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REVIEW ARTICLE

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Adhesive Bonding to Computer-aided Design/Computer-aided Manufacturing Esthetic Dental Materials: An Overview

[1]Mohamed Moustafa Awad, [2]H Alqahtani, [3]A Al-Mudahi, [4]MS Murayshed, [5]A Alrahlah, [6]Shilpa H Bhandi

ABSTRACT

Aim: To review the adhesive bonding to different computer-aided design/computer-aided manufacturing (CAD/CAM) esthetic restorative materials.

Background: The use of CAD/CAM esthetic restorative materials has gained popularity in recent years. Several CAD/CAM esthetic restorative materials are commercially available. Adhesive bonding is a major determinant of success of CAD/CAM restorations.

Review result: An account of the currently available bonding strategies are discussed with their rationale in various CAD/CAM materials.

Conclusion: Different surface treatment methods as well as adhesion promoters can be used to achieve reliable bonding of CAD/CAM restorative materials. Selection of bonding strategy to such material is determined based on its composition. Further evidence is required to evaluate the effect of new surface treatment methods, such as nonthermal atmospheric plasma and self-etching ceramic primer on bonding to different dental ceramics.

Clinical significance: An understanding of the currently available bonding strategies to CA/CAM materials can help the clinician to select the most indicated system for each category of materials.

[1-3]Department of Conservative Dental Sciences, Prince Sattam Bin Abdulaziz University, College of Dentistry, Alkharj, Kingdom of Saudi Arabia

[4]Department of Prosthetic Dental Sciences, Prince Sattam Bin Abdulaziz University, College of Dentistry, Alkharj, Kingdom of Saudi Arabia

[5]Department of Restorative Dental Sciences, College of Dentistry, King Saud University, Riyadh, Kingdom of Saudi Arabia

[6]Department of Restorative Dental Sciences, College of Dentistry, Jazan University, Jazan, Kingdom of Saudi Arabia

Corresponding Author: Mohamed Moustafa Awad, Department of Conservative Dental Sciences, Prince Sattam, Bin Abdulaziz University, College of Dentistry, Alkharj, Kingdom of Saudi Arabia, e-mail: dr.mm.awad@hotmail.com

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INTRODUCTION

The use of dental computer-aided design/computer-aided manufacture (CAD/CAM) restorations has increased remarkably in recent years.[1] In addition to its improved accuracy, cost, and time efficiency, CAD/CAM technology also enables the use of materials that cannot be fabricated using traditional laboratory-based workflows.[2] The CAD/CAM systems are classified into laboratory systems and chairside systems.[3] Ceramics and indirect composite resins are the two main groups of CAD/CAM esthetic restorative materials (Table 1).[4] Most CAD/CAM esthetic materials are presented in blocks; however, few materials are provided as disks (Fig. 1).

Dental ceramics have recently been classified into three main categories: Glass-matrix ceramics, polycrystalline ceramics, and resin-matrix ceramics or hybrid ceramics.[5] Effective adhesive bonding of indirect restorations may minimize microleakage, ensure marginal adaptation, improve fracture strength, and increase clinical success of indirect restorations.[6-8] Adhesive bonding is usually achieved via the use of composite resin cements for luting of indirect restorations. Advantages of resin cements include higher mechanical properties and possibility of adhesion to the restorative material and to the tooth structure.[9-11] Adhesive bonding

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Table 1: Examples of commercially available CAD/CAM esthetic materials

Category	*Material/Manufacturer*
Glass-matrix ceramics	IPS Empress CAD/Ivoclar Vivadent
	IPS e.max CAD/Ivoclar Vivadent
	Celtra Duo/Dentsply
	VITABLOCS® Mark II/ Vita Zahnfabrik
	Paradigm™ C Ceramic Blocks/3M ESPE
	VITA SUPRINITY® PC/ Vita Zahnfabrik
Polycrystalline ceramics	LAVA Frame/3M ESPE
	Ceron/Dentsply
	KATANA Zirconia/Kuraray
	IPS e.max ZirAD/Ivoclar Vivadent
Indirect composites	Lava Ultimate/3M ESPE
	Cerasmart Universal/GC
	Shofu block HC /Shofu
	Paradigm MZ 100 block /3M ESPE
	Katana Avencia/Kuraray
Hybrid ceramic	Vita Enamic/Vita Zahnfabrik

Fig. 1: Computer-aided design/computer-aided manufacturing blocks

of indirect restorations has two aspects: (1) Bonding to tooth structure and (2) bonding of composite resin to restoration.[12] The second aspect may be the weak link in this adhesive procedure.[13] This article provides an overview of bonding strategies of different CAD/CAM esthetic restorative materials.

Bonding to Glass Ceramics

The adhesive cementation procedure for glass-matrix ceramics involves hydrofluoric acid (HF) etching and silanization.[14,15] Hydrofluoric acid is an aqueous solution of hydrogen fluoride.[16] Based on ceramic composition, different HF concentrations and etching durations may be recommended. The HF selectively dissolves the glass components, resulting in an enlarged surface texture and increased surface microirregularities (Fig. 2) for micromechanical retention.[6,16-18] Moreover, HF etching increases surface energy of ceramic and reduces the contact angle for bonding agents.[19]

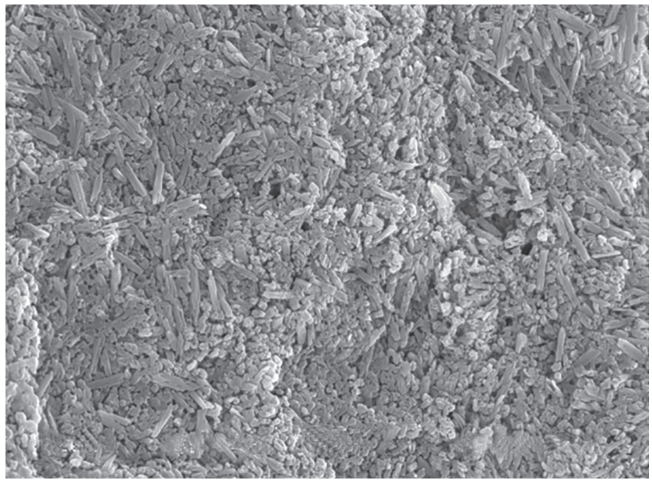

Fig. 2: Scanning electron microscopy (magnification 3000×) showing microirregularities of HF-etched lithium disilicate glass-matrix ceramic. The HF selectively dissolved glass-matrix while lithium disilicate crystals are prominent

Hydrofluoric acid etching is usually followed by application of silane-based primer to promote chemical bonding of resin-based materials to glass-based ceramics.[15,20,21] The most commonly used methacrylate silane monomer is γ-methacryloxypropyltrimethoxysilane.[22] Silane-based primers are mostly water-free solutions.[23] One-bottle and two-bottle silane-based primers exist.[7] Silanes are bifunctional groups that bond to resin by addition polymerization reaction between the methacrylate groups of matrix resin and silane molecules during the curing of the composite resin. In addition, bonding with ceramics occurs via a condensation reaction between a silanol group on the ceramic surface and a silanol group of the hydrolyzed silane molecule.[24] Also, some universal adhesives contain silane in their formulations.[22] Recent studies proved that silane-containing adhesives are not alternatives to silane-based primers.[22,25-28] The acidic nature of universal adhesives may be a result of silane instability, in acidic conditions, such as in the presence of 10-methacryloyloxydecyl dihydrogen phosphate (MDP) and water a self-condensation reaction might occur between the silanol groups of silane.[23]

Recently, novel self-etching ceramic primer that combines effect of HF and silane in one step has been introduced. Self-etching ceramic primer is based on an alcoholic-aqueous solution of ammonium polyfluoride and silane methacrylate.[20] Ammonium polyfluoride produces a rough etching pattern, whereas the thin uniform layer of silane promotes the chemical bond to glass-based ceramics.[20] Self-etching ceramic primer showed good short-term bonding performance to lithium disilicate ceramic.[29]

Bonding to Polycrystalline Ceramics

Yttria-stabilized tetragonal zirconium dioxide polycrystal (Y-TZP; zirconia) may be the most commonly used polycrystalline ceramic.[30] The popularity of zirconia restorations has increased in recent years due to its favorable esthetic and mechanical and biocompatible properties.[31,32] Recent studies suggested that zirconia restorations should be adhesively rather than conventionally cemented.[7,33] Adhesive bonding of zirconia restorations increases its long-term clinical success.[7] The appropriate clinical protocol of using adhesive cementation with zirconia restorations is still controversial; this may be due to the chemical inertia of this material, which may negatively affect the establishment of effective chemical bonding with resin-based materials.[14,34] This controversy has made bonding to zirconia a popular research subject.[35]

Different methods have been suggested to enhance the resin cement's bond strength to zirconia, such as air abrasion with alumina particles to facilitate resin–ceramic bonding by micromechanical means, physicochemical activation of the ceramic surfaces using silica-coated alumina particles followed by silanization, or chemical activation with functional-monomer–containing adhesive promoters or resin cements.[36-43] Other methods also have been investigated, such as selective infiltration etching, erbium-doped yttrium aluminum garnet laser irradiation, CO_2 laser treatment, and fluorination techniques.[44-47]

Air abrasion of zirconia can be performed using Al_2O_3 or silica-coated Al_2O_3 particles.[48] The abrasive particle size should be below 50 μm and the air pressure around 2.5 bars.[33] Air abrasion increases surface roughness, improves micromechanical interlocking, and modifies the surface energy and wettability of the ceramic.[12] However, air-abraded zirconia surfaces should be subjected to ultrasonic cleaning in order to remove loose residues prior to bonding.[39,49]

Primers play an important role in adhesive procedures of indirect restorations.[14] The MDP functional monomer may be the key for chemical bonding to zirconia. The MDP can improve bonding of resin materials to zirconia.[41] The MDP bonds directly to the zirconia surface forming a covalent bond between oxygen, phosphorus, and zirconia.[50,51] Organophosphate monomers contain polymerizable functional groups that can polymerize with the matrix of methacrylate-based resin materials.[50] Air abrasion at a moderate pressure followed by using MDP-containing primers and/or resin cements may ensure long-term durable bonding to zirconia ceramic.[33] Recently, MDP-containing universal adhesive has shown promising results enhancing resin-zirconia bond strength.[12,14]

Plasmas can be defined as partially ionized gases containing highly reactive particles, such as electronically excited atoms, molecules, and free radical species.[50] Based on gas temperature, plasmas can be categorized into two main types: Thermal (high-temperature) and nonthermal (low-temperature or cold) plasmas.[52] Nonthermal plasma surface treatment of Y-TZP resulted in significantly higher bond strength values to the air abrasion and/or phosphate primer.[53] Plasma treatment may remove organic and inorganic contaminants and increase the surface reactivity.[54] The contact angle obtained for the MDP primer dispensed on the Y-TZP surface was reduced to 0 after plasma treatment, indicating that total wetting of the surface was achieved.[55]

Bonding to Indirect Composite Resins

Indirect composite resins have different composition and higher degree of polymerization compared with direct composite resins and thus different bonding steps are indicated.[56] Most composite CAD/CAM blocks are recommended to be sandblasted prior to silanization.[57] However, sandblasting should be performed with reduced pressure to avoid chance for subsurface cracks formation.[56] Also, bonding effectiveness of some composite blocks can also be improved by etching with HF.[13,58]

Bonding to Hybrid Ceramic

Hybrid ceramic material is based on a polymer-infiltrated ceramic network material that consists of a dominant network ceramic reinforced by an acrylic polymer network resin, with both networks fully penetrating one another.[59] In accordance with recent recommendations of the International Academy for Adhesive Dentistry, available *in vitro* studies found HF acid etching in combination with silane to be a superior pretreatment.[1,13,60]

CONCLUSION

Bonding to CAD/CAM restorative materials is a multistep procedure. Selection of bonding strategy to such material is determined based on its composition. Further studies are required to evaluate the effect of new surface treatment methods, such as nonthermal atmospheric plasma and self-etching ceramic primer on bonding to different dental ceramics.

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