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Properties, Fabrication Techniques, and Clinical Outcomes of Lithium Disilicate, Zirconia, and Zirconia-reinforced Lithium Silicate Crowns: A Narrative Review

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ABSTRACT

All-ceramic crowns have gained immense popularity in modern day dentistry owing to their enhanced aesthetics, biocompatibility, and durability. Among these, Lithium Disilicate (LS_2), Zirconia (Z), and Zirconia-reinforced Lithium Silicate (ZLS) are three most desired restorative materials, each offering varying benefits. The advances of material science and digital dentistry are constantly refining their clinical behaviour, making material selection a major part of restorative decision making. This review article provides a general summary of these three all-ceramic crown materials and discusses their evolution, specifically the development in the translucency of zirconia and the transformation of ZLS as a hybrid material. It covers the most important properties of each of these materials, such as aesthetics, biocompatibility, strength, and bonding procedures. It also discusses the effect of traditional vs. computerised impression methods on their clinical success. A lot of this review also contrasts traditional and digital impression technology. It discusses how developments such as Intraoral Scanning (IOS) and Computer-Aided Design and Computer-aided Manufacturing (CAD/CAM) technology impact the accuracy, efficiency, and clinical success of crown restorations. Through critical examination of the literature, this review is intended to provide clinicians with information necessary for evidence-based decision making in material selection and impression-taking techniques, which will ultimately maximise patient outcomes and long-term restorative success.

Keywords: All ceramic crowns, Digital impression, Intra oral scanning

INTRODUCTION

Dental crowns are the foundation of restorative dentistry to restore function, aesthetics, and durability to non-existent or missing teeth. The success of the restoration is based on the material selected. Lithium silicate and zirconia crowns are two such materials that are commonly used, each with its own merits and demerits [1].

Lithium disilicate (SiO_2-Li_2O) was first utilised in glass ceramics in 1998 as core material. It was achieved by heat-pressing ingots, which provided a desirable arrangement of fine, needle like crystals. The core was veneered with fluorapatite-based ceramics for translucency and incorporated flexural strength. A newer type, Ivoclar Porcelain System (IPS) e.max Press, has been released since 2009, enhancing optical and mechanical properties [2].

Zirconia is a tetragonal, cubic, and monoclinic polymorphic crystal. It is stable at room temperature, which changes to tetragonal at 1170°C and to cubic at 2370°C [3]. Lithium silicate ceramics, such as lithium disilicate and ZLS, are very translucidus and can quite satisfactorily reproduce the tooth look and are the most suitable choice for anterior restorations in which aesthetics comes first [2,4]. However, their moderate rigidity requires strict monitoring of occlusal stresses and clinical requirements.

In contrast, the polycrystalline ceramic zirconia is characterised by increased strength and fracture toughness, and therefore best suited for high-stress situations, like posterior crowns and bridges. Although the earlier zirconia were criticised for being non-translucidus, more recent versions have very good translucency, so allowing them to show their full aesthetic potential [5,6].

Furthermore, there has been progress in impression technology, i.e., digital IOS and CAD/CAM technology, which has impacted the accuracy and clinical success of such restorations [7]. The following article provides a comprehensive comparative overview of lithium silicate and zirconia crowns, assesses their mechanical properties, aesthetic behaviour, bonding, biocompatibility, and how the utilisation of conventional versus digital impression methods affects their clinical success.

PROPERTIES OF LITHIUM DISILICATE, ZIRCONIA, AND ZIRCONIA-REINFORCED LITHIUM SILICATE (ZLS) CROWNS

Lithium Disilicate Crowns (LS_2)

Lithium Disilicate (LS_2) is another preferred material for ceramic restorations because it is aesthetically acceptable and highly workable. It can be produced either via traditional CAD/CAM techniques or ceramic-press techniques, but zirconia can only be processed by CAD/CAM techniques. CAD lithium disilicate glass ceramic has an amorphous glassy matrix prior to crystallisation, which converts into a crystalline material made up of approximately 70% orthorhombic $Li_2Si_2O_5$ crystals. Its translucency, mechanical properties, and aesthetic characteristics are due to $Li_2Si_2O_5$. It is therefore utilised widely for restorations [2,8].

Its flexural strength and fracture toughness are average, and hence it can be utilised for anterior restorations. Bonding demands adhesive cementation, and it can be utilised for veneers, inlays, onlays, and single-unit crowns. It is less resistant to fracture compared to zirconia [2].

Zirconia Crowns

Zirconia (zirconium dioxide) is a polycrystalline ceramic known for its exceptional strength and durability. Different generations of zirconia have been developed to improve translucency while maintaining high mechanical properties [9]. The material has high flexural strength and excellent fracture toughness; however, It has lower aesthetic properties than LS_2. It can be cemented conventionally or adhesively and is commonly used in posterior crowns, multi-unit bridges, and implant-supported prostheses [10]. However, it is less translucent than lithium silicate [3,5].

Zirconia-reinforced Lithium Silicate (ZLS)

The ZLS ceramics from Vita and Dentsply, produced with CAD/CAM technology, feature a glassy matrix that is homogeneous with lithium metasilicates, orthophosphates, and tetragonal zirconia fillers to enhance strength. The materials differ in microstructure; for instance, Celtra Duo-a ZLS ceramic-is characterised by the presence of larger metasilicate crystals compared to other materials. Compared to LS_2, ZLS ceramics are mechanically stronger, more fracture-resistant, and durable, offering superior biocompatibility and clinically acceptable marginal gaps [11,12].

Bergamo ETP et al., tested the reliability of ZLS molar crowns of different thicknesses. Monolithic ZLS crowns of 1.0 mm and 1.5 mm were milled, cemented on epoxy resin replicas, and tested under single load-to-failure [13]. Both thicknesses survived approximately 90%, with bulk fracture being the most common mode of failure, highlighting the significance of crown thickness in design and fabrication.

Influence of Digital Impressions on the Crowns

Digital impression technology has revolutionised all-ceramic crown fabrication [Table/Fig-1]. Post milling processing does not affect ZLS crowns' internal adaptation, highlighting the potential of 3D evaluation techniques for clinical use [14]. Chipping remains a common issue for Z and LS_2 crowns, with rates varying between 1.4% and 31.4% depending on material type [14-16]. A review by Benli M et al., found that Z and LS_2 crowns exhibit similar endodontic and periodontal outcomes as metal-ceramic crowns, making them viable alternatives [17].

A systematic review of 32 studies assessed IOS accuracy of Intraoral Scanners (IOS), finding it reliable for short-span scanning but less precise for full-arch impressions [18]. A clinical trial comparing digital and conventional impressions in 42 patients showed that digital methods were more efficient, improved occlusal contacts, and enhanced patient experience [19]. Direct digitalisation provided a superior marginal fit compared to indirect methods [20].

A study by Arezoobakhsh A et al., indicates that zirconia frameworks in digital workflows exhibited smaller marginal gaps than those produced through conventional methods, all within clinically acceptable limits [21]. Digital impressions offer comparable accuracy to traditional methods for crowns and short-term prostheses, but are less precise for full-arch impressions [22]. Despite some challenges, digital workflows improve efficiency and patient comfort, with ongoing research aimed at refining their accuracy for complex cases [Table/Fig-1] [14-22].

Comparative Analysis of Zirconia, Lithium Disilicate, and Zirconia-reinforced Lithium Silicate (ZLS) Based on the Literature [23-36].

Lithium disilicate, ZLS, and zirconia are popular restorative materials, each with specific benefits. Zirconia has a higher mechanical strength and fatigue strength, extremely durable properties for posterior restorations [23]. Although LS_2 has lower strength compared to ZLS and Z, it provides sufficient strength for most restorations while offering superior aesthetic outcome, making it ideal for anterior restorations [24-26]. ZLS, being a hybrid material, has an intermediate middle ground between zirconia's strength and lithium disilicate's translucency, an aesthetically acceptable and structurally stable substitute [23].

Cyclic loading fatigue failure is common to the three materials, with the nature of the loading protocol determining fatigue life. Zirconia exhibits maximum fracture resistance, followed by ZLS, which provides slightly inferior but acceptable clinical performance, and then lithium disilicate [27]. Translucency continues to be a major discriminator-lithium disilicate is the most translucent, followed by ZLS, with zirconia being less so despite advance in material technology [26].

Wear dynamics are affected by the properties of the materials, the surface roughness, the opposing tooth structure, and the oral environment [28,29]. Woraganjanaboon P et al., quantified maximal vertical wear, volume wear, and surface properties of antagonist enamel to monolithic zirconia and lithium disilicate crowns in a study [29]. In one study of 24 patients, either a lithium disilicate or a 5 mol% yttria-stabilised tetragonal zirconia (5Y-TZP) crown was matched to natural first molar teeth. No evidence of difference in antagonist enamel wear was found between zirconia crowns and lithium disilicate crowns, indicating that both materials are as similar to natural teeth as regards wear pattern. ZLS, with the changed glass matrix structure, exhibits lithium disilicate-type wear resistance with excellent mechanical properties [29].

Bonding and cementation are essential for long-term success with restorations. Surface treatment and adhesion protocols differ between the two materials-lithium disilicate and ZLS develop greater bond strengths through hydrofluoric acid etching, whereas zirconia needs air abrasion for best adhesion [30-34]. Clinical crown and endocrown survival rates are excellent with all three materials, but long-term data are necessary to evaluate possible failure modes and durability in detail [35,36].

PERFORMANCE ANALYSIS OF ZIRCONIA, LITHIUM DISILICATE, AND ZLS CROWN

Digital vs. Conventional

The majority of studies indicate no significant difference in marginal fit between digital and conventional impression techniques [37-39].

Features	Lithium disilicate	Zirconia	Zirconia-reinforced Lithium Silicate (ZLS)	Influence of digital impressions
Marginal and internal fit	Requires precise adhesive bonding for optimal fit.	Can be cemented conventionally, but surface treatment improves bond strength.	Offers good marginal fit, slightly improved over lithium disilicate but less than zirconia.	Improves adaptation and precision, reducing marginal gaps.
Fracture resistance and longevity	More prone to chipping in high-load areas; best for anterior restorations.	Superior fracture resistance; ideal for posterior crowns and bridges.	Higher strength than lithium disilicate but lower than zirconia; suitable for single crowns and short-span bridges.	Enhances precision, leading to better stress distribution and longer-lasting restorations.
Aesthetic outcomes	More translucent, better for anterior restorations requiring high aesthetics.	More opaque, but newer translucent zirconia options provide improved aesthetics.	Offers a balance between lithium disilicate and zirconia, with good translucency and strength.	Enhances colour selection and consistency (digital shade matching).
Bonding and cementation	Requires hydrofluoric acid etching and silane application.	Requires air abrasion and zirconia primers (e.g., 10-Methacryloyloxydecyl Dihydrogen Phosphate MDP-containing primers).	Can be bonded adhesively like lithium disilicate or cemented conventionally like zirconia.	Improves cementation accuracy by reducing fit errors.
Biocompatibility and gingival response	Generally well-tolerated, but some patients may experience minor irritation from bonding agents.	Excellent biocompatibility, minimal plaque accumulation, and optimal soft-tissue response.	Biocompatible, with good gingival response; less plaque accumulation than lithium disilicate.	Reduces errors that could lead to marginal overhangs, improving gingival health.

[Table/Fig-1]: Influence of digital impressions [14-22].

While some studies show slight variations or advantages for one method in specific situations (e.g., internal fit in certain areas or specific scanners performing better), the overall trend suggests that both methods can achieve clinically acceptable marginal fit [24,25]. However, Berrendero S et al., suggest that digital may offer advantages in other clinical parameters, such as interproximal contacts [40].

Fabrication Techniques

Studies comparing different fabrication techniques (e.g., milled vs. pressed, CAD/CAM vs. conventional) demonstrate that milled or CAD/CAM techniques often result in better marginal and internal fit than pressed or conventional methods [41,42]. This is particularly noticeable in studies involving endocrowns.

Scanner Influence

Kim SS et al., and Carrilho Baltazar Vaz IM et al., investigated the impact of different IOS on marginal fit [43,44]. While Kim SS et al., found no significant difference, Carrilho Baltazar Vaz IM et al., observed variations, suggesting that scanner technology can influence the outcome [43,44]. This points to the need for careful selection and calibration of scanning equipment.

Strength and Fatigue Resistance

Zirconia, especially in 5Y-TZP type, consistently presents higher mechanical strength (fracture load, flexural strength) than lithium disilicate and ZLS crowns. This renders it more indicated for high-stress locations like posterior restorations and bridges. Although zirconia exhibits greater strength, all three materials are susceptible to fatigue failure when subjected to cyclic loading. A study point out that the mode of loading protocol significantly affects fatigue life [35]. What that implies is that clinical loading parameters (magnitude, frequency) bear importance for long-term success. Although lithium disilicate is not quite as strong as zirconia, it remains sufficiently strong for the majority of indications and, in some studies, showed greater performance under select loading conditions.

ZLS is a material recently introduced to combine the advantages of both lithium disilicate and zirconia with higher strength while leaving room for a degree of translucency. Zirconia continues to be the material of choice where strength is most important. Yet, lithium disilicate is a proper substitute in most situations, particularly in aesthetic regions. ZLS crowns present an intermediate option, with translucency and strength being balanced against each other, suitable for those cases where durability and greater aesthetics are desired. The particular zirconia form and ZLS formulation also must be taken into account when selecting materials [32-34].

Aesthetics and Translucency [Table/Fig-2] [23-36]

Lithium disilicate exhibits better translucency than zirconia and ZLS, both initially and after artificial ageing. This makes it more suitable for anterior restorations, where aesthetics is a primary concern [26]. While traditionally less translucent, zirconia formulations (like 5Y-TZP) have improved significantly, but still do not match lithium disilicate's aesthetic potential. ZLS crowns were developed to address this limitation, offering improved translucency compared to conventional zirconia while maintaining better strength than lithium disilicate alone.

Features	Zirconia (5Y-TZP unless specified)	Lithium Disilicate (LS2)	Zirconia-reinforced Lithium Silicate (ZLS)
Fracture strength (with endodontic Access)	Decreased with fine diamond instrument use. No difference with coarse diamond or no access.	No negative effect from endodontic access (fine or coarse diamond).	More resistant than lithium disilicate, but slightly lower than zirconia.
Marginal adaptation (endocrowns and veneers)	Almost equal to lithium disilicate in endocrowns. Superior vertical marginal fit in veneers at 0.5 mm thickness.	Almost equal to zirconia in endocrowns. Larger vertical marginal discrepancy in veneers at 0.5 mm thickness.	Marginal adaptation superior to lithium disilicate and close to zirconia.
Translucency (effect of aging)	Less translucent than lithium disilicate after aging.	More translucent than zirconia after aging.	Higher translucency than zirconia, but slightly lower than lithium disilicate.
Survival rate (laminate veneers)	High survival rate (100% at 2.6 years in one study, but no long-term data).	High survival rate (comparable to feldspathic and leucite-reinforced glass-ceramic).	Comparable to lithium disilicate, with potentially improved durability.
Complication rate (laminate veneers)	No complications reported in short-term studies. Long-term data needed.	Lower long-term complication rates than feldspathic and leucite-reinforced glass-ceramic.	Similar to lithium disilicate, but with potentially lower risk of chipping.
Wear (surface roughness)	No correlation between wear and surface roughness. Similar wear to natural enamel in vivo.	Correlation between roughness parameters and wear after 1.2 million cycles. Similar wear to natural enamel in vivo.	Wear properties between lithium disilicate and zirconia. Less wear than lithium disilicate under heavy loads.
Crown reliability (ultrathin, posterior)	Lower reliability than lithium disilicate at 100N and 200N. Similar at 300N but all materials weaken.	Higher reliability than zirconia at 100N and 200N. Reliability decreases significantly at 300N.	More reliable than lithium disilicate in posterior crowns, but slightly lower than zirconia.
Debonding with Er:YAG laser	Debonding time influenced by yttria content (faster with higher content).	Debonding time faster than all zirconia types tested.	Debonding time between lithium disilicate and zirconia.
Mechanical strength (in-vitro)	Higher mechanical strength than lithium disilicate.	Lower mechanical strength than zirconia.	Strength between zirconia and lithium disilicate, providing a balance of toughness and aesthetics.
Adhesive cementation strength (In-vitro)	Similar to lithium disilicate CAD-CAM.	Similar to zirconia.	Bonding properties similar to lithium disilicate but may benefit from MDP primers like zirconia.
Biocompatibility (In-vitro)	Good biocompatibility.	Better biocompatibility than zirconia in one study.	Comparable to lithium disilicate, with potential advantages in plaque accumulation and soft-tissue response.
Clinical success (crowns)	High short-term success rate when conventionally cemented or adhesively bonded. No significant difference compared to lithium disilicate except for marginal adaptation.	High short-term success rate when adhesively bonded. No significant difference compared to zirconia except for marginal adaptation.	Similar clinical success rates to both zirconia and lithium disilicate.
Shear bond strength (in-vitro)	Higher shear bond strength with air abrasion with diamond particles. Lower shear bond strength with hydrofluoric acid etching.	Higher shear bond strength with hydrofluoric acid etching compared to zirconia. Lower shear bond strength when air abraded.	Stronger than zirconia in etching, closer to lithium disilicate in adhesive bonding.
Translucency (In-vitro)	Lower translucency than Zirconia-reinforced Lithium Silicate (ZLS).	Higher translucency than lithium disilicate.	More translucent than zirconia, slightly lower than lithium disilicate.
Fatigue behaviour (in-vitro)	Highest fracture load and flexural strength. Fatigue life varied depending on loading protocol.	Lower fracture load and flexural strength compared to zirconia. Fatigue life varied depending on loading protocol.	Fatigue resistance superior to lithium disilicate, but slightly lower than zirconia.
Endocrown clinical efficacy	Similar clinical efficacy to lithium disilicate and feldspathic ceramic in a two-year study.	Similar clinical efficacy to zirconia and feldspathic ceramic in a two-year study.	Comparable efficacy to both lithium disilicate and zirconia, with a balance of strength and adaptability.

[Table/Fig-2]: Comparative analysis of Zirconia, Lithium Disilicate, and Zirconia-reinforced Lithium Silicate (ZLS) based on the literature [23-36].

For anterior teeth and highly aesthetic cases, lithium disilicate remains the preferred choice. Zirconia is typically used in posterior restorations where strength is a priority. ZLS serves as a middle-ground option, allowing for better translucency than zirconia while providing superior strength compared to lithium disilicate, making it ideal for cases where both factors need to be balanced [34].

Wear and surface roughness [Table/Fig-1,2]: Wear is a multifaceted phenomenon influenced by material properties, surface roughness, opposing tooth structure, and the oral environment. Simple roughness parameters might not fully predict wear behaviour [28]. More research is needed to fully understand the long-term wear behaviour of these materials, especially with newer high-translucency zirconia and modified ZLS variants. Clinical studies remain vital for confirming laboratory findings and establishing best practices for long-term durability.

Bonding and cementation: Proper surface treatment is essential for achieving uniform bonding to zirconia, lithium disilicate, and ZLS crowns. Air abrasion is especially important for maximising the bond strength of zirconia, while lithium disilicate and ZLS respond well to hydrofluoric acid etching and salinisation. All three materials are typically bonded using resin cements, particularly with lithium disilicate and ZLS, to enhance their mechanical strength and bonding. Literature suggests that debonding can be a simpler process in zirconia-based restorations; but ZLS and lithium disilicate may be susceptible to fracture during removal [31]. Adhesion protocols are extremely valuable long-term, and following suggested surface treatments and cementation protocols tailored to each material is necessary.

Clinical performance and applications: All three materials have excellent short-term clinical success for crowns and endocrowns. However, the data provided, tends to be mostly short-to-medium-term in nature. Further long-term trials are needed to properly evaluate long-term behaviour and determine possible modes of failure. The material of choice is based on the provided clinical scenario presented: zirconia is preferred for high-strength locations, lithium disilicate for areas requiring high aesthetics, and ZLS serves as a compromise between translucency and strength. Each material types' of special characteristics and limitations needs to be taken into account [Table/Fig-2].

All three tested materials for endocrowns seem to be a valuable treatment choice for endodontically treated teeth where indicated, and all have had high success rates reported. Both lithium disilicate and zirconia are excellent restorative materials and the ZLS crown is another option that is aesthetic and strong [24,36]. Precise case selection, correct choice of material according to functional and aesthetic demands, and strict clinical technique are most important for the delivery of predictable long-term outcomes. Ongoing research, especially long-term clinical trials, will continue to elucidate our knowledge regarding their performance and direct clinical choice. Evolution of new materials and techniques is sure to continue to refine the use of all three materials.

CONCLUSION(S)

This review, in conclusion, provides a comparison of lithium disilicate, zirconia, and ZLS crowns, reflecting their pros and cons in dental applications. Lithium disilicate is best in aesthetics and translucency, making it an excellent choice for anterior restorations, while zirconia stands out for its superior strength and durability, making it ideal for high-stress areas like posterior teeth and bridges. Recent advancements in material technology, such as high-translucency zirconia and reinforced lithium silicate, have helped to bridge the gap between strength and aesthetics, increasing their clinical applications.

Selecting the right material depends on individual patient needs, taking into consideration factors like the location of the restoration, aesthetic preferences, functional demands, and long-term durability. For long-term, research should focus on enhancing the longevity of these materials by improving wear resistance, adhesive properties, and overall clinical success rates. Also, the continued evolution of digital workflows and material innovations will further refine the precision, efficiency, and customisation of dental restorations, ultimately leading to better patient outcomes.

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