

# Mechanical Aspects Of Metallic Biomaterials In Human Hip Replacement

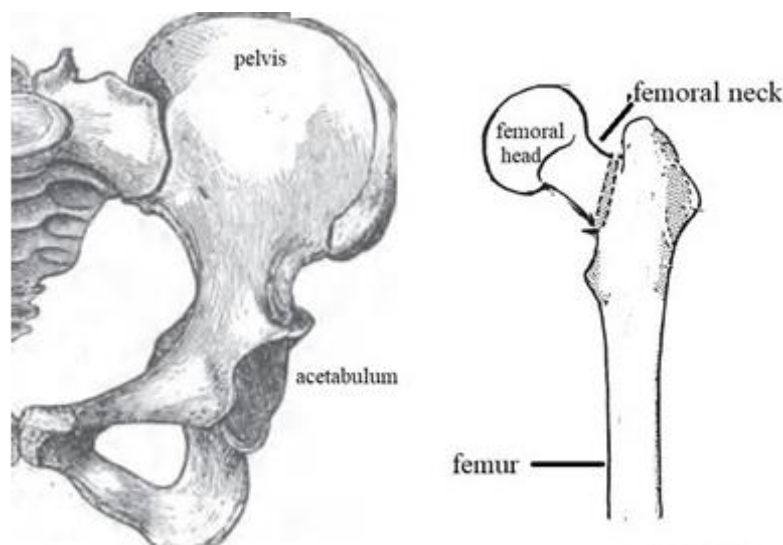
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**Abstract :** The significance of total hip replacement is due to continuous improvement in population and ageing people who are in pursuit of high-quality life. If there is any malfunctioning in hip joint, the reason of which may be the hip fracture, osteoporosis, and injury due to recurrent falls in old age, hip replacement is the perfect solution. Total hip replacements enhance the motile and gratification of life of the patient by mitigating pain and disability. The material which used in total hip replacements should have excellent properties in the term of, resistance to fracture, mechanical, corrosion resistance, high strength, reliable in load bearing and wear resistance which became the cause of great lifespan for the implant as well as compatibility inside the body. Due to these reasons, Metallic materials are very suitable for the hip implant. Continuous research to obtain improved biomaterials for excellent performances is going on worldwide. The standard lifespan of human increases so the requirement of the excellent lifespan of the implant also highly increased due to this reason the material, which used for implants, required improvement in properties of materials. This article focuses on the discussion of mechanical aspects of metallic biomaterials which used for human hip joint replacement. Specific metallic biomaterials made from stainless steels, alloys of cobalt, Ti based alloys, discussed in this article.

**Keywords** - Biomaterials, Hip Joint, Co-Cr alloys, Mechanical, Stainless Steel, Ti alloys

## Introduction

Total hip replacement in human is an effective procedure in surgery [1]. The human hip joint is synovial joint, and this is ball and socket arrangement type stable weight bearing joint. The ball-shaped head fits in the acetabulum which is a socket in the pelvis, so the ball considered as femoral head, the acetabulum as the socket, this configuration is the root of its inherent strength due to this hip joint can bear large forces, if there is some disorder in this arrangement, it may be the cause of exceptional stresses throughout the joint cartilage and bone which may be the cause of degenerative arthritis which leads to further damage of hip. The space in a joint cavity of synovial joints filled with the fluid known as the synovial fluid, it is for lubrication, which results, greater mobility and reduction of friction in between bones [2-4]. Joint has the high range of internal and external motion; extension, abduction, flexion, adduction is due to triaxial motion. A standard hip joint works correctly in almost all type of motion required for everyday activities like moving sitting, bending meanwhile acetabulum aligned adequately with the femoral head [5]. The shape of a femoral head is similar to sphere and size is around 20 to 30mm radius which varies with the weight of the body, this is key of the transmission and absorption of stress due to weight bearing, to the femoral neck's dense cortical bone [6].



(a)

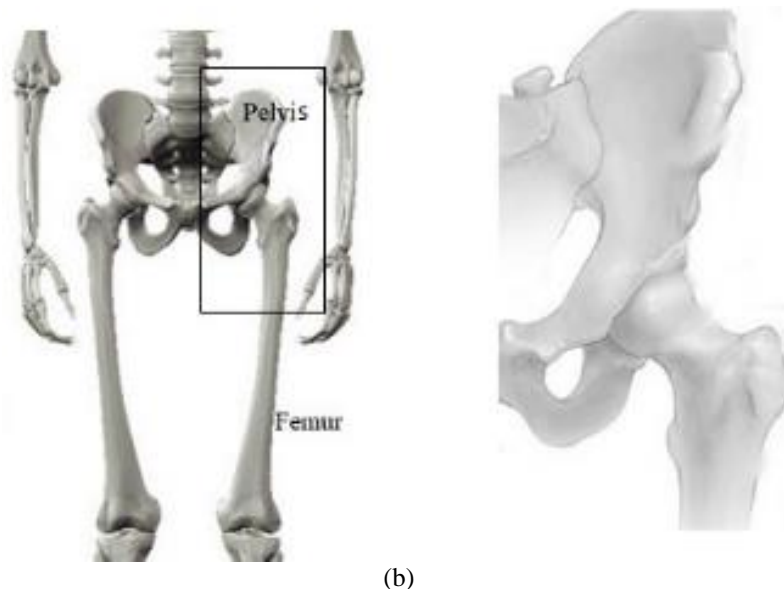


Figure 1: (a) Individual components for Hip Joint. (b) Hip Joint in THR [50]

Bone is critical for the human as it supports body weight. Before development as well as the application of a new biomaterial for bone replacement the function of bone tissues and about bone tissues at various scale level should understand precisely as Bone having a very complicated structure which may be described as hierarchical and anisotropic tissues due to this a noticeable difference found in mechanical properties, microstructure and other related function between bone and artificial material. Fracture toughness, fatigue strength, ductility, ultimate strength, stiffness and yield strength are essential properties of bone. Femoral head, femoral stem, liner and the acetabular shell are components of the artificial hip implant. [7-8].

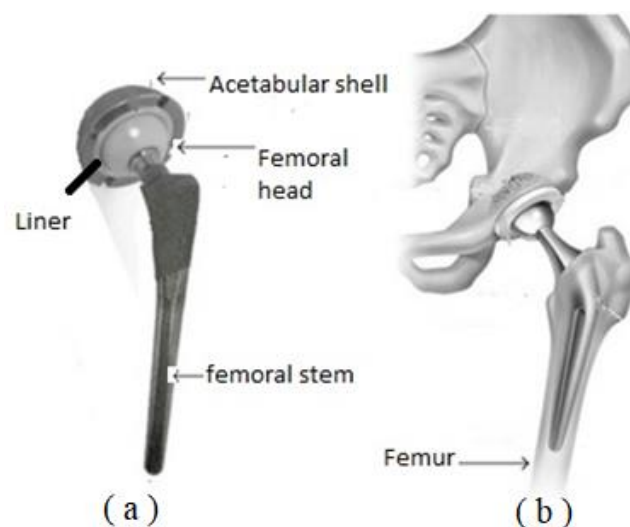


Figure 2: (a) The artificial Hip Joint Components (b) Placed Components [51]

### Metallic Biomaterials

Widely used metallic biomaterials are Ti-based alloys, stainless steel and Co-Cr alloy. The materials must have biocompatible, good resistance to wear and corrosion, strong resistance to fatigue, and reasonably priced which used in Total hip replacement. Metallic biomaterials generally used in orthopedic applications especially for joint replacements because of excellent mechanical properties [9].

Biocompatibility is the performance of material which is intended to use in close interaction with living tissue material should have properties like, non-cytotoxic, not releasing harmful materials, not causing adverse reactions, including allergic and inflammatory reactions with host tissues, organs [10-11].

### (1) Co-Cr alloys

Co-based alloy developed the early 1900s, in 1930 a cast alloy based on Cobalt-Chromium-Molybdenum known as Vitallium (Co-28Cr-6Mo), developed and used for the prosthetic acetabular cups until 1960, in 1960 total replacement operation introduced and in early 1960 other Co-Cr alloys developed [12-17].

Co-Cr alloy recognized for great corrosion resistance and its wear resistance well known because it is superior to the other metallic biomaterial. In, hip artificial joint wear resistance property is essential especially in sliding parts of hip joints [18-21]. Mechanical properties like ductility, strength of Co-Cr alloy may be changed by adding an alloying element and by thermomechanical treatment. Addition of Zr to cast Co-28Cr-6Mo alloy will enhance tensile strength as well as elongation. If the addition of the maximum acceptable value of nitrogen less than 0.10 mass%, it increases workability, elongation and mechanical strength [22-26].

Mechanical properties illustrated in fig 3, of Co-Cr alloys, generally used for hip replacement.

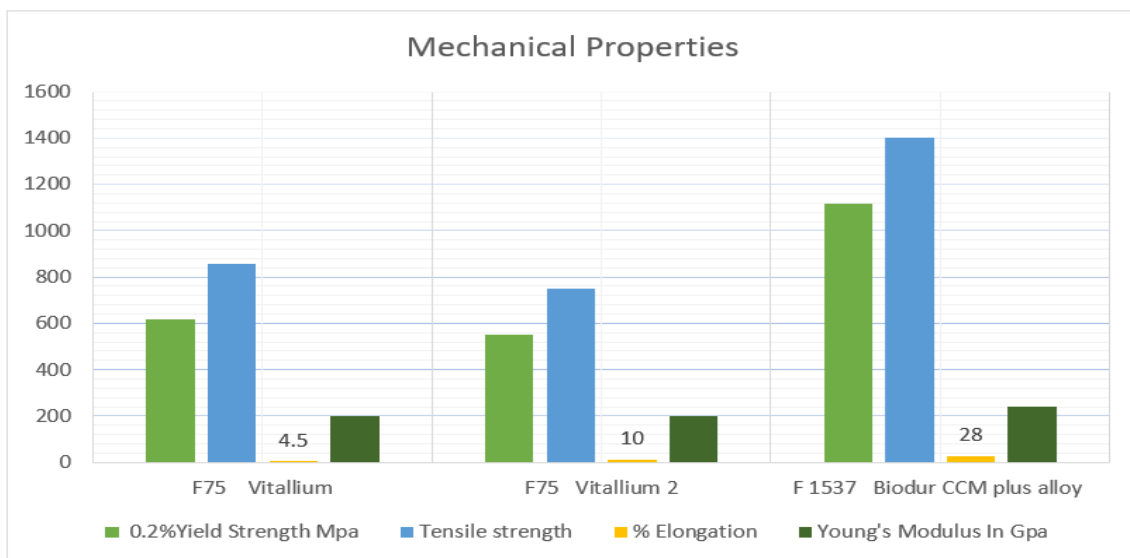


Fig 3 : Mechanical Properties (Co-Cr Alloys)[52-53]

### (2) Ti-Based alloys

Titanium and alloys of titanium are well-accepted biomaterials for biomedical applications by cause of excellent biocompatibility, exceptional mechanical strength, superior corrosion resistance, the lower value of elastic modulus and lower weight density as in compared with alternative metallic biomaterials. [27-30].

According to microstructure Titanium alloy may be divided as  $\alpha$ -type titanium alloys and  $\beta$ -type titanium alloys and ( $\alpha + \beta$ )-type titanium alloys.  $\beta$  titanium alloys generally used in total hip replacement.  $\beta$  alloys have higher strength, low elasticity modulus and good resistance toward corrosion hence used as the biomaterial for hip joint [31-35].

The modulus of elasticity for ASTM standard biomedical titanium alloys such as for Ti-6Al-4V is 100-110Gpa. and for Ti-12Mo-6Zr-2Fe is 74-85GPa. while for Ti-35Nb-7Zr-5Ta is 55Gpa. Addition of zircon in titanium results increased elongation and fatigue strength. Ti-6Al-4V used in femoral stems, heads, as well as femoral components while Ti-5Al-2.5Fe and Ti-Al-Nb used in Femoral stems, heads [36]. According to the value of modulus of elasticity, rigidity can decide, the high value of modulus of elasticity shows the high rigidity or vice versa. The material used in hip replacement, generally having high young modulus than bone due to this difference stress shielding which is known as a reduction in bone density can occur in hip implants, which diminished the life of implant because of a difference in stiffness between implant material and bone [37,38].

Fig 4, depict mechanical properties of stainless steel which generally used in hip replacement.

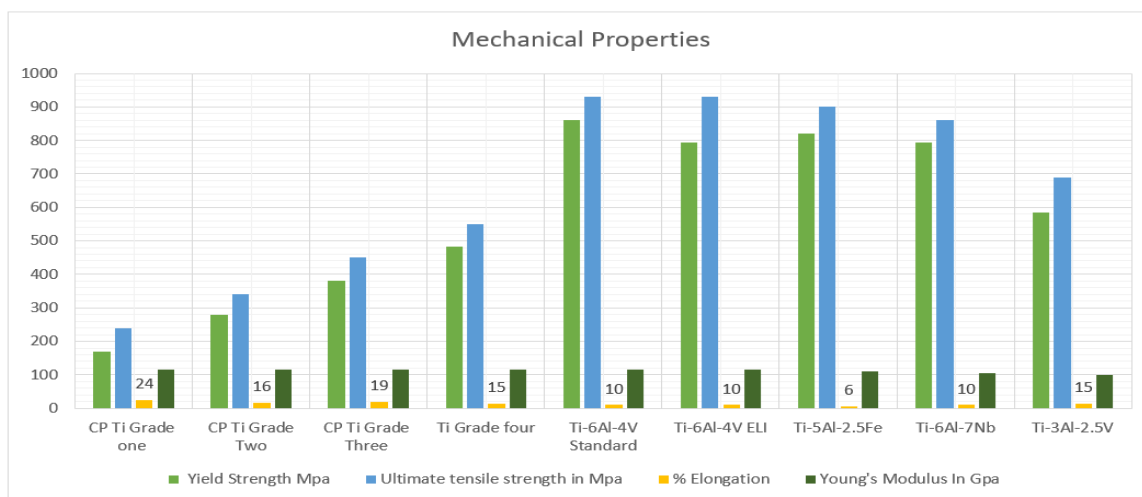


Fig 4 : Mechanical Properties(Ti Alloys) [54-55]

**(3) Stainless steel**

In 1938 the first stainless steel total hip replacement used and it is the source of the idea for the total hip replacement [39]. Stainless steels may be divided in chromium type and chromium-nickel type steels in consonance with chemical compositions and according to microstructure, ferrite (BCC) and austenite (FCC)[40].

Chromium-Nickel type austenitic stainless steels used for biomedical application especially in orthopedic which contain Cr (17-20 %), Mo (2-3 %), Ni (12-15 %) and other materials which are in a very small amount. A316L stainless steel used for orthopedic applications, which containing good ductility and high strength Because structure of unit cell is FCC. This steel containing Carbon percentage below 0.03% [41-44]. Nickel ions released by this steel in body which produce very harmful effect in human body which can result as allergy, pain or even cancer. Nitrogen steel is the solution to this problem, this steel having sufficient corrosion resistance and strength, which is higher in comparison of Ti alloy. The nitrogen percentage should be below 0.9% which become the reason to avoid brittleness in this steel. Otherwise, brittleness will increase [45-49].

Fig 5 illustrates the mechanical properties of widely used stainless steel for human hip replacement.

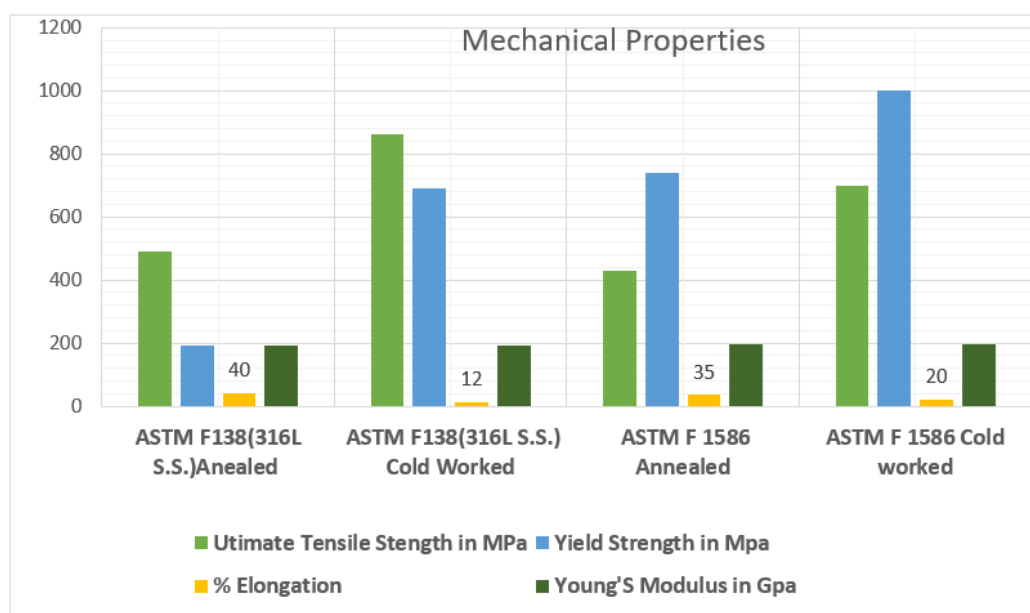


Figure 5: Mechanical Properties (Stainless Steel) [56]

## Conclusion

This study compared the mechanical properties of different metallic biomaterials as well as suitability for use in biomedical applications which also includes mechanical biocompatibility and biological biocompatibility of implant. The lifespan of metallic biomaterials based implants is around the 20-25 years, and after 15 years failure can occur. So it is an essential requirement for research of materials, which can work perfectly in line with human lifespan, especially for hip replacement. The failure of an implant in a human body may be due to wear, corrosion, low fracture toughness, inflammation, low fatigue strength, a big difference in modulus of elasticity in bone and implant material so these factors generally considered in the selection of material for orthopedic implant in the human. For total hip replacement, metallic biomaterials are the best option. Interdisciplinary research is essential for the biomaterial required for orthopedic implants because, in the human body, the demand of the Biomedical implant is increasing continuously. Still, the failure rate of the implant is high.

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