Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/15510
DOI URL: http://dx.doi.org/10.21474/IJAR01/15510

RESEARCH ARTICLE

APPLICATION AND SUCCESS RATES OF ZIRCONIA- A REVIEW

Dr. Leena Tomer[1], Dr. John George[2], Dr. Mandeep Kaur[2], Dr. Swati Tyagi[2], Dr. Aiswarya J.[2] and Dr. Nazreen P.V[2]

1. Professor and Head Department of Prosthodontics, Divya Jyoti College of Dental Science And Research, Modinagar, Ghaziabad.
2. Post Graduate Student, Department of Prosthodontics, Divya Jyoti College of Dental Science And Research, Modinagar, Ghaziabad.

Manuscript Info

Manuscript History
Received: 15 August 2022
Final Accepted: 18 September 2022
Published: October 2022

Key words:-
Zirconia, Veneers, Crowns, Implants

Abstract

Purpose: This review aimed to evaluate the application and success rate of zirconia in various fields of dentistry.
Materials and Methods: electronic databases were searched for original studies reporting on the application, performance and success rates of various zirconia based prosthesis, including PubMed, Cochrane Library, and Science direct.The electronic search was accompanied with manual searches of the bibliographies of all retrieved full text articles and reviews as well as hand search of the following journals: International Journal of Prosthodontics, Journal of Oral Rehabilitation, International Journal of Oral & Maxillofacial Implants, Journal of Indian Prosthodontic Society, and Clinical Oral Implants Research.

Introduction:-

The use of **zirconia** in restorative dentistry has grown exponentially over the past decade. Early zirconia formulations were used for frameworks because of their high flexural strength and unesthetic opacity in porcelain-fused-to-zirconia restorations. Through processing refinements, materials with increased translucency were introduced so that veneering with feldspathic porcelain was not required and the material could be used in monolithic form.[1] Zirconia has become a popular alternative to alumina as biomaterial and is used in dental applications for fabricating endodontic posts, crown and bridge restorations and implant abutments. It has also been applied for the fabrication of esthetic orthodontic brackets.[2]

Zirconia is organized in three different patterns: monoclinic (M), tetragonal (T), and cubic (C).

Pure zirconia is monoclinic at room temperature and remains stable up to 1170°C. Above this temperature, it transforms into tetragonal and then into cubic phase that exists up to the melting point at 2370°C. During cooling, the tetragonal phase transforms back to monoclinic in a temperature ranging from 100°C to 1070°C.[2] Zirconia ceramic is comprised of the metallic element zirconium (Zr) and the non-metal oxygen.

At room temperature in its natural state, zirconia occurs in a monoclinic crystal lattice. Zirconia has the unusual trait of shrinking as it is heated; contraction occurs at 1170º C when the crystal assumes tetragonal form, and again at 2370º C when a cubic lattice occurs. Upon cooling back to room temperature, a nearly 4.5% linear expansion occurs as the native monoclinic lattice recurs. The cubic lattice is less relevant to dental restorations.

Corresponding Author:- Dr. Leena Tomer
Address**:-** Professor and Head Department of Prosthodontics, Divya Jyoti College of Dental Science And Research, Modinagar, Ghaziabad.

In ceramic dental restorations, a major problem occurs when a custom-made shape is fired; as it cools from the tetragonal to monoclinic lattice, the accompanying expansion fractures the restoration. Thus, several types of doping agents have been added to avoid this so called **tetragonal to monoclinic** ('t-to-m') transition during the cooling of fired dental restorations.

In the last decade, zirconia-based restorations have become increasingly common in dentistry. Because of the esthetic limitations of first-generation Zirconia materials, however, veneering used to be mandatory to satisfy patient's demand for esthetic restorations.[3]

Survival estimates for PFM fixed dental prostheses are typically about 97% over seven years or more. Success may be defined as the intact survival of a prosthesis with acceptable surface quality, anatomic contour, and function, and where applicable, with acceptable esthetics. Since the probabilities of success over time are rarely 100% for established prosthodontic treatments. [4] Typical survival rates for all ceramic restorations range from 88 -100 % after 2-5 years in service and 84-97% after 5-14 years in service.[5]

Types Of Materials:-

Although many types of zirconia-containing ceramic systems are currently available, only three are used to date in dentistry. These are **yttrium cation-doped tetragonal zirconia polycrystals (3Y-TZP), magnesium cation-doped partially stabilized zirconia (Mg-PSZ) and zirconia-toughened alumina (ZTA)**[6]

Tetragonal Zirconia Polycrystals (3Y-TZP)

Biomedical grade zirconia usually contains 3mol% yttria (Y_2O_3) as a stabilizer (3Y-TZP). While the stabilizing Y^{3+} cations and Zr^{4+} are randomly distributed over the cationic sites, electrical neutrality is achieved by the creation of oxygen vacancies. Y-TZP is available in dentistry for the fabrication of dental crowns and fixed partial dentures.

The restorations are processed either by soft machining of presintered blanks followed by sintering at high temperature, or by hard machining of fully sintered blocks.[6]

The mechanical properties of 3Y-TZP strongly depend on its grain size.

Partially stabilized zirconia (Mg-PSZ)

Although a considerable amount of research has been dedicated to magnesia partially stabilized zirconia (Mg-PSZ) for possible biomedical applications, this material has not been successful due mainly to the presence of porosity, associated with a large grain size (30–60m) that can induce wear.

The microstructure consists of tetragonal precipitates within a cubic stabilized zirconia matrix. The amount of MgO in the composition of commercial materials usually ranges between 8 and 10mol%. In addition to a high sintering temperature (between 1680 and 1800 ◦C), the cooling cycle has to be strictly controlled, particularly in the aging stage with a preferred temperature of 1100 ◦C.[6]

Glass-infiltrated zirconia-toughened alumina (ZTA)

Zirconia particles are combined with a matrix of alumina forming a structure known as **zirconia-toughened alumina (ZTA).**

Glass infiltration, in which glass was infiltrated into the zirconia substrate, significantly increases the strength of zirconia. The resultant structure involves an outer glass layer, which was followed by a **graded glass-zirconia layer** and **a dense zirconia** interior. The coefficient of thermal expansion (CTE) of the glass also needs to match that value of zirconia to prevent the development of the long-range thermal stress in graded structure.[6]

Properties Of Zirconia

Zirconia (zirconium dioxide, ZrO_2), also named as "**ceramic steel",** has optimum properties for dental use:

1. superior toughness
2. strength
3. fatigue resistance, in addition to excellent wear properties and biocompatibility.

Mechanical Properties:

Mechanical properties of zirconia were proved to be higher than those of all other ceramics for dental use and similar to those of stainless steel.[7]

Strength of Zirconia

To date, polycrystalline high-strength ceramics are being increasingly used as core materials for crowns and fixed dental prostheses (FDPs) due to the noticeable aesthetic demand of the patients, also in the presence of higher occlusal loads than those borne by the conventional ceramics of the past.

In particular, partially stabilized zirconia is characterized by higher mechanical properties than those showed by all of the other dental ceramics like the flexural strength (900–1,200 MPa) and the fracture toughness (9– 10 MPa m1/2) mainly due to the well-studied phenomenon of "transformation toughening.[8]

According to **Candido et al. (2018**) Flexural strength did not present significant difference between monolithic and conventional zirconia.[9]

Carrabba et al. (2017) stated that here was an inverse relationship between strength and translucency for the materials tested. Addition of Al_2O_3 and increased yttria content strongly downgraded the mechanical properties.

Beuer et al. (2012) concluded that higher strength was for monolithic compared to veneered zirconia.

Chougule et al. (2017) concluded that Flexural strength was significantly higher after glazing but not after polishing.

Kumchai et al. (2018)proposed that Overglazing significantly decreased the flexural strength.[9]

Radioactivity

Zirconia powder contains small amounts of radionuclides from the uranium-radium (^{226}Ra) and thorium (^{228}Th) actinide series. However, after purifying procedures, zirconia powders with low radioactivity (< 100 Gyh-1) can be achieved which were below the European radiation limits for human body external exposure of organs and tissues and comparable to those of alumina ceramics and Co-Cr alloys.[10]

Optical Characteristics

Yttria-stabilized zirconia (YSZ) shows high refractive index (2.1 to 2.2), low absorption coefficient, and high opacity in the visible and infrared spectrum. The increased opacity of zirconia is very useful in esthetically demanding clinical situations to mask polychromatic substrates like blackened teeth, pins and metal cores.

Because of its opacity, it must be covered with translucent ceramics to yield natural tooth-like appearance. The high radiopacity of zirconia ceramics, comparable to that of metal alloys, enhance the radiographic evaluation of marginal integrity, removal of cement excess and recurrent decay.[11]

Ageing

Ageing or low temperature degradation (LTD) is the spontaneous, slow transformation of the metastable tetragonal phase to the more stable monoclinic phase, in the absence of any mechanical stress, occurring over time at low temperatures.

It is exacerbated in the presence of water, steam or fluids. LTD is based upon the same mechanism as phase transformation toughening (PTT); that is, it requires the presence of t-ZrO_2 grains in thermodynamic metastability which can undergo t-m transformation.

The slow transformation of tetragonal crystals to the stable monoclinic phase starts at the surface in isolated grains by a stress corrosion type mechanism and later progresses inwards to the bulk of the material.

The transformation of one grain is accompanied by an increase in volume that induces stresses on the surrounding grains.

This causes a surface uplift and microcracks which offers a path for the water to penetrate down into the specimen.

Water penetration then exacerbates the process of surface degradation and the transformation progresses from neighbour to neighbour.

The main factors affecting the aging phenomenon are the grain size, the type and the amount of stabilizer and the presence of residual stress. Although ageing reduces mechanical features of zirconia, the decrease falls into clinically acceptable values.[12]

Glaze

Glaze is the final firing of porcelain in which the surface is vitrified until a high gloss and surface compression state are achieved. Glazing is a laboratory procedure aimed to provide natural gloss, color stability and to reduce the plaque retention and antagonist tooth wear.[13]

Glazing can be created either by firing a small coating of transparent glass onto the surface or by heating the restoration up to glazing temperature for 1 or 2 minutes to get shiny gloss surfaces.[14]
Kumchai et al. (2018) found that Overglazing significantly decreased the flexural strength.[9]

Abrasion and wear

Wear is defined as a gradual loss of material originated by the mechanical interaction between two contacting surfaces that are in relative motion under a given load. Physical separation during the process occurs mainly due to microfracture and chemical dissolution, creating telltale marks on the worn surface characteristic to the wear mechanisms that originated. [15]

Application and success rates of zirconia

Zirconia Fpd

Based on the exceptional mechanical properties of zirconia (eg, high flexural strength and fracture resistance), Y-TZP is the most recent framework material for the fabrication of all-ceramic FPDs either in anterior or posterior sites.

Zirconia-based FPDs may exhibit a good long-term prognosis if connectors are properly designed and fabricated.
Furthermore, it has been observed that when zirconia FPDs are subjected to the peak of tensile stresses, the properties of the feldspathic porcelain, used for veneering of high-toughness core materials, may control the failure rate of the restoration.[16]

Limones A et al (2020) compared the survival and complication rates of zirconia ceramic (ZC) versus metal-ceramic (MC) restorative material in multiunit tooth-supported posterior fixed dental prostheses (FDP). The study stated that posterior multiunit ZC restorations are considered a predictable treatment in the medium term, although they are slightly more susceptible to chipping of the veneering ceramic than MC restorations.[8]

Quigley N P et al (2020) investigated the survival rate of resin-bonded zirconia fixed partial dentures (FPDs), inlay retained zirconia FPDs, and zirconia veneers. Eight studies were ultimately included. Three studies examined posterior inlay-retained FPDs with estimated survival rates of 12.1% at 10 years, 95.8% at 5 years, and 100% at 20 months. Five studies reviewed anterior, resin-bonded FPDs, all of which had a 3- to 10-year survival rate of 100%.[1]

Manicone P F et al (2007) proposed that zirconia (ZrO_2) is a ceramic material with adequate mechanical properties for manufacturing of medical devices. Zirconia stabilized with Y_2O_3 has the best properties for these applications.[17]

Mechanical properties of zirconium oxide FPDs have proved superior to those of other metal-free restorations. Clinical evaluations, which have been ongoing for 3 years, indicate a good success rate for zirconia FPDs. Zirconia implant abutments can also be used to improve the aesthetic outcome of implant-supported rehabilitations.[17]

Tinschert et al. compared survival time of different metal-free core for three unit fixed prostheses and reported that zirconia-ceramic with alumina oxide had the highest initial and most favorable long-term strength.[2]

Sailer et al. investigated 58 zirconia bridges fabricated by the direct ceramic machining system clinically. Their results exhibited a survival rate of 84% in a period of 3.5 years.[2]

Sorrentino R et al (2011) evaluated that the clinical performance of three-unit posterior zirconia fixed dental prostheses (FDPs) after 5 years of clinical function. All FDPs completed the study, resulting in 100% cumulative survival rate and 91.9% and 95.4% cumulative success rates for patients wearing one and two FDPs, respectively. Five-year clinical results proved that three-unit posterior zirconia-based FDPs were successful in the medium term for both function and aesthetic.[18]

Peláez J et al (2012)statedthat after 3 years of evaluation, the clinical performance of zirconia (Lava) 3-unit posterior fixed dental prostheses found to be reliable in dental treatment.[19]

Bilayer veneers

The fabrication of bilayer veneers made from a veneered high-toughness ceramic core is suggested in order to enhance both esthetics and strength. The 0.2 mm to 0.4 mm modified core may be fabricated from various high-toughness ceramic materials such as zirconia.The clinical application of zirconia bilayer veneers may offer a high-strength veneer restoration with better masking ability for a given discoloration.[16]

Quigley N P et al (2020) investigated the survival rate of resin-bonded zirconia fixed partial dentures (FPDs), inlay retained zirconia FPDs, and zirconia veneers They concluded that with correctly designed buccal and lingual coverage retainers and minimal if any veneering porcelain, zirconia-based, posterior, inlay-retained FPDs seem to have a high clinical survival rate.[1]

Tanıs A et al (2020) evaluated the shear bond strength between various CAD/CAM veneer materials and the zirconia ceramic core and it was found that the application of fusion porcelain to bond zirconia and digitally produced veneering material can serve as an alternative veneering method to the conventional layering method by accelerating and facilitating clinical and laboratory stages.[20]

Bomicke W et al (2017) evaluated the short-term clinical performance and esthetics of monolithic and partially (i.e., facially) veneered zirconia single crowns (MZC and PZC, respectively) . It was concluded that monolithic and partially veneered zirconia crowns can be used clinically with excellent short-term survival and success and without compromising esthetic appearance.[21]

Monolithic zirconia

Two main zirconia restoration categories include zirconia-based and monolithic zirconia restorations.

Monolithic zirconia restorations, which are prepared with only zirconia ceramics, have some advantages over zirconia-based restorations, such as no need for layering and a simpler and shorter CAD/CAM process.

Manziuc M - M et al (2019) assessed the effect of material, thickness and glazing upon the color, translucency, and roughness of monolithic zirconia. The study concluded that as a result of glazing, only color changes were statistically significant. Translucency varied among brands of precolored monolithic zirconia; the differences increased for greater thicknesses.[22]

BaldissaraP et al (2018) evaluated the optical properties of novel cubic ultratranslucent (UT) and supertranslucent (ST) zirconia by comparing them with lithium disilicate (L-DIS) glass-ceramic for the manufacture of monolithic computer-aided design and computer-aided manufacturing (CAD-CAM) molar crowns. He stated that the ST1.0 and UT1.0 crowns, even at the maximum thickness tested (UT1.5), showed significantly higher translucency than L-DIS.[23]

Y. Zhang et al (2017)proposedzirconias, the strongest of the dental ceramics, are increasingly being fabricated in monolithic form for a range of clinical applications. He reviewed the progressive development of currently available and next-generation zirconias, representing a concerted drive toward greater translucency while preserving adequate strength and toughness.[13]

Zirconia posts

Introduction of custom made all-ceramic posts and cores or zirconium dioxide (ZrO_2) prefabricated posts, a unique esthetic approach has been developed in combination with all-ceramic crowns. Dentin-like shade all-ceramic posts and cores contribute to a deeper diffusion of light and therefore provide an appropriate depth of translucency.[16]

ZeynepOzkurtKayahan et al (2010) stated that the use of a zirconia post with an all ceramic crown optimized the esthetic effect at the root, while maintaining an adequate level of strength.[24]

Tariq Abduljabbar et al (2012)concluded that customized zirconia posts and cores resisted a higher mean load (765.1 + 48.5) when compared with other post and core systems.[25]

Ahmed YaseenAlqutaibi et al (2022) states that in a clinical trial, Zir ceramic posts had high success rates. Similarly, Zirconia posts with direct composite cores had an excellent clinical success rate after 4.7 years.[26]

Paul and Werder investigated zirconia posts and observed good clinical success of zirconia posts with direct composite cores after a mean clinical service of 4.7 years.[27]
The mechanical properties of zirconia posts were tested in in vitro study by **Kwiatkowski and Geller** [14]. Their results demonstrated that the zirconia posts had higher strength compared to those reported for other all ceramic post and cores.[27]

Zirconia core
One of the strengthening methods of all-ceramic systems is to use zirconia as the core material. Zirconia has high strength and toughness. Because zirconia is opaque, it is veneered with porcelain to provide good esthetic.[16]

Tinschert compared lifetime of different metal-free core for FPD and reported that Zr-ceramic with alumina oxide had the highest initial and most favorable long-term strength. In a comparison between 3, 4 and 5-unit zirconia fixed partial dentures and minimal connecting surface resulted, respectively, 2.7 mm^2, 4.0 mm^2 and 4.9 mm^2. Height of abutment is fundamental to obtain ZrO_2 frameworks with correct shape and dimension in order to ensure mechanical resistance of restoration.[2]

Zirconia implants
Y-TZP is currently considered an attractive and advantageous endosseous dental implant material because it presents enhanced biocompatibility, improved mechanical properties, high radiopacity, and easy handling during abutment preparation. Zirconia ceramic is well-tolerated by bone and soft tissues and possesses mechanical stability.[16]

Siegfried Jank et al (2016)that two-piece zirconia implants show competitive success rates, improved from >96.7% to >98.5% over three product generations.[28]

Josep Oliva et al (2014) concluded that zirconia dental implants with roughened surfaces might be a viable alternative for tooth replacement.

Zirconia implant abutments
Abutments made from zirconia besides strength considerations, Y-TZP implant abutments offer enhanced biocompatibility, metal-like radiopacity for better radiographic evaluation, and, ultimately, reduced bacterial adhesion, plaque accumulation, and inflammation risk.[16]

Superstructure
Superstructures is the connection between the crown and the implant. Superstructure act like a screw in the implant, and the part that remains above the implant is made crowns.

Zirconia superstructures have superior esthethic appearance than titanium superstructures. Yttria-stabilized zirconia has been used for implant superstructures because of sufficient esthetic properties.[29] The Malo's clinical ceramic bridge is the most aesthetically advanced form of fixed prosthodontic rehabilitation for the fully edentulous patients. This prosthesis is the epitome of biomedical engineering combined with Computer aided design/ computer assisted machine CAD/CAM technology.

The bridge is initially constructed as a removable occlusal screw retained superstructure on four titanium implants placed according to the concept to rehabilitate the fully edentulous jaw like all-on-four.[30]

Pozzi et al (2013) reported an overall implant and prosthetic survival rate of 100% and prosthetic success of 89% on 26 screw-retained complete-arch Implant stabilised zirconia fixed partial dentures,delivered at implant level up to years.

AlessandroPozzi et al (2021) conducted study on the long-term clinical and radiographic outcomes of zirconia-based partial and complete screw-retained implant-supported zirconia fixed dental prostheses for up to 12 years. The study showed that implant survival rate was 99.4%, and the prosthetic survival rate was 98.2%. The cumulative prosthetic success rate was 91.9%.[31]

Zirconia dental auxiliary components

Orthodontic brackets

Y-TZP orthodontic brackets provide enhanced strength, superior resistance to deformation and wear, reduced plaque adhesion, and improved esthetics. In addition they exhibit good sliding properties with both stainless steel and nickel-titanium arch wires and the same frictional characteristics as polycrystalline alumina brackets.[16]

Kim J et al(2017) evaluated the effect of different surface treatments of zirconia for bracket bonding and reported that sandblasting yielded the heighest bond strength of bracket to zirconia.[32] Hosseini MH et al (2016) studied the SBS of bracket to zirconia after surface treatment with Er:YAG laser, sandblasting and saline application. They showed that sandblasted samples yielded the heighest shear bond strength.[33]

Precision attachments

The clinical application of prefabricated zirconia attachments is based on the wear and strength characteristics of the material. Two different types of Y-TZP attachments are currently in the market: a ball attachment for overdentures as a part of a zirconia post (Biosnap, Incermed) available in three diameters for three levels of retention and an extra- coronal, cylindrical, or ball attachment for removable partial dentures (Proxisnap, Incermed).[16]

NaglaNassouhy et al (2017) proposed that Zirconia attachment yields comparable clinical and radiographic results as metal attachments for distal extension cases within a follow-up period of one year.[34]

Cutting and surgical instruments

Newly developed zirconia cutting instruments (ie, drills, burs) can be used in implantology, maxillofacial surgery, operative dentistry, and soft tissue trimming (eg, CeraDrillTMCeraBurTM K1SM CeraBurTMCeratip, respectively, all Gebr. Brasseler).

These instruments offer optimal cutting efficiency with smooth operation and reduced vibration while their proven resistance to chemical corrosion promises a long-lasting performance.surgical instruments such as scalpels, tweezers, periosteal elevators, and depth gauges can be made out of alumina-toughened zirconia (ATZ) by injection moulding.[16]

Conclusion:-

Application of zirconia in various filed of dentistry has been reviewed. This review also focuses on the development and current status of the zirconia that was based on recent reviews. Methods for the improvement and development of properties of zirconia were based on data reported in the literature and on other studies by the authors.

Koutayaset al concluded that Zirconia applications seem to consolidate a well-established position in clinical dentistry, due to the improvements in CAD/CAM technology and to the material’s exceptional physical properties.[16]

Whereas **Raigrodski et al** concluded that Zirconium dioxide-based posterior FDPs performed well in terms of clinical fracture resistance, marginal integrity, marginal discoloration, and recurrent caries after 5 years of service.[35]

Ahamed A et al(2014) reviewed recent progress in the improving in biological and mechanical properties of zirconia. Although there was major improvement in the mechanical properties of zirconia, further studies are recommended to confirm their properties.[2]

Zirconias have not yet achieved the opalescent qualities of more aesthetic (but weaker) lithia-based glass-ceramics, which remain the preferred material for anterior prostheses. However, the refinement continues, and novel aesthetic Y-TZP zirconias suitable for anterior prostheses (graded and nanoscale microstructures) are emerging.[15]

References:-

1. Niall P Quigley, Denice S S Loo, Clinton Choy, William N Ha . Clinical efficacy of methods for bonding to zirconia: A systematic review. Jpd 2020
2. **Ahmed A. Madfa, Fadhel A. Al-Sanabani, Nasser H. Al-Qudami, Jabr S. Al-Sanabani, Abdullah G. Amran**. Use of Zirconia in Dentistry: An Overview . The Open Biomaterials Journal, Volume 5 , 2014,.
3. Wolfgang Bömicke, Peter Rammelsberg, Thomas Stober, Marc Schmitter. Short-Term Prospective Clinical Evaluation of Monolithic and Partially Veneered Zirconia Single Crowns. J. Esthet. Dent 2016.
4. K. J. Anusavice. Standardizing failure, success, and survival decisions in clinical studies of ceramic and metal–ceramic fixed dental prostheses. Dent. Mater. J. 2012
5. AlhanoofAldegheishem, George Ioannidis, WaelAtt, Haralampos Petridis. success and survival of various types of all ceramic single crowns: a critical review and analysis of studies with mean follow up of 5 years or longer.Int J Prosthodont . 2017
6. Isabelle Denry[1], J Robert Kelly et al. State of the art of zirconia for dental applications. Intl. Elsevier health 2008
7. ChandkiramGautam[1], Jarin Joyner[2], AmarendraGautam[3], Jitendra Rao[4], Robert Vajtai[2]. Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications. R. Soc. Chem.2016 Dec 6;45(48):19194-19215.
8. Alvaro Limones, Pedro Molinero-Mourelle, Luis Azevedo, Marta Romeo-Rubio, André Correia, Miguel Gómez-Polo. Zirconia-ceramic versus metal-ceramic posterior multiunit tooth-supported fixed dental prostheses. J Am Dent Assoc. 2020 Apr;151(4):230-238.e7.
9. EleanaKontonasaki, Panagiotis Giasimakopoulos, Athanasios E. Rigos, Strength and aging resistance of monolithic zirconia: an update to current knowledge, Japanese Dental Science Review,Volume 56, Issue 1, 2020, Pages 1-23,
10. O. S. A. El-Ghany.Zirconia based ceramics, some clinical and biological aspects: Review. Futur. Dent. J. 2 (2016) 55-64
11. Meral Kurt[1], MerveBankoğluGüngör[2], SeçilKarakocaNemli[2], Bilge Turhan Bal[2]. Effects of glazing methods on the optical and surface properties of silicate ceramics. J. Prosthodont. Res.2020 Apr;64(2):202-209
12. ChandkiramGautam[1], Jarin Joyner[2], AmarendraGautam[3], Jitendra Rao[4], Robert Vajtai[2]. Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications. R. Soc. Chem.2016 Dec 6;45(48):19194-19215.
13. Y Zhang[1], B R Lawn. Novel Zirconia Materials in Dentistry J. Dent. Res.2018 Feb;97(2):140-147.
14. Hee-Kyung Kim, Sung-Hun Kim, Jai-Bong Lee, Jung-Suk Han, In-Sung Yeo. Effect of polishing and glazing on the color and spectral distribution of monolithic zirconia. J AdvProsthodont2013 Aug; 5(3): 296–304
15. M. Wendler,[1,2] M.R. Kaizer,[1,3] R. Belli,[4] U. Lohbauer,[4] and Y. Zhang[1]. Sliding contact wear and subsurface damage of CAD/CAM materials against zirconia .Dent. Mater.2020 Mar; 36(3): 387–401.
16. SpiridonOumvertosKoutayas[1], ThaleiaVagkopoulou, Stavros Pelekanos, PetrosKoidis, Jörg Rudolf Strub. zirconia in dentistry: part 2. Evidence-based clinical breakthrough. EurJ. Esthet. Dent. Winter 2009;4(4):348-80
17. Paolo Francesco Manicone[1], Pierfrancesco Rossi Iommetti, Luca Raffaelli. An overview of zirconia ceramics: Basic properties and clinical applications. J. Dent.2007 Nov;35(11):819-26.
18. Sorrentino, R., De Simone, G., Tetè, S. et al. Five-year prospective clinical study of posterior three-unit zirconia-based fixed dental prostheses. Clin Oral Invest **16**, 977–985 (2012).
19. Peláez J, Cogolludo PG, Serrano B, Lozano JF, Suárez MJ. A prospective evaluation of zirconia posterior fixed dental prostheses: three-year clinical results. J Prosthet Dent. 2012 Jun;107(6):373-9.
20. ÇakırbayTanış M, Kılıçarslan MA, Bellaz İB. In Vitro Evaluation of Bond Strength between Zirconia Core and CAD/CAM-Produced Veneers. J Prosthodont. 2020 Jan;29(1):56-61.
21. Bömicke W, Rammelsberg P, Stober T, Schmitter M. Short-Term Prospective Clinical Evaluation of Monolithic and Partially Veneered Zirconia Single Crowns. J EsthetRestor Dent. 2017 Feb;29(1):22-30.
22. Manuela-Maria Manziuc[1], Cristina Gasparik[1], Alexandru V Burde[1], Horaţiu A Colosi[2], Marius Negucioiu[1], Diana Dudea[1]. Effect of glazing on translucency, color, and surface roughness of monolithic zirconia materials. J EsthetRestor Dent. 2019 Sep;31(5):478-485.

23. Paolo Baldissara [1], Vinícius Felipe Wandscher [2], Ana Maria EstivaleteMarchionatti [3], Candida Parisi [4], Carlo Monaco [5], Leonardo Ciocca [6] Translucency of IPS e.max and cubic zirconia monolithic crowns (J Prosthet Dent 2018 Aug;120(2):269-275
24. ZeynepOzkurt, UfukIşeri, Ender Kazazoğlu.Zirconia ceramic post systems: a literature review and a case report . Dent Mater J 2010; 29(3)
25. Tariq Abduljabbar, HaneefSherfudhin, S.A. AlSaleh, Abdulaziz A. Al-Helal, Saleh S. Al-Orini, Naif A. Al-Aql, Fracture resistance of three post and core systems in endodontically treated teeth restored with all-ceramic crowns,.King Saud University Journal of Dental Sciences,Volume 3, Issue 1,2012,
26. Alqutaibi AY, Ghulam O, Krsoum M, Binmahmoud S, Taher H, Elmalky W, Zafar MS. Revolution of Current Dental Zirconia: A Comprehensive Review. Molecules. 2022 Mar 4;27(5):1699.
27. **Stefan Paul**, **Peter Werder**.Clinical success of zirconium oxide posts with resin composite or glass-ceramic cores in endodontically treated teeth: A 4-year retrospective study. The International journal of prosthodontics. 2004,17(5):524-8
28. Jank S, Hochgatterer G. Success Rate of Two-Piece Zirconia Implants: A Retrospective Statistical Analysis. Implant Dent. 2016 Apr;25(2)
29. Seji Ban. Classification and Properties of Dental Zirconia as Implant Fixtures and Superstructures. Materials 2021, 14, 4879
30. DeepikaBainiwal. Malo' S Bridge An "All-on-4" Diem-2 Immediate Function Concept. J. Dent. Sci 2017
31. Alessandro Pozzi, Lorenzo Arcuri, Giacomo Fabbri, Guido Singer, Jimmy Londono,Long-term survival and success of zirconia screw-retained implant-supported prostheses for up to 12 years: A retrospective multicenterstudy,The Journal of Prosthetic Dentistry, 2021,
32. Kim J, Park C, Lee JS, Ahn J, Lee Y. The effect of various types of mechanical and chemical preconditioning on the shear bond strength of orthodontic brackets on zirconia restorations. Hindawi. 2017;2017:01-10.
33. Hosseini MH, Gorjizadeh F, Etemadi A, Baghaeian P. Shear bond strength of metal brackets to zirconia treated with Er:YAG laser sandblasting and silane. J Islam Dent Assoc Iran. 2016,28(3):110-17
34. NaglaNassouhy Mohamed Farouk Abdalla. Zirconia versus metal cad/camextracoronal attachments for the bilateral distal extension removable partial denture. E.D.J. Vol. 63, No. 3
35. Ariel J. Raigrodski, Alika Yu, Gerard J. Chiche, J. L. Hochstedler, Lloyd A. Mancl, PhD, and Shawky E. Mohamed. Clinical efficacy of veneered zirconium dioxide-based posterior partial fixed dental prostheses: five-year results. J Prosthet Dent 2012;108:214-222.