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Zirconia Implants- Future Of Implant Dentistry

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Abstract

Despite being regarded as the gold standard for filling up edentulous areas, titanium-based implant systems have come under fire for a number of unavoidable faults. Demands for more aesthetically pleasing and tissue compatible materials for implant manufacturing have increased due to the advent of hypersensitivity reactions, biocompatibility problems, and an unsightly grey colour. With better biological, cosmetic, mechanical, and optical qualities than traditional titanium- based implant systems, zirconia is emerging as a possible substitute. The purpose of this review is to assess the reliability of zirconia implants as a titanium substitute for prosthetic rehabilitation.

Keywords: Hypersensitivity reactions, prosthetic rehabilitation Titanium, Zirconia

Introduction

The aesthetic, phonetics, and chewing efficiency are all affected by tooth loss. Therefore, replacing missing teeth becomes essential. There are many possibilities when it comes to tooth replacement, including dental implants complete dentures, removable partial dentures, and fixed partial dentures (FPD).

A dental implant is an alloplastic substance or device that is surgically inserted into the oral tissue beneath the mucosal or periosteal layer or within the bone for functional, therapeutic, or aesthetic objectives, according to B Guillaume.1

The benefits of dental implants (DI) are as follows:

1. DI maintains natural look as a result of emergence profile.
2. DI improves ability of eating and chewing as it is fixed.
3. DI prevents bone loss as they provide functional stimulus to bone.
4. DI doesn't damage adjacent teeth like in preparing abutment teeth in FPD.

It's fascinating to see dental implants develop. Since the period of the Egyptian and Mayan civilizations, numerous attempts have been made to replicate a tooth-like device that can be placed into the jaw bone.2 A fixed bridge was made by Phoenicians using ivory teeth that were stabilised by gold wire around the year 300 AD.

The Mayan civilization is credited with developing dental implants first, excelling in the use of shell fragments as implants to replace mandibular teeth about the year 600 AD. Radiographs of Mayan mandibles obtained in the 1970s reveal compact bone growth surrounding the implant, which is similar to bone observed around blade implants.

Additionally, the early Honduran culture first prepared and implanted a stone in the mandible approximately AD 800.

The term osseointegration was first introduced by Professor Per-Ingvar Branemark in the 1952s. He described osseointegration as the direct structural and functional connection between the living bone and surface of a load bearing implant.4 Osseointegration of bone to titanium implants was an accidental discovery. In 1952, Per-Ingvar Branemark implanted a titanium chamber to the rabbit bone to investigate the effect of blood flow in rabbit bone. After completion of the test, when he wanted to remove the chamber, he recognized that the chamber had integrated with bone and could not be removed easily. At that point, he discovered bone growth into the titanium chamber and good integration of bone and titanium implant. He called this phenomenon "osseointegration".5

Toxicity Of Titanium Implants

The American Society for Testing and Materials (ASTM) lists four grades of commercially pure titanium (CpTi) used in implant biomaterial. These grades have different purity grades, with different amounts of interstitial elements (carbon, oxygen, nitrogen, hydrogen, and iron). The most commonly used alloy is Ti-6Al-4V. Nanometerials are also used for the surface treatment of titanium-based dental implants. Two titanium-contained coating materials, Ti and TiN (Titanium Nitride), have been studied to improve the chemical and wear resistance of titanium implants.

However, wear and corrosion still occur, especially in extreme environments like oral ones. The released particles can come from the titanium coating layer or from the titanium implant itself. Recent studies have reported that particles of implants were found in peri-implant tissues, which may strongly suggest that a corrosive process has occurred on the titanium implant. Environmental factors such as low pH or high concentration of fluoride have been studied, with corrosion being significant in conditions with low pH or high fluoride concentrations.

In vitro studies by Strietzel et al. detected the influence of the presence of fluorine on titanium corrosion, with corrosion further enhanced at lower pH and less influenced by organic acids and their pH values. Schiff et al. tested the effects of fluorine and pH on titanium and titanium alloys, finding that fluorine ions could destroy and corrode titanium and titanium passivation layer. Penarrieto Juanito et al. evaluated ion releases from dental implant systems in fluoride and hydrogen peroxide and examined the surface changes in this process.

Recently, there are more studies working on the linking of titanium implants and implant complication or failure. Wachi et al. reported that Ti ions may be involved in the deteriorating effects of peri-implant mucositis, which can develop into peri-implantitis accompanied by alveolar bone resorption. Olmedo et al. reported two cases of reactive lesions of peri- implant mucosa associated with titanium dental implants, one diagnosed as pyogenic granuloma and the other as peripheral giant cell granuloma.

Previous studies have found macrophages loaded with titanium particles as indicators of the corrosion process in the soft peri-implant tissue of failed human dental implants. Olmedo et al. performed the exfoliative cytological test and observed particles inside and outside the epithelial cells and macrophages. The concentration of implant particles in the peri-implantitis group was significantly higher than in the control group.

Addison et al. used synchrotron X-ray microfocus spectroscopy to detect trace distribution of Ti in tissue, showing a scattered and heterogeneous distribution of Ti in inflamed tissues taken from around skin- penetrating Ti implants. The location and distribution characteristics of Ti particles suggested that debris from implant placement are unlikely to be the major contributors. One of the causes of implant failure can be attributed to allergic reactions to titanium. There have been reports of hypersensitive reactions such as erythema, urticaria, eczema, swelling, pain, necrosis, and bone loss due to titanium dental implants. However, the reliability of the patch test for current titanium is not guaranteed for clinical use, and future studies and countermeasures are necessary.

Zirconia As An Implant

Akagawa et al. studied the initial interface of implant- bone with 1-stage zirconia screw implants and various conditions of occlusal loading after three months in beagle dogs. They found no sign of superstructure in the non-loaded group, while the loaded group contained metal superstructures. The bone response to zirconia implants at four weeks was shown by Scarano et al., with a value of BIC of 68.4%.

Dubruille et al. compared the BIC on three types of dental implants: alumina, titanium, and zirconia. They found no statistically noticeable difference between the implants. Scarano et al. showed that bony healing is greater on zirconia surfaces than on the surface of titanium. Kohal et al. assessed the hard and soft tissue conditions of sand blasted zirconia implants, finding mean mineralized BIC values of 72.9% and 67.4% for titanium and zirconia implants respectively.

Hoffman et al. focused on the degree of early bone apposition around zirconia dental implants at two weeks and four weeks after insertion. Zirconia implants showed a slightly higher degree of bone deposition compared to titanium implants at two weeks, but bone apposition was higher in titanium compared with zirconia at four weeks. Langhoff et al. studied the BIC of chemically altered titanium implants and sand blasted large grit acidetched (SLA) zirconia implants. Deprich et al. compared 24 screw type zirconia implants with acid etched surfaces, finding positive results of ultrastructural evidence of osseointegration.

Surface analysis revealed that surface roughness increased by airborne particle abrasion and acid etching, but no significant differences were observed among zirconia groups and SLA titanium for 6 and 12 days. Gahlert et al. found that machined zirconia implants exhibited statistically significant lesser values of RTQ than other implant types after eight and twelve weeks.

Implant systems providing zirconia implants Commercial zirconia implant systems currently available are the following: 9

1. Ceraroot (Oral Iceberg, Barcelona, Spain)
2. Sigma (Incermed, Lausanne, Switzerland)
3. White Sky (Bredent Medical, Senden, Germany)
4. Z-Systems (Z-Systems, Konstanz, Germany)
5. Zit-Z (Ziterion, Uffenheim, Germany)
6. Ziunite (Nobel Biocare)

Zirconia Ceramic Systems In Dentistry

Three zirconia-containing ceramic systems used in dentistry are 1. Yttrium-Stabilized Tetragonal Zirconia Polycrystals (3Y-TZP)

Glass-Infiltrated Zirconia-Toughened Alumina (ZTA)

Alumina Toughened Zirconia (ATZ)

Most commonly used material amongst all in manufacturing oral implants is yttria-stabilized tetragonal zirconia polycrystal (Y-TZP, short: zirconia) with or without addition of a small percentage of alumina. To improve material characteristics, HIP process (HIP: hot isostatic post compaction) is used which give rise to highly compacted structures with fine grain size and high purity of Y-TZP.

V. Mechanical Properties Of Zirconia:

Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) materials offer superior corrosion, wear resistance, and high flexural strength compared to other dental ceramics. ZrO2 is a polymorphic material with three forms: monoclinic, tetragonal, and cubic. Alloying pure zirconia with stabilizing oxides like CaO, MgO, Y2O3, or CeO2 can retain the metastable tetragonal structure at room temperature. Dental procedures can trigger a conversion from tetragonal to monoclinic, leading to volume expansion and compression of cracks. However, extreme environmental conditions can cause the material to transform aggressively into the monoclinic phase, which is not recommended for dental implants. This mechanical property is known as "aging" and is particularly enhanced in water or vapor. Aging can be avoided by accurate processing and reducing grain size and stabilizing oxide content.

Osseointegration And Tissue Response Of Zirconia Implants:

Osseointegration, the process of implant-bone contact leading to bone-to-implant anchorage, is crucial for the success of endosseous implants. Surface topography of biomaterials, such as zirconia, has been studied to promote implant osseointegration. Studies have shown that zirconia implants with modified surfaces integrate into bone in the same way as titanium implants. However, the osseointegration of zirconia implants has not been thoroughly explored.

Depprich et al. (2008) found that titanium surfaces had somewhat better bone implant contact than zirconia surfaces, but there was no statistically

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significant difference between the two groups. Placko et al. (2012) found that surface coating cobalt chrome implants with titanium or zirconium/titanium enhanced their total osseointegration, making them desirable material combinations for orthopedic implants. The bone tissue response to novel zirconia implants with changed surfaces was compared to generally existing titanium dental implants and currently accessible zirconia implants.

Rocchietta et al. (2009) found no statistical significance between the chemically changed implants and the topographically modified zirconia implants in terms of interfacial shear strength. Additional chemical alterations of topographically modified zirconia implants do not appear to improve bone-to- implant contact or boost interfacial shear strength. A study by Sennerby et al. found no significant differences in osseointegration (BIC) between non- modified and modified zirconia implants. Surface modifications can enhance bone integration of titanium implants in various animal models. Surface roughness and topography influence osseointegration of zirconia implants to a greater extent. Surface modification by acid-etching affects not only the microtopography but also submicrometric and nanometric topography of implant materials. These topographic features determine cell reactions, including orientation, changes in motility, adhesion, and shape. Differences in the physico-chemical properties of the material also affect cell responses. The successful integration of zirconia implants into native bone tissue and comparable BIC was demonstrated by Depprich et al. (2008). However, modified zirconia implants exhibited lower Ra values compared to titanium implants. The process of osseointegration of zirconia implants showed similarities to that known for titanium implants.

Biocompatibility Of Zirconia Implants

Biocompatibility refers to a biomaterial's ability to perform its desired function without causing inflammatory, allergic, immune, toxic, or carcinogenic effects in the recipient. Zirconia, known for its aesthetic and mechanical properties, has gained popularity for its biocompatibility in various clinical applications, including crowns, bridges, implant abutments, and bone grafting procedures.

Reduced Bacterial Colonization

The mouth's humid environment, with a constant temperature of 36.68ºC, provides numerous ecological niches for bacterial microflora. This flora is a dynamic equilibrium between microorganisms' adhesion capacity and removal forces in the mouth. Teeth, crowns, dental prostheses, and endosseous implants facilitate the formation of thick biofilms, leading to dental pathologies and failures in implantology. The adhesion process is dependent on surface roughness, wettability, and chemical composition of the biomaterial. Surface roughness and irregularities facilitate plaque accumulation in vivo. Surface roughness and irregularities can influence the adhesion of bacteria on surfaces, affecting plaque accumulation.

Biological Properties

Zirconia has been used as non-dental implants since 1988 for hip replacements due to its biological inertness to acids and bases. It can be used in patients with allergic reactions to titanium. Factors influencing implant healing include biomaterial, surface treatments, controlled surgical procedures, bone quality, bacterial ecosystem, peri-implant gingiva health, and functional loading. In 2004, Glauser and co-workers evaluated in humans an experimental self-made zirconia abutment with an objective of studying the peri- implant hard and soft tissue reaction as well as fracture resistance over time (four years).224 While observing that no fractures occurred, a mean index plaque, bleeding on probing, and measures of mucosal sulcus depth around implant via clinical and radioscopic analysis revealed near identical outcomes to that of teeth and a reduced marginal bone loss was reported (1.2 mm).

Peri-Implant Tissue Around Zirconia Implants

Zirconia implants have bio-inert properties that promote the rapid proliferation of human gingival fibroblasts over the implant surface, forming a good mucosal barrier. However, factors such as surface characteristics, implant material, and roughness influence the mucosal seal around zirconia implants. A smooth implant surface promotes a good soft tissue seal, while peri-implant mucosa expression is more up-regulated on smooth zirconia implants compared to titanium.

Zirconia implants also have a higher content of collagen and a shorter length of the sulcular

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epithelium, providing better soft tissue integration and reduced bacterial infiltration. Zirconia implants inhibit bacterial adhesion and biofilm formation due to their hydrophobicity, bio-inert properties, optimal smoothness, reduced surface free energy, and surface wettability. They also have a reduced number of cocci and rods around zirconia implants, preventing bone resorption and soft inflammation.

A low inflammatory response around zirconia implants is attributed to increased release of angiogenic factors and anti-inflammatory cytokines compared to titanium. However, pro-inflammatory cytokines levels are higher around zirconia implants compared to healthy teeth. Zirconia implants have similar levels of interleukin-1RA, interleukin-8, granulocyte colony-stimulating factor, macrophage inflammatory protein-1beta, and Tumor necrosis factor alpha compared to titanium implants. Further longitudinal long-term studies are warranted to compare the onset, prognosis, and severity of peri-implantitis around zirconia and titanium implants.

Advantages Of Zirconia Implant Superior Aesthetics:

Titanium implants can wear and create a grey shadow, negatively impacting aesthetics. Zirconia, on the other hand, offers greater efficiency in aesthetics due to its matching natural tooth color and masking capacity. The material's optical behavior changes based on composition, crystal size, grain distribution, and processing methods, allowing for good opacity and translucency. ZrO_2's non-metallic appearance appeals to patients seeking metal- free implants, particularly those with thin gingival biotypes, and is often chosen as the first choice.

Suitable For Patients With Metal Allergy:

Patients often opt for Zirconia implants due to allergies to titanium or other metals. Although rare, cases of allergic reactions have been reported. Implants contain varying amounts of metals.

Reduces Plaque Build-Up Around Implants:

Zirconia dental implants reduce plaque and calculus build-up, promoting gum health and reducing infection risk. Zirconia's smooth surface and hydrophobicity reduce early bacterial adhesion compared to titanium implants. ZrO_2 surfaces also reduce bacterial accumulation and plaque growth, making them suitable for patients with compromised conditions like diabetes and immunocompromised patients. These properties may reduce the risk of chronic inflammation-associated diseases.

Resists Corrosion And Thermal Conduction:

Zirconia implants are poor thermal and electrical conductors due to their lack of battery or galvanic effects. They exhibit excellent corrosion resistance due to their unique composition and surface properties. Thickening the native ZrO_2 film and anodizing surface can improve corrosion resistance.

Non-Toxic:

Zirconia, a ceramic material, is not cytotoxic and does not enhance bacterial adhesion, unlike titanium. In vitro and in vivo studies have shown that it does not induce cytotoxicity in soft tissues. In a study by Hubert et al., zirconia implants showed no signs of toxic or carcinogenic effects in rabbit muscles.

Limitation Of Zirconia Implant

1. Zirconia implants have limited design and component options compared to titanium implants due to their early development cycle.
2. Zirconia implants have questionable long-term efficacy, with rates of success between 94- 98%.
3. Zirconia has lower flexural and fracture strength and is more brittle, making it more prone to fractures or long-term complications.
4. Zirconia implants are not suitable for patients missing all their teeth or requiring implant dentures, as they require significant planning and a variety of components.
5. Small diameter implants, typically used in cases with small space between teeth or thin jawbone density, can risk fractures.
6. Zirconia ageing and surface grinding can also reduce its properties, affecting its reliability and strength.

Conclusion

Dental implants have improved patient quality of life, with titanium and titanium alloys being the most popular due to their biocompatibility, mechanical properties, and long-term success. However, titanium has disadvantages like unaesthetic greyish color, galvanic reactions, inflammation, and toxicity, leading to systemic diseases. Zirconia dental implants

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have emerged as an alternative due to their biocompatibility, osseointegration, soft tissue response, and aesthetics. Further clinical trials are needed to determine long-term failure resistance.

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