

## NOVEL USE OF 3D RECONSTRUCTION TECHNOLOGY FOR EAR FRAMEWORK CONSTRUCTION- THE CARTILAGE MODEL

Narender Manickavachakan<sup>1</sup>, Naren Shetty<sup>2</sup>, Vijay Thomas Mathyoo Joseph<sup>3</sup>

<sup>1</sup>Assistant Professor, Department of Plastic and Reconstructive Surgery, ST John's Medical College and Hospital, Bengaluru.

<sup>2</sup>Associate Professor, Department of Plastic and Reconstructive Surgery, ST John's Medical College and Hospital, Bengaluru.

<sup>3</sup>Professor and HOD, Department of Plastic and Reconstructive Surgery, ST John's Medical College and Hospital, Bengaluru.

### ABSTRACT

#### BACKGROUND

The skill required to fashion a 3-dimensional ear framework out of costal cartilages, that simulates a normal ear and lasts a lifetime, is indeed tremendous. How to decide from where is it best to harvest the different component parts of the framework, given that the anatomy is variable and, especially when the surgeon has limited experience.

#### MATERIALS AND METHODS

Could this daunting task be simplified by creating an exact 3-dimensional replica of the costal cartilages well before the actual surgery, and then planning at leisure how to go about this? We describe an innovative approach of obtaining 3-D images of the costal cartilages and then using a 3-D printer to obtain a close simulation of the actual costal cartilages.

#### RESULTS

The 3-D models were of significant help in the planning and execution of the case.

#### CONCLUSION

This innovative approach holds promise, and may prove to be beneficial to younger plastic surgeons, embarking on the journey of ear reconstruction.

#### KEYWORDS

3-D Costal Cartilages, Ear Framework Reconstruction.

**HOW TO CITE THIS ARTICLE:** Manickavachakan N, Shetty N, Joseph VTM. Novel use of 3D reconstruction technology for ear framework construction- the cartilage model. J. Evid. Based Med. Healthc. 2018; 5(9), 814-816. DOI: 10.18410/jebmh/2018/164

#### BACKGROUND

Ear cartilage framework creation is a challenging process in itself, with a lot of committed training essential to simulate the normal human external ear. The commonest techniques of ear framework construction include BRENT's,<sup>1</sup> NAGATA's,<sup>2</sup> and FIRMIN's.<sup>3</sup> These techniques involve harvesting costal cartilages from 6<sup>th</sup> to 9<sup>th</sup> ribs and cutting out the component parts from each rib, shaping them and finally attaching them with steel wires/ sutures to create the composite 3-dimensional ear framework, which is buried in a sub-cutaneous pocket at the site planned for the ear reconstruction. This process of ear framework creation is a daunting task for the novice surgeon. Traditionally, the opposite normal ear is mapped out onto a transparent X-ray film, cut out and used as a template for designing the new ear framework (2D). The individual components of the framework, namely the base plate, helical rim, anti-helix, tragus and anti-tragus, are also cut out from the x-ray film,

sterilized and laid upon the ribs at the time of harvest, to optimize the component preparation. The different parts once harvested and refined, are anchored with steel wires/sutures to create the new ear framework.

At our institute, 3D models made of polylactic acid (PLA), are regularly made for patients who are being planned for orthognathic surgery. The surgical cuts are carried out on this model as a trial run, and this helps to improve and refine the actual surgical procedure. We wondered if it could be possible to create similar 3D models of costal cartilage. This would allow us to plan out exactly how to go about the harvest of the various pieces well before the actual surgery. This is a tremendous advantage especially in young children with microtia, who might have narrow ribs and costochondral junctions. This would not only help to refine the framework construction, but also avoid pitfalls such as ossified ribs and/or narrow ribs, missing ribs, etc. Further, operative time can be significantly reduced by this better planning.

#### MATERIALS AND METHODS

A 17-year-old boy presented with non-syndromic unilateral microtia of the lobule type (Nagata Classification) Figure 1. Routine examination was unremarkable, except for mild conductive hearing loss in the involved ear, and normal facial nerve function bilaterally. He had no prior chest trauma, with minimal deformed residual cartilage.

*Financial or Other, Competing Interest: None.*

*Submission 10-02-2018, Peer Review 12-02-2018,*

*Acceptance 21-02-2018, Published 23-02-2018.*

*Corresponding Author:*

*Dr. Narender Manickavachakan,*

*No. 851, 8<sup>th</sup> Cross, 8<sup>th</sup> Block,*

*Koramangala, Bangalore- 560095.*

*E-mail: dr.m.narender@gmail.com*

*DOI: 10.18410/jebmh/2018/164*



After detailed discussion with our radiologists, we developed a protocol to image his costal cartilages. We performed a Computerised Tomography scan of the chest with Intra-venous contrast, using the 1 mm DICOM format. The images were then digitally coalesced into a 3D Reconstruction format, with a Window setting of "SOFT-TISSUE". This helped to visualise only the costal cartilages, distinct from the rest of the ribs and thorax. Using this information, our 3D model collaborators (Osteo-3D, www.osteo-3d.com) were able to generate a 3-dimensional model of the patient's costal cartilages –sixth, seventh and eighth.

As a first, we used a variant of flexible polyamide to prepare the costal cartilages, in order to simulate their natural flexibility.

We had two models made, and tried out different combinations of component harvest for the ear framework construction. Figure 2. Visualizing the synchondrosis also helped us to decide where to harvest the component parts for the framework construction. Preparing the ear framework ex-vivo, helped us to refine our eventual work. Further, we were able to show the patient, and his attenders, exactly how we were going to proceed with the ear framework construction. Figure 3. It gave us a lot of confidence during the actual procedure itself. Figure 4.

The cost of the two models worked out to a very reasonable price for the comfort of better planning. This method would be particularly useful in middle aged patients desirous of ear reconstruction following road traffic accidents, where one is unsure of how much cartilage remains, and where to exactly locate it.

**RESULTS**

The 3-D models were of significant help in the planning and execution of the case.



**Figure 1. 17-year-Old Patient with Left Microtia**



**Figure 2. The Costal Cartilages (6<sup>th</sup>, 7<sup>th</sup> & 8<sup>th</sup>) Model Made using a Variant of Polyamide and Starch. Both Sets are of the Same Side, though One has been Flipped in this Picture**



**Figure 3. Different Combinations of the Cartilage Framework Pieces Planned for Harvest, from the Two Sets, to Maximize the Utilization of the Costal Cartilages**



**Figure 4. The Final Ear Cartilage Framework used in the Case, and the 3-D Model used as a Guide, on the Left**



**Figure 5. With the Cartilage Framework in-situ**

## DISCUSSION

This is a novel application of the conventional 3-dimensional imaging modality combined with the emerging field of 3-D model creation. Having the exact replica of the costal cartilages prior to surgery and preparing a good ear framework, gives the surgeon- especially the beginner, tremendous confidence during surgery. Further, valuable time can be saved intra-op when narrow/ injured or ossified ribs can be avoided, and only suitable ones harvested as per this protocol. Thus, this would be particularly suitable for ear reconstruction in older age groups where there is a higher possibility of ossification of rib cartilages. Further, it would be possible to significantly reduce technical errors in harvest once it has been practised on a simulated model.

The potential disadvantage of this system is the need to subject the patient to a CT scan and the cost involved in this and in the process of creation of the 3D models. However, we believe that in light of its many advantages, this is a worthy investment.

Our technique presents significant advantages over the earlier reported work of Sandeep M Thadani, et al<sup>4</sup> wherein model replicas of costal cartilage were made free hand and then converted into silicone – dental acrylic compounds and used for practise. Needless to say, the individual variability cannot be re-produced in such a manner. The computer-aided design and 3D printing to produce a Costal cartilage 3D model as performed by Dr Angelique Marie, MD, et al<sup>5</sup> of Michigan is particularly noteworthy in this regard. Their team has gone to greater lengths to ensure the simulation of the costal cartilages is as close to the real thing, with three different strengths of compounds being tried out and rated by three experienced microtia surgeons in a double-blind study. They showed that using a high level of technical expertise in the C.A.D. (3D mesh model- modelling software) and using a high starch: silicone composite was closest to actual costal cartilages. In the future, we hope to be able to

work with similar high-quality facilities, not available at present in our low-cost set-up.

Another fascinating article from Byoungjun Jeon, et al<sup>6</sup> describes the making of 3D model of the normal ear using moulds and a LASER scanner, and using a mirror image of this to create a 3D model of the same side to give the operating surgeon an exact idea of the desired ear shape to be constructed. Once again, the technology used (3D laser scanner HD) is not widely available in our country.

3D printing is one of the fastest developing technologies of today, with newer applications being discovered in multiple arenas. In the area of ear reconstruction, 3D printing has been studied for its potential to make a 3D bio-degradable porous scaffold that could one day eliminate the need for cartilage harvest.<sup>7</sup>

## CONCLUSION

This is a novel strategy to enable better preparation prior to a major surgical endeavour of ear cartilage framework creation. With locally available technology and materials, it is now possible to simulate with a high amount of accuracy, the costal cartilages and use this favourably for the actual procedure. Given all these advantages, we feel that this protocol would be advantageous to the many budding plastic surgeons keen on embarking on the journey of ear reconstruction.

## REFERENCES

- [1] Brent B. Microtia repair with rib cartilage grafts: a review of personal experience with 1000 cases. *Clin Plastic Surg* 2002;29(2):257-271.
- [2] Nagata S. A new method of total reconstruction of the auricle for microtia. *Plast Reconstr Surg* 1993;92(2):187-201.
- [3] Firmin F, Marchac A. A novel algorithm for autologous ear reconstruction. *Semin Plast Surg* 2011;25(4):257-264.
- [4] Thadani SM, Ladani PS. A new method for training of ear framework creation by silicon dental impression material. *Indian J Plast Surg* 2012;45(1):134-137.
- [5] Berens AM, Newman S, Bhrary AD, et al. Computer-aided design and 3D printing to produce a costal cartilage model for simulation of auricular reconstruction. *Otolaryngol Head Neck Surg* 2016;155(2):356-359.
- [6] Jeon B, Lee C, Kim M, et al. Fabrication of three-dimensional scan-to-print ear model for microtia reconstruction. *Journal of Surgical Research* 2016;206(2):490-497.
- [7] Zopf DA, Mitsak AG, Flanagan CL, et al. Computer aided-designed, 3-dimensionally printed porous tissue bioscaffolds for craniofacial soft tissue reconstruction. *Otolaryngol Head Neck Surg* 2015;152(1):57-62.