Comparison of Microshear Bond Strength between Hydrophilic and Hydrophobic Pit and Fissure Sealant

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Abstract

Pit and fissure sealants are effective in preventing dental caries. The stronger it can bond to the enamel surface, the greater is its longevity. There is a scarcity of evidence on the bonding ability of a newly introduced hydrophilic sealant which rationalizes the need for the present study. The study aimed to compare the microshear bond strength of a hydrophilic sealant (UltraSeal XT™ hydro™) with that of a conventional hydrophobic sealant (Clinpro™) and to evaluate their modes of failure. Fourty-eight enamel slices were obtained from buccal and lingual surfaces of sound extracted premolars and polished flat. Each specimen was randomly assigned into two groups: Group A (Clinpro™) and Group B (UltraSeal XT™ hydro™). Test surfaces for Group A and Group B were prepared according to the manufacturer's instructions. After a thermocyling of 5,000 cycles, the bonded specimens were stressed in a Universal Testing Machine with a shear load 0.5mm/min until failure occurred. The difference in mean microshear bond strength between two groups was analyzed using independent sample t-test with a significant level of 0.05. The mean bond strength values for group A and Group B were 13.62 ± 2.57 MPa and 16.54 ± 2.56 MPa respectively. Group B presented with a significantly higher bond strength than Group A (p-value <0.001). The mode of failure of all Group B specimens and two-thirds of Group A specimens were mixed failure. Hydrophilic sealant had a superior bond strength than the hydrophobic sealant when the surfaces were prepared according to the manufacturer's guide.

Keywords: *Fissure Sealants, Hydrophilic Sealant, Hydrophobic Sealant, Microshear Bond Strength, Universal Testing Machine*

1. Introduction

Pit and fissures have a complex morphology that makes them prone to dental caries. They are difficult to clean through routine toothbrushing as an average toothbrush bristle cannot enter the bottom of the fissures efficiently. Besides that, the lack of salivary access down to the fissure system minimizes them from achieving the benefits of fluoride and remineralization (Bromo, Guida, Santoro, Peciarolo, & Eramo, 2011). This favors accumulation of food debris and shift in the ecological system of the bacterial biofilm leading to a net mineral loss of dental hard tissues and formation of dental caries (Conrads & About, 2018). Therefore, pit and fissure sealants have been recommended for both primary and permanent molars in preventing carious lesion. They serve as a physical barrier between the cariogenic bacteria and the occlusal fissure system (Ahovuo-Saloranta et al., 2017; Wright et al., 2016).

In modern dentistry, conventional resin-based sealant materials used in conjunction with an acid etching procedure are regarded as the gold standard, having demonstrated acceptable long-term retention rates (Kühnisch et al., 2020). The prerequisites for placement of these sealants are optimum isolation from moisture contamination, appropriate cleaning of the tooth surfaces, etching and application of a thin bonding layer for maximum benefit (Naaman, El-Housseiny, & Alamoudi, 2017). They are highly sensitive technique in presence of moisture. This is due to the presence of a viscous resin called Bisphenol A glycidyl methacrylate (BIS-GMA) in their chemical composition which gives them the hydrophobic characteristic. It is difficult to achieve a complete dry etched enamel in situations such as partially erupted molars with soft tissue impingement, a field setting with inadequate isolation and patients lacking in cooperative behavior. So their use is limited in these clinical cases (Bhat, Konde, Raj, & Kumar, 2013).

In order to address this issue, there has been advancement in the formulation of traditional resin-based sealant by altering their hydrophobic resin chemistry into a hydrophilic one. Manufacturers have incorporated di-, tri, and multi-functional acidic acrylate monomers in a proprietary formulation with a carefully designed hydrophilic-hydrophobic balance and are marketed as hydrophilic resin-based sealants. They are believed to have a moisture tolerant ability and overcome challenges where complete isolation is difficult to achieve. According to the systematic reviews, hydrophilic sealants were found to be as effective as traditional hydrophobic sealants. However, there were few available studies and the vast majority of them utilized a single brand of sealant, namely Embrace Wetbond™ (Alsabek, Al-Hakeem, Alagha, & Comisi, 2021; Priscilla, Prathima, Mohandoss, & Kavitha, 2022). Therefore, additional research should be done to demonstrate the effectiveness of other brands of hydrophilic sealant.

UltraSeal XT™ hydro™ sealant is one such brand of hydrophilic sealant that has been recently introduced to the Thai market. The primary outcome of sealant's success is evaluated by how well it can retain to the pit and fissures. In laboratory, the retentive ability can be evaluated by bond strength testing. The stronger it can adhere to the enamel surface, the greater is its longevity. Jayashri et al. reported the first study on shear bond strength of UltraSeal XT™ hydro™ sealant and attained a higher shear strength than hydrophobic sealant when placed in dry enamel surface condition (Jayashri Prabakar, John, Arumugham, Kumar.R, & Srisakthi, 2018). There is a scarcity of evidence on the bond strength property of this hydrophilic sealant. More research is required to determine the material's strength especially when placed in moist surface condition to assess the material's tolerance to moisture. The null hypothesis was that there is no difference in microshearbond strength between the hydrophilic (UltraSeal XT™ hydro™ sealant) and hydrophobic (Clinpro™) sealant.

2. Objective

The objective of the present study was to compare the microshear bond strength of a hydrophilic sealant (UltraSeal XT™ hydro™) with that of a conventional hydrophobic sealant (Clinpro™) and evaluate their modes of failure.

3. Materials and Methods

The study protocol was approved by the Ethical Institutional Review Board of Mahidol University. This study employed 24 soundly extracted human premolars that were removed for orthodontic purposes and preserved in 0.1% thymol solution for no more than six months. The teeth were cleaned with an ultrasonic scaler to remove the periodontal ligament and washed with running water to eliminate any storage solution residue. The roots of each tooth were separated from the crown approximately 2 mm below the cemento-enamel junction, and the crowns were sectioned longitudinally in a mesio-distal direction to obtain buccal and lingual enamel slices of approximately 1 mm thickness using a low-speed precision sectioning saw (IsoMet; Buehler, Lake Bluff, IL, USA) with water irrigation. Therefore, 48 enamel slices were tested for assessing the microshear bonding strength.

The enamel surfaces were hand-polished using #600, #800, and #1000 silicon carbide abrasive paper to obtain a standardized flat surface for testing, and then cleaned for 5 minutes in an ultrasonic cleaner (SonorexDigitec, Bandelin electronic GmbH & Co. KG, Germany). The 48 enamel slices were randomly divided into two groups. Group A was Clinpro™, hydrophobic sealant group and Group B was UltraSeal XT™ hydro™, hydrophilic sealant group (Table 1). Prior to etching, each specimen was rinsed and air-dried for 10 seconds to eliminate excess water and prevent any variation in phosphoric acid concentration. The enamel surfaces of both groups were prepared as follows:

Group A (Clinpro™, hydrophobic sealant): enamel surfaces were etched with 35% phosphoric acid gel (Scotchbond™ Etchant; 3M ESPE) for 30 seconds, washed for 15 seconds and completely air dried for 10 seconds using a three-way syringe.

Group B (UltraSeal XT™ hydro™, hydrophilic sealant): enamel surfaces were etched with 35% phosphoric acid gel (Scotchbond™ Etchant; 3M ESPE) for 30 seconds, washed for 15 seconds and excess water was removed by a small, sterilized cotton pellet for 5 seconds to achieve a slight moist enamel surface condition (Bhat et al., 2013; Ku, Lee, & Ra, 2017).

Microbore tygon tubing (Saint Gobain Fluid Transfer TygonS3 E-3603 Transparent Process Tubing, Saint Gobain Performance Plastics, Akron, OH, USA) with an internal diameter of 0.8 mm was cut into small cylinders of 1 mm heights (Figure 1). They were seated on enamel surface to restrict the bonding area. Sealants were injected into the tube based on their respective groups and light cured for 10 seconds at an intensity of 1,200mW/cm^2 (BluphaseN,IvoclarVivadent). The tygon tubes were carefully removed and checked for any interfacial gap formation or bubble inclusion at the bonded area under an optical microscope (10x). Any visible defected specimen was excluded and replaced by new ones. All specimens were then stored in distilled water at 37°C for 24 hours followed by thermocycling for 5,000 cycles between 5 and 55 °C with a dwell time of 30 seconds and transfer time of 5 seconds. Each bonded specimen was mounted on the Universal Testing Machine (Lloyd instruments LFPlusSeries;SteyningWay,Bognor Regis, UK)(Figure 2) and stressed with a shear load parallel to the bonded interface by an orthodontic ligature wire (0.2 mm diameter) (Figure 3) at a crosshead speed of 0.5 mm/min until failure occurred. The bond strength values were automatically computed in MegaPascals (MPa) by dividing the load at failure (N) by the sealant surface area (mm^2) in the NEXYGEN Plus 3.0 software.

Half of the samples were selected randomly for analyzing the modes of failure under scanning electron microscope at 90x and 500x magnifications. The failure modes were evaluated and classified as one of the three types: Type 1: adhesive failure (failure exclusively at the adhesive interface), Type 2: cohesive failure (failure exclusively within the material) and Type 3: Mixed failure (both adhesive and cohesive failures presented).

The data for microshear bond strength were obtained as mean and standard deviation (SD) and its normality was checked by Shapiro Wilk test. Independent sample t-test was used to compare the microshear bond strength between the two groups of sealants. Statistical analysis was performed with IBM® SPSS® Statistics Version 26 for Windows with a significance level set at P≤0.05.

Table 1 Materials used in this study

Material	Type	Composition	Batch no.	Manufacturer
Group A (Clinpro™)	Unfilled resin based sealant	Triethylene glycol dimethacrylate, BISGMA, tetrabutylammonium tetrafluoroborate, dichloride methylsilane, silica, dye	NE30914	3M ESPE
Group B (UltraSealXT™ hydro™)	53% filled resin based sealant	Triethyleneglycoldimethacrylate, diurethanedimethacrylate (DUDMA), aluminum oxide, methacrylic acid, titanium dioxide, sodium monofluorophosphate	BL1BF	Ultradent
Scotchbond™ Etchant	etchant	35% phosphoric acid	NC66384	3M ESPE

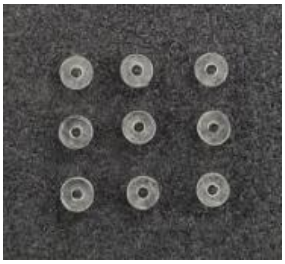

Figure 1 Tygon tube (0.8mm internal diameter and 1mm height)

Figure 2 Universal Testing Machine

Figure 3 Shear force produced by orthodontic wire around the bonded specimen.

4. Results and Discussion

4.1 Results

There were 24 specimens in each group for bond strength testing. The distribution of bond strength values was normal as analyzed by Shapiro Wilk test. The mean values and standard deviations for Group A (Clinpro^{TM}) and Group B (UltraSeal XT^{TM} hydro^{TM}) were 13.62 ± 2.57 MPa and 16.54 ± 2.56 MPa respectively. The mean bond strength of Group B was significantly higher than Group A ($p < 0.001$) (Table 2). The modes of failure were presented in table 3. One third of specimens in Group A showed adhesive failure (Figure 4) and the remaining specimens in Group A showed mixed failure (Figure 5). All observed specimens in Group B showed mixed failure (Figure 6). No cohesive failures were found in any groups.

Table 2 Mean difference in microshear bond strength between the two groups

Groups	**Mean**	**Standard Deviation**	**p-value**
Group A	13.62	± 2.57	<0.001
Group B	16.54	± 2.56	

Table 3 Modes of failure of samples

Groups	Adhesive failure	Cohesive failure	Mixed failure	Total
Group A n (%)	4 (33.3%)	0	8(66.7%)	12 (100%)
Group B n (%)	0	0	12 (100%)	12 (100%)

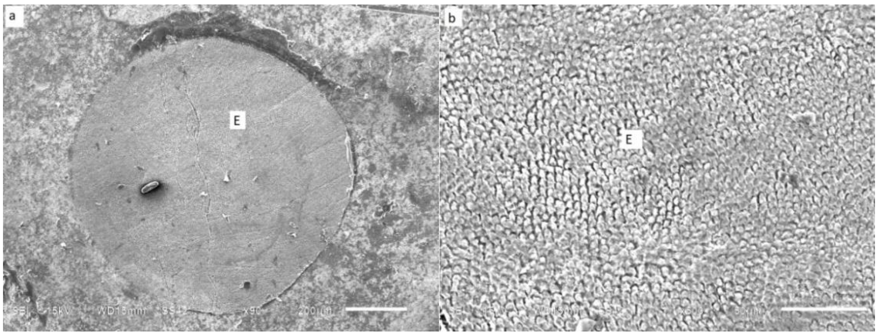

Figure 4 SEM photomicrography illustrating an adhesive failure for Clinpro™ at 90x (a) and 500x (b) magnifications; (E-etched enamel surface)

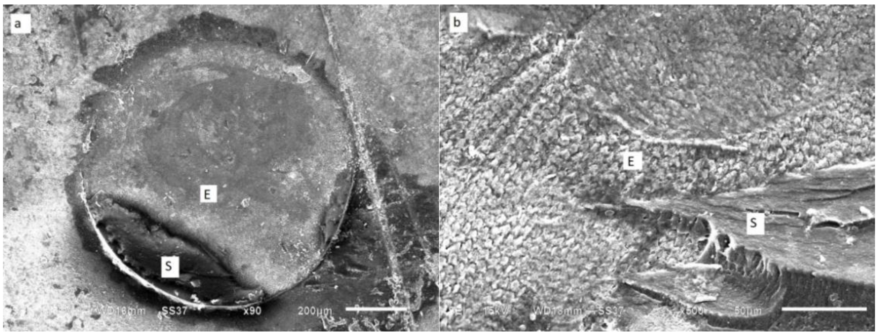

Figure 5 SEM photomicrography illustrating mixed failure for Clinpro™ at 90x (a) and 500x (b) magnifications; (E-etched enamel surface; S-sealant)

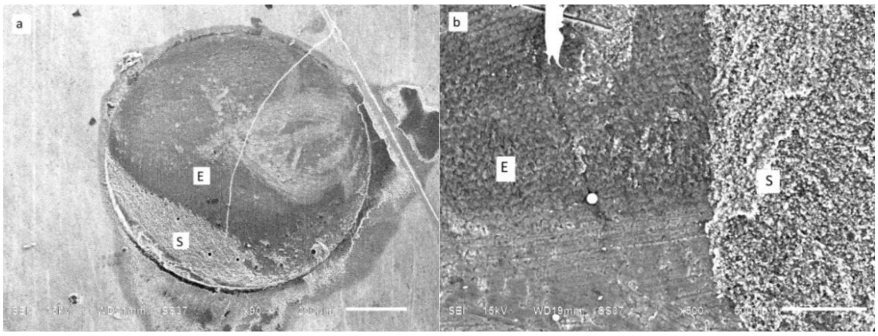

Figure 6 SEM photomicrography illustrating mixed failure for UltraSeal XT™hydro™ sealantat 90x (a) and 500x (b) magnifications;(E-etched enamel surface; S-sealant)

4.2 Discussion

The bonding mechanism of resin-based pit and fissure sealants is micromechanical retention, where resin monomers infiltrate the microporosities created by the etching procedure (Welbury, Raadal, & Lygidakis, 2004). Shear bond strength tests have been commonly used to test the bonding ability of dental adhesives due to its simplicity. However, its limitation is related to more cohesive failures and delimitation of bonding area which have been criticized in the literature. In this regard, the microshear bond strength test has been developed, which requires a test area smaller than 1 mm^2. This allows a lower probability of critical size defect and a more uniform stress distribution (Sirisha, Rambabu, Ravishankar, & Ravikumar, 2014). Microshear bond strength test has also been considered more accurate in differentiating among adhesives, less laborious, and less susceptible to pretest failures than microtensile bond strength test (El Zohairy, Saber, Abdalla, & Feilzer, 2010). Owing to its advantages, microshear bond strength test was employed in this study. To our knowledge this was the first study on microshear bond strength of hydrophilic resin-based sealant.

Clinpro™ sealant was taken as a control in the present study. It is an unfilled traditional Bis-GMA based sealant and hydrophobic in nature. It has a color changing property which gives an advantage of recognizing the sealed surfaces. According to a systematic review, a resin-based sealant with the properties of light polymerizing, unfilled, and opaque was considered a suitable choice among other traditional sealants (Naaman et al., 2017). The unfilled hydrophobic sealants are preferred over filled sealants because they have a lower viscosity that provide greater penetration into fissures and better retention (Reddy et al., 2015). Furthermore, a low viscosity sealant was found to penetrate fully and form a resin-infiltrated layer in enamel beyond the etched depth (Irinoda et al., 2000). Our bond strength value for Clinpro™ (13.62±2.57 MPa) stands in line with that of studies reported by Rirattanapong et al, Bao et al and Prabakar et al with bond strengths of 12.42 ± 2.95 MPa, 12.79 ± 2.13 MPa and 13.71±0.94 MPa respectively (Bao, Sun, Fan, Wang, & Wang, 2022; Jayashri Prabakar et al., 2018; Rirattanapong, Vongsavan, & Surarit, 2011). Hence the control taken in this study may be considered as the standard.

UltraSeal XT™ hydro™ sealant is an acrylate-based resin sealant containing 53% filler. Di, tri, and multifunctional acrylate monomers have been incorporated into their chemical composition with advanced moisture-activated acid-integrating chemistry which make them hydrophilic in nature (Priscilla et al., 2022). It is said to have a thixotropic characteristic that chases moisture deep into pit and fissures on a microscopic level. On the bright side, hydrophilic sealant, despite being highly filled exhibited a lower viscosity and formed resin tag of sufficient length than unfilled hydrophobic sealant (J. Prabakar, John, Arumugham, Kumar, & Sakthi, 2018).

The result of our study showed that UltraSeal XT™ hydro™ sealant had a statistically significant higher mean microshear bond strength value than Clinpro™ sealant. Therefore, the null hypothesis was rejected. This study was in concurrence with that of Prabakar et al. who reported a higher shear bond strength of UltraSeal XT™ hydro™ sealant (20.39 ± 0.98 MPa) than hydrophobic sealant (Jayashri Prabakar et al., 2018). The superior bond strength of hydrophilic sealant may be attributed to two reasons. First, its multifunctional acrylate monomeric composition that might have contributed to an enhanced adhesive property of sealant. Second, its thixotropic characterstic that gave them an enhanced flow property and an ideal viscosity.

However, the bond strength value obtained for hydrophilic sealant in our study was lower than the previous study. This may be due to the different surface preparation for the sealant placement and storage regimens used before testing. In that study, all enamel surfaces were dried with air spray for 20 seconds after acid etching procedure and the bonded specimen were stored in distilled water at 37°C for 24 hours before testing. In our study, the test surfaces for UltraSeal XT™ hydro™ sealant were kept moist by removing the excess water with cotton pellet and the bonded specimen were subjected to a vigorous regimen of thermocycling of 5,000 cycles to simulate 6 months of clinical function of the sealants. By considering both the reports, it is noticeable that UltraSeal XT™ hydro™ sealant performed well in both dry and moist enamel surface conditions than hydrophobic sealant.

Failure mode analysis is a useful parameter for understanding the results obtained after bond strength testing. Some authors found a positive correlation between bond strength values and mode of failure (Sami, Naguib, Afifi, & Nagi, 2021). Adhesive failure is interfacial bond failure between the adhesive and the substrate. Cohesive failure occurs when the substrate remains covered with the adhesive (Ebnesajjad, 2014). Mixed failure is a mixture of both adhesive and cohesive failure at the same time. This is due to the partial degradation of the interface. Bonds which fail by cohesion exhibit a high strength. Mix failure indicate a bond strength lower than cohesive failure strength while adhesive failures exhibit low strength (Davis & McGregor, 2010). In our study, UltraSeal XT™ hydro™ sealant had a higher number of mixed failures (100%) than Clinpro™ sealant (66.7%). This supports the higher bond strength value obtained for hydrophilic sealant. It is in agreement with reports where groups with more mixed failures and cohesive failures showed better bonding than those with more adhesive failures (Bao et al., 2022; Memarpour, Rafiee, Shafiei, Dorudizadeh, & Kamran, 2021; Rirattanapong et al., 2011).

The thermocycling protocol was one of the strengths in our study. It is a laboratory procedure in which restorative materials are repeatedly exposed to hot and cold temperatures in a water bath to simulate thermal changes in the oral cavity. A regimen of 5,000 cycles of thermocycling was chosen for our study to correspond 6 months of clinical function of the sealants. Another strength could be regarded as the use of wire loop method for the load application. The use of a knife-edge chisel was reported to cause severe stress concentration at the load application area of the substrate resulting in premature cohesive fracture even before the maximum force is applied to rupture the adhesive interface (Sirisha, Rambabu, Shankar, & Ravikumar, 2014). We presumed that a uniform stress was distributed at the resin-enamel interface in our study through the wire loop.

According to the manufacturer's instructions forUltraSeal XT™ hydro™ sealant, the surfaces of the teeth should be slightly moist and should not be desiccated. It is very challenging to prepare and control this condition for all specimens so that all of them are identical. Some studies have prepared this moist surface condition by light air drying using a triple air syringe while other studies used a cotton pellet to remove the excess water (Bhat et al., 2013; Ku et al., 2017). In our study, a cotton pellet was used instead of triple air syringe to prevent any drying out by gust of air. To control this step, a time of 5 seconds was ascribed for holding the cotton lightly over the washed specimen.

The limitation for this study was related to the flattening the enamel surface. It was done to create a standardized adhesion area. This process removes the prismless outer layer which does not simulate the typical clinical situation for pit and fissure sealing. The outer prismless layer is more mineralized and resistant to acid etching process than the subsurface enamel (Kulkarni & Mishra, 2016). However, ISO/TS 11405 recommends a standard, reproducible and flat surface for assessment of the relative performance of materials. The enamel surfaces in this study were grounded flat enough for placement of tygon tubes. Although in vitro studies do not simulate the clinical settings completely, but they are a useful method for comparing dental materials that are being introduced at the market with the standard control.

5. Conclusion

The newly introduced UltraSeal XT™ hydro™ (hydrophilic sealant) had a superior bond strength than Clinpro™ (hydrophobic sealant) when the surfaces were prepared according to the manufacturer's instructions. The compatibility of hydrophilic sealant with moisture could be an alternative option for clinicians in situations where moisture control presents a challenge, particularly in children with limited cooperation.

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