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Clinical Aspects Of Adhesion Of All Ceramics: An Update

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Abstract

The clinical success of resin bonding procedures for ceramic restorations depends on the quality and durability of the bond between ceramic and the resin.The quality of this bond depends upon the bonding mechanisms that involve surface treatments that promotes micromechanical and chemical bond to the substrate. With the great diversity of the available materials, there is a need for establishing general concepts for bonding all-ceramic restorations.Ceramics differ in nature of their composition of glass-to-crystalline ratio which affects their properties and hence usage for restorations. Also, the cementing techniques and design of the restoration have great influence on the adhesion mechanisms. Thus, there is a need for establishing general concepts for bonding all-ceramic restorations and there are many clinical aspects that are important for success with all-ceramic materials. Recent studies have focused on various new techniques, that involve different bonding strategies to different ceramics, which is essential to achieve a strong and durable bond.

Key Words

ceramic restorations,bonding, adhesion to dentin, inlays and onlays

Introduction

Over the last decade, it has been observed that there is an increasing interest in the ceramic materials in dentistry. Even though the combination of strength and reasonable esthetics has continued to make traditional metal ceramic restorations popular,[1] patient demand for improved esthetics has driven the development of ceramics for use with inlays, onlays, crowns, FPDs and implant supported restorations.[2] Esthetically these materials are preferred alternatives to the traditional materials. The use of conservative ceramic inlay preparations, veneering porceleins is increasing, along with all-ceramic complete crown preparations.[3] It has been observed that typical survival rates for all ceramic restorations range from 88 to 100% after 2-5 years in service.[4],[5],[6] and 84- 97 % after 5-14 years of service.[7],[8]

Bonding is Pre-requisite for clinical success

Achieving strong and reliable bond to all-ceramic restorations is a pre-requisite for long term clinical success of the restoration. It is observed that establishing a good bond to all-ceramic restorations improves their retention, reduces micro-leakages, and enhances the fracture resistance. Various studies have shown that the strength of an all ceramic restoration is dependent on the ceramic material used, core veneer bond strength, design of the restoration, and the bonding techniques.[10] However, the clinical success of resin bonding procedures for ceramic restorations depends on the quality and durability of the bond between ceramic and the resin and, the quality of this bond depends upon the bonding mechanisms that are controlled in part by the surface treatment that promotes micromechanical and chemical bond to the substrate.[11] For a successful bond the surfaces of parts to be bonded should be thoroughly conditioned to obtain a tight junction between the molecules of the bond and the work-pieces. This link must be strong enough to withstand stresses in the bonding agents generated due to polymerization shrinkage. Thus, this review evaluates the factors that influence adhesion of ceramics and thus, lead to clinical success of the restoration.

Challenges in adhesion to dentin

Adhesion to dentin is not as reliable as adhesion to enamel, because of the morphologic, histologic, and compositional differences between the two substrates i.e enamel and dentin. To overcome the challenges in dentin bonding, various advancements have been made in the field of adhesive dentistry.[29],[30] Dentin not only has a more complex histologic structure than enamel, but and composition occur not only with differences in depth, but also from region to region of the tooth. The permeability of occlusal dentin is higher over the pulp horns than at the center of the occlusal surface, proximal dentin is more permeable than occlusal dentin, and coronal dentin is more permeable than root dentin. [31],[32] The mean diameter of dentinal tubules ranges from 2.37 µm at the pulpal side to 0.63 µm at the periphery. Likewise the number of tubules decreases from about 45,000/mm^2 near the pulp to about 20,000/mm^2 near the surface with the average of 30,000 tubules/mm^2 in the middle part of the cut human dentin.[33] Also, the relative area of dentin occupied by tubules decreases towards the DEJ, from about 22-28% of the cross-sectional area near the pulp to only 1-4% near the enamel.[34] Also, the smear layer poses a problem while bonding to dentin. It consists of debris (such as ground enamel and dentin) that is burnished against, and bound to, the dentin surface during instrumentation. Depending on factors such as the type of cutting instrument used, the smear layer is typically just 0.5-5.0µm thick, but occludes the orifices of the dentinal tubules. Although the smear layer acts as a diffusion barrier that decreases dentinal permeability, it also can be considered an obstruction that prevents resin from reaching the underlying dentin substrate.[35]. For the above reasons, it is necessary to differentiate between the kind of restoration whether in enamel or dentin, while choosing resin or conventional cements for adhesion of all ceramic restorations.

Nature of ceramic material and restoration

Ceramics can be classified by their microstructure (amount crystalline phase and glass composition) and processing techniques (powder liquid, pressed or machined).[13] At microstructural level, ceramics are defined by the nature of their composition of glass-to-crystalline ratio.

- Composition Category 1 - Glass based systems (mainly silica)
- Composition Category 2 - Glass based systems (mainly silica) with fillers, usually crystalline (typically leucite or, more recently, lithium di-silicate)
- Composition Category 3 - Crystalline- based systems with glass fillers (mainly alumina)
- Composition Category 4 - Polycrystalline solids (alumina and zirconia)

On the basis of processing techniques ceramics are classified as:
(1) Powder/liquid, glass based systems; (2) Machinable or pressable blocks of glass-based systems; and (3) CAD/CAM or slurry, die-processed, systems. Out of these, the strongest ceramics are aluminum oxide and zirconium oxide ceramics. They are 100% crystalline but also very opaque. Spinel Ceramics can be very translucent to very opaque.

Fabrication of inlays/onlays

Glass-infiltrated, partially sintered alumina was introduced in 1988, and marketed under the name In-Ceram. The system was developed as an alternative to conventional metal-ceramics, and has met with great clinical success.[14],[15],[16] The crystalline phase consists of alumina, alumina/zirconia, or an alumina/magnesia mixture appropriately named “spinell” that is fabricated by a process called slip casting, or it can be milled from a pre-sintered block of either material. The alumina or spinell framework is then infiltrated with a low-viscosity lanthanum glass at high temperature. Extremely high flexural strengths have been reported for this new class of dental ceramic, three to four times greater than any other class of dental ceramic.[17],[18],[19] Several clinical studies have shown that, In-Ceram alumina had the same survival as that of PFMs up to the first molar, with a slightly higher failure rate on the second molar.[20] The alumina/zirconia material should only be used on molars because of its very high opacity, which is not ideal for anterior esthetics. For anterior teeth, the alumina/magnesia version of In-Ceram (called spinell) is ideal because of its higher translucency. More recently, powder-liquid versions were made for the specific veneering of alumina-based core systems, eg, In-Ceram® (Vita Zahnfabrik, distributed by Vident, Brea, CA). These materials have been developed into very fine-grain machinable blocks, such as Vitablocs Mark II (Vident) for use with the CEREC® CAD/CAM system (Sirona Dental Systems, Charlotte, NC). This material is the most clinically successfully documented machinable glass for the fabrication of inlays and onlays, with all studies showing a < 1% per year failure rate, which compares favorably with metal-ceramic survival data, CEREC, and metal-ceramic references.[21]

Fabrication of veneers

Low-to-moderate leucite-containing feldspathic glass are called "feldspathic porcelains" by default. These materials are typical powder-liquid materials that are used to veneer core systems and are also the ideal materials for porcelain veneers. The original materials had a fairly random size and distribution of leucite crystals, with the average particle size being around 20 μm. This random distribution and large particle size contribute to the material's low fracture resistance and abrasive properties relative to enamel. Newer generations of materials(VM 13, Vita) have been developed with much finer leucite crystals and very even particle distribution throughout the glass and are less abrasive and have much higher flexural strengths.[22],[23]

Adhesion for restoration with margins located in the enamel(inlays, partial crowns, veneers).

It is absolutely advisable to use resin cements for bonding when restoration margins are located in the enamel and perfect moisture control with rubber dam is possible. Bonding with enamel results in a compound system with stabilization of the ceramic. That is the reason for high success rate of a veneers and inlays. [36]

Fabrication of anterior crowns

High leucite containing (approximately 50%)glass. The most widely used version is the original IPS Empress®(Ivoclar Vivadent, Amherst, NY) but there are several other products in this category. This material is called a glass ceramic, which has had the crystalline phase grown within the glass matrix by a process called "controlled crystallization of glass." Conventional porcelain has the crystalline leucite added to the glass matrix. Pressable and machinable versions designed for both the CEREC and E4D(D4D Technologies, LLC, Richardson, TX) of high-leucite ceramics have performed excellently clinically. Vitabloc Mark II for the CEREC and pressable and machinable versions of IPS Empress ideally suited for inlay and onlay restorations, anterior crowns and veneers.[24],[25],[26]

Fabrication of full contour restorations

Lithium-di-silicate glass ceramic is a new type of glass ceramic introduced by Ivoclar as IPS Empress® II (now called IPS e.max®), where the alumino-silicate glass has lithium oxide added. This material can be very translucent even with the high crystalline content which is due to the relatively low refractive index of the lithium-di-silicate crystals. Because of its higher strength and fracture toughness, E max has the potential to be used for any type of single restoration anywhere in the mouth. According to the manufacturer, E.max can be conventionally cemented, but because of the glass matrix it can also be etched and bonded.[27]

Fabrication of three - unit bridges

Zirconia has unique physical characteristics that make it twice as strong and twice as tough as alumina-based ceramics.[28] Reported values for flexural strength for this new material range from over 900 MPa to 1,100 MPa. Zirconia materials are supplied by virtually all dental ceramic manufacturers; the most recognizable names are Lava™ (3M ESPE, St. Paul, MN), Vita YZ (Vident/ Vita), and Cercon® (DENTSPLY, York, PA). These materials were designed as a PFM alternative for single crowns and three-unit bridges anywhere in the mouth.

Adhesion for restoration with margins located in the dentin (full crowns and bridges)

In many cases full crowns are made two or three times when the margins of the replaced restorations are located subgingivally and in the dentin: leading to clinical handling problems. Furthermore, sulcus fluid and saliva negatively affect the quality of the bonding surface after pre-conditioning. If the perfect bond between ceramic, dentin and the luting is not guaranteed, there is no guarantee of obtaining a compound system. In case the restorative margin is in dentin, it makes no sense of using a resin cement, because the polymerization shrinkage of composite will lead to gap formation, with its negative consequences of the bacterial invasion.[37],[38]

Selections of cements for adhesion[39]

The cements used for bonding all ceramic restorations fall under three types of resin cements-adhesive, esthetic, and self-adhesive resin cements.

Esthetic Resin Cements

- Self-etch or total-etch bonding agent is needed for bonding to tooth substrates.
- Silane or ceramic primer is needed for all-ceramic restorations.
- Curing mode options can be light or dual-cured.
- Light-cured cement is available for veneers.
- Stronger mechanical properties than self-adhesive resin cement.
- Multiple shades available.
- Most esthetic resin cements provide water soluble try-in pastes.

Adhesive Resin Cements

- Primer is needed for bonding to tooth substrates.
- Silane coupling agent is needed for silica-based ceramics.
- Can bond directly to zirconia without primer.
- Curing mode options-can be light-, dual-, or self-cured.
- Several shades available.
- May release fluoride.

Self-adhesive Resin Cements

- Self-etching-no phosphoric acid or special primer needed for bonding to tooth substrates.
- Can bond directly to zirconia without primer.
- Curing mode options-can be light, dual, or self-cured.
- May release fluoride.
- Usually available in universal, translucent and opaque shades.

Bonding/cementing techniques for ceramics based on their microstructure

Feldspathic Porcelains: These require resin cement bonded to both tooth structure and ceramic. Dual-cured esthetic resin cement with a dual-cured total-etch (etch-and-rinse) bonding agent should be used for thicker or more opaque veneers. Etching of the porcelain should be done with hydrofluoric acid etchant. For bonding to the porcelain, silanating agent or appropriate ceramic primer should be used. Silica-based ceramics (feldspathic porcelain, leucite-reinforced ceramic, lithium disilicate ceramic) should be bonded with adhesive or esthetic resin cements using appropriate bonding agents and primers.

Leucite-reinforced Ceramics: These require resin cement bonded to both tooth structure and ceramic. Dual-cured esthetic resin cement with a dual-cured total-etch (etch-and-rinse) bonding agent can be used for thicker or more opaque veneers. For the tooth, an adhesive resin cement or a dual-cured esthetic resin cement should be used.

Lithium Di-silicate Ceramics: These should be bonded with an esthetic resin or an adhesive resin cement for best retention and esthetics. A dual-cured esthetic resin cement with a dual-cured total-etch (etch-and-rinse) bonding agent should be used for thicker or more opaque veneers. For bonding to tooth structure, use an adhesive resin cement or a dual-cured esthetic resin cement. Lithium di silicate ceramics can be cemented with traditional crown and bridge cements when retention is adequate.

Zirconia-based Ceramics: Zirconia (zirconium oxide)-based ceramics are a rapidly growing type of esthetic restoration. Due to their high strength, they have more indications than other all-ceramic restorative choices. In addition, because of their high strength, zirconia-based ceramic restorations can be cemented with traditional cements or bonded with adhesive resin cements. Self-adhesive resin cements offer less technique sensitivity than traditional cements, making them excellent choices for the cementation of appropriate zirconia based ceramic restorations. When additional retention is required, zirconia-based restorations can be bonded with adhesive resin or dual-cured esthetic resin cements using tooth and ceramic primers.Zirconia-based ceramics with ideal retention can be cemented with traditional crown and bridge cements or bonded with resin cements. Zirconia-based ceramics with less than ideal retention require a resin cement bonded to both tooth structure and ceramic. Use adhesive resin cement, dual-cured esthetic resin cement, or self-adhesive resin cement when bonding is required. Sandblast (Micro Etcher IIA, Danville Materials) the intaglio surface of zirconia using 50 um alumina at 30 psi for increased bond strength. Use zirconia primer on the intaglio surface of zirconia when increased bonding is required. Silanating agents are not compatible with zirconia. Hydrofluoric acid is not compatible with zirconia. manufacturers' instructions for proper bonding of the restoration to tooth structure.

Design of the restoration

The design of the restoration also influences selection of resin cement. When the tooth preparation has adequate cervical-occlusal height: height > 3 mm and adequate taper i.e 2-5 degrees, then cementation with self-adhesive resin is preferred. For teeth with short clinical crown: height < 3 mm and an over-tapered preparation i.e > 5 degrees bonding with adhesive resin cement or esthetic resin cement is recommended.

Conclusion

Adhesive bonding techniques and modern all ceramic systems offer a wide range of highly esthetic treatment option. Ceramics differ in nature of their composition of glass-to-crystalline ratio which affects their properties and hence usage for restorations. Also, the cementing techniques and design of the restoration have great influence on the adhesion mechanisms. With the great diversity of the available materials, there is a need for establishing general concepts for bonding all-ceramic restorations and there are many clinical aspects that are important for success with all-ceramic materials. Thus, we should have significant knowledge and training in these areas for success with all-ceramic materials.

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