© December 2022| IJIRT | Volume 9 Issue 7 | ISSN: 2349-6002

# Modeling of a hip joint

Mr. R. Syam Sudhakar Rao
*Associate Professor, Guru Nanak Institutions Technical Campus, Ibrahimpatnam*

***Abstract*— The hip joint is a ball and socket type of synovial joint that connects the pelvic girdle to the lower limb. The hip joint is largely responsible for mobility. Nowadays many people are facing problems due to hip pain. Pain in the hip is mainly caused by types of arthritis such as osteoarthritis, rheumatoid arthritis, and ankylosing spondylitis. Also, sometimes this pain is caused by injuries, Bursitis, Structural abnormalities, and Perthes disease in childhood. Doctors replace the original hip joint with an artificial hip joint to relieve hip pain. They adopt a trial-and-error method during the selection of the artificial hip joint, which is almost identical to the original hip joint.**

**An important aspect of this paper is that CT scan digital images of the hip were taken and these images were measured using 3D slicer and 3D tool software. By using these measurements, 3D models of hip joint prosthesis were designed in CATIA V5 R20 software and all parts of hip joint prosthesis were fabricated in 3D printing machine. The prosthetic part of the hip is fabricated on a 3D printing machine using PLA material. It is mainly used for medical demonstration.**

***Index Terms*— Catia V5 R20, Hip joint, 3D Printing machine, 3D Slicer Software, 3D TOOL**

## I. INTRODUCTION

The hip joint is a ball and socket synovial joint, formed by an articulation between the pelvic acetabulum and the head of the femur. In vertebrate anatomy, hip (or "coxa" in medical terminology) refers to either an anatomical region or a joint. The hip region is located lateral and anterior to the gluteal region, inferior to the iliac crest, and overlying the greater trochanter of the femur, or "thigh bone".

## II. HIP JOINT STRUCTURE

The hip joint forms a connection from the lower limb to the pelvic girdle, and thus is designed for stability and weight-bearing – rather than a large range of movement. In the anatomy of the hip joint, it includes the articulating surfaces, ligaments, and neurovascular supply shown in the figure.

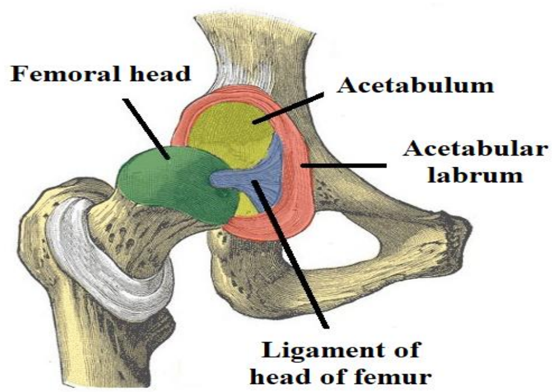



Fig 1. Structure of Hip joint

## III. IMAGES OF HIP JOINT

Common imaging tests used to diagnose hip disorders include X-ray, Ultrasound, Bone scan, MRI scan, and Arthrography.

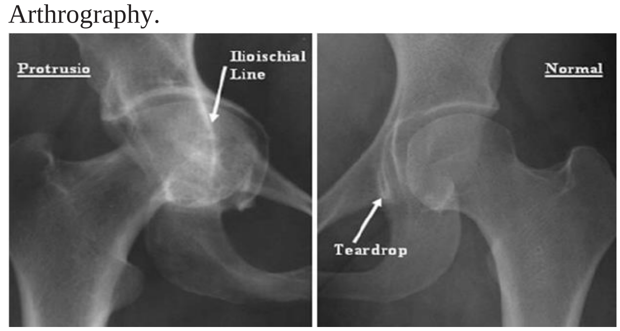



Fig 2. X-ray image of Hip joint


Fig 3. Ultrasound waves of hip deformation

Fig 4. Coronal MRI T1 WI

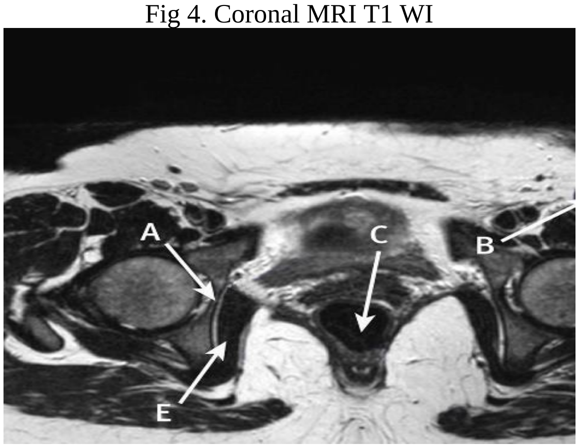



Fig 5. Axial T1 WI MRI

Fig 6. Coronal T2 WI MRI

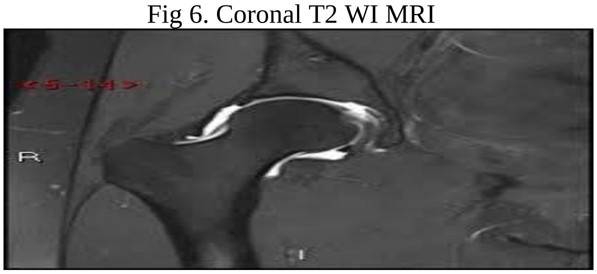


Fig 7. Arthrogram image of hip joint

## IV. MODELING PROCEDURE

Creation of a 3-D model in CATIAV5R20 can be performed using three workbenches i.e., sketcher, modelling, and assembly.

A. Modeling of Acetabular Component

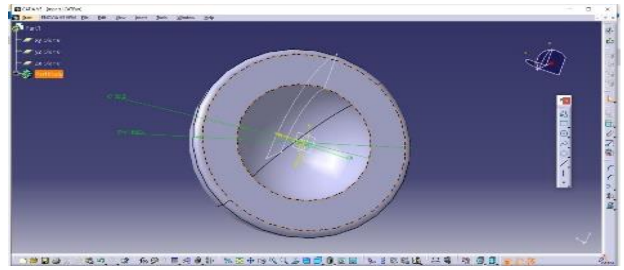


Fig 8. Acetabular component

B. Modeling of femoral head

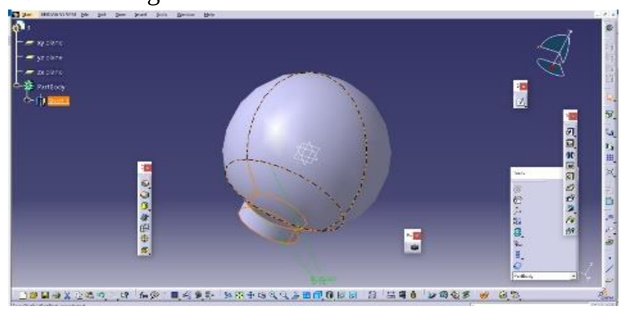


Fig 9. Femoral head

C. Support between the femoral head and the body

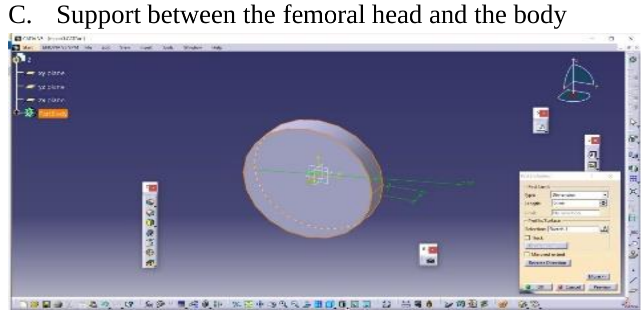


Fig 10. Support

D. Modelling of femoral stem

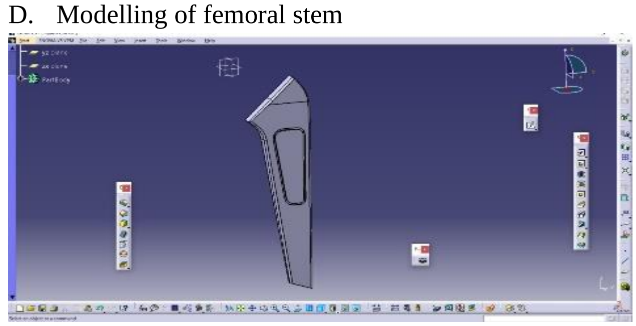


Fig 11. Femoral stem

E. Assembly of femoral head and stem

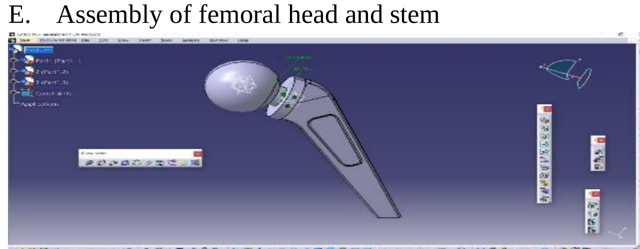


Fig 12. Hip joint

## V. FILAMENT MATERIAL SELECTION

PLA plastic or polylactic acid is a vegetable-based plastic material, which commonly uses cornstarch as a raw material. PLA is a fully biodegradable thermoplastic polymer consisting of renewable raw materials. Among all 3D printing materials, PLA is part of the most popular materials used for additive manufacturing.

Characteristics of Polylactic acid material

1) This material is used in thermoforming processes. It can be combined with other materials like glass fiber to create engineering resins.
2) Poly lactic acid is easy to print since it has low warping.
3) It can also be printed on a cold surface.
4) It can print with sharper corners and features compared to other materials.
5) This material is available in different colours.
6) Poly lactic acid is a user-friendly thermoplastic with a higher strength and stiffness.
7) Poly lactic acid filament is made from sugar cane and corn starch which is organic materials.
8) Poly lactic acid is considered safer than ABS in addition, it is easier and more convenient to use for 3D printing.

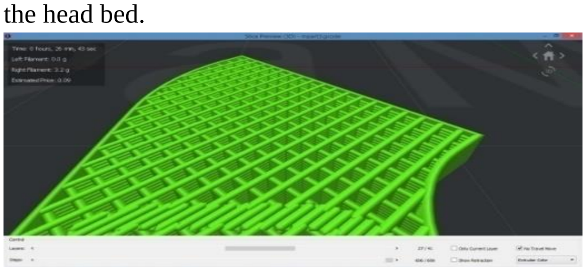
Physical and Mechanical properties

| Property | Units | PLA Material |
|---|---|---|
| Tensile strength | MPa | 59 |
| Elongation at break | % | 7 |
| Modulus of elasticity | MPa | 3750 |
| Density | $Kg/mm^3$ | 0.00105 |
| Colour | - | Various |

Table 1. Physical and Mechanical properties

## VI. 3D PRINTING

The STL files of the hip joint are sent to the Idea Maker software and adjust the position of the hip joint so that the maximum surface of the gear should touch the head bed.



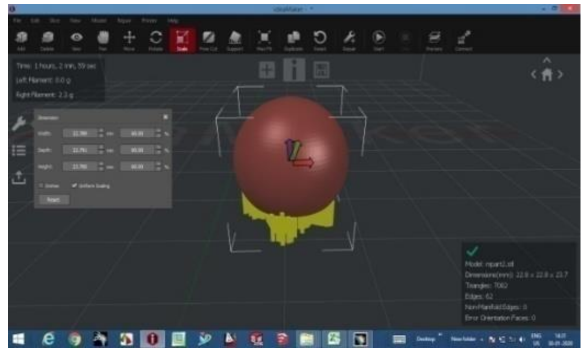


Fig 13. Opening the STL file in Idea maker

The hip joint size should be adjusted using the scale tool. Decreasing the scale from 100% to 25% reduces the size of the hip joint.

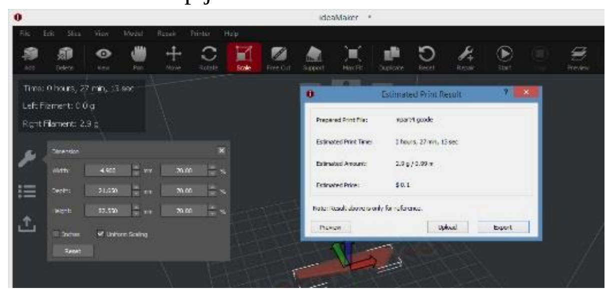


Fig 14. Adjusting the size of the Hip joint

After adjusting the position and scale of the hip joint in idea maker, proceed to making the slice. Then select High Quality- N2-PLA and click on Slice option.

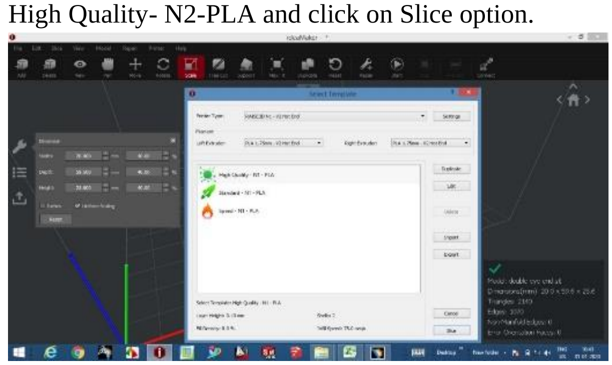


Fig 15. Selecting a quality of printing and editing of template

The hip joint is ready to be printed. Export the file to the printing machine.

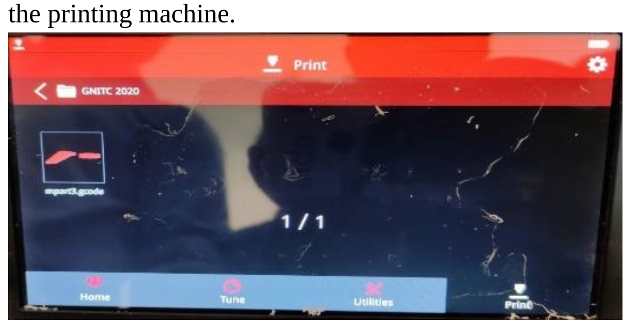



Fig 16. Exporting the file to 3D printer

For the final printing of the hip joint, the file is exported to a printing machine with PLA filament.

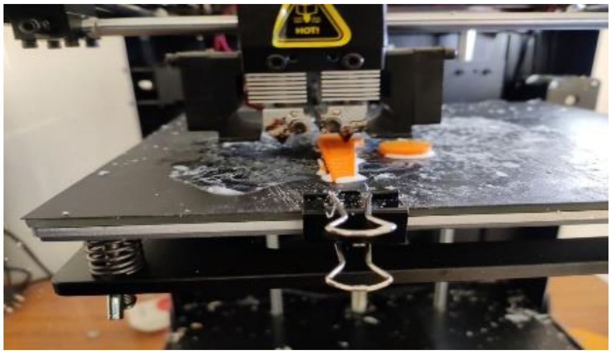


Fig 17. 3D Printing of Hip joint

## VII.RESULTS AND DISCUSSIONS

Values obtained while 3D printing the prototype of hip joint in 3D Printer (RAISE 3D N1 PRINTER):
Limits: 20×20×20 cm
Printer name: Raise 3D N1
Nozzles: 2
Nozzle Diameter: 0.41mm
Right nozzle temperature: 240$^o$ C
Left nozzle temperature: -
Heat bed temperature: 100$^o$ C
Filament type: PLA Plus
Nozzle feed rate: 100 mm/sec
Right Nozzle flow rate: 94
Scale: 60%
Fill density: 40%
Touch Platform: Heat bed

## HIP JOINT PROTOTYPE

Fig 18. Prototype of Hip joint

## CONCLUSION

The results of this study show the significant advantages of fused deposition modeling (FDM) as a method for manufacturing functional tooling. Among the benefits derived is a significant amount of cost and time savings. There is a huge difference in lead time and cost between the conventional tooling process and the rapid tooling process. In conventional process, the lead time is between 2-3 weeks, but in rapid tool it takes only 30 to 90 minutes. The manufacturing cost per part of FDM 3D printing is also lower than injection moulding.

It is also worth noting that the cost of 3D printed FDM tooling is at least 3 orders of magnitude lower than conventional metal tooling. However, the life of conventional metal tooling can also be significantly longer than that of 3D printed tooling, especially in the case of complex parts. However, 3D printed tooling is a viable option for low volume manufacturing.

Additionally, replacing conventional tooling with 3D printed tooling may be justified where frequent design modifications are expected. Due to the decreasing cost of 3D printing, rapid tooling has become economically viable and it also reduces lead time and provides the necessary freedom for design changes.

## REFERENCES

[1] AhnSung H, Lee CS, Jeong W. Development of translucent FDM parts by post processing. Rapid Prototype J. 2004; 10:218–224.
[2] Herbert N, Simpson D, Spence WD, Ion W. A preliminary investigation into the development of 3-D printing of prosthetic sockets. J Rehabilitation Res Dev. 2005; 42:141–146.
[3] Javaid M, Haleem A, Shuaib M, Kumar L. Product design and development using combination of Steinbichler comet 3D scanner and projet 3D printer. In: National conference on innovative trends in Mechanical Engineering-2017 held at Department of Mechanical Engineering, Shri Mata Vaishno Devi University Katra, Jammu, from 3–4 March 2017.
[4] Song C H, Yang Y Q, Wang Y, Yu J K, Wang D. Personalized femoral component design and its direct manufacturing by selective laser melting. Rapid Prototyping Journal, 2016, 22, 330–337.
[5] Dong CH, Wang ZM, Zhao XL and Wang AM. The use of damage control orthopaedics to minimize negative sequelae of surgery delay in

elderly comorbid patients with hip fracture. Eur Rev Med Pharmacol Sci 2016; 20: 2505-2514.

[6] Negi S., Dhiman S., Sharma R.K. Basics and applications of rapid prototyping medical models. Rapid Prototyping J. 2014; 20:256–267.

[7] Salmi M., Tuomi J., PaloheimoKaija S. Patient-specific reconstruction with 3D modelling and DMLS additive manufacturing. Rapid Prototyping J. 2012; 18:209–214.

[8] Arrieta, C., Uribe, S., Ramos, G., et al.: Quantitative assessments of geometric errors for rapidprototyping in medical applications. Rapid Prototyp. J. 18, 431–442 (2012)

[9] Won SH, Lee YK, Ha YC, Suh YS and Koo KH: Improving pre-operative planning for complex total hip replacement with a Rapid Prototype model enabling surgical simulation. Bone Joint J 95-B: 1458-1463, 2013.

[10] Malley OF. Research to inform the improved accuracy of zygomatic implants placed using computer design and additive manufactured surgical guides. In: ADT 5th triennial congress Beijing, China 6th–8th September 2014.

[11] Anthony, R. W., Evans, M., Rennie, A. E. W., Kirkby, E. (2011). Opportunities offered by additive manufacturing in creative businesses: informing designers. In DS 69: Proceedings of E&PDE 2011, the 13th International Conference on Engineering and Product Design Education, London, UK, 08.-09.09. 2011.