PATIENT SPECIFIC IMPLANT DESIGNING

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Abstract
The uniqueness of the human body poses a huge problem for the replacement of any damaged part of the body. This can be countered using implants designed specifically for a given case. The implants can be designed using various software however, the cells are incapable of growth on such implants. (Yongtae Juna, Kuiwoon Choi, 2010) In this project, a structure is designed such that it provides cells the ability to grow within the implant allowing full acceptance by the body hence are structurally biocompatible.
Keywords: Specific, Implant, structurally biocompatible

1   Introduction

The inability to use shelf implants for unique and specific organs or parts of the body due to the mismatching structures has been the cause for many medical mishaps (especially dental). (Laura Gaviria, John Paul Salcido, Teja Guda and Joo L. Ong, 2014) Many implants have been designed for the specific patient however, there is no set method and the implants are usually not biocompatible. In this report, the human ear is taken as an example. The implant designing method is set to be constant and a set of rules and steps have been assigned.

A paper was issued in 2001 stating all possible ways of 3D designing of such organs. (Bojarski, et al., 2001) It is found that the mirroring technique was the most efficient for parts of the body that are similar in structure. The human body is generally symmetrical, and most parts can be replicated using the mirror image. However, organs such as the Liver cannot be designed in this way. A proposed solution for this is to use another person's scans and then compare it to the cavity in the patient's body and design the structure accordingly. The ear does not pose such a problem.

Despite the improvement in the designing pattern concerning shape, there is an additional parameter to be considered. The cells must be able to grow into the implant. For this reason, a method was used to make the implants porous. This would allow the biocompatibility.

The 3D bioprinting of cells on the designed structure has been researched upon and the results show the possibility of growth in a mesh-like structure with small intersecting cylinders. (Murphy & Atala, 2014) Cells are able to grow on the scaffold and can form a similar structure to the naturally grown ear. The cells thus grown can only be of one kind and so far, there hasn't been any way to form a cellular network consisting of the cells and the surrounding and the interactions between the cells and the extra cellular matrix. Hence organ printing is still not possible with the existing technology. (Atala, et al., 2016) Problems observed in previous experiments such as incapability to obtain controllable and uniform EB's can be countered using this structure. (Xu, et al., 2011)

There have been many practical applications of this technology and the patients have recovered fully after use of 3D printed implants. (Ralph J. Mobbs, Marc Coughlan, Robert Thompson, 2017) The patients received solid implants and the cells of the body were able to accept it in the body without any major reactions. (Yongtae Juna, Kuiwoon Choi, 2010) This proves that cells have the capability to integrate with an external object and accept it as their own in most cases. Despite this there have been cases where the patient had recurring diseases or immune responses due to which the implant had to be removed. (Girolami, et al., 2018)

However, the implant may prove to be a problem when there is growth in the body as the implant is incapable of growth. Hence a novel method as used in this report is introduced. Once the cells grow in the implant, the implant material must be chosen such that it is biodegradable over a certain period of time. This would imply that only the natural cells remain, and the scaffold falls away.

The results of this report show a structure capable of supporting cell growth and the method that has been used can be used for designing any 3D organ provided the CT or MRI scans are available. This model is structurally biocompatible as the shape is the same as the patients. The body is already familiar with it and hence makes acceptance easier.

2   Procedure and Software used

This report is based on the formation of an ear for a patient born without on. Hence the second year is taken as a blueprint. The procedure used in this report is as given below:
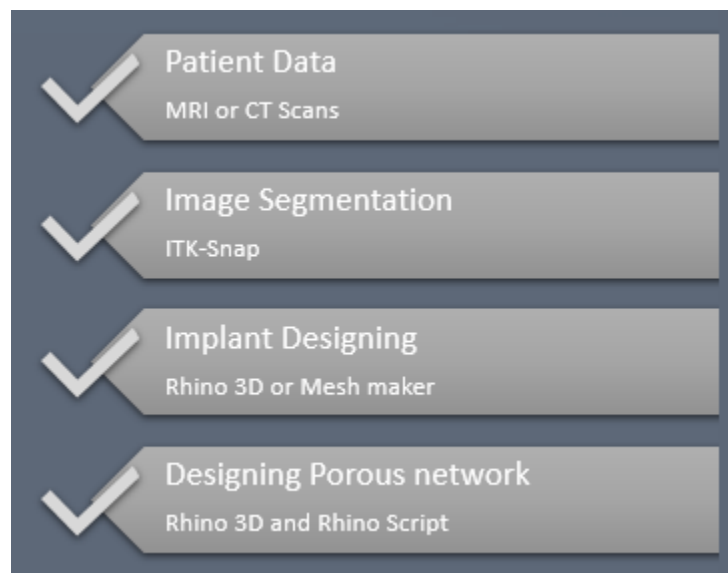

Figure 1: Steps for 3D designing

There are 4 steps to this process, first we separate the ear from the skull using ITK-Snap then we use Autodesk Meshmixer to remove all excess bits from the ear and to mirror the ear and then we use the Rhino software to create a mesh-like structure which is compatible for cell growth.
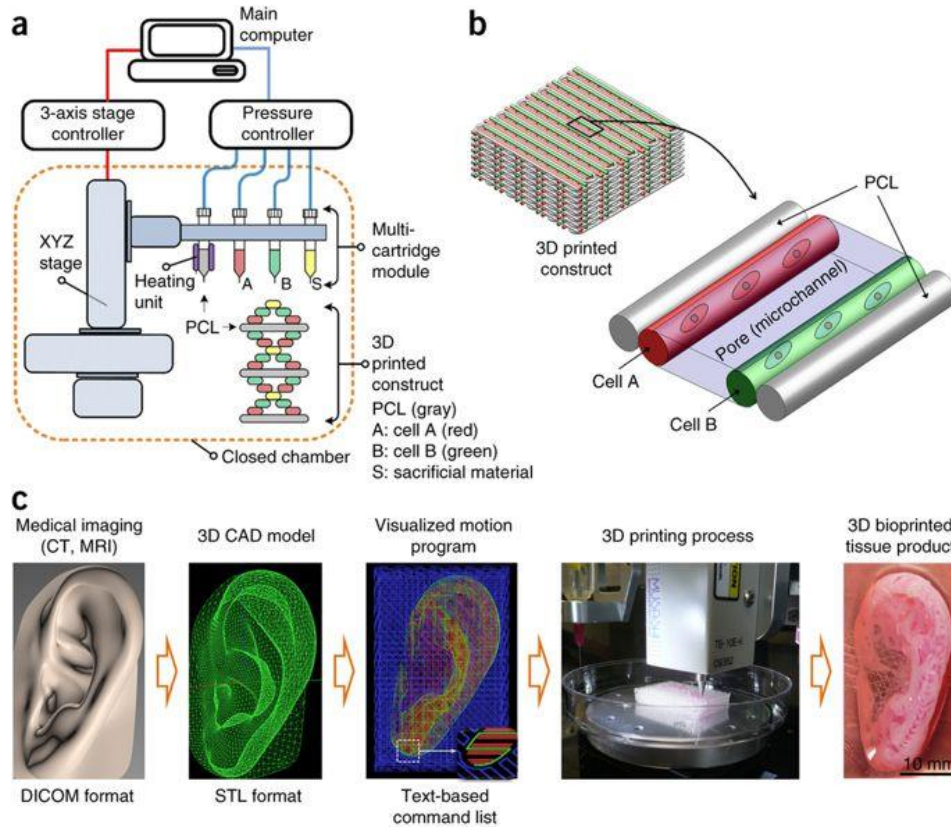
Figure 2 The complete process

Figure 2 shows the complete process for the implantation of the designed ear. As the project aims at only design of the implant, the 3D printing and implantation of the thus created model is out of the scope for this project.

2.1 ITK-Snap

This software is used for segmentation. Segmentation itself has three steps:

1. Pre-segmentation
2. Initialization and
3. Evolution

2.1.1 Pre-segmentation

This step is for the selection of the part of the body. The software first asks to create a general boundary around the area to be segmented. This boundary is created by drawing a box using the segmentation tool around the portion to be segmented. This is shown in Figure 3 MRI scan of skull in DICOM format as a red box.
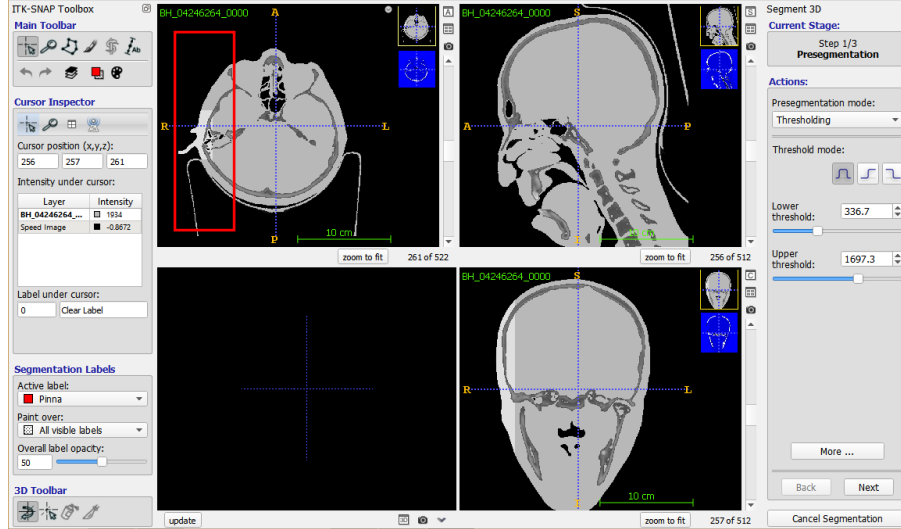
Figure 3 MRI scan of skull in DICOM format

2.1.2   Initialization and evolution

Following pre-segmentation, the software requires to select certain bubbles which will be expanded three dimensionally to fill in the area. This step is called evolution. As seen in Figure 4 Segmented ear using ITK-Snap in DICOM format the portion of the skull containing the ear is isolated and only that bit is remaining. The red colored portion is what we required to continue our design. And **Figure 5** shows the STL format as the result
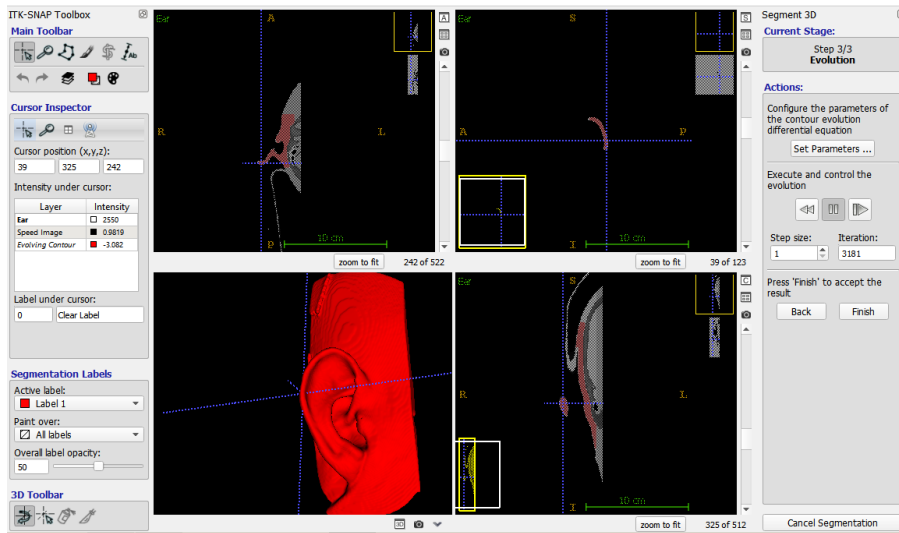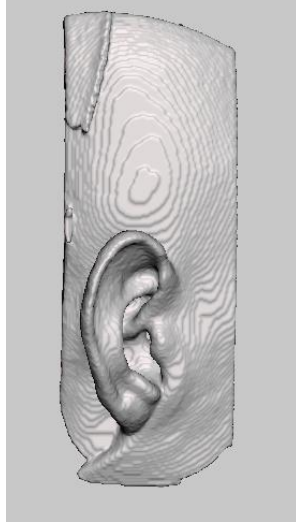

Figure 4 Segmented ear using ITK-Snap in DICOM format

**Figure 5 The final product
of ITK-Snap in
STL format**

2.2   Autodesk Meshmixer

Autodesk is used to remove all the excess bit from Figure 5 and then the quality of the figure is improved as well, the ear has certain dips and blemishes which are cleared out using Autodesk Meshmixer and then the ear is as seen below. Figure 6 shows the different perspectives of the ear as seen on the Meshmixer interface.
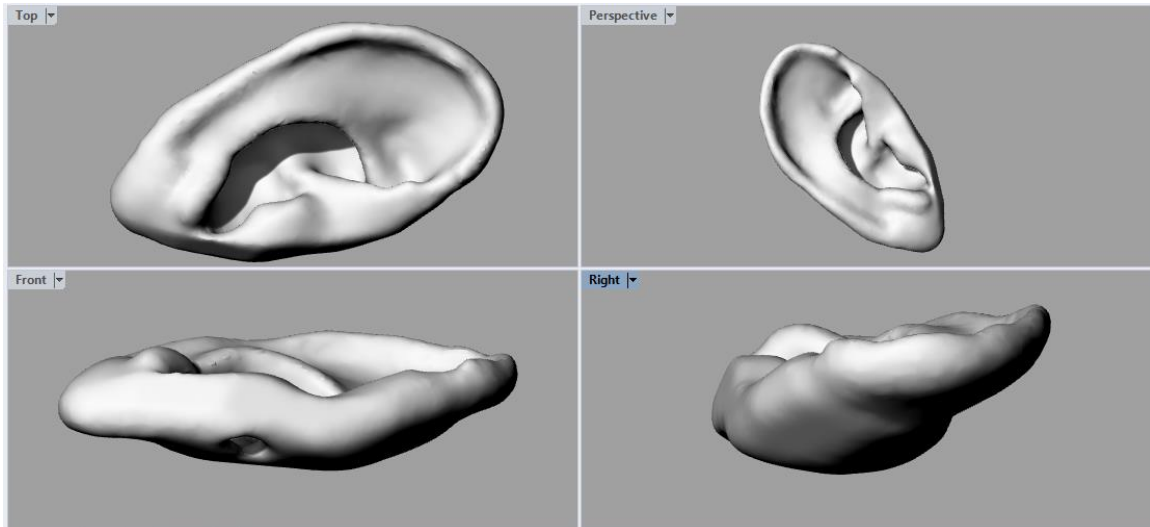

Figure 6 The ear isolated from the skull using Meshmixer

2.3   Rhinoceros

This software is used to convert the solid structure into a mesh-like structure. This is done using small cylinders which are stacked together on top of each other in layers of alternating angles. Each

layer perpendicular to the previous one. Following this we attain the ear as shown in Figure 7. This had to be done using rhino script. The pseudocode for the script is given below:

```
Dim base, height, width, minCoordinate, maxCoordinate
Base = constant getCoordinates of mesh
For y = Height = min_yCoordinate of ear to max_yCoordinate of ear
For x = min_xCoordinate of ear to max_xCoordinate of ear
Addcylinder (base, height)
Loop
Loop
```

Once this ear is designed, its ready for printing. This implies that the cells can grow in the cavities made by the structure below. If the cells are printed onto the scaffold first, it improves the chances of biocompatibility and hence makes it easier to accept into the body.
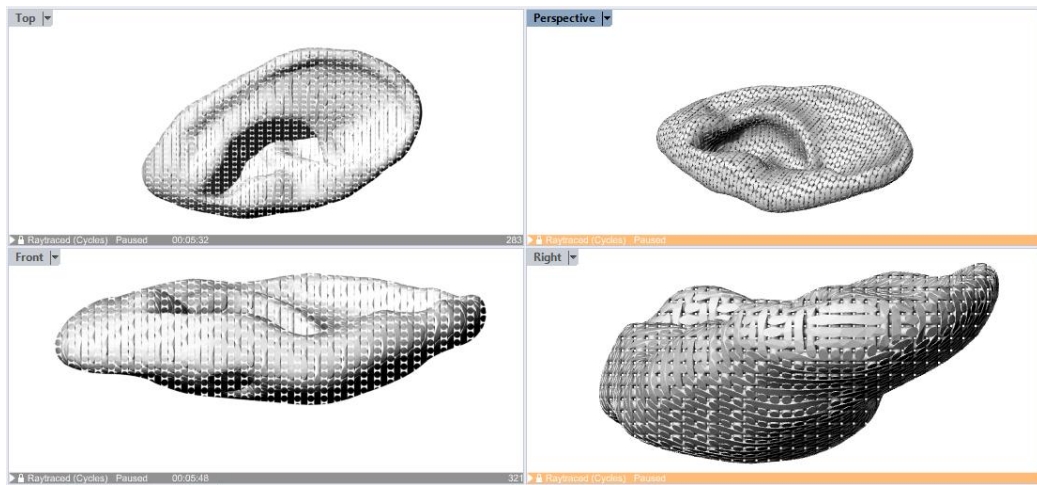

Figure 7 The mesh-like structure made using Rhino to facilitate cell growth

3   Conclusion and Future Work

The design as shown above is a mesh framework. It is effective and can be used as an implant. The cells have a stable and effective scaffold to grow upon. The implantation is carried out by first allowing a few cells to grow on the implant and then by using skin from another part of the body and covering the implant with it. This helps in growth of the cells which are similar in composition to the individual. The cells are of the same type and hence reduces the possibility of rejection. The issues that arise are the selection of a biodegradable material that can be used and the types of cells to be grown on the implant. Ideally the implant should be biodegradable in an amount of time. This is so once the cells have grown around it, it can degrade, and the entire structure would be primarily composed of the cells. There is another subject for future research. The cell culture using a bioprinter is only possible for one type of cell at a time. The ear itself consist of many nervous cells, blood vessels, cartilage cells and hence it would be difficult to grow a completely natural ear. The ear grown using this method would only be made of one type of cell. If the printer is made capable of growing many cells and their interactive phases, the ear can be grown as its natural form. This would also make it possible to print organs which are much more complex because each cell in an organ has an interactive function and play an important role in the well-being of an individual.

4   Bibliography

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