A Review Report on Prototyping of Knee Joint using FDM Technology

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Abstract: A variety of prosthetic knee joints have been manufactured globally over the past decade and they have been ambiguity over prescription criteria, design parameters, kinematic performance of it various designs and counter parts. The aim of this research work is to Fabricate knee joint prototype. In this research, a proposed three-dimensional model of knee is modelled and converted STL file in AutoCAD fusion 360 by using Fused Deposition modelling additive manufacturing process. Fabricated specimen is modelled in software like AutoCAD fusion 360. After getting 3D model, it is then given to FDM machine for building. The knee joint printing time and material consumed is determined. AutoCAD fusion 360 is the first 3D CAD, CAM, CAE and PCB tool of kind, connecting your entire product development process into one cloud-base software. It is the computer aided modelling software to design the model. The model to be designed easily in AutoCAD fusion 360 compared to other software. The modelled prototype is easily converted to STL fie in this software. The resulting knee joint prototype and the process is useful for future development of knee implant for the doctor for surgery and advanced manufacturing process to help the patients who suffering from knee pains.

Keywords: Knee Joint, Prosthetic, Computer aided modelling FDM (Fused deposition modelling).

1. INTRODUCTION

A prosthetic implant is an artificial device that replaces a missing body part that may be lost due to trauma, disease, or a condition present at birth (congenital disorder). Prostheses are designed to restore the normal functions of a missing body part. Amputation rehabilitation is primarily coordinated by a physiatrist as part of an interdisciplinary team consisting of physiatrists, prosthetists, nurses, physiotherapists and occupational therapists. Prostheses can be created by hand or using computer-aided design (CAD), a software interface that helps designers design and analyse creations using computer-generated 2D and 3D graphics, as well as analysis and optimization tools. Prosthetics originated in the ancient Near East around 3000 BC, with the earliest evidence of prosthetics appearing in ancient Egypt and Iran.

Prosthetic knees can be divided into mechanical or computer. All prosthetic knees require some type of stabilization mechanism; this can be a manual or weight-activated locking system. They also require a way to control flexion and extension movement, which can be done by friction or hydraulic/pneumatic control. Different prosthetic knee technologies will be mentioned below; manufacturers use a combination of these technologies together to create different types of prosthetic knees. There are many types of prosthetic knees on the market and this page only covers concepts and not specific brands. When evaluating a patient for the first time or upgrading a prosthesis, it is important to go ask about the prosthesis or search the web to read more about the knee/prosthesis and watch the available videos. Each knee has different characteristics that will affect an individual's walking and rehabilitation with respect to sitting or standing, ramps, stairs, uneven terrain and walking and different speeds [1].

1.1 Types of prosthetic knee joints

1. Mechanical knees
    - Single-axis knee
    - Polycentric knee
    - Manual locking knee
    - Weight-activated stance control
    - Pneumatic or Hydraulic knees
2. Computerized knees

2. LITERATURE SURVEY

Rajesh Boorla, Prabeena T. knee joint using FDM technology, the author discussed the procedure of knee joint using FDM technology and the various knee components to be printed. As we aim to model the knee joint in AutoCAD fusion 360 this paper helped a lot to search the process and the method to make a prototype using FDM technology. In this article he used MeshLab and Catia to design the knee joint and he printed on MAKERBOT REPLICATOR 2X machine using ABS material. In this article Knee implant is designed by taking the dimensions from STL file in CATIA software. The printing time and material consumed for specified and commercial knee implants are 25min, 9.24gms and 50min, 18gms. Finally, the authors obtained the printing of tibia part and fabrication of patient specific knee implants is done using FDM machine. [19]

Abhishek Soni, Yashwant Kumar Modi, Sanat Agrawal. Computed tomography-based 3D modelling and analysis of human knee joint. In this article the author used reverse engineering technique to modelled the knee joint through CT scan and DICOM format to obtain the knee joint and the knee joint is tested in Ansys software. However, the final results are dependent on the quality of CT scan data, skill to operate image processing software, correct and optimum values of Hounsfield value during thresholding of the images. Involvement of an orthopaedic surgeon may further improve the results. A surgeon may help identifying and separating right ROI. Finite element analysis of knee joint for two different material shows that CoCrMo alloys is a better option as an implant material, as it shows lower deformation. CoCrMo alloy possess excellent biocompatible and mechanical properties such as high tensile and yield strength, high stiffness and great wear resistance. Apart from this, it also possesses excellent polish-ability which is required for knee and hip implants to provide smooth surface interaction. These all properties make CoCrMo an ideal implant material for orthopaedic implants [20].

Raju Vaishya, Vipul Vijay, Abhishek Vaish, Amit Agarwal. Computed Tomography based 3D printed Patient Specific Blocks for Total Knee Replacement. In this article the author discussed the knee plant surgery and prosthetic knee joint by 3D printing. The author uses CT scan and MRI to design the knee joint in software. This article helped a lot to know the procedure of modelling a knee joint. The results of the article are the role of 3D printed jigs in total knee arthroplasty have been found in the prediction of femoral valgus angle, component sizing and in retained hardware. They have shown promise with studies suggesting they might improve the overall mechanical alignment of the knee. There are studies which have also studied the combined role of patient specific instruments with navigation. 3D printing technology is an exciting opportunity, and its role in total knee arthroplasty is multifold. 3D printing in orthopaedics is done using additive manufacturing and can be used for planning and educational purposes. 3D printed patient specific jigs can be used for prediction of component sizes in total knee replacement which can help in improving OR efficiency and decreased armamentarium. Its role has also been studied in the prediction of patient-specific distal femoral valgus angles, and the results are encouraging. Their role in retained hardware is unequivocal with significant advantages. 3D printed patient specific jigs have been shown to improve post-operative mechanical alignment in total knee replacement. Their usage is still in its early stage and more studies with larger number of patients and longer follows up will help in establishing their role in total knee replacement [22].

S. Almouahed, C. Hamitouche, E. Stindel. Optimized Prototype of Instrumented Knee Implant: Experimental Validation. In this paper an experimental prototype of instrumented tibial baseplate has previously been proposed, developed and tested. A few shortcomings have been observed and identified during the experimental testing. In this study, the design of the proposed prototype was optimized to avoid the mechanical failure of the embedded piezoelectric generator/sensor. Furthermore, piezo ceramics of greater height and smaller section were accommodated and tested in the optimized prototype to generate more electric power. This optimized prototype was also experimentally tested using a knee simulator to validate the optimization result. The optimization made to the self-powered sensor proposed previously to monitor in-vivo the mechanical loading evolution of knee implant has been validated experimentally [26].

K. Anirudh, Shivraj Narayan Yeole. Development of a 3D printed knee protective pad prototype. In this paper the knee joint made through reverse engineering. There are two types of reverse engineering - contact and non-contact type. During accidents, joint dislocation is one of the majorly occurring injuries. Recent studies reveal that injuries to knee occur in around 20 to 40% of accidents and primarily while playing sports like basketball, soccer etc. Wear out of cartilage is the main factor for cause of knee injury. Sudden impact on the knee leads to the dislocation of knee. Orthopaedic surgeons have prescribed utilizing orthopaedic aids, medicines and providing rest to the dislocated joint. Usage of knee protective pads is observed to reduce the impact force but generalized designs that are manufactured conventionally are not found to be in a satisfied state. To resolve this issue, an attempt is made to provide an alternative to the traditionally made orthopaedic pads by designing and developing a customized 3D printed protective knee pad. By referring this article, it helped me a lot about our project [29].

3. EXPERIMENTATION

3.1 Steps to make a polycentric knee joint

- First design a model in AutoCAD fusion 360.
- Then the design is converted in STL file.
- Then STL file is sliced using Cura software.
- After slicing the g-codes is given to the FDM 3D printing machine.
- Then final prototype is prepared.

3.2 Design of knee joint

3.2.1 Femoral Component

The top-bottom bone part of the knee joint part is known as Femoral component. By using AUTOCAD fusion 360 the cartilage is drawn through with 2D commands and modification tool. The below fig. shows the part of it. It is used to move up and down of the knee movement.

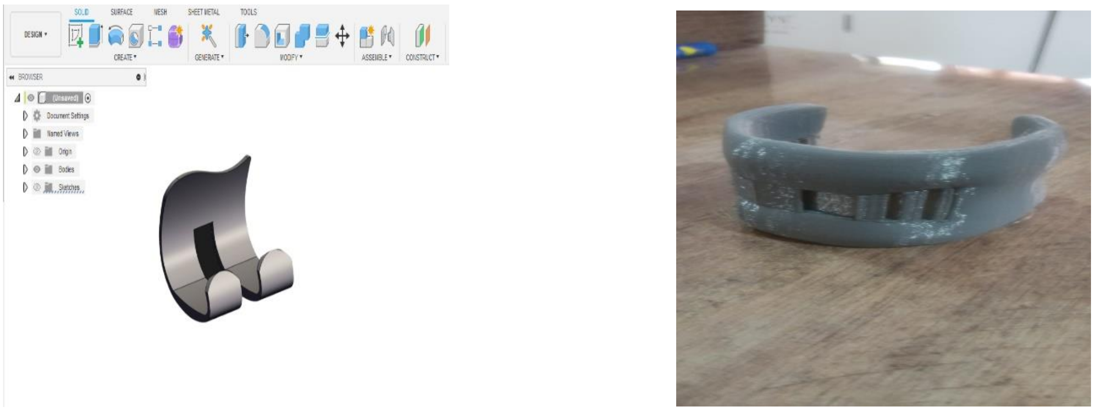

Figure 1 CAD model of Femoral component

3.3.2 Meniscus Component

The Meniscus Component is the middle part of the knee joint. And it is used to make movement to the knee. The below fig. shows the middle part of the knee joint. The design is made through 2D command circle and 3D command extrusion with modification tool in AutoCAD fusion 360.

Figure 2 CAD model of Meniscus component

3.3.3 Tibial Component

The final part of the knee joint is known as Tibial. The base is used to hold the down part of the knee for walking. The base is drawn through circle command and extrusion. This part of the knee joint is simple to design. It holds the plastic section and knee for proper walking. The fig. of base is shown in the below.

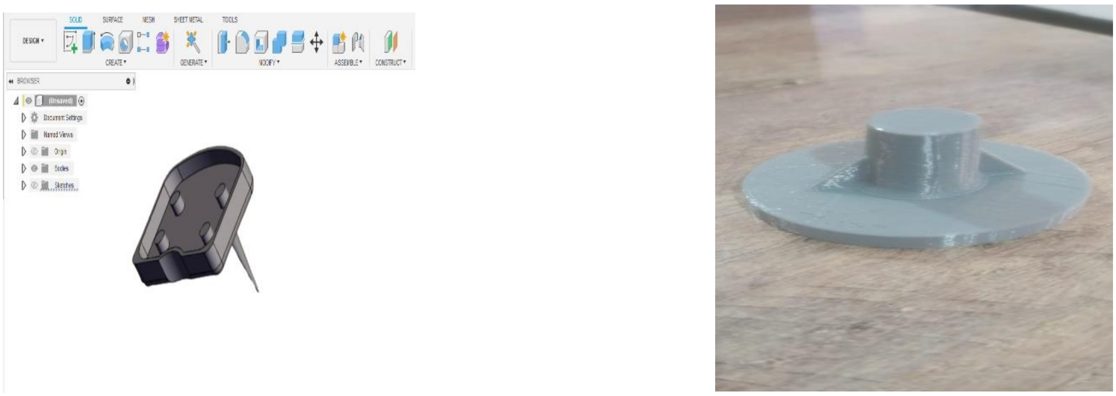

Figure 3 CAD model of Tibial component

3.3.4 Assembly of knee joint

Firstly, the femoral joint is fixed after that the meniscus is attached to the knee and then the tibial is attached to the plastic section. As designed above knee joint in AutoCAD 360 the complete assembly of the joint is shown in the below figure. The final product design is completed.

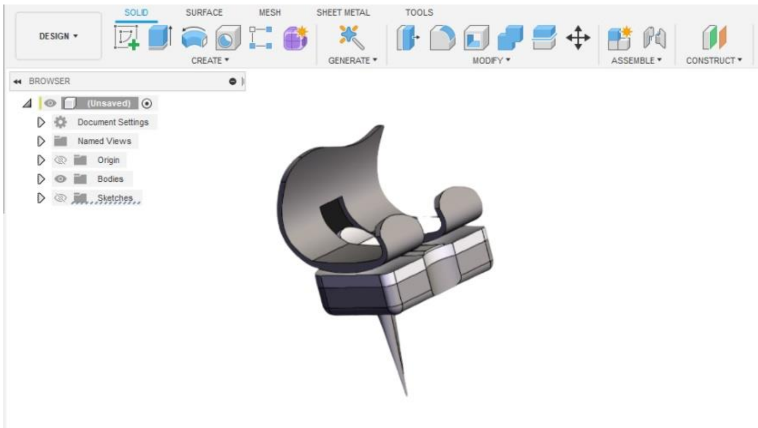

Figure 4 Assembly of the component

3.4 Conversion of design to STL file

First the design is completely checked whether there are mistakes in that. If the design is mistaken then incorrect STL file forms and the prototype design is disturbed or not perfect. And any complications needed for design correction is done. Then the completed design is converted to STL file through AutoCAD fusion 360. Within the software itself the design is converted to STL file. Then the STL is given to the 3D printing machine. The STL file contains the data of the design in terms of dimensions of vertices, length, width, height.
Then the 3D printing machine analyses the data of the STL file and with plastic polymer with layer by layer the design is printed. After the completion of the prototype the extra material attached to the prototype is removed.

3.5 Slicing the knee model

The act of converting a 3D model into a set of instructions for 3D printers is called Slicing. It literally "cuts" the 3D model into thin layers and then determines how each layer should be printed (tool path) to get the minimum time, best strength, etc. The slicer software takes a 3D CAD model, which is generally an STL file, and converts it into g-code that gives commands to the printer. The following are the three main types of settings that can be controlled in the slicer software.

1. Print Settings: layer heights, shells, infill per cent, and speed
2. Filament Settings: filament diameter, extrusion multiplier, the temperature of the extruder,and print bed.
3. Printer settings: nozzle diameter, print bed shape (L x W), and Z offset.

3.6 FDM 3D Printing

This FDM technology is most common and is also known as Fused Deposition Modelling. This isa technology that has been patented by Stratasys and it is a technology that enables the creation ofprototypes in a very short timeframe. This technology is also known as Fused Filament Fabricationor FFF 3D printing. All Tractus3D industrial printers make use of this technology. But what is itexactly and what are the things to consider to find the best FDM 3D printer that suits your needs. FDM 3D printing is a technology that works both horizontally and vertically, where an extrusionnozzle moves over a build platform. The process involves the use of thermoplastic material thatreaches melting point and is then forced out, to create a 3D object layer by layer. As the design takesshape, it is clear to the see each layer as a horizontal cross section. Following the completion of onelayer, the nozzle of the printer is lowered in order for the next layer of plastic to be added to thedesign. Once the object has been created, the materials that are used to support the object can thenbe removed.
After the slicing process the g-codes are given to the FDM 3d printing machine therefore accordingto the g-codes the extruder or nozzle printed the knee joint layer by layer. The printer confined to move in x and y axes, while it moves in z direction for changing the layers causing the knee joint prototype is printed on the board.

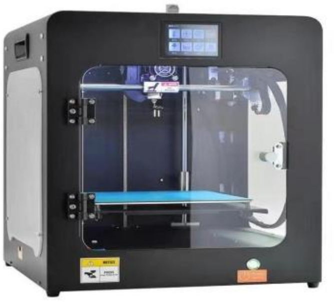

Figure 5 FDM 3D Printing Machine

4. RESULTS AND DISCUSSION

The resulted knee joint is done through 3D printing technology the cost and material waste, flexible design, strong and light weight parts of the knee joint is achieved.

Figure 6 Femoral component

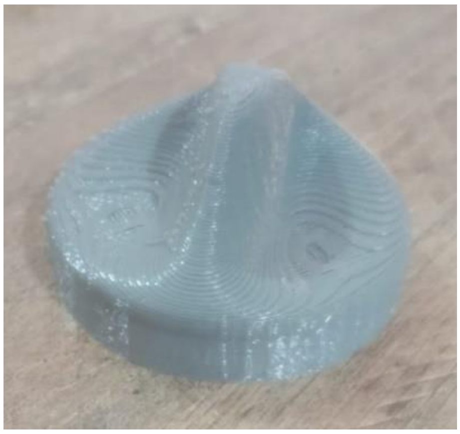

Figure 7 Meniscus component

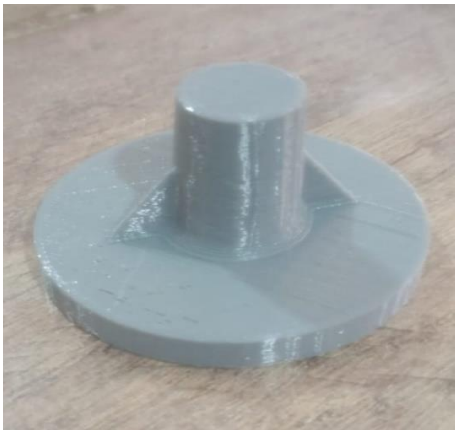

Figure 8 Tibial component

Figure 9 Assembly of Knee Joint

The model knee joint comprises of three main parts femoral, tibial and meniscus. The assembly of the 3D Printed knee joint is show in the figure 4.14. First the base and plastic section are attached together on the top of the knee is placed. The model of the knee joint prototype is similar to the human knee configuration. This prototype, a replication assembly model can be used for further studies where the prosthetic joints can be sophistically implemented based on analytical procedures to reduce the topological optimization, proper fitment studies and reduced clinical trials.

5. CONCLUSION

The prototype of knee joint is made by FDM technology because of the limitations of the normal manufacturing processes. The main concern in manufacturing process and Additive manufacturing is tool establishment and weight of the material. Hence Additive manufacturing an effective, novel, revolutionizing and rapidly growing technology especially in medical sector. Present study shows that the successful completion of prototype of knee joint using FDM technology. OSIRIX software is used to convert the MRT scan to STL file and file is imported to fusion 360 where the missing surface modifications are identified and regenerated to the required dimensions. However, the time consuming and surface finishing of the prototype is based on the FDM machine. This work on Knee joint can be used for further studies where the prosthetic joints can be sophistically implemented based on analytical procedures to reduce the topological optimization, proper fitment studies and reduced clinical trials.

6. REFERENCES

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