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# Zirconia Over Titanium Implants: The Evidences are not Enough

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**Abstract**

Implant therapy is a widely used treatment modality for completely and partially edentulous patient. It gives excellent long term results and has made practice of dental implantology astonishingly widespread. Titanium dental implants have proved to be successful means of prosthetic rehabilitation for more than six decades. Recently, ceramics have been proposed as an alternative to titanium. Zirconia implants with better aesthetics, mechanical and biological properties are showing a promising future in dental implantology. This narrative review analyses the evidences to compare titanium and zirconium implant in a systemic manner. The paper includes the mechanical, biological and clinical consideration involving both implant materials.

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## INTRODUCTION

Since its inception in 1960 Titanium implants (Ti) have dominated oral implantology. Titanium can be found in different combinations with other metals for use in dentistry. Titanium dental implants, considered gold standard in oral implantology and have stood the test of time in restoring partial and complete edentulism. They are also well suited to use as orthodontic anchors. The survival rate of titanium implant restorations is approximately more than 90% in different clinical studies.[1]

Titanium is dark greyish colour and gives unaesthetic huethrough the peri-implant mucosa. This situation becomes more pronounced in the presence of a thin mucosal biotype, gingival recession, unfavourable soft tissue conditions and is of great concern in maxillary anterior region.[2] Thus, patients' high

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aesthetic expectations and apprehension of titanium sensitivity, has fuelled the demand for metal-free dental implantology. Ceramic materials are thus considered alternatives to titanium.

Various ceramics such as biologically active bioglasses, and inert ceramics like aluminium oxide and zirconium oxide have been used as coatings on titanium implants.[3] Yttrium-stabilized tetragonal polycrystalline zirconia (Y-TZP), a form of ceramic is suitable substrates for dental implants fabrication and has good mechanical properties.[4]

Zirconium (Zr) has chemical and physical properties like Titanium and is considered a strong and durable metal. Incidentally, Zr and Ti are commonly used in implant dentistry as both of them do not inhibit the bone forming cells, osteoblasts which are critical for osseointegration. Zirconia (zirconium dioxide, ZrO2), known as "ceramic steel", in addition to biocompatibilityhas significant properties namely hightoughness, superior strength, and fatigue resistance. [5] Types of Zirconia used in dentistry are Yttrium-Stabilized Tetragonal Zirconia Polycrystals, Glass-Infiltrated Zirconia-Toughened Alumina, Alumina Toughened Zirconia (ATZ).[6]

**Material and Methods**

This narrative review started with a PubMed search using the following key words: zirconia or zirconium dioxide, dental, and titanium implant. The electronic or manual full texts of articles were preferably obtained and in their unavailability abstracts were screened. The included articles were related to zirconia and titanium dental implants. Articles about zirconia or titanium implants for orthopedic usage were excluded from the review.

**Discussion**

**Comparison of various Aspects of Zirconia and Titanium Implants**

**Osseointegration**

The biological fixation of implant relating to direct bone to implant contact (BIC) which makes implant fused with bone is known as osseointegration.[7] Systematic reviews[8,9] compared osseointegration of Titanium and Zirconia implants with BIC values and removal torque values. There were limited studies available for inclusion but most studies reported no significant differences in BIC and removal torque values. BIC ranged from 26% to 71% for zirconia implants and 24–84% for titanium implants. A histological analysis study of the soft and hard tissues and a histomorphometric analysis of BIC confirmed optimal osseointegration of zirconia implants without any signs of inflammation or foreign body rejection.[10]

**Mucointegration and Biofilm Formation**

The implant abutment-soft tissue interface is an important factor in its influence on the stability and health of the peri-implant tissues. The mechanical attachment between the implant surface and the peri-implant mucosa provides an improved seal which more effectively protects the underlying bone against inflammatory products. It is also observed that the dimensions of the periimplant mucosa are similar around titanium and zirconia. Many animal studies hypothesise that the longer junctional epithelium and the higher collagen fibers density around zirconia implants could result in more mature and stable mucointegration.[11] It is also shown that bacterial biofilm accumulation is lessand hence soft tissues around zirconia implants are less susceptible for periimplant inflammation.

A study found that zirconia abutments had a low surface free energy and surface wettability that results in reduced adhesion of bacteria.[12] A systematic review by Durks and Tomasi reported a prevalence of peri-implant mucositis ranging from 19 to 65%, peri-implantitis from 1 to 47% with titanium implants.[13] The limited clinical experience with zirconia implants however indicates that peri-implantitis seems to be less of a problem with these type of implants.

**Corrosion, Allergy and Hypersensitivity**

The assumption that titanium might stimulate an unwelcome host reaction is supported with little scientific evidence. It is mainly attributed to association between surface corrosion of titanium and hypersensitivity reactions.[14,15]

The systematic review by Javed F *et al* concluded that the titanium as a cause of allergic reactions in patients with dental implants remains unconfirmed. The allergic reactions reported can be due to other metal components/ impurities present in titanium alloys used for dental implants.[16] In a review by Siddiqi A *et al* it was indicated that studies reporting metal sensitivity are less documented in scientific

literature probably because of poor understanding of the mechanism that could induce hypersensitivity in susceptible patients and can be a risk factor for implant failure.[17] *In vitro* studies reported by Wang *et al*. showed genotoxicity and cytotoxicity in human lymphoblastic cells, with the induction of apoptosis following prolonged exposure to ultrafine Titanium dioxide.[18]

**Table: 1 Comparison of Zirconia and Titanium dental implants**

| Zirconia implants | Titanium implant |
|---|---|
| More aesthetics with zirconia implant | Poor aesthetics especially in thin gingival phenotype because of metallic grey colour of metal |
| Gingivae are healthy around ceramic and better preserved from bacterial adhesion | Bacteria accumulates more rapidly in metal surface |
| Zirconia is non-conductor of electricity and do not corrode | All metal suffers oxidation and corrosion and are good electric conductors which favour biofilm formation and may cause tissue toxicity |
| Zirconia is bioinert and non-allergic | Titanium may cause allergy and immune modulation |
| Bleeding and inflammation is rare around these implants | Bleeding and receding gingiva are more frequent |
| Zirconia implants are more prone to manufacturing defects which may cause implant failure | Titanium implants are structurally strong and resistant to minor imperfections |
| One piece zirconia implants reduce chances of micro movement, screw loosening and prosthetic complication although limiting prosthetic flexibility | Titanium implants has different prosthetic options with single and two piece systems |

**Table 2: Companies manufacturing Zirconia implants**

| MANUFACTURER | ZIRCONIA IMPLANT |
|---|---|
| Strauman | Straumann® Pure Ceramic Implant Systems |
| Noblebiocare | Noblepearl. |
| Zimmer biomet | Certain dental implants system. |
| Ceraroot. | Ceraroot |
| TAV Dental | TAV Zirconia |
| Bredent | White Sky implant |
| Zeramex | Zeramex XT , Zeramex P6 |

Scientific reports also suggest that nonspecific immunomodulation, cellular sensitization and autoimmunity can potentially be indruced by certain metals. Galvanic adverse effect of titanium with saliva and fluoride has been demonstrated in some patients. Considering all these facts, allergy testing should be done in susceptible patients and titanium implant alternative recommended.[2]

**One-Piece Zirconia Implant Design**

Traditional titanium implant systems consist of two metal components, the implant fixture and abutment joined together with a fixation screw. Micro-movement during extreme pressure of chewing, create shumid conducive micro-environment where anaerobic bacteria thrive, lead to biofilm formation and release toxins and other noxious substances.

This induces inflammation around the implant, increasing the possibility of implant failure. Zirconia implant is available mostly in a one-piece design that prevents micro-movement. Although review done by ArRejaie *et al* on clinical studies was inconclusive for lack of sufficient evidence of the benefits of single piece zirconia implant.[19] One piece implants also limit prosthetic flexibility especially in full mouth rehabilitation. Recently two-piece Zirconia implants have also been made available by some manufacturers.

**Clinical Studies**

Roehling S *et al* conducted a meta-analysis on performance and outcome of Zirconia dental implants and evaluated clinical studies on the basis of implant failure, technical and biological complications, aesthetics parameters.[20]

For commercially available (CA) Zirconia implants with follow-up of 12-61 months' technical complications (1.6%), implant fractures (0.2%) and biological complications (4.2%) were reported. CA Zirconia implants and Titanium implants showed comparable mean survival rates and peri-implant mucositis and periimplantitis. However, authors suggested more clinical long-term studies on same theme.

**Limitations of Zirconia**

Scientific understanding of biomechanical failure modes is essential to develop optimum zirconia implant design. Mechanical failure may occur during the surgical implant placement or subsequent functional loading.[21] Contrary to titanium implants, manufacturing imperfections and surface treatments may compromise strength of ceramic implants. Material flaws may propagate during occlusal load causing implant failure.[22] Peri-implant bone loss creates unfavourable crown to implant ratio, which creates a vicious cycle of increased magnitude of bending forces and with lateral occlusal loading, can result in early implant complications and eventually implant failure.[23] In type I dense bone, hand torqueing during implant insertion and application of non-axial forces generate bending forces which can be detrimental to implant success.[22] Zirconia implants with a small diameter are more prone to fracture in this regard. Furthermore, Zirconia implant crowns are generally cemented which may cause pericementitis and peri-implantitis.

**Conclusion**

Zirconia has emerged as an aesthetic alternative to titanium implants. Mechanically, Zirconia exhibits potential physical properties like high strength, fracture and wear resistance due to phase transformation toughening and additionally it has promising biological properties like biocompatibility, tissue integration and low susceptibility to biofilm formation. These properties might lower the risk for peri-implant inflammatory diseases. Zirconia remains sensitive to surface defects, therefore during designing and manufacturing zirconia implants all stress concentration sites should be avoided or minimized. Clinical long-term studies on Zirconia implants with detailed understanding ofbiological and technical complications, prosthetic and aesthetic outcomes and implant failures, are needed to confirm the promising short-term results. At present, the evidence for a final decision on Zirconia over Titanium dental implant is insufficient.

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**Conflict of Interest**

The authors do not have any conflict of interest.

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