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Overview of Lithium Disilicate as a restorative material in dentistry

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ABSTRACT

Lithium disilicate was first introduced to the dental field as an indirect restorative material in 1998. It was marketed under the name IPS Empress 2, and was intended for use with press technology. It was later replaced by modified versions including IPS e.max® Press and IPS e.max® CAD. Newer versions have since emerged, namely Amber Mill GC Initial and CEREC Tesseratwo. The latter has part crystal composition of lithium disilicate, embedded in a glassy zirconia matrix. The CAD version is provided in a meta-silicate state, characterised by 40% platelet-shaped lithium meta-silicate crystals and a glassy matrix that is bluish in colour. To obtain the desired lithium disilicate structure and tooth shades, a process of crystallization is required. This involves firing at 840 °C, for 25 minutes. The resulting glass-ceramic material has the benefit of providing maximum aesthetic translucency along with good fracture resistance of about 2MPa, and mechanical strength of 360MPa.

Developments in the all-ceramic dental materials have led to improvements in their physical properties and aesthetic appeal, leading to a substantial increase in their clinical use. This paper present a review of lithium disilicate with particular reference to its chemical composition, aesthetic versatility, and durability for use in crowns, veneers, and implant retained restorations. It also covers the recommended techniques prescribed to ensure predictable bonding and cementation. An electronic literature search on the use of lithium disilicate in dentistry was carried out using EBSCOhost search engine. This included all papers relating to its use for conventional veneers, crowns and bridge work, for CAD/CAM restorations, dentine bonding procedures and luting agents. It covered all papers published in peer reviewed journals from 1988 to 2021. The review indicates that lithium disilicate can be a useful and versatile material in dentistry providing it is handled correctly and the recommended tooth and restoration surface preparations and bonding procedures are carried out. The latter involves tooth etching and silane treatment of the fitting surfaces of restorations prior to cementation to improve adhesion and fracture resistance.

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LITERATURE REVIEW

The use of ceramics in dentistry dates back to the 19th century, with continued developments and improvements being made in terms of material properties and bonding techniques and materials. The dental ceramics that are currently used include metal-based and metal-free ceramics, layering and press ceramics, and analogue and digitally processed ceramics.[1]

The all-ceramic IPS e.max® system which is a lithium disilicate composition was launched in 2005. This material set new standards in terms of its optical and mechanical performance. It was the first modular, fully integrated all-ceramic system of its kind on the market offering excellent aesthetics, different levels of translucency, and increased strength when used in both press systems and with CAD/CAM technology. This has allowed it to be used for a broad spectrum of dental restoration.[1,2]

Lithium disilicate ($Li_2O_5Si_2$) is a glassy ceramic with an average flexural strength of 400Mpa and a favourable translucency, making it suitable for both anterior and posterior use.[3,4] Press ceramics have been on the market for almost 25 years and are now also available in the form of pressable multi-coloured ingots for highly aesthetic monolithic restorations.[1,2]

$Li_2O_5Si_2$ has many advantages over the traditional metal materials, macromolecule materials, and older ceramics. These include high mechanical and flexural strength, good wear resistance and excellent aesthetics.[5-11] However, despite the advances in adhesive dentistry, long-lasting bonds between indirect restorations and dentin has remained a challenge.[12] Retrospective studies on success rates of $Li_2O_5Si_2$ ceramic restorations from between three to ten years of follow up, showed survival rates (i.e. restorations that had remained in place without complications) of over 95%, with the monolithic crowns having less reported structural problems than layered crowns.[13-16]

Many studies revealed that a significant part of the restoration success depended on the dental luting technique[17] and treatment of the fitting surface.[18-21] Adhesive cements were shown to help improve retention and fracture resistance[22], While the marginal discrepancy was also affected by the luting agent, the fabrication technique, and the ceramic system used.[16,23]

Satisfactory bond union relies on the restoration being close-fitting, but is further aided by surface modification (surface area enlargement), achieved via etching with hydrofluoric acid (HF). This etching creates a surface roughness that aids mechanical interlocking of the luting substance to the treated surface. A further development in the bonding process between the resin cement and the ceramic restoration surface is the chemical bond created by surface silinisation.[24,25]

The microstructure of $Li_2O_5Si_2$ features a wide bimodal grain size distribution with large rod-like crystals epitaxially grown along with the seed and small crystals nucleated from the glass powder. This unique structure has helped improve the fracture toughness and increase its flexural strength.[26] The coexistence of large rod-like crystals and smaller ones formed by the solid-state reaction of crystal and SiO_2 glass has improved its mechanical properties.[27-32] By controlling the in-situ growth phase via the sintering process of lithium disilicate crowns, some grains grow elongated with a high aspect ratio, thus obtaining the bimodal microstructure similar to that of fibre reinforced composites.[33] This distribution plays a role in deflection and bridging cracks to improve the flexure, strength, and adhesive properties.[22,34] However, due to its intrinsic brittleness and low defect tolerance, the fracture toughness of lithium disilicate is still far less than that of zirconia.[10-15]

Etching

Various different etching regimes have been recommended by different manufacturers. These include etching the fitting surfaces of the restorations with micro brush application of either IPS Ceramic Etching Gel acid HF (4%) or VITA Ceramics etch (5%) for 20 seconds. These agents must then be thoroughly rinsed off with water and air dried. The diluted solution is treated with a neutralising powder composed of sodium and calcium carbonate (IPS Neutralizing Powder, Ivoclar Vivadent) for 5 minutes and placed in an ultrasonic bath. Ultradent recommend etching for 30 s with 35% phosphoric acid, followed by rinsing with water and drying for 5 seconds,[35,36]. Ivoclar advise that IPS e.max® CAD and IPS e.max® Press restorations be etched for 20 seconds with 5% HF.[37] However, Shahverdi et al. found that a combination of sandblasting, HF acid treatment and silane application was the most successful regime.[38]

On the other hand, Guilherme stated that treatments with alumina airborne-particle abrasion alone or etching with 95% HF for 30 seconds improved shear bond strength.[39] However, combining alumina airborne-particle abrasion with different HF etching procedures did not improve shear bond strength and HF alone was sufficient.[39]

Dental restorations in which enamel and dentin were prepared using the total-etch method attained bonds of up to 28Mpa in enamel[40] and 13–20Mpa in dentin.[41]

The bonds achieved with etch and rinse systems are stronger and more predictable on enamel surfaces, while those on exposed dentin show reduced fracture resistance.[42-43] Self-etching primers offer a more simplified bonding protocol and are reported to improve bonding to the dentin, as they etch the surface and penetrate it simultaneously.[44,45] Initial studies suggest that the self-etching primers show promise in terms of improving bonding to dentin,[46] However others have noted that the bond strength mediated by the self-etch primer Monobond Etch and Prime (MEP) was lower than that of the functional silane hydrolyzed3-methacryloxypropyl trimethoxy silane (MPTMS) or Mono Bond Plus with HF technique.[47,48]

Silanes

Silanes are a class of organic molecules that contain one or more silicon atoms (3-methacryloxypropyl trimethoxy silane), which act as a wetting agent and help to form covalent chemical bonds at the involved interfaces. Single-bottle silanes that are pre-hydrolysed typically consist of 1% to 5% silane in a water/ethanol solution with added acetic acid to achieve the desired pH of 4 to 5. They perform optimally if left for 5 minutes. Silane hydrolysis creates terminal hydroxyl groups on each silane molecule. These hydroxyl groups react directly with corresponding hydroxyl groups on the surface of feldspathic porcelain through the oxidation of SiO_2. A condensation polymerization reaction creates bonds between the silane and porcelain when the opposing hydroxyl groups interact with one another via hydrogen and covalent bonding.[49] Clinically, the surface of the porcelain should appear matt after silane application and drying. Once the inorganic end of the silane molecule has bonded to the porcelain, the methacrylate group can bond via free radical addition polymerization with methacrylate groups in the resin. Silica coating is not effective, or required, with $Li_2O_5Si_2$ because significant amounts of SiO_2 and free hydroxyl groups are already present.[4,37]

Cementation

Cementation with zinc phosphate provides mechanical retention and relies heavily on the contour of the prepared tooth and close adaptation of the restoration to provide retention. Clinically this mechanical retention is considered less effective than that obtained with bonding systems.[50] Composite resin cement Rely-X Ultimate in combination with Scotch bond Universal adhesive provided equal mean removal stress as for Multilink Automix used with Multilink Primer, with both generating high crown removal of,2.9 to 3.9 MPa. These all exceeded zinc phosphate cement adherence.[16]

Adhesively cemented dental ceramic crowns have a superior breakage resistance compared to traditionally cemented restorations. However this may also be dependent on the thickness of all-ceramic restorations especially in veneers.[51,53] Occlusal veneers with a thickness of 0.6–1.0 mm and 1.2–1.8 mm can resist forces of up to 800 N and 1000 N respectively.[54-56] In a study by Sasse et al.,[52] the fracture resistance of occlusal veneers made of $Li_2O_5Si_2$ was examined and showed that the thickness of the occlusal veneers should not fall below 0.7–1.0 mm.

Self-adhesive resin cements are used to simplify the technique due to their high viscosity and low etching capacity. The bond strength of self-adhesive resin cements is lower than that of resin cements and adhesive systems. To optimise the bond strength between cements and teeth, surface treatment with different conditioning agents have been suggested. Chlorhexidine is widely used as an antibacterial agent and has a broad antimicrobial spectrum. This solution has an inhibitory effect on the activity of MMP on dentin, which can prevent collagen collapse and the corresponding degradation and disintegration of the bond interface.

Lührs et al. and Shafiei and Memarpour verified a decrease in bond strength values of self-adhesive cements over time. When compared to conventional hydrophobic resin cements, water sorption was higher due to the acidic and hydrophilic character of the self-adhesive cements. Rely X U200 has a lower initial pH (<2) which increases its potential for demineralisation and contributes to higher bond strength if compared to Smart Cem 2. Both agents showed lower bond strength compared to conventional resin cements due to four factors: (1) acidic monomers have low etching capacity, minimising the surface demineralisation; (2) the buffering effect of the minerals present in the dentin can neutralise the pH of the cement; (3) the high viscosity of the cement hinders their penetration into the interfibrillar spaces; (4) non-removal or incomplete removal of the smear layer promotes a weakly bonded reinforced resin intermediate layer. The loss of integrity of the resin-dentin interface during function is affected by thermal, mechanical, and chemical actions. These actions are detrimental to the longevity of indirect restorations luted with resin cement.[12]

For luting $Li_2O_5Si_2$ crowns there are three suggested cement-adhesive combinations that may be used (RelyX Ultimate with Scotch Bond Universal, Monobond S, Multilink Automix with Multilink Primer A and B and NX3 Nexus with OptiBond XTR). All showed good retention (2.9-3.9 MPa; 387-522N) after six months. Cements using their matched dentin bonding agent as the ceramic primer were as successful as cements with a separate silane coupling agent, but self-adhesive resin cements such as U100 showed lower bond strength to dentin than RelyX ARC conventional resin cement.[16,64]

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