Chapter 1
Biomechanical Properties of Orthopedic and Dental Implants: A Comprehensive Review

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ABSTRACT

The demand for the orthopedic and dental implants has increased sharply in last decade due to physical traumas and age-related deficiencies. The material used for orthopedic and dental implants should be biocompatible to ensure the adaptability of the implant in the human body. The mechanical stability of implants is dependent on mechanical properties and surface characteristics essential to ensure corrosion and wear resistance. The requirement of mechanical properties also differs substantially from load-bearing to non-load-bearing implants. There are many problems arising due to lack of sufficient biocompatibility, like infection, poor osseointegration, and excessive foreign body response. Fatigue failure, stress shielding, and bone resorption are some major problems associated with lack of mechanical stability. Numerous conventional materials, coatings, and nanomaterials have been used to enhance the implant stability.

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INTRODUCTION

With increasing physical trauma, inherent structural defects and age related deformities, it is necessary to develop quantitative and qualitative enhanced orthopaedic implants (OI) and dental implants (DI). In 2016, Global OI's market was valued at $47,261 million and it is expected to rise to $74,796 million by 2023, registering compound annual growth rate (CAGR) of 6.8% during the forecast period 2017 - 2023 (TMR, 2016). The global dental implants market is projected to expand at a modest CAGR of 6.9% between 2017 and 2025 (Chandra, 2014). OIs are further divided into load bearing and non-load bearing implants. Load bearing OIs includes articulating joint replacement like hip, knee, shoulder and finger replacements and other prosthesis. While non load bearing includes various structural elements like pins, rods and plates which supports the damaged orthopedic parts when they heals them-self properly (Alivu et al.,2018). Historically, there have been two different types of DI: (1) endosteal and (2) subperiosteal. Endosteal refers to an implant that is "in the bone," and subperiosteal refers to an implant that rests on top of the jawbone under the gum tissue. Subperiosteal implants are no longer in use today because of their poor long-term results in comparison to endosteal dental implants.

Metals, ceramic and polymers have been used as bio-material in implants. In metals, titanium based alloys are leading material due to their unique properties. Other metals that have been used are steel and cobalt - chromium based alloys. In ceramics, calcium phosphate based composites are widely used due to their proximity with bone apatite. Hydroxyapatite ($Ca_{10}(PO_4)6(OH)2$) is most commonly used calcium phosphate bioactive ceramic. Other ceramics which have been used are alumina (Al_2O_3) and zirconia (ZrO_2) which fall in category of bioinert ceramics. Polymers have been used not only in OI and DI but also in tissue engineering and drug delivery due to their unique properties. In polymers, mainly ultra high molecular weight Poly ethylene (UHMWPE), Polytetrafluorethyelene (PTFE), Polymethyl methacrylate (PMMA), Polylactide (PLA), Polyglycolide (PGA) and Polyetheretherketon (PEEK) have been used. With recent advances in material science, various nanomaterials have been developed which enhanced the capabilities of implants. Nanomaterials have structural compatibility with hard tissues like bone. Nanomaterials based implants are qualitatively better because of enhancement in essential properties.

The prerequisite properties of materials for OI and DI are characterized as mechanical, biological and other surface properties. The performance of implants highly depends on these properties. It is necessary to focus the research on these prerequisite properties to develop future materials or enhance the capabilities of existing materials. This chapter discuss the necessary prerequisite properties of materials for OI and DI.

PREREQUISITE PROPERTIES

Orthopedic and dental structure of living bodies is like a mechanical system imbedded in a biological environment. The biomaterial which is intended to use in implantation should have desired mechanical and biological properties. Implant's material and design is most dominant factor which decides both the short term and the long term performance of the implant (Prakash et al.,2016). With increase in human life expectancy, the better quality and long life spanned OIs and DIs are needed (Narayan, 2012). The human body's internal environment is very austere having an oxygenated saline solution with salt content of about 0.9% at pH 7.4 and temperature of 37°C (Saro & Sidhu, 2012). This environment accelerates the fatigue failure, corrosion and wears rates several times that cause decrements in the implant life.