Current classification of zirconia in dentistry: an updated review

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ABSTRACT

Zirconia, a crystalline oxide of zirconium, holds good mechanical, optical, and biological properties. The metal-free restorations, mostly consisting of all-ceramic/zirconia restorations, are becoming popular restorative materials in restorative and prosthetic dentistry choices for aesthetic and biological reasons. Dental zirconia has increased over the past years producing wide varieties of zirconia for prosthetic restorations in dentistry. At present, literature is lacking on the recent zirconia biomaterials in dentistry. Currently, no article has the latest information on the various zirconia biomaterials in dentistry. Hence, the aim of this article is to present an overview of recent dental zirconia biomaterials and tends to classify the recent zirconia biomaterials in dentistry. This article is useful for dentists, dental technicians, prosthodontists, academicians, and researchers in the field of dental zirconia.

Subjects Bioengineering, Dentistry
Keywords Dental ceramic, Y-TZP, 3Y-TZP, 5Y-TZP, CAD/CAM, Translucency

INTRODUCTION

Zirconia (ZrO_2) is a crystalline oxide of zirconium and it holds good mechanical, optical, and biological properties (*Bapat et al., 2022*). This biomaterial has three basic chemical forms; monoclinic, tetragonal, and cubic (*Saridag, Tak & Alniacik, 2013*; *Bocanegra-Bernal & dela Torre, 2002*). The metal-free restorations, mostly consisting of all-ceramic/zirconia restorations, are becoming popular restorative materials in restorative dentistry choices for aesthetic and biological reasons (*Kongkiatkamon et al., 2021*). Recently, there have been significant improvements in restorative biomaterials including dental zirconia, and producing wide varieties of zirconia for prosthetic restorations in dentistry (*Kontonasaki et al., 2019*; *Kontonasaki, Giasimakopoulos & Rigos, 2020*; *Humagain & Rokaya, 2019*; *Amornvit et al., 2021*). With the advancement of digital technologies, intraoral scanners, and CAD/CAM systems, it has become possible to fabricate dental restorations digitally with easy processing, designing, and high accuracy (*Al-Qahtani et al., 2021*; *Ahmed et al., 2021*).

Pure zirconia exists in the monoclinic form at room temperature and with an increase in temperature (1,170 °C) or low-temperature degradation (LTD), it transforms to the tetragonal form (*Ban, 2021*). Further increasing temperature (2,370 °C), aging or

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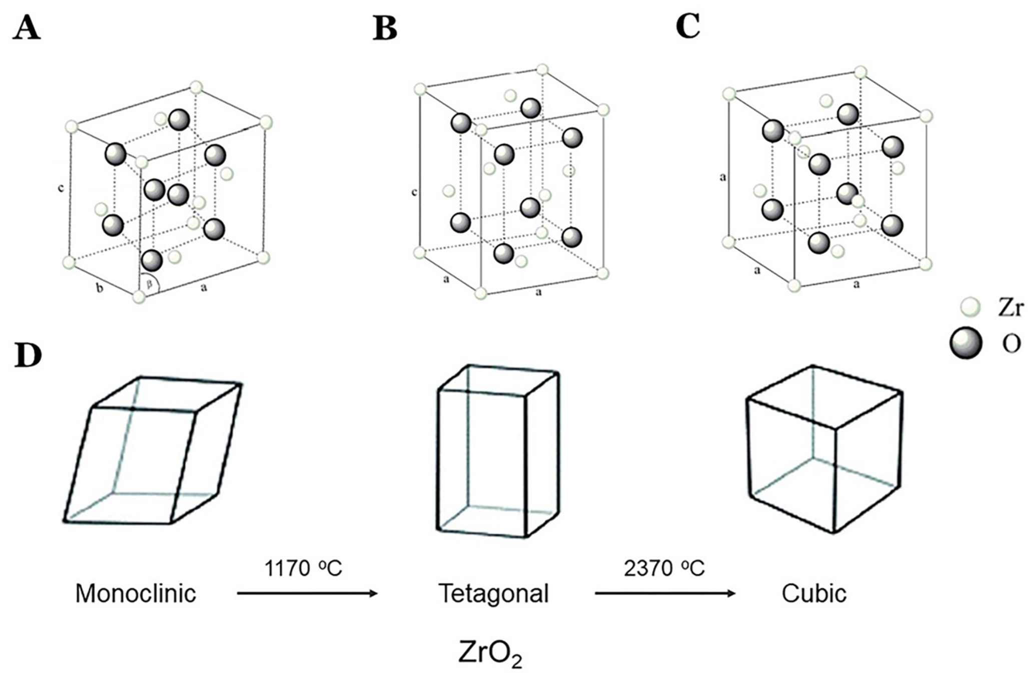

Figure 1 **Phases and its transformation of zirconia.** (A) monoclinic; (B) tetragonal; (C) cubic structure; and (D) phases of transformation of zirconia. Modified with permission from *Sorrentino et al. (2019)*.
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hydrothermal aging, progressive transformation to monoclinic phase takes place (*Piconi & Maccauro, 1999*; *Sorrentino et al., 2019*; *Rekow et al., 2011*) (Fig. 1). Then cooling, the tetragonal form transforms back to the monoclinic form. Achieving stable sintered zirconia ceramic is a little difficult because volumetric change (about 5%) occurs when the transformation from tetragonal to monoclinic. The zirconia can be monochromatic with uniform composition, polychromatic multilayer with uniform composition, and polychromatic multilayer and hybrid composition.

Proper bonding between the zirconia restoration and the tooth is important for the longevity of the prosthetic restoration (*Araújo et al., 2018*; *Melo et al., 2015*; *Heboyan et al., 2023*). Zirconia requires surface treatments with acid etching for surface abrasion to ensure adhesion with luting cement (*Araújo et al., 2018*). Although there are various surface treatment protocols have been recommended, common treatment included alumina particles followed by the application of primers or cements based on MDP (10-methacryloyloxydecyl dihydrogen phosphate) (*Melo et al., 2015*; *Aung et al., 2019*; *Shimizu et al., 2018*; *Silveira et al., 2022*; *Alammar & Blatz, 2022*). The surface modification improves the adhesive behavior of the materials (*Silveira et al., 2022*).

Dental zirconia has increased over the past years producing wide varieties of zirconia for prosthetic restorations in dentistry. Although some researchers have studied zirconia and classified dental zirconia in the past, (*Ban, 2021*; *Güth et al., 2019*; *Nistor et al., 2019*; *Grech & Antunes, 2019*; *Alqutaibi et al., 2022*) the current literature is lacking on the recent zirconia biomaterials in dentistry. The research question is there a recent classification of the recent zirconia biomaterials in dentistry? It is found that no article has the latest information on the various types of zirconia biomaterials in dentistry. Hence, the aim of this article is to present an overview of recent dental zirconia biomaterials and tends to classify the recent zirconia biomaterials in dentistry. This article is useful for dentists, dental technicians, prosthodontists, and researchers in the field of dental zirconia by providing updated information on the current literatures on various types of zirconia used in dentistry.

SURVEY METHODOLOGY

Articles on advances in dental zirconia ceramic were searched from January 1989 to December 2022 using Google Scholar, MEDLINE/PubMed, Web of Science, and ScienceDirect resources. Research and review articles in the English language were only included in this review. A total of 79 articles were selected and included in this review. Editorials, Letters to the Editor, and Case Reports were excluded from this review.

Yttria stabilized zirconia

Often in zirconia, various elements are dissolved such as yttrium (Y), cerium (Ce), calcium (Ca), magnesium (Mg), etc. to make it stable at room temperature (*Piconi & Maccauro, 1999*; *Chevalier, 2006*). The addition of Yttria (Y_2O_3) to zirconia stabilizes the tetragonal phase (*Leib et al., 2015*). Following LTD, yttria is exhausted through reaction causing the phase transformation (*Rekow et al., 2011*; *Chevalier, Cales & Drouin, 1999*; *Amat et al., 2019*). Yttria-doping can reduce grain growth, stabilize the tetragonal phase, and substantially improve thermal stability. Furthermore, the thermal stability of the cubic form of zirconia is obtained by the substitution of some Zr4+ ions (ionic radius of 0.82 Å) with larger ions, *e.g.*, Y3+ (ionic radius of 0.96 Å) in the crystal lattice. This doping of zirconia results in partially stabilized zirconia (PSZ) (*Leib et al., 2015*).

The yttria-stabilized dental zirconia is classified into 12 types (Fig. 2). Zirconia (TZP, tetragonal *zirconia* polycrystal) are of various types based on the yttria content: (*Zhang, 2014*; *Abdulmajeed et al., 2020*; *Arcila et al., 2021*) 3Y-TZP (3 mole % Y-TZP), 4Y-TZP (4 mole % Y-TZP), 5Y-TZP (5 mole % Y-TZP), and 6Y-TZP (6 mole % Y-TZP). The 3Y-TZP is early zirconia used in dentistry as a "white metal" (*Miyazaki et al., 2013*). Zirconia with lower yttria content (3Y-TZP, 3 mole % Y-TZP) has better mechanical properties and less translucency whereas 3Y-TZP (3 mole % Y-TZP) with increased yttria content (6Y-TZP, 6 mole % Y-TZP) has more translucency but presents lower mechanical properties. Yttria content consisting of >8 mol% has a stable cubic phase at room temperature and it is known as cubic stabilized zirconia (CSZ). Similarly, yttria content consisting of 3-8 mol% has tetragonal and cubic phases and it is known as partially stabilized zirconia (PSZ). And yttria content consisting of approx. 3 mol% has tetragonal phases (toughened) about 100% and it is known as a tetragonal zirconia polycrystal (TZP).

At present multilayer (M) zirconia has been introduced. Similarly, M3Y is highly translucent and M6Y is super highly translucent (Fig. 2). Some surface defects can be seen in all types of zirconia under scanning electron microscopy, although the 3Y-TZP demonstrates higher grain consistency. It has been found that the 5Y-PSZ presents the

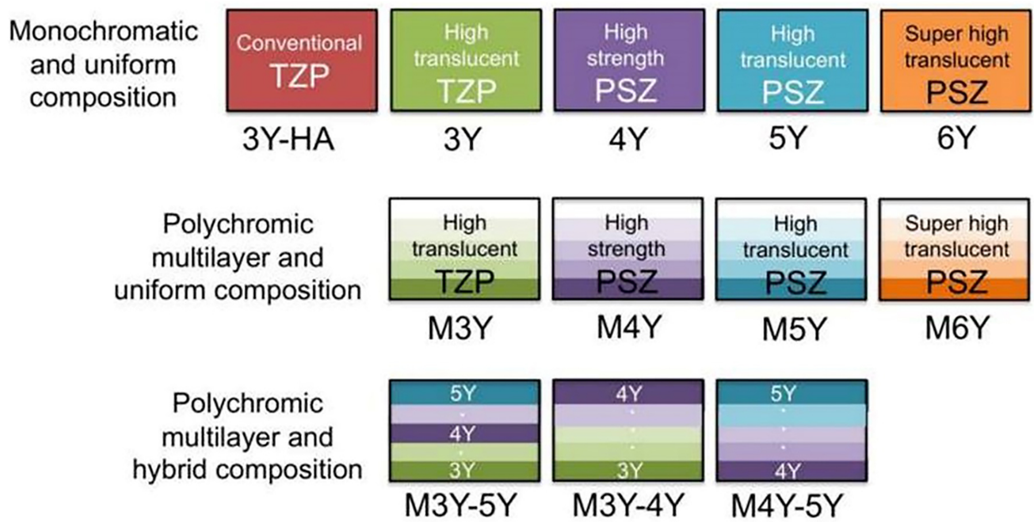

Figure 2 Classification of yttria-stabilized dental zirconia *Ban (2021)*. Y, Yttria, M, multilayer.
Full-size DOI: 10.7717/peerj.15669/fig-2

least strength and the 4Y-PSZ and 3Y-TZP present similar fatigue. It has been found that higher yttria content has lower mechanical strength but higher translucency of zirconia (*Ban, 2021*; *Harada et al., 2020*; *Cho et al., 2020*). Similar to yttria, ceria (CeO_2) is added to the zirconia to produce ceria in tetragonal stabilized zirconia (Ce-TZP).

Properties of zirconia

Physical properties

Zirconia is a stable restorative biomaterial. Dental zirconia is resistant to acid erosive attacks in the mouth although some erosive agents may have a negative effect on the surface roughness (*Tanweer et al., 2022*). It has extremely low thermal conductivity and the thermal expansion coefficient is $10 \times 10-6/°C$ and does not depend on the yttria content (*Ban, 2021*).

Mechanical properties

Zirconia has the highest hardness among the various restorative materials used in dentistry (*Ban, 2021*). Its flexural strength and hardness are extremely large compared to other restorative materials. Conventional zirconia has higher bi-axial flexural strength compared to high-translucent monolithic zirconia (*Kontonasaki, Giasimakopoulos & Rigos, 2020*). Furthermore, the fracture toughness of 5Y-TZP is almost 50% less compared to that of 3Y-TZP with the cubic phase content because of more yttria content (*Belli et al., 2021*). In a recent study, (*Liao et al., 2023*) showed that the flexural strength value was 584 (158) MPa for 3Y-TZP and 373 (104) MPa for 5Y-TZP.

Dal Piva et al. (2018) studied the influence of the milling system and aging on zirconia surface roughness and phase transformation and they found that the surface roughness of zirconia-based crowns was not influenced by the milling system or low-temperature degradation. But regarding the phase transformation, autoclaving and pH-cycling aging presented a monoclinic phase increase when compared to the control group and thermocycled group. Similarly, a study by *Flinn et al. (2012)* on the accelerated aging of Y-TZP found that the hydrothermal aging of Y-TZP can cause a significant transformation from tetragonal to monoclinic crystal structure with a significant decrease in the flexural strength of thin bars. Hence, the aging of zirconia increases the monoclinic phase.

The fracture strength of a zirconia implant is influenced by its design, composition, and kind of abutment preparation (*Bethke et al., 2020*). The 1-piece zirconia implant fixture has twice the fracture strength compared to the 2-piece fixture (*Kohal, Finke & Klaus, 2009*). There is a strong correlation between the fracture toughness and fracture loads of ceramic crowns on zirconia implants during the occlusal contact (*Rohr, Märtin & Fischer, 2018*). Therefore, proper selection of zirconia material should be done for the crown whether aesthetics or strength is needed.

Zirconia is supposed to cause the opposing teeth to wear. But smooth and well-polished zirconia does not cause tooth wear. Abrasive wear on the occlusal part of zirconia restoration affects the opposing teeth or restoration (*Mair, 1992*). When the zirconia restoration is a hard and rough surface, the tooth abrasive wear becomes severe.

Optical properties

Zirconia is an esthetic biomaterial, but its translucency is slightly less compared to the glass-ceramics. To maintain the translucency of the zirconia and glass-ceramic prostheses, suitable luting cement should be used (*Heboyan et al., 2023*; *Bilgrami et al., 2022b*; *Bilgrami et al., 2022a*). The addition of yttria content in zirconia increases the cubic phases and this increases the translucency, however, the strength is reduced due to a few tetragonal phases (Fig. 3). 5Y-TZP is more translucent by 20 to 25% but has less flexural strength by 40 to 50% compared to 3Y (*Ban, 2021*). Hence, 3Y-TZP can be indicated for bridges, especially of long spans, and is not suitable for the anterior teeth (*Ban, 2021*; *Liao et al., 2023*). Conversely, 5Y-TZP and M5Y are indicated for veneers and anterior crowns but are not suitable for long-span bridges (*Ban, 2021*). Similarly, for the hybrid multilayer and polychromatic zirconia types, such as M3Y-5Y, their uses are similar to 5Y-TZP which has low strength (*Jitwirachot et al., 2022*). Similarly, both 4Y-TZP and M4Y can be used in all areas requiring sufficient strength and translucency.

Zirconia has greater radio-opacity compared to aluminum and titanium. This is due to its intrinsically high density and effective atoms which can obtain high-contrast radiographic images useful for diagnosis (*Ban, 2021*). Speed sintering can reduce the translucency of the zirconia. It was found that regular sintering had larger gain sizes and increased translucency than speed sintering (*Kongkiatkamon & Peampring, 2022*).

Biological properties

Various animal and human studies conclude that zirconia is a biocompatible biomaterial (*Bapat et al., 2022*; *Josset et al., 1999*; *Christel et al., 1989*; *Uo et al., 2003*; *Abd El-Ghany & Sherief, 2016*; *Zarone et al., 2021*). *Christel et al. (1989)* investigated the effect of yttria-stabilized zirconia and alumina *in vivo* (implanted into paraspinal muscles of rats) and found no cytotoxicity. Similarly, *Josset et al. (1999)* also found that the human osteoblasts presented good adhesion and cell spreading, and the cells maintained their proliferation

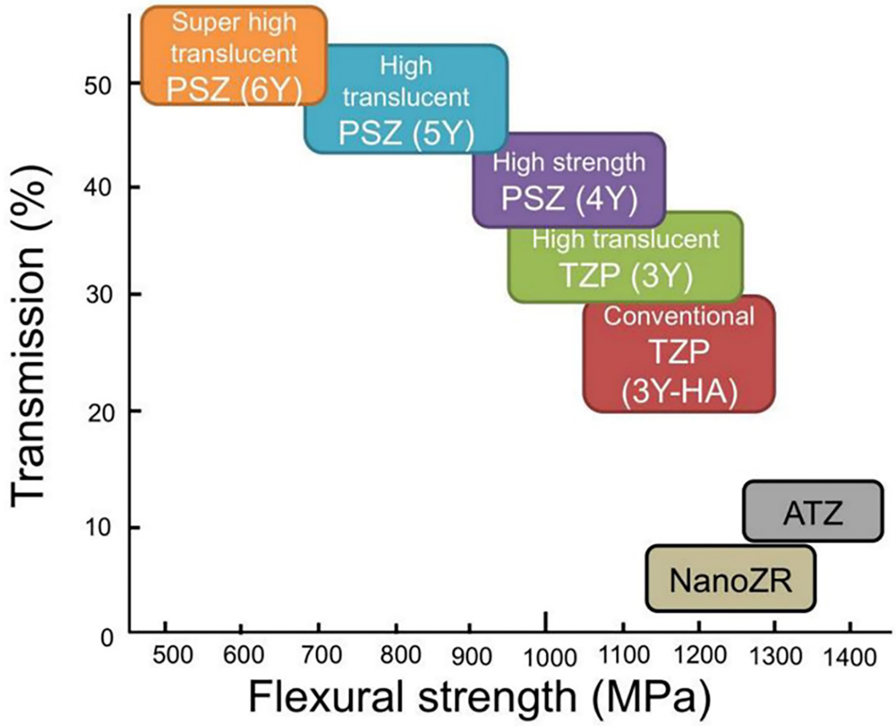

Figure 3 The translucency *vs* flexural strength of dental zirconia *Ban (2021)*.
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capacity and differentiation ability into osteogenic pathways. *Wu et al. (2015)* studied the wettability of ZrO_2 and found that its wettability was substantially enhanced by oxygen plasma treatment for maintaining a stable hydrophilicity surface. Water droplets can wet the hydrophilic zirconia surface (low contact angle) and this wetting condition that is suitable for oil-water separation is achieved by engineering the surface chemistry and surface roughness characteristics (*Rasouli et al., 2021*). Hydrophilic surface is an important factor that affects protein absorption and human gingival fibroblasts' cellular attachment to implant abutments (*Rutkunas et al., 2022*; *Barberi & Spriano, 2021*; *Kim et al., 2015*) Generally, a lower contact angle promotes fibroblast attachment (*Kim et al., 2015*).

Furthermore, zirconia does not cause mutations in the cellular genome (*Silva, Lameiras & Lobato, 2002*; *Warashina et al., 2003*). Moreover, ZrO_2 creates a less toxic reaction in tissue compared to titanium (*Degidi et al., 2006*). Zirconia also shows less bacterial adhesion and it is important in maintaining good periodontal health (*Scarano et al., 2004*). It was found that zirconia showed less adhesion of bacteria and less biofilm formation compared to titanium (*Ban, 2021*; *Scarano et al., 2004*; *Rimondini et al., 2002*). *Scarano et al. (2004)* found that bacterial adhesion was 12.1% on zirconia *vs* to 19.3% on titanium.

Sintering of zirconia

CAD/CAM technology used computer-aided design and fabrication of ceramic prostheses and the process is more time efficient than conventional techniques (*Padrós et al., 2020*; *Abduo & Lyons, 2013*). Sintering is responsible for providing the strengths to the zirconia restoration. Various sintering methods have been developed and they affect the structure, properties, and esthetics of zirconia (*Kilinc & Sanal, 2021*; *Juntavee & Attashu, 2018*; *Sanal & Kilinc, 2020*). Different studies compared different (slow and fast) sintering protocols of zirconia (*Amat et al., 2019*; *Kilinc & Sanal, 2021*; *Ordoñez Balladares et al., 2022*; *Ersoy et al., 2015*; *Liu et al., 2022b*). *Juntavee & Attashu (2018)* studied the role of sintering duration and temperature on the mechanical properties of zirconia and found that a long sintering time with high sintering temperature results in increased flexural strength zirconia. Similarly, *Kongkiatkamon & Peampring (2022)* evaluated the surface microstructure, flexural strength, and translucency of 5Y-TZP zirconia using regular and speed sintering. They found that the regular protocol showed bigger gain sizes and more translucency than the speed protocol. The speed sintering had higher biaxial flexural strengths which can be due to changes in the material structure from the degradation of the metal salts (*Sulaiman et al., 2017*). Similarly, *Liu et al. (2022a)* also found that the Y-PSZ with conventional sintering had a bigger average grain size and fewer fine grains compared to the speed sintering of zirconia. *Ahmed et al. (2020)* found no dimensional change between normal and fast sintering of zirconia. *Liu et al. (2022b)* investigated the optical properties of 3Y-TZP and 5Y-TZP and noticed that speed sintering had less lightness without affecting the surface roughness.

Surface treatment and adhesion of zirconia

Bonding between resin cement and zirconia is difficult to achieve because of their chemical inertness and lack of silica content (*Scaminaci Russo et al., 2019*). Hence, surface treatments of the zirconia restoration increase the adhesive, micro tensile bond strength, and longevity of the prosthetic restoration (*Araújo et al., 2018*; *Melo et al., 2015*; *Heboyan et al., 2023*). At present various surface treatments for zirconia and ceramics are available for better bonding to the tooth structure (*Campos et al., 2016*; *Guarda et al., 2013*; *Sato et al., 2016*). Airborne-particle abrasion and tribo-chemical silica coating are the pre-treatment methods. Adhesion can be increased after physicochemical conditioning of zirconia (*Scaminaci Russo et al., 2019*). One common treatment includes alumina particles followed by the application of primers or cement-based on10 MDP (methacryloyloxydecyl dihydrogen phosphate) (*Melo et al., 2015*; *Aung et al., 2019*; *Shimizu et al., 2018*; *Silveira et al., 2022*; *Alammar & Blatz, 2022*) However, the effect of the bond strength with the new generation of high-translucent zirconia materials is not clear and further studies are needed.

Classification of zirconia

The previous classifications of zirconia were done according to the types of polycrystalline (zirconia, Alumina, PSZ, TZP, and yttria-stabilized dental zirconia; Generation 1–3) (*Sato et al., 2016*). Zirconia can be of various types as shown in Table 1. Commonly, zirconia can be uniform or hybrid in composition and monolayer or multilayer.

Since there are various ceramic materials in the market and it is often confusion regarding choosing the material. Hence, the authors would like to categorize the zirconia materials based on their composition, and an indication of the commercially available zirconia materials (Table 2 and Figs. 4–5).

Table 1 Dental zirconia materials in the market.

Zirconia	Yttria content (mol%)	Indications
A. Ammanngirrbach		
Super High Translucent (SHT)		
1. Ceramill Zolid Fx White	5%	Anatomical crowns and bridges (<3 units extending to the molar region) Veneers, Inlays, Onlays
2. Ceramill Zolid Fx Multilayers	5%	
High Translucent (HT)		
1. Zolid gen x	4%	Anatomical crowns and 4- to multi-unit bridges Multi-unit screw-retained constructions on Ti bases
2. Zolid drs multilayer	4%	Crowns and bridges (<3 units up to molar region) Veneers, inlays, onlays Individual abutments
3. Zolid ht+ preshades	4%	Anatomical crowns and 4- to multi-unit bridges Multi-unit screw-retained constructions on Ti bases
4. Zolid ht+ white	4%	Anatomical crowns and 4- to multi-unit bridges Multi-unit screw-retained constructions on Ti bases
Low Translucent (LT)		
1. Ceramill Zi	3%	Custom abutments on titanium bases Crowns and 4-unit to multi-unit bridge frameworks Multi-unit, screw-retained restorations on titanium bases
B. Vita YZ		
1. YZ T	3%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior tooth region Primary telescopes
2. YZ HT	3%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior tooth region Primary telescopes
3. YZ ST	4%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior region Inlays, onlays, veneers, table top
4. YZ XT	5%	Anatomical single-tooth crowns and up to 3-unit bridges Inlays, onlays, veneers, table top

(*continued on next page*)

Table 1 (*continued*)

Zirconia	Yttria content (mol%)	Indications
5. YZ ST Multicolors	4%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior tooth region Inlays, onlays, veneers, table top
6. YZ XT Multicolors	5%	Anatomical single-tooth crowns and up to 3-unit bridges Inlays, onlays, veneers, table top
C. Cercon		
1. Cercon base	3%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region
2. Cercon ht	3%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Primary telescopes
3. Cercon xt	5%	Anatomical crowns and bridges (<3 units extending to the second premolar region)
4. Cercon ht ML	3%	Anatomical crowns and up to 14-unit bridges in the anterior and posterior tooth region Primary telescopes
5. Cercon xt ML	5%	Anatomical crowns and bridges (<3 units extending to the second premolar region)
D. Lava 3M		
1. Lava Plus	3%	Full-arch bridges Splinted crowns up to 4 units Primary telescopes Crowns (anterior and posterior)
2. Lava Esthetic	5%	3-unit bridges (<1 pontic between 2 crowns) Anterior and posterior crowns
3. Lava Chairside Zirconia	3%	Single crown 3-unit bridges (<1 pontic between 2 crowns)
E. GC Initial		
1. Standard Translucency (ST)	3%	Anterior and posterior crown Hybrid abutment
2. High Translucency (HT)	3%	Implant framework Multi-unit bridge
3. Ultra High Translucency (UHT)	3%	Inlay, onlay, veneer Anatomical single-tooth crowns and up to 3-unit bridges
F. Sagemax		
1. NexxZr S: High Strength	3%	Single crown Frameworks up to multi-unit frameworks
2. NexxZr T: Translucent	3%	Single-unit restorations up to multi-unit bridges
3. NexxZr T Multi: Translucent	3% (cervical) & 5% (incisal)	Single-unit restorations up to multi-unit bridges

(*continued on next page*)

Table 1 (*continued*)

Zirconia	Yttria content (mol%)	Indications
4. NexxZr+: Hight Translucent	4%	Single-unit restorations up to multi-unit bridges (white) or 3-unit bridges (preshaded)
5. NexxZr Multi: High Translucent	4% (cervical) & 5% (incisal)	
G. Dental Direk		
1. DD cubeX²® –Super High Translucent (SHT)	5%	High esthetic monolithic crowns and bridges (<3 units, including molar restorations)
2. DD cube ONE® –High Translucent Plus (HT+)	4%	High esthetic monolithic crowns and bridges (≥ 4 units) High esthetic veneering
3. DD Bio ZX² –High Translucent (HT)	3%	Monolithic crowns and bridges (of any span range)
4. DD Bio Z –High Strength (HS)	3%	Monolithic crowns and bridges (of any span range) Implant superstructures Abutments
H. Katana		
1. LT	3%	
2. HT	3%	Single-unit frameworks and long-span bridges
3. HTML	3%	
4. STML	4%	Single-unit or <3-unit posterior bridges
5. UTML	5%	Anterior crowns and veneers, inlays/onlays, and posterior single crowns.
6. YML	3% (cervical) & 5% (incisal)	Veneers, Inlays, Onlays Single crown (Anterior and posterior), Longspan bridge, Framework
I. Emax Zir CAD		
1. MT Multi	4% (dentin) & 5% enamel)	Full contour crown, 3-unit bridge
2. MT	4%	Crown, 3-unit bridge, Implant-supported superstructures
3. LT	3%	Crown copings Multi-unit bridges with <2 pontics
4. MO	3%	Crown coping Multi-unit bridges with <2 pontics

Finally, this review article provides updated information on the various dental types of zirconia used in dentistry. As this review does not use the PICO method, this review can be extended to do a more extensive review following the PICOS method.

CONCLUSIONS

Zirconia can be of various types based on the yttria content, uniform or hybrid composition, monochromatic or polychromatic, and monolayer or multilayer. Increased yttria content in zirconia results in higher translucency but reduces the strength. Zirconia with lower yttria

Table 2 Current classification of the zirconia-based on the yttria content and indications.

Types	Indications
Type 1A: 3Y-TZP (conventional) (1) **Ceramill Zi** (2) **Vita YZ T** (3) **Cercon base** (4) **Kantana LT** (5) **Emax Zir CAD LT**	–Substructure –Custom abutment –Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior tooth region (primary telescopic)
Type 1B: 3Y-TZP with reduced alumina (1) **Vita YZ HT** (2) **Cercon HT** (3) **Lava Plus** (4) **Lava chairside** (5) **GC Standard Translucency (ST)** (6) **GC High Translucency (HT)** (7) **GC Ultra High Translucency (UHT)** (8) **Nexx Zr S** (9) **Nexx Zr T** (10) **DD Bio Z High Strength (HS)** (11) **DD Bio ZX^2 High Translucent (HT)** (12) **Katana HT** (13) **Katana HT ML** (14) **E Max Zr CAD MO**	–Substructure –Custom abutment –Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior tooth region (primary telescopic)
Type 2: 4Y-TZP (1) **Zolid gen x** (2) **Zolid drs multilayer** (3) **Zolid ht+ preshades** (4) **Zolid ht+ white** (5) **Vita YZ ST** (6) **Vita YZ ST Multicolor** (7) **NexxZr+: Hight Translucent** (8) **DD cube ONE® –High Translucent Plus (HT+)** (9) **Katana STML** (10) **Emax Zircad MT**	–Single-tooth and up to 14-unit bridges on screw-retained restorations in the anterior and posterior region –Inlay, onlay, tabletop
Type 3: 5Y-TZP (1) **Ceramill Zolid Fx White** (2) **Ceramill Zolid Fx Multilayers** (3) **Vita YZ XT** (4) **YZ XT Multicolors** (5) **Cercon XT** (6) **Cercon XT ML** (7) **LAVA Esthetic** (8) **DD cubeX^2® –Super High Translucent (SHT)** (9) **Katana UTML**	— Anatomical crowns and bridges (<3 units extending to the second premolar region)
Type 4: Combination of 3Y/ 4Y and 5Y-TZP (1) **NexxZr T Multi: Translucent** (2) **NexxZr Multi: High Translucent** (3) **Katana YML** (4) **Emax Zir CAD MT Multi**	–Single unit –Multiple unit bridge

content (3Y-TZP, 3 mole % Y-TZP) has better mechanical properties and less translucency whereas 3Y-TZP (3 mole % Y-TZP) with increased yttria content (6Y-TZP, 6 mole % Y-TZP) has more translucency but presents lower mechanical properties. Speed sintering

Figure 4 **Examples of zirconia-based on the yttria content.** A, 3Y-TZP, B, 4Y-TZP, and C, 5Y-TZP.
Full-size DOI: 10.7717/peerj.15669/fig-4

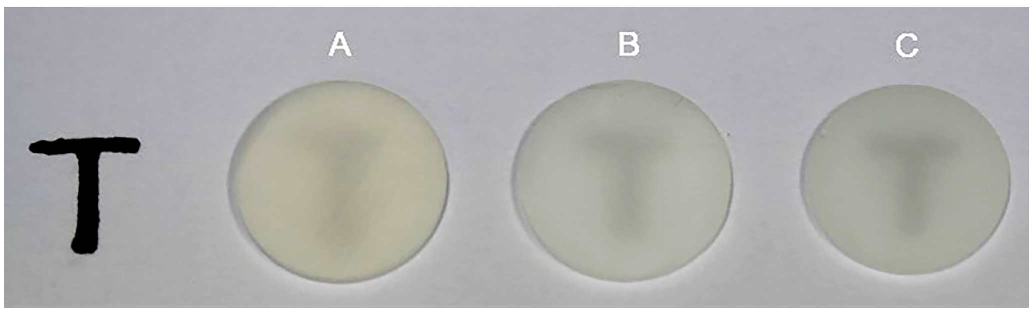

Figure 5 **Translucency of zirconia-based on the yttria content.** A, 3Y-TZP, B, 4Y-TZP, and C, 5Y-TZP.
Full-size DOI: 10.7717/peerj.15669/fig-5

of zirconia has resulted in higher flexural strength and regular sintering of zirconia has shown bigger gain sizes and more translucency.

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Dinesh Rokaya is an Academic Editor for PeerJ.

Author Contributions

- Suchada Kongkiatkamon conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Dinesh Rokaya conceived and designed the experiments, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Santiphab Kengtanyakich analyzed the data, authored or reviewed drafts of the article, and approved the final draft.

- Chaimongkon Peampring analyzed the data, authored or reviewed drafts of the article, review, and approved the final draft.

Data Availability

The following information was supplied regarding data availability:

This is a literature review.

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