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Analysis of Human Bone, Implants and Development of Artificial Bone by Rapid prototyping (3D Printing) Technology

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Abstract

The replacement of damaged bone is done by design of bone then analyzing its properties, In Human body Bone plays important role in body. Which support & protect body parts. Bones comes in a variety of shapes and sizes and has complex internal and external structure. During daily activities, the skeletal system is subjected to a complicated loading exerted by the different loading conditions. Such loading modes for femur bones are include tensile, compressive, bending, and torsional forces applied to the bones of the skeletal system. In this project we have done FEA Analysis with different materials like Stainless steel, Titanium, ABS, PLA and develop artificial bone by 3D printing technology. The aim of this work is analysis & manufacture femur bone which can replace characteristics. Then it is to be printed by 3D Printer as prototype model.

Keywords: Analysis Femur Bone, 3D Printing, Artificial Human Bone etc.

1. Introduction

It is important in body to distribution of load. Bone structure is such that it is rigid, which will sustain the static or dynamic load during daily activities. The femur bone is the longest bone in a human body and is of utmost important as most loaded bone. This bone always under stress and the stress is axial. Internally connected with hip bone, where the ball of femur fits in the socket of pelvis bone with the help of muscles. Secondly it is externally connected through cortical bone. Connected to the shank bones or the tibia and fibula and the patellar ligament or the Kneebone it present in the front to protect the joint [1].

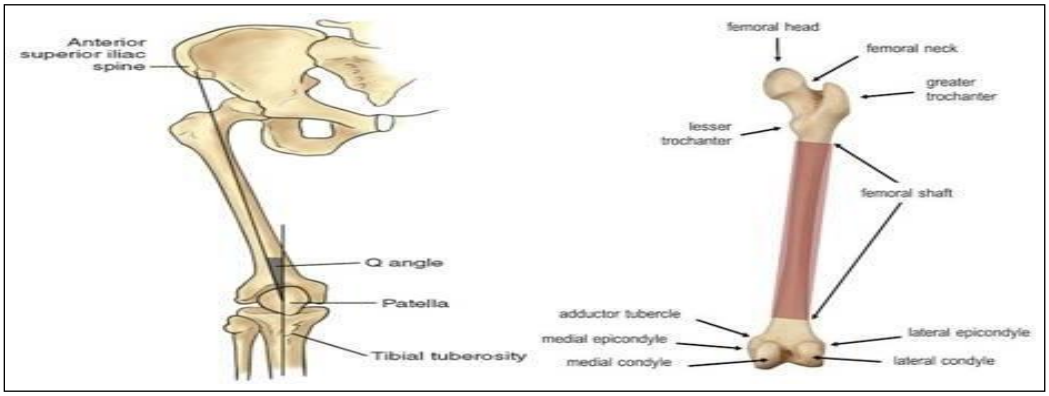

Figure 1: Femur Bone and its actual position in human body

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The entire structure of bone is made by cortical and trabacular bone. Where cortical bone is covered external part of bone [2]. It is a stiff bone and porosity of about 5 to 10%. The porosity of the bone is measured. The porosity is defined as the measure of the void (i.e. empty) spaces in a material, is a fraction of the volume, between 0-1, or as a percentage between 0-100 percent. The term is used in multiple fields including pharmaceutics, materials, manufacturing, earth, sciences, soil mechanics and engineering. The cortical bone is much denser, stiffer and stronger than the trabecular bones. On the other hand, the trabecular bone has a higher surface area and is known to be extremely porous. Spongy bone is called highly vascular and it is responsible for blood cell production. cancellous bone is one of two types of osseous tissue that form bones. If compared with cortical bone, which is other type of osseous tissue, it has a higher surface area but is less dense, softer, weaker, and less stiff. This found at the ends of long bones, proximal to joints and within the interior of vertebrae. Cancellous bone is highly vascular and frequently contains red bone marrow where hematopoietic, the production of blood cells, occurs [3]. The primary anatomical and functional unit of cancellous bone is the trabecular so it is important to analysis of the failure behaviour of bones under all of these loading Conditions. Also, important to develop artificial bones which can easy manufacture with less time and can be replace instead of damaged bone.

2. Literature review

Table 1: Related papers

Sr. No.	Name of Research Paper	Author Name	Published Year
1	New Methodology for Diagnosis of Orthopedic Diseases through Additive Manufacturing Models.	Leonardo Frizziero, Giampiero Donnici.	April 2019
2	Bio-Modeling and Biomechanics Of Ilium and Femur Bones.	K Michael, Jai Kumar.	October 2018
3	Novel Biomaterials Used in Medical 3D Printing Techniques	Karthik Tappa, Udayabhanu Jammalamadaka,	January 2018.
4	Application of 3D Printing for Human Bone Replacement.	Azem Yahamed, Pavel Ikonomov.	January 2015
5	FEA analysis of a femur to deconstruct the paradox of bone curvature	Sameer Jade , Kelli H. Tamvada	2014

3. Problem definition

- Now day's implants are available but they are costly and require more time to manufacture comparatively artificial bones.
- It is important to analysis of human bone, implants in order to Design & develop artificial bone and to do so currently there is no artificial bone which can replace metallic implants instead of fracture bones.

4. Numerical analysis

CT scan data in DICOM format then from mimics software convert point data to surface model and Solid Design of human bone in 3D CAD software & analysis by FEM method in analysis software [4]. Using this cad model and import into Rapid prototyping (3D printing) machine. This will create artificial bone. In order to fabricate artificial bone, the AM technique is applied to the bio-fabrication process, this process is known as Bio- Additive Manufacturing (BAM). Different from previous construction methods, BAM uses computer aided design technology to realize the customized manufacture of the bone defect, with an internal 3D-structure that is also similar to the human bone.

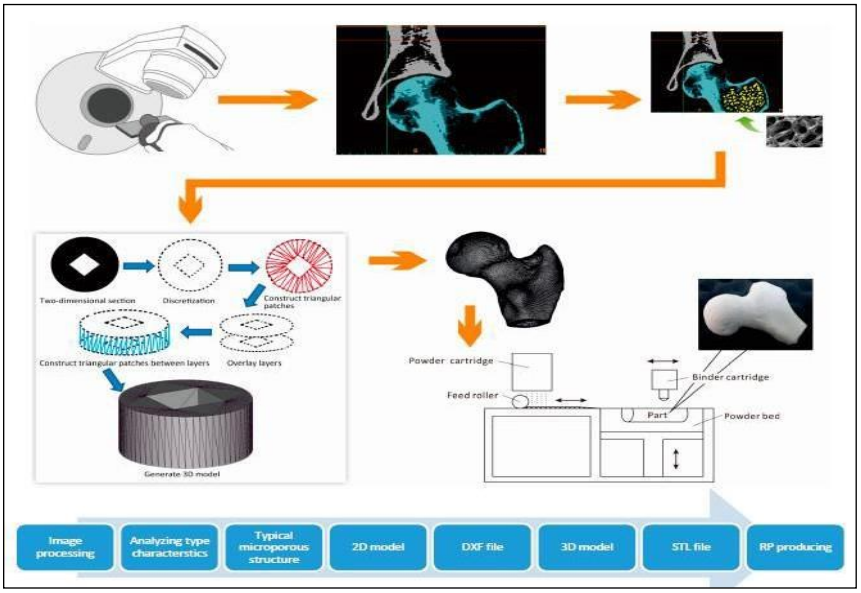

Figure 2: Bionic design and manufacturing process of the inner microstructure of artificial bone scaffold

4.1. Block diagram of process

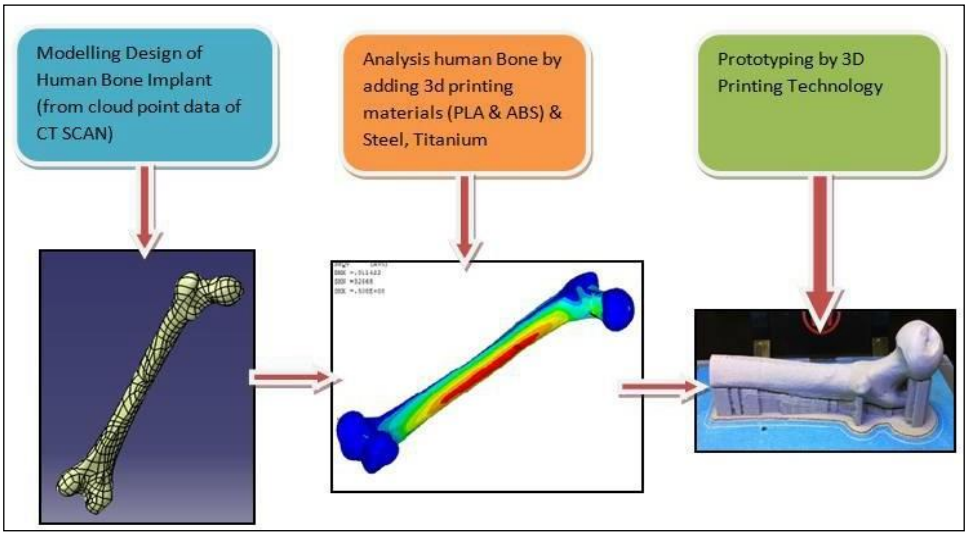

Figure 3: Block Diagram of the process

4.2. Point data converted into 3D model

The point cloud is a set of data points in some coordinate system. In 3D coordinate system, these points are defined by X, Y, and Z coordinates, and often is intended to represent the external surface of an object. Point clouds may be created by 3D scanners [5]. Which measure in an automatic way a large number of points on the surface of an object, and often output a point cloud as a data file. These points are represents the set of points that the device has measured. As the result of a 3D scanning process point clouds are used for many purposes, including creating 3D CAD models for manufactured parts, metrology/quality inspection, and a multitude of visualization applications. The point clouds are not directly usable in 3D applications due to this they converted to polygon or triangle mesh models or CAD models through a process commonly referred to as surface modeling reconstruction. There are many options for converting a point cloud to a 3D surface. Some examples Delaunay triangulation, ball pivoting and alpha shapes build a network of triangles over the existing vertices of point cloud [6]. The another option to convert the point cloud into a volumetric distance field and reconstruct the implicit surface so defined through a marching cubes algorithm. While the point clouds will also used to represent volumetric data for example in medical imaging [7]. The point clouds multi-sampling and data compression are achieved.

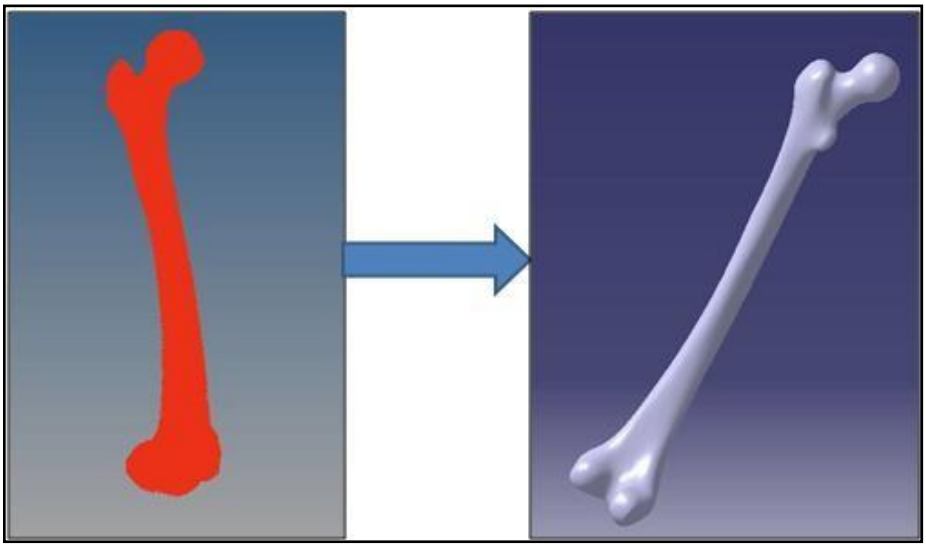

Figure 4: (a) Cloud point data model, (b) Modeling of Human Femur Bone

4.3. Analysis of Bone Implant by FEA

The file is imported to the ANSYS software Then generate option is clicked. Now the model is ready for analysis. The imported geometry in ANSYS is shown in Fig. 6. Femur was assumed to be isotropic and linearly elastic and the material properties for the cortical bone [8].

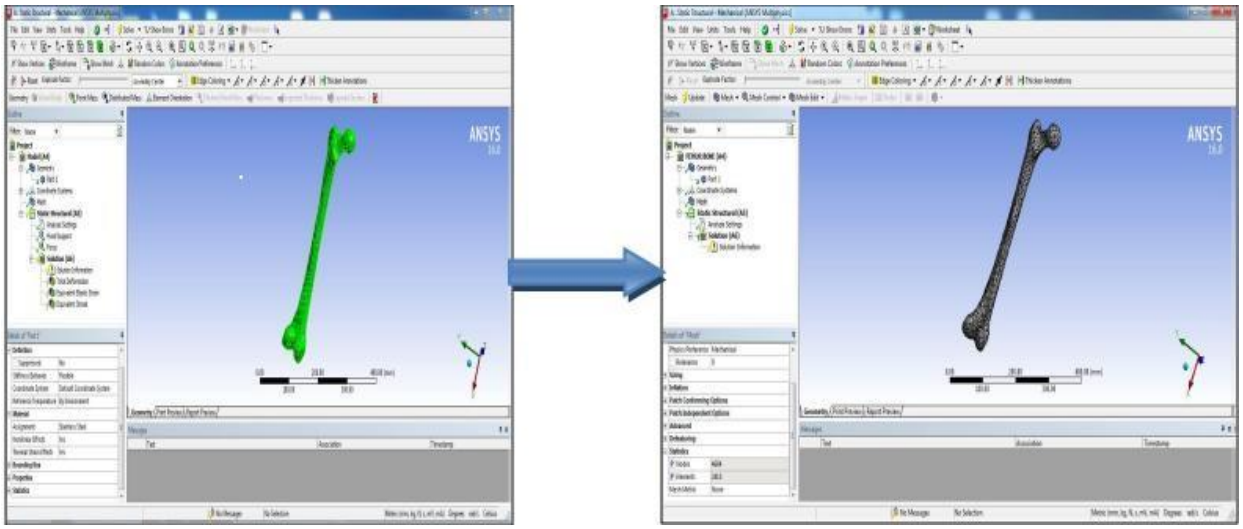

Figure 5: (a) Imported geometry in Ansys, (b) Meshing Model (Nodes-4604 and Elements 2415)

4.4. Boundary Conditions and results

Femur bone is inflexible condition and the analysis of geometrical model is subjected to eccentric and concentrates loading conditions. In this boundary condition applied load of 250N, 500N and 1000N applied on the head bone and fixed support is provided at lower surface.

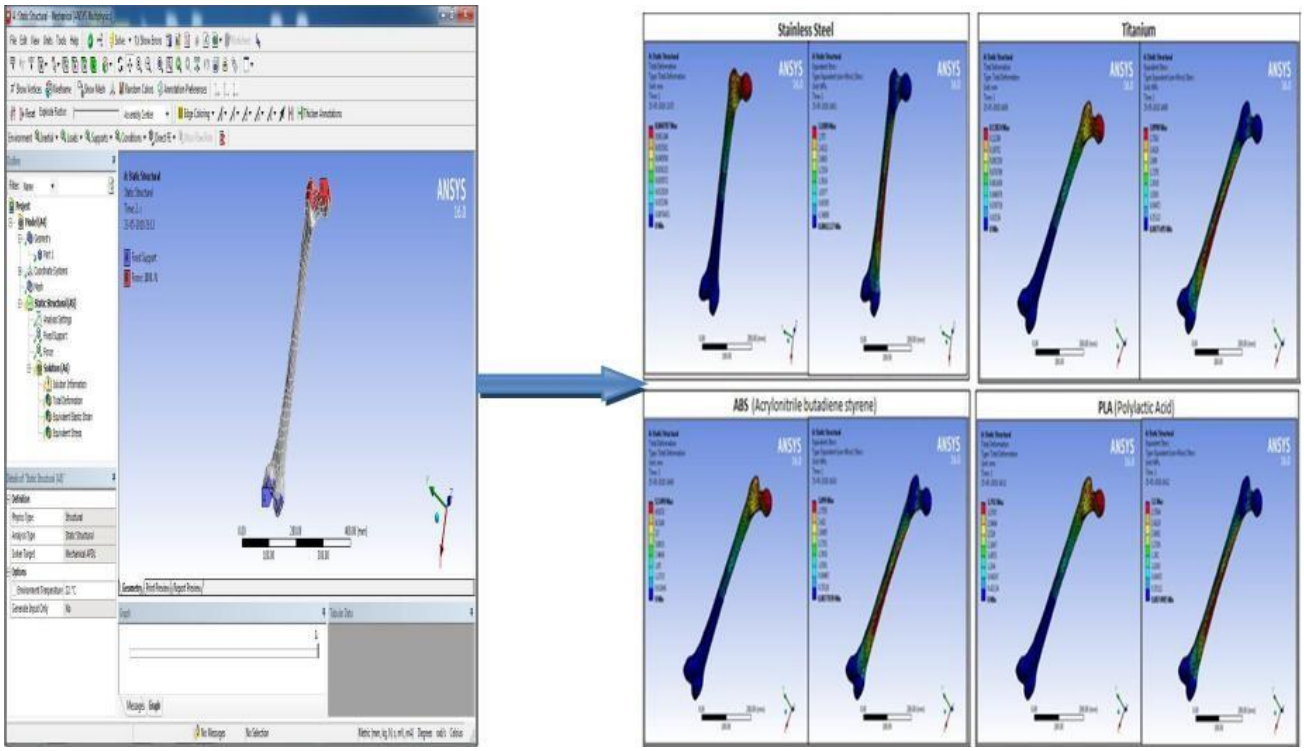

Figure 6: Boundary Conditions and result

5. Results and discussion

Table 2**:** Analysis result with different loads and material

Material	Load (N)	Von-Misses Stress (MPa)	Deformation (mm)
Stainless Steel	250	3.1009	0.068787
	500	6.2018	0.13757
	1000	12.404	0.27515
Titanium	250	3.0998	0.13824
	500	6.1996	0.27648
	1000	12.399	0.55295
ABS (Acrylonitrile, Butadiene and Styrene polymers)	250	3.099	5.5499
	500	6.1979	11.1
	1000	12.396	22.2
PLA (Polylactic Acid-thermoplastic polymer)	250	3.1	3.792
	500	6.2001	7.584
	1000	12.4	15.16

5.1. Rapid prototyping Technology (3D printing)

The technology is additionally called Additive Manufacturing Technology (AM), refers to processes used to create a three-dimensional object in which the layers of material are formed under computer control to create an object. Any shape of object or geometry and they are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file. Stereo Lithography (STL) is one of the most common file types that 3D printers can read. 3D printing or AM builds a three-dimensional object from computer-aided design (CAD) model or AMF file by successively adding material layer by layer.

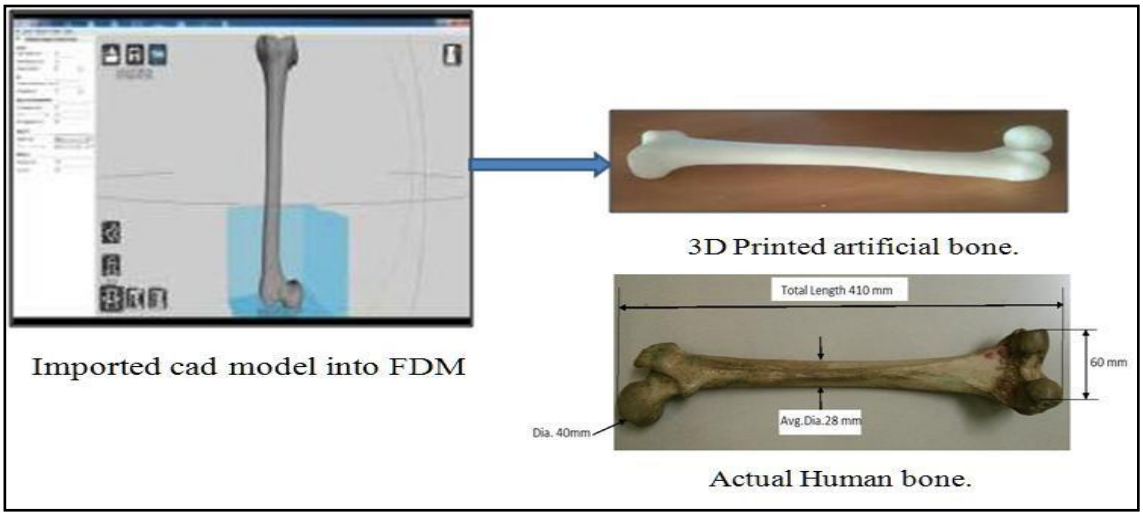

Figure 7: Final result after 3D printing

6. Conclusion

Currently, there are only a limited number of biodegradable polymers available for 3D printing. Most of those 3D printing biomaterials are used for either drug delivery or space-filling implantation function purposes. Therefore, there is significant would like for analysis to fabricate biopolymers with tuneable bio-properties which will restore practically at the positioning of application. Inexpensive, readily available lactic acid based polymers (such as PLA and PCL) are focused on, mainly due to their abilities to perform well in most types of 3D printing technologies. Additionally, they have excellent mechanical and biodegradable properties. These polymers are mixed with ancient biomaterials (such as HA, TCP) and used as composites to provide higher printability, mechanical stability, and greater tissue integration for orthopaedic applications.

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