Original article

Effect of Different Composite Placement Molds on Resin-Enamel/Dentin Shear Bond Strength

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ABSTRACT

Background: Different types of molds are being used to place resin composite and build composite buildup in shear bond strength test. However, a little information is available in the literature regarding their effects on resin-enamel/dentin bond strengths.

Aims: The aim of the present study was to investigate the effect of different composite placement molds on shear bond strength (SBS) of composite resin bonded to enamel and dentin.

Methods & Material: Three different composite placement molds (silicone mold, one-piece fixed plexiglass mold, two-piece removable plexiglass) and two substrates (enamel and dentin) were used in this study. Composite resins were bonded to enamel and dentin surfaces with using one of the tested placement molds (n=20) and SBS tests were performed using universal testing machine.

Results: The findings showed that bond strength was not influenced by different composite placement molds (p=0.147), but influenced by bonding substrate (p=0.000).More cohesive failures in enamel were evident with one-piece fixed mold. It can be concluded that composite placement molds have no effect on resin-enamel and dentin bond strengths, but it affects failure mode distributions in resin-enamel bonding.

Key Words: Shear bond strength, enamel, dentin, composite, mold

INTRODUCTION

Adhesive dentistry has gained increased attention in recent decades due to being less invasive in nature and providing good esthetic potential [1]. However, the long-term clinical success of adhesive restorations rely on mainly on bonding effectiveness of adhesive systems to dental substrates, and one of the key factors for assessment the bonding effectiveness of current adhesive system is bonding strength [2].

Conventional shear strength test is still widely used to assess bond strength to dental substrates, in spite of the increased popularity of the “micro” bond strength tests. This means that many of the available data on dental adhesion still comes from conventional shear bond strength test. The preference for conventional shear test is justified because it is easy to perform, requiring minimal equipment and specimen preparation [3, 4].

Moreover, it is difficult to obtain accurate and reliable data as a result of the use of numerous test methods and parameters [5, 6]. For instance, some factors influence shear bond strength results, such as the cross-head speed [7], differences in surface areas [8], loading type [9], chisel width [10], and the direction of shear force [11]. Therefore, a precise and reliable in-vitro assessment method is crucial for achieving effective clinical application of adhesive systems, and just as important differences in test methods should be determined and standardized for consistency.

Another aspect that has been overlooked is the composite placement molds that help to operator to place composite material in proper dimensions on the prepared surfaces. Molds should be used to define bonded surface area in shear bond strength test[12]. So that, different mold designs have been used in the literature, such as elastic silicone molds [13, 14], two-piece removal rigid molds [15, 16], and one-piece fixed rigid molds [17, 18]. However, to the best knowledge of us, there is a limited knowledge regarding to effect of different composite placement molds on resin-enamel and resin-dentin bond strength in the literature. Therefore, the null hypothesis that different composite placement molds don’t affect resin-enamel/dentin bond strength was tested in the present study.

MATERIALS AND METHODS

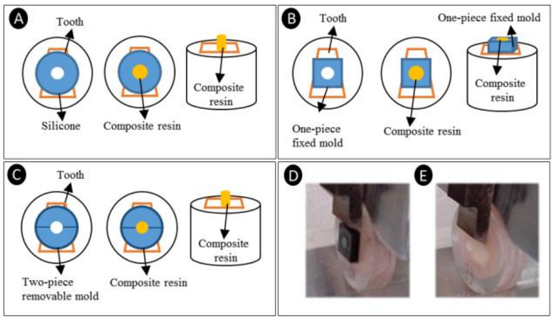
Specimen preparation

One hundred and twenty bovine incisors with no visible defects in enamel were used in the present study. Teeth were stored in dry condition until needed and immersed into distilled water for 2 weeks before being used [19]. Roots were severed by low speed diamond saw under water-cooling. Teeth were randomly divided into two groups i.e. enamel and dentin groups. For enamel groups, enamel surfaces were primarily flattened by using 320-grit silicone carbide (SiC) abrasive papers by hand. For dentin groups, dentin surfaces were exposed by using 320-grit SiC papers by hand. Then, all crowns were embedded into self-cure acrylic resin in plexiglass cylinders individually in order to allow for standardized and secure placement during shear bond strength test. Enamel and dentin surfaces were finished with polishing machine (Buehler Metaserv, LakeBluff, IL, USA) using 600-grit SiC abrasive papers.

Bonding procedures

The enamel and dentin surfaces were acid-etched with 35% phosphoric acid (30 s for enamel, 15 s for dentin, respectively), washed and gently dried according to the manufacturer's instructions. The adhesive system Single Bond (3M ESPE, St Paul, MN,USA) was applied on the etched enamel and dentin surfaces using a micro brush and polymerized with LED curing unit (3M ESPE Elipar S10, 3M ESPE, Seefeld, Germany) at 1000 mW/cm^2 for 10 s. Following adhesive procedures, enamel and dentin groups randomly assigned to three subgroups according to different composite placement molds as following (*n*=20):

Fig. 1: Three different composite placement molds and the shear bond strength test apparatus. (A) The method of placing composite resin on bonding substrate using elastic silicone mold. (B) The method of placing composite resin on bonding substrate using one-piece fixed plexiglass mold. (C) The method of placing composite resin on bonding substrate using two-piece removable plexiglass mold.(D) A bonded sample of shear bond strength testing from one-piece fixed mold group.(E) A bonded sample of shear bond strength testing from silicone mold and two-piece removal mold groups



Silicone mold group: A cylindrical-shaped composite buildup placed with two 2-mm thick layers of a micro hybrid resin composite (Valux Plus, 3M ESPE, St Paul, MN, USA) using a silicone mold (3 mm-diameter and 4-mm height) (Figure 1A). Silicone mold was removed after polymerization of the last layer. Each composite increment was cured for 10 s using LED curing unit at 1000 mW/cm^2.

*One-piece fixed plexiglass mold group:*A cylindrical-shaped composite buildup placed with two 2-mm thick layers of a micro hybrid resin composite using a one-piece plexiglass mold (3 mm-diameter and 4-mm height) (Figure 1B). Plexiglass mold was not removed after the polymerization of the last layer (Figure 1D). This method was called as chisel-on-iris in the literature [20].

Two-piece removable plexiglass mold group: A cylindrical-shaped composite buildup placed with two 2-mm thick layers of a micro hybrid resin composite using a two-piece plexiglass mold (3 mm-diameter and 4-mm height) (Figure 1C). Two-piece plexiglass mold was removed after the polymerization of the last layer (Figure 1E).

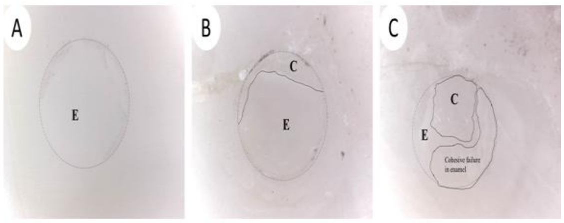
Shear bond strength test

The bonded teeth were stored in the water for 24 h at 37^{o}C before bond strength testing. Specimens were loaded in shear mode until fracture happened with the use of universal testing machine (Instron 3220, Instron Corporation, Canton, MA) at crosshead speed of 1.0 mm/min using knife-edged chisel. The direction of the applied load was from the cervical to the incisal of the tooth. The shear bond strength (in MPa) was calculated bydividing the maximum load by the cross-sectional area of thebonded surface.

Analysis of failure mode distributions

Following the SBS tests, all of the failure specimens were observed with generic video microscope at 10x to determine the failure modes. Failure modes were divided into adhesive, cohesive and mixed failure (Figure 2).

Fig. 2: Presentative images from stereomicroscope of failure modes of shear bond strength test. E: enamel, C: composite. (A) adhesive failure. (B) mixed failure. (C) cohesive failure



SEM Analysis

One sample in each group was randomly chosen for scanning electron microscope (SEM) evaluation. Following drying in desiccator for 24-h, samples were gold sputter-coated, then fixed on metal stubs and observed under a field emission SEM (Zeiss Evo LS10, Bruker, Bremen, Germany)equipped with an SE (secondary electron) detector.

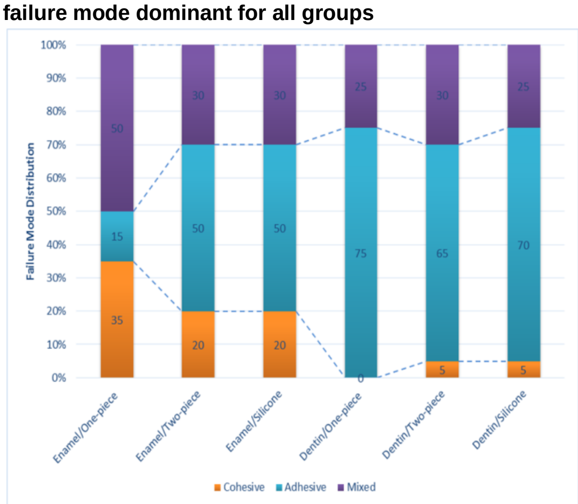
Statistical analysis

A two-way analysis of variations (ANOVA) was conducted to determine the effect of the composite placement mold, bonding substrate and the interaction of these two factors on the bond strength. In order to compare the bond strength of different molds, one-way ANOVA tests were used. Tukey HSD test was used for pairwise comparisons. All tests were done using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) at a significance of 0.05.

RESULTS

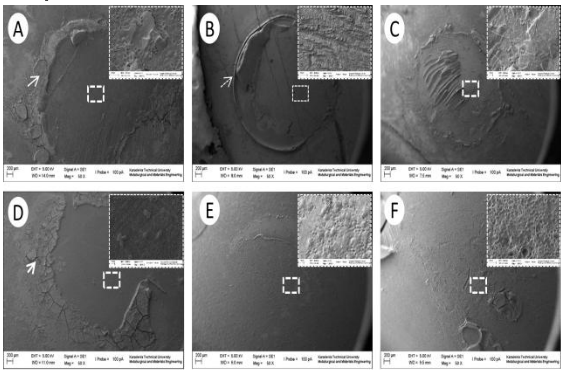
The mean shear bond strength means and standard deviations on enamel and dentin were shown in Tables 1. Two-way ANOVA revealed that significant differences for substrate (p=0.000), whereas showed no differences for mold (p=0.147) and interaction between factors (p=0.635). Results indicated that bonding to enamel provided higher bond strength than bonding to dentin, independent of the composite placement mold.

Fig. 3: The failure mode distribution of the shear bond strength test. The group with mono-block composite placement mold express higher cohesive failures among enamel groups. However, incidences of adhesive failures were higher for two-piece mold and silicone mold enamel groups. For dentin, adhesive failure mode dominant for all groups



Incidences of cohesive failure occurred with the use of one-piece fixed mold was higher than those of other molds for enamel. However, adhesive failure mode was dominant for dentin bonding regardless the composite placement mold the used (Figure 3). SEM evaluation revealed that composite flashes had occurred outwards to bonding area for enamel and dentin more than those seen in other groups (Fig 4 A,D). In the one-piece fixed mold group, no such composite flashes were evident.

Fig. 4: SEM micrographs of the failure interfaces of shear bond strength test of different composite placement mold groups (50x). (A) Silicone mold-enamel, (B) one-piece fixed plexiglass mold-enamel, (C) two-piece removal mold-enamel, (D) Silicone mold-dentin, (E), one-piece fixed plexiglass mold-dentin, (F) two-piece removal mold-dentin



DISCUSSION

The null hypothesis that different composite placement molds don't affect resin-enamel/dentin bond strength was tested in the present study was failed to be rejected since; there was no significant differences among test groups for both of enamel and dentin.

It is accepted generally that in-vivo studies are imperative for assessment of performances of adhesive systems in the oral environment [21]. However, due to the fast change and introduction of adhesive systems on the market, it has become needed to find quick methods for assessing their efficiency, as clinical trials are time consuming and too expensive [4,22].Consequently, in vitro bond strength tests have been developed, the most common being the shear bond strength test [4].

The shear bond strength test is defined as a test in which an adhesive agent connects two different materials and forced in shear plane until failure happens; the bond strength is calculated by dividing the maximum applied load by the bonding area. Shear bond strength test is comparatively easy to perform, permitting quick results to be achieved [4]. But some critical issues must be noted in using this test to expect the clinical performance of resin adhesive systems. First, data from in-vitro tests may not be generalized directly to clinical conditions as, together with other evaluations, it is important in expecting the performance of the materials tested.

Second, the important differences in shear bond strength test findings have made the test doubtful [16, 23].

An effort is a necessity consequently be complete to homogenize shear bond strength test methods to improve the effectiveness of this in vitro test [16]. Some significant issues should be taken into consideration, such as storage conditions, dentinal depth-specimen preparation, cross-head speed, thermal cycling, and cross-section area [6]. Studies have been made to evaluate each one of these.

Another aspect that has been overlooked may be the composite placement molds. It seems that different molds setups have been used in the literature. Therefore, this study tested the influence of different composite placement molds on shear bond strength of resin adhesive to enamel and dentin. Our findings indicate that enamel and dentin bond strengths did not depend on the molds tested.

The results clearly demonstrate that the etch-and-rinse adhesive used in this study produce high bond strength to enamel than dentin, regardless the type of the composite placement mold. These results are in accordance with those of previous studies [24, 25]. Bonding to enamel with etch-and-rinse approach is a reliable method to obtain high bond strength, whereas bonding to dentin with etch-and-rinse adhesives remains challenging due to high technique sensitivity of etch-and-rinse approach and complex structure of dentin tissue [25].

It is critical that an analysis of failure modes be performed to assess if the failure happened at the adhesive interface [26]. Therefore, failure mode distributions were analyzed in the present study. The results showed that 35% of cohesive failure occurred in one-piece fixed mold for enamel. In other molds groups, this percentage was only 20%. However, within dentin groups, where bond strengths were significantly lower than those of enamel, adhesive failure modes were dominant in all mold groups. Although the correlation between shear bond strength means and failure modes was not statistically assessed, the data obtained suggest that one-piece fixed mold when used for enamel bonding which provides high bond strength lower adhesive failure rate. This could mean, the use of one-piece fixed mold might yield the poorer sensitivity of the shear bond strength test in determining bond strength of adhesive interface between resin composite and enamel.

Scanning electron microscope evolution of debonded specimens revealed that extensive composite flashes around composite cylinder in the silicone mold group (Figure 4A,D). This indicates that elastic silicone mold may not demarcate bonding are very well. However, shear bond strength mean of this group was not significantly different from means of other molds. SEM images of one-piece fixed mold group, well-defined distinctive bonded areas were evident. However, thin composite remnants were seen along with bonded area borders (Figure 4B). This may indicate that stress distribution might not very well with this mold.

One-piece fixed composite placement mold tested in this study was called as chisel-on-iris mold in the literature [27]. Previously, it was suggested that this method might reduce the cohesive dentin failure in shear bond test [27]. Similarly, we found no cohesive dentin failure in this study.

Placing resin composite into mold during shear bond strength specimen preparation could be challenging for operators in order to reduce internal flaws and composite flashes. Our study suggested that operators could use any composite placement mold tested in this study as resin- enamel and resin-dentin bond strengths did not depended on different composite placement molds. However, it should be noted that one-piece fixed mold might yield more cohesive failure in enamel when compared to other molds.

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