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Effect of two-step and one-step surface conditioning of glass ceramic on adhesion strength of orthodontic bracket and effect of thermo-cycling on adhesion strength

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ABSTRACT

Purpose: The adhesion strength of orthodontic brackets bonded to dental glass ceramics was evaluated after ceramic surface was treated with two-step and one-step surface conditioning systems, and subjecting to thermo-cycling.

Materials and method: A total of forty specimens were fabricated from silica based glass ceramic (lithium disilicate) by duplicating the buccal surface of maxillary first premolar. The specimens were randomly assigned to two experimental groups ($n = 20$), group one specimens were treated with two-step surface conditioning system (IPS ceramic etching gel™ and Monobond plus™) and group two specimens were treated with one-step surface conditioning system (Monobond etch and prime™). The surface roughness of the specimens after treatment with two-step and one-step surface conditioning system was measured using non-contact surface profilometer. Ten randomly selected specimens from each group were subjected to thermo-cycling and the remaining ten served as baseline. The shear bond strength of the specimens was measured using universal material testing machine. The adhesive remnant index score was calculated, and the results of surface roughness and bond strength were tabulated and subjected to analysis of variance and *post hoc* tukey's test at a significance level of $p < 0.05$.

Results: The results of the study showed that the specimens treated with two-step conditioning system had higher surface roughness and bond strength than one-step conditioning system. The majority of the specimens treated with both two-step and one-step conditioned specimens showed adhesive failure after subjecting thermo-cycling.

Conclusions: Traditional two-step conditioning provides better bond strength. The clinical importance of the study is that, the silane promoted adhesion significantly reduces on exposure to thermo-cycling.

1. Introduction

The number of young adult patients seeking orthodontic treatment is increasing considerably and, at the same time clinicians come across teeth restored with various restorative materials including metal, metal ceramic and all ceramic restorations (Pannes et al., 2003; Al-Hity et al., 2012; Grewal Bach et al., 2014). Clinician have to follow different surface conditioning protocols to bond brackets to different materials other than natural enamel (Ozcan and Volpato, 2015). In dentistry surface conditioning of the cementing surfaces is an imperative step in bonding two dissimilar materials (Matinlinna and Vallittu, 2007a, 2007b). The bonding between two dissimilar materials such as ceramic to enamel and ceramic to metal is achieved by careful surface conditioning (acid etching and application of silane coupling agent) of cementing surfaces (Abu Alhaija et al., 2010). Currently acid etching and silane application are used to condition the cementing surface. Etching and silane application increases wettability of the cementing surface to luting cements, and also, acid etching increases surface free energy by increasing surface roughness (S_a) (Matinlinna et al., 2006a, 2006b, 2006c).

The natural enamel is etched using 35% phosphoric acid which removes smear layer and exposes dentinal tubules for the penetration of

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adhesive cements (Sofan et al., 2017). Bonding orthodontic brackets to ceramic surface is more challenging, several techniques such as sandblasting, using diamond burs to roughen the surface, laser etching, and tribochemical silica coating have been proposed to roughen the surface in order to increase the adhesion strength (Durgesh et al., 2016a, 2015, 2016b). Acid etching and subsequent application of silane has gained more popularity when bonding brackets to silica based glass ceramic restorations (Ramakrishnaiah et al., 2016). Etching of silica based glass ceramic is done using 5% hydrofluoric acid, this procedure selectively dissolves glassy phase around dispersed crystal phase and makes the surface rough and porous to provide micro-mechanical retention through resin tags and also exposes hydroxyl ions for chemical bonding via subsequently applied silane primer. However, this is not applicable for zirconia ceramic (Ramakrishnaiah et al., 2016; Aboushelib et al., 2009; Addison et al., 2007; Amaral et al., 2011; Ayad et al., 2008).

Silane coupling agents (silanes) are synthetic hybrid inorganic-organic compounds that possess at least one direct –Si-C- bond in their molecular structure. Chemistry of Si with its so called empty *d*-orbitals provide peculiar chemical properties (Matinlinna et al., 2005). On the other hands, silanes are silicon hydrides and silicon esters and their derivatives, used as surface modifying agent for adhesion promotion (dental composite fillers) and surface conditioning agent (a coupling agent for composite to conditioned ceramic and composite surface to silica-coated metals and alloys) (Matinlinna and Lassila, 2010). Silanes are non-hazardous, non-cytotoxic and they exhibit moderate thermal stability. In prosthetic dentistry silane coupling agents are routinely used to increase the surface free energy of silica-coated or silica-containing indirect restorations to luting resin cements (Matinlinna et al., 2005). Generally, silanes used to promote adhesion are organofunctional silanes and silane esters (R-Y-SiX3, where R is a non-hydrolyzable organic group, Y is a linker, and X is a hydrolysable group). Hence silanes are primarily used to bond two dissimilar materials, i.e., capable of unifying organic and inorganic materials (Ramakrishnaiah et al., 2018a). In general, silanes have non-hydrolysable groups (such as methacrylate) and hydrolysable groups (such as ethoxy), which is why they are chemically bifunctional. When reactive silanes are applied over the etched ceramic surface, the hydrolysable alkoxy groups react with exposed hydroxyl groups, and non-hydrolyzable organic groups polymerize with unset resin composite cement to provide durable chemical bond (Matinlinna et al., 2005; Matinlinna and Lassila, 2010; Ramakrishnaiah et al., 2018a). Since durable bond of brackets is a key for successful orthodontic treatment, careful surface conditioning (etching and priming) in the daily clinical practice is considered crucial.

Currently, 3- MPS diluted in ethanol-water solution, ca. 1–2%, pH adjusted to 4–5 with acetic acid is the most commonly used silane coupling agent in dentistry because of the strong bond forming capacity. In the current clinical scenario, the surface conditioning of the ceramic for bonding orthodontic brackets is done in two steps where the surface is first etched with hydrofluoric acid (HF) and then treated with silane (Matinlinna and Vallittu, 2007a, 2007b; Ramakrishnaiah et al., 2016, 2018a). With the introduction of one-step etch and prime system (Monobond Etch and Prime ™) the etchant and silane primer is used together as single step system. Where both the etching and priming procedures can be completed in one-step, reducing both chairside time and patient discomfort. Several studies have reported the effect of etching, duration of etching on bond strength of orthodontic brackets (Ramakrishnaiah et al., 2016; Ayad et al., 2008; Borges et al., 2003; Bottino et al., 2015), But the effect of two-step and one-step conditioning systems on the long-term durability of the lithium disilicate ceramic-orthodontic bracket bond is unknown. It is also reported that, the silane promoted adhesion tends to deteriorate over a period of time on exposure to oral fluids and change in the oral temperature (Arkles, 2011; Heikkinen et al., 2013; Ramakrishnaiah et al., 2018b). Hence the two main objectives of this study were 1. to determine the adhesion strength of the orthodontic brackets bonded to ceramic surface conditioned using two-step and one-step surface conditioning system, and 2. to evaluate the effect of thermo-cycling on silane promoted bond strength.

2. Materials and methods

2.1. Specimen preparation

Forty lithium disilicate glazed glass-ceramic (IPS e-max Ceram™, Ivoclar Vivadent, Schaan, Liechtenstein) facets were fabricated by duplicating the buccal surface of a maxillary first premolar. The samples were mounted on an auto-polymerizing acrylic resin such that the cementing surface was placed above the level of acrylic resin base, care was taken to keep the cementing surface clean. The specimens were randomly assigned to two equal study groups: group 1 and group 2 having 20 samples each

Group 1: the cementing surface was conditioned with two-step conditioning system: the surface was etched with 5% HF for 20 s (IPS Ceramic etching gel™, Ivoclar Vivadent, Schaan, Liechtenstein) as recommended by the manufacturer, rinsed thoroughly with water for 30 s to remove acid remnants. After etching, the etched surface was neutralized with neutralizing agent to neutralize the pH of the etched ceramic surface and to arrest the further topographical changes due to acid action by the acid remnants present in the pores (Ramakrishnaiah et al.,). The surface was neutralized for 60 s (IPS Ceramic Neutralizing Powder™, Ivoclar Vivadent, Schaan, Liechtenstein), rinsed with water for 30 s and finally dried. The etched surface was treated with silane coupling agent (Monobond Plus™, Ivoclar-Vivadent, Schaan, Liechtenstein).

Group 2: the cementing surface was conditioned with one-step conditioning system: the one-step etch and prime liquid (Monobond™ Etch and Prime Ivoclar-Vivadent, Schaan, Liechtenstein), was applied on the cementing surface and agitated into the surface for 20 s with application tips with low pressure, allowed to react for 40 s and excess liquid was washed with copious amount of water until the green color of etch and prime liquid had been removed and later dried with water and oil free air.

2.2. Surface roughness (S_a) analysis

The S_a of group 1 and group 2 samples was measured using computer controlled non-contact surface profilometer (Bruker Contour GT, Tucson, AZ, USA). The surface topographical parameters of each sample were measured using automatically controlled nano lens AFM module as described by the author in previous study (Ramakrishnaiah et al., 2016). Three randomly selected areas were scanned and the mean of three readings were taken as final S_a of the respective specimen. The images were captured at 3 × magnification using integrated "Vision64" software (Bruker Corporation, Billerica, MA, USA).

The light cured composite resin (Transbond XT™, 3M Unitek, Monrovia, CA, USA) was applied onto the standard premolar brackets (TP orthodontics, Inc. Indiana, USA), accurately positioned and pressed firmly. The excess resin from the margins was carefully removed with the plastic instrument and light cured for 20 s using a light curing unit (Elipar™ Free Light 2, 3M ESPE, Seefeld, Germany) with the wavelength of 420–540 nm and the blue light output power of 1505 mW/cm^2 (MARC™ system, Blue Light Analytics, Halifax, Canada) as described by author in previous study (Ramakrishnaiah et al., 2018a).

Ten samples from each group were tested for shear bond strength without subjecting to thermo-cycling and remaining ten samples shear bond strength was determined after subjecting to thermo-cycling ($n = 10$). During thermo-cycling the specimens were subjected to 5000 cycles in water at 5–50 °C with a dwelling time of 30 s and transfer time of 10 s (Huber 1100, SD Mechatronik, Feldkirchen, Westerham, Germany).