Development of Virtual Environment for Pre-Operative Assessment of Interactive Tympanoplasty Surgery

Pavai D[1], Prakasan K[2] , Anantharaj T[3]
[1]PG Scholar, Department of Production Engineering,
PSG College of Technology,
Coimbatore, India.

Abstract: **Virtual reality has been introduced to the medical field and it is now used in education as an alternative high fidelity simulator. Successful learning of surgeries using virtual reality systems are the ability to provide repetitive practice under controlled environment, self learning and proved construct validity. This paper deals with the development of such surgical simulator for carrying out virtual tympanoplasty surgery. Tympanoplasty surgery involves reconstruction of perforated eardrum. For that, modeling of outer ear, inner ear and surgical instruments for virtual surgery are done using MAYA. The point cloud data is used for construction of 3D CAD model by fitting free form NURB surface between these points and then fitting surface between these curve networks by swept blend technique. Extraction of point cloud data from physical ear model by reverse engineering approach using microscribe is done. Selection of appropriate surgical instruments, simulation and the sequence of use of them is based on actual surgical procedure. The software paves a way for innovative visualization paradigm for surgical simulation that is anticipated to enhance user interaction.**
Keywords— Tympanoplasty, Point cloud, Microscribe

I. INTRODUCTION

Virtual reality is an artificial environment that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real environment. Virtual reality can be divided into: the simulation of a real environment for training and education, the development of an imagined environment for a game or interactive story. Virtual reality holds promise for a wide range of present and future applications in many fields which includes medical, manufacturing, construction, aerospace, entertainment, etc,. Medical applications for virtual reality are just beginning to became visible. These include virtual surgical simulators, telepresence surgery, medical database visualization, and reconstruction. These applications are mediated through the computer interface and as such are the embodiment of VR as an integral part of the paradigm shift in the field of medicine.

The surgical simulator which makes the students to feel as if they are working in real environment. The surgical instrument is mainly used for eye-hand coordination during surgery. It is entirely through the use of the hands manipulating the proper instruments with the organ. The simulator is an attempt to represent the real world and is based on a real-time dynamic model to produce responses that reflect real-time laws of nature. This includes some collision detection necessary for determining when the instruments make contact with the organs as well as when the organs make contact with one another.

The use of virtual reality in surgical training enables surgeons to be better prepared, and more skilled, as they prepare for real-world procedures. The surgical simulators also prove useful to the veteran surgeons by enabling them to practice for rare or unusual cases prior to an actual procedure. Virtual reality simulation uses computer-generated model to present a training environment. It aims to increase educational outcomes over traditional methodologies, to enable surgical education to occur before entering theatre, and to provide a more flexible way to teach medical students. Several roles have been identified for simulation in surgical education, which include: 1) improved educational methods using virtual reality; 2) enabling surgical education to occur before entering the operating theatre; and 3) more flexible ways to teach learners. By simulating scenarios for students, experience can be imparted to facilitate learning. Simulations allow scenarios to be conducted in an arena where failure is allowed, and students can learn from these mistakes without causing harm to the actual patients. This capacity to learn surgical procedures requires actual experience and a period of reflection to consolidate the students' understanding, and an accumulation of surgical experience provides an increase in performance and confidence regardless if it is simulated or real. Tools such as data glove will be used to interact with the virtual body where the interaction is detected using collision detection test. Data glove helps the user to select the available instruments using which the surgery has to be performed.

II. FUNCTION OF NORMAL EAR

Sound is nothing but a kind of wave that travels from external ear through the ear canal and reaches the ear drum where ear drum is a thin membrane which vibrates according to the sound wave that is being received. Those vibrations are being travelled to temporal bone and cochlea. This cochlea converts the vibrations into electrical signal they are being

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recognized by brain with the help of cerebellum. Figure 1 shows the structure of human ear.

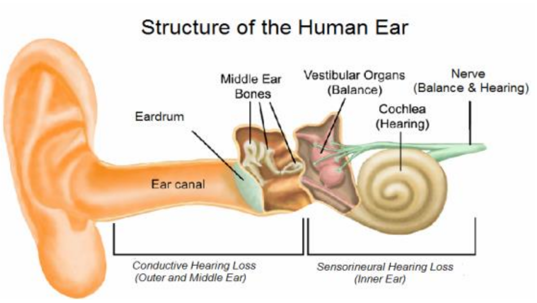

Fig.1 structure of human ear

III. SURGICAL PROCEDURE

Anear infection may cause damage to eardrum that must be corrected with surgery. Damage to eardrum can result in hearing loss and an increased risk of ear infections. If the hole in eardrum is large that cannot be cured with antibiotics, a surgeon may perform a tympanoplasty. This surgery will be placed under general anesthesia, so will be unconscious. First, the surgeon will use a laser to carefully remove any excess tissue that has built up in middle ear. Then, take a small piece of your own tissue from a vein or muscle sheath and graft it onto eardrum to close the hole. The surgeon will make a small incision behind ear and access eardrum that way. The surgical procedure takes two to three hours. During the surgery, the eardrum is lifted up like a trap door and the material used to repair the hole (called a tympanic membrane *graft*) is slipped behind the eardrum. Then, the eardrum is put back where it started and the hole is patched from behind. The graft material is supported with some packing material which slowly dissolves over the next 2 to 3 months. During this time, the eardrum heals over the graft and gets normal appearance.

IV. MODELING

The three important parts of the ear such as outer ear (pinna), ear canal and tympanic membrane were modeled using the MAYA software.

A. CLOUD POINTS

Geometric model is a mathematical of representation X, Y, Z coordinates representation of any three-dimensional object using collection of points in 3D space, connected by various geometrical entities such as triangles, lines, curved surfaces, etc. It can be used in non-graphical computer simulations and calculations for scientific purposes. Two common methods of 3D models are 3D Scanner and 3D Modeling. 3D scanner is a device that analyzes the object to collect data on its shape and its appearance to construct a 3D model. Important usage of 3D scanner is reverse engineering process. Reverse engineering is defined as the process of obtaining a geometric cad model from 3d points acquired by scanning. There are several instruments used for obtaining cloud points in reverse engineering suchas CMMs, laser scanners, structured light digitizers, and Industrial CT Scanning (computed tomography) machines. In this work, collection of points was done using microscribe and the cloud points are shown in figure 2. The data points were converted into a more usable format such as a triangular-faced mesh, a set of NURBS surfaces, andfinallyaCAD model.

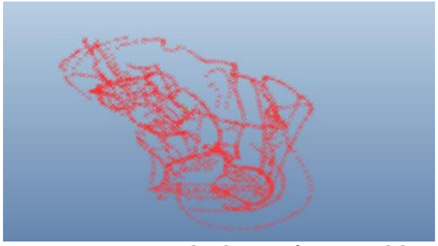

Fig 2 Cloud points for ear model

The point cloud data is used for construction of 3D CAD model by fitting free form NURB surface between these points and then fitting surface between these curve networks by swept blend technique. Extract point cloud data from physical ear model by Reverse Engineering approach.

This point cloud data is to be processed for CAD model generation which begins with the acquisition of physical ear model.

3d model of an ear is being modeled with the help of cloud points that are collected in reverse engineering process. Then those points are imported into MAYA and they are connected which helps in forming a complete model. To create a surface model of the object with mathematically defined curves and surfaces, it is first necessary to create a network of curves that fit or smooth the underlying data points.

B.MESHED EAR

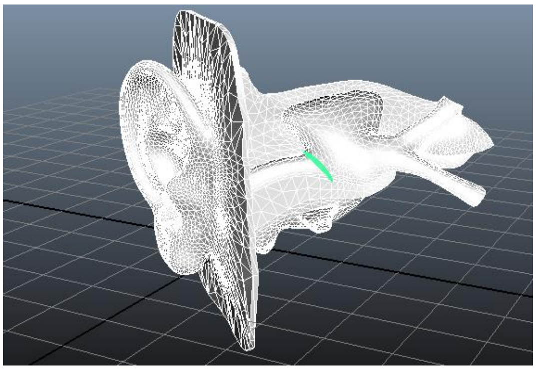

Fig.3 Meshed ear

The external auditory meatus, which is also known as external acoustic meatus (EAM) and ear canal, is a tube running from the outer eartothemiddle ear is meshed and shown in figure 4. A crude mesh will initially appear.

This is because the triangular size default too large. The quad mesh method with the mesh smoothing set to 3 can create nice clean meshes. Finite element analysis systems represent an object (e.g., an organ) by using multiple linked, simplified representations of different regions of the object on a mesh. In order to improve the image and have smooth touch-response, some systems refine the mesh with more elements. These "fine meshes" resolve some of the problems of mass-spring systems, but they also slow down response time, limit the number of contact points between virtual tools and tissues, and demand significant memory – all of which sacrifice flexibility in response to changing environments.

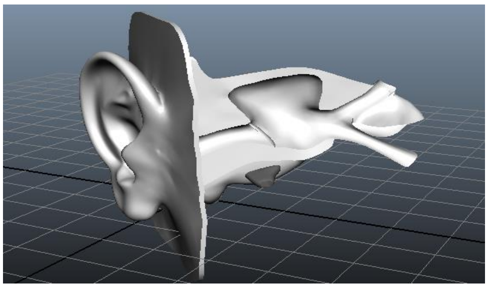

Fig.4 Ear and Inner Ear

C.SURGICAL INSTRUMENTS

The scalpel, or lancet, is a small and extremely sharp bladed instrument used for surgery. Bovie tool is used to suck the blood during surgery. This tool is helpful to proceed surgery process and reduce the blood flow The following figure 5 shows the model of a scalpel and boovie.

V. ANIMATING THE SCENE

The texture applied in ear anatomy and tools which are modeled using MAYA is shown in figure 6. After marking, the cut has made using scalpel tool. The blood texture is applied inside the anatomy. Using crocodile the perforated ear drum reconstructed with facia tissue. Finally the stitching process completes the surgery. This above process is created as animation using MAYA and rendered.

A.SIMULATION

A surgery simulator is computer technology developed to simulate for the purpose of training medical professionals, without the need of a patient. The surgical procedures are as follows, initially anesthesia is given to the patient which has high content of hydrogen helps in reducing the blood flow during the surgery. The next step is carried out with the help of scalpel tool for making incision behind the ear. Facia tissue is taken out from fat between skin and bone then it is placed in room temperature.

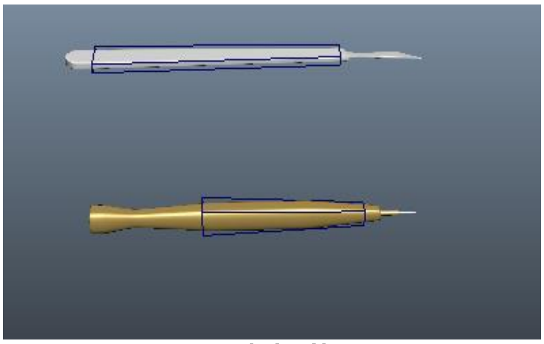

Fig 5. Scalpel and boovie

Flesh which is around the eardrum that can be removed using boovie tool which also controls the blood flow during surgery. That facia tissue is grafted on the perforated eardrum. After grafting, sodium packets are filled as a precaution of ear infection. Finally stitching has done behind the ear.

Figure.6 Texture of ear

Surgical simulator are best suited for two types of skills neededforsurgery,eye-hand coordination and the ability to perform three dimensional actions using a two-dimensional screen as a guide. Eye-hand coordination is improved because the simulation can give both visual feedback by way of a screen, as well as touch feedback that simulates the manipulation of organs and tissue. The simulator uses a computer screen displaying a three-dimensional graphic of theorgans being operated on. Various surgical tools or gloves are connectedto motion sensors and haptic or touch feedback mechanisms where the user can physically feel the difference in simulated tissue and organs.

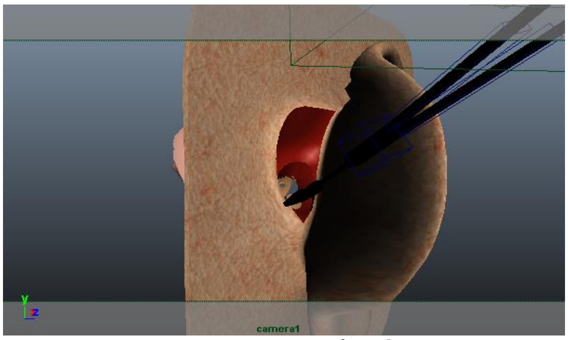

Fig.7 Reconstruction of ear drum

The user can "perform surgery" upon the virtual organs by manipulating the tools, which are also displayed on the screen as the user moves them, and the tools also provide force-feedback and collision detection to indicate to the user when they are pushing on or moving some organs or tissue. Figure 7 shows the reconstruction of ear drum.

V1. CONCLUSION

A detailed study has been made related to the surgical procedures of tympanoplasty. The interactive tympanoplasty surgical simulation software has been developed in virtual reality environment. Better eye hand coordination has been achieved. Possibilities of committing any mistake in the real surgery have been avoided. This simulation software provided detailed practical training and the feel of operating in the real world to the medical students.

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