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Review

Is zirconia a viable alternative to titanium for oral implant? A critical review

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ABSTRACT

Purpose: Titanium based implant systems, though considered as the gold standard for rehabilitation of edentulous spaces, have been criticized for many inherent flaws. The onset of hypersensitivity reactions, biocompatibility issues, and an unaesthetic gray hue have raised demands for more aesthetic and tissue compatible material for implant fabrication. Zirconia is emerging as a promising alternative to conventional Titanium based implant systems for oral rehabilitation with superior biological, aesthetics, mechanical and optical properties. This review aims to critically analyze and review the credibility of Zirconia implants as an alternative to Titanium for prosthetic rehabilitation.
Study selection: The literature search for articles written in the English language in PubMed and Cochrane Library database from 1990 till December 2016. The following search terms were utilized for data search: "zirconia implants" NOT "abutment", "zirconia implants" AND "titanium implants" AND "osseointegration", "zirconia implants" AND compatibility.
Results: The number of potential relevant articles selected were 47. All the human in vivo clinical, in vitro, animals' studies were included and discussed under the following subheadings: Chemical composition, structure and phases; Physical and mechanical properties; Aesthetic and optical properties; Osseointegration and biocompatibility; Surface modifications; Peri-implant tissue compatibility, inflammation and soft tissue healing, and long-term prognosis.
Conclusions: Zirconia implants are a promising alternative to titanium with a superior soft-tissue response, biocompatibility, and aesthetics with comparable osseointegration. However, further long-term longitudinal and comparative clinical trials are required to validate zirconia as a viable alternative to the titanium implant.

Contents

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1. Introduction

The rehabilitation of edentulous spaces in patients with an osseointegrated dental implant is a scientifically accepted and well-documented treatment modality. Branemark in 1908, first discovered the concept of osseointegration as a serendipity when blocks of titanium placed into the femur of rabbit got ankylosed with the surrounding bone and could not be retrieved. Since then, numerous investigations and clinical studies have established titanium as a reliable biomaterial for oral rehabilitation and reconstruction. Various modifications in the structure, composition, and design of titanium implants have been made since then to enhance its physical, mechanical and optical properties [1–4]. However, the development of undesirable allergic reactions, cellular sensitization, galvanic current formation and aesthetics gray hue have raised demands for more aesthetic and biocompatible implant material [5–9]. Zirconia is emerging as a promising alternative to conventional Titanium based implant system for oral rehabilitation with superior biological, aesthetic, mechanical and optical properties. Zirconia implant is made from a lustrous, grey-white, strong transition metal named Zirconium (Symbol Zr). Zirconia is the oxide form of zirconium. Jons Jakob Berzelius in 1824 was the first to isolate zirconium in an impure form. Initially, zirconia was used in various orthopedic surgical procedures for manufacturing ball heads for total hip replacements, artificial hips, finger and acoustic implants prosthesis. Later it was introduced in dentistry for fabrication of endodontic posts, crown/bridge, restorations, esthetic orthodontic brackets and implant abutments for rehabilitation of partial and complete edentulous arches [10–20]. It was only in 1968, that the first ceramic implant known as the Sigma implant (Sanhause, Incermed, Lausanne, Switzerland) was developed by Sandhaus. Recently the demand for zirconia-based implant system is rising tremendously due to an increased demand for aesthetics. However, it is important to understand the similarities and differences between zirconia and titanium implant system so as to enable the clinician to provide the best treatment outcomes for their patients. This review aims to analyze the credibility of Zirconia as an alternative to replace Titanium based implant system.

2. Material and methods

2.1. Focus question

Is zirconia a viable alternative to titanium for oral implant?

2.2. Search strategy

The following search terms were utilized for data search: “zirconia implants” [All Fields] NOT “abutment” [All Fields], “zirconia implants”[All Fields] AND “titanium implants” [All Fields] AND “osseointegration” [All Fields], “zirconia implants” [All Fields] AND compatibility [All Fields]. Articles written only in English language in PubMed and Cochrane Library database from 1990 till December 2016 were selected.

2.3. Inclusion/exclusion criteria

The inclusion criteria for selecting articles include: type of study design (randomized clinical trial comprising of longitudinal study design, cohort study, case-control study, and cross-sectional study), nature of randomization, risk of bias, sample size and statistical and clinical significance of the outcome. All human in vivo, in vitro, animals’ studies, using zirconia implant were included. Case reports and case series were not considered.

2.4. Data collection

The number of potential relevant article identified and screened were 174. Only those articles that fulfilled the criteria of adequate sample size with equal distribution, outcomes across the study with statistical and clinical significance, correct method of randomization, low risk of bias and adequate blinding were selected. Only 47 article were included for review.

3. Results

The result were discussed under the followings sections: Chemical composition, structure and phases of zirconia implants; Physical and mechanical properties; Aesthetic and optical properties; Osseointegration and biocompatibility of zirconia implants; Surface modifications of zirconia implants, Peri-implant tissue compatibility, Inflammation and soft tissue healing around zirconia implants, and long term clinical trials on prognosis.

3.1. Chemical composition, structure, and phases of zirconia implants

The pure form of Zirconia occurs in two major forms: (a) the crystalline zirconia which is soft, white, and ductile, (b) the amorphous form which is bluish-black powder in nature. The powder form of Zirconia is refined and subsequently treated synthetically at high temperatures to yield optically translucent form of crystalline zirconia. After purification, the powder form of zirconium is filled into malleable dies and processed under high pressure (2000–4000 bar) and temperature molds to form homogenous implants of exact dimension [11–19].

Three crystalline phases occur in zirconia implants: monoclinic (m), tetragonal (t) and cubic (c). The monoclinic phase of Zirconia exists at room temperature and is stable for up to 1170 °C. Above 1170 °C, the monoclinic phase changes to tetragonal phase with 5% decrease in volume. At 2370 °C, the cubic phase starts appearing. Upon cooling, a tetragonal to monoclinic transformation with a 3–4% increase in volume takes place for about 100 °C till 1070 °C. This increase in volume and resultant expansion without a mass transfer upon cooling generates stress and causes it to become unstable at room temperature [17]. To prevent this phenomenon and to generate a Partially Stabilized Zirconia (PSZ) with stable tetragonal and/or cubic phases, various stabilizing oxides [16 mol% magnesia (MgO), 16 mol% of limestone (CaO) or 8 mol% Yttria (Y_2O_3)] are added to zirconia implants [17,20]. This martensitic-like phase transformation toughening significantly increases the crack resistance, fracture toughness, and longevity of zirconia endosseous implant [17,18,21].

Other variants of zirconia implants include 12Ce-TZP (Ceria-stabilized zirconia) and ATZ (Alumina toughened Zirconia). Alumina has also been added to Yttria stabilized-tetragonal Zirconia polycrystal (Y-TZP) in low quantities (0.25 wt%) to yield tetragonal zirconia polycrystal with alumina (TZP-A) with significant improvement in the durability and stability of zirconia crystals under high temperatures and humid environment. This

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