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Finite Element Analysis of HIP & TMJ Implants Used in Human Body

Prashant Vijay Patait M.E. student, SGDCOE, Jalgaon, M.S., India

Prof. Raghunath Y. Patil H.O.D. and Asst. Professor, Mechanical Department, SGDCOE, Jalgaon, M.S., India

ABSTRACT *Aim of this work is to study & analysis Hip & TMJ implant used in human body. The study is conducted in three steps. First step is the measurement of the shape and size of the implant using commercial implants available in market. Second step is drafting of the implant using CAD (Computer Aided Design) software. Next step is importing the CAD model of the implant into ANSYS, Finite Element Analysis (FEA) software. After setting up various boundary conditions, the implant are analyzed and the stresses developed in the implant are obtained*

KEYWORDS :

1) INTRODUCTION

In human body there are various joint but following Hip joint is important in human body. There is one bone which connects the knee with hip is known as Thigh bone which also called as Femur. Femur is a largest and heaviest bone in the skeleton. There are two femurs in human body each of which carries half weight of human body, so weight is not cause of failure of hip joint

TYPES OF FEMUR BONE FRACTURE

The femur is one of the largest and strongest bones in the body. The femur is the Thigh bone it extends from the hip joint down to the knee joint. A femur fracture occurs, either a large force must be applied or something is wrong with the bone. The most common causes of femur fractures include

- Accidents
- Fall from a height

Many types of fractures about the hip joint are known as 'hip fractures'.

The following femur fractures are commonly referred to as hip fractures. The differences between them are important because each factures treated differently.

- Femoral head fracture consists of fracturing the femoral head. This is a result of high energy shock and a dislocation of the hip joint often accompanies this fracture.
- Femoral neck fracture denotes a fracture between the head and the greater trochanter. These fractures have a tendency to damage the blood supply to the femoral head, due to death of cell tissue associated with vessels.
- Intertrochanteric fracture denotes a break in which the fracture line is between the greater and lesser trochanter on the intertrochanteric line. It is the most common type of 'hip fracture' and it is avoided if the patient is healthy otherwise bony healthy.

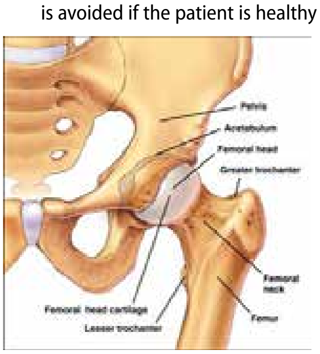


Figure 1 Normal working hip

PATHOGENESIS/RISK FACTOR

- Subtrochanteric fracture actually involves the shaft of the femur which is immediately below the lesser trochanter.
- Osteoarthritisis the main reason of hip failure, where the cartilage of a person is broken down. Cartilage is the connective tissue that covers the head of the hip bones. When the cartilage is being worn away, the femoral head and the acetabulum will rub one another. This will cause wear on the bone Hip OA is a disorder of the entire joint, involving cartilage, bone, synovium, labrum, and capsule
- Metastatic cancer deposits in the proximal femur may weaken the bone and cause a Pathological hip fracture.

2) IMPLANTS

An object made from non-living material that is deliberately inserted by a surgeon into the human body where it is intended to remain for a significant period of time in order to perform a specific function.

Metallic Biomaterials

The materials that are used as biomaterials include polymers, metals, ceramics and composites. The metals used as biomaterials include titanium and its alloys, cobalt-chromium alloys, stainless steels, gold, silver and platinum. Out of those metals, the SS 316L is one of the most commonly used biomaterial.

Figure 2 Degenerated hip

3) TEMPOROMANDIBLE JOINT ANANTOMY

A) TEETH

The human skull is composed of an upper jaw, lower jaw, and teeth. There are thirty-two teeth, sixteen top and sixteen bottoms, in the jaw. There are two main tooth sections, the crown and root. The crown is the part of the tooth that can be seen above the gum line while the root is hidden in the jaw.

B) BONES
The bones act as the structural support to the body. The three main structural components in the skull associated with mastication are the lower jaw (mandible), the upper jaw (maxilla), and the lateral side of the skull (temporal) as shown in Figure.1

C) BLOOD VESSELS AND NERVES
Like any other portion of the body the jaw is surrounded by blood vessels and nerves. The blood vessels carry blood to the muscles and bones, supplying them with necessary nutrients such as oxygen. The nerves work as the communication system between the brain and all parts of the body.

D) LIGAMENTS
A ligament is a band of fibrous tissue that attaches bone to bone or bone to cartilage. The purpose for ligaments in The TMJ is to guide and prohibit excessive movements of the mandible while also protecting sensitive tissues such as nerves and blood vessels.

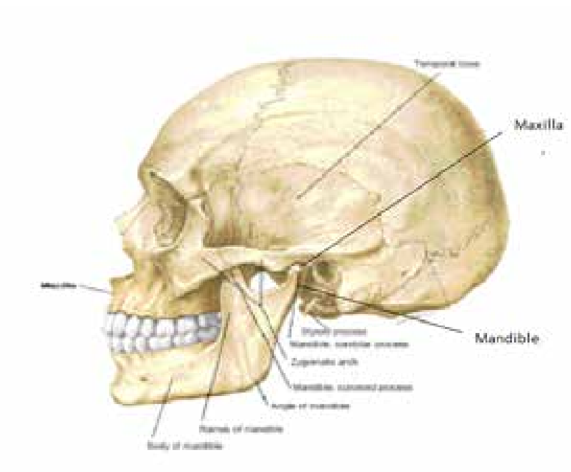


Figure 3 Side view of human skull showing masticator bone structures

Disorders of the jaw joint and chewing muscles—and how people respond to them—vary widely. Researchers generally agree that the conditions fall into three main categories: [1]

- Myofascial pain, the most common temporomandibular disorder, involves discomfort or pain in the muscles that control jaw function.
- Internal derangement of the joint involvesa displaced disc, dislocated jaw, or injury to the condyle.
- Arthritis refers to a group of degenerative/inflammatory joint disorders that can affect the temporomandibular joint.

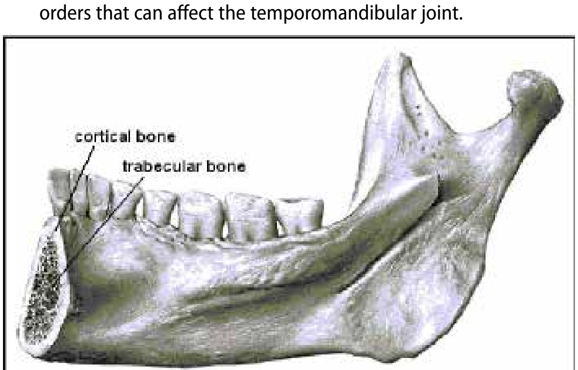


Figure 4. The bone structure of the human mandible

4) MATERIAL AND METHOD.
Metallic Biomaterials

A biomaterial is a synthetic material that is used to produce artificial parts as a substitution to the failed human body parts in a safe, reliable, economic and physiologically acceptable manner. It is always in intimate contact with living tissue. The materials that are used as biomaterials include polymers, metals, ceramics and composites. The metals used as biomaterials include titanium and its alloys, cobalt-chromium alloys, stainless steels, gold, silver and platinum. Out of those metals, the SS 316L is one of the most commonly used biomaterial.

Stainless Steel

Stainless steel is a very strong alloy, and is most often used in implants that are intended to help repair fractures, such as bone plates, bone screws, pins, and rods. There are many different types of stainless steel, the austenitic stainless steelespecially 316L most widely used for implant fabrication, because it has following advantage. [2]

- Possesses better corrosion resistance than any other steel.
- The inclusion of molybdenum enhances resistance to pitting corrosion in salt water.
- Fatigue resistance.
- Easy to manufacture.
- Easy to available

PROPERTY	Material		
	SS 316L	Ti-6Al-4V	Co-Cr-Mo
Yield Strength (MPa)	690	795	450
Ultimate Tensile Strength(MPa)	635	860	655
Elongation (%)	12	10	9
Elastic Modulus (Gpa)	190	114-120	220-240
Density (g/Cm^3)	7.9	4.5	8.3
Cost (Rs)	Less	More	More

Table 1. Properties of Some Metallic Biomaterials (ASTM 1980)

Above Table 1 shows comparative study of Biomaterials which are used for manufactured an implant.

Titanium Alloy

The advantage of Titanium alloy is it is light in weight and having a good physical properties, but titanium has poor shear strength. This characteristic makes it less desirable for bone screws and plates. It also tends to affect suddenly when in sliding contact with itself or other metals.

Following table 1shows the comparative study of Metallic Biomaterials which are used for manufactured an implant.

5) SOLID MODEL
Creating solid models of hip prosthetics, TMJ prosthetics etc. The PRO/E software offers several different approaches to develop a solid model of prosthetics like part design, surface design etc. A 3D model was developed from the existing the real implant. The measurements of the individual components were measured using the vernier calliper, and a solid model was created using Pro-E 4.0. Once all the components were modelled, each component was taken into the assembly module of Pro-E 4.0 and it was assembled to get a complete assembly of the standard artificial implant.

Hip and TMJ Implant

Modelling of hip implant requires following steps:

1. Getting a 2-D (Two Dimensional) sketch of an implant.
2. Operations carried out in Pro/E WILDFIRE 4.0:-
a) Sketching
b) Dimensioning
c) Revolve

d) Protrusion id 98
e) Extrusion
f) Mirroring
g) Draft
h) Round

3. Save drawing as Pro/E part file and IGES file format, for analysis purpose.

Figure 5 Metallic Hip Implant and CAD Model of Hip Implant

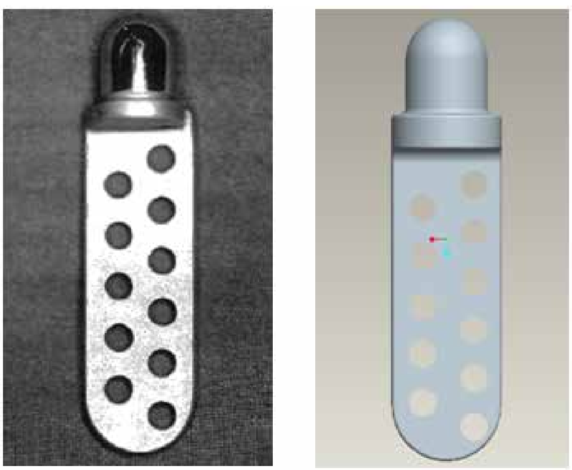


Figure 6 Metallic TMJ Implant and CAD Model of TMJ Implant

6) ANALYSIS OF HIP IMPLANT

Load (N)	Deformation (max) mm	Shear Stress (max) mpa	vonmises Stress (max) mpa
500	0.002408	16.852	50.322
1000	0.004816	33.708	100.64
1500	0.007225	50.587	150.97

Table 3. Analysis Results for Hip Implants (SS 316L)

In femur analysis first import a femur model in ANSYS software in .sat file format then material is selected for femur implant, after selecting material an implant divided into a small number of solid finite elements, this processes known as meshing. A load (500N, 1000N, 1500N) is applied on implant by fixing its one end and then behavior of each element is analyzed. Table No. 3 shows Hip Implant (SS 316L) result after analysis.

Load (N)	Deformation (max) mm	Shear Stress (max) mpa	vonmises Stress (max) mpa
500	0.00049261	7.049	19.754
1000	0.00098522	14.098	39.509
1500	0.0014778	21.147	59.263

Table 4. Analysis Results for Hip Implants (Co-Cr-Mo)

Load (N)	Deformation (max) mm	Shear Stress (max) mpa	vonmises Stress (max) mpa
500	0.0038877	16.978	50.936
1000	0.0077468	33.956	100.64
1500	0.01162	50.934	150.97

Table 5. Analysis Results for Hip Implants (Titanium alloy)

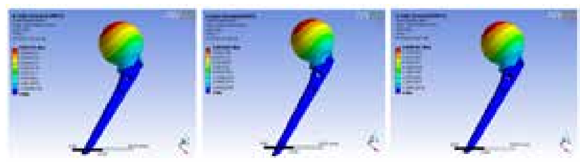
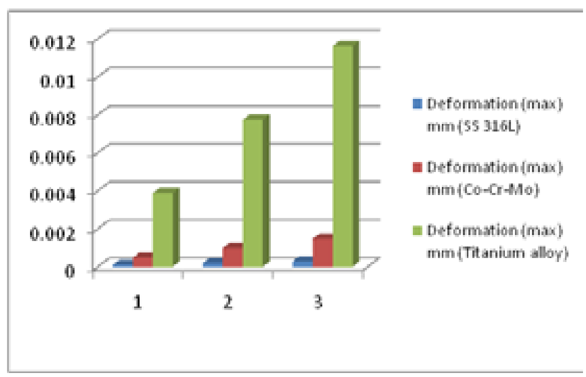
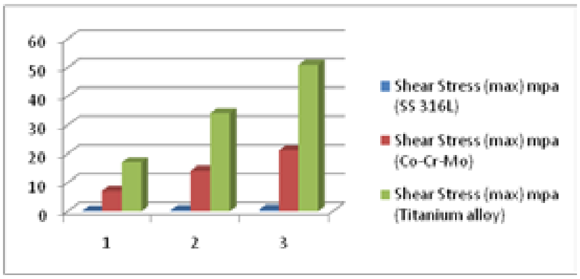


Figure 7 Deformation (500N) Deformation (1000N) Deformation (1500N)



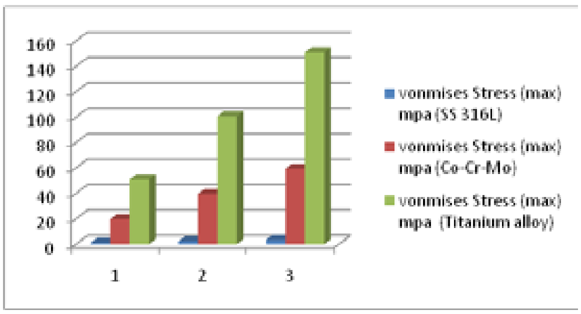
Graph 1 Deformation of Material (SS316L, Co-Cr-Mo, Titanium Alloy)

Figure 8 Shear Stress (500N) Shear Stress (1000N) Shear Stress(1500N)



Graph 2 Shear Stress of Material (SS316L, Co-Cr-Mo, Titanium Alloy)

Figure 9 Von mises Stress (500N) Von mises Stress (1000N) . Von mises Stress (1500N)



Graph 3 Vonmises Stress of Material (SS316L, Co-Cr-Mo, Titanium Alloy)

7) ANALYSIS OF TMJ IMPLANT

In TMJ implant analysis first import a TMJ model in ANSYS software in .sat file format then material is selected for TMJ implant, after selecting material an implant divided into a small number of solid finite elements, this processes known as meshing. A load (60N, 80N, 120N) is applied on implant by fixing its one end and then behaviour of each element is analyzed. Table No. 6 shows TMJ Implant (SS 316L) result after analysis. Above procedure is repeated for TMJ Implant (Co-Cr-Mo) and (Titanium alloy) its result shows in Table No 6 resp.

Load (N)	Deformation (max) mm	Shear Stress (max) mpa	vonmises Stress (max) mpa
60	0.005344	1.5288	19.431
80	0.007126	2.0384	25.907
120	0.010689	3.0576	38.861

Load (N)	Deformation (max) mm	Shear Stress (max) mpa	vonmises Stress (max) mpa
60	0.008596	1.4651	16.754
80	0.011461	1.9534	22.346
120	0.01792	2.9301	33.519

Table 6 Analysis Results for TMJ Implants (SS 316L) and analysis Results for TMJ Implants (Co-Cr-Mo)

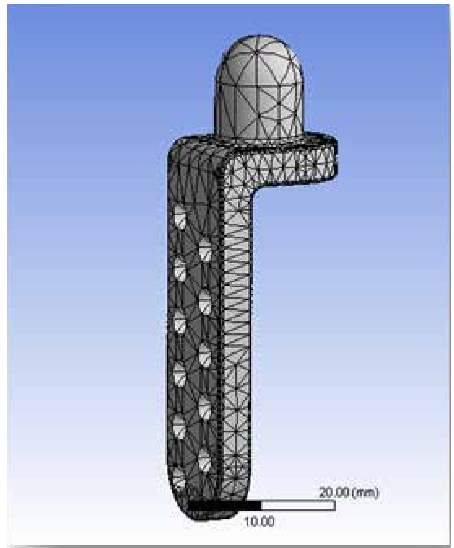


Figure 10 Meshing model of TMJ implant

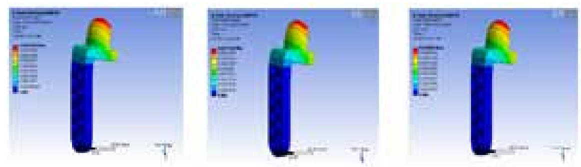


Figure 11 Deformation (60N) Deformation (80N) Deformation (120N)

8) CONCLUSION

- SS 316L has excellent Bio-compatible properties along with physical properties which makes it an ideal implant material for fractures, when compared to other materials.
- SS 316L alloy being medium light with 7.9gm /c[3] density does not have any adverse effect on the patient's movement i.e while lifting the leg, running, jumping, walking etc
- The maximum values of von mises stresses for TMJ implants of SS 316L ranges from 19.431 to 38.861 MPa is much lower when compared to the yield strength of SS 316L (690 MPa).
- Stress shielding is comparatively reduced in stainless steel, as the modulus of elasticity is lower when compared to Cobalt Chromium Molybdenum.
- The present Hip implant made up of SS 316L has the following significant advantages:

▪ Improvement in primary stability.
▪ Optimal fit and fill of the prosthesis.
▪ Improvement in primary stability.

- 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 material. After finite Element analysis it was found that SS-316L material is best suited.
- The maximum values of von mises stresses for Hip implants of SS 316L ranges from 50.322 to 150.97 MPa which is much lower as compared to the yield strength of SS 316L(690 MPa). The maximum von mises stresses are observed near the neck.

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