Content available at: https://www.ipinnovative.com/open-access-journals

DJ COLLEGE OF DENTAL SCIENCES & RESEARCH

Journal of Orofacial and Health Sciences

Journal homepage: www.johs.in

INNOVATIVE PUBLICATION

Review Article

Zirconia implants – A review

Dakshayani KVS[1]*, Jagadish Konchada[2], Siddhesh Kumar CH[1], Srikanth L.[1], Bhavana Tatineni[1] Muppalla Sai Bhargav[1]

[1]Dept. of Prosthodontics and Crown and Bridge, Sree Sai Dental College and Research Institute, Srikakulam, Andhra Pradesh, India.
[2]Dept. of Dentistry, Annamalai University, Tamil Nadu, India.

Abstract

Background: Zirconia implants have gained prominence as a promising substitute to traditional titanium-based dental implants because of their superior biocompatibility, aesthetic appeal, and corrosion resistance. Zirconia (ZrO_2), a ceramic material, exhibits excellent mechanical properties, including high fracture toughness, wear resistance, and low thermal conductivity. Additionally, zirconia's bioinert nature minimizes the risk of inflammatory reactions and allergies, making it suitable for patients with metal sensitivities. Recent studies have demonstrated that zirconia implants achieve comparable, if not superior, osseointegration to titanium, ensuring stable and long-lasting outcomes.

Keywords: Biocompatibility, Osseointegration, Surface modification, Aesthetic implants.

Received: 01-08-2025; **Accepted:** 25-09-2025; **Available Online**: 10-11-2025

1. Introduction

Dental implants have revolutionized restorative dentistry, providing a reliable solution for replacing missing teeth. Titanium dental implants are today a cornerstone of modern prosthetic restoration after tooth loss. Although titanium is still the material of choice for dental implants, it can trigger immunological reactions and because of its greyish colour, has aesthetic limitations, when the implant neck is exposed. Due to nascent demands for dental implant aesthetics and the request for metal-free restorations, the general interest in tooth-coloured zirconia (zirconium dioxide, ZrO2) ceramic dental implants has increased in recent years.

Zircon has been treasured as a gemstone since ancient times. The name of the metal zirconium originates from the Arabic word "Zargon," which means golden in colour, and this term comes from the Persian words "Zar" (gold) and "Gun" (colour). The Research & Development on zirconia as a biomaterial was started in the late 60's.[1] Zirconia, a ceramic material, offers several advantages over titanium, including superior aesthetics, biocompatibility, and resistance to corrosion. With the advancement of digital technology, it has become possible to fabricate dental restoratives with high fitting accuracy using CAD/CAM systems.[2] Zirconia, which has excellent mechanical, aesthetic, and biological properties, is available as a ceramic implant fixture.[3-6] This review aims to explore the properties, advantages, challenges, and clinical performance of zirconia implants.

2. Properties of Zirconia

Zirconia (ZrO2) is a ceramic material known for its exceptional mechanical properties and biocompatibility. The key properties that make zirconia suitable for dental implants include:

ZrO2 is a polymorphic material and occurs in three forms: Monoclinic, tetragonal, and cubic. The monoclinic phase is stable at room temperatures up to 1170°C, the tetragonal at temperatures of 1170–2370°C, and the cubic form at over 2370°C.[7,7] Alloying pure zirconia with stabilizing oxides, such as CaO, MgO, Y2O3, or CeO2, allows the retention of the metastable tetragonal structure at room temperature. Dental procedures, such as grinding or

Corresponding author: Dakshayani KVS
Email: venkatasaidakshu@gmail.com

https://doi:10.18231/j.johs.12665.1759902389

sandblasting, can trigger a tetragonal to monoclinic transformation in the surface region.[1]

Transformation from tetragonal phase to monoclinic phase is associated with volume expansion. This phase transformation results in compression of cracks, thereby retarding its growth and enhancing fracture toughness. This martensitic-like mechanism is known as "transformation toughening".[9]

Zirconia has fracture toughness between 6 and 10 MPa m1/2, which is almost twice as high all that of aluminium oxide ceramics. It has a flexural strength of 900–1200MPa and a compression resistance of 2000 MPa. An average load-bearing capacity of 755N was reported for zirconia restorations. Fracture loads ranging between 706N, 2000N and 4100N were reported; all of the studies demonstrated that in dental restorations zirconia yields higher fracture loads than alumina or lithium disilicate.[9-14]

3. Osseointegration of Zirconia

Zirconia is a viable alternative to titanium for dental implants due to its tooth-like appearance and biocompatibility. Studies show that surface-modified zirconia implants achieve osseointegration and bone-implant contact comparable to titanium. Surface roughening methods like sandblasting, acid etching, and laser treatment improve bone response and implant stability, though zirconia's hardness makes modification challenging. While titanium generally shows higher removal torque values, zirconia implants still demonstrate clinically acceptable stability and integration, with lower bacterial adhesion and favourable soft tissue response. However, concerns like low-temperature degradation highlight the need for continued research and refinement.[15]

4. Biocompatibility

Zirconia is highly biocompatible, showing no cytotoxic or inflammatory effects on bone or soft tissue, and supports cell attachment and matrix formation. Soft tissue response and healing are comparable to titanium, though results vary slightly across studies. Laser surface modification improves cell adhesion. Bacterial adhesion on zirconia is generally lower or similar to titanium, suggesting reduced plaque formation, though findings remain inconclusive.[16]

5. Advantages of Zirconia Implants

1. Aesthetics: The white colour of zirconia closely mimics natural teeth, making it an excellent choice for patients with high aesthetic demands. Zirconia implants eliminate the risk of a greyish hue that can occur with titanium implants, especially in patients with thin gingival biotypes.[17,18]
2. Biocompatibility: Zirconia's biocompatibility reduces the risk of allergic reactions and peri-implantitis, a significant concern with titanium implants in susceptible individuals.[19]
3. Low Plaque Affinity: Zirconia surfaces have a lower affinity for plaque accumulation compared to titanium, potentially reducing the risk of peri-implant diseases.[20]
4. Metal-Free: Zirconia implants are an ideal choice for patients with metal allergies or sensitivities, providing a completely metal-free restorative option.
5. High strength: zirconia has high strength and decent fracture resistance, holds up against wear and corrosion relatively well.[20]

6. Challenges and Limitations

1. Mechanical Properties: Although zirconia is strong, it is more brittle compared to titanium. This brittleness can lead to fractures under certain conditions, particularly with small-diameter implants or in areas of high occlusal load.[21]

2. Osseointegration: To enhance the osseointegration of the zirconia implants surface modifications and treatment protocols are continually being developed to enhance the bone-implant interface.[20]

3. Limited Long-Term Data: Zirconia implants have not been in use as long as titanium implants, and long-term clinical data are still limited. More extensive studies are required to fully understand the long-term performance and success rates of zirconia implants.

4. Cost: Zirconia implants are generally more expensive than titanium implants, which can be a limiting factor for some patients.

7. Clinical Performance

Recent studies have shown promising results for zirconia implants in terms of osseointegration, stability, and success rates. Clinical trials indicate that zirconia implants can achieve comparable success rates to titanium implants, especially when placed in ideal conditions and with appropriate case selection. Moreover, patient satisfaction is often higher due to the superior aesthetic outcomes.

1. Osseointegration: Studies have demonstrated that zirconia implants can achieve good osseointegration, with histological analyses showing direct bone-to-implant contact.[24]

2. Survival Rates: Short- to medium-term studies report survival rates of zirconia implants ranging from 90% to 95%, which are comparable to those of titanium implants.

3. Peri-Implant Health: Zirconia implants tend to exhibit lower rates of peri-implant mucositis and peri-implantitis, attributed to their low plaque affinity and favourable soft tissue response.[18]

8. Titanium Vs Zirconia Implants

Titanium, especially in the Ti6Al4V alloy form, is the most established material for dental implants due to its proven clinical success and mechanical strength.[25] However, zirconia—used as yttria-stabilized zirconium oxide—has emerged as a strong alternative, offering high biocompatibility and superior aesthetics. Some studies have reported lower plaque accumulation and inflammatory response with zirconia implants, though others have found no significant differences in peri-implant tissue health compared to titanium. Despite similar biological integration, the difference in material stiffness (with zirconia having nearly double the Young's modulus of titanium) can influence the way mechanical forces are transmitted to surrounding bone, potentially affecting healing and long-term stability.[26]

Implant stability, critical to successful osseointegration, depends on minimizing micromovement at the bone-implant interface. This is commonly assessed using insertion torque (IT) and resonance frequency analysis (RFA).[27] While IT measures resistance during implant placement, excessive torque can risk bone damage. RFA, expressed in ISQ values, offers a non-invasive method to evaluate lateral stability and predict implant success. Although values above 30 Ncm (IT) and 70 ISQ (RFA) are generally considered suitable for immediate loading, the influence of implant material itself on these parameters remains underexplored. Thus, clinicians must primarily consider bone quality, implant design, and surgical technique to ensure optimal outcomes, regardless of the material used.[28]

9. Future Trends

The future of zirconia implants looks promising, with ongoing research and development aimed at addressing their current limitations. One area of focus is enhancing the material properties of zirconia. Researchers are exploring new formulations that could improve the toughness and flexibility of zirconia, reducing its brittleness and making it more durable under functional loads. Surface modifications are another area of active research.[29]

By modifying the surface properties of zirconia implants, scientists aim to enhance osseointegration and reduce bacterial colonization. These improvements could lead to better clinical outcomes and reduce the risk of complications such as peri-implantitis [20]

Long-term clinical trials are essential for establishing the reliability and success rates of zirconia implants over extended periods. As more long-term data becomes available, it will provide a clearer picture of the benefits and potential drawbacks of zirconia implants, helping clinicians make more informed decisions.

10. Discussion

Zirconia implants have emerged as a reliable and aesthetically superior alternative to titanium in dental applications, primarily due to their excellent biocompatibility, corrosion resistance, and natural tooth-like appearance. Composed mainly of yttria-stabilized tetragonal zirconia polycrystals (Y-TZP), they offer high flexural strength and fracture toughness, supporting their performance under functional loads. Clinically, they exhibit strong osseointegration and favourable soft tissue interactions, contributing to long-term stability and reduced risk of inflammation. While they hold several advantages, including non-allergenicity and resistance to metal ion release, limitations such as brittleness, higher cost, and limited long-term data remain concerns.[30,31] Ongoing advancements aim to enhance zirconia's durability and surface characteristics, potentially improving outcomes and broadening their clinical use in the future.

11. Conclusion

Zirconia implants represent a significant advancement in implant dentistry and Orthopedics, offering a combination of biocompatibility, aesthetics, and mechanical integrity. Their unique combination of biocompatibility, aesthetic appeal, and favourable mechanical properties has driven significant interest and research within the medical community.

As the body of clinical evidence grows, zirconia implants are expected to gain broader acceptance and play a crucial role in patient care. They provide a durable and aesthetically pleasing solution for tooth and bone replacement, addressing the needs of patients who seek both functional and visual improvements. Despite existing challenges, there is a growing optimism about the future of zirconia implants, positioning them as a key component in patient-centered care.

The future of zirconia implants looks bright, with potential for widespread adoption and continued innovation in the field of implantology.

12. Source of Funding

None.

13. Conflict of Interest

None.

References

1. Piconi C, Maccauro G. Zirconia as a ceramic biomaterial. *Biomaterials*. 1999;20:1–25.https://doi: 10.1016/s0142-9612(98) 00010-6
2. Nishihara H, Adanez MH, Att W. Current status of zirconia implants in dentistry: preclinical tests. *J Prosthod Res.* 2019;63(1):1-4. https://doi:10.1016/j.jpor.2018.07.006
3. Gross C, Bergfeldt T, Fretwurst T, Rothweiler R, Nelson K, Stricker A. Elemental analysis of commercial zirconia dental implants-Is

"metal-free" devoid of metals?. *J Mech Behav Biomed Mater*. 2020;107:103759. https://doi:10.1016/j.jmbbm.2020.103759
4. Osman RB, Swain MV. A critical review of dental implant materials with an emphasis on titanium versus zirconia. *Materials*. 2015;8(3):932-58. https://doi:10.3390/ma8030932.
5. Cionca N, Hashim D, Mombelli A. Two-piece zirconia implants supporting all-ceramic crowns: Six-year results of a prospective cohort study. *Clin Oral Imp Res.* 2021;32(6):695-701. https://doi:10.1111/clr.13734
6. Comisso I, Arias-Herrera S, Gupta S. Zirconium dioxide implants as an alternative to titanium: A systematic review. *J Clin Exp Dent*. 2021;13(5):e511. https://doi:10.4317/jced.58063.
7. Chevalier J. What future for zirconia as a biomaterial?. *Biomaterials*. 2006;27(4):535-43. https://doi:https://doi:10.1016/j.biomaterials.2005.07.034.
8. Aayo MJ, Porter WD, Rawn CJ. Crystallite and grain-size-dependent phase transformations in Yttria-Doped zirconia. *J Am Ceram Soc.* 2003;86:360–2. https://doi:10.1111/j.1151-2916.2003.tb00025.x
9. Asharaf S, Karthigeyan AS, Deivanai M, Mani R. Zirconia: properties and application" a review. *Paki Oral Dent J.* 2014;34(1):
10. Asbell MB. Dentistry: A historical perspective: Being a historical account of the history of dentistry from ancient times, with emphasis upon the United States from the colonial to the present period. (No Title). 1988.
11. Bankoglu Güngör M, Aydın C, Yılmaz H, Gül EB. An overview of zirconia dental implants: basic properties and clinical application of three cases. *J Oral Implantol*. 2014;40(4):485-94. https://doi:https://doi:10.1563/AAID-JOI-D-12-00109.
12. E. Implantation of artificial crown and bridge abutments. *Dent Cosmos.* 1913;55:364.
13. Linkow LI, Dorfman JD. Implantology in dentistry. A brief historical perspective. The New York state Dent J. 1991;57(6):31-5.
14. Burch RH. Pinkney Adams-A dentist before his time. Arkansas dentistry.1997;68(3):14-5.
15. Depprich R, Zipprich H, Ommerborn M. Osseointegration of zirconia implants compared with titanium: an in vivo study. *Head Face Med.* 2008;4:30. https://doi:10.1186/1746-160X-4-30
16. Barewal RM, Stanford C, Weesner TC. A randomized controlled clinical trial comparing the effects of three loading protocols on dental implant stability. *Int J Oral Maxillofac Imp.* 2012;27(4):945-56.
17. Ban S. Evolution of dental zirconia and features of new high translucent multi-layer type. *Dent Diam.* 2016;41:140-51. https://doi.org/10.1186/s12903-024-04070-7
18. Fujisaki H, Kawamura K. Dental zirconia "Zpex" coloring grade and Zpex Smile with enhanced translucency. *Tosoh Res Tech Rev*. 2014;58:43-7.
19. Kukreja BJ, Bhat KG, Kukreja P, Nayak A, Kotrashetty VS, Dindawar S. et al. Regeneration of periodontal ligament fibers around mini dental implants and their attachment to the bone in an animal model: A radiographic and histological study. *J Indian Soc Period*. 2023;27(2):167-73. https://doi:10.4103/jisp.jisp_314_22
20. Deville S, Chevalier J, Gremillard L. Influence of surface finish and residual stresses on the ageing sensitivity of biomedical grade zirconia. *Biomaterials.* 2006;27(10):2186-92.
21. Kukreja BJ, Bhat KG, Kukreja P, Nayak A, Kotrashetty VS, Dindawar S. et al. Regeneration of periodontal ligament fibers around mini dental implants and their attachment to the bone in an animal model: A radiographic and histological study. J Indian SocPeriodontol. 2023;27(2):167-73. https://doi:https://doi:10.4103/jisp.jisp_314_22
22. Kolkewitz M, Mueller C. Alumina-reinforced zirconia implants: survival rate and fracture strength in a masticatory simulation trial. Clin Oral imp Res. 2010;21(12):1345-52. https://doi:10.1111/j.1600-0501.2010.01954.x
23. Hoque ME, Showva NN, Ahmed M, Rashid AB, Sadique SE, El-Bialy T. Titanium and titanium alloys in dentistry: Current trends, recent developments, and future prospects. Heliyon. 2022;8(11):e11300.
24. Meredith N, Alleyne D, Cawley P. Quantitative determination of the stability of the implant-tissue interface using resonance frequency analysis. Clin Oral Imp Res. 1996;7(3):261-7. https://doi10.1034/j.1600-0501.1996.070308.x
25. Brizuela-Velasco A, Álvarez-Arenal Á, Gil-Mur FJ, Herrero-Climent M, Chávarri-Prado D, Chento-Valiente Y. Relationship Between Insertion Torque and Resonance Frequency Measurements, Performed by Resonance Frequency Analysis, in Micromobility of Dental Implants: An: In Vitro: Study. Imp Dent. 2015;24(5):607-11. https://doi:10.1097/ID.0000000000000318
26. Schierano G, Mussano F, Faga MG, Menicucci G, Manzella C, Sabione C. et al. An alumina toughened zirconia composite for dental implant application: in vivo animal results. BioMed Res. Int. 2015;2015. https://doi:10.1155/2015/157360.
27. Busch A, Wassenaar D, Zinser W, Jäger M. A bicentric approach evaluating the combination of a hemispheric cup with a novel ceramic head in total hip arthroplasty. Ortho Rev. 2021;13(1): https://doi:10.4081/or.2021.8794
28. Nawa M, Nakamoto S, Sekino T, Niihara K. Tough and strong Ce-TZP/alumina nanocomposites doped with titania. Ceramics International. 1998;24(7):497-506. https://doi.org/10.1016/S0272-8842(97)00048-5.
29. Komasa S, Nishizaki M, Zhang H, Takao S, Yin D, Terada C. et al. Osseointegration of alkali- modified NANOZR implants: An in vivo study. Int J Mol Sci. 2019;20(4):842.
30. Passos SP, Nychka JA, Major P, Linke B, Flores-Mir C. In Vitro Fracture Toughness of Commercial Y-TZP Ceramics: A Systematic Review. J Prosthod. 2015;24(1):1-1. https://doi:10.1111/jopr.12179
31. Östman PO, Hellman M, Sennerby L. Direct implant loading in the edentulous maxilla using a bone density–adapted surgical protocol and primary implant stability criteria for inclusion. Clin Imp Dent Related Res. 2005;7:s60-9.

Cite this article: Dakshayani KVS, Konchada J, Siddhesh Kumar CH, Srikanth L, Tatineni B, Bhargav MS. Zirconia implants – A review. *J Orofac Health Sci.* 2025;12(3):148-151.