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Methylmethacrylate Casting Model of Temporal Bone: A Simple Technique for Skull Base Research and Education

ABSTRACT—Methylmethacrylate casting model of the temporal bone simulating the translabyrinthine approach from the bone surface down to the internal auditory canal was developed in order to help to understand the complex anatomy that is often encountered during skull base surgery. Using a cadaver temporal bone and applying dental impression technique, fine structures, such as semicircular canals and facial nerve, were precisely reproduced in a life-size resin casting model. This simple cost-effective modeling method would facilitate both anatomical research and medical education by improving our understanding of the complex anatomy of the temporal bone.

The understanding of the anatomy of the temporal bone is essential for the practice of skull base surgery, not to mention otolaryngology. Acoustic neuroma is the foremost tumor which is often resected by translabyrinthine approach.¹ Additional innovative approaches through the temporal bone have also been developed for the resection of tumors such as petroclival meningioma, glomus tumor, and jugular foramen tumors.^{1,2}

Although these approaches have been incorporated into the armamentarium of neurosurgery, many neurosurgeons would find it difficult to perform these approaches by themselves because of the complexity of the temporal bone. Spatial orientation can not be acquired simply by reading anatomy books, and temporal bone dissection is not readily available to every neurosurgeon.

For all these reasons we made a methylmethacrylate casting model of the temporal bone at each step of the translabyrinthine approach so that a well oriented anatomical knowledge could be obtained using these models. The actual process of temporal bone dissection can be preserved in a series of these models. Also, we showed that these models are inexpensive and relatively quick to prepare during the dissection practice.

MATERIALS AND METHODS

One piece of dry temporal bone from the mastoid surface to the petrous apex including the mastoid process, the external auditory canal, the zygomatic root,

the sigmoid sulcus, and the internal auditory canal, was used for one series of models. The jugular foramen and the carotid canal should be opened beforehand because these structures may become large undercuts which would cause trouble when taking an impression.

From this bone the first resin model of the series was made as a starting point of mastoidectomy. We employed a two-step impression technique of dentistry using two silicone impression materials.³ In this method, a rough impression is made with putty and then a fine impression is taken with paste placed on the rough putty impression.

For the preliminary impression, a lump of a putty material, Optosil P (Heraeus Dental Material Inc., Japan), mixed with an adequate amount of catalyst, was kneaded into a rectangle large enough to contain the temporal bone. This procedure is easier if an appropriately sized rectangular box is used as a mold. The prepared temporal bone was immediately pressed into the putty oriented with the petrous apex and the petrous edge inferiorly (Fig. 1A). After the material was set, the bone was removed and the uneven surface indented in the putty was carved out with a scalpel to make the space wide and so that the bone will go into this space without any resistance (Fig. 1B).

Then, the secondary impression was taken using a paste material called Xantopren H (Heraeus Dental Material Inc., Japan) which easily yields to fine contours by flowing into minute structures. After mixing with an appropriate amount of catalyst, the paste was poured into the preliminary impression and spread over the medial side of the temporal bone (Fig. 1C). The bone bearing this material was brought into the original place in the preliminary impression. At this point the bone should be half buried on its medial side in the impression material which served as the lower half of the mold afterward (Fig. 1D).

After the paste hardened, the upper half of the mold began to be made using the putty and the paste in this order, as described above. Briefly, a lump of the putty large enough to cover the lower mold was pressed firmly over the bone to take the rough impression of the lateral half (Figs. 1E and 1F). Again this indentation was widened by trimming away undercuts. After it is determined that this putty can cover the bone smoothly, the same paste material as before was poured into the putty and spread over the lateral side of the bone. Then the putty loaded with the paste was brought over the bone and combined firmly to the lower mold. At the final stage of molding the bone should be sandwiched completely between the upper and lower mold (Fig. 2A). Then the upper and lower mold were carefully separated from the bone by applying gentle force (Fig. 2B). To make this detachment easier, Vaseline® can be thinly spread over the bone

surface and on the detachment plane of the mold just prior to combining. Even if small fragments of the paste material are left in the undercuts of the bone at the time of detachment, they can be carefully taken out using a fine dissector and reattached to the original place with an adhesive glue, which usually results in a satisfactory mold.

Finally, casting was performed with a dental resin material called Meta Fast (Sun Medical Co., Ltd., Japan) which is provided in powder and liquid and is composed mainly of polymethylmethacrylate and methylmethacrylate, respectively. Both substances were mixed in the proper ratio and poured into both of the upper and lower mold. Before the resin cured, this pair of molds was combined in the original spot with pressure applied to release the excessive resin from the seam. After it solidified, the mold was removed and the casting model was turned out. As a final touch, irregular surfaces were smoothed with drilling.

Thereafter, standard mastoidectomy and labyrinthectomy was performed following instructions of a dissection manual.⁴ At each critical stage, a resin casting model was produced with the same procedure described above.

RESULTS AND DISCUSSION

In Figure 3 a set of four resin models at each level is presented in a row; from the left, the level of the bone surface, opening of the antrum, the semicircular canals and facial nerve, and finally the internal auditory canal. Magnification showed that the shape of the semicircular canals and the descending portion of the facial nerve were precisely reproduced in the model (Fig. 4A). On opening of the semicircular canals, even finer structures in the canals, such as ampulla and common crus, can be reproduced in this model (figure not shown). On the posterior surface the transverse crest in the internal auditory canal and the vestibular aqueduct are recognizable (Fig. 4B). The critical landmarks on the superior surface, the arcuate eminence and the groove for the greater petrosal nerve are also identified (Fig. 4C).

From our experience one model can be produced in less than one hour. And it is possible to make a few copies from the same mold.

However, large complex undercuts such as tympanic cavity and carotid canal will not be reproduced by this method. However, for needs of this nature, stereolithography is superior to our method, as it can copy the identical bony structures including the internal ones unseen from outside with the use of three-dimensional CT and laser technology.^{5,6} But stereolithography costs much more, takes a long time, and is not realistic for our

Figure 1. The procedure of making a mold with two-step impression technique. (A) The temporal bone is pressed firmly into the putty material to take a preliminary impression. Note the orientation of the bone to the putty. (B) Large undercuts which will hinder taking an impression are trimmed away with a scalpel. (C) The paste material is put into the preliminary impression and on the medial side of the bone. (D) The bone is half buried in the lower half of the mold. (E) A lump of the putty is brought over to the bone to take the impression of the lateral half. (F) A rough impression is completed in the upper half of the mold.

Figure 2. Photographs showing the last stage of making a mold. (A) The mold containing the temporal bone. (B) The upper mold was detached to reveal the bone still in the lower mold. Two layers of impression materials are shown: the putty outside and the paste inside.

purpose. On the contrary, our model is easy to make and only requires readily available materials.

This model making method has the potential to be applied to other areas of dissection research associated with bony structures, especially in skull base and spinal surgery. Also in the clinical setting, a similar casting

technique is now used to make an acrylic bone flap for cranioplasty.⁷

These models can serve as excellent teaching, training, and research materials, and may contribute to the general understanding of the complex structure of the temporal bone.

Figure 3. A set of models in a row, from the left, the temporal bone before mastoidectomy, opening of the antrum, the level of the semicircular canals and facial nerve, and the level of the internal auditory canal.

Figure 4. Magnified views of the model. (A) The semicircular canals and the descending portion of the facial nerve (FN) were accurately reproduced in the cavity after mastoidectomy. (ASC: anterior semicircular canal. LSC: lateral semicircular canal. PSC: posterior semicircular canal). (B) The transverse crest (arrow) in the internal auditory canal and the vestibular aqueduct (arrow head) were duplicated on the posterior surface of the petrous bone. (C) The arcuate eminence (AE) and the groove for the greater petrosal nerve (double arrows) are identified on the superior surface.

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