



Translucent Zirconia: A Literature Review

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Article information

Received: October 13, 2023

Accepted: December 17, 2023

Available online: March 15, 2024

Keywords

Multilayer zirconia Translucent zirconia, Yttria, Zirconia.

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Abstract

Aims: Translucent zirconia has emerged as a promising material for aesthetic dental restorations due to its high translucency. **Materials and methods:** This review explores various methods to enhance its translucency, including aluminum oxide additives, increased lanthanum oxide content, a higher percentage of yttria, reduced grain size, and reduced sintering time. Strategies to minimize pores and impurities are also discussed. Mechanical properties, such as flexural strength and fracture resistance, are critical factors for successful restorations. **Results:** Comparisons with conventional zirconia and lithium disilicate reveal favorable flexural strength for monolithic translucent zirconia, making it a suitable replacement for enamel. Additionally, the review examines bonding techniques, such as air abrasion, surface conditioning, and laser treatments, to achieve reliable and durable adhesion between translucent zirconia and resin cement. Proper case selection and handling are essential for achieving optimal outcomes. **Conclusions:** Translucent zirconia presents a promising option for aesthetic restorations, but careful consideration of clinical requirements and further research on bonding techniques are crucial for its successful integration into modern dental practice. Continued advancements and expanded applications are expected as this innovative material continues to evolve in restorative dentistry.

الزركونيم الشفاف: مراجعة مقال

المخلص

الأهداف: ظهرت الزركونيا الشفافة كمادة واحدة لترميم الأسنان التجميلي بسبب شفافيتها العالية. **المواد وطرائق العمل:** تستكشف هذه المراجعة طرقًا مختلفة لتعزيز شفافيةها، بما في ذلك إضافات أكسيد الألومنيوم، وزيادة محتوى أكسيد اللانثانم، ونسبة أعلى من الإيتريا، وتقليل حجم الحبوب، وتقليل وقت التلبد. وتناقش أيضًا استراتيجيات تقليل المسام والشوائب. تعتبر الخواص الميكانيكية، مثل قوة الانثناء ومقاومة الكسر، من العوامل الحاسمة لنجاح الترميمات. **النتائج:** تكشف المقارنات مع الزركونيا التقليدية وسيليكات الليثيوم عن قوة انثناء مناسبة للزركونيا الشفافة المتجانسة، مما يجعلها بديلاً مناسباً للمينا. بالإضافة إلى ذلك، تتناول المراجعة تقنيات الربط، مثل كشط الهواء، ومعاملة السطح، والمعالجة بالليزر، لتحقيق التصاق موثوق ودائم بين الزركونيا الشفافة والأسمنت الراتنجي. يعد اختيار الحالة والتعامل معها أمرًا ضروريًا لتحقيق النتائج المثلى. **الاستنتاجات:** تمثل الزركونيا الشفافة خيارًا واعدًا للترميمات التجميلية، ولكن الدراسة المتأنية للمتطلبات السريرية وإجراء مزيد من الأبحاث حول تقنيات الربط أمر بالغ الأهمية لنجاح دمجها في ممارسة طب الأسنان الحديثة. من المتوقع استمرار التقدم والتطبيقات الموسعة مع استمرار تطور هذه المادة المبتكرة في طب الأسنان الترميمي.

DOI: 10.33899/RDENJ.2023.143906.1228, © Authors, 2024, College of Dentistry, University of Mosul

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INTRODUCTION

Translucent zirconia has emerged as a highly promising material in modern restorative dentistry, offering a compelling combination of aesthetics and mechanical properties. Its ability to mimic natural tooth appearance, combined with improved mechanical strength compared to other ceramics, has sparked growing interest among dental professionals seeking optimal solutions for aesthetic restorations. ⁽¹⁾

The pursuit of enhanced translucency has been a central focus in zirconia research. Various strategies, such as aluminum oxide additives, increased lanthanum oxide content, higher yttria percentages, and reduced grain sizes, have been investigated to achieve superior light transmission. Notably, reducing grain size below the visible wavelength range (<100 nm) and minimizing defects have shown promise in significantly increasing translucency. ⁽¹⁻⁵⁾

The term “translucent” is mostly used as a marketing term and does not necessarily reflect a significant improvement in light transmittance. The adjectives “high”, “super”, and “ultra” are also used to describe the level of translucency. ⁽⁵⁾

If traditional formulations show a translucency of 20% at 1.0 mm thickness and 5Y formulations show 24% at the same thickness, is that considered a “translucent” material? Even at a reduced thickness of 0.5 mm, the increment in translucency from 3Y to 5Y is 5% (5).

Furthermore, shorter sintering times have shown promise in yielding smaller grain sizes and increased light transmittance in translucent zirconia ceramics, while higher sintering temperatures result in a more compact

polycrystalline structure with decreased porosity. ⁽⁶⁾

Minimizing residual pores and impurities has been a crucial aspect of enhancing translucency, as they contribute to optical scattering on the zirconia surface. ⁽⁷⁾

In terms of processing techniques, hot isostatic pressing (HIP) and spark plasma sintering (SPS) have been proposed to fabricate fine-grained translucent zirconia, overcoming the limitations associated with larger grain sizes. ⁽⁸⁻¹⁰⁾

Mechanical properties play a pivotal role in determining the longevity and success of dental restorations. While monolithic translucent zirconia exhibits lower flexural strength than conventional tetragonal zirconia, it still surpasses that of lithium disilicate, making it a viable enamel replacement option. However, concerns about low thermal degradation and potential strength reduction must be carefully addressed when selecting translucent zirconia for specific cases. ⁽¹¹⁻¹⁴⁾

Bonding translucent zirconia to resin cement is a critical aspect of its successful clinical application. Various surface conditioning techniques, including air abrasion, laser treatments, and glass particle fusion, have been explored to enhance bonding reliability. These methods aim to create an ideal surface topography that promotes both mechanical interlocking and chemical bonding, ensuring strong and durable adhesion. ⁽¹⁵⁻¹⁹⁾

In determining appropriate clinical indications for translucent zirconia, its high translucency proves advantageous for thin and limited restorations, particularly for laminate veneers and partial crowns. Medium translucency is recommended for dentin

replacement, while low translucency may be ideal as a core material or for concealing discoloured abutments. ⁽²⁰⁻²²⁾

As research in this field continues to evolve, we anticipate that translucent zirconia will further transform the landscape of contemporary restorative dentistry, offering clinicians a versatile and durable solution for achieving natural and beautiful smiles for their patients. This article aims to provide a comprehensive overview of the methods used to enhance the translucency, mechanical properties, bonding, and indications of translucent zirconia through an in-depth exploration of the methods to enhance translucency, mechanical properties, bonding techniques, and clinical indications.

MATERIALS AND METHODS

The data included in this review were collected from: (PubMed, Ovid MEDLINE and EBSCO, Science Direct, Elsevier, and Wiley Online Library) and additional studies were searched in the reference lists of all articles

Zirconia was introduced to dentistry in the early 1990s as a filler for porcelain and later used in ceramic brackets and post systems. ⁽²³⁻²⁵⁾ The progressive adoption of CAD/CAM technology allowed for the production of custom crowns. ^(26,27) Pure zirconia has three phases, but stabilizing oxides like yttrium oxide are added to improve its mechanical properties, resulting in a tetragonal phase that provides enhanced fracture strength and toughness through a phase transformation toughening mechanism. ⁽²⁸⁻³⁰⁾

The use of zirconia in dentistry has evolved through four generations. The 1st generation, 3 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP), showed exceptional

mechanical properties but had limitations in opacity, leading to its initial use in combination with more aesthetic porcelain or glass-ceramic veneers. ⁽³⁰⁻³³⁾ The 2nd generation, high translucent TZP with 3 mol% yttria and low alumina content (3Y), allowed for monolithic posterior crowns without the need for porcelain veneers, improving aesthetics and reducing chipping risks. ^(30,32,34,35) The 3rd generation, partially stabilized zirconia (PSZ) with about 5 mol% yttria (5Y), provided enhanced translucency but compromised strength due to the absence of stress-induced transformation in the cubic grains. ⁽³⁶⁻³⁸⁾ The 4th generation introduced multichromatic zirconia with shade and translucency gradients, offering more options for monolithic restorations with varying yttria content to balance translucency and mechanical properties. ^(37,39,40)

Identification of translucency and optical properties

The term "translucent" in relation to zirconia materials lacks a standardized definition, leading to confusion in the dental industry. Manufacturers use adjectives like "high," "super," and "ultra" to describe varying levels of translucency for different formulations, but there is no consensus on what constitutes each level. The lack of agreement in marketing and actual yttria content of each zirconia material further complicates the understanding of their translucency characteristics. As a result, the term "translucent" is primarily used as a marketing term without clear guidelines on light transmittance or thickness for measurement. ^(5, 30)

In clinical practice, high-translucent zirconia (HTZ) has been used for monolithic anterior crowns and ultrathin restorations due to

its increased translucency achieved by a higher Y₂O₃ content (above 3 mol-%), leading to a higher percentage of the transparent cubic-phase. However, HTZ materials have lower flexural strength (550-800 MPa) and poorer adhesive behaviour with resin-based cement compared to conventional zirconia (900-1400 MPa), which can lead to challenges in crown documentation and cementation failure for ultrathin restorations. ^(14,41-43)

Translucency plays a crucial role in achieving a life-like appearance in restorations and can be adjusted by controlling light absorption, reflection, scattering, and transmission through the material. ⁽⁴⁵⁾ The addition of yttria into zirconia has resulted in different levels of translucency, ranging from HTZ to super (STZ), ultra (UTZ), and top (TTZ) translucency zirconia, with claims of surpassing the translucency of E-max material in the latter. ⁽⁴⁶⁾

Methods for increasing translucency of zirconia

Several methods to increase the translucency of zirconia include:

-Adding aluminium oxide as an additive during sintering hinders crystalline grain growth and enhances resistance to low-temperature degradation. A smaller amount (0.1 mass%) of aluminum oxide is better distributed in the microstructure, leading to increased translucency. ^(28, 47, 48)

-Increasing the content of lanthanum oxide to 0.2% mol, along with considering grain size and sintering temperatures, has been used to improve zirconia translucency. ^(3,43, 49)

-Stabilizing zirconia by increasing the percentage of yttria results in isotropic cubic zirconia material, reducing light scattering from birefringent grain boundaries and achieving higher translucency. ^(5, 43)

Translucent zirconia exhibits improved translucency by reducing grain size (ideally below 100 nm) and minimizing defects, though extremely small grain sizes (around 200 nm) may compromise strength and fracture resistance. ^(1, 4,29, 43)

Shorter sintering times yield smaller grain sizes and increased light transmittance in translucent zirconia ceramic, while higher sintering temperatures create a more compact polycrystalline structure with decreased porosity. ⁽⁶⁾

Enhanced translucency is achieved by reducing residual pores and impurities, and minimizing optical scattering on the surface of zirconia. ^(1,7)

Various processing techniques like hot pressing, hot isostatic pressing (HIP), and spark plasma sintering (SPS) have been proposed to fabricate more translucent zirconia. SPS has shown promise in producing fine-grained translucent zirconia and overcoming the issue of larger grain sizes associated with HIP. ^(9,10,50)

Properties of translucent zirconia

Mechanical properties of translucent zirconia differ from conventional zirconia, with lower flexural strength (around 600-800 MPa) compared to tetragonal zirconia (1000-1200 MPa) but still higher than IPS e.max lithium disilicate (460 MPa), monolithic translucent zirconia exhibits higher flexural strength than core ceramics stratified with layering porcelain. Studies suggest that translucent zirconia accumulates microbial biofilm similar to veneered materials, but more research is needed to evaluate its biological behaviour with different compositions. ^(12,13,51) Shading of translucent zirconia can be achieved by incorporating metal oxides before or after

sintering, which does not significantly affect its flexural strength. ^(52,53)

Zirconia aging or low thermal degradation (LTD) negatively impacts mechanical properties, higher yttria content, and larger grain sizes associated with increased LTD. ⁽⁵⁴⁻⁵⁶⁾ Sintering temperature and thickness of zirconia restorations affect their translucency, aesthetics, and fracture resistance. ⁽⁵⁷⁻⁶¹⁾

Monolithic zirconia restorations offer better resistance to chipping than ceramic-veneered zirconia-based restorations. ⁽⁶²⁾ Conventional zirconia has excellent strength, but its color is white and opaque as chalk; to individualize the color and translucency of a natural tooth, it requires important post-milling work, like stratification of feldspathic porcelain. ⁽⁶³⁾

More recently, pre-shaded, multilayer and high-translucent zirconia discs have been developed to mimic the natural gradient in color and translucency, reducing the need for surface stains and post-milling work. ⁽⁶⁴⁾ The connector area of two translucent zirconia crowns should be adjusted to ensure comparable fracture resistance to lithium disilicate restorations. ^(63,65)

Overall, while translucent zirconia offers promising advantages, further research is needed to fully comprehend its biological behaviour, optimize its properties, and explore its potential for various clinical applications.

Abrasive properties

Polished translucent zirconia exhibits the least abrasiveness, while sandblasted and glazed zirconia causes the highest wear on antagonist enamel. ⁽⁶⁶⁾ The smooth surface resulting from homogenous crystal distribution in monolithic translucent zirconia leads to less abrasive behaviour and reduced enamel wear compared to other ceramic restorative materials, despite slightly greater wear than natural enamel. ⁽⁶⁷⁻⁶⁹⁾

Indications of translucent zirconia

Translucent zirconia has different indications based on its translucency levels:

-High Translucency Zirconia: Suitable for thin, limited restorations such as laminate veneers and partial crowns, particularly for replacing enamel without excessive dental volume increase. However, excessive translucency should be avoided to prevent a greyish appearance. ⁽²⁰⁾

-Medium Translucency Zirconia: Indicated for dentin replacement, but veneering is necessary for achieving a good aesthetic result when used for enamel replacement. ⁽²¹⁾

-Low Translucency Zirconia: Recommended as a core material for dentin replacement, while high-opacity zirconia is useful for masking underlying abutments with discoloration, metal posts, or metallic abutments. The aesthetic appearance of translucent zirconia restorations may be affected by the dichromic background, and the final color can also be influenced by the luting cement used. ^(21,22)

Bonding and cementation of translucent zirconia

Various methods have been explored to enhance the bonding of translucent zirconia, which possesses a dense polycrystalline structure with no vitreous phase, making its surface processing challenging. Some of these methods include:

Air abrasion with alumina or silica-coated alumina particles: This technique leaves the zirconia surface with a thin silica layer that can react with silane, increasing bond strength. However, caution is needed with coarse particles to avoid microcracking. ^(14,70,71)

Air abrasion followed by surface conditioning: Combining air abrasion with alumina or silica-coated alumina particles and further surface conditioning with an MDP-containing primer provides both mechanical

interlocking and chemical bonding to the zirconia surface, leading to improved adhesive strength. ^(7,73)

Glass particle fusion: The fusion of glass particles on the zirconia surface creates a chemical bond between zirconia and cement through silane bonding and modifies the surface topography, thereby increasing bond strength. ⁽⁷⁴⁾

Surface treatment with laser: Various short-pulse lasers have been suggested for zirconia surface treatment, but some, like Er:YAG and CO₂ lasers, may cause surface microcracking and reduce flexural strength. Femtosecond lasers, which produce ultra-short pulses of high intensity, offer precise micropatterning without thermal damage. ⁽⁷⁵⁾

Surface cratering with femtosecond laser: Femtosecond laser application creates rough zirconia surfaces without triggering phase transformations or thermal damage. Laser-generated plasma ablation results in increased microroughness within the grooves, improving bond strength. ^(76,77)

Laser irradiation pattern and angulation: Different irradiation patterns and angulations of the laser can affect the bond strength between the ceramic surface and resin-based material. Optimizing laser surface patterning can further enhance bond strength in translucent zirconia. ^(76,78)

Resin cement are commonly used for bonding ceramic restorations, with dual-cure resin cement being the best choice for zirconia restorations. Using a zirconia primer can enhance bond strength, while try-in-paste cement aids in selecting the right shade for translucent zirconia restorations, meeting increased aesthetic demands. ⁽⁷⁹⁾

These methods provide promising ways to improve the bonding of translucent zirconia, allowing for better clinical outcomes in restorative dentistry applications. However, further research and optimization are still needed to achieve the best results and ensure the long-term success of these bonding techniques

CONCLUSION

In conclusion, translucent zirconia offers a valuable option for aesthetic dental restorations due to its improved translucency, strength, and wear properties compared to conventional zirconia. Methods to increase its translucency involve additives like aluminum oxide, increasing lanthanum oxide content, and reducing grain size.

The mechanical properties of translucent zirconia, including its flexural strength and fracture resistance, make it suitable for a wide range of clinical applications.

Bonding techniques such as air abrasion, surface conditioning, and laser treatment show promise in enhancing the bond strength of translucent zirconia. However, further research and optimization are needed to fully exploit its potential in restorative dentistry applications

While translucent zirconia offers significant advantages, it is essential for clinicians to carefully assess the individual clinical requirements and consider the specific indications for its use. Proper case selection, material handling, and bonding protocols are crucial for achieving successful outcomes with this innovative material in aesthetic dental restorations.

ETHICAL STATEMENT

All authors (should) confirm that the manuscript meets the ethical standards including proper

statistical investigations and thorough ethical reviews by the data-owning organizations.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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