Review Article

Evolution of Implant Biomaterials: A Literature Review

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Abstract

Since centuries, clinicians are making constant efforts to replace completely and partially edentulous dental arches with dental implants. Implantology has become the mainstream practice and is clinically accepted as the desirable treatment modality for the patients. Thus, it is very much essential to analyze the various parameters for their long-term success in the oral cavity. This literature review summarizes the evolution of biomaterials, its characteristics, effects on tissues and its impact on the treatment outcome. It also compares the conventional titanium with the recently popular zirconium implants. Thereby, helping the clinician to choose the ideal implant biomaterial in clinical practice.

Keywords: *Biomaterials, dental implants, evolution, titanium, zirconium*

Introduction

Biomaterial is defined as "A nondrug substance suitable for inclusion in systems which augment or replace the function of bodily tissues or organs."[1] A universal criterion for a dental implant biomaterial is to achieve osseointegration with the bone. It was discovered in the year 1952 by Dr. Per Ingvar Branemark. He introduced threaded implant design constituting of pure titanium which achieved osseointegration.

In this current literature review, we have dealt with the evolution of implant biomaterials from 1955 till date [Table 1]. As a wide array of implant biomaterials has been in use with different properties, it is the clinician who chooses the best which essentially influences the longevity of the implant.

Classification of Biomaterials

Based on biocompatibility

Biomaterials are broadly classified into three major categories: bioinert, bioactive, and bioresorbable.

i. Bioinert: These are the materials which when placed has minimal interaction with the tissue surrounding it, thus leading to osteogenesis. Some of the examples are stainless steel, titanium, zirconium, alumina, and ultra-high-molecular-weight polyethylene
ii. Bioactive: These are the materials once placed inside the oral cavity react with the hard tissues as well as the soft tissues. Examples are synthetic hydroxyapatite, glass ceramic, and bioglass
iii. Bioresorbable: These materials on placement begin to resorb which get slowly replaced with bone. Examples are tricalcium phosphate, polylactic–polyglycolic acid copolymers, calcium oxide, calcium carbonate, and gypsum.

Thus, bioinert and bioactive materials are called as "osteoconductive" materials as they have the ability to act as "scaffolds" for bone deposition on its surfaces.[7]

Based on chemical composition

Biomaterials can also be classified into metals, ceramics, and polymers.

i. Metals: titanium, titanium alloys, stainless steel, cobalt chromium alloys, gold alloys, and tantalum
ii. Ceramics: alumina, hydroxyapatite, beta-tricalcium phosphate, carbon, carbon/silicon, bioglass, zirconia, and zirconia-toughened alumina
iii. Polymers: polymethyl methacrylate, polytetrafluoroethylene, polyethylene, polysulfone, polyurethane, and polyether ether ketone.[8]

Properties of implant biomaterials

Mechanical properties

i. Modulus of elasticity: Should be equivalent to bone (18 GPa). It is selected for equal stress

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Table 1: Evolution of implant biomaterials

Year	Invention
16th and 17th century[2,3]	Discovered by ancient Egyptians and South Americans, usage of stone and ivory implants was reported
	Albucasis de condue wrote a paper on "transplants" in edentulous areas
20th century[2,3]	
1809	Maggio introduced implant made of gold
1887	Harris introduced porcelain teeth with lead-coated platinum posts
1890	Zamenski used in porcelain, gutta, and rubber implants
1898	RE Payne placed silver capsules in socket
1900	Lambotte used implants made of alum, silver, brass, red copper, gold, magnesium, and soft steel plated with gold and nickel
1901	RE Payne invented the technique of capsule implantation
1903	Sholl introduced porcelain corrugated root implants
1913	Dr.Edward. J. Greenfield discovered " Submerged implant", "Healing tissue", and "Dental implant immobility" concept came into existence
	Combination of iridium and 24-carat gold implant was placed
1935-1978	Introduction of synthetic polymers, ceramics, and metal alloys
	Strock made a vitallium screw dental implant and mounted with porcelain crown. This was the first implant to have the success period of 15 years
1969[4-6]	Milton Hodosh invented polymer implants
	Usage of metal and metal alloys, cobalt–chromium alloys, iron–chromium–nickel-based alloys
1975	Cranin *et al.* conducted first research work on zirconia
21st century	Widely popular titanium implants, ceramics, aluminum, and zirconium oxide implants came into existence
At present	Zirconia and titanium–zirconium alloy (Straumann Roxolid) is widely used

distribution at implant and to reduce the mobility of the implant

ii. Tensile, shear, and compressive strength: Should essentially be high to prevent implant failure
iii. Yield and fatigue strength: Should be high to prevent brittleness of the material
iv. Ductility: Minimum of 8% is required as per American Dental Association (ADA) for coining of the implant.

Chemical properties

Corrosion is defined as loss of metallic ions from the surface of a metal to the surrounding environment.[9] There are four types, namely, pitting corrosion, crevice corrosion, galvanic corrosion, and electrochemical corrosion.[10-12]

i. Pitting corrosion: It is a rapid process which occurs in an implant with small surface pit which when placed in a solution, the metal ions which are present near to the pit dissolve, thereby losing its positive ions and combines with chlorine ions leading to pitting corrosion
ii. Crevice corrosion: It occurs at the bone–implant interface. When metallic ions dissolve, they create positively charged environment, thus resulting in crevice corrosion
iii. Galvanic corrosion: The difference in electrical gradients results in galvanic corrosion. The ions which get leaked into saliva at the implant interface later pass on to peri-implant tissues, thus leading to implant failure as a result
iv. Electrochemical corrosion: With the presence of passive oxide layer at the implant metal surface, anodic oxidation and cathodic reduction can be prevented to a greater extent.[7,13]

Comparative evaluation between conventional titanium and zirconium

Titanium

Titanium was first introduced by Wilhelm Gregor in 1789. It has been credited as a successful implant material in the recent years due to its excellent property of biocompatibility and its ability to form stable oxide layer. It is also widely recommended as a material of choice for intraosseous implants.

However, its major drawback is its dark gray color which shines through the peri-implant mucosa which proves to be an esthetic concern for the patients.

Extensive research to solve the problems related to esthetics leads to the discovery of tooth-colored implants, and thus, zirconia came into existence.[8]

Zirconia

The first extensive research work on zirconia was done by Cranin *et al.* in the year 1975. The first implant system to be developed is the SIGMA implant in 1987. Zirconia proved to be a superior material of choice as it was inert along with minimum ion release had higher fracture resilience and higher flexural strength. It achieved osseointegration with minimal plaque accumulation, thus, a better maintenance of soft tissues was achieved, and it also proved to be esthetically pleasing.[14]

Titanium–zirconium alloy (Straumann Roxolid)

Roxolid developed by Straumann consisted of superior mechanical properties such as increased fatigue strength and elongation than the pure titanium, thereby satisfying all the criteria of dental implantologists and accounting for being 50% much stronger than the titanium.[9,15]

Conclusion

Nowadays, although dental implants tend to be more expensive than the conventional dentures, due to their property to replace the roots of the natural teeth and also procuring excellent esthetics, they provide better improvement in quality of life related to oral health compared to the other treatment options. Even among patients, preference for the traditional removable and fixed denture prosthesis has markedly declined compared to implants, thereby proving to be a benchmark in the field of dentistry.

Thus by evaluating the past and the present of biomaterials, one can foresee the future. Clinical success is mainly decided upon the apt implant biomaterials that the clinician selects for the treatment. Thereby, a thorough knowledge is required to eliminate the other materials and choose the finest. Thus, zirconia stands as a "gold standard" for implant fabrication and is known to have a promising future in years to come.

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Conflicts of interest

There are no conflicts of interest.

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