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Development and Analysis of Composite Material for In-Situ Hip Prosthesis

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ABSTRACT:

The metallic materials such as stainless steels alloys, Ti alloys and cobalt-chromium alloys have been widely used as bone implant which is of 6-7 times stiffer then human bone which is replaced by composite materials. Bio active material as a replacement of metallic implant ceramic and polymers are two kinds of lightweight materials ,which shows better biocompatibility and corrosion resistance in body compared to that of metals /alloys. Among different ceramic, materials, Hydroxypatite (Hap), zirconia, alumina and bio-glass are widely researched materials for implant applications and being commercially produced. Among these materials, Hap is the most investigated bioactive materials for compositional similarities with human bone and teeth. the other On hand different biocompatible polyethylene (PE) based materials are being used as low load bearing application in THR socket. In order to minimize stress- shielding effect which High density polyethylene have been successfully reinforced with Alumina oxide(Al2o3) and PANI Clay Nano-Composite for replacement or healing of bone. The work includes static, dynamic and contact analysis of artificial metallic composite femur bone is done successfully.

INTRODUCTION:

The Lubinus SPII hip system is one of the most used in Sweden, accounting for almost 57% of the total number of prostheses applied in 2007. It came on the market fairly recently to replace the Luninus SPI system and at the moment presents a success rate of 98% for 10 years and for 25.620 cases and 87.2% for

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16 years (Furneset al., 2007). According to the research at AIIMS, New Delhi, the IOTA interlocking femoral stem is a hydroxypatite-coated stem with the option of interlocking the stem distally. The aim was to evaluate the short term results of IOTA interlocking stem. The results of 18 total hip arthroplasties in 17 patients performed between July 2002 and 2004 using the IOTA interlocking stem. The bone deficiency was classified based on the AAOS classification .Average age at the time of revision was 57 years. Total hip Arthroplastry (THA) is a successful mechanical reconstruction of diseases hip joints. One of the main constituent is the femoral stem type component. Mechanical failure of the cemented metallic femoral stem-type hip components still remains as a major problems (T.L.Norman et al, 1966). Attempts to reduce the risk of femoral components.

In 2007, carbon fiber reinforced poly etheretherketone (CFRPEEK) was introduced onto the market as an alternative bearing to UHMWPE in the hip. This composite has shown extremely low wear rates and comparable biological activity to UHMWPE .Also, multiwall carbon nano tubes (MWCNTs) have been added as a reinforcing component for UHMWPE .Carbon nano tubes(CNTs) have excellent mechanical properties such as high tensile strength and are ultralight weight, which makes them an attractive alternative for reinforcing polyethylene. More recently, graph has generated great interest as reinforcement for polymer matrices due to its excellent in-plane strength and high surface area, which might lead to enhanced load transfer sites between the polymeric matrix and reinforcement.

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A recent study performed showed the ability of graphene oxide to improve the friction and wear behavior of conventional UHMWPE. Clearly, new alternatives for orthopedic applications are being investigated. However, due to the limited clinical experience of these new materials in joint replacement components, caution and more research is required in order to establish the biological consequences of the use of these materials in this clinical application.

(S.Grosset al.2001) If the stem is more rigid, it would transfer fewer loads proximally so the stress shielding of the proximal femur would be greater. Therefore the usage of a femoral stem with low stiffness such that of a titanium alloy will transfer more load to the femur proximally, thereby resulting in the stress-shielding of the femur. But the usage of a less stiff stem alone would not be sufficient to achieve implant longevity .Therefore the design of the implant plays a major factor in the reduction in the stress shielding of the bone. The usage of tapered ,parallel and hollow stem design results in an increases in the proximal stress in bone .The benefits of using hollow stems have a major role on the control of the rigidity ,in the maintenance of an approximate fit, and also a significant reduction in the stress shielding.

Blake Latham et al.(2004)The short list of variables that may affected the performance of an implant are patient age (dealing with mobility of the patient),material parameter ,geometric parameter ,bone imaging ,biological parameters (implant properties in vivo), implant techniques (fixation of the implant).In a hip implant geometry factors include femoral stem length ,femoral stem diameter ,head diameter ,neck diameter ,neck angle ,presence or absence of a collar on the medial side of the proximal femur .As the head diameter increased ,the stresses in the femoral stem decreased .In regards to the diameter ,even though larger head diameter transfer less stresses to the femoral components ,they also have a higher surface contact area, which can lead to increased wear.

The modular implant had a 28 mm head ,and the integrated a 32mm head. The modular implant had 12-14 mm neck; while the integrated implant had a 14mm

S.Griza.(2009) The results of this research show that resorption of the femoral neck is un-favorable for all prosthesis, whether collared uncontrolled or .Clinically, bone loss is frequently reported with collared stems, and need not occur with uncontrolled versions. Long term movement of implants, collared and collarless, with respect to the bone commonly occurs. The difference in the nature of the movements between collared and collarless implants may account for the less frequent bone loss associated with collarless implants. The use of cylinder distal portion, matt surface and collar can reduce the stability in a loosened cemented hip stem. The matt surface design concept was developed early in 70s and is applied to improve stem cement stability .The numerical simulation model used did not considered the effect of the matt surface obtained by shot penning.

A Problem Hip

A problem hip, the worn cartilage no longer serves as a cushion. As the roughened bones rub together; they become irregular, with a surface like sandpaper. The ball grinds in the socket when you move your leg, causing pain.



Fig: 1.3. Roughened hip



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A Prosthesis

An artificial ball replaces the head of the thighbone, and an artificial cup replaces the worn socket. A stem is inserted into the bone for stability. These parts connect to create your new artificial hip. All parts have smooth surfaces for comfortable movement once you have healed. The total hip replacement operation replaces the worn head of the femur with a stainless steel ball mounted on a stem and re-lines the socket (acetabulum) with a cup made of a special plasticpolyethylene. These two components are usually fixed to the bone by a type of cement called methyl metha crylate .In special cases other types of stems (prostheses) may be used. This new joint aims to relieve pain, decrease stiffness and in most cases restores leg length and hence helps improve mobility. Osteoarthritis of the hip is generally a disease of the older person, but may occur in younger people following rheumatoid arthritis, fractures of the hip and other rarer conditions.



Fig.1.4.Prothesis hip

Risks and Benefits of Total Hip Joint Replacement

With your decision to proceed with total hip joint replacement, you will have already discussed the benefits and risks of this surgery with your surgeon. To date, over six million hip joint replacements have been performed worldwide. They have proven to be extremely durable. Ninety to ninety-five percent success rates at ten to twenty year check-ups are common. As with any operation, total hip joint replacement has a number of potential risks. These include:

- Anesthetic complication.
- Death (0.7%).
- Infection (approximately 0.5%).
- Slow healing.
- Post-operative dislocation (0.4%).

• Leg length discrepancy (occasional occurrence).

- Thigh pain.
- Limp.

PROSTHESIS MATERIAL Metallic – implants material:

Commercially pure titanium **Ti6Al4V Alloy :** (Ti CP) and extra low interstitial Ti-6Al-4V (ELI) are the two most common titanium base implant biomaterials. However, they do not promote any adverse reactions and are tolerated well by the human tissues.Titanium is very light with a density of 4.5 g/cm3.

PROPERTIES OF TI ALLOYS

Property	Grade	Grade	Grade	Grade	Ti6Al
	1	2	3	4	4 V
Tensile	240	345	450	550	860
strength					
(MPa)					
Yield	170	275	380	485	795
strength					
(MPa)					
Elongation	24	20	18	15	10
(%)					

Consequently, the recent trend in research and development of titanium for biomedical applications is to develop alloys composed of non-toxic and nonallergenic elements with excellent mechanical properties.

6Al-7Nb (ASTM F 1295)	
3. Ti-6Al-4V (ASTM F 1108)	4. Ti-
6Al-4VELI(ASTM F 136)	
1. Titanium CP (ASTM F 67)	2. Ti-



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HDPE-HAP-ALUMINA SYSTEM:

Calcium phosphate + collegen = Cortical bone, Synthetic calcium phosphate(Hap) + HDPE = Calcium phosphate/polymer composite.

COMPOSITE PREPARATION:

Pressure=92Mpa,Temperature =130c,Time=0. 5hr preparation of composite hip prosthesis:



Material composition

Materiak	Tenvile strength (Mp a)	Compression Strength (Mpa)	Elastic Modulus (Mpa)	Fracture toughness (Mpa/m)
Cortical bone	345	350-600	117	60
Ti-alloy	780-1050	450-1850	110	40-70
Alumina	270-500	3000-5000	380-410	3
Нар	40-300	300-900	80-130	0. m -1
Ti	345	350-600	117	6 0

Composite hip



DESIGN OF COMPOSITE HIP PROSTHESIS:

The femoral head and the acetabular component comprising of the acetabular cup and the acetabular liner. The material used for the femoral component with comprises of the femoral stem and head is 316L stainless steel and Ti-6Al-4V.The material used for acetabular component is made up of 316L stainless steel and Ti-6Al-4V.UHMWPE(Ultra High Molecular Weight Polyethylene) is used for the acetabular liner.

Components Of Hip Prosthesis:

The hip prosthesis consists of following components

- 1.Femoral Stem
- a. Primary stem.
- B. Secondary stem.
- 2. Acetabular cup.
- 3. Acetabular Line.
- 4.Ball.

According to the design they are of eight different models which is designed according to the standards by using Pro-E Software.

RESULTS

TOTAL HIP ASSEMBLY

1. Partially Composite 2.Full Composite





Fig: 7.1.Total hip assembly

Fig: 5.1.Pro-E hip prosthesis model Fig: 5.2.Meshed model



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Composite Cortial DYNAMIC ANALYSIS



Mode	Frequency [Hz]
1.	1825.1
2.	3929.8
3.	6984.9
4.	12846
5.	13319
6.	20005

COMPARISON OF RESULTS

Properties	Cortical bone	Model1	Model2	Model3	Model4
Von-mises stress(mpa)	6.213	5.843	2.02	5.082	7.732
Von-mises strain(mpa)	0.3e-5	0.4e-5	3.4e-5	0.8e-5	0.8e-5
Total Deformation (mm)	885	499	602	141.28	425

CONCLUSION

The model 1 and 4 has the close similar to cortical bone has a composite upper and lower stem. If the stem is of single stem the stress acts is of higher more than the cortical bone. The metal/alloys makes corrosion and for composite its of similar to bones but has high displacements and high or low stiffness based on combination of materials by combining metals and composite we can achieve properties nearly to human bone. Fair contact is between the both contact region the maximum sliding and pressure is between the HDPE and ti-alloy.

According to the model analysis the Mode2 frequency of 3929.8Hz as minimum deformation of 243.25mm and mode6 of frequency of 20005Hz as maximum deformation 328.28mm Finally the analysis of artificially metallic composite femur bone is successfully done. The partially metallic hip prosthesis can also used for total hip replacements HDPE causes more displacements it can be replaced by metallic or any other composite similar to the bone. In future Fatigue loading can also be taken into account and dynamic analysis could be performed over whole gait cycle of walking.

Moreover, due to computational limitations, different materials used in the present study, which are actually anisotropic, have been assumed to be isotropic in nature. Long term clinical follow up of patients having THA with large femur head diameter should be done to, ascertain the effect of large femur head on dislocation.



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For a more optimized design a combination of different cross sections needs to be studied which may more likely result into better stress distribution.

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