Custom Tailored 3D Printed Anatomic Models for the Training in Temporal Bone Surgery

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In a time of extraordinary technological advancements, one of the main challenges in the medical field for all doctors is to be in time with these improvements and have the capacity to use these technologies at their full potential. In order to achieve this goal, one of the most important aspects, especially for surgeons, is taking part in hands-on trainings. If at first, these courses were performed mainly on cadavers, nowadays the tendency is to use anatomic models as similar as possible to the real structures, regarding both the aspect and the feel during training. The reasons are numerous, ranging from ethical problems to the limited number of available cadavers associated with the high demand. Regardless of the motivation, any advancement that will help us create a more accurate model of an anatomical structure with a good cost-efficiency ratio will translate into a better training for the medical staff and the possibility of performing faster elaborate interventions. The aim of this article is to present a new alternative for the training of ENT surgeons in cochlear implantation, using a novel 3D printed anatomical model and an alternative surgical approach. We consider these to be an excellent option for surgeons who are at the beginning in the field of cochlear implantation, as it will allow them to perform the necessary training in a safe manner and specialize in a field that is still underdeveloped in our country.

Keywords: cochlear implant, anatomic model, 3D print

The continuous improvements in medical research, teaching and surgical procedures take us further and further day by day and also closer to methods that seemed untouchable in the close future. The use of organ transplants, rehabilitation of the senses such as hearing and sight brought dreams to reality.

In the teaching and training in medical school and postgraduate education great progresses were made mainly by using high tech holograms and other electronic media. For the anatomic and surgical part most centers align to new ethical standards and tend to avoid the use of cadavers.

Under these circumstances the need for 3D printed anatomic models of the human body regions came naturally [1,2]. However the costs of these structures are still quite high and the price is depending on the level of detail that is obtained [3]. If the price could be considered high for solely teaching anatomy the situation is quite opposite as we take the discussion further to the surgical training [4].

So nowadays the goal to reach is quick results in health research and the immediate practical application of the conclusions with minimum costs, within the possibilities [5].

During the last 2 years an increase of the articles regarding this 3D movement can be seen in the medical databases. Whether we are talking about simple anatomic studies, preoperative planning, training of surgeons or even synthetizing prosthetics or tissue, the high interest on the potential of achieving a scientific goal using a 3D printer is obvious [6,7].

Experimental part

Considering the direction described above in current research [8,9], the authors try through their effort to approach a niche in the otology surgery – training for cochlear implantation and highlighting an alternative surgical approach (fig.1 and fig. 2). Our mainly experimental work meant obtaining 3D printed anatomic models of the part of middle cranial fossa corresponding to the cochlea and demonstrating that it can be reached by drilling safely (fig. 3). First, we reviewed data from our anterior study regarding distances between the cochlea and the surrounding structures of the skull base and temporal bone. As planned, we randomly chose 10 studies from the initial

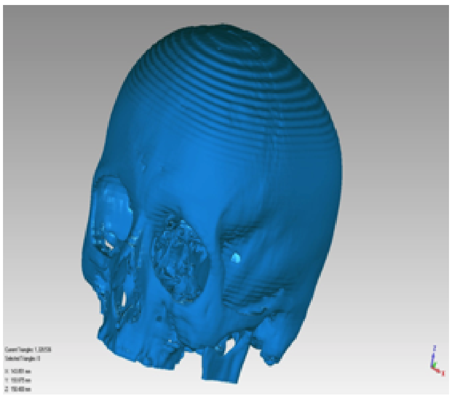

Fig. 1. 3D computer reconstruction of the skull using data from CT examinations.

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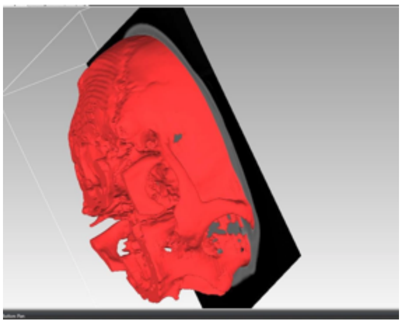

Fig.2. 3D computer image of the entire mastoid

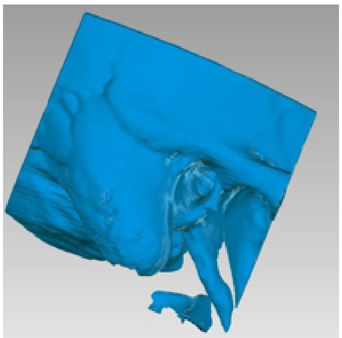

Fig. 3. Computer 3D reconstruction of the anatomical region of interest

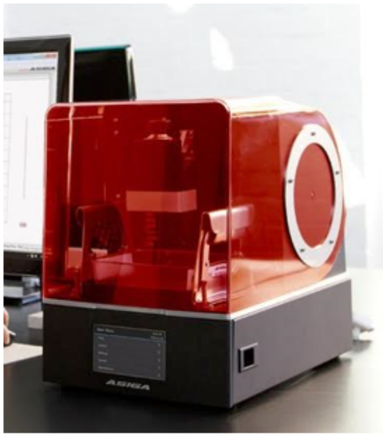

Fig. 4. The 3D printer

Fig. 5. The 3D printed model

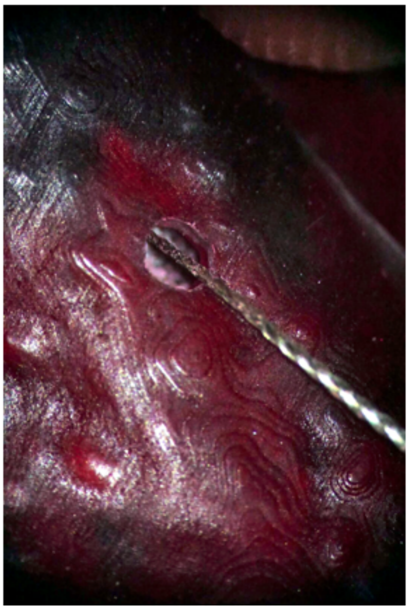

Fig. 6. The anatomical model during drilling (the resistance is similar to the real bone)

497, using the files in order to obtain real scaled anatomic models.

The 3D printer type was Asiga pico 2 (fig. 4). Data from the 3D reconstructions of the cochlea region of the skull were loaded one at a time from each computed tomography study. The images were tailored with care in order to obtain the exact section for our interest.

The material used for 3D printing was SuperCast, which consists of hazardous ingredients such as 7,7,9-trimethyl-4,13-dioxa-5,12-diazahexadecan-1,16-diol-dimethacrylat, tetrahydrofurfuryl-2-methacrylat and neopentylglycol-propoxylate-diacrylate, processed under a 12-hour burnout cycle. It leaves no ash or residue and is considered suitable for bone casting.

The process starts from ambient temperature (23 ^{o}C) and increases by 5^{o}C / min. The heating then goes for 2 h at 149^{o}C, 2 h at 371^{o}C, 2 h at 482^{o}C, 4 h at 750^{o}C and then 2 h at cast temperature.

The authors wanted to minimize the costs and focused on the alternative cochlear basal turn approach through the skull base, therefor we only produced sections of the temporal bone of our interest (fig. 5).

After obtaining the anatomic models, these prints underwent a microscopic examination and drilling procedure in order to demonstrate the presence of the surgical landmarks and the possibility to reach the cochlea by this alternate approach (fig. 6).

Results and discussions

The sections of the anatomic models were printed adequately and could be drilled safely. The basal turn of the cochlea was found easily in all specimens. The bone like structure respected the aerated structure of the temporal bone.

The drilling was performed with usual cutting and diamond otology burrs and instant images and videos obtained during this process show the quality of the process.

The cost was quite low, at an average of 25 USD per specimen.

The color of the specimen was red and did not respect the true color of the bone, but this however did not represent a problem for the surgeons.

The time for processing the data and obtaining the models was good, at an average of 12 h per one piece.

No specimen broke during the obtaining or the drilling procedures. The surgeons described a 90 percent feeling of real bone drilling during the experimental part of the study.

Conclusions

The 3D print model of a section of a temporal bone is an excellent alternative for the training of surgeons interested in temporal bone surgery. It provides a reliable, repeatable model of the anatomical land marks with the same behavior during drilling procedures as the real bone. The low costs are another advantage, allowing a mass production that will help benefit more people.

Considering the high number of ENT surgeons interested in *hands-on* courses, we must underline the importance of such models, that will allow the training of more specialists. Thus, it is preferable to first practice on anatomical models, rather then live patients, due to ethical reasons, and, equally important, the fact that an adequate training will help us provide the best standard of care to our patients.

However, one of the disadvantages associated with all 3D anatomical models is that these models do not offer anatomical variations, as one encounters during the actual surgery. Also, these will not help the surgeon prepare for the pathological changes we might encounter during all surgeries. What we are trying to emphasize is, that although these models are extremely useful in the first steps of training, they will not be able to substitute the whole learning curve. However, in our effort to surpass these disadvantages, we made several models, which were based on the anatomical variations of 10 different patients, thus offering us more options. The surgeons learning on these models will not encounter the problem that, once they drilled one model, the next one will be exactly the same.

One great advantage of these models, due to the short time of manufacture and low costs, is the fact that the surgeon can recreate the mastoid of a patient prior to surgery and use it for practice, before performing it on the patient.

That being said, we consider our model and alternative approach to be a viable option, with possible excellent results in the training of ENT surgeons, providing all steps will be followed.

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