

COMPARATIVE EVALUATION OF CERAMICS AND ZIRCONIUM DIOXIDE RAW MATERIALS USED IN ORTHOPEDIC DENTISTRY

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Abstract: The article highlights the composition, properties, and practical significance of ceramic and zirconium dioxide materials used in dentistry. These materials are widely applied in orthopedic dentistry due to their high aesthetic appearance, biocompatibility, and chemical stability. The article examines the components of dental ceramics and zirconium dioxide, as well as their properties. In addition, their application, history, origin, and advantages are analyzed. According to the research results, their importance in the fabrication of veneers, bridge prostheses, and other orthopedic constructions has been studied.

Keywords: ceramics, zirconium dioxide.

When it comes to ceramics, these restorative materials can be described with two terms: porcelain and ceramics. The word “ceramics” comes from the Greek word “keramice,” meaning clay or pottery. The history of ceramics dates back many centuries. D.I. Vinogradov (1736) was sent together with M.V. Lomonosov and R. Reiser by the Saint Petersburg Academy of Sciences to “German lands” to study mining and manuscript arts. After returning eight years later with the title of “Bergmeister,” he conducted experiments with the “recipe” for porcelain paste. These experiments proved successful, and on March 19, 1753, an advertisement for orders of porcelain items appeared in issue No. 23 of the “Sankt-Peterburgskie Vedomosti” (Saint Petersburg Gazette). Since then, the recipe for porcelain made from kaolin, feldspar, and quartz has remained unchanged.

The use of ceramics in dentistry is associated with French pharmacist Alexis Duchateau, who was the first to fabricate a denture for himself using porcelain teeth.

Between 1844 and 1883, industrial production of porcelain teeth began in England, Germany, and America. At the end of the 19th century, Dr. Land developed a method for fabricating dental crowns from platinum foil. In 1962, the production of metal-ceramic dental crowns began, marking the start of the metal-ceramic era. At the end of the 20th century, new ceramic compositions and new technologies for fabricating all-ceramic prostheses were developed. At that time, porcelain was very brittle; therefore, various components were later added to improve its properties. Today it is used in a number of industrial enterprises.

In terms of physical properties, ceramics are isotropic. They can transition from a hardened state to a liquid state without forming a new phase. Porcelain exists in powder form and is prepared mainly by heating with fluxes, which form glass from this component. Porcelain achieves the desired color when re-fired with metal oxides. After cooling, it is ground into fine powder and sent to the dental laboratory.

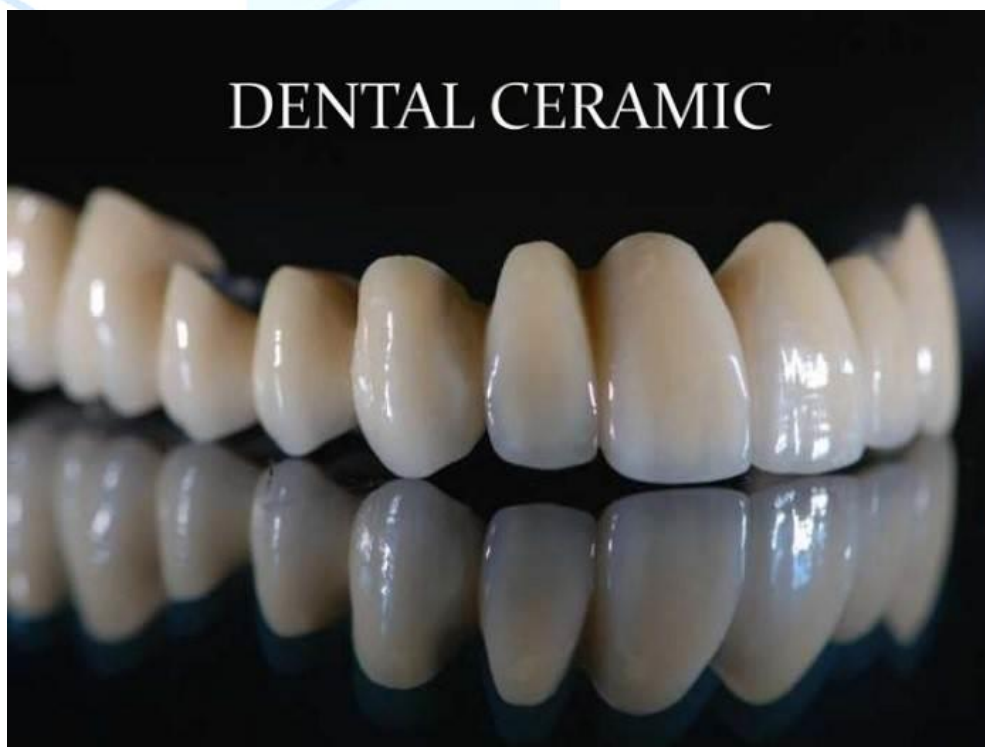
Classification by Melting Temperature

Type	Melting Temperature	Function
High-fusing	1300–1371°C	Removable prostheses, artificial teeth
Medium-fusing	1090–1260°C	Artificial crowns, inlays, bridges
Low-fusing	870–1066°C	Restorations, inlays

Key Properties of Ceramics

- 1) Hypoallergenic

- 2) Color stability
- 3) Strength
- 4) Durability
- 5) Optical properties: used in creating aesthetic prostheses. Light hitting the tooth surface can be absorbed, reflected, or refracted.
- 6) More resistant to corrosion than plastics.
- 7) Wide range of colors; their use helps achieve a high aesthetic effect.



The disadvantages of ceramic materials are considered to be their lack of plasticity and the resulting brittleness of prostheses. Combined with low friction resistance, this requires not only specific medical indications but also special precision in reproducing the shape and occlusal relationships in all mandibular movements, as well as strict compliance with all technological requirements. The most widespread method in orthopedic dentistry is layered fabrication of veneers from ceramic masses of various compositions, properties, and purposes, followed by sintering in a vacuum electric furnace. The layers of ceramic masses in an artificial veneer imitate natural

tooth tissues and are divided into base (opaque), dentin, enamel, and glass layers. Some sets also include glazes and mineral dyes.

The base (opaque) porcelain mass is non-translucent because it contains a number of opacifiers (metal oxides) and is the main color-forming layer of the ceramic veneer, providing its strength. The thickness of this layer is 0.3–0.4 mm. The dentin mass is applied over the first layer and is used to shape the veneer and achieve the required color (dentin layer 0.5–0.8 mm). Enamel and glass are used in the incisal edge region to create varying degrees of translucency. Dyes allow coloring of the crown margins, thereby individualizing it to match the shade of neighboring teeth. Glaze is used to achieve a shiny smooth surface and the natural luster of the artificial porcelain veneer.

Strength Parameters:

Compressive strength ≈ 170 MPa

Tensile strength ≈ 50 –75 MPa

Composition of Porcelain Components

Kaolin comprises 3% to 65% of the porcelain composition. The higher the kaolin percentage, the less translucent but the stronger the porcelain, with a higher firing temperature. Melting point: 1800°C. Kaolin's function is to provide mechanical strength and stability to the porcelain.

Feldspar reaches up to 60–70% in porcelain composition. It consists of anhydrous aluminosilicates of potassium, sodium, and calcium. Melting temperature: 1180–1200°C. At high temperatures it forms a glassy phase in which other components (quartz and kaolin) dissolve. The glassy phase provides plasticity and binds the components together. The more feldspar in the mixture, the more translucent the fired porcelain mass. During firing, feldspar acts as a flux by lowering the melting point of the mixture.

Composition of Dental Ceramic Materials (%)

Com ponents	Alu minous Ceram ic	D entin	E namel	D entin	E namel	L ow- fusin g	I PS e.max Press (Li ₂ O· 2SiO ₂)	I PS e.ma x Cera m Laye ring Cera mic
SiO ₂	35. 0	6 6.5	6 4.7	5 9.2	6 3.5	6 0–70	5 7–80	4 5–70
Al ₂ O ₃	53. 7	1 3.5	1 3.9	1 8.5	1 8.9	5 –10	0 –5	5 –22
CaO	1.1	2 .1	1. 8	–	–	1 –3.0	–	1 –11
Na ₂ O	2.8	4 .2	4. 8	4 .8	5. 0	1 0–15	–	4 –13
K ₂ O	4.2	7 .1	7. 5	1 1.8	1 2.3	1 0–13	0 –13	3 –9
B ₂ O ₃	3.2	6 .6	7. 3	4 .6	0. 1	0 –1.0	–	–

ZnO	—	—	—	0	0.	—	0	—
				.6	1		—8	
ZrO ₂	—	—	—	0	0.	0	0	—
				.4	1	—1.0	—8	
Li ₂ O	—	—	—	—	—	0	1	—
						—0.1	1—19	
P ₂ O ₅	—	—	—	—	—	—	0	0
							—11	.5— 6.5
TiO ₂	—	—	—	—	—	1	—	—
						—3.0		
Pigm ents etc.	—	—	—	—	—	—	0	0
							—8/0— 10	—3
Sinter ing/firing temp. (°C)	980	9	9	9	9	6	9	7
		80	50	00	00	50— 700	45	50

Quartz constitutes 25–32% of the porcelain composition. It is silicon dioxide (SiO₂). Melting temperature: 1710°C. It provides ceramics with strength, hardness, and chemical resistance. Quartz increases the viscosity of molten feldspar during firing.

Dyes — metal oxides such as titanium dioxide, chromium, zinc, and others.

Fluxes — substances that lower the melting point, such as sodium carbonate, calcium, and lithium.

Ceramic materials by purpose:

- 8) As veneers for metal frameworks, removable and fixed prostheses;
- 9) For metal-free (all-ceramic) prostheses;
- 10) For veneering non-metal prosthetic frameworks.

Alumina Ceramics

Until the 1960s, high-fusing porcelain was used for fabricating all-ceramic crowns. Due to the relatively low strength of this type of porcelain, McLean and Hughes (1965) proposed developing an aluminum oxide-reinforced porcelain material for crown fabrication. Alumina-reinforced dental crowns were primarily considered for anterior teeth due to their aesthetic appearance. However, their strength under the occlusal load of posterior teeth was uncertain. One method of fabricating aluminous porcelain crowns involved forming a tin oxide coating on a platinum foil. The purpose of this technique was to attach a thin platinum foil to the inner surface of the prepared tooth for cementation. Oxidation in the furnace produced a continuous tin film, reducing microcrack formation and increasing fracture resistance. The clinical performance of these crowns was very good for anterior teeth; however, approximately 15% fractured within 7 years of cementation with glass ionomer cement in molar teeth.

Zirconium Dioxide (Zirconia)

Zirconia has been used as a biomaterial since 1970.

Composition:

- 11) Zirconium dioxide — main substance: 90–95%
- 12) Yttrium oxide — 3–5%
- 13) Aluminum oxide — 0.1–0.5%
- 14) Hafnium oxide — trace amounts.



Crystal Phases of Zirconia

Crystal Phase	Temperature Range	Note
Monoclinic	$< 1170^{\circ}\text{C}$	Not used in pure form
Tetragonal	$1170\text{--}2370^{\circ}\text{C}$	High strength and hardness
Cubic	$> 2370^{\circ}\text{C}$	Maximum translucency

Zirconia is a silver-white metal, hard and refractory. Its corrosion resistance surpasses that of other resistant materials such as niobium and titanium. Zirconia manufacturing methods provide higher purity than titanium, because titanium reacts with hydrogen at temperatures up to 200°C during processing. An important property of zirconia is its antiseptic nature. Non-metallic zirconia has very low thermal conductivity — approximately 20% higher than aluminum oxide. It is chemically inert,

corrosion-resistant, and non-deformable. It has the ability to restore its structure at the molecular level when microcracks appear. The thickness of the zirconium dioxide coating is 0.04 mm. Zirconia does not irritate biological tissues and stimulates the growth of fibroblasts and osteoblasts, which in turn improves the clinical fixation of prostheses. Significantly less plaque accumulation around zirconia-coated prostheses provides a better microbiological environment, ensuring optimal adhesion to soft tissues and good adaptation of bones to loads. The low thermal conductivity of zirconium dioxide allows teeth to be protected from cold and hot temperatures — sometimes with very strong reactions — without fear (there is no need to devitalize the tooth).

Pure zirconia has a monoclinic crystal structure at room temperature and transforms into tetragonal and cubic zirconia at higher temperatures. The large volumetric expansion that occurs during the transition from cubic to tetragonal and from tetragonal to monoclinic phases leads to structural expansion and high tensile stress, which causes zirconia to crack when cooled from processing temperature. To overcome this problem, stabilizers such as magnesium oxide, yttrium oxide, calcium oxide, and cerium oxide are added to zirconia.

In its pure state, when zirconium dioxide is heated to temperatures between 1470°C and 2010°C and then cooled, its crystal structure begins to change from tetragonal to monoclinic phase at approximately 1150°C. During cooling to room temperature, as it transitions from tetragonal to monoclinic crystal structure, its volume increases by several percent.

Comparative Properties of Dental Ceramic Materials

Properties	Leucite	Lithium Disilicate	Zirconium Dioxide (Y- TZP)	GAP Nano- crystalline Ceramic for Veneering Y-TZP
Crystallinity	35	70	297.5 (incl. HfO, Al ₂ O, NaO, FeO etc.)	—
Flexural strength (MPa)	85–112	215–400	900	85– 110
Fracture toughness	1.3–1.7	2.2–3.3	8–10.3	0.75– 1.0
Vickers hardness (GPa)	5.9	6.3	8.8–11.8	4.8– 5.4
Expansion coefficient	15.0– 15.4	9.7–10.6	10.0–11.0	9.8
Elastic modulus (GPa)	65–86	95–103	210	65
Chemical composition	100– 200	30–50	30	10–20

References

- 1) Kalivradzhiyan E.S., Bragin E.A., Abakarov S.I., Zholudiyev S.I. — Textbook of Dental Materials Science.
- 2) Trezubov V.N., Mishnyov L., Zhulyov E.N. — Orthopedic Dentistry (2008).
- 3) Poyurovskaya I.Ya. — Dental Materials Science (2007).
- 4) Khafizov R.G., Shaykhutdinova D.I., Khafizova F.A., Azizova D.A., Zhitko A.K., Khairutdinova A.R. — Materials Science in Orthopedic Dentistry (2015).
- 5) Kenneth J. Anusavice — Phillips' Science of Dental Materials.
- 6) Akbarov A.N., Ziyadullayeva N.S. — Faculty Orthopedic Dentistry (2025).