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Lithium Disilicate Ceramics in Prosthodontics: Unveiling Innovations, Current Trends, and Future Horizons

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Abstract

In contemporary dentistry, ceramic restorations have experienced a surge in popularity. This paper aims to review the current state of literature and recommendations concerning the application of lithium disilicate glass-ceramic IPS™ e.Max. This comprehensive review also covers material science, mechanical intricacies, and optical properties of glass-ceramic material. Further, this review extends valuable clinical insights, presenting recommendations for the effective utilization of IPS e.Max CAD restorations in dental practices.

Keywords: Lithium Disilicate, IPS™ e. Max, CAD, Ceramics, Translucency.

1. Introduction

With an increasing emphasis on achieving aesthetic outcomes in contemporary dentistry, all-ceramic restorations have assumed a pivotal role. Among the diverse spectrum of all-ceramic materials, Lithium disilicate stands out, offering a compelling combination of robust mechanical properties and exceptional esthetics [1]. The introduction of Lithium disilicate dental ceramics dates back to 1988 when it was first unveiled as a heat-pressed core material, commercially known as IPS™ Empress 2 and marketed by Ivoclar Vivadent in Lichtenstein [2].

Glass-matrix ceramics have a long-standing history of utilization in dentistry due to their chemical composition rich in silica, endowing the material with high translucency, biomimetic qualities, and biocompatibility [2]. The composition comprises approximately 65% volume fraction of lithium disilicates, 34% volume fraction of residual glass, and 1% volume fraction of porosity post-heat treatments [3]. The fabrication of lithium disilicate restorations can be achieved through either the hot-press technique or the CAD-CAM system [4].

2. Dispension

IPS Empress 2, IPS e.max Press, and IPS e.max CAD are available in the form of ceramic ingots or blocks, tailored to distinct fabrication techniques in dentistry. IPS Empress 2, available in ingot form, is utilized in the lost-wax hot-pressing technique, where the material is shaped through heat pressing within a porcelain furnace [5,6]. Similarly, IPS e.max Press, dispensed in ingot form, follows the lost-wax hot-pressing method for ceramic molding. This technique minimizes processing errors typically associated with traditional sintering and has demonstrated enhanced mechanical stability. On the other hand, IPS e.max CAD is provided as blocks suitable for computer-aided-designed/ computer-aided-manufactured (CAD/CAM) milling procedures, affording versatility for use in both dental office settings, particularly chairside CAD/CAM systems, and dental laboratories. The choice among these materials depends on the specific clinical requirements and the preferred fabrication technique [6,7].

3. Methods of fabrication

Various methods are available for the fabrication of Lithium disilicate restorations, including heat pressing and computer-aided design and manufacturing (CAD-CAM). In the heat pressing approach, Lithium disilicate is typically manufactured in a fully crystallized state, provided in the form of ingots. These ingots, when subjected to heat, become viscous and are pressed using a lost wax technique [8,9]. On the other hand, the CAD-CAM technique involves the preparation of Lithium disilicate by manufacturers in the form of partially crystallized (Li_2SiO_3) blocks. After the milling process, these blocks require firing to attain the final crystallization stage ($Li_2Si_2O_5$). The firing cycle enhances the mechanical properties and aesthetic appearance of Lithium disilicate. The crystallization process unfolds in two primary phases: nucleation and crystal growth. The ultimate microstructure of Lithium disilicate comprises highly interlocked crystals with dimensions of 5mm in length and 0.8 mm in diameter [8].

4. Properties

$Li_2Si_2O_5$ exhibits a lack of chemical stability in the oral environment and undergoes degradation in mechanical properties. To address this issue, the incorporation of oxides has been undertaken to enhance both the chemical and mechanical stability. Various oxides, including Al_2O_3, K_2O, ZnO, ZrO_2, CaO, and P_2O_5, were experimented with to improve the properties of lithium disilicate glass-ceramic, rendering it more suitable as a restorative material in dentistry. The utilization of IPS™ e. Max CAD has witnessed a surge in popularity since its introduction, primarily owing to its outstanding mechanical properties. Extensive studies have been conducted, ranging from elucidating the material's evolution to comparing its performance against existing all-ceramic and CAD-CAM products available in the market [10].

The subsequent sections provide an overview of the physical and mechanical characteristics associated with the partially crystallized starting material, alterations occurring throughout the firing procedure, and relevant insights into the mechanical attributes of the final tempered material. An assessment of the material in its partially crystallized "blue state" has been conducted to ascertain its initial properties.

4.1 Colour and optical properties

In the field of restorative dentistry, patient satisfaction and the success of restorative procedures significantly depend on colour and optical properties [3]. Lithium disilicate has gained prominence for its application in esthetic rehabilitation, and maintaining the colour integrity of lithium disilicate is a pivotal factor influencing the long-term clinical success of such restorations. The colour of ceramics, including lithium disilicate, is typically influenced by both intrinsic and extrinsic factors [11].

Intrinsic factors such as the composition of the ceramic and the application of the glaze layer, and extrinsic factors, including dietary habits, food and liquid colorants, and oral hygiene products, can impact the stability of colour in ceramic materials. Glazing the ceramic restorations before the final cementation process is important as this significantly contributes to the colour stability and resistance to staining in ceramic restorations [11]. Additionally, the aesthetic appearance of ceramics is influenced by the shade of the resin cement used and the thickness of the cement layer.

IPS™ e.Max CAD is offered in the standard A through D shades and includes a range of bleach shades. In ceramic materials, the colour is influenced by colourant ions dispersed within the matrix. For IPS™ e.Max CAD, the primary ions responsible for colouration include V^{+4}/V^{+3} (blue/yellow), Ce^{+4} (yellow), and Mn^{+3} (brown). All colour formulations are provided in the initial "blue state," and during the firing process, the oxidation states of colouring ions, particularly Vanadium, change, resulting in a noticeable colour shift [4]. Further refinement of the final colour of the restoration can be achieved by applying stain and glaze to the surface before the tempering process.

Translucency is a crucial optical characteristic that significantly impacts the visual appeal of a material. Variances in the microstructure of the material result in distinctions in translucency. IPS™ e.Max CAD offers three levels of translucency, namely medium opacity (MO), high translucency (HT), and low translucency (LT) [4,9].

4.2 Flexural strength

A primary challenge faced by many manufacturers is achieving the right balance between strength and translucency in ceramic materials. Strength, a critical mechanical property influencing the performance of brittle materials, is assessed through various testing methods. These include the three-point bending test, four-point bending test, non-destructive test method, and biaxial flexural strength test, incorporating techniques like ring on ring, ball on ring, and piston on three balls tests [12,13]. Research highlighted the impact of factors such as the firing cycle, temperature, rate of temperature increase, holding time, and cooling time on the distribution of sintering, glass, and crystal phases within the microstructure of the porcelain [12]. IPS e.max CAD group possesses greater flexural strength than IPS e max press [10,12].

4.3 Marginal fit

The success of restorations is contingent upon the marginal fit, which is influenced by both vertical and horizontal discrepancies. The marginal gap is specifically defined as the vertical distance from the internal surface of the restoration to the finish line of the preparation [13]. Horizontal discrepancies, exemplified by crown overhangs, can lead to significant misfits. While adjustments for horizontal overhangs can be made to a certain extent within the oral cavity, vertical marginal gaps necessitate sealing with luting cement. However, the application of luting cement may render the tooth surface rough and porous. It is noteworthy that the larger the marginal discrepancy, the faster the rate of cement dissolution would occur [13]. In cases where the marginal fit of restoration is suboptimal, it can potentially harm the tooth, periodontal tissue, and the restoration itself. An augmented marginal discrepancy (MD) may contribute to issues such as cement dissolution, microleakage, and the accumulation of plaque. These factors, in turn, can lead to conditions such as caries, gingival inflammation, and pulpal lesions [13,14].

Various studies demonstrated the smaller marginal gaps with IPS e.max press crowns compared to CAD-manufactured crowns [14,15]. Crowns fabricated using the intra-oral digital impression technique displayed a better marginal fit than those made with extra-oral scanning and conventional techniques [16].

4.4 Shear bond strength

Bonded restorations have several advantages over conventionally cemented ones. Appropriate bonding reduces marginal defects and the requirement of minimal removal of sound dental tissues during cavity preparation.
The conventional method for bonding lithium disilicate ceramics comprises several sequential steps. Initially, the process involves chemical etching with 9.5% buffered hydrofluoric acid (HF-acid), followed by water rinsing, acid neutralization, another round of water rinsing, and eventual air drying [17]. Subsequently, the second step entails the application of a silane coupling agent (primer) for 60 seconds and air-dried for 5seconds [17]. Hydrofluoric acid etching of the inner surface of the porcelain veneer generates a retentive etch pattern. Analysis through scanning electron microscopy (SEM) of the etched porcelain surface reveals an amorphous microstructure with numerous porosities. These micro-porosities augment the surface area for bonding, facilitating a micro-mechanical interlocking of the resin cement [17].

Opting for co-jet application or hydrofluoric acid etching is a favourable approach in the cementation of lithium disilicate restorations, enhancing the bond with resin cement [18]. Total etch resin cements prove to be dependable luting agents, ensuring a durable bond between lithium disilicate and the dental substrate [19].

4.5 Wear mechanism

Research has explored the friction and wear effects of lithium disilicate on the enamel of the opposing natural tooth, both with and without fluorapatite coating. The findings indicate that these effects were less severe in specimens without veneer [20]. The abrasive wear process can be categorized into two types: 2-body and 3-body abrasive wear.

In 2-body abrasion, wear results from the movement of hard projections on one surface sliding over another. On the other hand, in 3-body abrasion, particles become trapped between two surfaces but have the freedom to roll and slide [20]. Like other glass-ceramics, lithium disilicate can undergo intraoral repairs in case of chipping [20]. Processes such as grinding, glaze-coating, and fluorapatite ceramic veneering have the potential to escalate wear, affecting both the antagonist teeth and the restoration itself [21].

5. Indications

Originally employed for its aesthetic framework, inlay and onlay capabilities, and anterior veneering applications [3,9], IPS™ e.Max CAD witnessed an expanded scope in 2016 with updated manufacturer indications. The revised guidelines suggested that IPST™ e.Max CAD could now be utilized as veneering material, for inlays and onlays, and for the making of partial and full crowns. Furthermore, it gained approval for use in three-unit fixed partial dentures (FPD) across the anterior, premolar, and posterior regions [3,9,20,21]. Notably, the 2016 manufacturer indications specifically advocate for the implementation of IPS™ e.Max CAD in minimally invasive crowns, emphasizing a material thickness of 1 mm [3].

A study on fatigue testing has suggested that the risk of bulk fracture in a monolithic lithium disilicate crown can manifest at forces as low as 1,100 to 1,200 N. Several investigations focusing on properties at a thickness of 1 mm indicate a potential for complications when employing such thin restorations [3]. Despite the caution, there is a wide range of indications for producing monolithic lithium disilicate restorations, spanning from veneers to 3-unit bridges. Leveraging the high strength of ceramics, both full and partial crowns in the posterior and anterior regions can be crafted with exceptional esthetics, further enhanced by staining techniques. Minimally invasive crowns that prioritize tissue preservation, particularly for young patients with vital teeth, can be successfully created with a thinness of 1 mm in both the anterior and posterior regions. The contemporary trend of minimal preparation smile rehabilitation is popularly achieved using ultra-thin veneers at 0.3 mm thickness [9].

The capacity for implant superstructures extends up to three units, and this capability is constrained, particularly in the premolar region [9]. Several in vitro studies indicate that monolithic lithium disilicate crowns, whether produced through CAD-CAM or hot-pressed methods, exhibit greater resistance to fatigue fracture compared to their bilayered counterparts with hand veneering. The monolithic crowns demonstrate higher fracture loads, reaching up to 1900 N [20]. Furthermore, these studies highlight that both monolithic lithium disilicate crowns and fixed dental prostheses (FDPs), whether crafted through CAD/CAM or hot-pressed techniques, exhibit superior resistance to fatigue fracture when compared to bilayered crowns with hand veneering. The fracture loads observed, reaching 1900 N, are comparable to the standard seen in metal-ceramic restorations [20].

6. Contra-indications

Due to the inherent brittleness of glass ceramics, their use is contraindicated in specific clinical scenarios. These include instances of parafunctional habits such as bruxism, where the material's susceptibility to fracture may be heightened. Additionally, glass ceramics are not recommended for sharp edge preparations and very deep subgingival preparations, as their brittle nature may pose challenges in terms of durability and stability in these situations [9].

7. Future scope

The future scope for IPS™ e.Max CAD in restorative dentistry holds promising avenues for exploration and refinement. Research endeavours can be directed towards optimizing the material for thin restorations, addressing challenges while ensuring optimal strength and durability. Advancements in manufacturing processes, such as exploring novel techniques, may contribute to enhancing both esthetic and mechanical properties. Long-term clinical studies will provide valuable real-world insights into the performance and durability of IPS™ e.Max CAD restorations. Continuously evaluating and expanding the indications for its use, especially in novel clinical scenarios or specific patient demographics, remains a significant focus. Integration of digital technologies for precise design and fabrication, along with exploring patient satisfaction beyond technical aspects, are essential considerations. Further studies on biocompatibility in diverse clinical situations will ensure the material's safety and effectiveness over the long term. Collectively, these avenues can contribute to the ongoing evolution and improvement of IPS™ e.Max CAD in restorative dentistry.

10. Conclusion

IPS™ e.Max CAD emerged as a versatile and resilient option in restorative dentistry, evolving from its initial aesthetic framework applications to encompass veneering, inlays, onlays, and diverse crown constructions. The 2016 manufacturer indications endorse its use in minimally invasive crowns, emphasizing a 1 mm thickness. However, caution is necessary due to potential complications in thin restorations. Studies underline its superior fatigue resistance, especially in monolithic forms, enhancing its appeal for various restorations. Nevertheless, the brittleness of glass ceramics prompts careful consideration, rendering them unsuitable for specific clinical scenarios such as parafunctional habits, sharp edge preparations, and deep subgingival applications. This comprehensive understanding is essential for achieving successful and enduring outcomes in restorative dentistry.

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