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# ANALYSIS OF CUSTOM MADE IMPLANT USING FEA

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**ABSTRACT**
*Metal orthopedic implants have been used for many decades with great success. Replacement joints and plates for bone fractures are usually made from biocompatible material. Through recent advancements in bio-modeling, custom orthopedic implants can be designed. Finite element analyses (FEA), in the design implant a near optimal fit between the patients in bone. In this paper analysis of custom made implant of lower limb is conducted. A case study of patient lower limb data of a bone is taken from x-ray. The cad model is prepared from the modeling software and analysis is conducted using the data calculated and data analyzed by using FEA software. The comparison of analytical and actual data was compared.*
**Keywords**: Custom made implant, CT and X- ray scan, CAD model, FEA.

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## INTRODUCTION

The custom-made implant, it is not popular for the normal patients, but the custom-made implant must fit and fill the maximum medullar shape design of custom made implant. Computer Tomography (CT) or x-ray medical imaging is a diagnostic technique which examines the inner body structures. In this paper case study of patient, to aim design of cad model from collection of patient data from computer Tomography (CT) or x-ray under guidance of physician.

DEIGN OF CUSTOM IMPLANT

Implant means - An orthopedic implant is a medical device manufactured to replace a missing joint; In other word, to support a damaged bone, enhance an existing it has a manmade device [1]. biological structure. Internal fixation is an operation in orthopedics that involves the surgical implementation of implants for the purpose of repairing a bone. Among the most common types of medical implants are the pins, rods, screws and plates used to anchor fractured bones while they

heal. [2]

What is custom implant?

Custom made implant is specifically made in accordance with a request by a health professional specifying the design characteristics or construction of the medical device; and is intended to be used only in relation to a particular individual.

Principal benefits of customized implants are:

a.Less time in surgery -

b.Faster recovery

c.Greater range of motion

d.A longer-lasting implant

e. No compromise with the size of the implant.

f. Provides better fit of the implant as the implant conforms to the patient's unique

g. Preserves more natural bone

PROCESS OF DESIGN CUSTOM MADE IMPLANT

As per the benefits, design of custom implant we have knowledge of anatomy of joint that we have replace. The leg is the lower limb of the body that supports the body when standing and provides the ability to walk, run, jump, and other movements. The leg extends from the hip joint to the ankle, which includes the largest bone in the body. The leg is composed of five sections: upper leg, knee, lower leg, ankle, and foot. The upper leg begins at the hip and continues down to the knee. The sole bone in this region is the femur, the largest bone in the body. The femur's head creates the ball of the ball-and-socket-style hip joint [3]. The base of the femur makes up part of the knee. The knee is a complex pivotal hinge joint in the leg that connects the bones in the upper and lower leg. It is the largest joint in the human body. The knee is where the femur in the upper leg meets with the tibia and fibula bones in the lower leg. Another bone, the patella or kneecap, is at the center of the knee. The lower leg contains two bones. The tibia is the second largest bone in the leg. It meets the femur to create the knee. The fibula, the other bone in the lower leg, is connected to the tibia below the knee joint. It stores the elastic energy needed for running, jumping, and other physical activity [4]. The ankle is where the tibia and fibula meet the foot. Containing seven bones and numerous other structures, the ankle rotates and flexes the foot, which is important for movement and balance.

Custom made implant, must need data patient such as age, weight, height, length of bone measured and other. This includes, data collection from patients for design of implant, bio mimetic shapes based on measured data, biomechanics studies for functional and motions, mechanical design based on basic shapes and motion requirements revealed during biomechanics study (since natural joint's bones are coupled by ligaments), material selection (biocompatible, high strength to weight ratio).

Computer Tomography (CT) or x-ray medical imaging is a diagnostic technique which examines the inner body structures through two-dimensional X-ray images, This technology is particularly used to the good contrast between bones and the X rays; on the other side, it is an invasive medical diagnostic technique, which must be used with care X-ray exposure [5].

Modeling involves using a set of measured anthropometric parameters to construct a CAD (Computer Aided Design) model of implant. This will be a 3-dimensional computerized model of the actual bone. Recent advances in computing technologies both in terms of hardware and software have helped in the advancement of CAD in applications beyond that of traditional design and analysis. CAD is now being used extensively in the biomedical industry in applications of clinical medicine, customized medical implant design. This has been made possible due to developments in

imaging technologies. The primary imaging technique is CT or X-ray etc [6].

Customization implant can be achieved using different design tools and patient data. The data used is dependent on the implant being designed. Typical data may include patient age, weight, activity, and others, coupled with the natural bone design, to create a solid model of implant. There was many software that can be used by many researcher for modeling a human joint like CATIA, PRO-E, AUTOCAD, SOLIDWORKS etc. This software is programmed for designing perfect parts. CATIA provides a unique set of tools that provide benefits like faster design, reduced lead times, quality of surfaces, associative drawings and innovative solutions. Moreover, CATIA V5 R20 has been widely used for modeling biomechanical prosthesis and implants [7].

Finite element (FE) analysis has a popular technique in the study of human joint biomechanics, as it allows for detailed analysis of the joint behavior under complex, clinically relevant loading conditions. In the finite element analysis, the IGES files of implant are imported to the ANSYS V14.0 software. FEA is a computational technique that is used and calculated critical loads and weights are applied on it for the results in terms of equivalent von-mises stresses. It is possible to analyze computes the stress, strain, forces and other parameter [8].

## MATERIALS AND METHOD

### PATIENT HISTORY

A 65 year old man, suffering from a pain in his right leg knee from last six years, his knee was operating two times as per physician discussion and history of patient. Both surgery was fails because there no such improvement in curing the knee pain. The physician observed that there is no improvement and continuously wearing in tibia and femur bone. After repetitive surgery on knee joint, which was discarded component of the patient, the patient has again faced another accident his result in dislocation of patella and chance of getting it cured, by orthopedic surgery where reared after ortho investigation orthopedic surgery traced on the necessity of custom made implant.

X- RAY SCAN DATA


**Figure 1: X-ray of lower limb using custom made implant of stainless steel material (316L)**

**Figure 2: Customized implant in lower limb after surgery of patient in right leg, fixing at both end by nail**

Pre-operative radiological measurements, from x-ray to calculate physical data and history of patient in lower limb right leg, physical data of patient given by physician, length of tibia15.5 inch (393 mm) ,length of femur 17 inch (432 mm) Height 5.7' weight 65kg total length of leg is 852mm long, implant being designed.

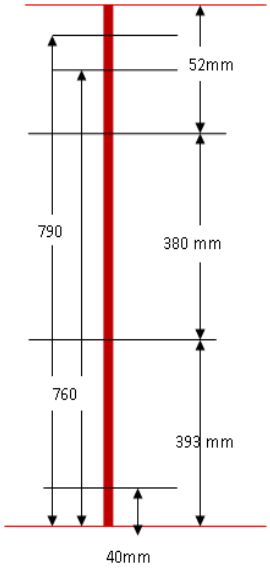


**Figure 3 Free body diagram of Custom made implant**

ANALYTICAL METHOD

The manners of securing the end connection of strut /column are termed as end condition /end construction. One or both the end may be fixed in position and are free in direction. Such as end condition is called hinged end. y is lateral displacement of vertical axis of column ,then in case of hinged end

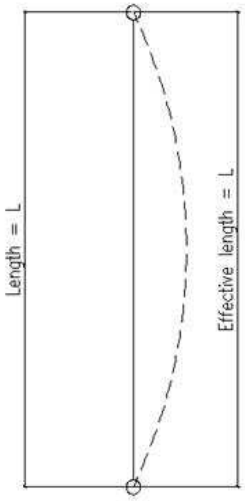


**Figure 4 Condition for buckling of column both ends are pinned**

Slenderness ratio defined as, $= \frac{\text{Height if column}}{\text{Least radius of gyration}} = \frac{l}{k}$

As per condition of slenderness ratio, slenderness ratio is greater than 120, so the critical load is calculated using the Euler's formula.

$$Pcr = \frac{n\pi^2 EI}{L^2}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{\pi^2 E}{(\frac{l}{r})^2}$$

where,

$\sigma_{cr}$ - critical bucking stress
$P_{cr}$- Critical buckling load
E - Modulus of elasticity
I - Moment of Inertia
A - Cross sectional area

FINITE ELEMENT ANALYSIS

FEA models of body structures utilizing information of CT or X ray data other imaging data considered. CAD data (also in IGES) can be corrected and converted into a format acceptable by various FEA software packages. For the finite element analysis of implant, the IGES files of model was imported to the ANSYS 14.0 software and various critical loads and weights are applied on it to see the results in terms of equivalent von-mises stresses. FEA is a computational technique that is used to solve real problems. It is possible to analyze computes the strain developed in an implant when subjected to a force or stress.

**Table 1: Boundary conditions for analytical and FEA**

| Parameters | Analytical and FEA |
|---|---|
| Force in N | 1621.03 |
| Passion ratio | 0.25 |

| | |
|---|---|
| Tensile strength Mpa | 170 |
| Modulus of Elasticity Gpa | 200 |
| Density of material kg/$m^3$ | 8027.17 |

## RESULTS AND DISCUSSION

Custom made rod in lower limb designed in CATIAV5R20 proves to be a good representation of the lower limb geometry but it is not enough for further analysis. An accurate method of modeling would be to reconstruct the femur bone from X-ray data. The stress response can then be observed by actually inserting the implant into the bone as done during surgery. Table 2 shows the results obtained by analytical and finite element analysis.

**Table 1: Stress obtained using analytical and FEA**

| Results | Analytical method | FEA |
|---|---|---|
| Stress N/$mm^2$ | 19.342 N/$mm^2$ | 18.778 N/$mm^2$ |

The results shown in table 1 of analytical and finite element analysis the stress obtained matched of about 82%.

## CONCLUSION

FEA analysis of custom made implant gives us better and easy method of replacement of rod in lower limb. With the accurate and exact size of joints so that patient can have minimum complications such as infection, blood clotting, loosening, dislocations. It is not easy to produce implant with high accuracy and finish. Bone material is best suited to human body, but there is no availability of natural bone materials. It is found that Stainless steel 316L material is best suited for custom made implant in human body. Hence it is retrieved that the custom made implant can change the life of our patient.

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