



The Effect of Chemomechanical Caries Removal and Different Bonding Systems on Shear Bond Strength of Carious Dentin (In Vitro Study)

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Abstract

The purpose of this in vitro study was to determine whether shear bond strength (SBS) to chemomechanically excavated dentine by Carisolv (CS) differed from the SBS after conventional caries removal by bur (CB), with the use of the following adhesive systems: [Total-etch (TE), etch and Compobond1, etch, prime and bonding resin]; [Self-etch (SE), Xeno v, one component self-etching dental adhesive] and [No-etch (NE), Compobond1, prime& bond only]. Fifty human molars with occlusal caries were used to prepare dentin samples which were assigned to 5 groups: group I and III the prepared samples treated by CB and CS respectively then with TE, group II and IV the prepared samples treated by CB and CS respectively then with SE, while in group V the prepared samples treated by CS and then with NE. For each sample there was light cured composite core build up. After water storage, the samples were tested in a single-plane shear test assembly. The results demonstrated that there were statistical significant differences with in the mode of caries removal groups and also there were statistical significant differences between the bonding systems which affect SBS of carious dentin at $p < 0.01$, with in favor of the TE over SE. The present data demonstrate that with the use of CS on (carious dentin, there was either increase or decrease in bond strength in relation with different bonding systems.

Keywords: Carisolv, shear bond strength, dental adhesives.

Introduction

Although the conventional method (rotary bur) is in universal use, there are still problems that need to be overcome. The main disadvantages of this system include the perception by patients that drilling is unpleasant, local anesthetic is frequently required which is another aspect of dental treatment that renders patients particularly anxious, also drilling can cause pain associated with cavity preparation⁽¹⁾ and deleterious thermal⁽²⁾ and pressure effects on the pulp⁽³⁾.

Moreover, the use of the handpiece may result in removal of softened but uninfected dentin resulting in the excessive loss of tooth tissue^(1,4,5). Nowadays, modern dentistry aims to preserve tooth structure using minimally invasive procedures. Chemomechanical removal of caries is a new method with the advantage of selective removal of severely demineralized dentin. In addition, the method enhances the clinician's ability to diagnose caries. Ensuring chair side

caries diagnosis and removal, based on biologic principle, helps to preserve as much healthy tissue as possible⁽⁶⁾. The chemomechanical caries removal technique involves the application of chemical agents for softening of the carious dentin and facilitates removal by gentle excavation⁽⁷⁾. This system utilizes a mixture of sodium hypochlorite and three amino acids (glutamic acid, leucine and lysine) in a gel preparation and is used with previously developed hand instrument^(8,9). Several studies evaluating the clinical effectiveness of using Carisolv for treatment of permanent teeth^(4,8,10,11) have been reported. From the clinical point of view, these reports suggest that Carisolv did not cause any disadvantage to either carious or sound dentin, except for a significant decrease of the bond strength to sound primary dentin that was etched and bonded with dual-cured resin⁽¹²⁾. In addition to the development of the mechanisms of caries removal, there are other recent developments have lead to more simplification of the bonding procedure. So in addition to total etch, there is self etching adhesive, that incorporate the classic steps of etching, priming and bonding into one solution have become increasingly popular^(13,14). More information is needed to understand the influence of Carisolv treatment with different adhesive resin systems. Therefore, in this study, there will be an evaluation of the influence of Carisolv and different adhesive systems on shear bond strength (SBS) of carious dentin. Evaluation of the influence of this treatment on dentin should provide a basis for improving our understanding of their effect during treatment of caries lesions.

Materials and Method

Samples Selection: Fifty human permanent molars (wisdom teeth) extracted for periodontitis, pericoronitis causes from patient's age range between 20 to 30 years old were used in this study. These teeth with no visual signs of mechanical trauma, cracks or restoration. Occlusal surfaces of these teeth had carious lesions, clinically with a maximum cavitation entrance of 1 mm in depth by probing and with x-ray examination the lesion in mid way between DEJ and pulp. These teeth were stored in frozen physiologic saline soon after extraction till their use⁽¹⁵⁾.

Samples Molding: Each tooth was embedded with epoxy resin just below cemento enamel junction in a specimen mould (40×30×30mm in dimension) of the single-plane shear test assembly⁽¹⁶⁾.

Samples Preparation: To prepare the samples different materials and equipment were used, fig.1. So to prepare flat dentin surfaces, by using fissure diamond bur of 1mm in diameter, groove was created in the occlusal fissure in depth of 1mm to be a marker, above it coronal third of each sample was removed buccolingually, this was by grinding with a water-cooled air turbine using diamond bur and then abraded with 600 grit wet silicon carbide burs, one bur used for each five samples.

Samples Grouping: The samples were divided randomly into 5 groups (GI to GV). Each group contains 10 teeth. Group I: Bur (CB) was used to remove remaining carious dentin, and then Cica and Compobond 1, Total-Etch (TE), were applied. Group II: like samples of GI but then Xeno v, Self-Etch (SE), was applied. Group III: Carisolv (CS) was applied to remove remaining carious dentin, then TE were applied. Group IV: like samples of GIII but then SE was

applied. Group V: CS was applied to remove remaining carious dentin, then Compobond1 was applied with out etching with phosphoric acids, NO etch (NE), (Fig.2). Different materials were applied according to manufacturer instruction. From group III to V Carisolv was applied more than one time until the cavity is free from caries ⁽¹⁷⁾, for each application, cover the cavity with gel and wait for 30 seconds until the carious dentine has been softened then softened caries can be scraped away using the Carisolv hand instruments for 10 seconds, (Fig.3). Sequential caries removals were controlled by visual and tactile sensation (probing). The tactile sensation criterion with dental explorers were used for caries detection procedures, until hard dentin surfaces were detected, with leather-hard texture was reached or a sharp scratching sound was heard as suggested by previous studies ⁽¹⁸⁾. The remaining enamel and sound dentin from each tooth removed by abrading the entire occlusal surface with 600-grit silicon carbide papers, until a flat surface was created close to the original excavated caries lesion. For all groups the bonding areas were defined using a circular perforation in a self-adhesive Myla sheet, measuring 3 mm in diameter ⁽¹⁹⁾. The bonded surfaces were coupled with a plastic matrix fixed with a sticky wax in which a hybrid resin composite was applied in 2-mm-thick increments and polymerized in a light-emitted-dioed (LED) curing unit at 400-900 mW/cm² to form 4-mm-thick cores as in (Fig. 4). The teeth with composite build-ups will store in water at room temperature for 7 days ⁽²⁰⁾.

Shear bond testing: - for shear bond testing the loading were conducted in

a universal testing machine fig. 5 at a cross-head speed of 1 mm/min until failure. The force applied at the interface between dentin and adhesive. The force necessary for separating the sample were divided by the cross-sectional bonding area (3mm in diameter) to obtain SBS in MPa ⁽¹⁷⁾. The separate mode of each specimen was determined with the use of a light microscope at 20X magnification. The mode of fracture was classified as follows: dentin fracture if 100% of the bonded dentin were fractured; adhesive fracture if 100% of the bonded interface failed between the dentin and the bonding resin; cohesive resin fracture if 100% of the failure were in the resin composite.

Results

The results of microscopic examination for all samples were adhesive failure. Table (1) shows that when TE was used (GI& GIII), the mean of SBS test of samples treated with CS equal to (27.57) which is higher than the mean of SBS test of carious dentin samples treated with CB, that equal to (14.50).

While when SE was used (GII & GIV), the mean of SBS test of carious dentin samples treated with CS equal to (7.10) which is less than the mean of SBS test of carious dentin samples treated with CB, that equal to (11.063). The results revealed that the mean of SBS test of dentin samples treated with TE, (GI&GIII), equal to (14.50, 27.57) respectively which is higher than the mean of SBS test of (GII & GIV) treated with SE equal to (11.063, 7.10) respectively as it is shown in table (1).

Results of SBS with CS Versus CB Caries Removal Groups: statistically, a high significant

difference were found in SBS test between groups I & III, ($p=0.000$). Also high significant difference were found in SBS test between groups (II & IV), ($p=0.000$), table (2). The results indicated that the bond strength is highly increase when CS method was used with TE, while it is greatly decrease when CS method was used with SE compared with CB method, (Fig.6).

Results of SBS with TE Versus SE Bonding System Groups: the SBS in which samples are treated with TE (GI & GIII), showed a significant difference compared with the samples are treated with SE (GII & GIV), $p=0.008$; $p=0.000$ respectively, as it is shown in table (3). The results represented increase in the bond strength of the dentin samples after treatment with total etch compared with the samples with self etch bonding system whether mechanical or chemomechanical method were used, (Fig.6).

Results of SBS of TE and NE Groups with CR groups: a high significant difference were found in SBS test between groups III (mean=27.57) & V (mean=10.02), ($p=0.00$), table (4). SO the bond strength is greatly decrease when CR method was used with NE.

Discussion

Although, occlusal dentin tends to give lower bond strength than proximal / buccal dentin due to the regional variability of dentin wetness, occlusal dentin is the bonding substrate used in this study as was done by David *et al*, in 1995 ⁽²¹⁾. Further, with the composite resin becoming more popular as a restoration for occlusal surface of posterior teeth, the occlusal dentin was selected, to give a more

predictable and clinical relevant bonding surface ⁽²²⁾.

Studies have examined the dentin composite bond strength as a function of duration of storage. It was stated that, at least 24 hours of storage is necessary to permit polymerization shrinkage of the composite to take place and the composite to equilibrate with water. Water equilibration may take up to 7 days depending on the filler content of the composite. Further, composite / dentin bonds need to be exposed to water to simulate in vivo conditions ⁽²³⁾. Thus, in this study duration of 1 week of storage period was employed.

The bonded surface area used in this study for shear bond test was 3 mm in diameter. This is in accordance with the earlier studies where 3, 5, 10 mm diameters of bonded surface area had been used. Larger specimens contain more defects than smaller ones, and hence, there was a decrease in bond strength. Thus, for optimal results while using the shear bond test, a surface area of 3 mm was chosen ⁽²¹⁾.

Although, the ISO standard has recommended that in shear bond test, the load should be applied with a cross head speed of 0.75, 0.3 mm/min ⁽²²⁾. In this study a cross head speed of 1 mm / min was used to minimize the effect of the deviation of applied force away from the adhesive interface and minimizing the effect of this variable on the shear bond strength ⁽²⁴⁾.

In the present study the bond strength values of both the bonding agents were much lower than test reported in product literature. This may be due to the fact that these bond strength values were recorded after duration of 1 week after distilled water storage. It has been reported in earlier studies that bond strength decreases due to hydrolytic degradation with time. Secondly, the bonding was carried out in vitro; where in all the in

vivo conditions of a hydrated dentin surface could not be simulated. This may have resulted in a dehydrated dentin surface on exposure to air after sample conditioning⁽²²⁾.

To produce a shear bond failure, the applied force must be located at the interface between the dentin and adhesive. In blunt edge shear testing device or wire loop method the applied force is located away from the interface and is more likely to produce a tensile failure rather than a shear failure⁽²²⁾. Hence, the knife edge shearing device was employed in the present study as recommended by American Dental Association^(25,26), therefore all samples were with adhesive failure and this in agreement with Mizuho *et al* in 2010 who revealed that all specimens in their study were found with fracture mode at the interface between dentin surface and composite. The possible explanation that the force applied by knife edge shearing device loaded exactly at the dentin substrate surface⁽²⁷⁾. Previous studies have evaluated bond strength of resin composites after CR. However, the test conditions varied from one study to another. Some researchers have used carious teeth while others have used sound teeth. Moreover, substrate for bond testing also varied from human to bovine dentine. Hence, comparison among these studies is difficult if not impossible⁽²⁸⁾.

Discussion Results of SBS (CR versus CB Techniq)

Numerous reports are available regarding bonding properties between resin composites and normal dentine, but attention was rarely given to caries-affected dentine^(29,30). In contrast to normal dentine the ultrastructure of caries-affected sites showed morphological variations like intra- tubular deposits at various

depths in the inner carious layers or empty and occluded tubules⁽¹⁷⁾.

The aim of CR is not to remove the outer, permanently damaged layer of carious (infected) dentine only, but also to leave the demineralized 'affected' dentine which can be healed later on intact, while the CB more efficient in remove all carious tissue (infected & affected) dentin, and leave sound normal dentin⁽³¹⁾.

The results of current study demonstrated that the CR revealed statistically higher SBS, when used with TE in affected dentin G(III), than the samples prepared with CB which lead to sound dentin in GI. While demonstrated lower SBS when used with SE in affected dentin G(IV), than the samples prepared by CB which lead to sound dentin in GII table (2). The results in this study agree with Al-kholany *et al* in 2005 who revealed that the CR system to prepare dentin surfaces enhanced the dentin/adhesive bond strength, when used with etch and rinse adhesives system⁽³²⁾. The possible explanation could be that the mode of caries removal influences bond strength to carious substrates. In contrast to the homogeneous topography of the smear layer's surface after rotary preparation, CR showed more and rougher irregular surfaces⁽³³⁾. The extent by which the surface would be covered by smear layer-like deposits depends on the mechanical action of hand instruments used for application of the caries dissolving reagent. Subsequently, an increase in surface energy with higher wettability⁽³⁴⁾ and a reduced mineral content of the dentine surface has been observed after CR⁽³⁵⁾ in addition, it was revealed that the effect of Carisolve treatment on resin bond strength also depended on the adhesive system that

was used⁽¹⁵⁾. It was proved, the mineral phase of the carious dentin is remodeled by repeated sequences of demineralization and remineralization which usually produce occlusion of the tubules with mineral crystals⁽³⁶⁾, therefore the presence 35% phosphoric acid with Compobond1 which facilitated the removal of these minerals, thus lead to improved monomer infiltration and this agree with Nakajima *et al* in 2000 who revealed the improved monomer infiltration caused by the application of the 35% phosphoric acid which seems to solubilize the intratubular mineral deposits in caries-affected dentin⁽³⁷⁾. Also Partially demineralized nature of intertubular dentin in caries-affected dentin permits deeper acid demineralization and deeper monomer infiltration than those in normal dentin. The present result about self-etching system in agreement with Xuan *et al*, in 2010 who revealed that the Xenon generated significantly lower bond strength when applied to caries-affected dentin than to normal dentin⁽¹⁴⁾. The possible explanation might be due to structure of carious affected dentin⁽¹⁷⁾, and it is relation to composition and highly hydrophilicity of self etching adhesives systems, which lead to work like a semi permeable membrane⁽³⁸⁾, and this subsequently effect on hybrid layer & resin tag formation⁽¹⁴⁾.

But the results about etch and rinse systems, disagree with (Xuan *et al*, 2010) who revealed that the two-step etch-and-rinse adhesive systems yielded similar bond strength in both normal and caries-affected dentins⁽¹⁴⁾. The possible explanation might be due to technique sensitivity⁽²²⁾.

Discussion Results of SBS with TE Versus SE Bonding System Groups

This study evaluated shear bond strength of fifth generation bonding agents which employed the total etch (TE) concept of bonding and seventh generation bonding agent which involved the self etch (SE) concept of bonding. The previous studies proved that the adhesion of restorative materials to enamel has become routine and is a reliable aspect of modern restorative dentistry, but dentinal adhesion has proved to be more difficult and less predictable. Bonding of an adhesive to the dentin is complex and bond strength is one of the most important performance parameters of dental adhesives^(37,39). This is due to its complex structure, formation of smear layer as debris which is burnished on to the dentinal surface while dentin is cut or ground⁽⁴⁰⁾, also dentinal adhesion is a technique sensitive⁽²²⁾. Other studies have been suggested that the bond strength depends on both the type of dentin and the adhesive used due to the inherent characteristics of the dentin as well as the compositions of different adhesives^(37,41), comprehensive evaluations of dentin type-dependent bond strength of different categories of adhesives are still lacking.

The result of the present study has revealed higher strength values with the total etch and wet bonding technique compared to the self etch approach table (3). So the results about Compobond 1 & Xeno v were agree with those obtained by Xuan *et al* in 2010, Who reported for Compobond 1, had higher bond strength than Xeno v in both normal and caries-affected dentin in general⁽¹⁴⁾. With Compobond 1, the 35% phosphoric acid was used to remove

the smear layer, demineralize the superficial dentin and expose a microporous network of collagen that is nearly deprived of hydroxyapatite^(42,43). The dissolution of the peritubular dentin results in the formation of the funnel-shaped resin tags after the monomer infiltration. Total-etching adhesives formed resin tags were much longer than those found in self-etching adhesives samples and revealed numerous small lateral extensions of microtags branching from the main resin tags, which was a clear sign of proper adaptation and sealing⁽⁴⁴⁾.

These resin tags and the resin infiltration into the lateral branches via the dentinal tubules anastomosis might have contributed to the increase of the bond strength⁽⁴⁵⁾. Compobond 1 utilized wet bonding technique which is considered as a common procedure. A moist dentin surface as the substrate is ideal to bond, since if the etched dentin surface is over-dried or over-wet, the collagen matrix collapses and prevents effective infiltration of the primer, thereby resulting in low bond strengths and excessive microleakage⁽⁴⁶⁾.

Other important component of Compobond 1 is the solvent, which is acetone, and this promotes the penetration of the monomers in the collagen network of the demineralized dentin⁽⁴⁷⁾, thus might result in high bond strength.

While the one-step self-etching adhesives, Xeno v, yielded low bond strength when applied to normal and affected dentin. Such one-step adhesives are highly hydrophilic and behave like a semi-permeable membrane⁽³⁸⁾, thus could be cause weakening the bond strength. Also when this HEMA-rich adhesive dentin interface was evaluated, many separation zones located near the

adhesive resin-composite interface were systematically observed⁽⁴⁴⁾. These separation zones, resembling droplets. These droplets seem to be the result from water absorption from dentin through osmosis^(38,48), and this water is transmitted from dentin following a diffusion process^(38,49). The location of the droplets near the adhesive resin-composite interface indicates that a "hypertonic" (high concentration of molecules and low concentration of water solution is present here⁴⁸). The low molecular weight and the strong hydrophilic character of HEMA explain why osmosis occurs in self etching adhesives systems. It will result in a fragile zone.

In contrast to total etch, the self-etching adhesives vary in their acidity by virtue of the composition and concentration of polymerizable acids and acidic resin monomers in these systems, and the attained bond strength is affected by the adhesive's acidity⁽⁵⁰⁾. In Xeno v groups, the Self etching primer might disclose less etching ability because of their relative high pH when compared with the pH of phosphoric acid of Compobond 1 etchant regardless of Carisolve treatment⁽¹⁵⁾.

Other studies explain etching ability of self-adhesives systems depending on etching aggressiveness, the self-etching adhesives could be subdivided into three categories, strong, moderate and mild adhesives⁽⁵¹⁾. The stronger the etchant used, the deeper the demineralization of tooth structure. Strong self-etch adhesives remove hydroxyapatite from dentin completely, while mild self-etch adhesives demineralize the dentin surface only partially⁽⁵²⁾. The residual hydroxyapatite has been shown to bond chemically to the functional monomer, producing a dual-retentive hybrid layer consisting

of a micromechanical interlocking with the underlying collagen matrix and a chemical bonding with the residual dentin hydroxyapatite crystals⁽⁵³⁾. It is believed that the dual retentive mechanism is responsible for the mild self-etch system's higher resistance to debonding stress and the restoration's superior marginal adaptation⁽⁵³⁾.

However, it seems that the pH value of self-etching adhesives does not influence the morphology of the dentin-resin interfaces; therefore the pH is not a determinant factor conditioning the action of self-etching adhesives⁽⁵⁴⁾.

Discussion Results of TE and NE Groups with CR samples

The results of this study illustrated that the Carisolv treatment of carious teeth showed statistically lower SBS when used with Compobond 1 without etching with phosphoric acid (NE), G (V), in comparison with the Carisolv treatment of carious teeth with Compobond 1 (TE), G(III), table (4). These results agree with Haak *et al* in 2000 and also in agreement with Hosoya *et al* in 2001 who revealed that the Carisolv alone was less effective than etching for resin adhesion to dentin^(17,55). The possible explanation that the mineral content of smear layer cannot be removed by Carisolv alone, thus the presence of etching with phosphoric acid can remove these mineral and this subsequently improve the monomer infiltration to underlying exposed collagen and might be lead to increase bond strength⁽³⁷⁾.

Conclusions

chemomechanical caries removal significantly increase SBS of total-etch bonding system, but significantly

decrease shear bond strength of no-etch and self-etch bonding system to affected dentin. Total-etch bonding system has significantly higher SBS than self-etch bonding system to sound and affected dentin.

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Fig.1 Materials & Equipments used in this Study

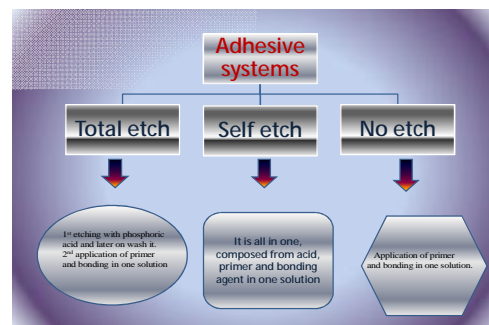


Fig.2 Bonding Systems



Fig.3 Results of Carisolv Application



Fig.4 Composite Core build up



Fig.5 Universal Testing Machine

Table (1) Descriptive statistic for the all groups

Groups	N	Mean	St Dev	SE
I	10	14.50	3.16	1.0
II	10	11.063	0.591	0.19
III	10	27.57	2.44	0.77
IV	10	7.10	1.74	0.55
V	10	10.02	2.55	0.81

Table (2) T-test for shear bond strength of chemomechanical and mechanical caries removal groups

Groups	T-Value	T- Tab	P- value	Sig.
G I	10.36	2.120	0.000	HS
G III				
G II	6.80	2.201	0.000	HS
G IV				

Table (3) T-test for shear bond strength test of total etch and self etch groups in carious dentin

Groups	T-Value	T- Tab	P- value	Sig.
GI	3.38	2.262	0.008	HS
G II				
G III	21.60	2.120	0.000	HS
G IV				

Table (4) T-test for shear bond strength of total etch and no etch groups with CR

Groups	T-Value	T- tab	P- value	Sig.
G III	15.75	2.110	0.000	HS
G V				

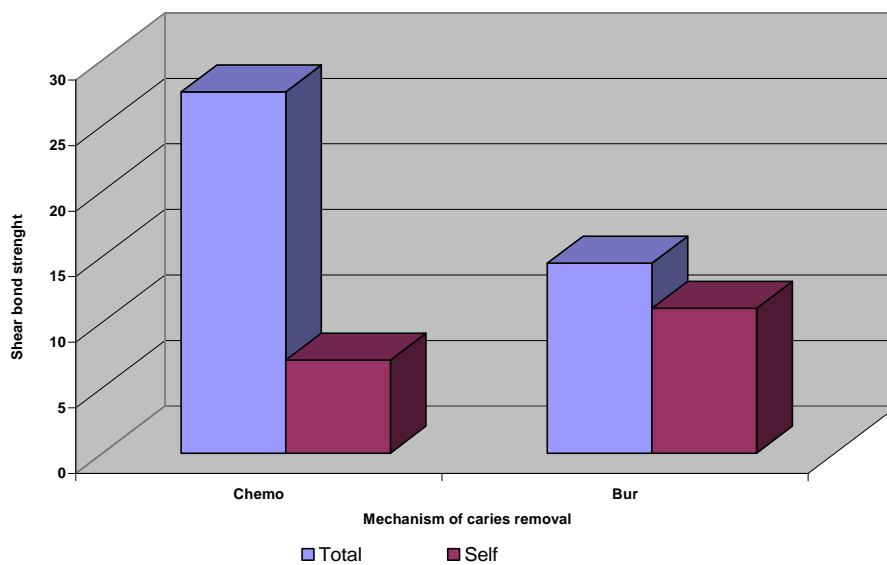


Fig. 6 Bar Chart for carious samples