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Recent Advances in Implant Biomaterials - A Review

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ABSTRACT

Usage of Implants in dentistry is tremendously increasing in recent times. This has led to the invention of new biomaterials for dental implants by the researchers. Continuous evolution has occurred in the field of dental implant biomaterials in the last two decades leading to the emergence of innovative biomaterials. This article summarizes the different implant biomaterials and the recent advances in this field. The material science and they are various biological and physical properties affecting their treatment outcome are discussed. Throughout the years, myriads of dental materials have been tried for replacement of missing tooth. Now titanium remains the gold standard as a dental implant material. Over the recent period, many Implant biomaterials have evolved. It includes composites, glass-ceramics, metal alloys, ceramics, glasses, and polymers. Nanotechnology is an emerging application in the branch of implant dentistry. Nanotechnology can improve the properties of dental implants for achieving good osseointegration. It is imperative for dental practitioners to have a good idea about the various biomaterials used for dental implants.

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INTRODUCTION

The biomaterial is a substance that is used to augment or replace any tissue or organ, thereby facilitating the function of the body. Implant materials should have ideal physical, chemical, mechanical and biological properties. Dental implant biomaterial must be biocompatible and should function well when forces are applied. According to the biologic response or chemical composition, biomaterials used for manufacturing dental implants can be classified. (Table 1) (Sykaras *et al.*, 2000).

MATERIALS AND METHODS

Titanium and its alloys

Six types of titanium are used as dental implant materials. It includes CpTi and Ti alloys (ASTM). Based on oxygen residuals of metals, the properties of CpTi vary.

There are three structural forms of Titanium alloys which include alpha (α), beta (β) and alpha-beta. The alpha-beta combination alloy is commonly used in dental implants. They are used because of their low density, good strength, and high resistance to

Table 1: Implant materials can be classified based on the type of material used and the biologic response they elicit when implanted

Biodynamic activity	Chemical composition		
	Metals	Ceramics	Polymers
Bio-tolerant	Gold Co-Cr alloys Stainless steel Niobium Tantalum		Polyethylene Polyamide Polymethylmethacrylate Polytetrafluroethylene Polyurethane
Bio-inert	Commercially pure titanium Titanium alloy (Ti-6AL-4U)	Al oxide Zirconium oxide	
Bioactive		Hydroxyapatite Tricalcium phosphate Bioglass Carbon-silicon	

Table 2: Ceramic materials are available as dental implants and coatings

Materials	Chemical composition
Hydroxylapatite (HA)	Ca10(PO4)6(OH)2
Tricalcium phosphate (TCP)	α, β, Ca3(PO4)2
Fluorapatite (FA)	Ca10(PO4)6F2
Tetracalcium phosphate	Ca4P2O9
Calcium pyrophosphate	Ca4P2O7
Brushite	CaHPO4, CaHPO4• 2H2O
Bioglasses	SiO2-CaO-Na2O-P205-MgO, etc.
Aluminium oxide	Al2O3
Zirconium oxide	ZrO2

corrosion. They also have a low modulus of elasticity, achieving implant success (Bidez and Misch, 1992).

Titanium Sensitivity associated with Dental Implants

Titanium hypersensitivity can result in several adverse reactions and rapid implant exfoliation (Mitchell *et al.*, 1990; Preez *et al.*, 2007). Review studies suggest that titanium hypersensitivity can lead to implant failure and such events are under-reported (Müller and Valentine-Thon, 2006; Chaturvedi, 2013). In contrast, some studies claim that the role of titanium in causing allergic reactions is unproven (Javed *et al.*, 2013; Siddiqi *et al.*, 2011).

Failure Mode of Titanium

Incidence of fracture of a titanium implant is from 0% to 6% (Balshi, 1996; Tolman and Laney, 1993). Implant fracture is caused by faulty implant design; manufacturing defects; a non-passive fit of the framework or physiological and biomechanical overload (Jemt and Lekholm, 1994; Zarb and Schmitt, 1990; Piattelli *et al.*, 1998).

Ceramics

Ceramics as Dental Implant Coatings

Several types of ceramic coatings are used on dental implants (Table 2). It includes bioactive ceramics and inert ceramics. Coatings can be dense or porous with varying thicknesses.

There are various methods of coating metal implants (Lacefield, 1998). Bioactive ceramics release calcium phosphate ions around the implants (Groot, 1994; Morris *et al.*, 2000). Plasma-sprayed dense hydroxyapatite and fluorapatite are the most popular calcium phosphate coating materials (Barrère *et al.*, 2003; Guéhennec *et al.*, 2007).

Polymers

Several types of polymers are used as dental implant materials. Due to many disadvantages of polymers like poor mechanical properties, lack of adhesion to living tissues, and adverse immunologic reactions, the use of polymers as coatings for implants are not validated nowadays.

Future trends in implant biomaterials

Rapid prototyping or additive manufacturing

Rapid prototyping or additive manufacturing is a new technology for manufacturing next-generation dental implants. Advantages of this technique include minimal material wastage and printing of multiple objects at a time.

Application of nanotechnology in dental implants

With the use of newer technologies, hydroxyapatite (HA) and calcium phosphates (CaP) are coated onto the surface of implants (Knowles *et al.*, 1996). However, there are some controversial and contradictory reports as well, claiming HA coatings as not very beneficial (Wang, 2004). There is an increasing interest to use bio-glass in the fabrication of dental implant coatings (Hench, 1991). But attempts to coat bioactive glass on metallic surfaces failed due to interaction between metal and glass (Wilson *et al.*, 1993). It is difficult to fabricate an ideal coating with a single technique or material. A combination of techniques and materials are required to manufacture a material with good properties and achieve a thickness in nanometers.

Biodegradable Implant Materials

Bio-ceramics are bioimplant prostheses that help to regularize physiological functions. Biomaterials are classified into single crystals, polycrystals, glass, glass-ceramics, polymers and composites. Tissue implant can be bio-toxic, bioinert, bioactive, bioresorbable/biodegradable.

Bio-ceramics

Currently, bio-ceramics are used for several medical and dental applications (Lin *et al.*, 2003). Bioinert bio-ceramics from zirconia (ZrO2) (Lohbauer *et al.*, 2008) and alumina (Al2O3) (Wittenbrink *et al.*, 2015) was developed initially, followed by bioactive ceramics. Several materials with good biocompatibility like Calcium phosphates (CPs) (Bohner, 2000), hydroxyapatite, dicalcium phosphate dihydrate and tricalcium phosphate are used as bone replacement materials. Bioactive ceramics helps in osteo-conduction due to their inorganic phase (CP) (Groot, 1993).

Roxolid narrow-diameter implants

Recently roxolid narrow-diameter implants are introduced from Switzerland. It consists of 83%–87% titanium and 13%–17% zirconium with superior mechanical properties.

CONCLUSIONS

Dental implant biomaterials and their design have evolved over the period of time with the advance of biotechnology. With recent advancements, researchers have successfully incorporated artificial structures within biologic systems. Dental practitioners must have a good knowledge of osseointegration properties of different biomaterials used in dental implants for successful clinical practice. A prompt diagnosis and treatment plan is important for selecting a particular dental implant material according to the patients' needs.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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