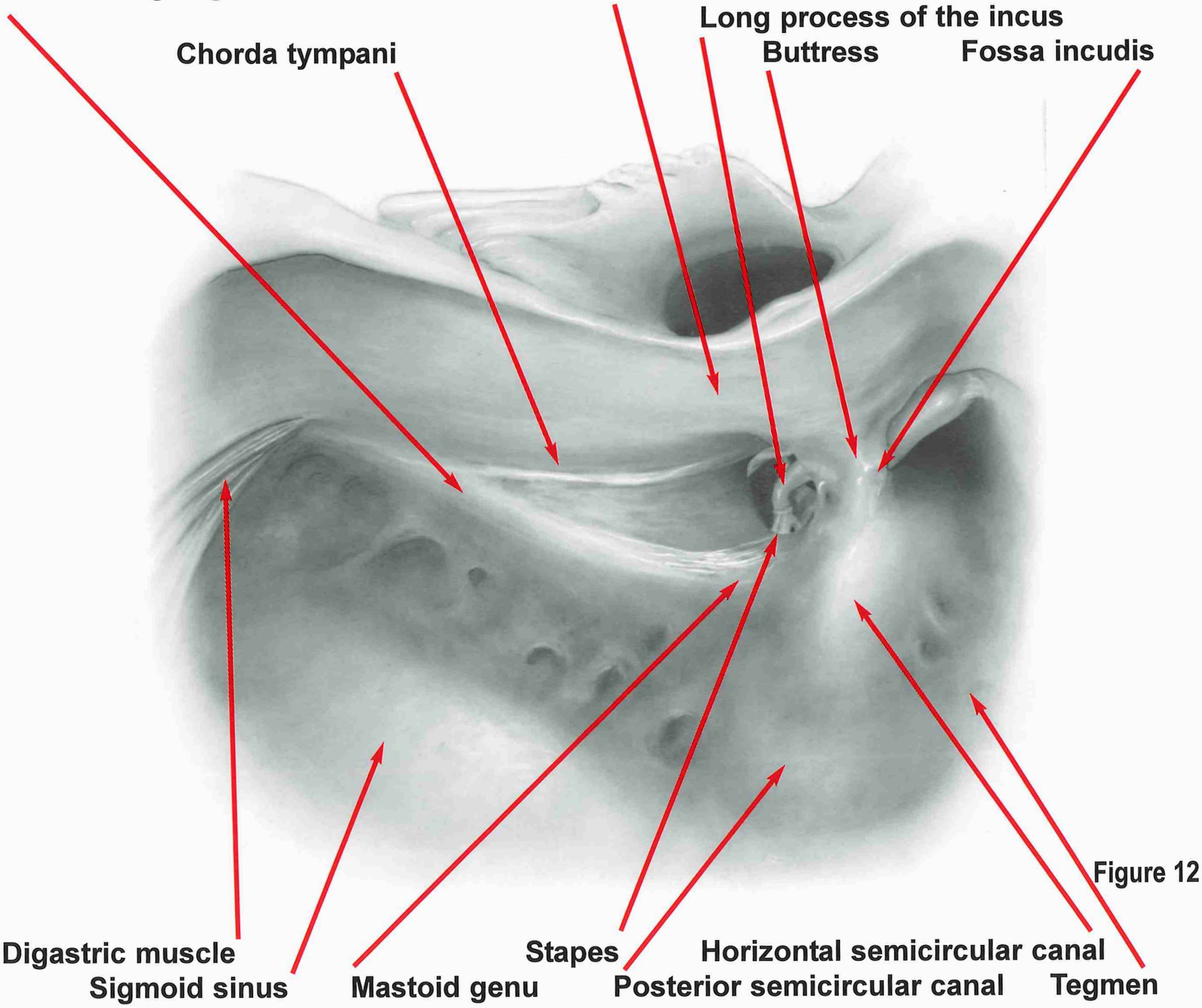

Figure 12

Facial Recess, Epitympanum
Step 4 (Fig. 13):

Landmarks:

- Facial nerve
- Incus
- Lenticular process
- Incudostapedial joint
- Stapes
- Round window
- Cochleariform process
- Chorda tympani
- Horizontal canal

The Middle Ear Through the Facial Recess

With the facial recess fully opened, one can easily identify the horizontal portion of the facial nerve, the lenticular process of the incus, the incudostapedial joint, the capitulum of the stapes, the stapedial tendon, and, with proper angulation, the cochleariform process.

The round window is identified inferior to the stapes. Superiorly, a buttress of bone is preserved between the short process of the incus and the facial recess. This is commonly termed "the buttress." Drilling through the buttress causes disruption of the ligaments to the short process of the incus and incudal dislocation is a possibility.

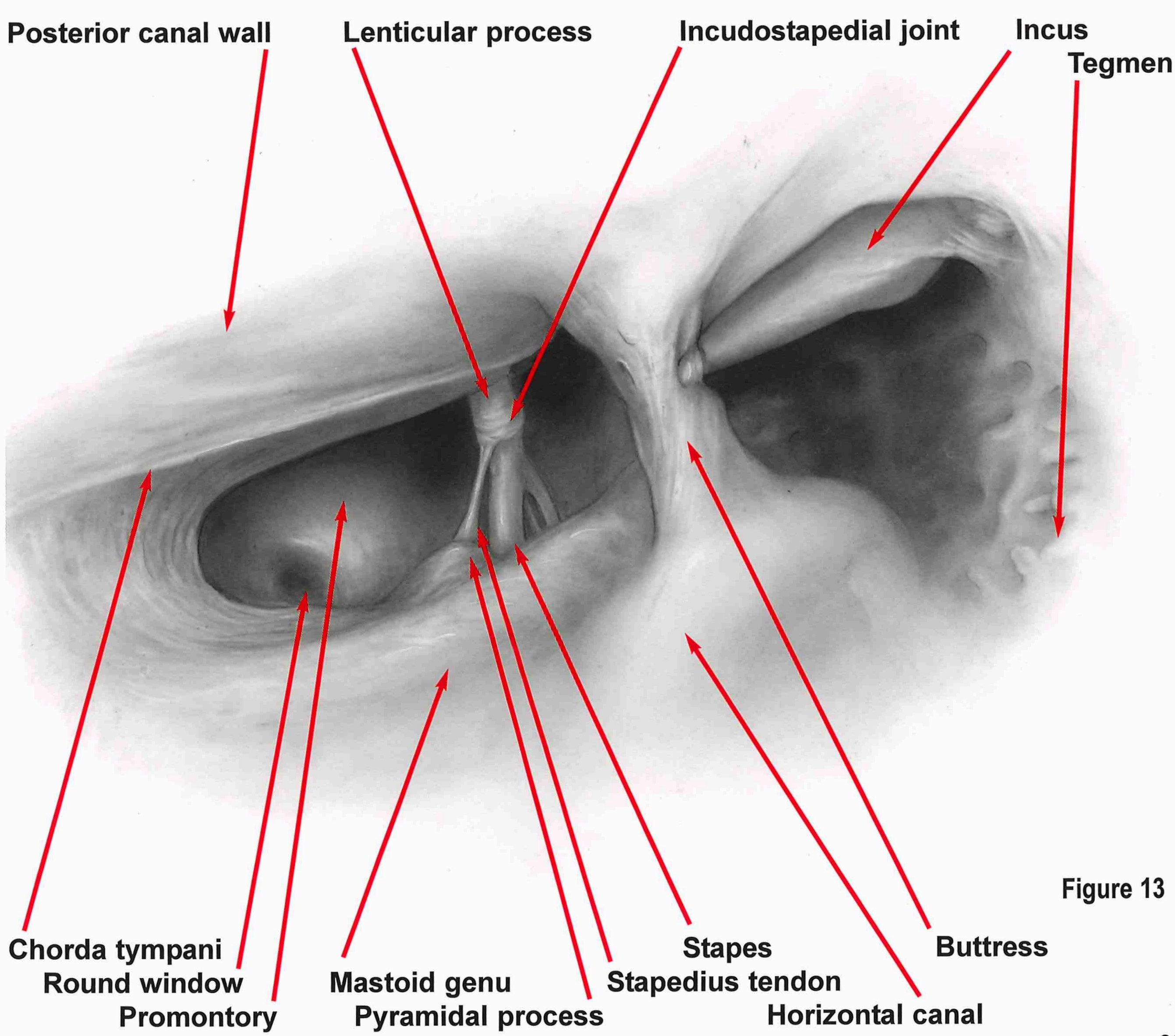

Figure 13

Facial Recess, Epitympanum

Step 5 (Fig. 14):

Landmarks:

Incus
Malleus
Tegmen
Horizontal canal
Facial nerve

Unroofing the Epitympanum

In chronic otitis media, the epitympanum is a common site for cholesteatoma. It often has destroyed the ossicles; more frequently it has involved the incus and the head of the malleus. Complete exposure of the epitympanum without destruction of the scutum can be obtained by removal of additional air cells in the root of the zygoma. This is done with use of the tegmen tympani and the thinned posterior canal wall as landmarks.

An adequate size diamond burr is necessary if the middle fossa dura and its underlying bony plate, the tegmen tympani, lie low. If necessary, this dissection may be carried anteriorly toward the zygomatic root to the glenoid fossa. The floor of the dissection is the horizontal canal, the superior semicircular canal, and the facial nerve.

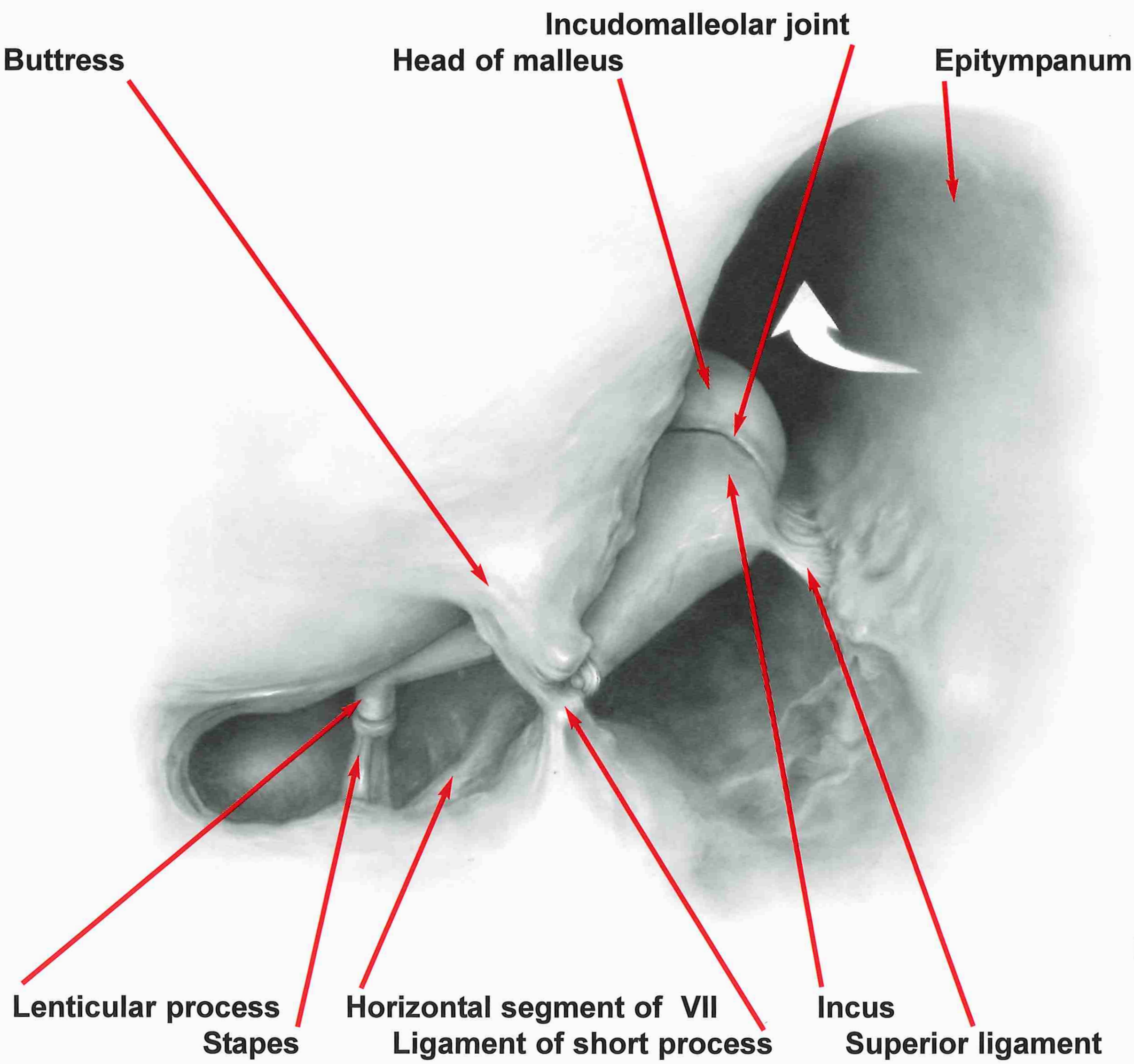

Figure 14

Facial Recess, Epitympanum

Step 6 (Fig. 15)

Landmarks:

- Facial nerve
- Horizontal canal
- Chorda tympani
- Stapes
- Posterior canal wall

Removing the Buttress

When cholesteatoma involves the incus, the facial recess may be connected to the attic by removing the buttress after the remnant of the incus has been disarticulated from the stapes. This continuity between the attic and facial recess gives an extensive view of the middle ear from behind. In cases in which cholesteatoma involves the stapes, this technique can be used to provide both an anterior and a posterior exposure of the stapes. This allows more complete and safer removal of the cholesteatoma from these difficult areas. With this approach, exposure of the facial recess is so complete that the surgeon rarely has doubt about complete removal of cholesteatoma in facial recess cells.

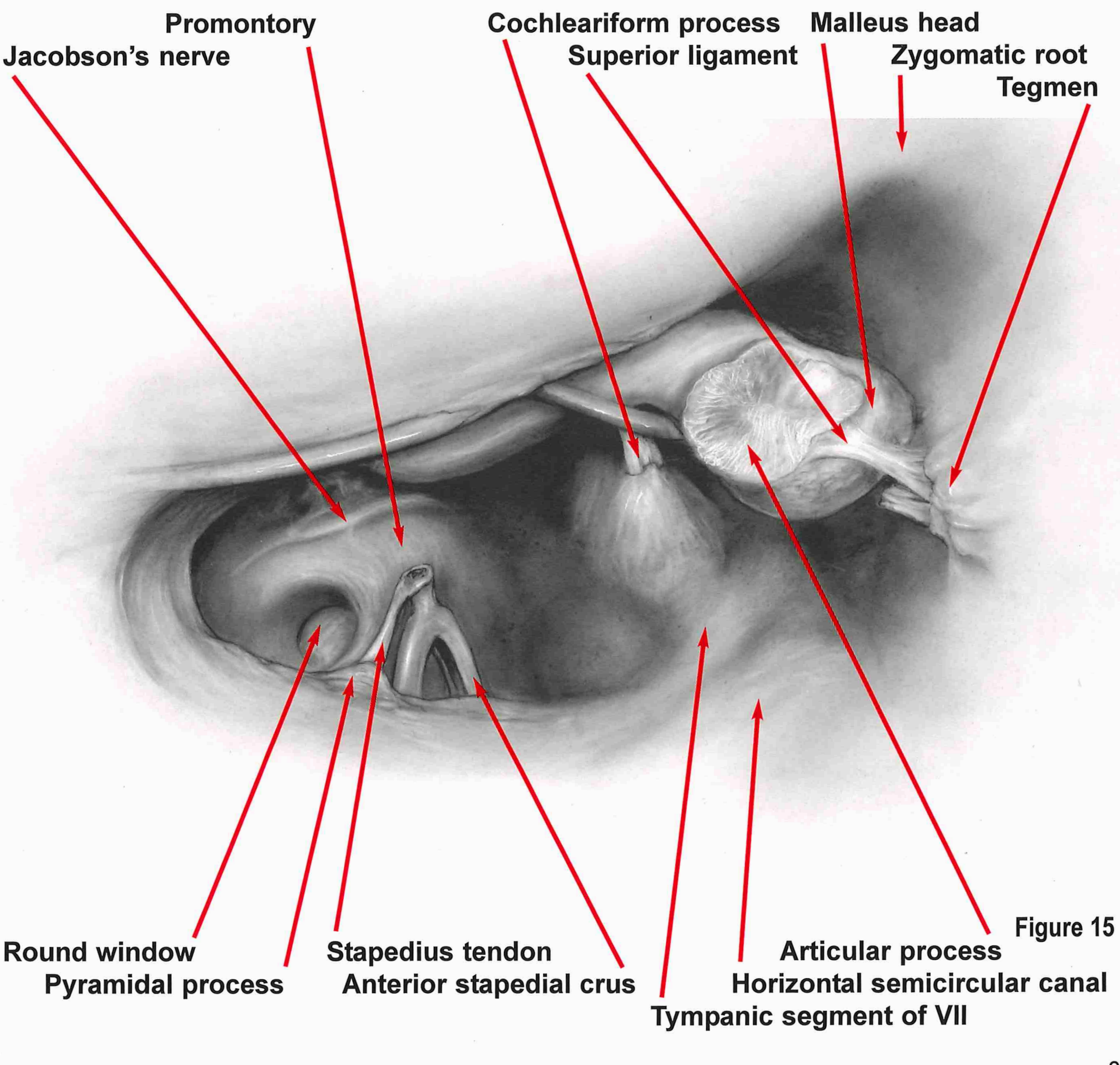

Figure 15

Facial Recess, Epitympanum
Step 7 (Fig. 16)

Landmarks:

Stapes
Facial nerve
Cochleariform process
Handle of malleus
Eustachian tube
Cog

Exposure of the Anterior Epitympanum

After removal of the head of the malleus and body of the incus, this dissection allows direct inspection of all epitympanic areas. In a well-pneumatized bone, air cells extending anteriorly into the petrous apex may also be seen.

The figure shows the ample exposure obtained with this technique. Note the cog, a bony ledge extending into the epitympanum from the tegmen anterior to the head of the malleus. This spicule separates the epitympanum into posterior and anterior compartments. Removal of cholesteatoma that is present anteriorly, which is common, requires careful burring away of the cog.

This step completes dissection of the facial recess and epitympanum.

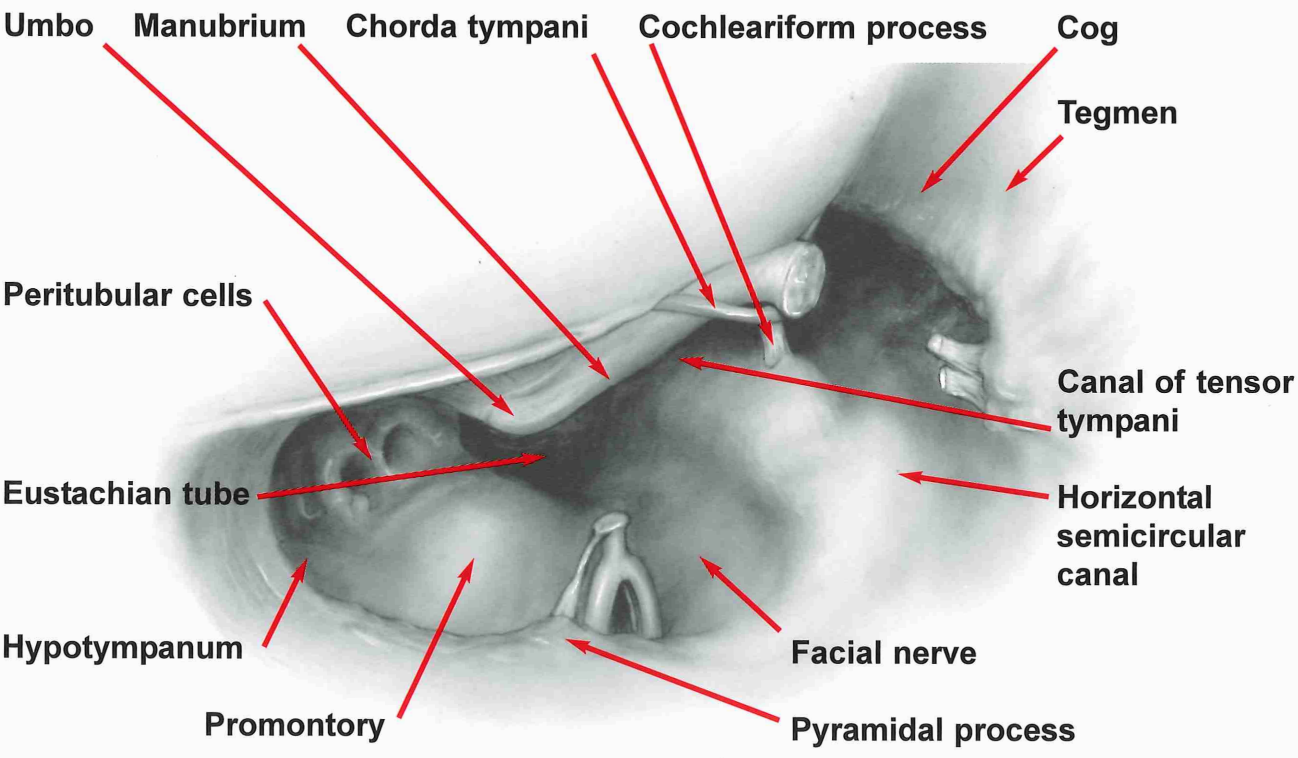

Figure 16

3

Postauricular Facial Nerve Decompression

Postauricular Facial Nerve Decompression
(Fig. 17):

Step 1: Simple Mastoidectomy (See Chapter 1)
Step 2: Opening the Facial Recess (See Chapter 2)

Orientation: Fig. 17 shows the general orientation of the facial nerve. Notice the position of the nerve in relation to the posterior canal wall, the fossa incudis, and the horizontal semicircular canal. The facial recess is a key to facial nerve decompression.

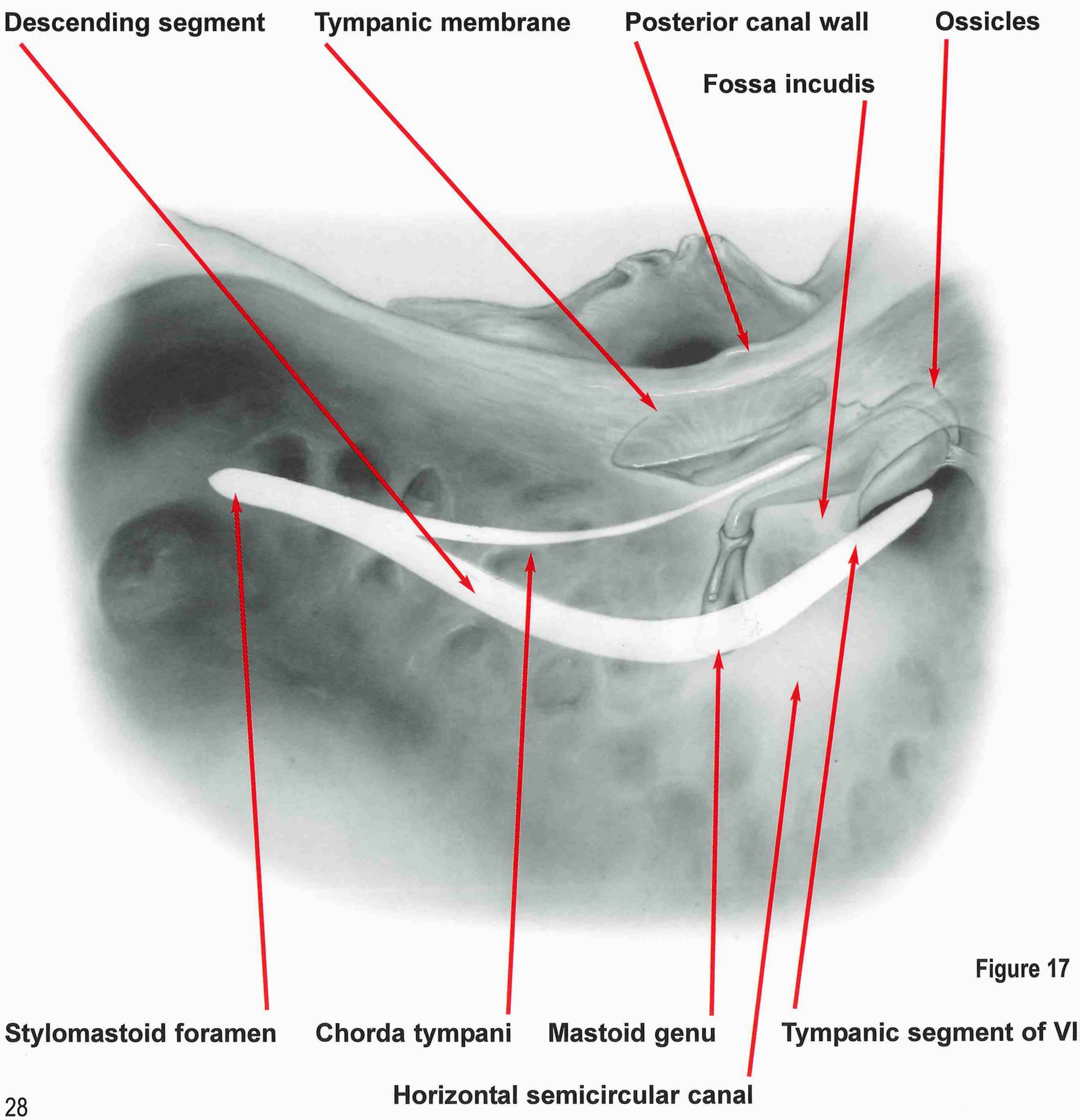

Figure 17

Postauricular Facial Nerve Decompression
Step 3 (Fig. 18):

Landmarks:

Mastoid genu
Vasa vasorum of facial nerve
Chorda tympani
Stylomastoid foramen
Digastric muscle

Skeletonizing the Descending Portion of VII
(the facial nerve)

During complete simple mastoidectomy, most of the facial nerve has been well delineated. For decompression, the nerve is followed from the exposed mastoid genu and the mastoid segment to the stylomastoid foramen. As the stylomastoid foramen is approached, the periosteum of the digastric muscle will blend with the sheath of the facial nerve. This, in essence, is the stylomastoid foramen. The digastric muscle itself is used as a landmark to find the descending portion of the facial nerve at the stylomastoid foramen. In this method, after the nerve is located at the foramen, the mastoid segment is followed superiorly back to the area of the mastoid genu and facial recess. The bone over the descending portion is thinned with use of a diamond burr and copious irrigation to prevent frictional heating of the nerve. An eggshell covering of bone is preserved over the posterior one-half of the descending portion of the nerve. This is necessary to decompress the nerve satisfactorily and to prevent its prolapse through a narrow opening in the bone. This part of the nerve is not routinely uncovered anteriorly because of the external auditory canal, laterally because of the chorda tympani, or medially because it is not necessary. (See page 31, “Barber Poling".)

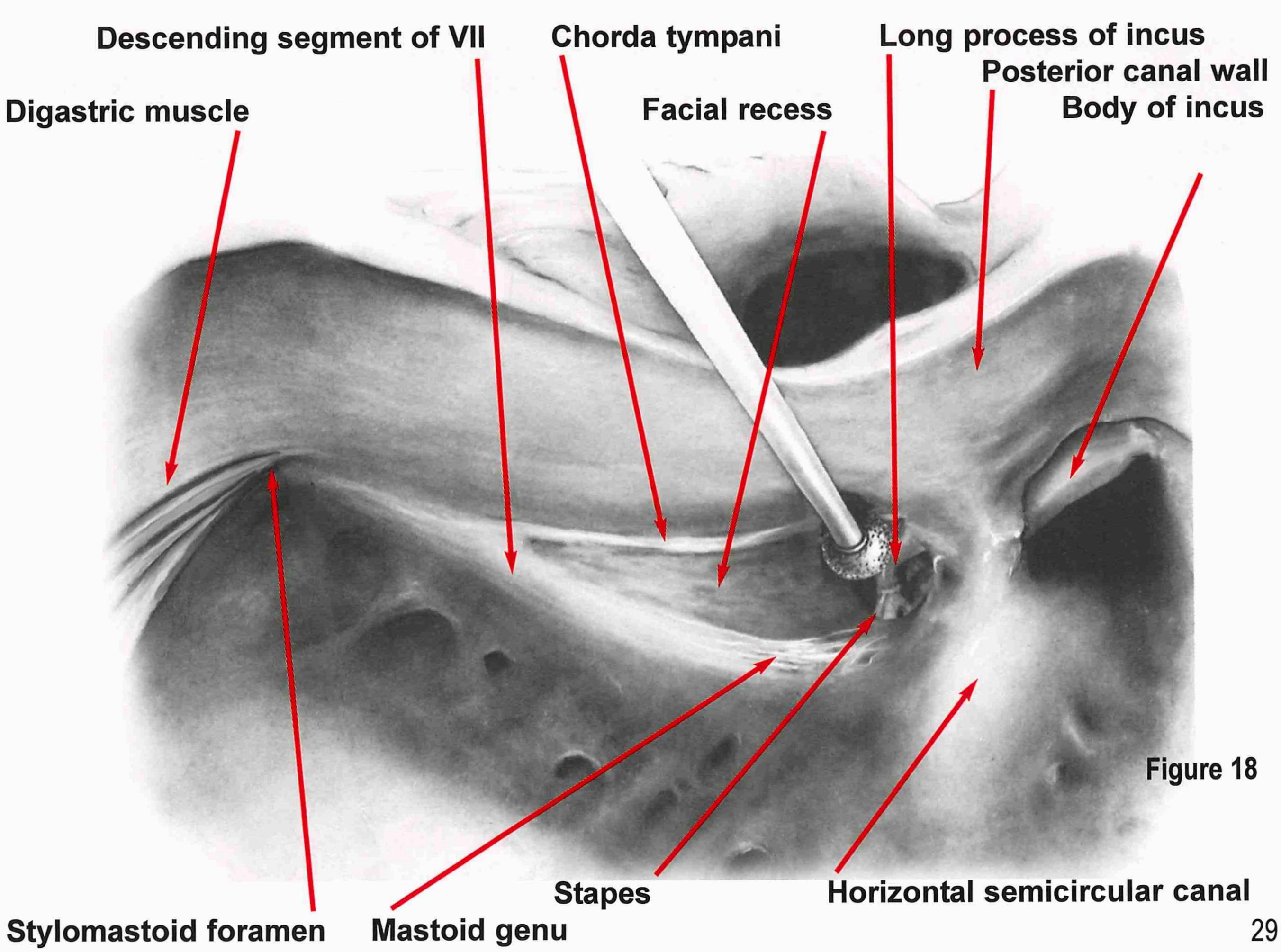

Figure 18

Postauricular Facial Nerve Decompression

Step 4 (Fig. 19):

Landmarks:

- Facial nerve
- Chorda tympani
- Incus buttress
- Fossa incudis
- Incus (long process)
- Stapes
- Horizontal canal

Horizontal Portion of VII

The facial nerve is further exposed medial to its mastoid genu into the facial recess, as in the approach to the facial recess for chronic otitis media. This exposure allows identification of the horizontal portion of the nerve anteriorly toward the cochleariform process and then superiorly to the tegmen, where the geniculate ganglion is located. Because the facial recess cell tract parallels the nerve, the tract runs anterior/superior to posterior/inferior. Therefore, the surgeon can best see VII by readjusting to a position over the mastoid so as to look directly up the facial recess cell tract. Dissection of the epitympanic space through the normal antrum-attic approach frequently allows some exposure of the more medial portions of the horizontal segment. The bone over the nerve is thinned enough so that the bone can be easily lifted off the nerve with an elevator. The facial recess area will normally admit the smallest diamond burrs (1.5-2mm) under the incus without dislocation of the ossicular chain. Rarely must the incus be disarticulated from the stapes. A small suction-irrigator removes bone dust and debris from the facial recess opening. Again, irrigation must be adequate to prevent heating of the nerve. Suction may be inserted through the epitympanic space to provide circulation of irrigating fluid while the burr is used in the facial recess.

Bone should be thinned 180 degrees across the lateral aspect of the mastoid genu, and over the entire inferior/anterior one-half of the horizontal (tympanic) segment of the facial nerve.

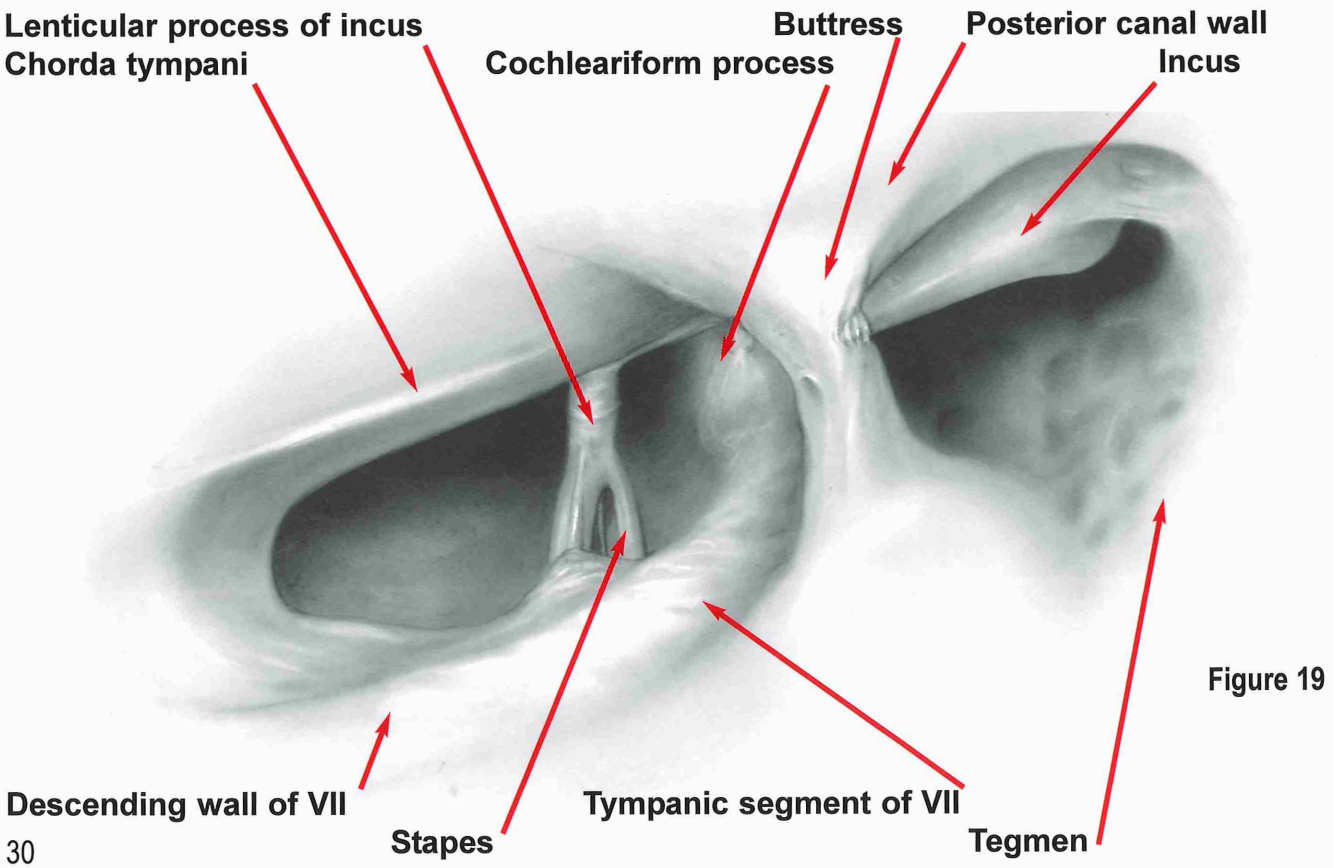

Figure 19

Postauricular Facial Nerve Decompression
Step 5 (Fig. 20):

Landmarks:

Facial nerve
Horizontal canal
Stapes
Chorda tympani
Incus
Cochleariform process

"Barber Poling" the Facial Nerve

Bone thinning for bone removal is performed in a "barber pole" fashion. This effect is produced when: (1) the descending portion of the mastoid segment between the stylomastoid foramen and the mastoid genu is unroofed on the posterior aspect; (2) the mastoid genu and facial recess portion of the nerve is unroofed on its lateral aspect; and (3) the horizontal segment of the nerve is unroofed along its inferior/anterior border to the level of the cochleariform process (See Figure 19). This rotation of the unroofing process from posterior to lateral to anterior allows removal of bone without injury to the surrounding structures. In the descending portion, decompression on the lateral side will result in sacrifice of the chorda tympani. At the level of the mastoid genu, removal of bone on the posterior side will lead to fenestration of the horizontal canal. Burring posteriorly or superiorly in the horizontal segment will lead to injury of the horizontal canal. This thinning process should be completed over the entire mastoid and middle ear segments of the facial nerve.

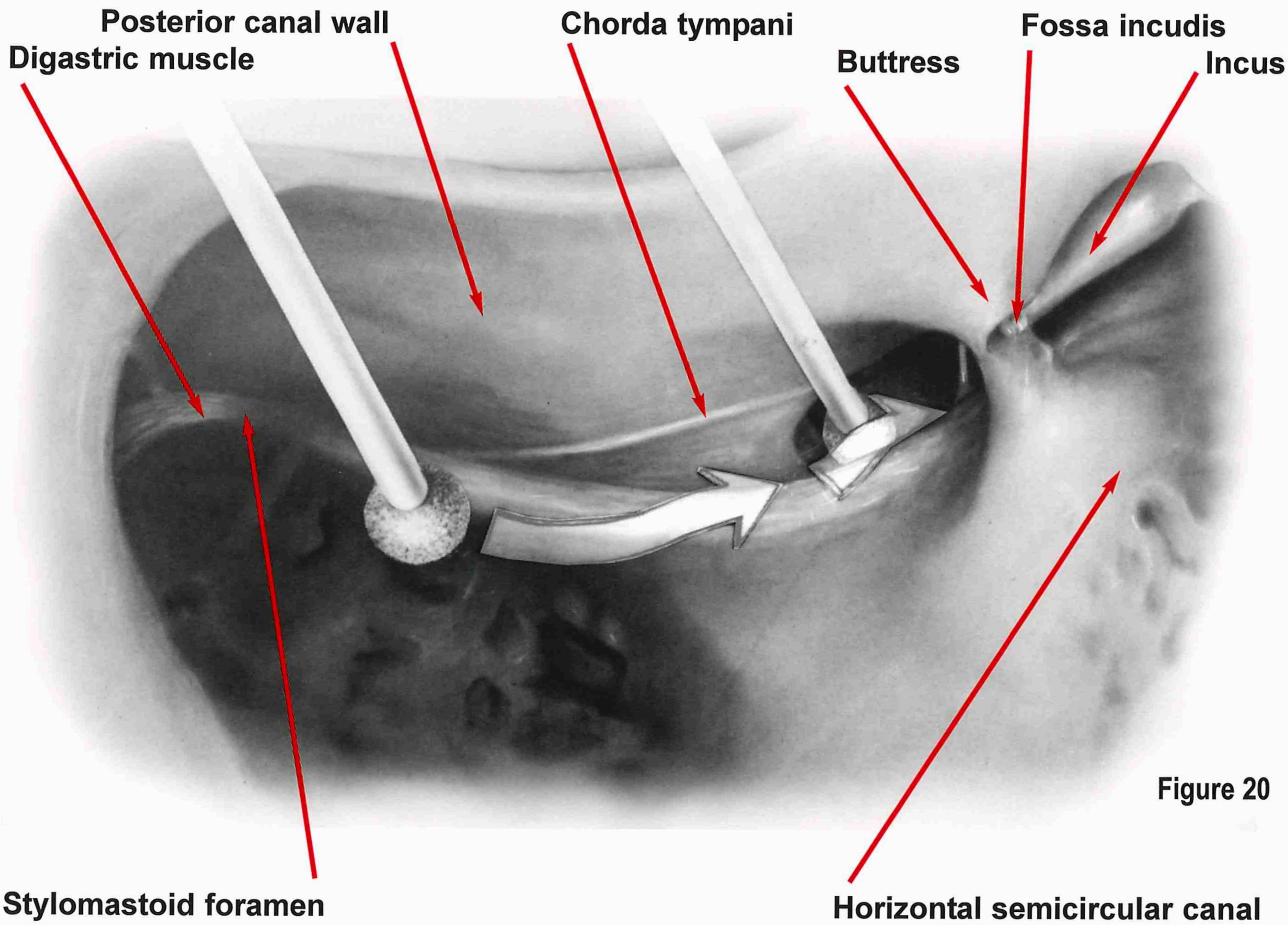

Figure 20

Postauricular Facial Nerve Decompression
Step 6 (Figs. 21, 22):

Landmarks:

Facial nerve

Uncovering the Facial Nerve Perineurium

The eggshell-thin bone is gently pried off the sheath of the facial nerve. A small dental excavator, with its twist like that of the "whirlybird" of middle ear surgery, works extremely well. Right- and left-hand excavators must each be available for optimum angulation. Complete control of the tip of the pick can be maintained at all times by proper use of a fulcrum. Do not use the facial nerve as a fulcrum; rather, brace the elevator against nearby bone. The accompanying figures show the more familiar Rosen needle being used to elevate the bone.

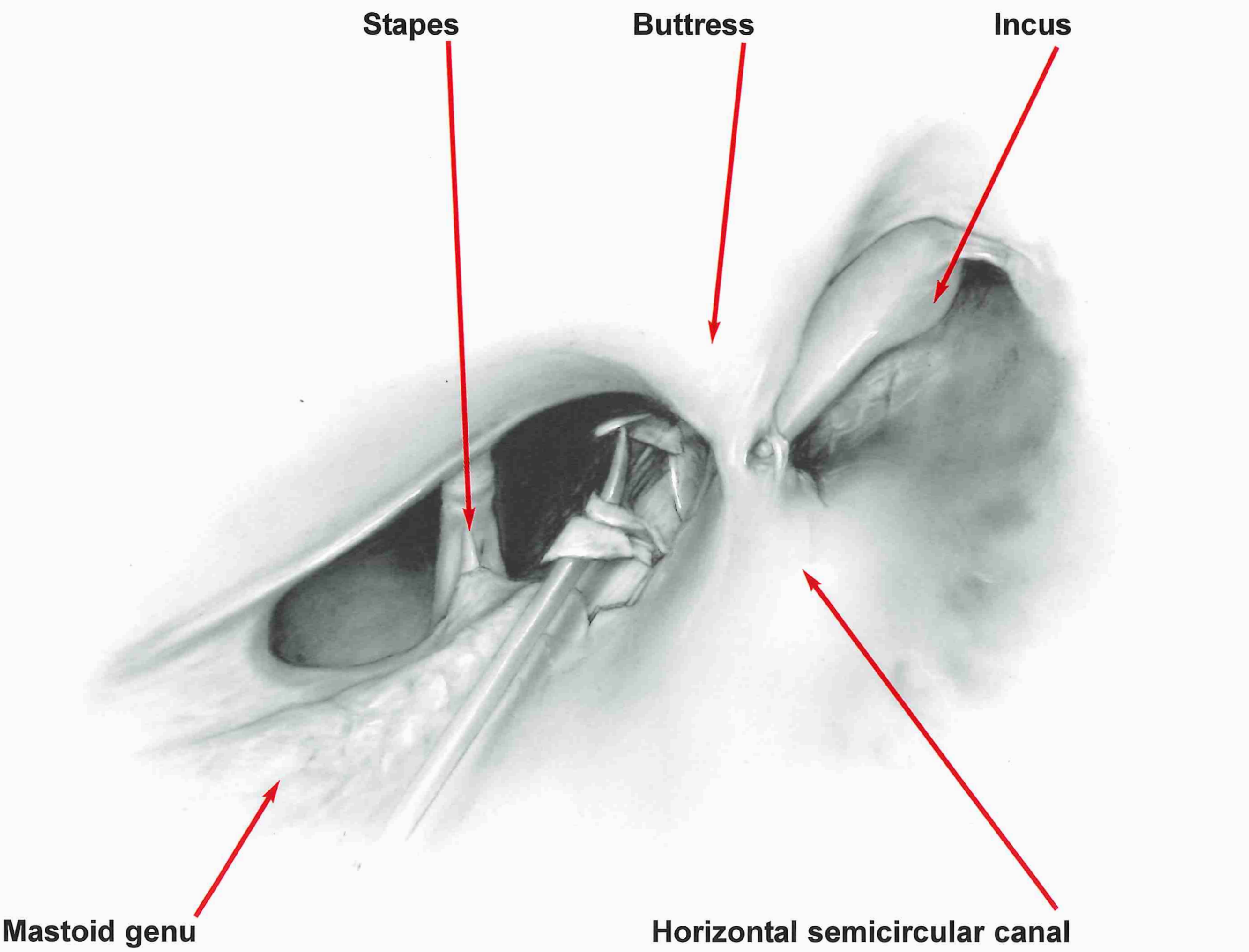

Figure 21

Postauricular Facial Nerve Decompression
Step 6 (Figs. 21, 22):

Uncovering the Facial Nerve Perineurium

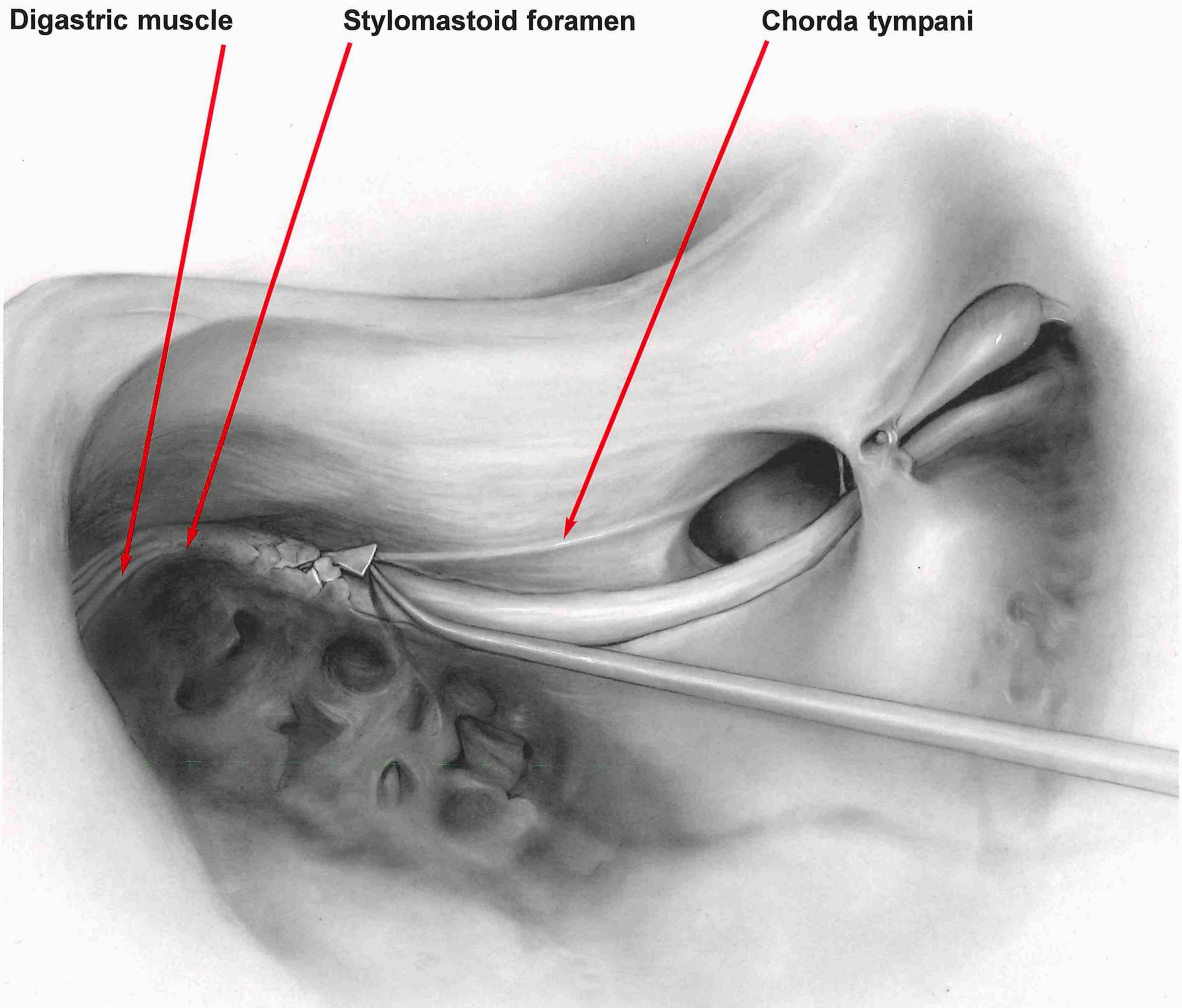

Figure 22

Postauricular Facial Nerve Decompression
Step 7 (Figs. 23, 24):

Landmarks:

Facial nerve

Opening the Sheath

The sheath is opened with a #59 Beaver® knife. It is a very sharp instrument shaped like a sickle knife with slightly less curve. Because it is disposable, it is never dull. A dull blade might cause tugging on the nerve during slicing of the sheath, which is quite tough and relatively thick.

Be certain to examine the nerve for circular fibrous bands that will constrict the nerve fibers. These bands must be lysed.

The mastoid and middle ear portions of the facial nerve are now decompressed. Further decompression of the labyrinthine segment must be carried out through the middle fossa, although some of the labyrinthine portion may be decompressed via the mastoid, depending on the degree of pneumatization. The medial porus of the fallopian canal cannot be opened from this approach. This is the narrowest part of the canal and the area most susceptible to constriction.

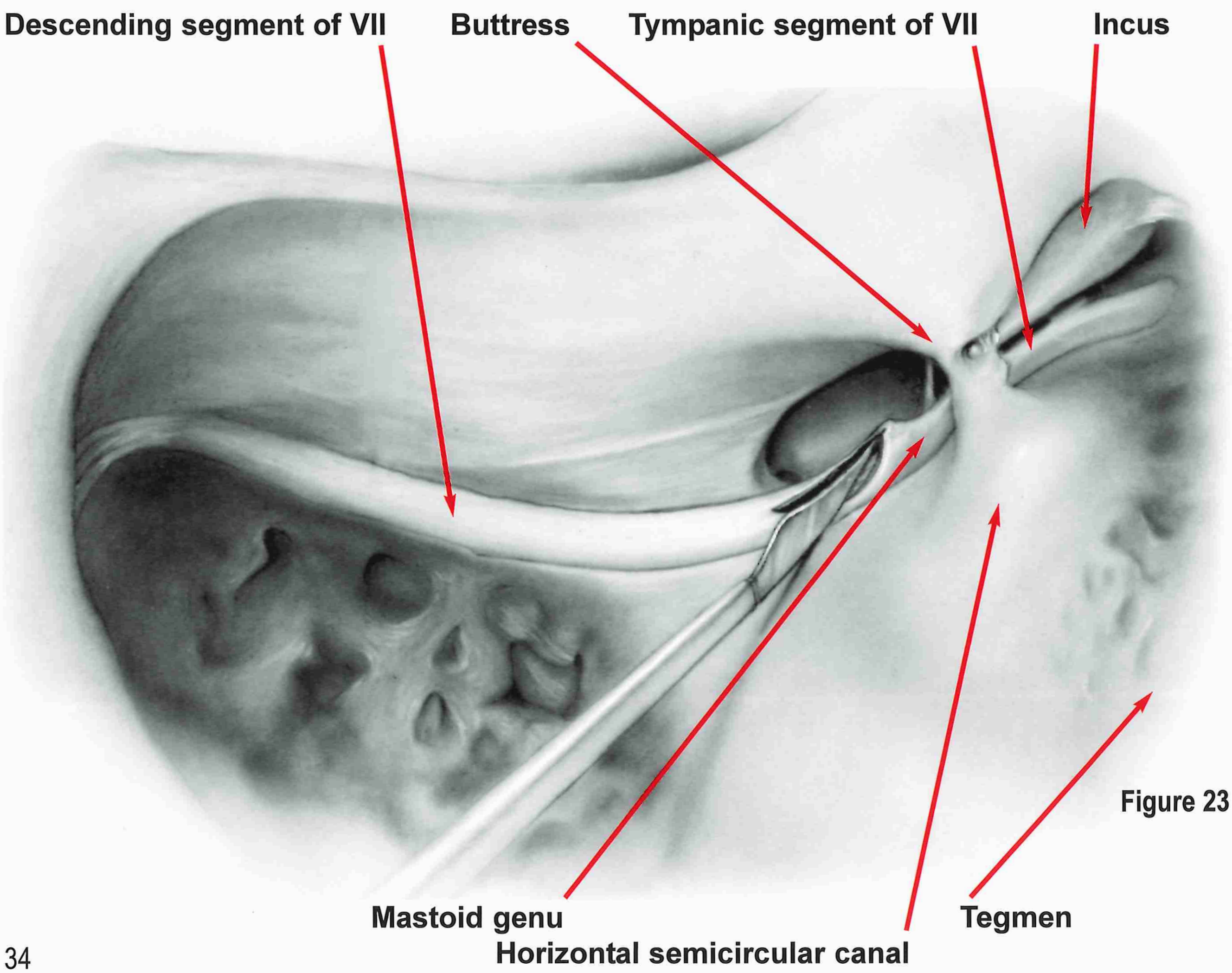

Figure 23

Postauricular Facial Nerve Decompression
Step 7 (Figs. 23, 24):

Opening the Sheath

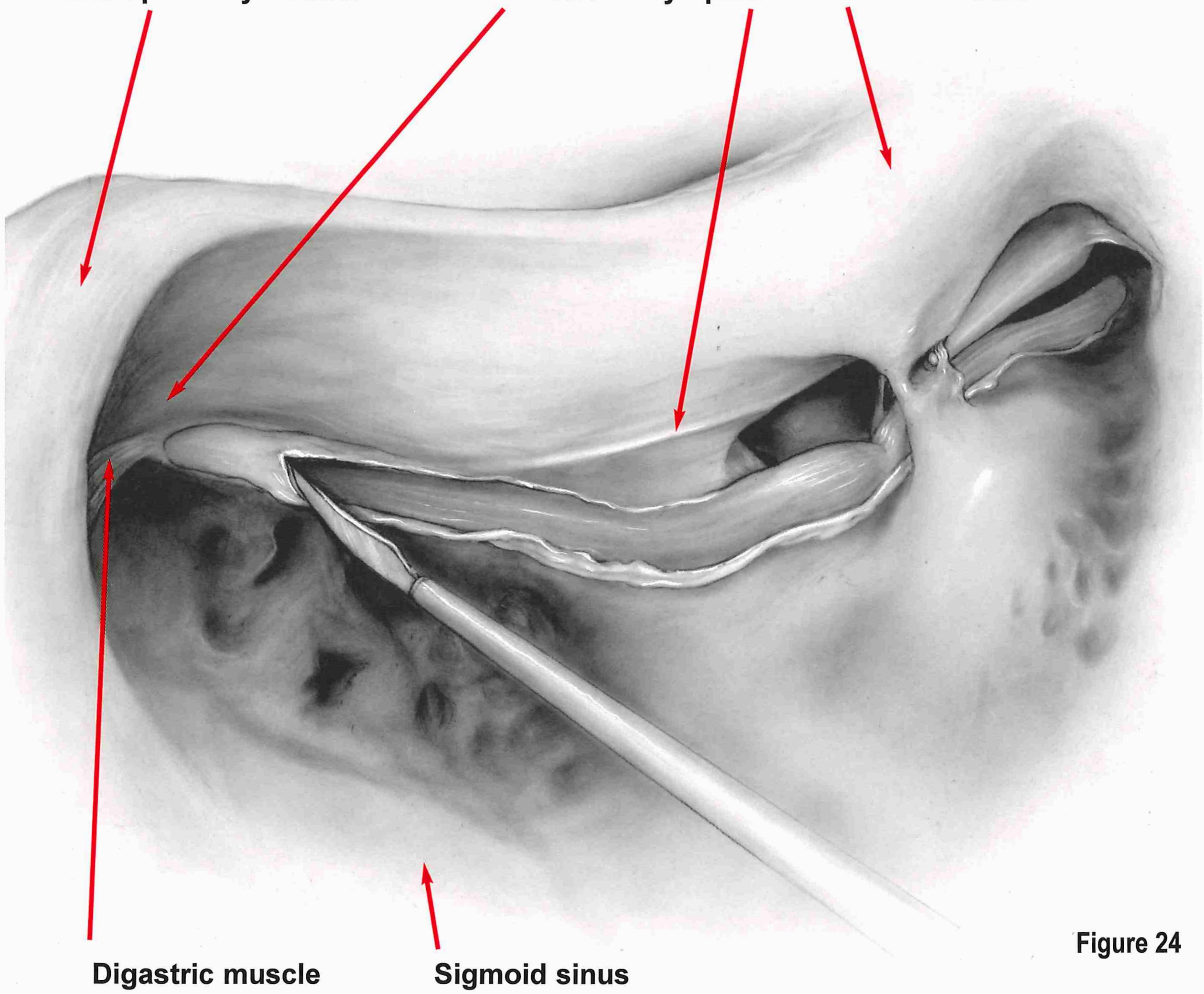

Figure 24

Notes:

4

Endolymphatic Sac and Extended Facial Recess Dissections

Endolymphatic Sac Dissection

Step 1 (Fig. 25):

Landmarks:

- Horizontal canal
- Posterior canal
- Donaldson's line
- Sinodural angle
- Sigmoid sinus
- Fallopian canal
- Mastoid tip cells
- Dural plate

Topography

The endolymphatic sac is located in a thickened portion of posterior fossa dura medial to the sigmoid sinus and posterior and inferior to the posterior semicircular canal. The sac is readily found by performing a simple mastoidectomy with particular attention to skeletonizing the sigmoid sinus and thinning the posterior fossa dural plate immediately medial to the sinus and posterior semicircular canal. Although blue-lining the posterior semicircular canal was once routine, it is only rarely required and is now avoided because it carries greater incidence of hearing loss. The area of the sac extends from the medial aspect of the sigmoid sinus anteriorly into the retrofacial area inferior to the posterior canal and superior to the jugular bulb. The exact location of the sac, which varies, is identified by the presence of thickened white dura next to the normally darker, single-layered dura, or by the presence of hypervascularity on the surface of the sac. The sac also has been known to occupy the medial wall of the jugular bulb. The most likely cause of inability to locate the endolymphatic sac is that the dissection is not carried far enough into the retrofacial recess. Of course, to delineate the sac safely in this area, the descending portion of the facial nerve must be located and carefully preserved. Donaldson's line is an imaginary line in the plane of the horizontal canal back to the sigmoid sinus. It often marks the top of the endolymphatic sac. Only 4% of endolymphatic sacs cannot be surgically identified.

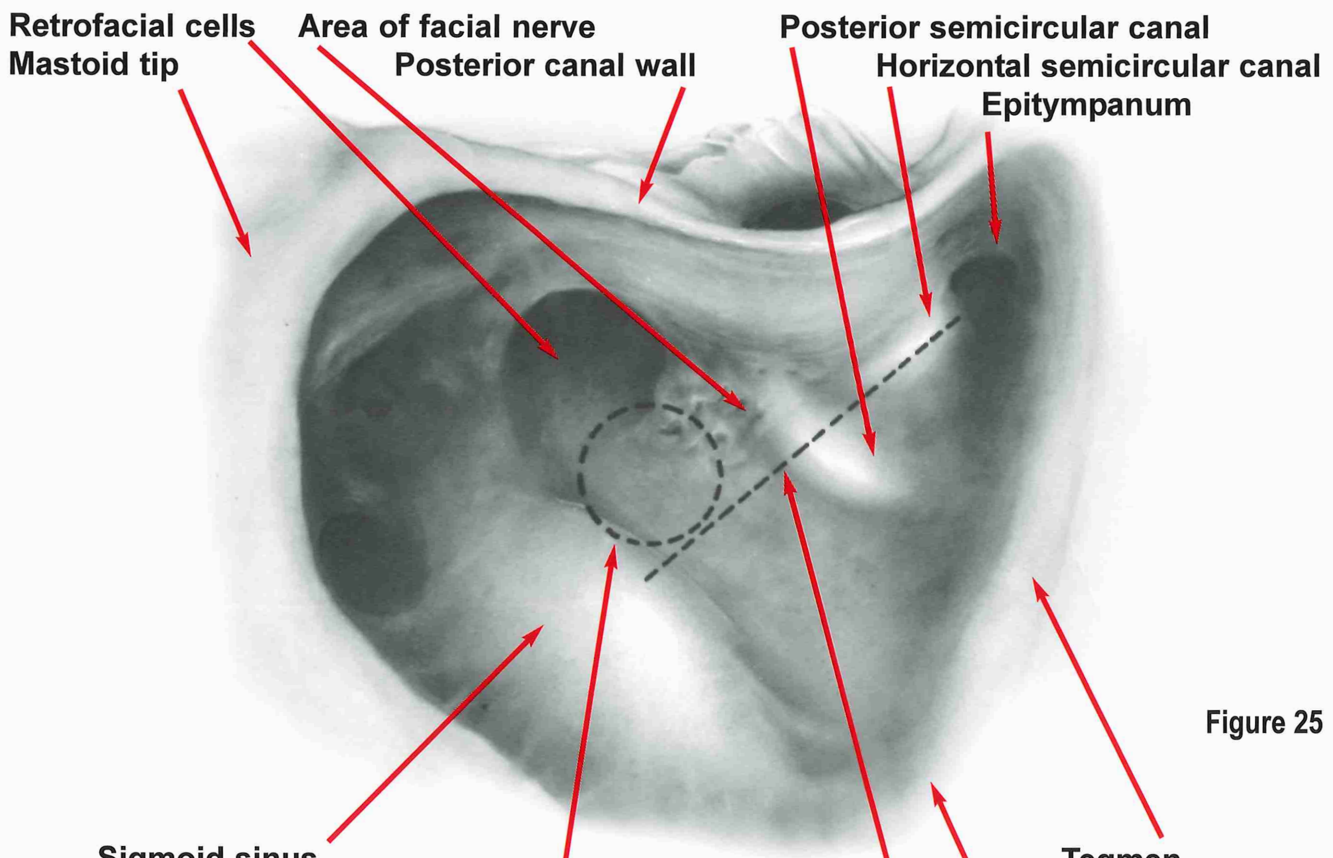

Figure 25

Endolymphatic Sac Dissection

Step 2 (Fig. 26):

Landmarks:

Sigmoid sinus
Labyrinthine bone
Dura

Uncovering the Sac

The dural plate over the sac is thinned with a diamond burr. Wide exposure is performed. Retrofacial and mastoid tip cells may be opened for wide exposure and dural plate bone is thinned to the posterior canal. Again, do not blue-line this canal. The endolymphatic duct may be seen as the apex of a fan-shaped extension of the sac under the posterior canal. When the sac is depressed with an elevator, this apex is often tented from the labyrinthine bone where the duct exists deep to the canal. The eggshell-thin dural plate is then picked away from the dura.

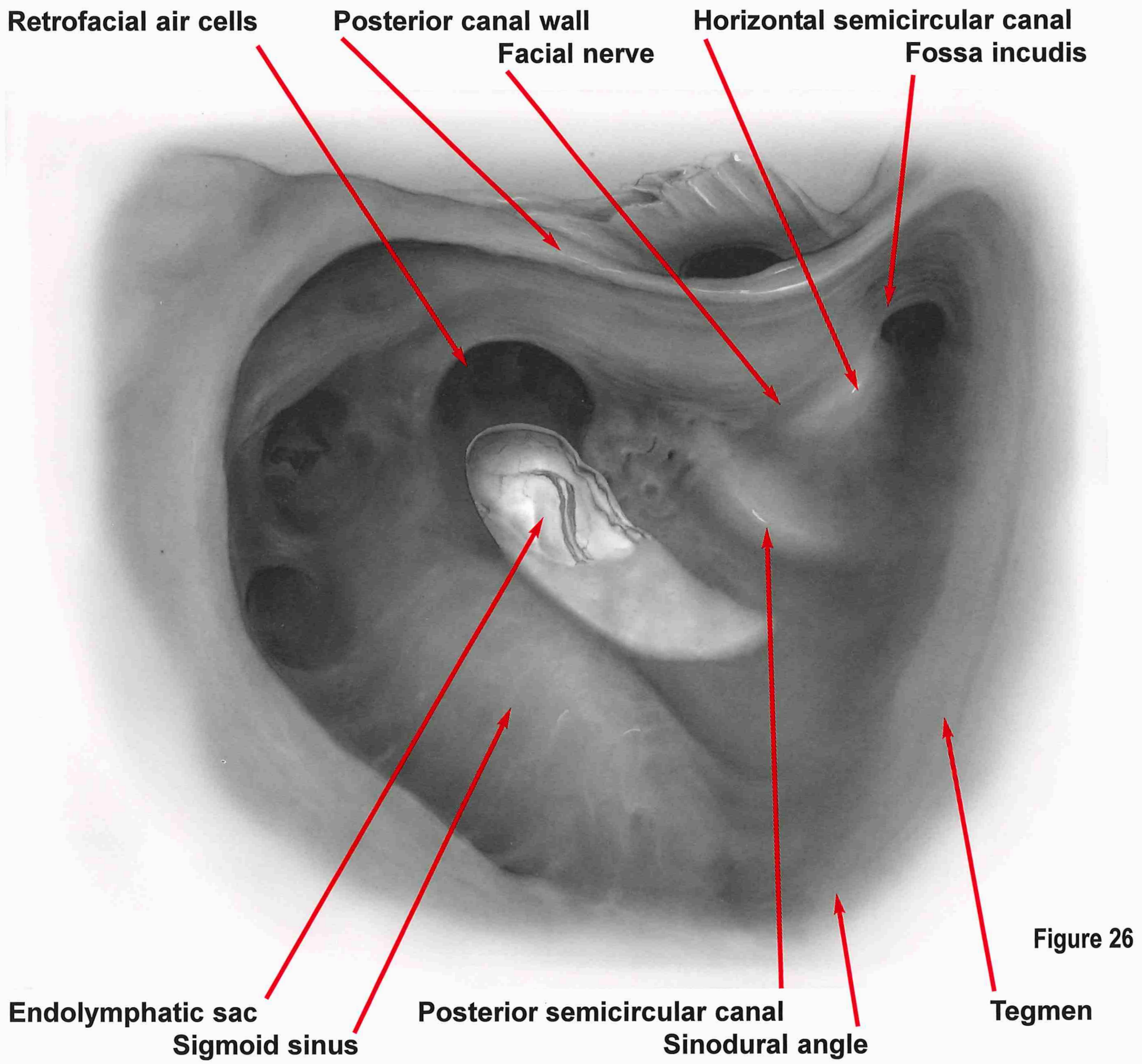

Figure 26

Incising the Sac
Step 3 (Fig. 27):

Landmarks:

Endolymphatic sac
Sac lumen
Subarachnoid space

The lateral wall of the sac is incised and the interior exposed. There is a smooth, glistening lining which, in the living specimen, is moist. The incision on the lateral surface of the sac is made with a sharp right angle instrument without penetrating the medial wall of the sac and beyond into the subarachnoid space.

A thin .005 weight "T"-shaped piece of silastic is inserted through the incision into the sac, allowing the flange to remain in the sac lumen. The vertical portion of the "T" protrudes into the mastoid.

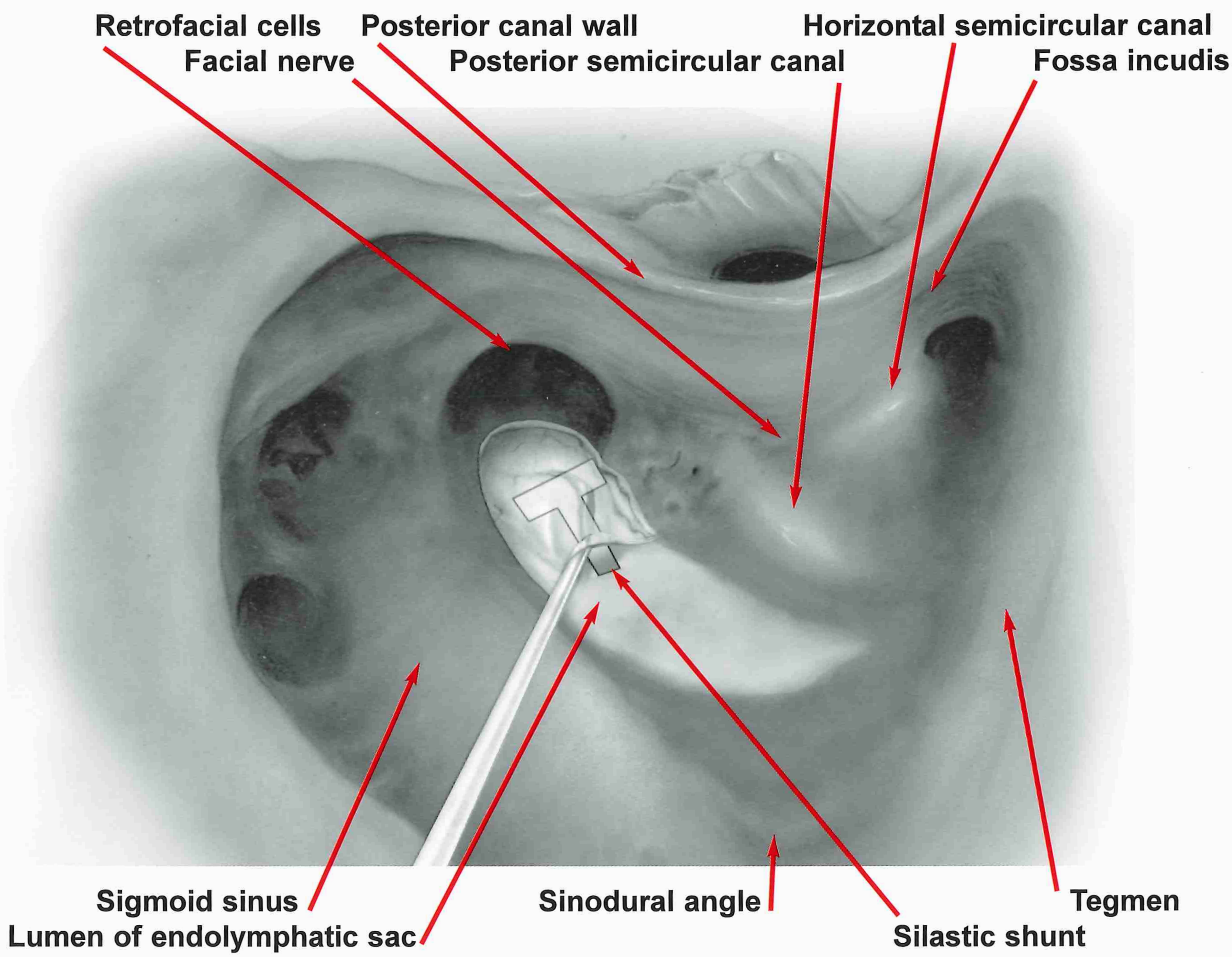

Figure 27

Extended Facial Recess Dissection

Step 1 (Fig. 28):

Landmarks:

- Fossa incudis
- Incus buttress
- Facial recess
- Facial nerve
- Chorda tympani
- Stapes

Topography

Inferiorly, the facial recess dissection may be extended with sacrifice of the chorda tympani. Such an exposure provides identification of the hypotympanic area and access to the so-called "crotch" jugulocarotid spine where the jugular bulb meets the carotid artery. The primary landmarks for this dissection are the descending portion of the facial nerve as the medial limit of dissection, the annular ligament of the tympanic membrane laterally, and the jugular bulb inferiorly. This approach is used for smaller glomus tumors. Further dissection in the inferior portion of the mastoid cavity may be carried out in the retrofacial area, which is inferior to the posterior canal and medial to the facial nerve. This approach enables complete exposure of the hypotympanum if it has been invaded by hypotympanic and retrofacial cholesteatoma. This also is a route for exposure of larger glomus tumors. Limits of this dissection are the posterior canal and cochlea superiorly, posterior fossa plate posteriorly, and the jugular bulb inferiorly and anteriorly. This approach can be combined with transcochlear, infratemporal and translabyrinthine approaches to reroute the facial nerve in cases of large congenital cholesteatoma or large glomus jugulare tumors.

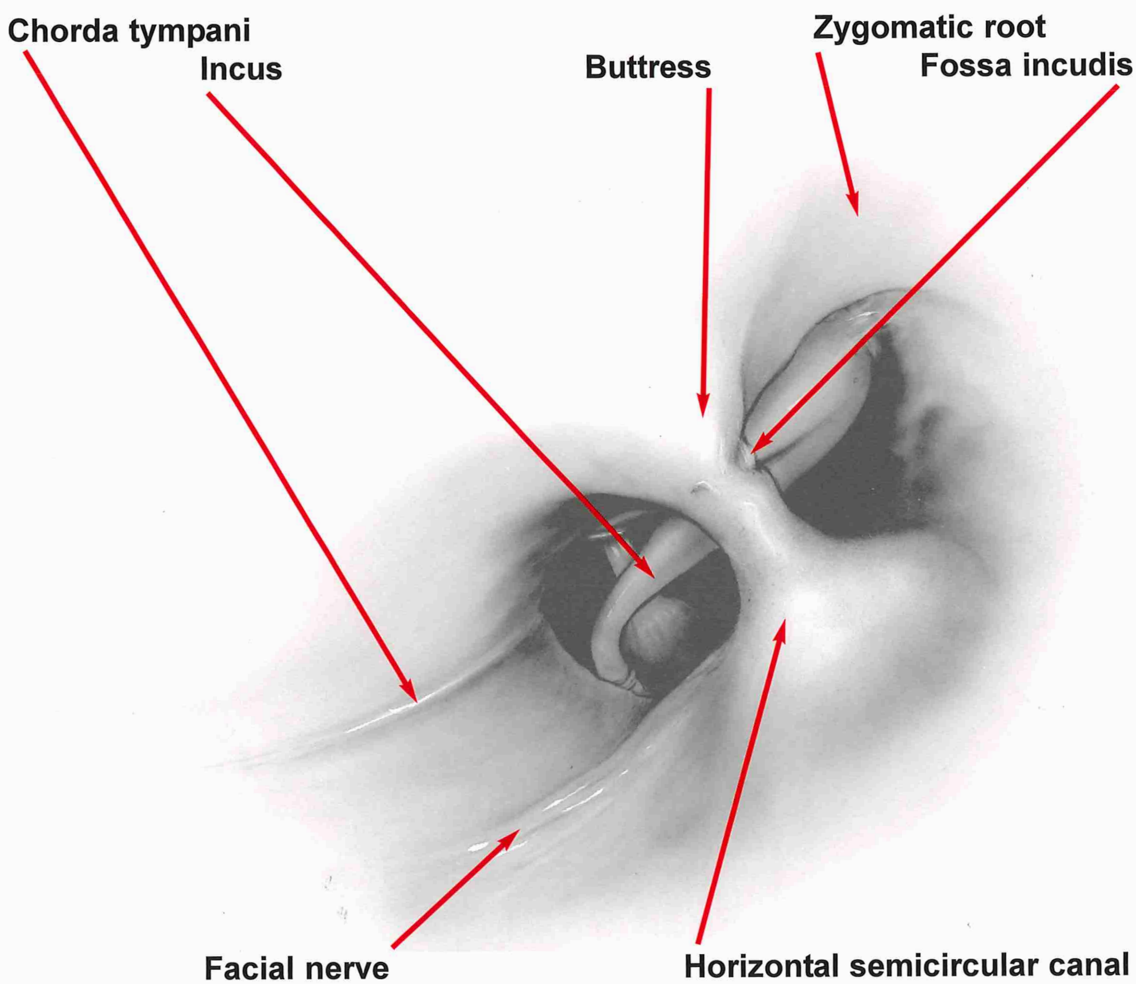

Figure 28

Extending the Facial Recess Step 2 (Figs. 29, 30):

Landmarks:

Facial nerve
Chorda tympani
Annulus
Tympanic membrane

Extending the Facial Recess

The facial recess is extended at the lateral aspect of the facial nerve by sacrificing the chorda tympani. This allows the recess to be opened inferiorly between the facial nerve and the fibrous annulus (See Figure 30). As the annulus turns anteriorly, it moves away from the facial nerve, which permits the surgeon to remove more bone. The annulus then becomes the prime landmark. As the dissection continues forward through hypotympanic bone, a new structure is encountered: the jugular bulb as it rises into the hypotympanum. This provides the exposure necessary to remove a small glomus tumor or extensive hypotympanic cholesteatoma.

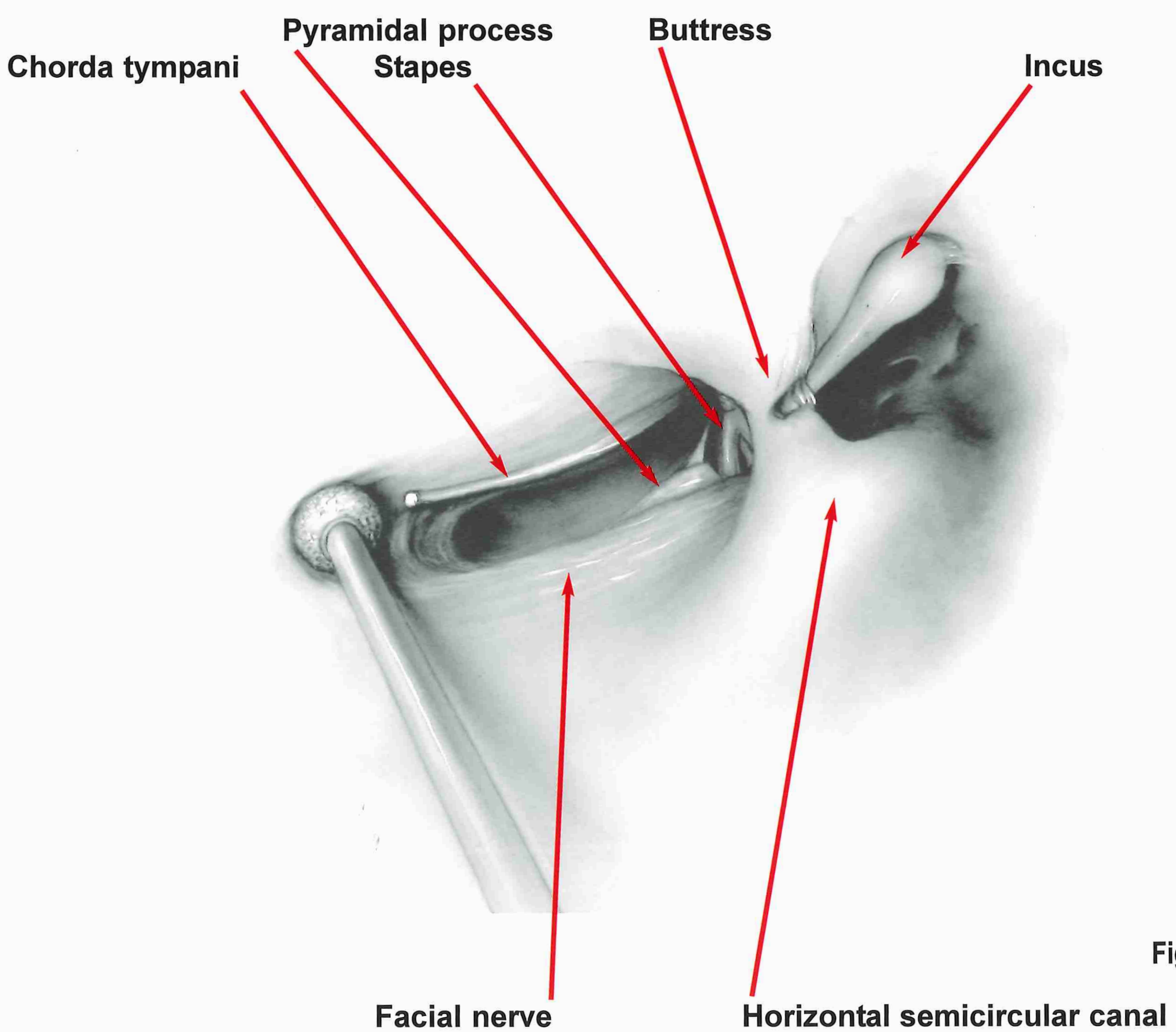

Figure 29

Extending the Facial Recess
Step 2 (Figs. 29, 30):

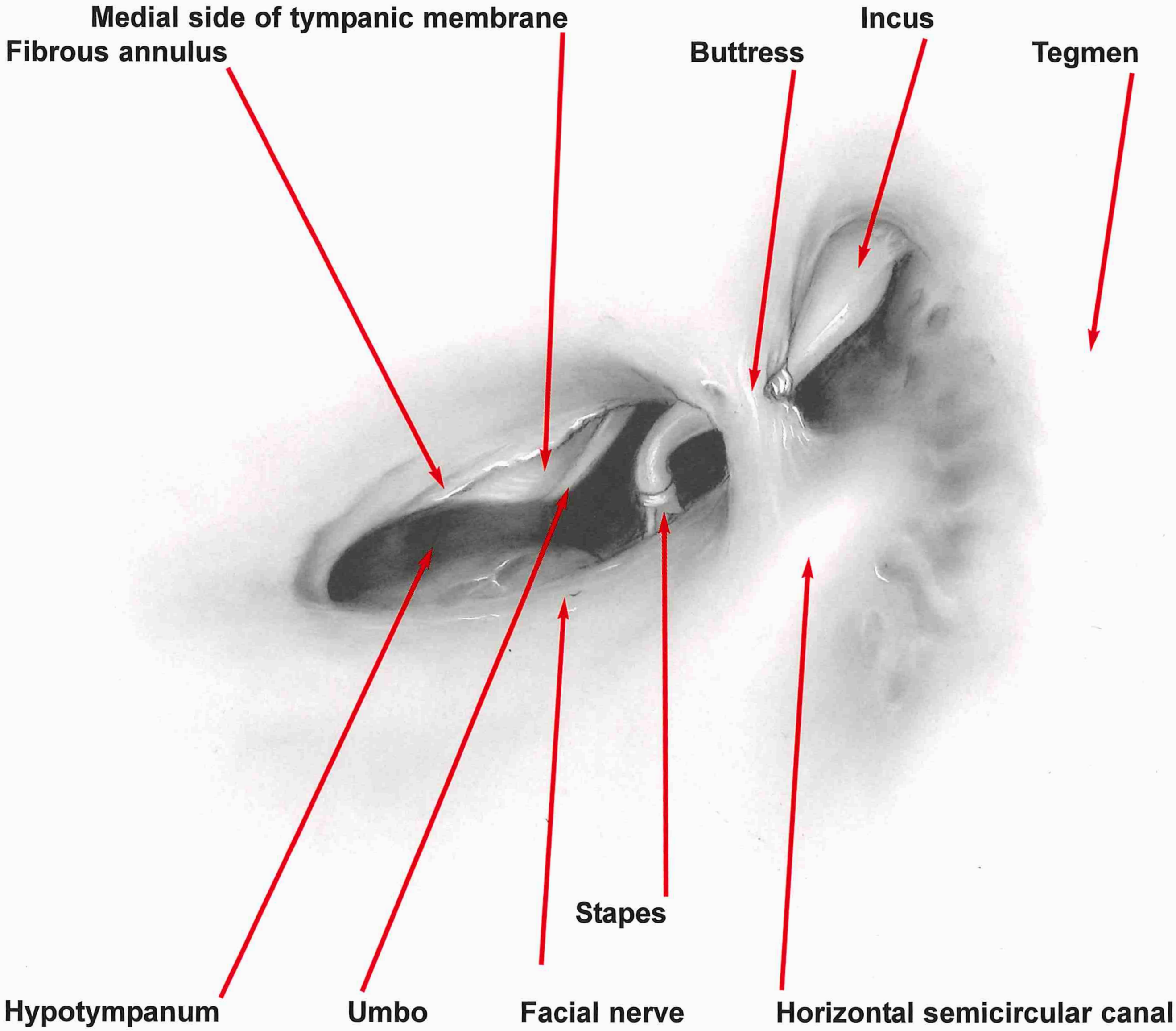

Figure 30

Jugular Bulb/Carotid Artery

Step 3 (Figs. 31, 32):

Landmarks:

Facial nerve
Fibrous annulus
Sigmoid sinus
Jugular bulb
Carotid artery

If the surgeon extends the dissection inferiorly and anteriorly following the fibrous annulus, the bone of the inferior portion of the tympanic bone and mastoid tip may be removed lateral to the facial nerve. This gives wide exposure of the hypotympanum to the level of the eustachian tube.

Removal of retrofacial cells that extend from the mastoid into the middle ear allows one to follow the sigmoid sinus in its continuity with the jugular bulb. Carrying the dissection even more anteriorly, the carotid artery is encountered and the confluence of the two large vessels leaving the carotid sheath and entering the base of the skull can be seen. The bone occupying the part of the skull base where the carotid turns anteriorly and the jugular turns posteriorly is called the "crotch" (jugulocarotid spine). Follow these vessels. The jugular bulb can be opened and cranial nerves IX, X and XI are found in proximity to the multiple openings of the inferior petrosal sinus.

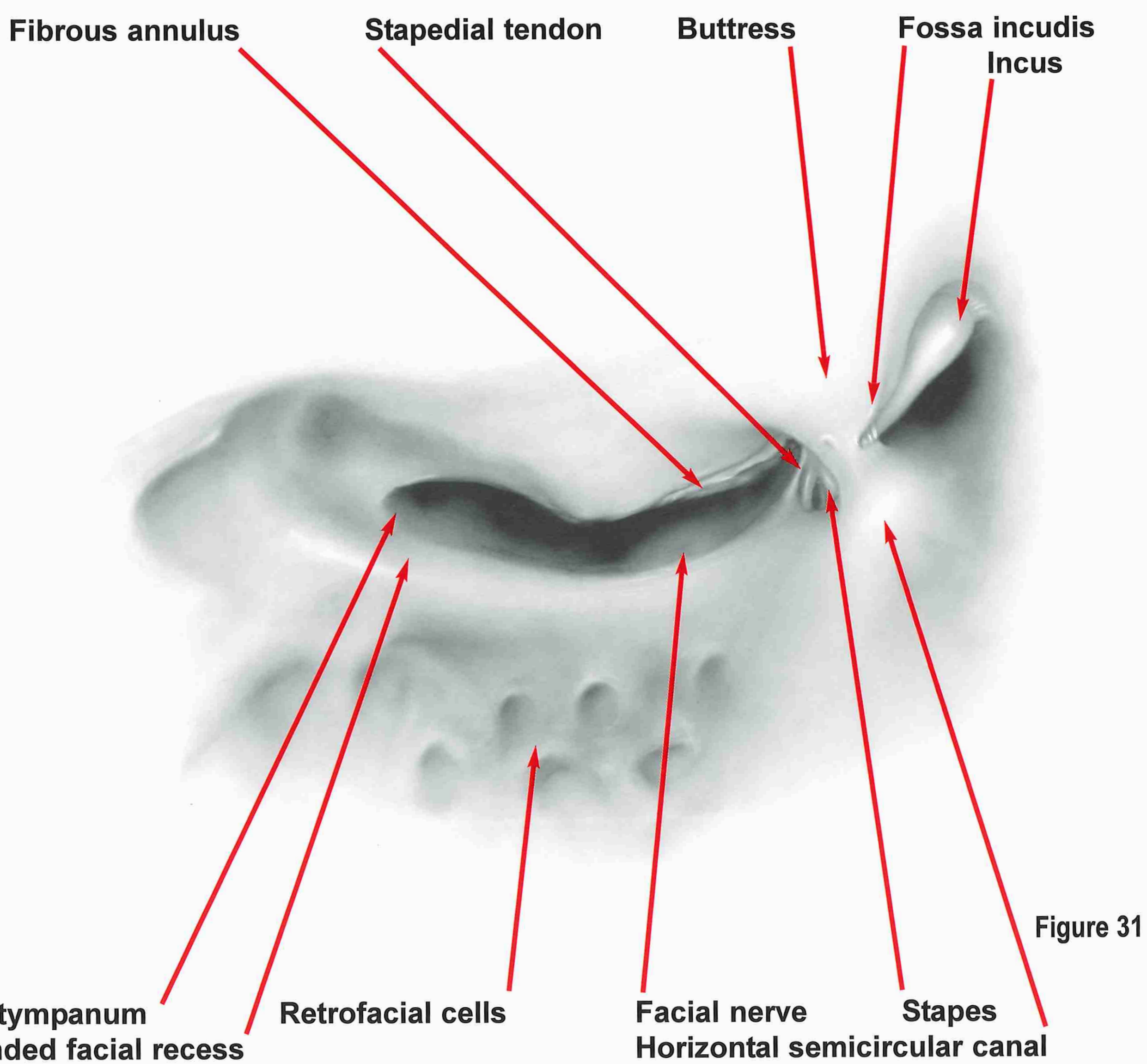

Figure 31

Jugular Bulb/Carotid Artery
Step 3 (Figs. 31, 32):

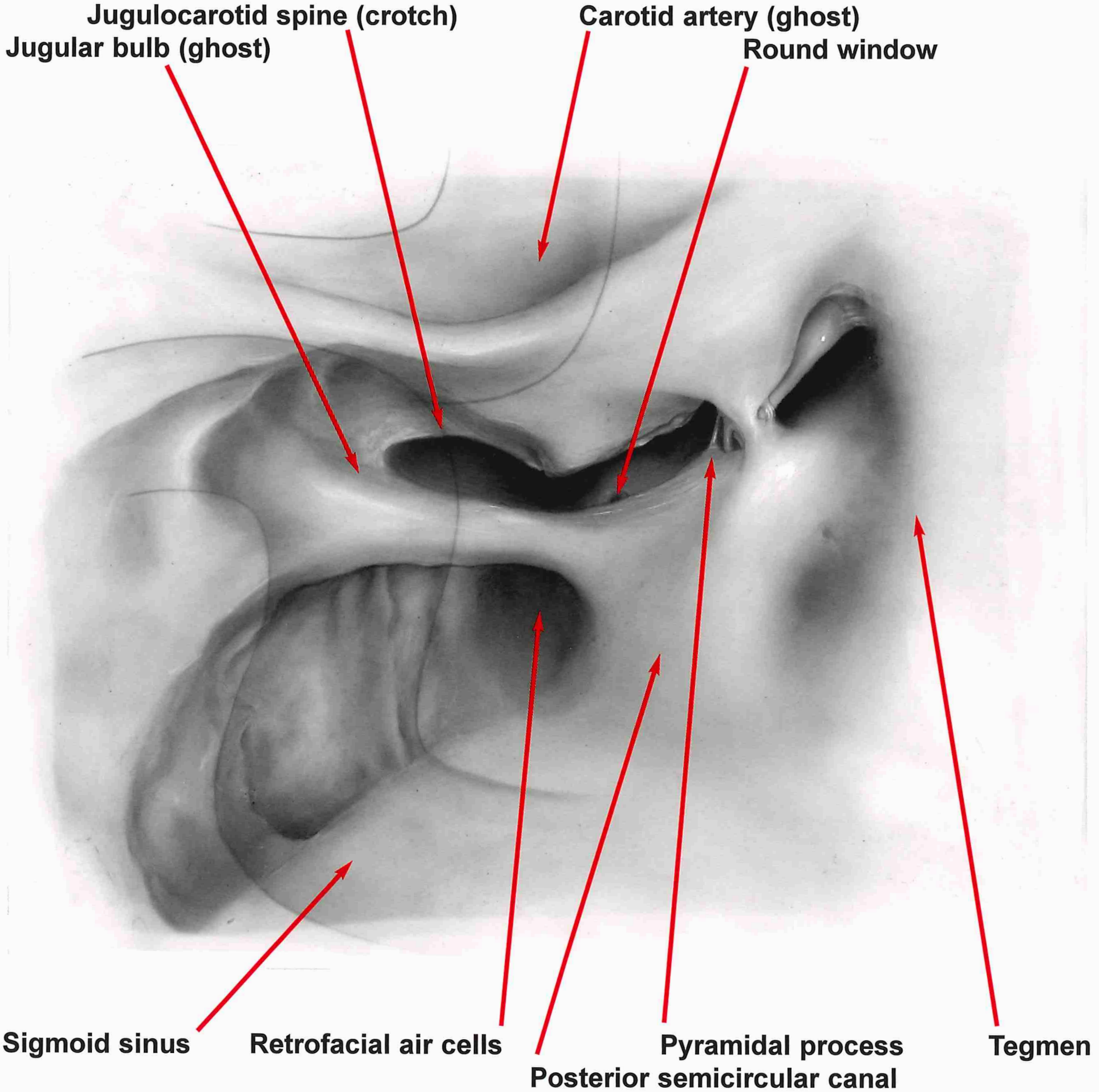

Figure 32

Notes:

5

Tympanic Bone Removal

Tympanic Bone Removal

Step 1 (Fig. 33):

Landmarks:

Zygomatic root
Jugular bulb
Temporomandibular joint

Removing the Tympanic Bone

Removal of the tympanic bone is indicated in the infratemporal approach when there is a carcinoma of the external ear canal. A procedure for cancer must be performed in an en bloc fashion with the skin of the ear canal, the tympanic membrane, and the bony canal walls removed together. This can be done by a combination of some procedures described previously and a dissection through the area of the zygomatic root and the temporomandibular joint. A standard postauricular simple mastoidectomy is performed, followed by an extended facial recess dissection under the posterior canal wall but lateral to the facial nerve. More anteriorly, the lateral portion of the jugular bulb is the most medial part of the dissection. The wall of the jugular bulb will lie next to the posterior wall of the internal carotid artery in the anterior hypotympanum medial to the eustachian tube. Superiorly, the dissection started in the antrum continues through the epitympanum and zygomatic root below the middle fossa dura until the area of the temporomandibular joint is entered. The auricle or the concha is then removed en bloc with a sleeve of tissue representing the bony and cartilaginous external auditory canal, including the tympanic membrane and malleus. The incus will normally be attached to the malleus and it must be disarticulated from the stapes.

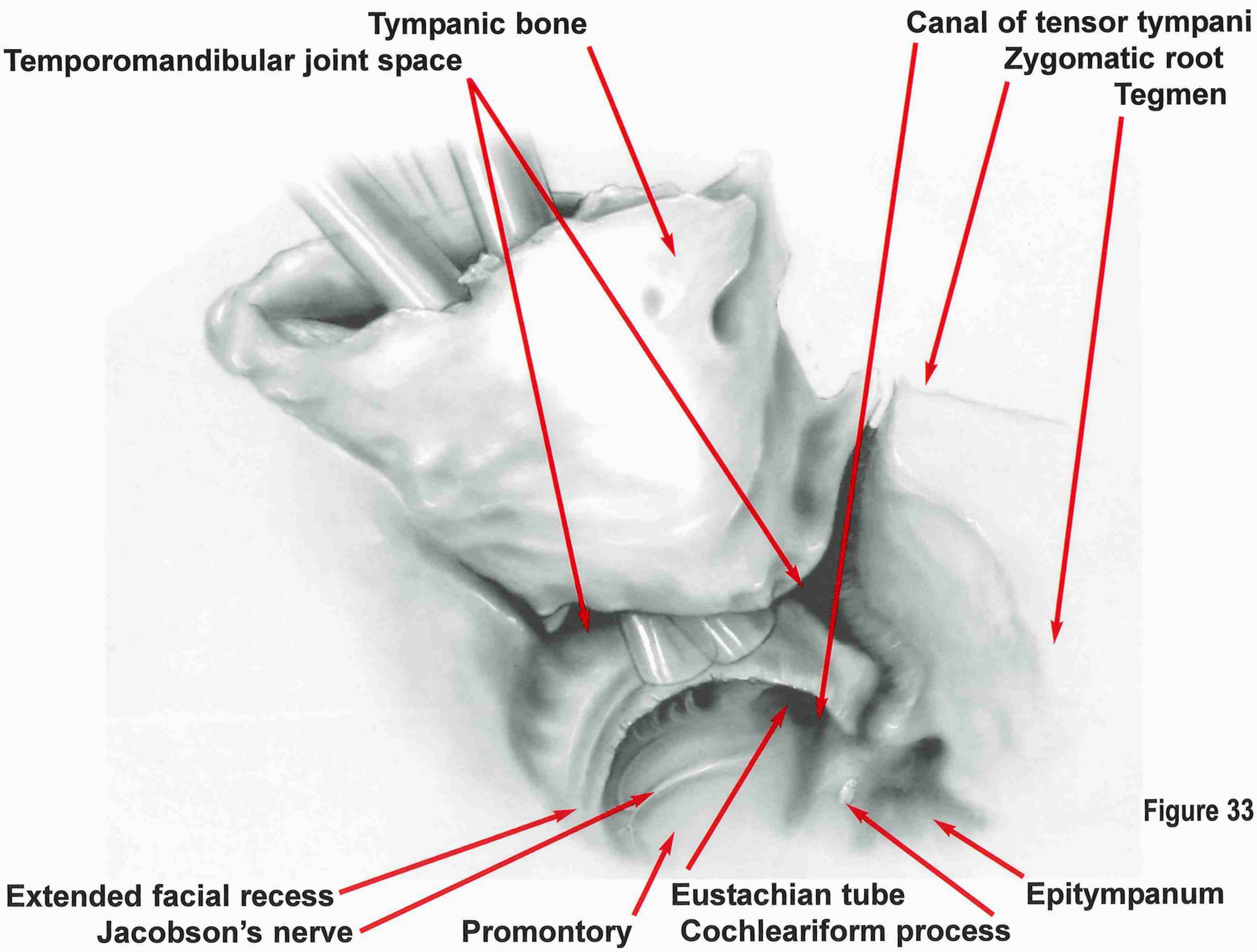

Figure 33

6

Postauricular Labyrinthectomy

Postauricular Labyrinthectomy

Step 1 (Fig. 34):

Landmarks:

- Posterior canal wall
- Incus
- Horizontal semicircular canal
- Posterior semicircular canal
- Tegmen tympani
- Facial nerve
- Sigmoid sinus
- Sinodural angle

Topography

The postauricular labyrinthectomy is designed to eradicate labyrinthine vertigo by complete removal of the semicircular canals and all soft tissue of the vestibule. A complete simple mastoidectomy is performed with the posterior canal wall left intact. The sinodural angle must be completely drilled out to provide adequate exposure of the area of the vestibule later. The middle fossa plate must be thinned completely to provide access to the superior semicircular canal. A cutting burr is used to open the sinodural angle posterior to the labyrinth. In this way, the flukes on the side of the cutting burr may be used to better advantage in removal of the extremely hard labyrinthine bone anterior to it.

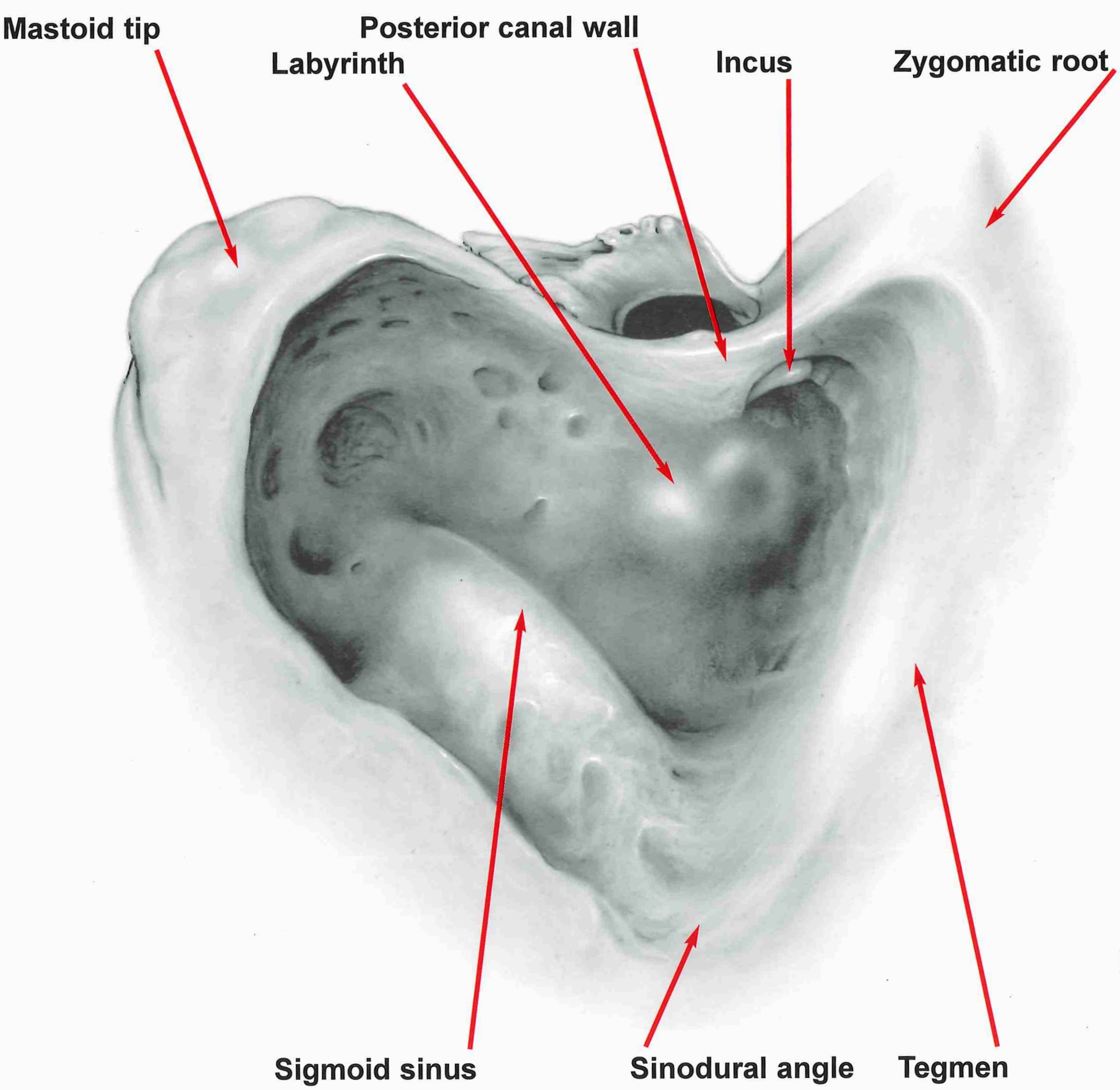

Figure 34

Postauricular Labyrinthectomy
Step 2 (Fig. 35):

Landmarks:

Semicircular canals
Facial nerve
Incus
Tegmen
Sigmoid sinus

Opening the Semicircular Canals

By dissecting the labyrinth, the superior aspect of the horizontal semicircular canal can be fenestrated and followed to the posterior and superior canals. The three semicircular canals are opened allowing the surgeon to develop a three-dimensional concept of the canal planes. The fenestrated canals are followed in their extent to provide continuing landmarks. The surgeon should eventually have a dissection that shows the orientation of each canal to its neighbors. Anterior to the horizontal canal, the mastoid genu and horizontal portions of the facial nerve can be skeletonized. Preservation of the anterior wall of the horizontal canal serves as a protection for these portions of the facial nerve until further thinning over the facial is necessary to expose more of the vestibule.

Profuse irrigation is necessary to remove vast quantities of bone dust and also to prevent frictional heating of the nearby bone and facial nerve.

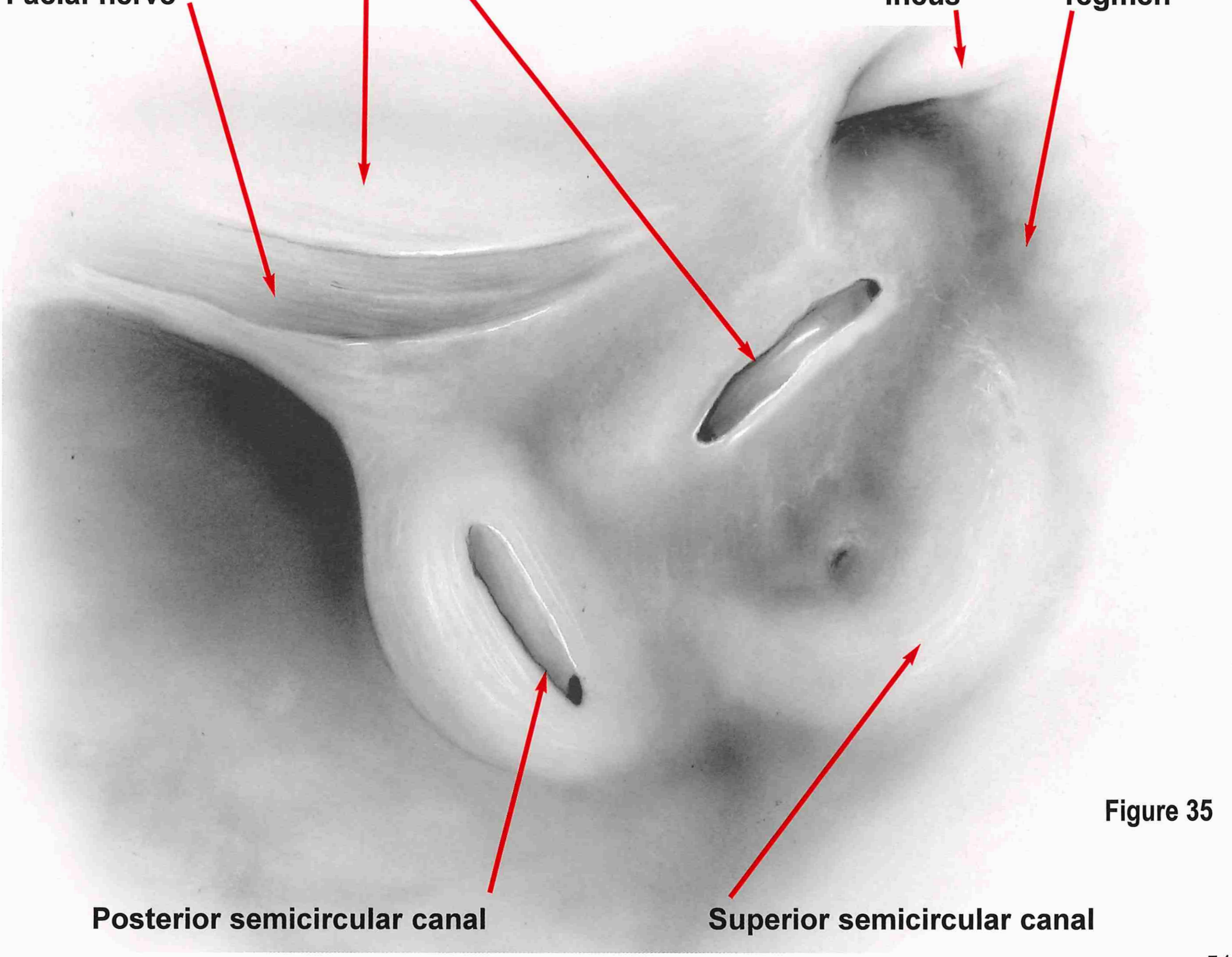

Figure 35

Postauricular Labyrinthectomy
Step 3 (Fig- 36):

Landmarks:

Facial nerve
Tegmen
Semicircular canals
Sigmoid sinus

Following the Semicircular Canals

The semicircular canals must be followed as they are highways into the vestibule. Transection without following will leave "snake eyes" and make the identification of the surrounding structures more difficult.

Superiorly, the superior semicircular canal arches in a posterior-medial direction underneath the middle fossa plate. This canal is traced posteriorly and medially until it becomes the common crus in its junction with the posterior semicircular canal. The subarcuate artery penetrates the labyrinthine bone in the center of the circle inscribed by the superior canal. The posterior canal is then followed inferiorly and anteriorly under the descending portion of the facial nerve. Look for the endolymphatic duct as it courses from its opening in the medial wall of the vestibule next to the common crus. It travels posteriorly in the medial wall of the common crus and then curves inferiorly and laterally as it passes under the posterior canal to enter the endolymphatic sac in the posterior fossa dura. There is a bony operculum or small bony cap overlying this portion of the sac as the duct enters it. The endolymphatic duct appears as a white, fibrous-like structure in the labyrinthine bone. Identify, open and probe the lumen of the endolymphatic sac.

Postauricular Labyrinthectomy
Step 3 (Fig. 36):

Following the Semicircular Canals

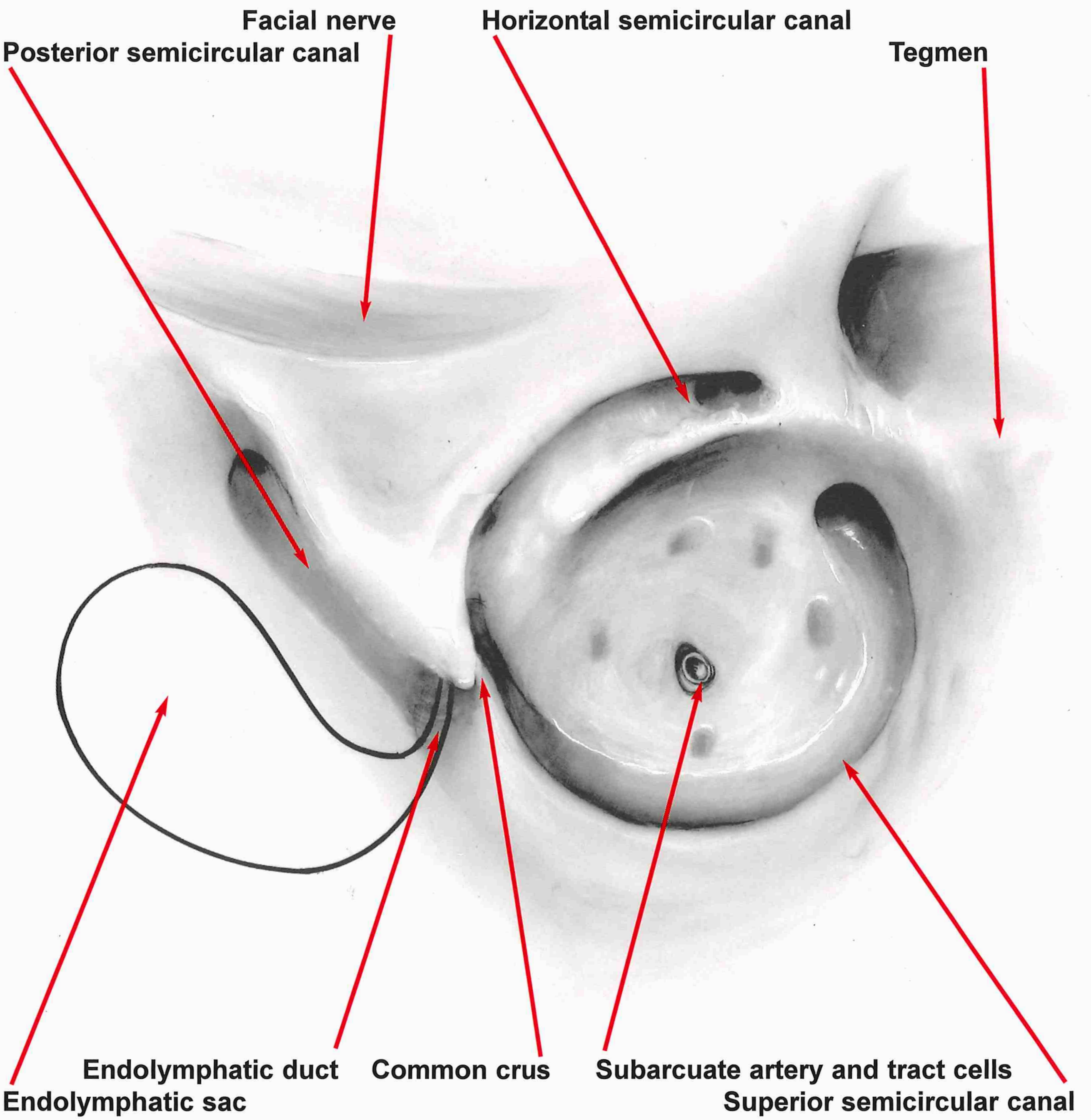

Figure 36

Postauricular Labyrinthectomy
Step 4 (Figs. 37, 38):

Landmarks:

- Facial nerve
- Tegmen
- Semicircular canals
- Elliptical recess
- Spherical recess
- Footplate of stapes
- Endolymphatic duct

Opening into the Vestibule

Follow the common crus forward into the vestibule and open it widely. The bone over the facial nerve is then thinned to provide good visual access to the vestibule. The medial side of the facial nerve is at risk during this step of the dissection. All of the semicircular canals are connected, and soft tissue is removed from the vestibule and semicircular canals to eliminate any remaining vestibular function. Before removing the soft tissue, identify the maculae of the utricle and its elliptical recess and the maculae of the saccule and its spherical recess. Probe the opening of the endolymphatic duct. Palpate the stapes footplate from its medial side. Removal of the three semicircular cristae and the two maculae completes the postauricular labyrinthectomy.

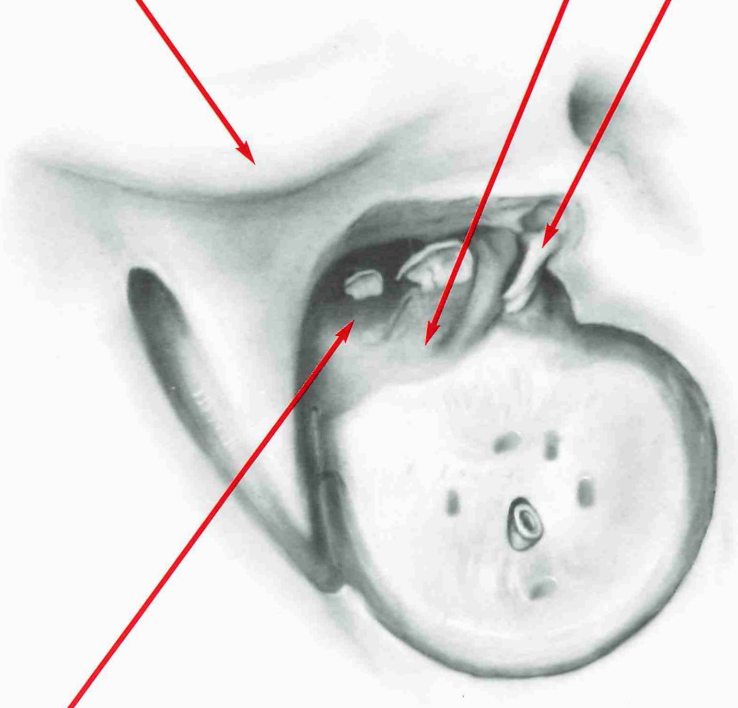

Figure 37

Postauricular Labyrinthectomy

Step 4 (Figs. 37, 38):

Opening into the Vestibule

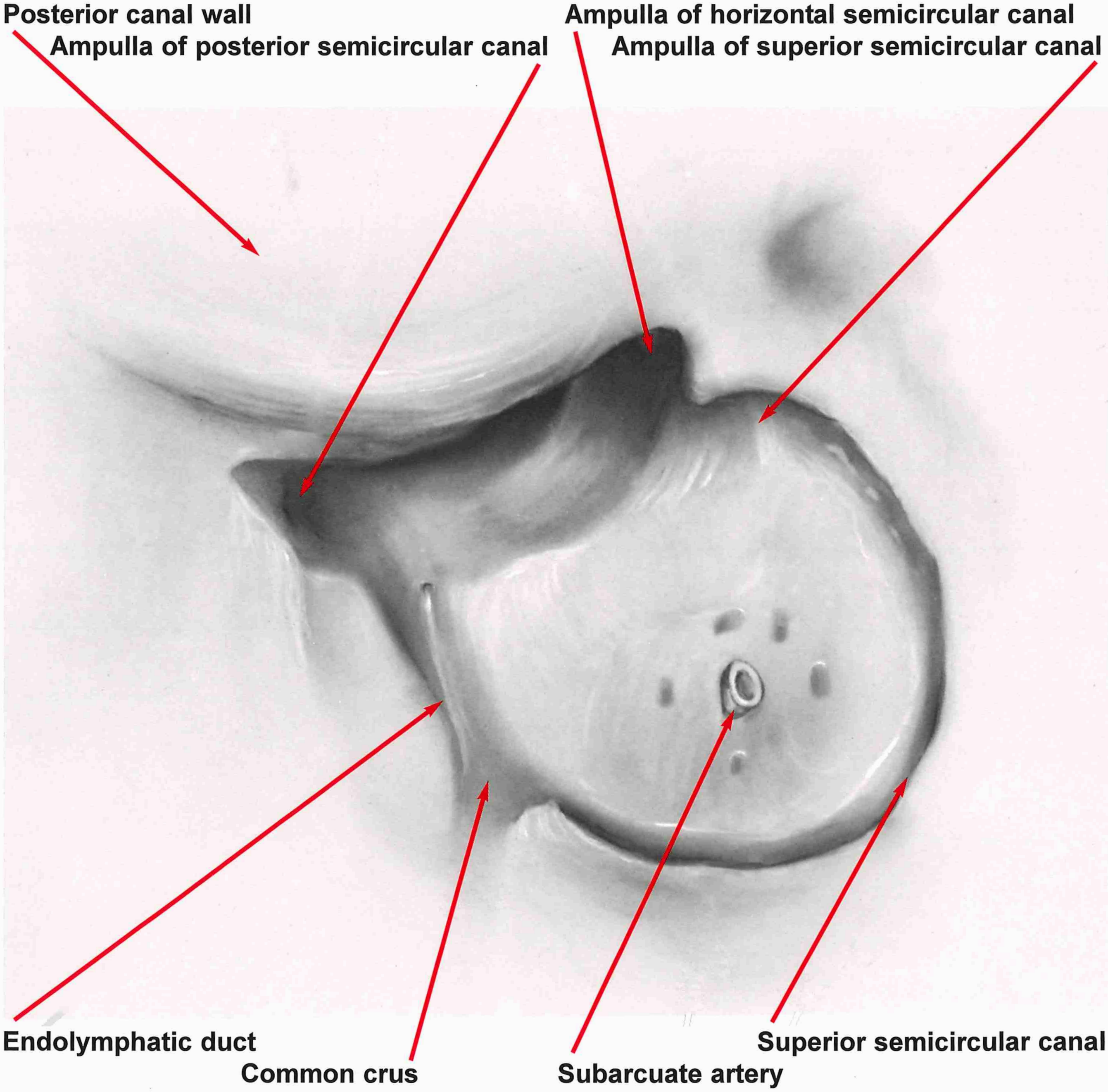

Figure 38

Notes:

7

Internal Auditory Canal

Internal Auditory Canal

Step 1 (Fig. 39):

Landmarks:

- Facial nerve
- Vestibule
- Tegmen
- Posterior fossa plate
- Superior canal ampulla

Topography

The simple mastoidectomy and postauricular labyrinthectomy are the first two stages of the approach to the internal auditory canal. This dissection requires that all the previous steps be accomplished properly to provide wide access for adequate identification and working room within the petrous bone. During labyrinthectomy in this procedure, the ampulla of the superior semicircular canal is preserved as a landmark to find the end of the superior vestibular nerve, Bill's bar, and the facial canal. In approaching the internal auditory canal, one must remember that the medial wall of the vestibule represents the lateral wall of the internal auditory canal fundus, where the nerves enter the inner ear structures. Therefore, minimal bone removal on the medial wall of the vestibule will expose the internal auditory canal.

Posteriorly, at the posterior fossa dura, the route to the porus acusticus is much deeper because the internal auditory canal is slanting away from the surgeon. The plane of the canal, in an anterior-posterior direction, is roughly from the mastoid genu to the sinodural angle. The superior border of the internal auditory canal is visualized between the superior semicircular canal ampulla and the posterior fossa dura. The subarcuate artery runs immediately superior to this line. The inferior border of the internal auditory canal is visualized between the posterior semicircular canal ampulla and the posterior fossa dura. Skeletonizing the bone between these two lines exposes the dura of the posterior wall of the internal auditory canal.

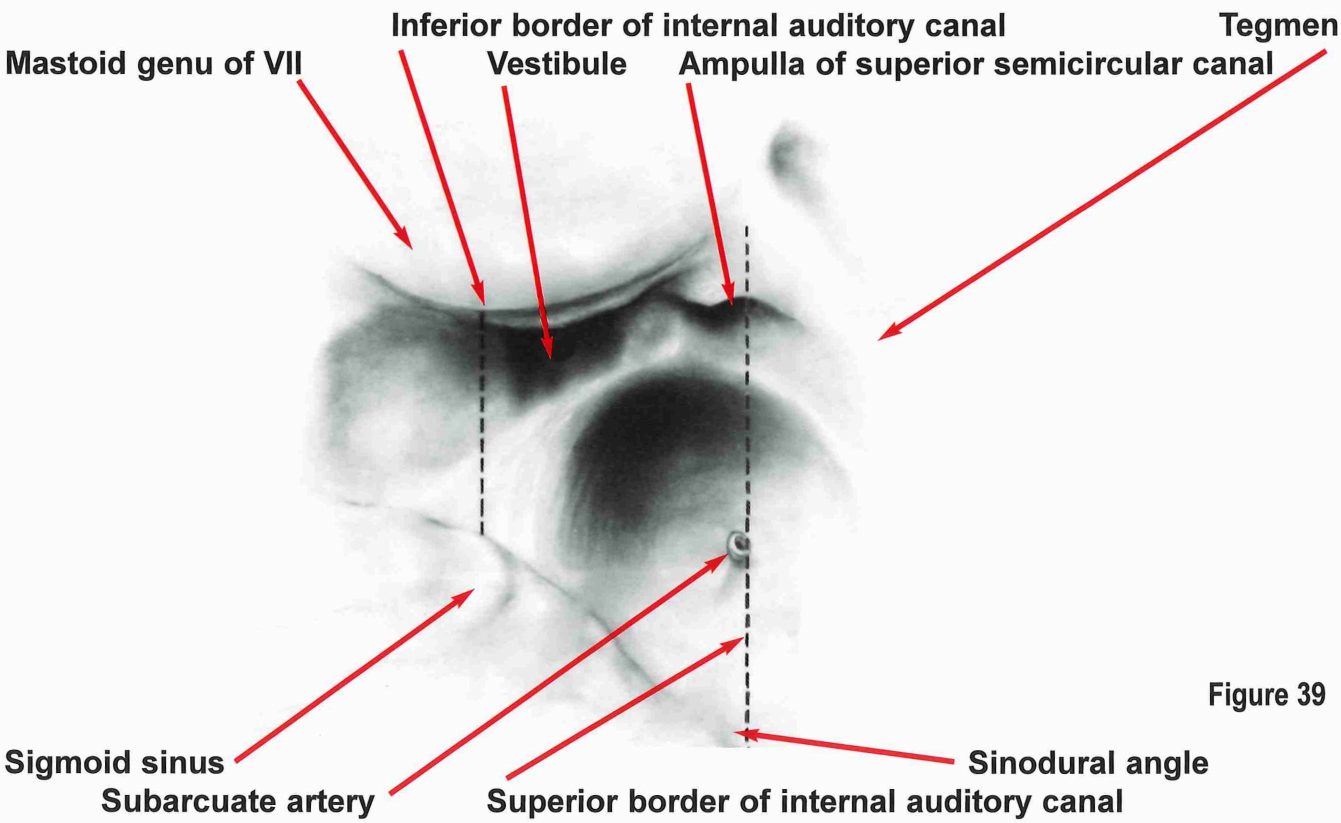

Figure 39

Internal Auditory Canal
Step 2 (Fig. 40):

Landmarks:

Tegmen
Sinodural angle
Vestibule
Ampulla of superior canal
Posterior fossa plate
Sigmoid sinus
Internal auditory canal

Removing Bone over the Internal Auditory Canal

The bone to be removed for exposure of the internal auditory canal forms a wedge or triangle. One side is the roof of the internal auditory canal and the superior portion of the dissection; the second side is the floor of the labyrinthectomy dissection; and the third side is the posterior fossa dura as it extends between the other two sides. The internal auditory canal can be recognized by the dark blue color changes in the bone.

Posteriorly in the sinodural angle, the blue-line of the superior petrosal sinus will show as it runs along the posterior superior border of the temporal bone from the apex to its entrance into the transverse sinus.

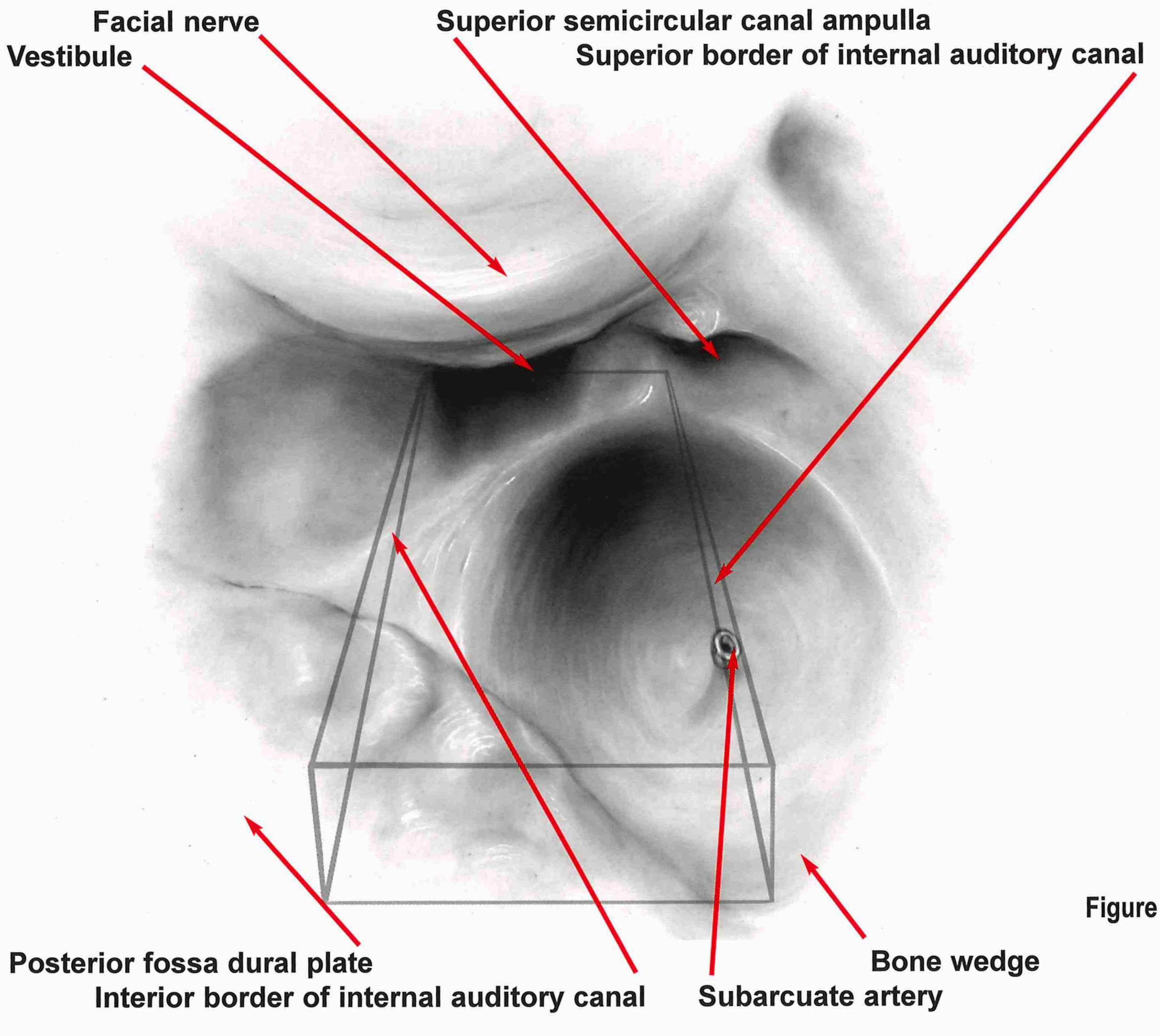

Figure 40

Internal Auditory Canal

Step 3 (Fig. 41):

Landmarks:

- Superior petrosal sinus
- Superior canal ampulla
- Vestibule
- Facial nerve
- Cochlear aqueduct
- Tegmen
- Jugular bulb
- Sigmoid sinus and posterior fossa plate

Blue-lining the Internal Auditory Canal

Skeletonization of the internal auditory canal for dissection purposes is accomplished through removal of bone for 180 degrees around the posterior portion of the canal extending from the area of the fundus to the porus acusticus. Such surgical exposure is to prevent the bony overhang that would make work within the canal difficult. Blind dissection under bony ledges carries the possibility of injury to a nerve or blood vessel within the canal. For such exposure, the surgeon must remove all bone superior to the canal extending from the area of the acusticus. This dissection is performed with diamond burrs and a suction-irrigator, which prevents the accumulation of bone dust from obscuring the underlying dissection area. The middle fossa dura is located and followed in an ever-deepening trench representing superior track air cells above the internal auditory canal, with preservation of a thin layer of bone over the superior portion of the internal auditory canal.

At the deepest portion of this dissection, which is at the superior lip of the porus acusticus, exposure is limited. With patience and persistence, however, the posterior superior portion of the internal auditory canal can be well exposed. With the posterior portion of the porus acusticus well defined at the junction of the posterior fossa dura and internal auditory canal, the inferior border of the internal auditory canal can be better defined. A trench with the jugular bulb inferiorly and the internal auditory canal superiorly is constructed between the posterior fossa dura and labyrinthine bone anteriorly. This dissection is carried anteriorly until a fibrous track of the cochlear aqueduct is entered which will often release cerebrospinal fluid. Extension of the dissection anterior to the cochlear aqueduct will identify cranial nerves IX,X, and XI.

If proper removal of bony covering has occurred throughout the exposure of the internal auditory canal, there should now be an eggshell-thin covering of bone from the fundus of the canal to the area of the jugular bulb inferiorly, to the superior petrosal sinus and middle fossa dura superiorly, and to the sigmoid sinus posteriorly. This bone may be removed for a wide exposure of the internal auditory canal and the posterior fossa dura. For procedures involving section of the vestibular nerve, such extensive exposure is not necessary. However, we encourage wide exposure to eliminate blind dissection through a small keyhole into the internal auditory canal fundus. Limited exposure also precludes the ability to deal with the potential problem of a bleeder from the sectioned nerve.

Internal Auditory Canal
Step 3 (Fig. 41):

Blue-lining the Internal Auditory Canal

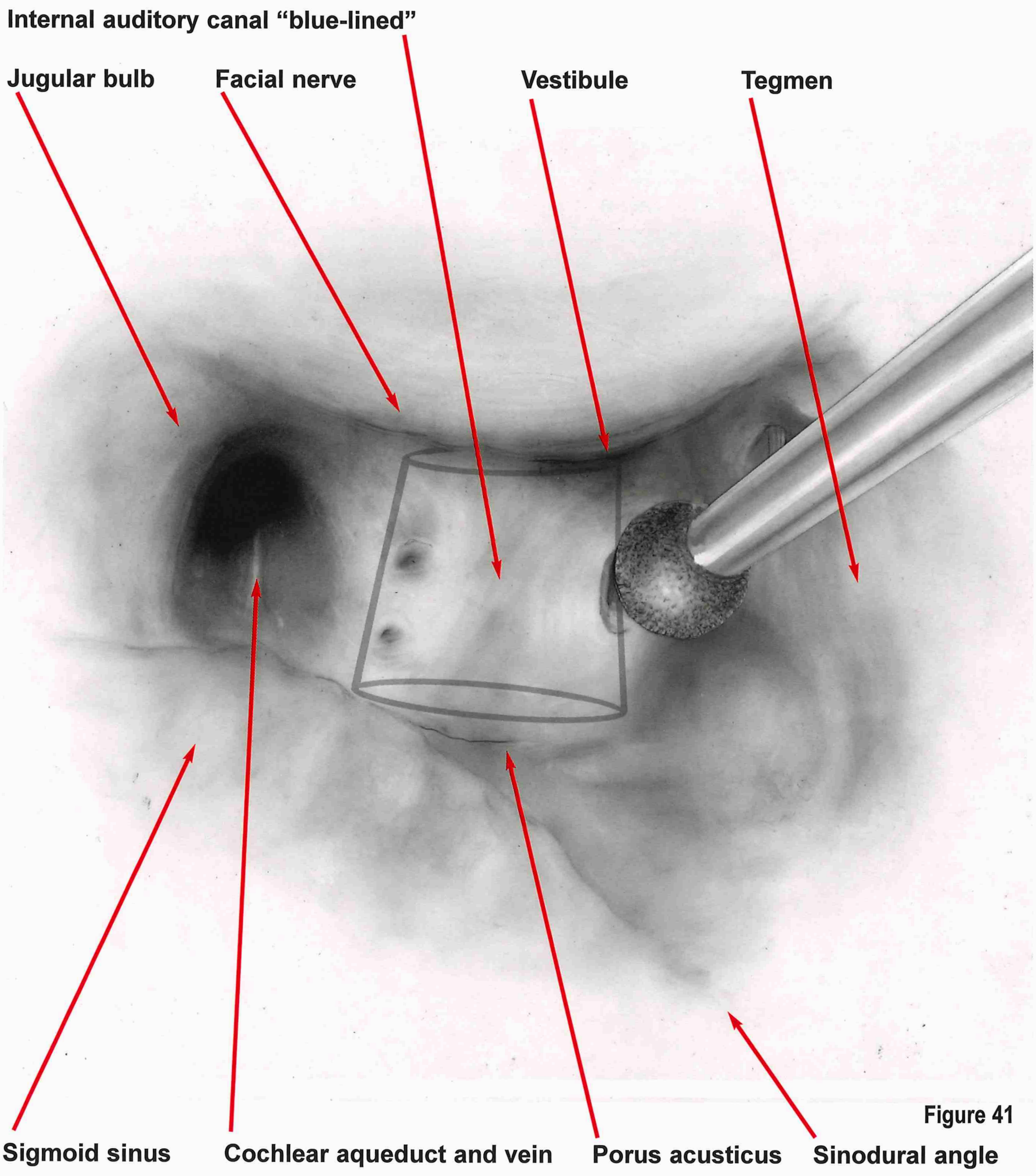

Figure 41

Internal Auditory Canal

Step 4 (Fig. 42):

Opening the Internal Auditory Canal

The bone removed, the exposed dura of the internal auditory canal is slit along the long axis of the canal at its inferior border. This precludes injury to the facial nerve superiorly in the occasional cases of variation (sometimes a tumor pushes the nerve posteriorly).

Within the internal auditory canal, the vestibular nerves are both posterior, whereas the facial nerve is anterior superior and the auditory nerve anterior inferior. To locate these structures from a lateral dissection approach to the internal auditory canal, we use the facial nerve as the principal landmark. The facial nerve is located anterior to the superior vestibular nerve. Therefore, we ordinarily preserve part of the ampulla to the superior semicircular canal, which assists identification of the superior vestibular nerve. A diamond burr is used to dissect the medial wall of the superior ampulla to expose the superior vestibular nerve as it enters the labyrinth at that point. If the bone has been removed from the superior wall of the internal auditory canal far enough anteriorly, the facial canal may be seen descending through its labyrinthine portion from the geniculate into the internal auditory canal (Bill's bar).

Internal Auditory Canal
Step 4 (Fig. 42):

Opening the Internal Auditory Canal

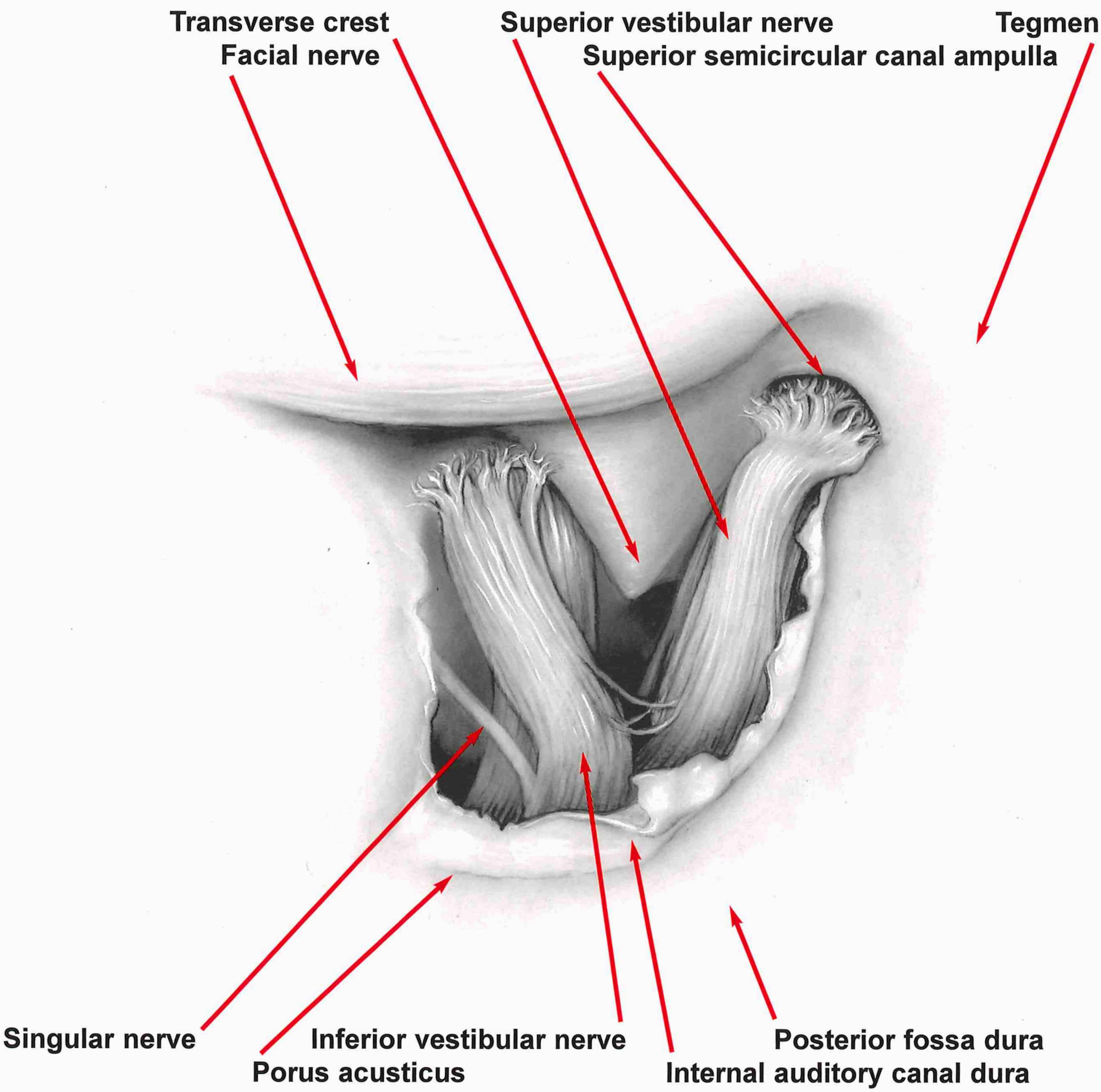

Figure 42

Internal Auditory Canal

Step 5 (Figs. 43, 44):

Landmarks:

Falciform crest (transverse)
Superior vestibular nerve
Bill's bar (vertical crest)
Facial nerve

Identification of the Nerves

When part of the superior ampulla is preserved, its medial wall represents the last remaining bone over the superior vestibular nerve at its termination in the ampulla. When this bone is removed, a brush-like ending of the nerve is encountered.

After the superior vestibular nerve is identified, a one-millimeter hook may be inserted deep to the vestibular nerve directly anterior and medial to the superior vestibular nerve to palpate the shelf of bone that separates the superior nerve from the facial canal. The superior vestibular nerve occupies a recess medially. The recess may be safely probed and the posterior edge of it palpated. Bill's bar, as this shelf of bone is called, represents the posterior wall of the fallopian canal. With identification of the bar and the fallopian canal, the superior vestibular nerve is then avulsed from its attachments in the ampulla area. When gently lifting the superior vestibular nerve, one should look for the facial nerve as it exits the fallopian canal into the internal auditory canal. Vestibulo-facial anastomoses that occur here should be carefully sectioned.

Inferior to the superior vestibular and facial nerves, identify the transverse crest, (falciform crest, or crista transversalis) that divides the canal into superior and inferior compartments. The crest is evident during exposure of the fundus and allows easy identification of the inferior vestibular nerve laterally and the auditory nerve medially. The singular nerve to the posterior semicircular canal is an offshoot from the inferior vestibular nerve within the internal auditory canal. This method of internal auditory canal exposure is used for translabyrinthine vestibular nerve sections and the translabyrinthine approach for acoustic neuroma removal.

Remove the bone of the fallopian canal starting at Bill's bar and proceed with decompressing the facial nerve from Bill's bar to the geniculate ganglion. Identify the greater superficial petrosal nerve. Then follow the nerve a few millimeters posteriorly into the middle ear.

Internal Auditory Canal
Step 5 (Figs. 43, 44):

Identification of the Nerves

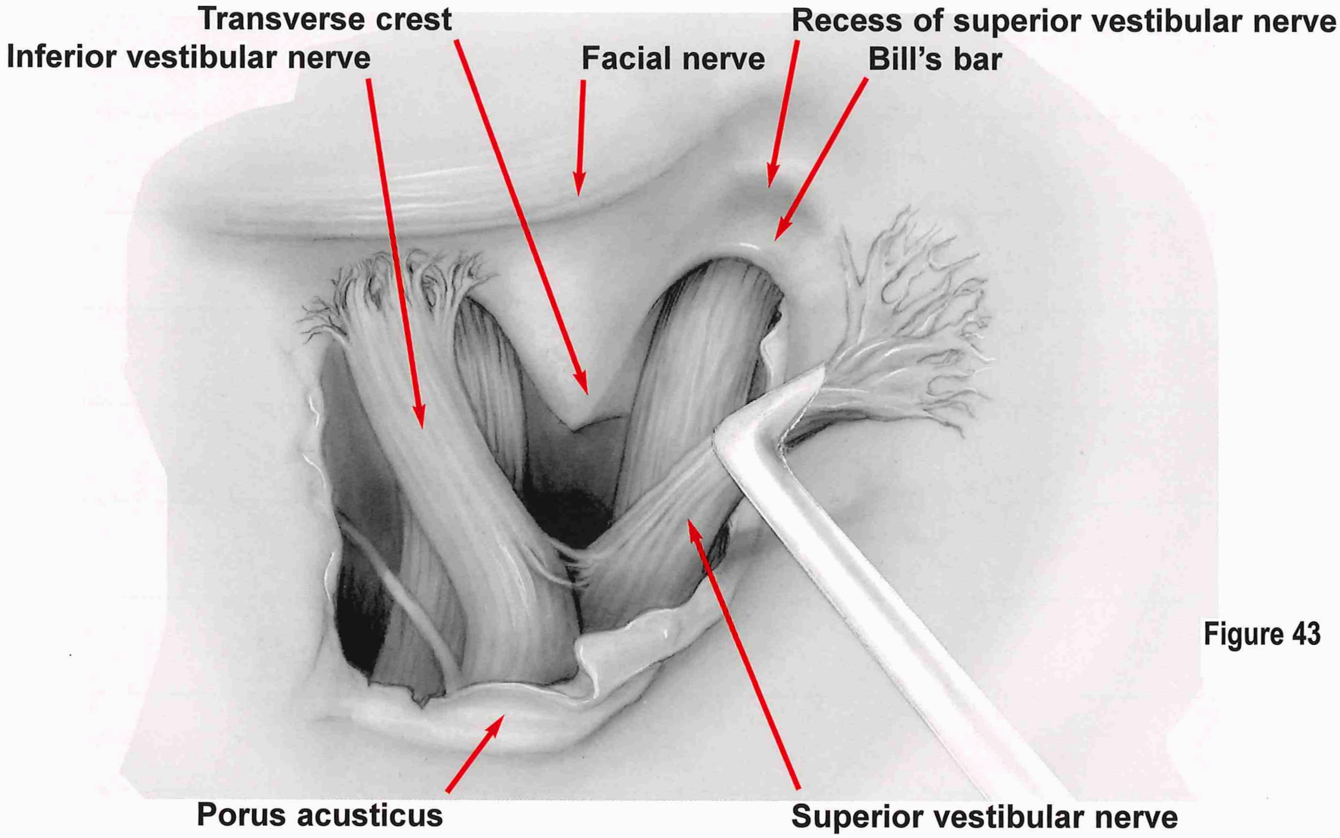

Figure 43

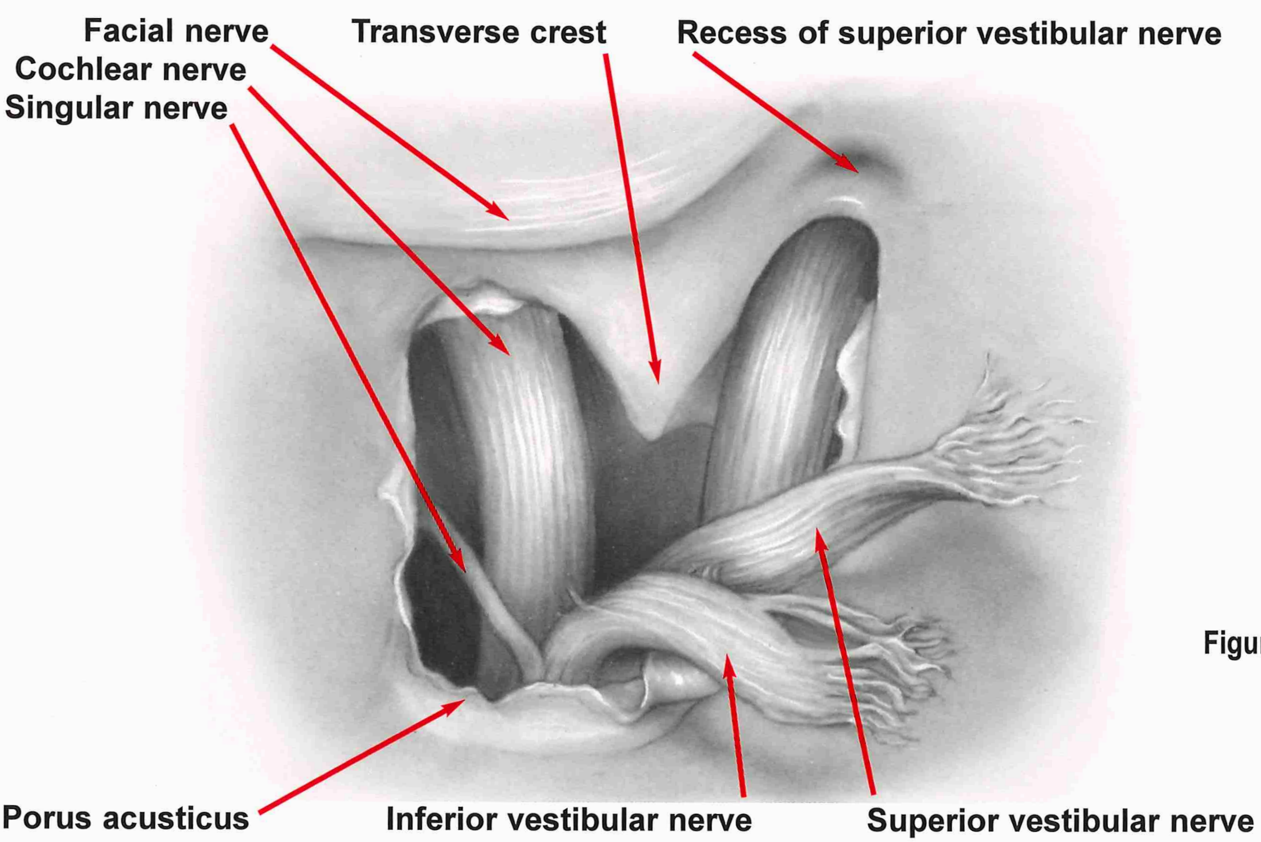

Figure 44

Notes:

8

Middle Fossa Approach

Middle Fossa Approach
Step 1 (Fig. 45A, B):

Landmarks:

Squamosa
Arcuate eminence
Middle meningeal artery
Superior petrosal sinus

Middle Fossa Topography

In middle fossa surgery of the temporal bone, the surgeon sits at the head of the patient. Place the bone in the cup as is done in mastoid surgery, then rotate the cup 90º. The surgeon should visualize the bone as if looking through a craniotomy window that has been inscribed in the squamosal portion of the temporal bone (Fig. 45A). The bone is positioned so that the surgeon looks directly down upon the middle fossa floor. Create a window above and anterior to the external auditory canal at the middle fossa floor as shown in Fig. 45A. Then dura should be stripped back from the roof of the temporal bone, as in the surgical procedure for this approach. The topography should be studied (Fig. 45B). Identify anteriorly the middle meningeal artery and follow it to the foramen spinosum. This marks the anterior limits of this dissection. As dura is reflected away from the squamosal portion of the bone, the floor of the middle fossa is revealed. Laterally, this is the tegmen overlying the aerated mastoid portion of the bone and epitympanum.

Anteriorly beyond the epitympanum, thin bone covers the eustachian tube. More anteriorly, the middle meningeal artery is the first major landmark to be encountered in elevating the dura. The foramen spinosum is located anteriorly to the bony cartilaginous junction of the eustachian tube. On the posterior side of the eustachian tube lies the internal carotid artery. After reflecting the dura, identify the greater superficial petrosal nerve entering the facial hiatus and follow it to the geniculate ganglion. The edge of the dura medially and posteriorly houses the superior petrosal sinus where the tentorium intersects the temporal bone. Identify the arcuate eminence and use it to skeletonize the superior semicircular canal. Follow the geniculate ganglion to the labyrinthine portion of the facial nerve. Open the roof of the middle ear and expose the ossicles.

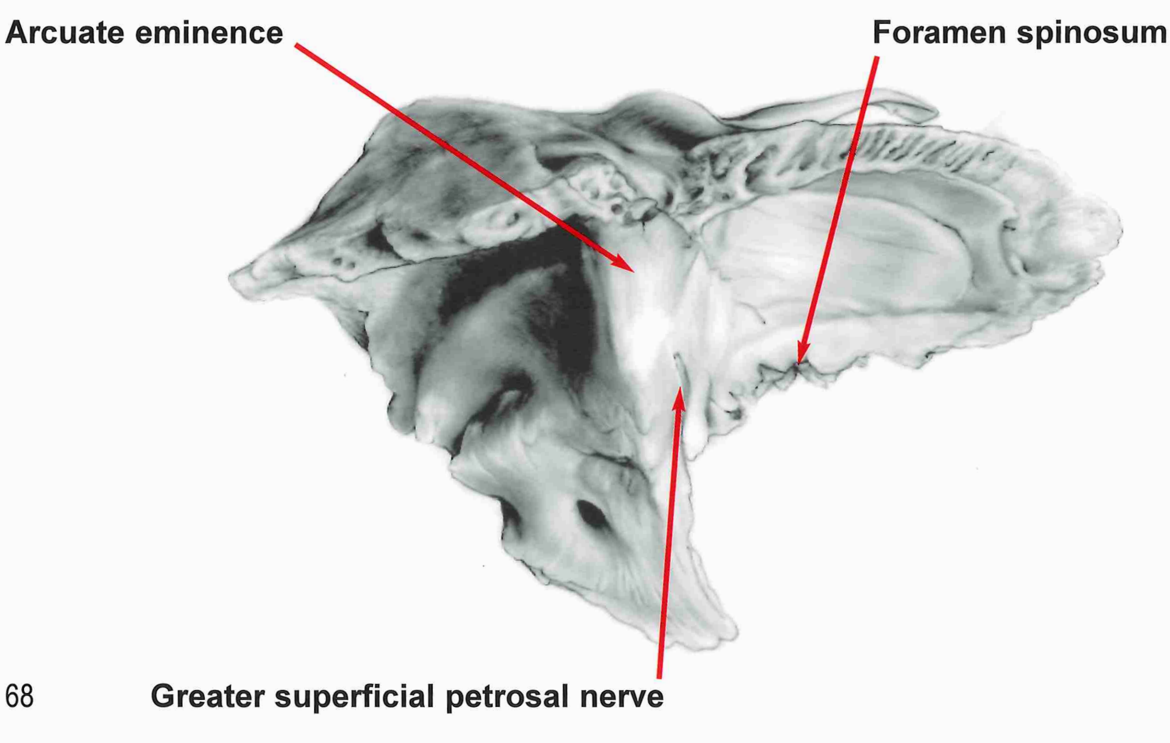

Figure 45b

Middle Fossa Approach
Step 1 (Fig. 45A, B):

Middle Fossa Topography

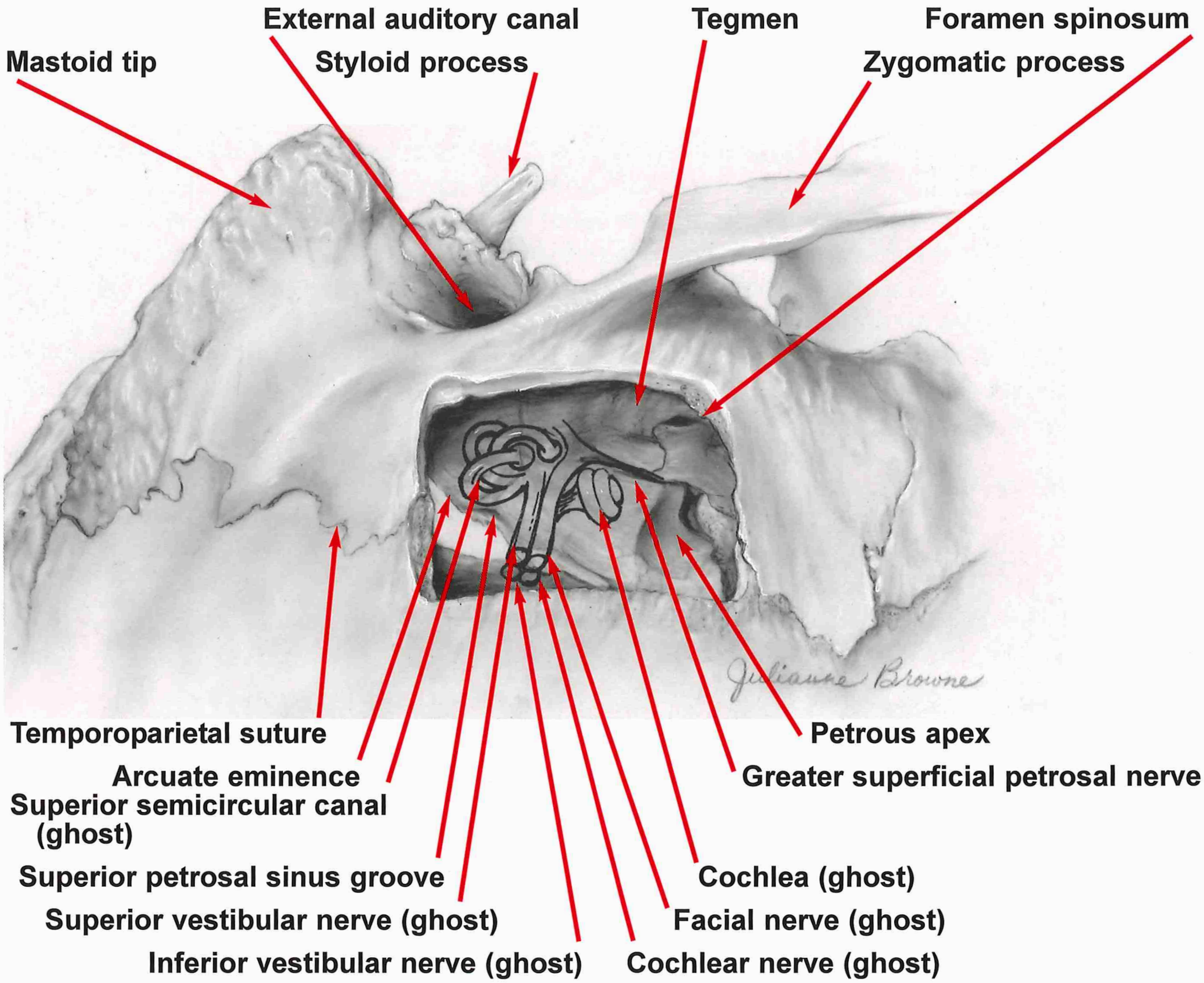

Figure 45a

Middle Fossa Approach

Step 2 (Fig. 46A, B, C):

Landmarks:

Greater superficial petrosal nerve
Geniculate ganglion
Superior semicircular canal
Epitympanum

Superficial Dissection

The first portion of the dissection involves unroofing the geniculate ganglion and tracing the facial nerve from the genu into the middle ear space. Identify the greater superficial petrosal nerve and follow it to the geniculate ganglion (Fig. 46A). The geniculate ganglion will be superficial; therefore, a minimum of bone should be removed. A diamond burr is used for this procedure with copious amounts of irrigating fluid to remove the bone dust. At the geniculate ganglion the nerve turns laterally, posteriorly, and inferiorly into the epitympanum. Although the nerve can be followed for quite a distance through this approach, the cochleariform process is the normal limit of dissection. Lateral to the facial nerve, the ossicular chain will be noted with the head of the malleus particularly prominent. Because the ampullated end of the superior canal is close to the medial portion of this dissection, one must be careful not to fenestrate the canal through the hard labyrinthine bone. The canal is usually blue-lined for definitive identification. From the geniculate ganglion, the labyrinthine portion of the nerve may be followed posteriorly, medially, and inferiorly, past the ampullated end of the superior canal as it turns deep into the anterior superior portion of the internal auditory canal (Fig. 46B). With adequate thinning of bone over the medial end of the facial nerve, one can identify the shelf of bone that separates the superior vestibular nerve as it enters the superior ampulla next to the facial nerve. This is Bill's bar (Fig. 46C).

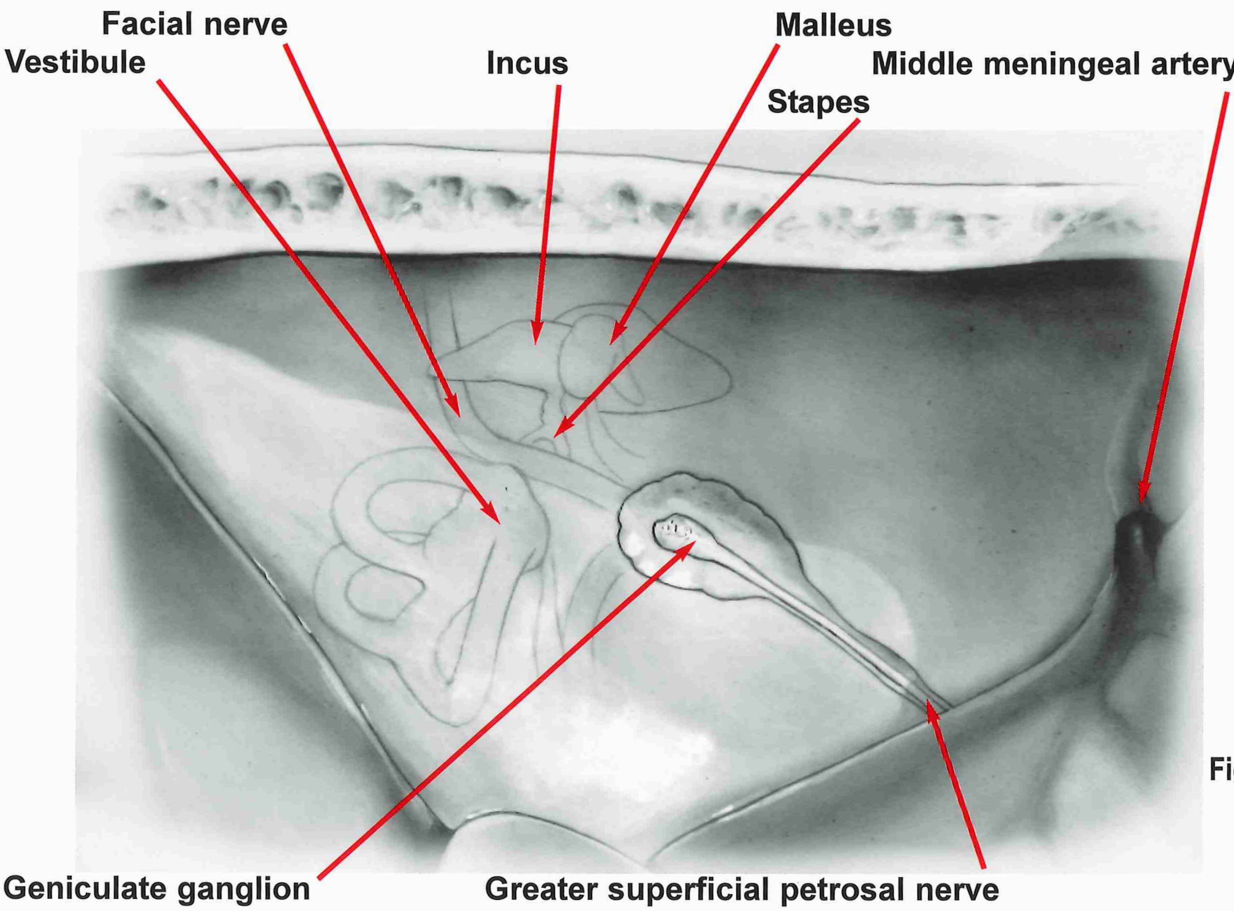

Figure 46a

Middle Fossa Approach
Step 2 (Figs. 46A, B, C)

Superficial Dissection

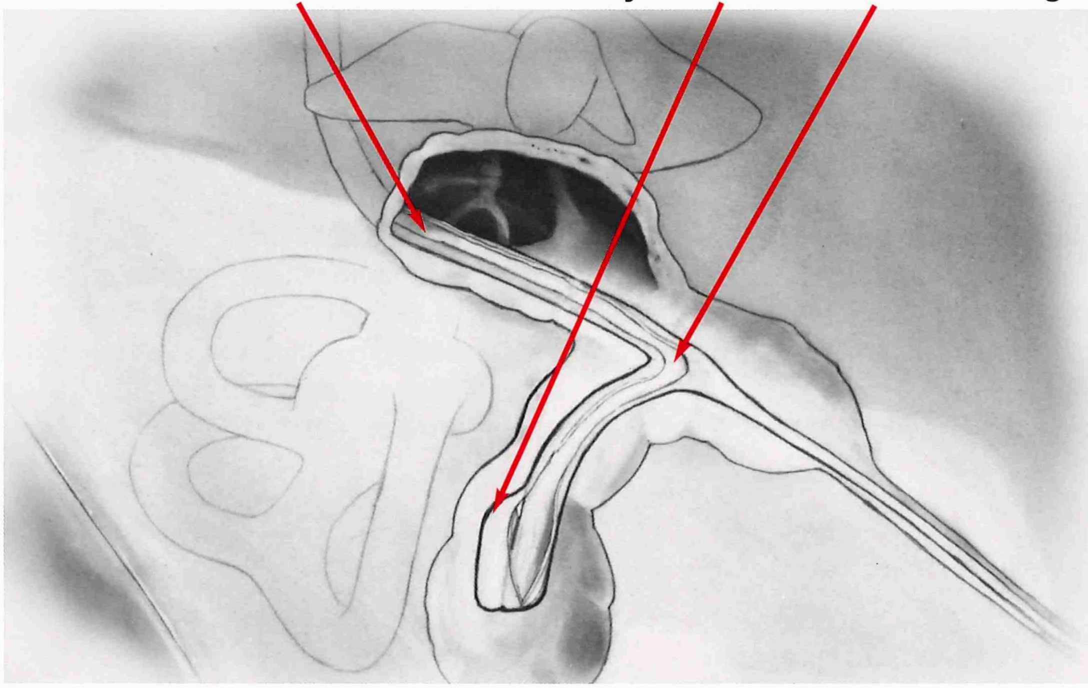

Figure 46B

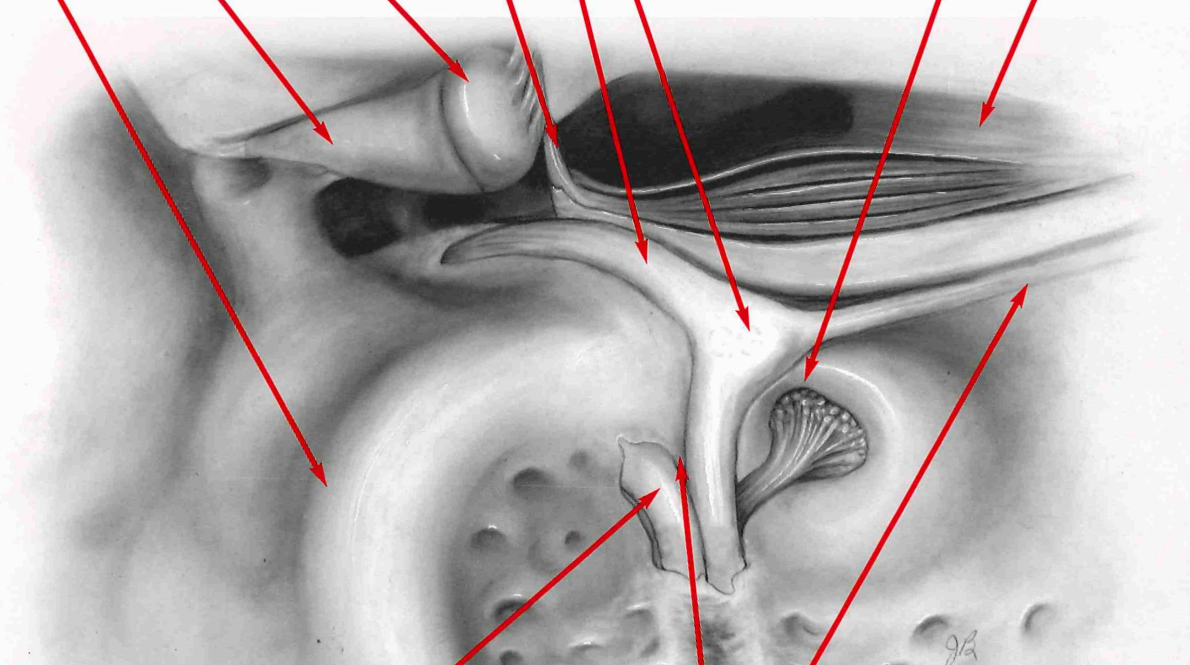

Figure 46C

Middle Fossa Approach
Step 3 (Fig. 47)

Landmarks:

- **Superior semicircular canal**
- **Bill's bar**
- **Facial nerve**
- **Cochlea**
- **Superior vestibular nerve**
- **Carotid artery**

Deep Dissection

During skeletonization of the internal auditory canal, the exposure is widened as the bone overlying the posterior fossa is removed. The cochlea lies anteriorly and laterally under the geniculate ganglion, and the superior semicircular canal is posterior to the internal auditory canal. Medial to the internal auditory canal is the petrous apex, which is filled with air cells. Anterior to these apex cells and anterior to the cochlea is the carotid artery. The middle fossa approach can be used for ligation or packing of the medial portion of the carotid artery in uncontrolled bleeding. Laterally the eustachian tube extends from the middle ear cavity forward medial to the middle meningeal artery and lateral to the carotid artery as the tube descends into the nasopharynx. Because the internal auditory canal can be widely exposed and well delineated, there is no reason to work under a bony shelf when entering the canal, and the same principle for wide exposure in the posterior approach to the canal is used here.

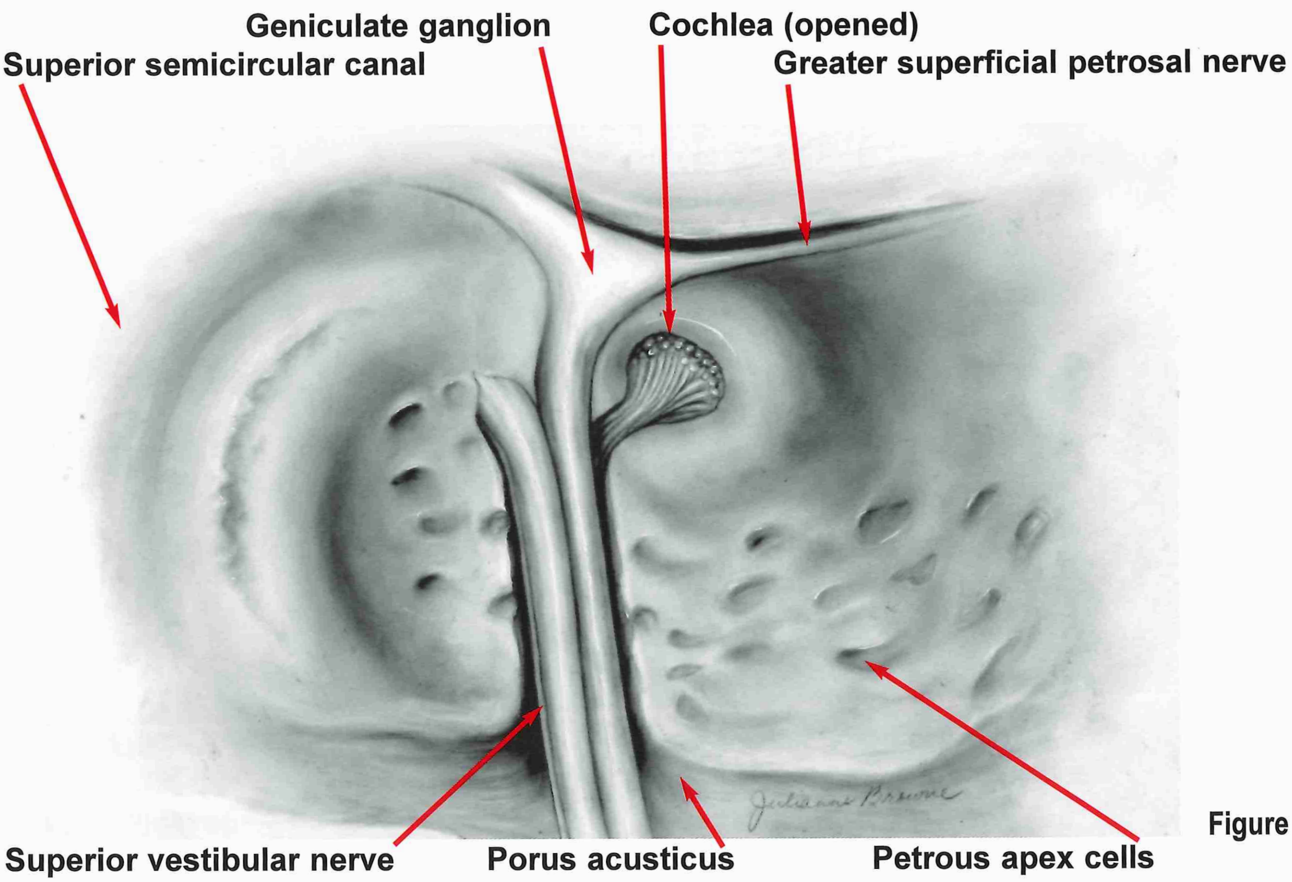

Figure 47

9

Middle Ear Dissection

Middle Ear Dissection

Step 1 (Fig. 48):

Landmarks:

Zygomatic root
Spine of Henle
Mastoid tip
Tympanic bone

Topography

Middle ear procedures can be practiced through a canal approach or a postauricular approach on the temporal bone as easily as in the patient. These techniques will familiarize the surgeon with actual operating room procedure and increase dexterity in procedures that are among the most demanding of the otologist's armamentarium. With the temporal bone in the surgical position, the surgeon operates through a speculum placed within the external auditory canal. The skin in the canal and the tympanic membrane of preserved bones tend to be like leather and do not simulate the feel of the skin of patients.

Middle Ear Dissection

Step 1 (Fig. 48):

Topography

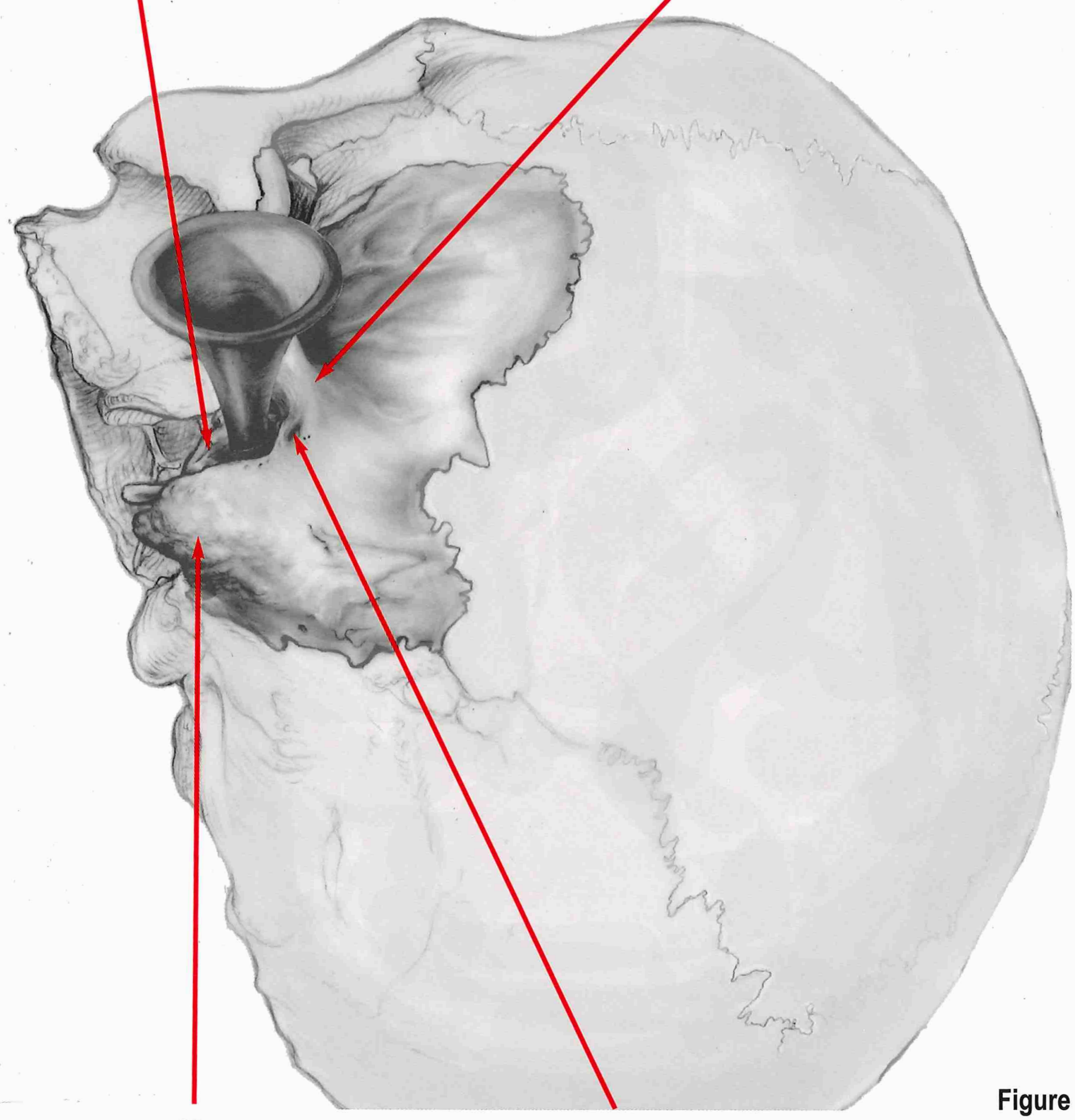

Figure 48

Middle Ear Dissection
Step 2 (Fig. 49):

Landmarks:

Bony-cartilaginous junction
Vascular strip
Tympanosquamous suture
Tympanomastoid suture
Fibrous annulus
Malleus

External Auditory Canal

An injection of the posterior canal wall skin should be attempted to define the vascular strip. The injection will expand the soft tissue between the tympanosquamous and tympanomastoid suture lines (Fig. 49). They are prime landmarks for making incisions in an overlay graft technique. Tympanomastoid and tympanosquamous suture line incisions should then be made with a #l knife. The incisions should be connected medially along the annulus with a #2 knife and laterally along the bony-cartilaginous junction with a scalpel. The sleeve of canal skin which is then removed is the same as in the standard overlay technique. It is removed with a round knife that is constantly kept against bone to avoid perforations of the very thin canal skin. The epithelial layer of the tympanic membrane is removed en bloc with the canal skin preserving the underlying fibrous layer. Then enlargement of the external auditory canal for excision of exostoses, for the lateral graft technique, or for canaloplasty can be practiced. The surgeon should also practice suctioning against the instruments, not the soft tissue, to prevent trauma to flaps and other soft tissue structures.

Middle Ear Dissection
Step 2 (Fig. 49):

External Auditory Canal

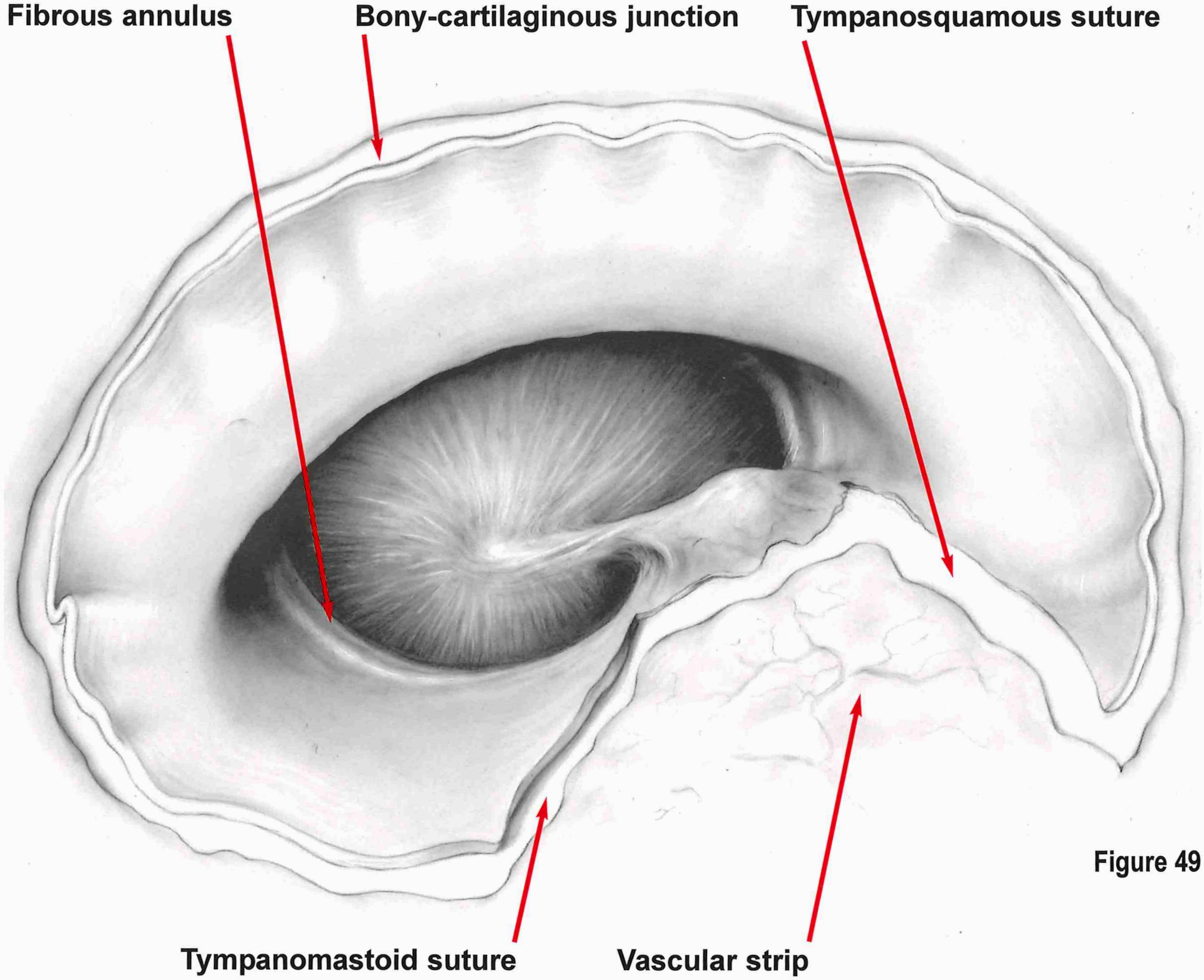

Figure 49

Middle Ear Dissection

Step 3 (Fig. 50):

Landmarks:

Annulus
Bony-cartilaginous junction
Malleus
Temporomandibular joint

Removing Anterior Canal Bulge

In the lateral graft technique, the anterior canal wall bulge overlying the glenoid fossa is reduced. Superiorly, just anterior to the tympanosquamous suture line, the excess bone is removed to achieve a smooth contour from the cartilaginous external auditory canal to the level of the annulus. This bony removal helps prevent blunting that occasionally occurs with this technique. The removal also allows one to determine how deep the temporomandibular joint actually lies without entering the joint capsule. Bone is then removed inferiorly again, to form a smooth contour from the cartilaginous external auditory canal to the level of the annulus. This eliminates any overhang that might prevent adequate identification of the sulcus inferiorly. These two areas of bone removal are then connected across the anterior canal wall bulge. Usually the chance of entering the temporomandibular joint is minimal since the depth of the joint has been established. Ultimately, enough bone should be removed so that in a transcanal view through the microscope, the entire annulus can be observed. There should be no need to readjust the microscope to see the anterior sulcus and the posterior annular area.

Middle Ear Dissection
Step 3 (Fig. 50):

Removing Anterior Canal Bulge

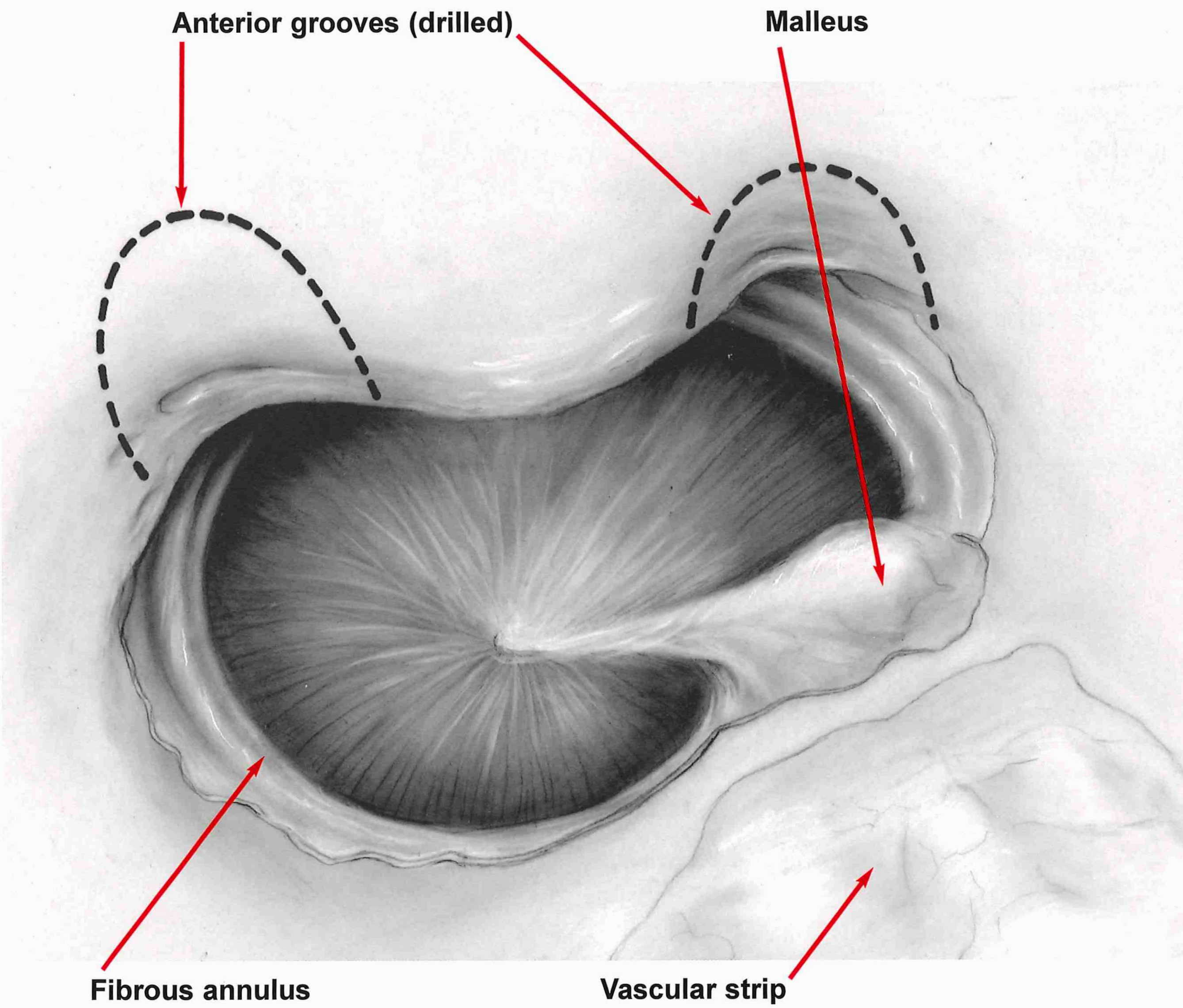

Figure 50

Middle Ear Dissection

Step 3 (Figs. 51, 52):

Landmarks:

Malleus
Incus
Chorda tympani
Jacobson's nerve
Round window
Oval window

Middle Ear Dissection

After the anterior canal wall bone is reduced, the annulus may be elevated in a standard tympanoplasty approach. The tympanic membrane is then folded forward to expose and identify the middle ear structures. During palpation of the malleus, movement of the stapes footplate along with the ossicular chain should be seen and, if fluid remains in the inner ear, a round window reflex can be obtained. Observe the topography of the promontory and note that Jacobson's nerve usually crosses the promontory in a bony groove or canal. Several branches of the tympanic plexus, which includes this nerve, can be seen. The scutum should be curretted for exposure. One can now incise the incudostapedial joint, cut the stapedial tendon, and attempt to fracture the superstructure of the stapes onto the promontory. In a cadaver bone, these steps will normally result in complete removal of the stapedial footplate with its superstructure (stapedectomy). One may then practice placing various prostheses upon the incus as in standard stapedectomy. This tympanotomy approach is also used for insertion of an incus replacement prosthesis around the malleus in cases in which the incus is missing following a previous stapedectomy.

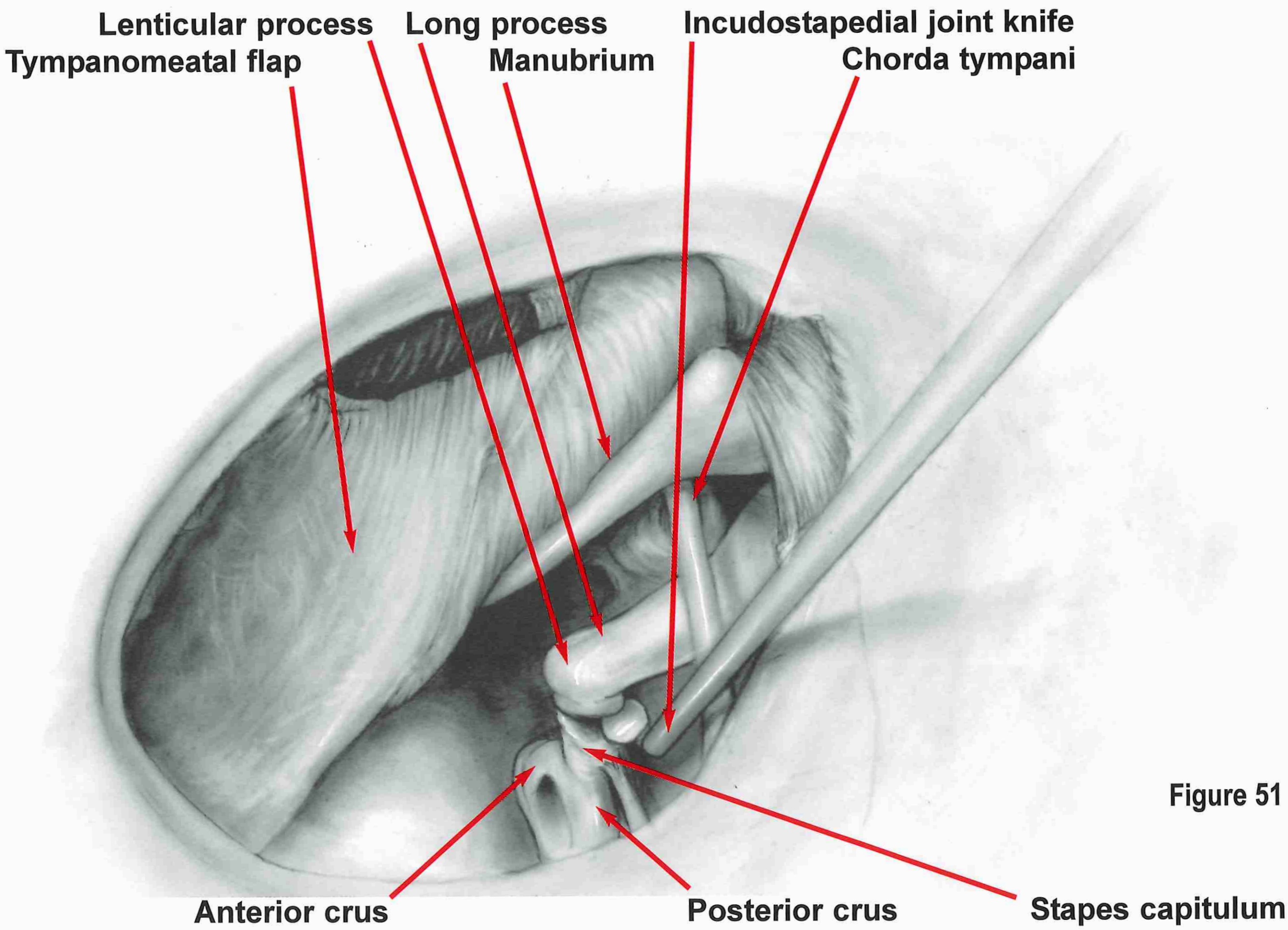

Figure 51

Middle Ear Dissection

Step 4 (Fig. 51, 52):

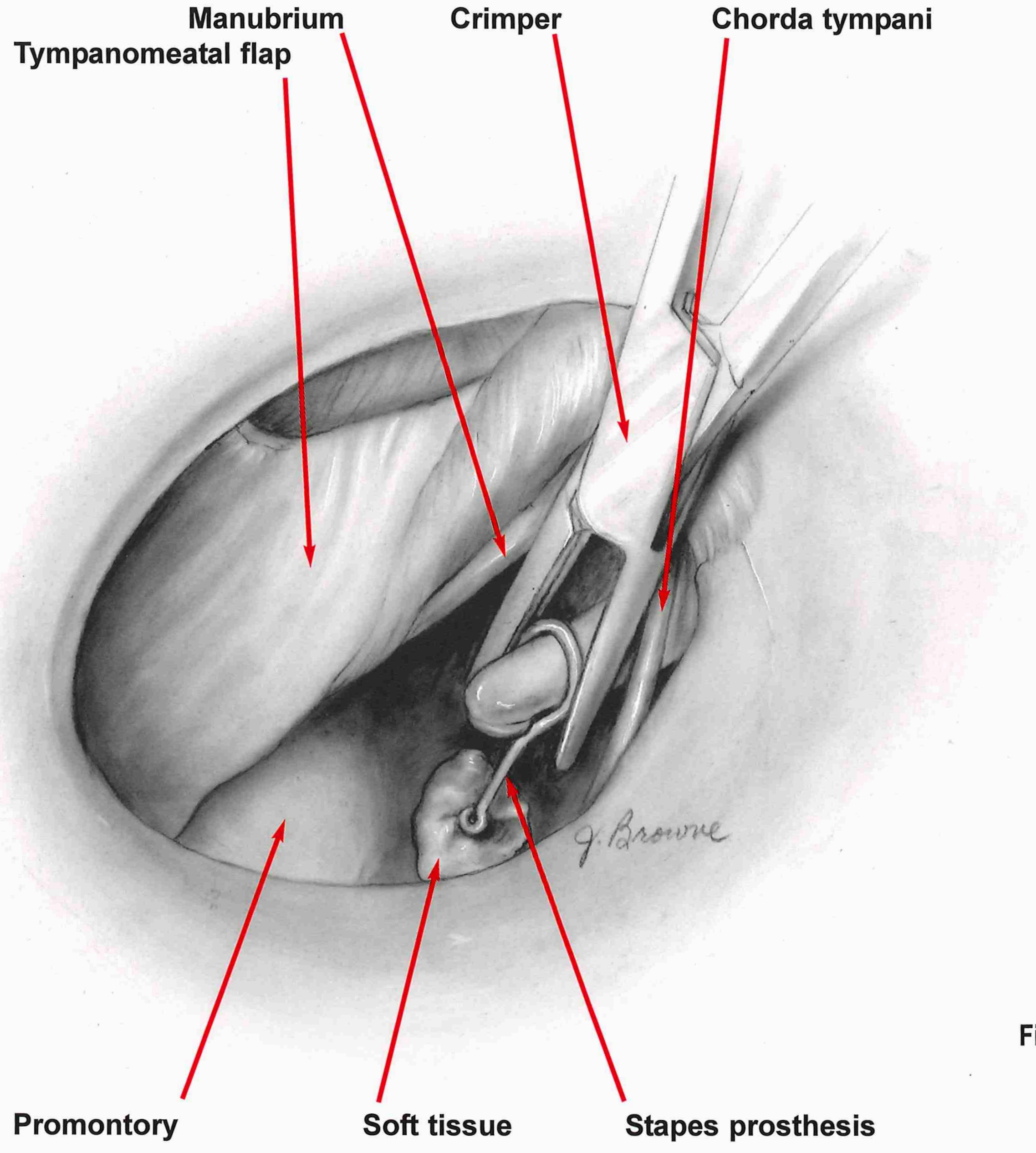

Figure 52

Middle Ear Dissection

Step 5 (Figs. 53, 54, 55):

Landmarks:

Malleus neck
Incus
Incudomalleolar joint
Chorda Tympani

Middle Ear Dissection

The incus is removed by insertion of a three-millimeter hook in the incudomalleolar joint and rotation of the hook so that the ossicle is brought out through the ear canal. A myringoplasty knife is used to incise the mucosa and fibrous attachments to the malleus from the underside. A tunnel is made under the mucoperichondrium of the malleus handle so that the incus replacement prosthesis (IRP) hook can be placed over the malleus without perforation of the tympanic membrane. The loop end of the IRP is then rotated into the oval window. With use of smooth alligator forceps to stabilize the wire, a hook is used to pull the wire into a crimped position around the malleus. The elimination of the tympanic membrane from the malleus handle is used in small congenital anterior cholesteoma, small glomus tympanicum and in transcanal labyrinthectomy.

The stapes is removed and the round and oval windows are connected. A three-millimeter hook is inserted into the vestibule to remove the ampullae of the semicircular canals and the two maculae.

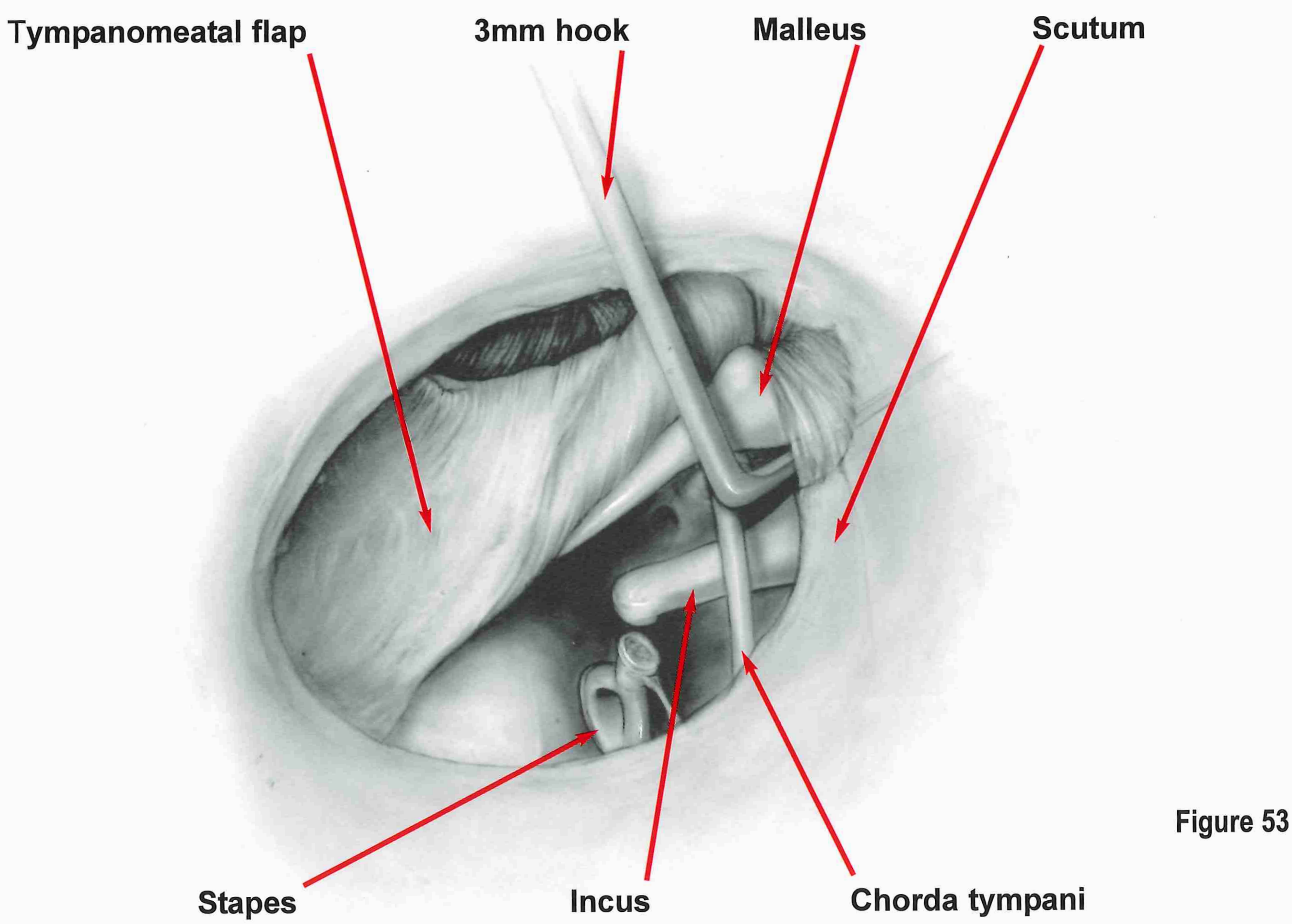

Figure 53

Middle Ear Dissection
Step 5 (Figs. 53, 54, 55):

Middle Ear Dissection

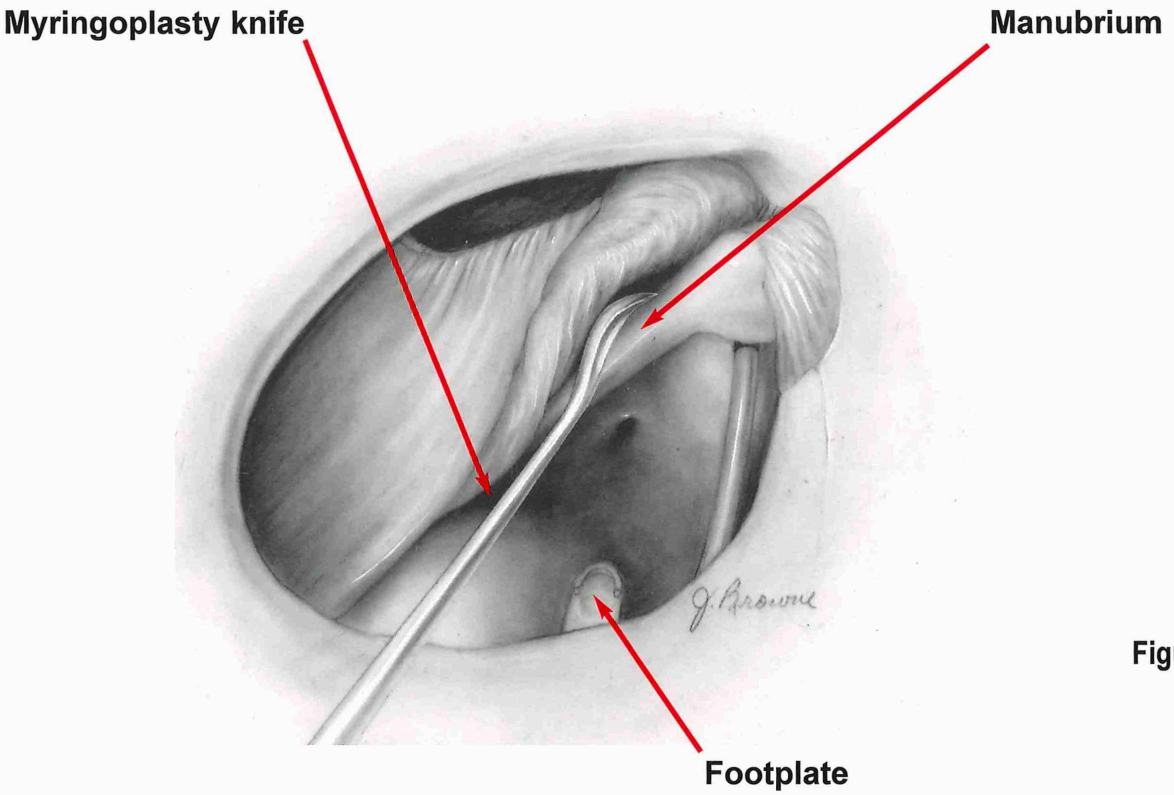

Figure 54

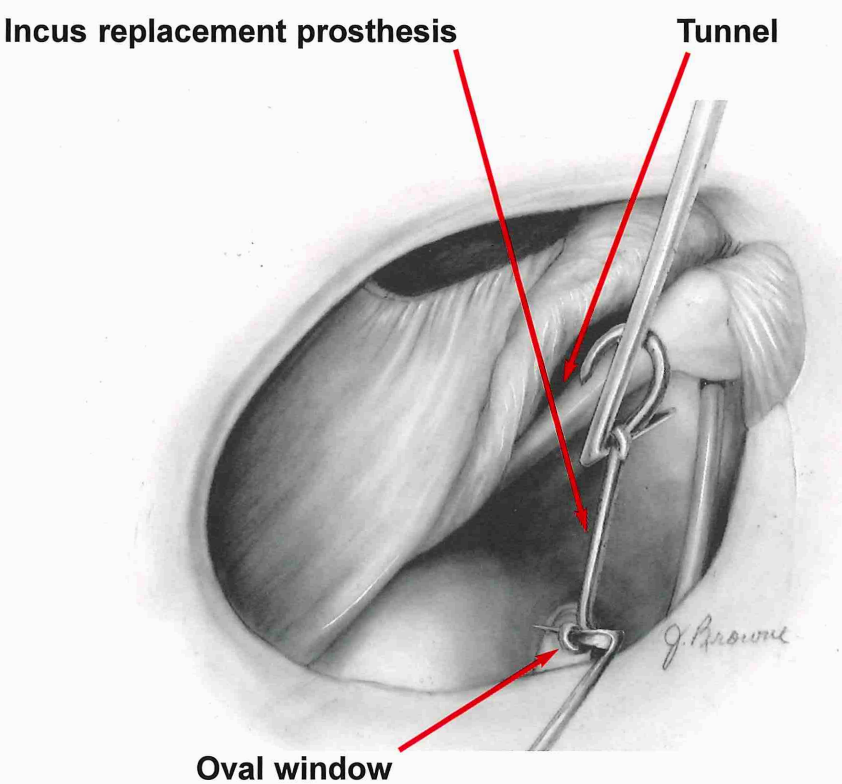

Figure 55

Notes:

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Wall Down Techniques

Wall Down Techniques

Step 1 (Figs. 56, 57):

Landmarks:

Posterior canal wall
Horizontal semicircular canal
Sigmoid sinus
Incus
Tegmen

Topography

We begin the canal wall down (open cavity) procedures in the same manner as the intact canal wall operations. The essential difference between the two procedures is removal of the posterior and superior bony canal wall. Thus, you may use a bone with a completed intact canal wall for this dissection.

The problems with open cavity mastoidectomy are: (1) incomplete removal of the posterior canal wall (high faced ridge), (2) inadequate meatoplasty, (3) an incomplete removal of the mastoid air cells (mastoid tip, sinodural angle and lateral wall of the attic) and, (4) absent tympanic graft. An incompletely removed buttress or a poorly lowered facial ridge frequently leads to cicatrix formation, which further reduces cavity access. Incomplete cleaning of the cavity is the usual consequence, continuous otorrhea, and possible cholesteatoma formation.

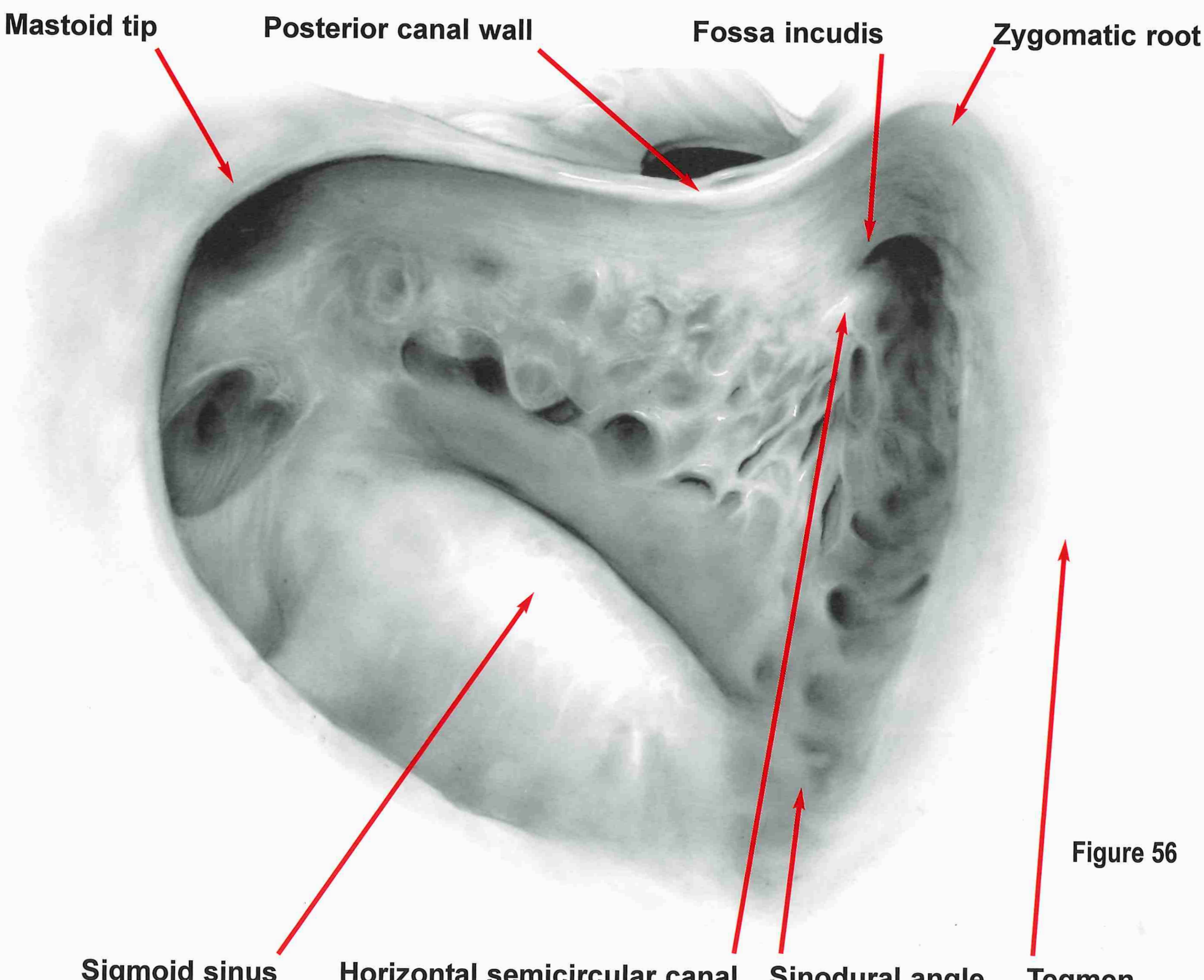

Figure 56

Wall Down Techniques
Step 1 (Figs. 56, 57):

Topography

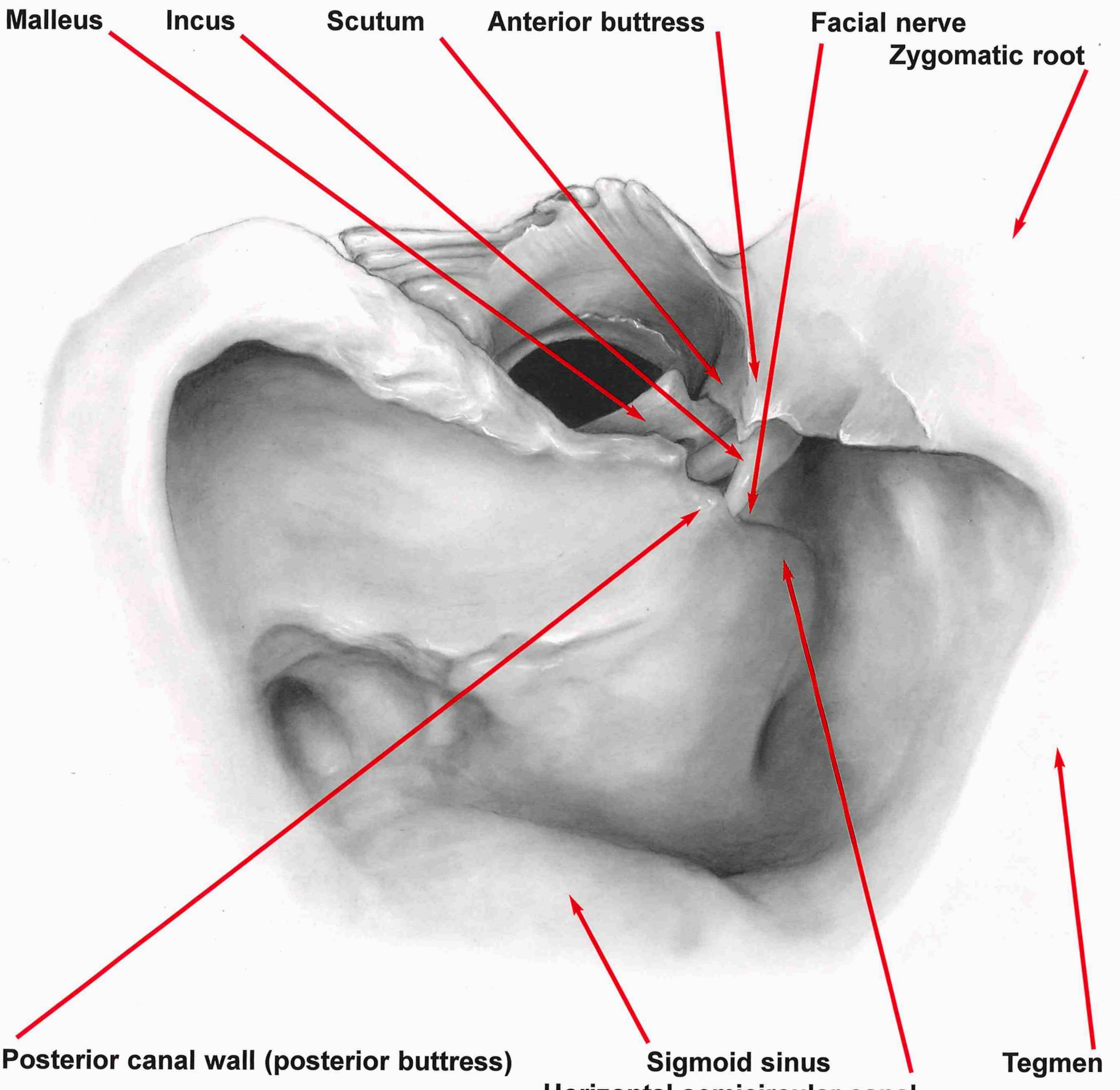

Figure 57

Wall Down Techniques

Step 2 (Figs. 58, 59, 60):

Landmarks:

Posterior canal wall
Incus
Facial nerve
Horizontal semicircular canal
Buttresses
(anterior and posterior)

Removing the Posterior Canal Wall

Proceed through a standard posterior approach to identify a thinned posterior bony canal wall, the skeletonized sigmoid sinus posteriorly, a thinned middle fossa dural plate, and the horizontal (lateral) semicircular canal. The fossa incudis and horizontal semicircular canal are used to begin dissection of the facial recess. The floor of the recess, which is the lateral wall of the fallopian canal at the mastoid genu, will be the most medial part of the dissection.

The anterior buttress is that bone where the posterior bony canal wall meets the temporal mandibular joint. Remove it totally to achieve a smooth continuum between the middle fossa tegmen and the anterior inferior wall of the external canal. The posterior buttress is where the posterior canal wall meets the floor of the external auditory canal lateral to the facial nerve. This area is especially prone to cicatricial blunting and, if not opened well, will result in a deep "blind" pocket at the mastoid tip. The best way to eliminate the area of the posterior buttress is to lower the facial ridge by skeletonizing the facial nerve. Then the floor of the external auditory canal slopes off into the mastoid tip.

All bone lateral to the facial nerve between the tegmen and the floor of the external auditory canal is removed to eliminate the posterior bony canal wall. The remainder of the mastoid bowl should be well saucerized, which in actual surgery allows soft tissue to better obliterate and shrink the remaining open cavity.

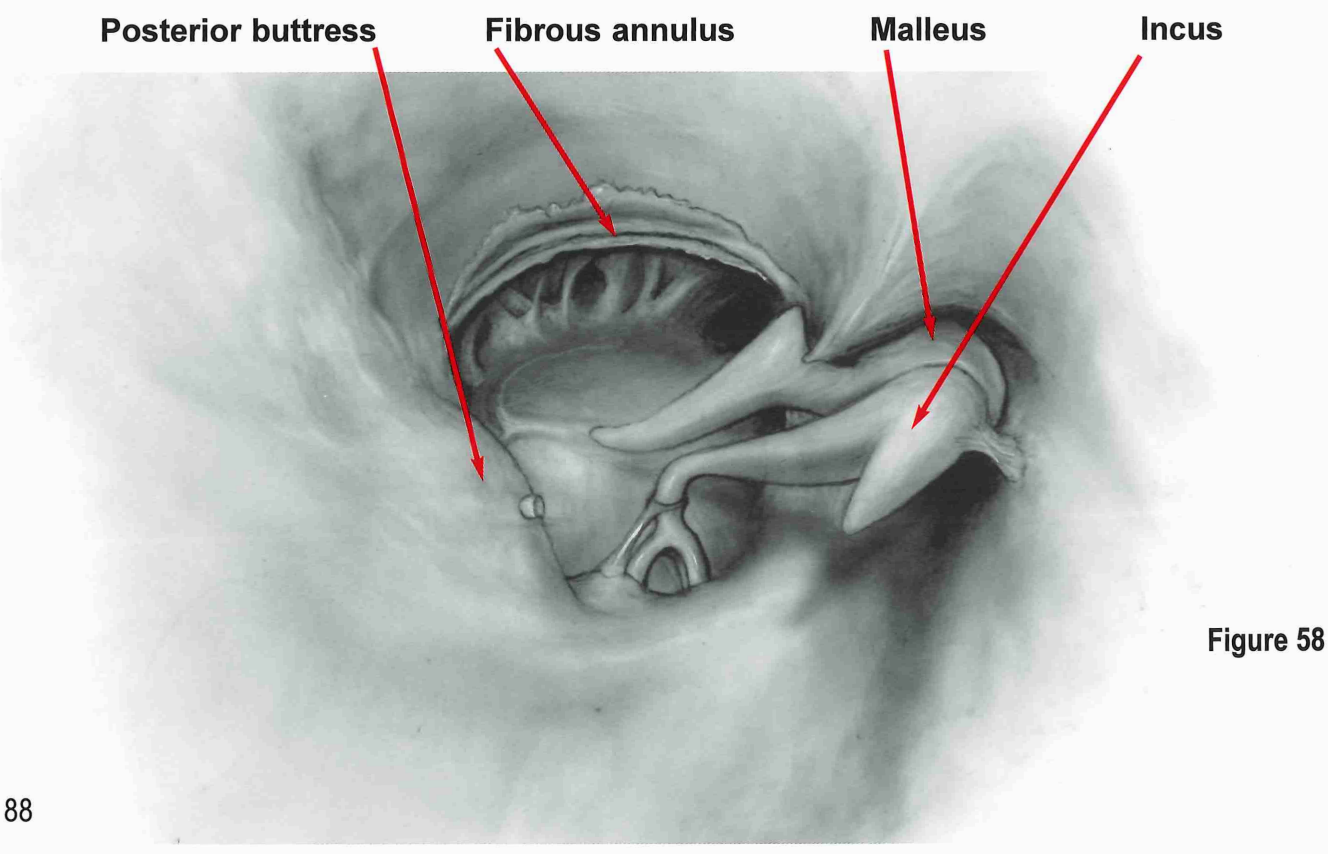

Figure 58

Wall Down Techniques
Step 2 (Figs. 58, 59, 60):

Removing the Posterior Canal Wall

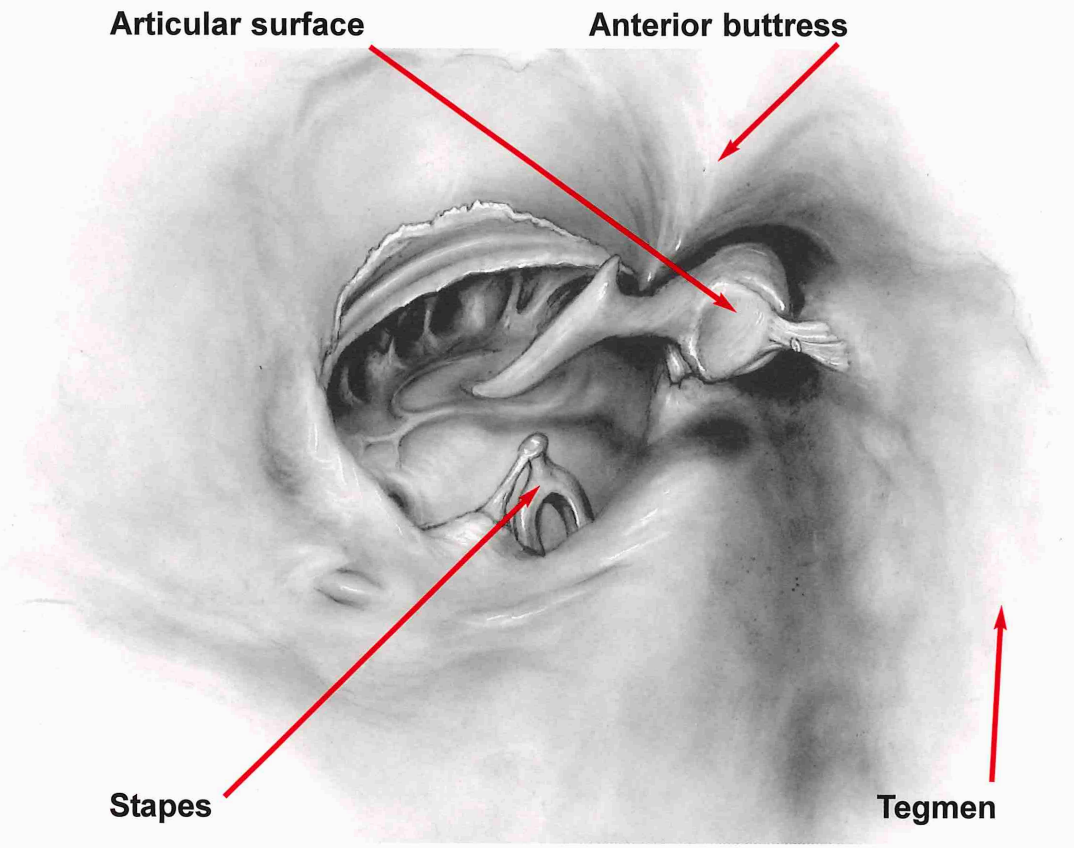

Figure 59

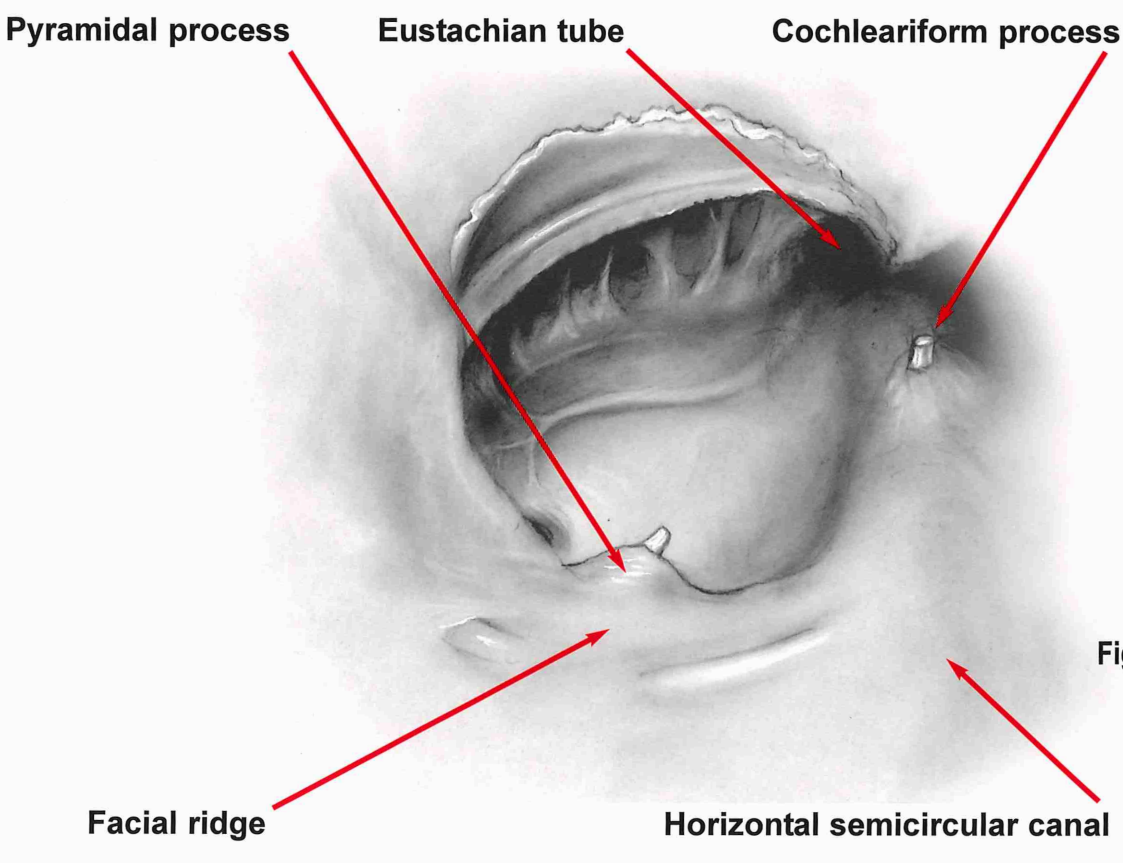

Figure 60

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