Review Article

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ZIRCONIA DENTAL IMPLANTS: AN OVERVIEW

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ABSTRACT:

The use of zirconia as an alternative to titanium implants has increased in recent years. However, long-term clinical studies regarding the success rates and clinical outcome of zirconia dental implants are inadequate for its routine use in oral rehabilitation. The purpose of this review was to summarize the current data regarding the clinical advantages and limitations of zirconia as an implant material. The available information suggests that zirconia ceramics have good biological and mechanical properties; and might be considered as a viable metal-free alternative for tooth replacement with a treatment outcome comparable to titanium implants.

Keywords: Zirconia, dental implant, zirconia implant

INTRODUCTION:

Although various materials such as ceramics, polymers, metals and metal alloys involving gold, stainless steel and cobalt chromium have been used for manufacturing dental implants, titanium and its biomedical alloys have become the most reliable treatment option for the replacement of missing teeth due to its superior biomechanical properties and favorable long-term clinical survival rates.[1-4] Nevertheless, there have been some concerns that surface corrosion of titanium by certain substances such as fluorides and hydrogen peroxide or wear in the oral cavity, might evoke hypersensitivity reactions and peri-implant inflammation.[5-7] Previous studies in literature also indicate a possibility of cytotoxicity, mutagenic and carcinogenic reactions due to the diffusion of Ti, Al, V into the bloodstream.[8] Another significant drawback is the dark grayish color of titanium, which often is visible through thin mucosal biotype and high smile line.[9]

However, recently introduced and increasingly popular zirconia implants may prove to be one possible solution to the aforementioned problems with

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titanium implants. Ceramics has already been utilized as dental implant material in the past such as the alumina Cerasand ceramic oral implant (Sandhaus 1987); Tubingen Implant; (Schulte & Heimke 1976); Bioceram system (Kyocera 1988); Bionit implant system (Muller, Piesold and Glien 1990).[10] However, the biomechanical qualities of oral implants fabricated from alumina were not sufficient for long-term success and sustainability. Newly proposed zirconia ceramics (yttria-stabilized tetragonal zirconia polycrystal, Y-TZP), are the current choice of material for ceramic implants. A special sintering process named "Hot Isostatic Pressing" (HIP) in combination with an inert atmosphere (argon) under high pressure reduces the porosity as well as material defects and increases the density.[11] Commercially available implant systems that are providing zirconia implants are the CeraRoot system (Oral Iceberg, Barcelona, Spain), the ReImplant system (ReImplant, Hagen, Germany), the White Sky system (Bredent Medical, Senden, Germany), the Goei system (Goei Inc, Akitsu-Hiroshima, Japan), the Konus system (Konus Dental, Bingen, Germany), the Z-systems (Z-systems, Konstanz, Germany), and the Ziterion system (Ziterion, Uffenheim, Germany).[12] However, this novel implant material must maintain the features that provide titanium implants with their high success rates to become the material of choice for dental implants.

I. **Mechanical properties:** Its mechanical properties are very similar to those of metals, by virtue of which zirconia has been called ''ceramic steel''.[13] Zirconia has a high flexural strength (900-1200MPa), hardness (1200 Vickers), Weibull modulus (10-12) and a compression resistance of about 2000 MPa, all needed for long term stability and success.[14-18] In high load situations, such as those encountered in mastication and parafunction, a crystalline modification wherein the metastable tetragonal phase transforms to the monoclinic phase, prevents the crack propagation. This phenomenon, known as transformation toughening, increases the fracture strength and fracture toughness of Y-TZP ceramics and makes zirconia a unique and stable material for use in high-load situations.[19] The stress distribution patterns of yttrium-partially stabilized zirconia implants was observed to be low, well distributed, and similar to commercially pure titanium implants.[20,21] Cales found that cyclical stresses are also tolerated well by zirconia implants.[22] However, a decrease in toughness and flexural strength were reported after surface grinding of zirconia.[23,24] Silva et al. examined the influence of crown preparation on the reliability of one-piece zirconia implants and found no decrease in the fracture strength at loads under 600 N.[25] On the other hand, Kohal et al. reported low fracture strength values for both one-piece and two-piece zirconia implants following the cyclic loading and implant preparations.[26,27] Early zirconia implant mechanical failures have been observed due to flaws created during ceramic implant fabrication and subsequent surface treatment that leads to crack propagation when combined with high bending moments or biomechanical overload.[28] When exposed to wetness and increased stresses, accelerated aging causes microcracking and increased wear of zirconia.[29] However, recent in-vitro studies showed that upon aging, the decrease in mechanical features of zirconia used for oral rehabilitation occurs within clinically acceptable values.[30]

II. Corrosion and wear resistance

The aqueous corrosion mechanism of dental ceramics is mainly an ion exchange reaction, where alkali ions in the material are replaced by hydronium ions from the solution. Y-TZP ceramics has an almost total tetragonal microstructure of small grain size (< 1µm) and extreme chemical stability.[11] It exhibits superior corrosion and wear resistance due to immobilization of the alkali ions when exposed to a corrosive environment.[37] Milleding performed an in-vitro study for evaluation of the hydrolytic resistance of ceramic materials in a 4% aqueous acetic acid solution at a temperature of 80°C for a time period of 18h and reported only minor changes in the surface elemental composition of zirconia. The superior corrosion resistance offered by zirconia may be due to the presence of crystalline phases that shows less susceptibility to acid attack as compared to the glass phase.[38]

III. Biocompatibility

Zirconia ceramics are chemically inert materials and do not provoke any inflammatory, allergic, immune, toxic, mutagen, or carcinogenic reactions in connective, immunologic, or bone tissues.[39-42] Sterner et al. reported that Ti and alumina particles are great inducers of the TNF-α inflammation marker versus zirconia (ZrO_2), which had no effects on human monocytic cell line.[43] The insertion of yttria-stabilized zirconia in animal bones also showed no local or systemic toxic effects.[44] Christel, inserted pins of zirconia (Y-TZP) and alumina into femurs of rabbits and did not observe any difference in bone reaction to implants.[45] Therefore, both in-vitro and in-vivo studies have confirmed the superior biocompatibility of high purity Y-TZP ceramics, especially when they are totally purified from radioactive contents.

IV. Osseointegration and bone-implant contact

Animal studies indicated similar osseointegration of zirconia and titanium implants after insertion in different sites and under different loading conditions. Successful osseointegration was observed in different animal models which demonstrated the mean bone-implant contact to be above 60%.[46-51] Moreover, zirconia is known to be osseoconductive, which means this ceramic is able to interact with osteoblasts by intimate contacts, and makes the cells capable of elaborating the extracellular matrix by synthesizing various essential and structural proteins.[52] Sennerby et al. investigated the influence of surface microtopography on the osseointegration of zirconia implants using oxidized titanium implants as controls. The resistance to removal torque forces observed with modified zirconia implants were similar to those of oxidized titanium implants and significantly higher compared to machined, non-modified zirconia implants. However, no significant difference regarding bone-to-implant contact was reported between the two different materials.[53] Several studies have investigated cell attachment, proliferation and differentiation of osteoblast-like cells on modified zirconia surfaces and confirmed that the surface-modified zirconia implants positively influences bone integration and improves initial bone healing.[54-59] Pirker et al observed a stable implant and an unchanged peri-implant marginal bone level around a zirconia immediate implant placed in the maxillary first premolar region after a follow-up period of 2-years.[60,61] On the other hand, Kohal reported increased radiographic bone loss (>2 mm) after one year around the immediately loaded one-piece zirconia implant system precluding its recommendation for clinical use.[62]

V. Peri-Implant Soft Tissue Response

Zirconia favor the attachment of human gingival fibroblasts and spontaneous regeneration of papillae, known as creeping attachment of the gingiva to obtain optimum periointegration around implants.[63] Various in-vivo and in-vitro investigations showed that zirconia implants achieve a comparable or even better soft tissue integration compared to conventionally pure titanium.[64,65] Degidi et al conducted a human histologic study to evaluate the peri-implant soft tissues in contact with titanium and zirconium oxide healing caps, and found higher values of vascular endothelial growth factor, nitrous oxide synthase, microvessel density and inflammatory infiltrate, with a subsequently higher rate of inflammation-associated processes in the titanium specimens compared to that of zirconium oxide specimens.[66] Brakel et al. found a greater decline in the mean probing depth in zirconia implant as compared to titanium.[67] Overall, the zirconia implants have been reported to maintain the biologic width, stable marginal bone levels and develop a peri-implant apparatus very similar to the natural dentition.

VI. Plaque/bacterial accumulation

Plaque-induced periimplantitis has been proposed to be one of the most critical factors of implant failures.[68,69] The study by Rimondini et al. compared bacterial adhesion on tetragonal zirconia polycrystal stabilized yttrium (Y-TZP) and machined grade 2 Ti (commercially pure titanium) specimens with equivalent average surface roughness (Ra) values both in vivo and in vitro. The in vivo study showed significantly lesser cocci and rods in relation to zirconia than titanium, whereas no differences were noted for Actinomyces spp. or P.

gingivalis in vitro.[70] Scarano et al. compared zirconia and titanium specimens with surface roughness values of 0.76 µm and 0.73 µm, respectively and reported a percentage of surface coverage by bacteria of 12.1% on zirconia as compared to 19.3% on titanium.[71] However, some studies reported similar biological properties in terms of protein adsorption, biofilm composition and bacterial adhesion on titanium and zirconia ceramic surfaces.[72,73]

VII. Esthetic outcome

Zirconia dental implants have the potential to overcome the possible esthetic compromises with titanium implants because of its toothlike color that precludes the dark shimmer of titanium implants in the presence of thin mucosal biotype or gingival recession.[74] Spectrophotometer analysis confirmed that zirconia implants induces lesser color change under thin mucosa.[75,76] Favourable soft tissue reactions seen with zirconia dental implants leads to better periimplant papilla dimensions and lesser gingival recession than the titanium implants. Newer zirconia implants being indistinguishable from natural teeth in color, can be considered as an alternative to titanium implants to meet the increased demand for improved esthetics in the recent years.

VIII. Clinical survival and success rates

The available clinical data from case reports, prospective and retrospective clinical studies conducted on one-piece zirconia implants, reported a survival rate of 74%–98% after 12–56 months and success rates of 79.6%- 91.6% after 6–12 months of prosthetic restoration.[77] Excellent esthetic and functional outcomes were observed for one-piece zirconia implants with different surface treatments after a follow-up period ranging from one to five years.[78] Two-piece zirconia implant design evaluated in recent prospective clinical studies also reported possible clinical application of zirconia implants for the replacement of missing teeth in partially edentulous jaws. The outcome of immediately provisionalised single-piece zirconia implants restoring single tooth gaps in the maxilla and mandible revealed comparable results to immediately restored titanium implants after 24 months of clinical function in a prospective case series.

CONCLUSION:

This review attempts a summary of the current scientific status of zirconia dental implants as based on a literature survey. Zirconia implants being indistinguishable from natural teeth in color, can be considered as an alternative to titanium implants to meet the increased demand for improved esthetics in the recent years. Nevertheless, long-term, randomized controlled trials are required to support the routine clinical application of zirconia implants. As new processing methods (CAD-CAM and hot isotactic pressing) and purification processes are being developed, the future of zirconia implants appears to be very promising.

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