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Review Article

Temporal bone dissection for display

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Abstract
Increasing concern with medicolegal issues has heightened the need for surgical simulation in training. Familiarity with the surgical anatomy of the temporal bone is essential for effective and safe otological surgery. Refinement of surgical technique and intimate knowledge of temporal bone anatomy can be gained by accurate dissection. The products of such endeavours are both illustrative and instructive. The issues, methods and techniques necessary for display of anatomical dissections are discussed.

Key words: Temporal bone

Introduction

Temporal bone dissection is an invaluable exercise for the trainee otologist as an intimate knowledge of temporal bone anatomy is essential for safe otological surgery. The profusion of temporal bone courses testifies to this principle. There are few other areas where the penalty for lack of anatomical knowledge is so high.

An appreciation of the three-dimensional relationships within the temporal bone can be most rapidly gained by cross-sectional studies which correlate well with radiological imaging. The temporal bone can be readily sectioned after decalcification or the microslicing technique can be used without specific preparation (Michaels *et al.*, 1983).

It is only by frequent and repeated temporal bone practice that the necessary surgical skills can be acquired, based on a thorough knowledge of temporal bone anatomy and its variants. Most units now have dissection facilities and it is almost unthinkable that mastoid surgery should ever be performed without preliminary temporal bone practice. Temporal bones are a valuable resource, as they are often hard to acquire. Fortunately, a single temporal bone can be used to practice most of the surgical techniques and suitable guides are available (Bojrab and Wiet, 1990; Goycoolea, 1991). The results of such practice can be retained to provide a useful record and reference for the otologist. All attempts to raise the standards of tympano-mastoid surgery are to be applauded and in this respect a dissection competition was conceived and started by Bill Gibson in 1982. Since then, interest in this discipline has flourished. There are clear benefits from such work for the individual, not only a better understanding of temporal bone anatomy but also a permanent three-dimensional model to refer to when planning more complex procedures. Interestingly, there is little written on the techniques and methods of this subject. While the dissection and preparation of soft tissue anatomical specimens are well covered in the literature, the requirements for temporal bone preparation are less well known.

Acquisition of temporal bones

The use of postmortem material is governed by statutory instruments, namely the Anatomy Act (1984) and the Anatomy Regulations (1988) which replaced the Human Tissues Act (1961). Any cadaveric material used for surgical simulation must be under the direction of a licensed teacher of anatomy.

The postmortem acquisition of temporal bones is not an easy task. A balance must be struck between delivering the entire temporal bone intact and the need to maintain the integrity of the skull base to allow appropriate reconstruction and preserve the cadaveric appearance. Once harvested, bones are commonly placed in formaldehyde or high concentrations of alcohol. While these agents preserve the tissues they also leach out some of the natural colour of the bone. This disadvantage becomes important when attempting a dissection to maintain the osseous labyrinth or facial nerve canal intact, because the subtle colour changes between the layers about the labyrinth are the only guide to the underlying structure. If however the tissue is frozen, the fresh frozen bone is easily preserved and thawed for use, normal consistency of the soft tissues and much of the colour and contrast of the living bone is maintained. It must be remembered that care in handling of any fresh postmortem material should be taken, to avoid the risk of viral infection particularly hepatitis.

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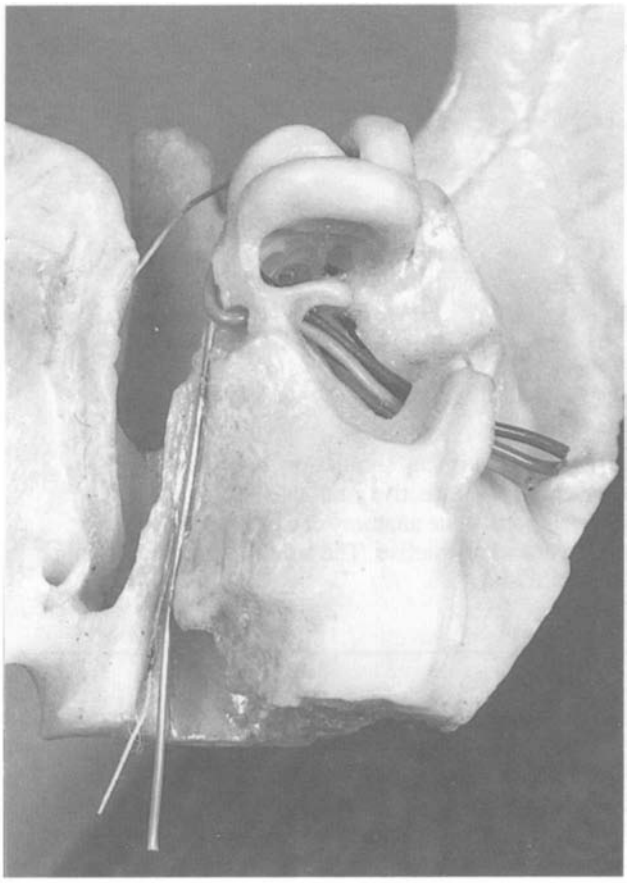

FIG. 1
Nervous pathways through the temporal bone. Internal auditory canal opened.

Dissection techniques

There are only a limited number of suitable dissections that can be employed individually or in combination. These may have either a surgical or anatomical orientation according to the emphasis chosen for certain structures together with the variation between bones. The principles of accurate dissection are exactly those of good surgery. Operations in less than ideal circumstances are seldom satisfactory and it is just as important to ensure everything is optimal before starting a dissection. Basic equipment demands a secure mounting for the bone in a desired position, a comfortable chair of adjustable height, appropriate instruments including a well-balanced drill with sharp burrs, a good microscope and adjustable suction irrigation. It is particularly important to achieve a comfortable position with good support for the hands before starting.

The enemies of a good result are impatience and fatigue which often go hand-in-hand. Clearly there is no serious penalty for error in the bone, unlike the patient, but the consequences besides a dust aggregate may include anger, frustration and a great deal of wasted time. Many short sessions are needed to achieve a good dissection with accurate detail. these may easily total more than 50 hours for each bone for presentation purposes.

Clearly there are close parallels between surgical procedures and anatomical dissections. However we are able to choose the nature of dissection for a given bone or find a suitable specimen for a specific purpose. Just as a sculptor would choose the best available stone for a given work, the careful choice of a temporal bone is equally important for a good result. Otherwise the old aphorism that 'you cannot make a silk purse from a sow's ear' can become painfully true after much hard work.

The choice of dissection includes the surgical approaches either by transcanal or transmastoid routes that are naturally familiar to the otologist. Within a mastoid cavity it may be chosen to outline the lateral sinus in which case a prominent sinus in a large bone with a high jugular bulb will help give definition to the great vessels in a dissection. The lateral sinus tends to be more prominent on the right side and it helps to choose a right-sided bone to emphasize this feature. The best results for most lateral exposures are achieved with a poorly pneumatized bone as it is easier to maintain the integrity of the middle fossa plate, although compact bone is harder to dissect. A well-pneumatized bone is more suited to a dissection involving the superior surface of the temporal bone because the tegmen is frequently dehiscent and this provides a guide to the mastoid tract. The distinction between well and poorly-pneumatized bones can easily be made by careful inspection of the tegmen tympani.

Middle fossa approaches are best performed with the bone positioned in an anatomical rather than a surgical position. The internal auditory canal can be skeletonized or opened according to preference (Figures 1 and 2). This structure is best outlined with a straight probe placed into the canal to aid the dissection which is best started medially, progressing laterally. The difficulty is at the lateral end of the internal auditory canal where the facial canal is only just deep to the middle fossa plate especially when the geniculate ganglion is dehiscent.

Anatomical approaches are by their nature more varied.

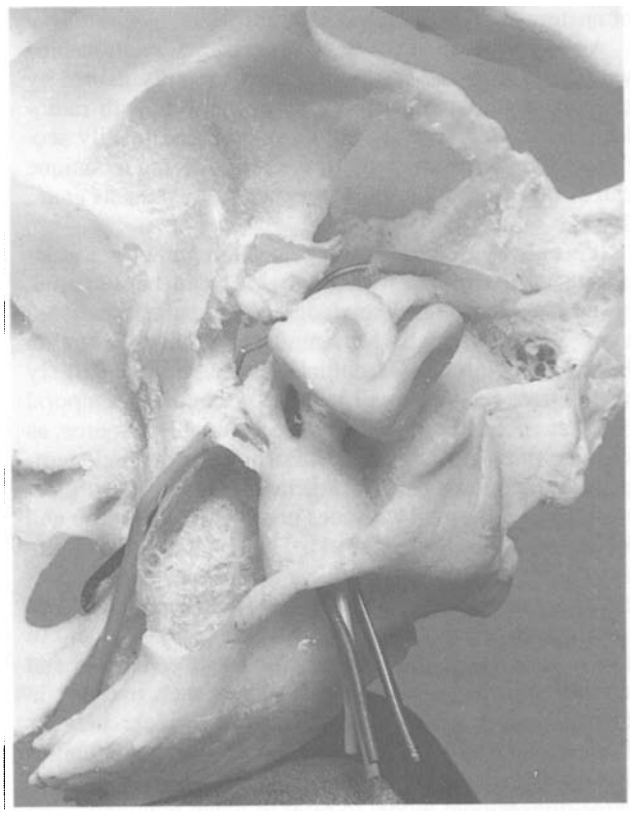

FIG. 2
Nervous pathways through the temporal bone. Internal auditory canal intact.

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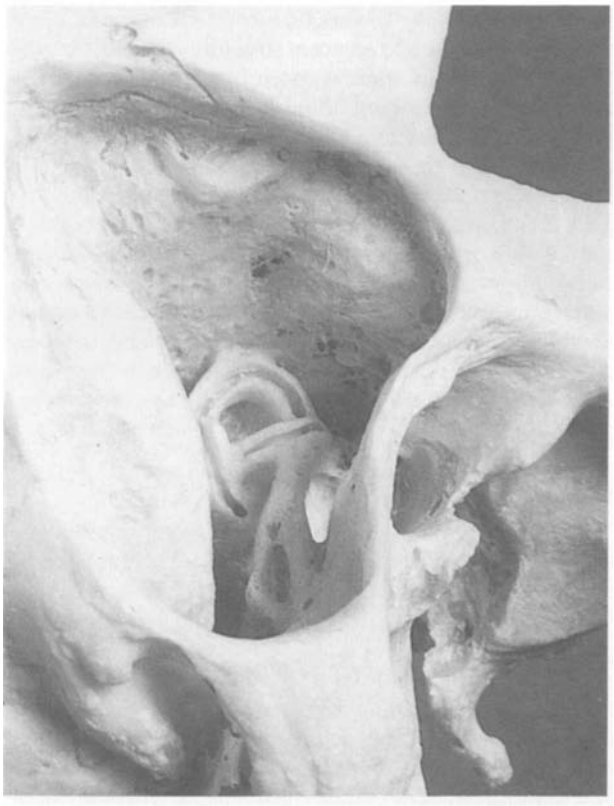

FIG. 3
Transmastoid dissection of right semicircular canals showing bifid facial nerve.

If the temporal bone is considered as a truncated pyramid then a dissection to display the enclosed structures can be made from any of it's six surfaces. The orientation of the labyrinth means that adequate exposure of the labyrinth and middle ear structures can only be achieved from the lateral, superior or inferior surfaces.

The labyrinth itself is a complicated shape with subtle variations in position and shape between bones. A dissection to display the osseous labyrinth intact is extremely difficult. Injection of methylene blue dye into the osseous labyrinth via the round window and the openings of the superior and inferior vestibular nerve canals, should produce a recognizable colour change in the labyrinth within the otic capsule. This artificial colouring will reduce the chance of the inopportune opening of the labyrinth and simplify the dissection as the otic capsule is progressively thinned with a small diamond burr. The dye can be easily bleached out later. Alternatively, the labyrinth can be generally defined and the semicircular canals opened along their axes (Figure 3). The remaining labyrinth and the canal walls can be readily thinned to a uniform thickness. The overall result is visually pleasing and technically much easier. It must be emphasized that any dissection about the labyrinth must be undertaken with a sharp diamond burr applied with the lightest sweeping movement possible. The use of poor equipment or undue pressure will inevitably fragment the bone as it nears wafer thickness.

Among the numerous nerves traversing the temporal bone, the facial nerve is arguably the most important. Like the labyrinth the facial nerve canal can be maintained intact or opened on an exposed surface and evenly thinned throughout its length for display purpose. Once the fallopian canal is opened the demonstration of the facial nerve branches becomes easier, although the branch to the stapedius can be a problem. This nerve can be identified through an extended posterior tympanotomy but becomes hard to represent once the stapedius muscle is withdrawn. The chorda tympani has two bony channels to be displayed,one anterior and the more familiar posterior spur of the facial nerve canal. The singular nerve, the intralabyrinthine branches of the vestibular nerves and the branches of the tympanic plexus all have osseous canals for part of their length but these are all difficult to display because of their size. Other canals worthy of display include those of the tympanic branch of the glossopharyngeal nerve and the lesser superficial petrosal nerve. It is therefore not surprising that the hardest dissection to accomplish is probably the display of the nervous pathways within the temporal bone.

Soft tissue structures

The retention of certain structures is difficult without producing a dog-eared appearance. The specific parts to retain are most commonly the tympanic membrane and ossicular ligaments. The dura, the saccus endolymphaticus and vessel walls may also be required. It is wise to complete all the bone work first and denude the bone of all redundant soft tissue. The structures to be retained should be defined with the aid of sharp dissection under magnification to avoid any unwanted strands. Once this is complete then these attached structures should be fixed by immersion of the whole bone in alcohol solutions of increasing strength starting at 50 per cent alcohol and finally immersing in 100 per cent alcohol for at least one and preferably two weeks. The immediate consequence of premature fixation in pure alcohol is tissue shrinkage. Failure to achieve adequate fixation will allow continued decomposition.

Bone preparation

Once the dissection is complete, the bone should be stripped of all extraneous soft tissue by sharp dissection. If there is no requirement to retain any soft tissue structures, then the bone can be boiled for two hours in water, cooled and any residue scraped off. The clean bone with or without soft tissue attachments should then be leached of fat by submersion in chloroform for four to six hours. This should be performed in a fume cupboard as the vapour is flammable. After fat dissolution, the bone is washed thoroughly in running water for at least six hours. Bleaching can be achieved with potassium hydroxide but hydrogen peroxide is better. Stronger solutions will bleach bone more rapidly but overtreatment risks weakening the bone. It is preferable to use a five to ten per cent solution of ten volume hydrogen peroxide with frequent inspection of the immersed bone. This will allow a careful bleaching of the bone with retention of the preferred structures. This stage is critical because if the bone is overtreated it will whiten, become brittle and later crumble. Once the final state has been reached the bone must be carefully washed in running water to remove any residual chemical. The bone can then be left to air-dry awaiting final touches. It is important when using any recommended preparatory technique to use a stripped bone for trial purpose first. A cautionary

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tale exists of one temporal bone prize entrant who was provided with ' the solution' in which to leave his dissected specimen only to return the following day to find a sediment deposit at the bottom of the jar.

Once the preparation is complete, final smoothing of the bone can be effected. Attention to the edges should be paid and it is a matter for personal preference whether these are square cut, bevelled or rounded. If the natural suture lines are available about the entire temporal bone the most aesthetic appearance is then achieved. The finish of the bone itself can be left to display the natural markings or smoothed to achieve a more surreal appearance using a buffing cloth. Sandpapers rarely leave a satisfactory surface even using a very high grade paper such as 1200 grade.

In a complicated dissection it is a rare accomplishment to avoid errors. These may be minor and the dissection modified to accommodate them as if they were intended, such as inadvertent entry into the facial nerve canal which can then be opened along its length. Alternatively there are times when a glaring defect is obvious; the choice being to start again or to repair the damage. The options of defect repair depend on size. A small hole of 2 mm or less can be repaired with a paste of bone dust and glue. A segment of bone prepared in the same way as the specimen can be used to provide bone dust of the same colour. When mixed with colourless glue, the paste is colour-matched against the site of the defect and applied to render the repair slightly proud. Once set, the mixture can be reduced with a diamond burr to a flush finish. A large hole can be repaired with the same technique or in combination with a bone chip.

Alternatively a good colour match can be gained with a coloured dental cement. The colour match that can be achieved with either method is remarkable. It is important to leave the bone in the repaired state without varnish because the uptake of varnish by bone and the repair site may be very different and expose the 'invisible repair' with startling clarity.

Dissection inserts

A technique that has all the honesty of a magician's card trick may produce visually striking results. The prime example involves the labyrinth. A dissection may be chosen to display certain features such as the relationship of the labyrinth to adjacent structures or to display the route to the petrous apex. A carefully chosen bone can be dissected to retain all important structures with the exception of the osseous labyrinth. A second bone (from the same side) can then be dissected to harvest a carefully shaped labyrinth which in turn can be placed in the first bone. In this way an accurate almost unbelievable contrast can be shown between the labyrinth, intact facial nerve canal and internal carotid canal (Figure 4). Similar transplants can be used including ossicles, nerve canals or part or all the osseous meatuses. However, disguising the joins is challenging in the extreme. At first glance the results of these techniques appear quite impossible by conventional dissection.

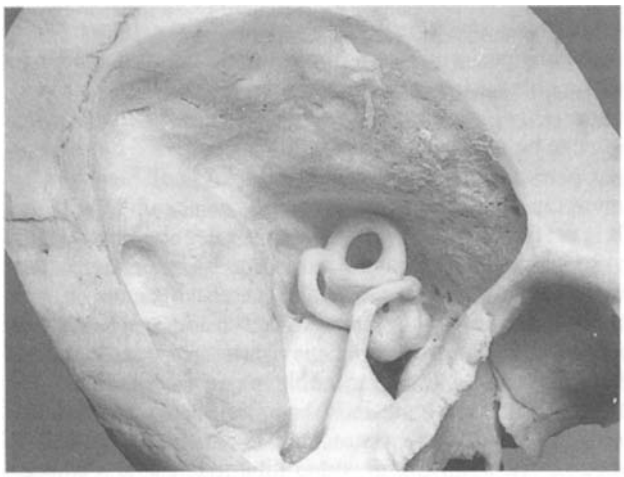

FIG. 4
Lateral dissection to show osseous labyrinth and facial nerve.

Hinges

While hinge sections may display features to advantage, a dissection incorporating a hinge section must be carefully considered from the outset. The risk is that bone will be lost in the construction of the section because of the thickness of the saw blade and this will produce some incongruity. The use of hinges themselves will ruin some anatomical detail. The most frequently used section through the temporal bone passes through the line of the middle ear cleft, lateral to the facial nerve. At the posterior end traditional small brass hinges may be inserted. Alternatively, the use of brass wire inserted through the plates of the bone at equivalent heights will, as interlocking loops, allow a hinge movement with the opportunity of adjustment to ensure accurate apposition and stability of the two sections. The hinged part can then be secured by a hook to a loop on the fixed part to show the bone in its normal position. Personal experience would suggest that the use of hinge sections requires extreme skill or the whole looks unappealing.

Demonstration of features

Where a nerve canal can be exposed and opened it is best demonstrated by the insertion of a strand of wool, thread, suture material, wire or moulded clay. The smaller pathways need a contrast colour such as black or yellow. It may be possible to bend a bristle into the correct position, otherwise the pathways that have grooved the bone can be represented by gently painting their outline onto the bone with the aid of magnification.

Wires are useful for nerve representation, as they are readily available in a variety of calibres and colours. The easiest available alternatives in this respect are telephone and hearing aid wires; somewhat thicker but suitable for the facial nerve is trimmer wire for lawnmowers. Braided wire can be laid into the canal and strands directed in the line of the relevant branches.

Paint is useful to provide colour and demonstrate nerve or vessel pathways or parts of the vestibule. Unfortunately, bone is extremely porous and only enamel paints can be used without diffusion through the adjacent bone. It is wise to use an artist's brush reduced to three or four bristles to place the enamel accurately with the aid of the microscope. If the enamel is inappropriately placed then it can be removed with a triangular knife or completely dissolved with the use of chloroform and subsequent intensive rinsing.

FIG. 5
Right temporal bone on a wooden cone.

Most dissections appear best using the osseous structures themselves. Colour and interest can be added with the use of paint either applied to the chosen element itself or to modelling clay. The structure of the great vessels or major nerves can be enhanced or represented by modelling clay such as 'Milliput' (The Milliput Company, Unit 5, The Marian, Dogellau, Mid Wales). This two-part clay can be rolled, shaped or cut in its curing stage and once set can be drilled, sanded or painted. It can be shaped and positioned either onto bone or onto wire to represent the nerves and their ganglia below the skull base.

Resins

Low viscosity resins have transformed the anatomical demonstration of any cavity-containing structure. The cavity can be filled by resin and the surrounding tissue removed. Such displays are colourful, appealing and elegant partly because of their unfamiliarity. Within the temporal bone casts can be made of the sigmoid sinus, internal carotid artery, the vessels of the middle ear cleft, themembranous or osseous labyrinth, facial nerve canal and air cell systems either singly or in combination. Resins may be coloured to choice, typically blue, red, or yellow for venous, arterial, or nervous structures, respectively. Resin casts of temporal bone cavities require thorough maceration of the bone which must be carefully washed to remove the resultant debris. The main difficulties arise with filling the cavities completely and preventing excess resin from escaping from the numerous apertures on the bone surface before the resin gels. These techniques are not truly those of dissection and are not discussed further but an excellent description exists of these delicate and elaborate methods (Tompsett, 1954, 1956).

Varnish

If the bone is to be varnished then thin coats of clear varnish should be used. Again it is wise to test any application on a similarly prepared bone first rather than on the specimen itself. The problem with varnish is that it will give a glossy appearance and impair perception of detail. Over a period the varnish may yellow and become unsightly giving an aged appearance. The use of varnish may highlight any necessary repairs. The benefits are that it will bond any paint applied to the bone and reduce its contrast and unnatural appearance. If significant amounts of fixed soft tissues are retained then several coats of thinned varnish will aid their preservation. As a rule most specimens are better left unvarnished.

Display

The presentation of a painstaking dissection deserves as much care and thought as the dissection itself. The choices depend upon the possible audience and the dominant features to be displayed. It should easily be appreciated that the size of the stem and the base should be in keeping with the bone itself (Figures 5 and 6). There are two prime considerations; one is artistic proportion and the other is mechanical stability. After careful work it is important that the bone is not easily knocked and damaged. If two bones are to be jointly displayed then a heavier base can be used but for visual effect both bones should be of a similar size and shape. Any significant disproportion will offend any artistic sensibility to the detraction of the dissection itself.

The base can be wood in either natural, polished or varnished state. This can be chosen from any timber merchant and shaped according to taste. The alternative is the use of prepared mounts from modelling companies with or without the use of glass domes. If the display is for museum purpose then the fragile bone needs to be enclosed within a perspex box. These are easily fashioned by accurate cutting of perspex sheets to the required size. The edges need to be carefully finished, sanded and secured with a suitable fixative such as a mixture of chloroform and perspex chips. The box is carefully formed with five secured sides ready to secure over the specimen and base.

A simple unobtrusive base can provide an elegant dis-

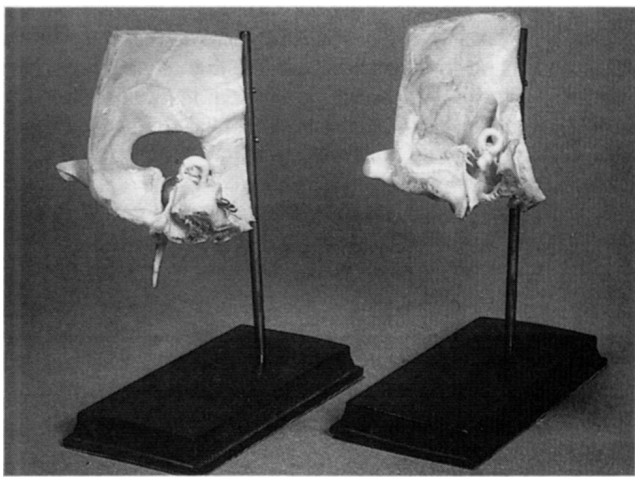

FIG. 6
Mounted temporal bones on narrow plinths.

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play without detracting from the dissection. The optimal combination of both might even allow an aesthetic result of artistic proportions. Display of features is probably best achieved with the centre of the orientated bone supported above the centre of the base. The choice of stem may be brass tubing, steel wire or wood. The stem to support the bone should be inserted into the centre of a circular base but may be placed eccentrically on any other base. A stem is most easily applied if straight and vertical. This can either be inserted, into a fashioned niche, into the base of the bone or can be used as a post from which a screw or bolt can be passed through the inferior aspect of the temporal bone or the attached occipital bone. Metal struts can be twisted in an 'S' to accommodate the need for central placement and vertical entry to both base and bone. It is obviously easier to align the stem into a drilled hole into an inferior tuberosity of the bone. This is secured with glue and the stability confirmed, once satisfied placement into the predrilled hole in the base can then be performed.

A particularly attractive mounting idea is to use a truncated cone with an angled bracket to secure the bone with a screw or bolt. If an all-round view is desired then mounting a stem through a mirror shaped to fit the base allows inspection of the inferior surface as well as the superior aspects. Any irregularity about the stem can be disguised with a carefully shaped small wooden bush.

An alternative to vertical display is simulation of the surgical perspective. The bone can be mounted by inset into a shelf within a presentation box to present the lateral surface and the dissected cavity. The idea can be extended to present a series of dissections to demonstrate the sequence of steps of a given procedure. A wide choice of lining material for the box is available to highlight the dissection.

Legend

A title is required to indicate the nature of a dissection especially where there are subtle features and a legend for explanation of coloured structures. On wood Letraset is suitable for titling but hard to register on a straight line with the even spacing necessary for a good appearance. When Letraset is used, it is wise to varnish the whole so that there is no separation of the letters with time. Titling can be engraved into the wood or onto the plate. In this respect there is no substitute for simplicity to maintain elegance. A simply easy read title is advantageous. Unless the base is large enough to bear the identifying scheme of multiple features these are better demonstrated separately on an adjacent card or a photograph of the dissection.

Conclusion

The discipline of temporal bone dissection is important to ensure the safe conduct of otological surgery. Extending traditional surgical dissections aids an appreciation of the anatomy of the temporal bone which becomes important for uncommon clinical excursions beyond the labyrinth. The accuracy and precision of careful anatomical refinement in the dissected temporal bone are time consuming and require the patience and finesse of one with true modelling instincts. The presentation and display of such work is not only gratifying for the individual but also provides inspiration for others and a demonstration of the subtlety of our speciality.

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