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Study of properties on polymer materials used as biomaterials for implants

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Abstract: Over the years metals like SS316l and its behavior and properties has established itself as the best available bio implant material. With the advancement in the field of material science, metallurgy and designing, the development for more advanced bio materials having better properties than metals is observed. It has been observed that one of the most important properties governing the suitability of the material to be a bio implant is 'wear resistance' 'Corrosion Resistance' and also the fatigue resistance. But in the recent trend metals as been completely replaced by other materials like alumina, composites, and also polymers which can have a very good biocompatibility then metals which as very good mechanical electrical and thermal properties compared to this type of material. In the biomaterials biocompatibility plays in main role in the behavior of implantation which recognize the pulse of the material which can be used as various polymer materials

KeyWords:Metals, Biocompatible, Polymers

I. Introduction

Materials that are used for biomedical or clinical applications are known as biomaterials. The following article deals with fifth generation biomaterials that are used for bone structure replacement. For any material to be classified for biomedical application three requirements must be met. The first requirement is that the material must be biocompatible, it means that the organism should not treat it as a foreign object. Secondly, the material should be biodegradable (for in-graft only); the material should harmlessly degrade or dissolve in the body of the organism to allow it to resume natural functioning. Thirdly, the material should be mechanically sound; for the replacement of load bearing structures, the material should possess equivalent or greater mechanical stability to ensure high reliability of the graft. This should pocess good mechanical properties and behavior when the implants of the material done in the various fields.There is a lot of development in surgery and prosthetic fields. For this purpose a lot of materials are used as implants for replacing them in place of damaged parts. These materials are called as bio materials, but biomaterials should have a very good properties for implants, these is done by lot of research and development about the biomaterials

Polymer Materials

Polymers are substances containing a large number of structural units joined by the same type of linkage. These substances often form into a chain-like structure. Polymers in the natural world have been around since the beginning of time. Starch, cellulose, and rubber all possess polymeric properties. Man-made polymers have been studied since 1832. Today, the polymer industry has grown to be larger than the aluminum, copper and steel industries combined. Polymers already have a range of applications that far exceeds that of any other class of material available to man. Current applications extend from adhesives, coatings, foams, and packaging materials to textile and industrial fibers, composites electronic devices, biomedical devices, optical devices, and precursors for many newly developed high-tech ceramics

Some of the Polymer Materials are:-

- ✓ Polyethylene
- ✓ Nylon
- ✓ PVC
- ✓ PEEK
  PEEK with carbon fibre and glass fibre

II. Biocompatibility

Biocompatibility testing is essential for all materials that will be used in medical devices to minimize any potential hazards to the patient. This should consist of in vitroassessments (studies carried out in an artificial environment) and in vivoassessments (studies carried out in living organisms) that are relevant to the device application. Testing should also include a medical device safety evaluation to assess the risks of normal use and any possible misuse of the device. No single test is sufficient to define biocompatibility and a variety of tests are necessary to determine biocompatibility, depending on the device and application.There are many different joint replacement systems available to the orthopedic surgeon An implant is said to have failed if it ceases to perform the function for which it was insertedThe biocompatibility of implant quality stainless steel has been proven by successful human implantation for decades. Composition, microstructure and tensile properties of titanium, cobalt chrome, zirconium and stainless steel and titanium alloys

Polymers Compare to Metals

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STEEL	BRONZE	ALUMINIUM
Polymer has cheaper manufacturing cost	Polymer has better mechanical properties	Polymer has cheaper manufacturing cost
Polymer has fewer leachables	Polymer is harder	Peek is harder
Polymer has better Dry Wear properties	Polymer has Better Wear & Friction	Peek has Better Wear & Friction
Polymer has 83% lower density	Polymer has 85% Lower Density	Peek has 50 Lower Density
Polymer has better Chemical Resistance	Polymer has better Chemical Resistance	Peek has better Chemical Resistance

Table 1: Comparison of Polymer Materials

The above comparison shows the typical comparison of the polymer materials which is better then metals which can be used as biomaterials by having this good mechanical properties

III. Polymers as Biomaterial

Polymer materials as used as biomaterial with the best mechanical properties and behavior it as with different testing conditions. Medical devices composed of polymers, like other biomaterial systems, are not immune to mechanically induced biological failures. The functional demands placed on an implant may elicit mechanical damage that is sufficient to liberate particulates or other constituents that can trigger a chronic inflammatory response in vivo, ultimately leading to the biological failure of the device. The performance of a medical device is quite complicated as there are several contributing and related factors, including the implant design, material selection, structural requirements of the device, processing or manufacturing modality of the implant, and clinical issues.the contributing factors that affect device performance. [1]These issues contribute to a multifactorial problem that often requires numerous iterations in the device design with a continuous feedback process that relies on assessment of device performance in its clinical application. An additional challenge in the medical device field is that it is extremely and thus bench tests rarely predict clinical performance of the implantthis implants of biomaterial. From the below chart which we can say that the different polymer materials used in biomaterials can be implanted with the [2]good properties and behavior of the implants considerations to be taken one or the other final day this implantation can be finally designated as the best materials for the future implantation.

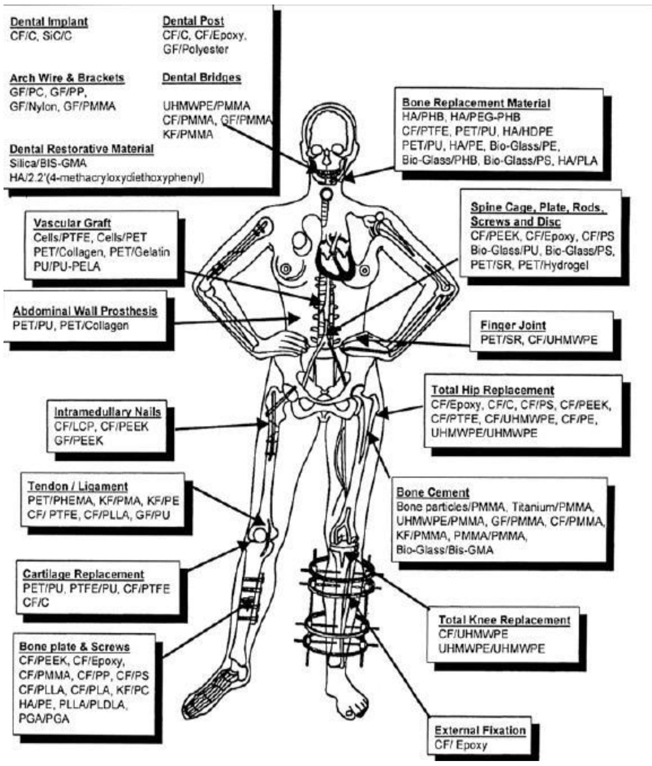

Chart 1: Polymer Materials on all Parts of the Body

3.1 POLYMERS ARE ATTRACTIVE BIO MEMS

- ✓ Improved and easier machinability
- ✓ Optical transparency for certain detection strategies
- ✓ Biocompatibility
- ✓ Acceptable thermal and electrical properties
- ✓ Ability to enclose high-aspect-ratio microstructures.
- ✓ Ability for surface modification and functionalization
- ✓ Biopolymers, including DNA and proteins are natural polymers
- ✓ Soft fabrication techniques often utilize polymer materials, both synthetic and natural.
- ✓ It Improves good mechanical and electrical properties in every part of the implantation
- ✓ The process implantation which is possible for implants is attractive toward the biomaterials.

VI. Femeur Bone

The human skeleton is made of individual or fused bones (such as in the skull, pelvis and sacrum), supported and supplemented by a structure of ligaments, tendons, muscles and cartilage. Bones all have an arterial blood supply, venous drainage and nerves. The non-articular surfaces of bones are covered with a tough fibrous layer called the periosteum.

The skeleton is not unchanging; it changes composition over a lifespan. Early in gestation, a fetus has no hard skeleton; bones form gradually during nine months in the

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womb. [3]At birth, all bones will have formed, but a newborn baby has more bones than an adult. On average, an adult human has 206 bones, but the number can vary slightly from individual to individual), but a baby is born with approximately 300 bones. The difference comes from a number of small bones that fuse together during growth, such as the sacrum and coccyx of the vertebral column. An infant is born with pockets of cartilage between particular bones to allow further growth. The sacrum (the bone at the base of the spine) consists of five bones which are separated at birth but fuse together into a solid structure in later years. Growing is usually completed between ages 13 and 18, at which point the bones have no pockets of cartilage left to allow more growth.

Bone is a biomaterial with a complex hierarchical structure, which gives it some impressive material properties. It is primarily composed of a bio ceramic (similar to hydroxyapatite) and collagen, a fibrous protein. At a microscopic level, it can be seen that the collagen-bone mineral composite forms concentric lamellar structures known as osteons, which are the main structural element of bone. The osteons are densely packed together in cortical bone and their long axes tend to run parallel to the long axis of the bone. In common with many biomaterials, bone is anisotropic: its mechanical properties differ depending on the orientation of the sample being tested. Hip replacements are a very common surgical procedure, particularly among older people, as bones can become more brittle with age. There are three main parts to a total hip replacement: the femoral stem, femoral head, and acetabular components. The main challenge with hip replacements is to find a material that has mechanical properties similar to that of bone, is capable of operating for many years in the biological conditions in the human body, and causes minimal adverse host response from the body. The femoral stem is the main load-bearing component. Increasingly the titanium alloy Ti-6Al-4V with 40% porosity is used, as it combines excellent material properties with the advantage of being, to a large extent, biologically inert. The main mechanical requirement of the femoral head and acetabular cup is to minimise wear. The femoral head is generally a highly polished metal or ceramic, and the acetabular cup is usually made of UHMWPE - a dense, crystalline polyethylene
With practically no increase in the amount of bony material used, there is a greatly increased stability produced by the expansion of the lower femur from a hollow shaft of compact bone to a structure of much larger cross-section almost entirely composed of spongy bone.

V. Properties of Polymer Materials

Nylon

The majority of nylons tends to be semi-crystalline and is generally very tough materials with good thermal and chemical resistance. The different types give a wide range of properties with [5] specific gravity, melting point and moisture content tending to reduce as the nylon number increases. Nylons can be used in high temperature environments. Heat stabilized systems allow sustained performance at temperatures up to 185°C

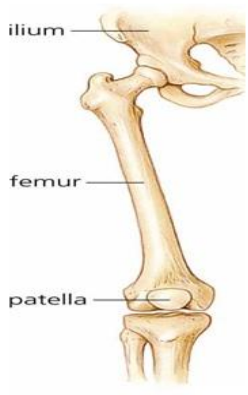

Figure 1: Femeur Bone

Physical Properties	Value
Tensile Strength	90 - 185 N/mm^2
Notched Impact Strength	5.0 - 13.0 KJ/m^2
Thermal Coefficient of Expansion	80 * 10
Maximum Continue Use of Temperature	150 - 185°C (302 - 365°F)
Melting Point	190 - 350°C (374 - 662°F)
Glass Transistion Temp (Nylon)	45°C (113°F)
Density	1.13 – 1.35 g/cm^3

Table 2: Properties of Nylon

PVC-HDPE

PVC is a versatile plastic that has been used for medical applications for more than 50 years. It has passed many critical tests and [4]gained acceptance by health regulators world-wide and is now the most widely used polymer in pre-sterilised single use medical applications

Physical Properties	Value
Tensile Strength	260 N/mm^2
Notched Impact Strength	2.0 – 4.5 KJ/m^2
Thermal Coefficient of Expansion	80 * 10^{-6}
Maximum Continue Use of Temperature	60°C (140°F)

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Melting Point	212°C (413°F)
Glass Transistion Temp (Nylon)	81 (178)
Density	1.18 g/cm^3

Table 3: Properties of PVC - HDPE

Ultra High Molecular Weight Polyethylene (Uhmwpe)

LDPE Properties:Semi-rigid, translucent, very tough, weatherproof, good chemical resistance, low water absorption, easily processed by most methods, low cost.
HDPE Properties:[6]Flexible, translucent/waxy, weatherproof, good low temperature toughness (to -60'C), easy to process by most methods, low cost, good chemical resistanceLDPE (Low Density Polyethylene)[10] is defined by a density range of 0.910 - 0.940 g/cm^3. It has a high degree of short and long chain branching, which means that the chains do not pack into the crystal structure as well. It has therefore less strong intermolecular forces as the instantaneous-dipole induced-dipole attraction is less. This results in a lower tensile strength and increased ductility. LDPE is created by free

Physical Properties	**Value**
Tensile Strength	0.20 – 0.40 N/mm^2
Notched Impact Strength	No break
Thermal Coefficient of Expansion	100 – 220 x 10^{-6}
Maximum Continue Use of Temperature	65 (140)
Melting Point	110 (230)
Glass Transistion Temp (Nylon)	-125 (-193)
Density	0.910 - 0.940g/cm^3

Table 4: Polyethylene UHMW (LDPE) properties

HDPE (High Density Polyethylene) is defined by a density of greater or equal to 0.941 g/cm^3. HDPE has a low degree of branching and thus stronger intermolecular forces and tensile strength. HDPE can be produced by chromium/silica catalysts, Ziegler-Natta catalysts or metallocene catalysts. The lack of branching is ensured by an appropriate choice of catalyst

Physical Properties	**Value**
Tensile Strength	0.20 – 0.40 N/mm^2
Notched Impact Strength	No break
Thermal Coefficient of Expansion	100 – 220 x 10^{-6}
Maximum Continue Use of Temperature	65 (140)
Melting Point	110 (230)
Glass Transistion Temp (Nylon)	+126 (-193)
Density	0.941 - 0.965g/cm^3

Table 5: Polyethylene UHMW (LDPE) properties

The properties of the material which is known to be the best materials for the future plants as shown compared with SS316L to the word of polymers which can be the best materials which is to provide the good material properties which mainly insists the regular promotion of the material in the bio-medical applications.SS316L is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. Grade 316L, the low carbon version of 316 and is immune [2]fromsensitisation (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). There is commonly no appreciable price difference between 316 and 316L stainless steel.The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.Compared to chromium-nickel austenitic stainless steels, 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures. PEEK or Polyetheretherketone refers to a semi-crystalline organic polymer thermoplastic exhibiting a highly stable chemical structure, which gives it an edge over other materials. It is a member of the Polyaryletherketone or PAEK polymer group. There are exclusive **PEEK properties** which make this material find numerous applications in various industries

VI. Conclusions

The Study on properties of Biomaterial will able to sustain the future material for better implantations with this we can conclude polymer can be the best material by considering the following views

- ✓ Polymer materials can be the better material by seeing all the properties for using it as biomaterial
- ✓ PEEK, PVC, Polyethylene, NYLON all are equal based polymer with the good properties for using it as a biomaterial
- ✓ Polymers has highly corrosion resistance, wear resistance material.
- ✓ This material is highly biocompatible to human body, which makes the material to suitable for the implantation.

- ✓ The Properties depends on the different types of material based and used it as biomaterial.
- ✓ Among all the materials polymers can be the best replacement materials because its of good mechanical properties.
- ✓ The highest percentage of the polymers with the properties involves for better biocompatibility of the future reference to the materials with ceramics and metals.
- ✓ The future materials trend can be completely replaced by all the materials with polymers to the medical applications to words the different areas which can be used as biomaterial.

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