EVOLUTION OF BIOMATERIALS IN DENTAL IMPLANTS  PART-2

CHIRAG J. CHAUHAN*, DARSHANA N. SHAH**, RUCHI PATEL***

ABSTRACT

Although the biologic principles underlying successful clinical implant are still not completely understood, it is clear that both physical and chemical attributes of the material may influence the clinical outcome. Knowledge of the stresses and strains in an implant system and superstructure is still incomplete, but micromotion at the interface must be avoided for bone fixation. The composition and topography of the implant surface influence the cellular events at the bone-biomaterial interface. These surface parameters require definition to interpret the tissue response to a particular material. The most critical aspect of bio-compatibility is of course, dependent on the basic bulk and surface properties of the bio-materials. Thus clinician should consider all the available information on material and design before embarking on extensive clinical trial. This article summarizes the properties of different implant biomaterials available in the market.

Key Words: Implant biomaterials, osseointegration, bioceramics, bone-biomaterial interface.

INTRODUCTION

As it has been discussed in previous article tooth loss from disease has always been a feature of mankind’s existence. For centuries people have attempted to replace missing teeth using implantation. Greek, Egyptian civilization used materials like bone, carved ivory, metal and even animal teeth. Since then many types of implant materials were introduced but consistent failures occurred with them. In 1952 Branemark developed a threaded implant design made of pure titanium that showed direct contact with bone. Henceforth popularity of implants reached new heights. Currently the implant materials available are diverse. Success and longevity of implant depends on fours B’s that is Biomaterial, Biomechanics, Biological tissues, Body serviceability.

The physical, mechanical, chemical and electrical properties of the basic materials components must always be fully evaluated for any bio-material application as these properties provide key inputs into the interrelated bio-mechanical analyses of function. Thorough knowledge of different biomaterials is required for their judicious selection and application in implantology.

Classification

Implant biomaterials and bioceramics range in biocompatibility from the ceramic oxides, which are inert in the body, to the other extreme of resorbable materials, which are eventually replaced by the materials which they were used to repair. The perfect material for medical applications would not only be biocompatible, but also have physical properties similar to those of the tissue being replaced or repaired. Bioceramics are used in many types of medical procedures. They are closely related to either the body’s own materials, or are extremely durable metal oxides. They can be classified into three types.

Bioinert: The term bioinert refers to any material that once placed in the human body has minimal interaction with its surrounding tissue, examples of these are titanium, Zirconium, alumina.
Bioactive: Bioactive refers to a material, which upon being placed within the human body interacts with the surrounding bone and in some cases, even soft tissue. Prime examples of these materials are synthetic hydroxyapatite, glass ceramic and bioglass.

Bioresorbable: It refers to a material that upon placement within the human body starts to dissolve (resorbed) and slowly replaced by advancing tissue (such as bone). Common examples of bioresorbable materials are tricalcium phosphate $[\text{Ca}_3(\text{PO}_4)_2]$ and polylactic, polyglycolic acid, copolymers. Calcium oxide, calcium carbonate and gypsum are other common materials that have been utilised during the last three decades.\(^1\)

Properties of implant Biomaterials & Bioceramics

BIOINERT

Titanium and Titanium alloys Ti6Al4V
Titanium is one of the most biocompatible material due to its excellent corrosion resistance. The corrosion resistance is due to formation of biologically inert oxide layer. It spontaneously forms tenacious surface oxide on exposure to the air or physiologic saline. Three different oxides are formed that is TiO (Anastase), TiO$_2$ (Rutile), Ti$_2$O$_3$ (Brookite). TiO$_2$ is the most stable and most commonly formed on titanium surface. This oxide layers is self healing i.e. if surface is scratched or abraded during implant placement it repassivates instantaneously. Also Titanium oxide layer exhibits low level of charge transfer, lowest among all metals. This is the main reason for its excellent biocompatibility. Modulus of elasticity (110 GPa) is half of the other alloys and 5 to 5.6 times greater than bone this helps in uniform stress distribution.\(^2\)

Alumina
It was outset as implant material in 1970s. It is very inert material and resistance to corrosive environment. Body does recognize it as a foreign material and tries to isolate it by forming a layer of non-adherent fibrous tissue around implant. It is highly inert under physiological condition, has excellent wear resistance and hardness and can be polished to a high surface finish. Its disadvantage is that it forms fibrous tissue around implants.

Zirconia
Zirconia ceramic implants somehow had a controversial history regarding their phase metastability, degradation in water lubricants in simulation studies and influence on friction and wear phenomena. But was used with success as implant material in 1960s. It has higher flexural strength, fracture toughness and high weibull modulus, lower young’s modulus and ability to be polished to a superior surface finish compare to alumina. Zirconium oxide is ivory in color, making it similar to the color of the natural tooth, which is important for restoring teeth in the mouth especially in the anterior region. Zirconium dental implants are a one piece structure they can only work in one position, unlike a two-piece implant for which angled abutments are available. Zirconia implants do absorb water and become prone to fracture.
Carbon and carbon silicon compounds
Carbon is a versatile element and exists in a variety of forms. Vitreous Carbon and Carbon compounds (SiC) were introduced in 1970 for use in implantology. Good compatibility of carbonaceous materials with bone and other tissue and the similarity of the mechanical properties of carbon to those of bone indicate that carbon is an exciting candidate for orthopedic implants. Unlike metals, polymers and other ceramics, these carbonaceous materials do not suffer from fatigue. However, their intrinsic brittleness and low tensile strength limits their use in major load bearing applications.

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BIOACTIVE
Glass ceramics
They are bioactive ceramics first introduced in 1971. Bioglass or Ceravital Silica based glass with additions of calcium and phosphate produced by controlled crystallization. It has high mechanical strength, less resistant to tensile and bending stresses, extremely brittle and they chemically bond to the bone due to formation of calcium phosphate surface layer.

Hydroxyapatite
It was successfully used as implant material in 1988 at north america and to begin with for repair of residual ridge resorption in 1970s. It is similar to the mineral component of bones and hard tissues in mammals. This material has capability to integrate in bone structure and support in growth of the bone. It is thermally unstable with low mechanical strength to withstand long term load bearing applications.

Plasma sprayed hydroxyapatite was first used by Herman in 1988.
Crystalline HA powder is heated to a temperature of 12000 to 16000 °C in a plasma flame formed by an electric arc through which an argon gas stream passes. HA particle size is approximately 0.04mm.
The particles melt and are sprayed on to the substrate, they fall as drops and solidify.
Round interconnected pores are formed. Coating bonds to substrate by mechanical interlocking. There is a lot of controversy regarding the ideal coating thickness of HA coating. Studies have shown that fracture occurred in coatings which were more than 0.1mm in thickness whereas bioresorption was unacceptably rapid with coatings less than 0.03mm. Ideal coating thickness of 0.05 mm is recommended.

Calcium phosphate
These ceramics have biochemical composition similar to natural bone and form direct chemical bonding with surrounding bone due to presence of free calcium and phosphate compounds as implant surface.
It has excellent biocompatibility, no local or systemic toxicity, no alteration to natural mineralization process of bone, lower mechanical tensile, shear and fatigue strength. It is Brittle with low ductility. It exists in dense or porous form. The
pores though decrease the strength they increase the surface area providing additional region for tissue in growth. Ideal pore size is around 150µm, same diameter as shown by inter trabecular spaces in bone. Calcium Phosphate Ceramics show varied degree of resorption or solubility in physiologic fluids. The resorption depends on Crystallinity. High crystallinity is more resistant to resorption. Large particles size requires longer time to resorb. Greater the porosity, more rapid is the resorption. Resorption is more at low pH eg. in case of infection or inflammation. Presence of impurities accelerate resorption. It has been seen that HA resorb less readily than TriCalciumPhosphate.

Polymers
Polymeric implants were first introduced in 1930s. However they have not found extensive use in implant due to low mechanical strength and lack of osseointegration.

Composites biomaterial and zirconia-alumina composites
Composite materials may be defined as those materials that consist of two or more fundamentally different components that are able to act synergistically to give properties superior to those provided by either component alone. Composites made of bioinert and bioactive ceramics are produced to achieve two important features, bioactivity and mechanical strength with good biocompatibility. They have advantages that their properties can be altered to suit clinical application.

CONCLUSION
A wide range of biomaterials are currently in use for implants. It becomes necessary to select apt biomaterial. Appropriate selection of biomaterials directly influences, clinical success and longevity of implants. Thus the clinician needs to have adequate knowledge of the various biomaterials and their properties for their judicious selection and application in his clinical practice. The recent materials like bioceramics and composite biomaterials which are under consideration and investigation have promising future.

REFERENCE