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Effect of Rotary Instrumentation on Composite Bond Strength with Simulated Pulpal Pressure

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Clinical Relevance

The bur and its speed may be a factor for improved bonding.

SUMMARY

This study evaluated the effect of cutting teeth with different types of burs at various speeds on shear bond strength using Prime and Bond NT (Dentsply/DeTrey). A simulated pulpal pressure of 25-mmHg, equivalent to 34 cmH$_2$O, was created in a false pulpal chamber filled with distilled water and maintained for seven days. The human teeth were divided into six groups of 10 teeth each: fine grit straight fissure diamond bur in air rotor (DA), fine grit straight fissure diamond bur in micromotor (DM), crosscut fissure carbide bur in air rotor (CCA), crosscut fissure carbide bur in micromotor (CCM), plain fissure carbide bur in micromotor (CM) and #600-grit silicon carbide paper (SiC). The tooth surfaces in these groups were cut under copious air-water spray and treated with Prime and Bond NT after etching with 38% phosphoric acid. Composite restorations were then prepared with TPH spectrum (Dentsply/ DeTrey). After soaking in water at 37°C for 24 hours, the specimens were loaded at a 45° angle to their longitudinal axes by using a Z 010 Universal Testing Machine (Zwick), and shear bond strengths were determined at a crosshead speed of 2 mm/minute. All of the specimens were then observed under Stereomicroscope at 10x. Statistical analysis was made using one-way and two-way ANOVA and *t*-test ($p<0.05$). The bond strengths achieved with a fine grit straight fissure diamond bur, a crosscut fissure carbide bur in air rotor and a crosscut fissure carbide bur in micromotor, were significantly higher than a fine grit straight fissure diamond bur, a plain fissure carbide bur and #600-grit silicon carbide abrasive paper in the micromotor. Therefore, selecting an appropriate bur and its speed may improve bonding for adhesive

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systems, although crosscut fissure carbide burs produced high bond strengths at either speed used.

INTRODUCTION

Effective bonding to tooth tissue using tooth-colored restorative materials is an absolute necessity for clinical success. Although enamel adhesion is a predictable and established entity in contemporary restorative dentistry, an adequate bond to dentin is more difficult to achieve. This is partly due to the biologic characteristics of dentin; namely, a high organic content, tubular structure with the presence of odontoblastic processes, continuous moist conditions due to the presence of dentinal fluid, intratubular pressure, permeability and the presence of the smear layer formed immediately after cavity preparation (Lopes & others, 2002). There are many variables that can influence the bond strength of resin composite to dentin (Pashley & others, 1995). These include substrate variables, etching variables, priming variables, bonding variables and testing variables.

Many *in vitro* studies regularly report high bond strength of newly developed dentin bonding systems (Ogata & others, 2001; Bouillaguet & others, 2001; Rosa & Perdigão, 2000). One of the drawbacks of these bond strength studies was that they had been conducted without maintaining intrapulpal pressure during bonding. Compared to laboratory conditions, dentin is an intrinsically hydrated tissue *in vivo*, penetrated by a network of 1.0-2.5-µm diameter fluid-filled dentin tubules. The flow of fluid from the pulp to the dentin-enamel junction is the result of a slight but constant pulpal pressure (Brännström, Linden & Johnson, 1968). It is also difficult to simultaneously achieve uniform wetness on the axial, pulpal and gingival walls and between the superficial and deep dentin in Class II cavities because of regional differences in hydraulic conductance (Ozok, Wu & Wesserlink, 2002). Although the flow along individual tubules is very small, the average velocity of outward fluid flow per tubule is 1-2 µm/seconds. This is sufficient to oppose and greatly reduce the inward diffusion of substances from the oral environment (Stead, Orchardson & Warren, 1996). Lower values of bond strength have been reported in previous studies when intrapulpal fluid pressure was maintained (Mitchem & Gronas, 1991; Pioch & others, 2001; Mitchem, Terkla & Gronas, 1988).

Moreover, these laboratory studies are performed on flat tooth surfaces prepared by using silicon carbide abrasive papers; whereas, in a clinical situation, complex cavity designs are prepared by different cutting instruments such as diamond or steel burs (Bouillaguet & others, 2001). This geometrically determined contraction stress has been described as the C-factor (configuration factor) by Davidson, de Gee and Feilzer (1984). C-factor is the ratio of bonded to unbonded walls of the preparation. The C-factor for dental restorations typically ranges from 0.1 to 5.0, with higher values (>1.5) indicating a greater likelihood of high interfacial stresses (Feilzer, de Gee & Davidson, 1987). Box-like Class I cavities in which the walls have equal dimensions would have a C-factor of 5; whereas a flat surface, as in veneering, would have a C-factor of 1 (Bouillaguet & others, 2001). Laboratory studies conducted at a C-factor of 1 tend to overestimate bonding performance compared with complex cavity preparations with high C-factors (Yoshikawa & others, 1999; Bouillaguet & others, 2001).

A key element for adhesion is the intimate association of the adhesive and substrate. The wetting ability and extent to which the adhesive penetrates the tooth surface play a major role in determining the quality of bonding (Erickson, 1992). A major factor in the surface wetting of bonding resins is the surface topography of the prepared tooth surface, since a roughened surface creates a greater surface area for the adhesive bond (Eick & others, 1972; Vaysman, Rajan & Thompson, 2003). Therefore, information on the effect of cutting teeth with different burs on resin-dentin bond strength is essential for the appropriate clinical use of dentin bonding systems (Ogata & others, 2001).

After mechanical preparation of the cavity with a dental instrument such as a bur, an amorphous layer of organic and inorganic debris, such as the smear layer,

Table 1: *Identification of Groups by Dentin Surface Preparation*

Group	Method of Preparation	Manufacturer	rpm
A	Fine grit straight fissure diamond bur in air rotor	Dentsply/Detrey Konstanz, Germany	150,000
B	Fine grit straight fissure diamond bur in micromotor	Dentsply/Detrey Konstanz, Germany	40,000
C	Crosscut fissure carbide bur in air rotor	Dentsply/Detrey Konstanz, Germany	150,000
D	Crosscut fissure carbide bur in micromotor	Dentsply/Detrey Konstanz, Germany	40,000
E	Plain fissure carbide bur in micromotor	Dentsply/Detrey Konstanz, Germany	40,000
F	#600 grit silicon carbide abrasive paper	Jawan Brand, India	40,000

is formed on the surface (Pashley, 1984). This dentin smear layer occludes dentinal tubules and reduces dentin permeability by 86% (Pashley, Livingstone & Greenhill, 1978). It is an established fact that the quantity and quality of the smear layer vary depending upon the manner in which they are created (Eick & others, 1970; Gilboe & others, 1980). Differences in smear layers prepared with bur cutting or abrasive paper have been reported to affect the bond strength of resin composite to dentin using self-etching primers (Ogata & others, 2001). Watanabe, Nakabayashi and Pashley (1994) reported that dentin bond strengths were affected by different smear layers created by different grits of abrasive papers using self-etching primers. On the other hand, Ogata and others (2002) reported that bond strength is affected by different types of smear layer in the case of self-etching primers only and not in the case of phosphoric acid etching.

Additionally, other factors which are under the control of the operator, such as cutting speed, have also been found to be a contributing factor for bond strength. It is still unclear whether the bur or speed is the crucial factor in bond strength determination. Bond strength determination and mode of failure estimates the adhesion quality of tooth-resin interface.

This study evaluated the effect of cutting teeth with burs of different types operated at various speeds on shear bond strength using Prime and Bond NT bonding agent. The null hypothesis was that different surface preparation methods would have no effect on bond strength at the tooth-resin interface.

METHODS AND MATERIALS

Sixty extracted, caries-free human molars were cleaned and stored in distilled water until used for shear bond strength testing. The teeth were divided into the following six groups, with 10 teeth in each group, according to the type of cutting instrument and speed used (Table 1).

A) Fine grit straight fissure diamond bur in air rotor (DA).

B) Fine grit straight fissure diamond bur in micromotor (DM).

C) Crosscut fissure carbide bur in air rotor (CCA).

D) Crosscut fissure carbide bur in micromotor (CCM).

E) Plain fissure carbide bur in micromotor (CM).

F) #600-grit silicon carbide abrasive paper (SiC).

All the teeth were kept under positive hydrostatic intrapulpal fluid pressure via pulp chambers filled with distilled water during tooth preparation and bonding procedures to simulate clinical conditions. To create a mechanism into the pulp chamber, a hole, 4-mm in diameter, was made in the furcation area of the teeth, between the roots. The roots were covered externally by a rubber sheath; the junction between the rubber sheath and tooth surface was covered by cyanoacrylate and clay to maintain the air-tight seal. The lower portion of the same rubber sheath covered a plastic tube filled with distilled water, which connected the pulp chamber to a water-filled plastic syringe (Nikaido & others, 1995). The column height of water was adjusted to 34 cm to provide approximately 25-mmHg of pressure, which is the average tissue pressure in healthy

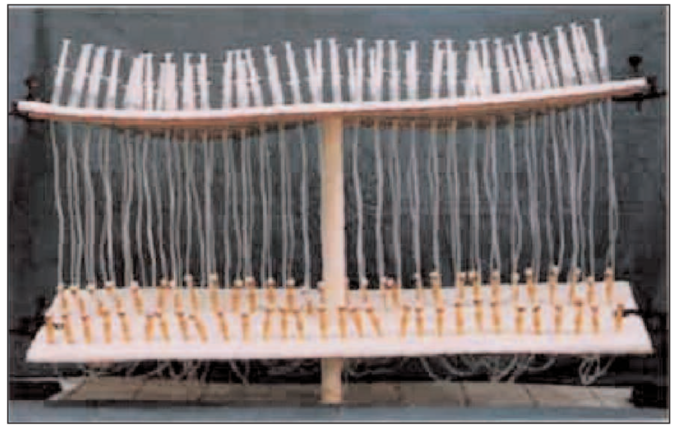

Figure 1. *Apparatus for maintaining intrapulpal pressure.*

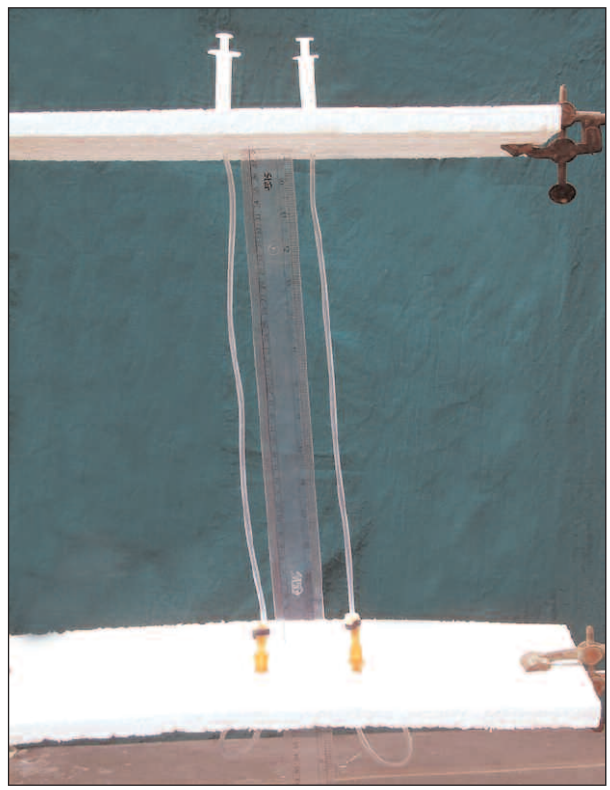

Figure 2. *A close view of the apparatus for maintaining intrapulpal pressure.*

pulp (Mitchem & others, 1988; Van Hassel, 1971). During tooth preparation and restoration, this intra-pulpal fluid pressure was maintained for seven days (Figures 1 and 2).

This study evaluated the bond strength of composites to both enamel and dentin. Class II proximal box-only cavities of standard dimensions 4-mm buccolingual, 4-mm occlusogingival and 2-mm mesiodistal, with facial and lingual walls straight and parallel to each other, were prepared. The standard dimensions included both the enamel and dentin surfaces (Figures 3 and 4). In all groups, an initial preparation was done by fine-grit straight-fissure diamond bur in air rotor, then the surface was finished with different types of burs. Teeth in the air rotor groups, A and C, were prepared with burs rotating in a dental turbine at a high speed of 150,000 rpm (Contraangle PANA AIR T air rotor handpiece, NSK, Nakanishi Inc, Tochigi-ken, Japan). Teeth in Groups B, D and E were prepared with their respective burs mounted in a contra angle micromotor handpiece at 40,000 rpm (NSK, Nakanishi Inc). Handpieces were hand-held to simulate clinical conditions. In Group F, #600-grit silicon carbide abrasive paper was used. A small piece of this paper was glued to a metallic blank bur with cyanoacrylate. This blank was mounted in the micromotor at slow speed (40,000 rpm), and 30 passes were made across the tooth surface under copious air-water spray. The surface was then prepared by 10 strokes with the same mounted silicon carbide abrasive paper on a blank bur when the micromotor was not rotating to create uniform scratches. The abrasive paper was changed as soon as it got distorted. In all groups, the tooth surface was prepared by the bur under copious air-water spray until uniform scratches by each bur covered the entire tooth surface. Each bur was changed after preparing three cavities.

The prepared enamel surface was etched with 38% ortho phosphoric acid (DPI tooth conditioning gel, Dental Products of India Ltd, Mumbai, India) for 30 seconds, with the help of a brush. Then, the etchant was applied to the prepared dentin surface for 15 seconds. This resulted in enamel etching for 45 seconds and dentin etching for 15 seconds. The etchant was rinsed with distilled water for 10 seconds with a high force of combined air-water spray and blot dried with a cotton pellet to keep the surface moist. For this purpose, excess water from a cotton pellet saturated with water was removed by blotting it on a gauze pad before using the pellet to blot the tooth. Then, one coat of the bonding agent Prime and Bond NT (Dentsply/DeTrey, Konstanz, Germany) was applied with a bristle brush. The surface was kept wet for 20 seconds and gently air-

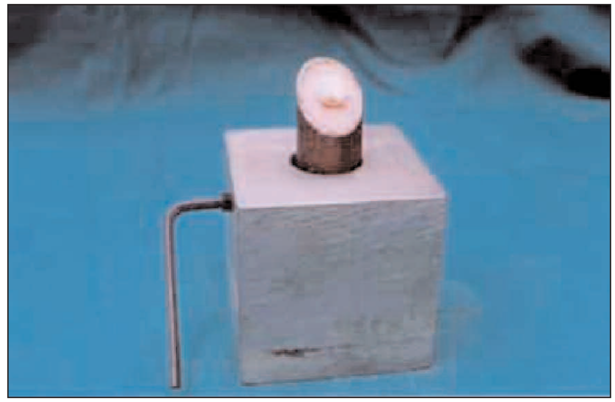

Figure 3. *A proximal box-only Class II cavity preparation in the tooth specimen.*

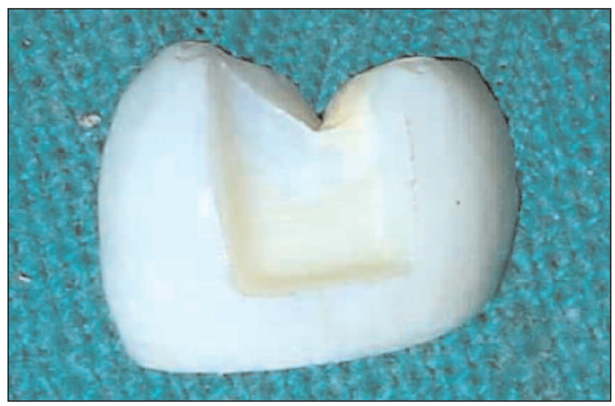

Figure 4. *An enlarged view of a proximal box-only Class II cavity preparation.*

Table 2: *Materials Used for Bonding*

Materials	Ingredients	pH	Procedure	Manufacturer
Tooth conditioning gel	38% orthophosphoric acid	0.02	a (30 seconds); b (15 seconds); c (10 seconds); d	Dental Products of India Ltd Mumbai, India
Prime & Bond NT	Di-and tri methacrylate resin, functionalized amorphous silica, PENTA, cetylamine hydrofluorid acetone	2.2	e (20 seconds); f (5 seconds); g (10 seconds)	Dentsply/Detrey Konstanz, Germany
TPH Spectrum	Bis GMA, Bis EMA, TEGDMA, initiators & stabilizers, Barium aluminosilicate, silicon dioxide		g (40 seconds)	Dentsply/Detrey Konstanz, Germany

Procedures: a) acid-etching of enamel; (b) acid-etching of both enamel and dentin; (c) rinse; (d) blot-dry; (e) apply one coat of adhesive; (f) gently air-dried and (g) light cured.

dried for five seconds to a glossy surface, then photopolymerized using a light intensity of 600 mW/cm^2 for 10 seconds. A mylar strip was now applied to cover the proximal box. Spectrum TPH, the hybrid resin composite, (Dentsply/DeTrey) was packed in 2-mm thick horizontal increments. The last layer was made flush with the enamel cavosurface margins. Each layer was exposed to the curing light for at least 40 seconds from the occlusal side. Details for all restoration materials are provided in Table 2. Finishing and polishing of the composite restoration was not done in order to eliminate the influence of these variables on the surface properties of the composite restoration. All teeth were stored in distilled water at 37°C for seven days, maintaining intrapulpal pressure.

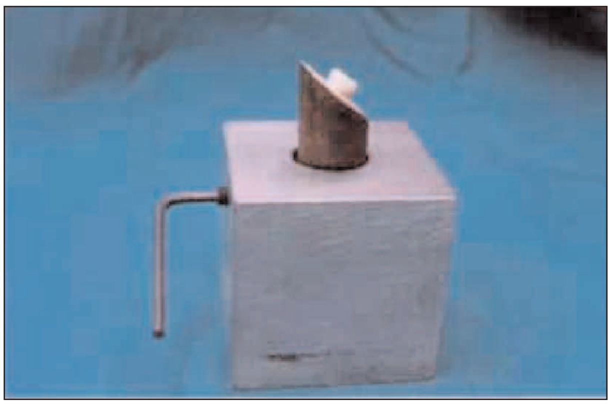

Figure 5. *Attachment holding the ring with mounted specimen at an angle of 45°.*

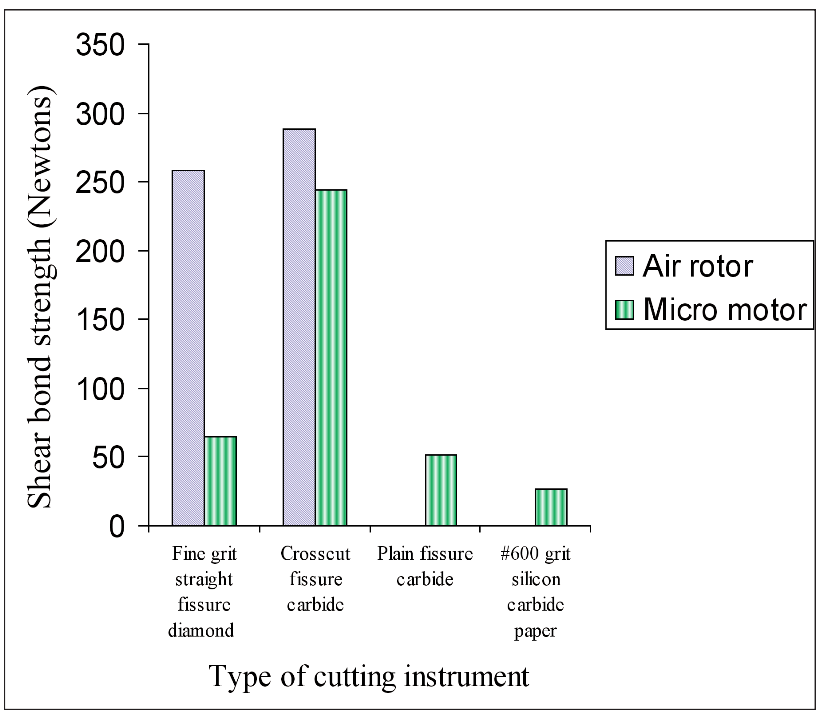

Figure 6. *The results of Shear Bond Strengths for each group.*

The specimens were removed from the assembly apparatus and placed in a fixture that positioned them for loading at an angle of 45° (Summitt, Della Bona & Burgess, 1994; Della Bona & Summit, 1998). For this purpose, metallic rings with a one- and two-inch high diameter were used. The upper half of the ring was cut at a 45° angle to the long axis of the ring (Figure 5). The rings were filled with auto polymerizing acrylic resin up to their uppermost margin. All the specimens were placed in the rings, with the roots covered with acrylic resin. The specimens were placed perpendicular to the acrylic resin surface. The mounted specimens in rings were stored in distilled water until testing was performed.

Bond strength between the restorative material and tooth surface was measured in the shear mode with the Universal Testing Machine Z 010 (Zwick, Ulm, Germany). The specimens were mounted in a jig, while a straight knife-edge rod 2-mm-wide was applied at the tooth-restoration interface at a crosshead speed of 2-mm/minute. This resulted in a shear force at a 45° angle to the tooth surface. Load was applied until restoration failure occurred. Bond strength was recorded in Newtons. The total bonded surface area of the proximal box cavity preparation was 40 mm^2, and it was calculated as the sum of the surface area of the gingival wall (8 mm^2), facial wall (8 mm^2), lingual wall (8 mm^2) and axial wall (16 mm^2). Loads were converted to MPa by dividing the loads in Newton by the total bonded surface area.

The mode of failure of the bond at tooth-restoration interface was determined with a Stereomicroscope at 10x magnification, then classified into three categories: adhesive, cohesive and mixed types of failure (Royer & Meiers, 1995).

1. Adhesive mode of failure was recorded if the restorative material was completely detached from the tooth surface.
2. Cohesive mode of failure was recorded if the bond failure occurred entirely within the restorative material.
3. Mixed mode of failure was recorded if the bond failure was a combination of the adhesive and cohesive modes of failure.

Statistical analysis of the shear bond strengths was performed using one-way, two-way ANOVA and *t*-test at the 95% level of confidence.

RESULTS

Figure 6 and Table 3 show the shear bond strength results of each group. For air rotor, there was no statistically significant difference

Table 3: *Results of Shear Bond Strengths for Each Group (mean ± SD)*

	Fine Grit Straight Fissure Diamond Bur	Crosscut Fissure Carbide Bur	Plain Fissure Carbide Bur	#600 Grit Silicon Carbide Abrasive Paper
Air rotor	258.04 ± 150.18 N 6.45 MPa (n=10)	288.501 ± 196.22 N 7.21 MPa (n=10)	__	__
Micromotor	64.81 ± 42.71 N 1.62 MPa (n=10)	243.86 ± 110.94 N 6.09 MPa (n=10)	51.03 ± 47.95 N 1.27 MPa (n=10)	26.93 ± 14.71 0.67 MPa (n=10)

(n) = Number of the slabs tested.

in mean bond strength among fine grit straight fissure diamond burs and crosscut fissure carbide burs: DA: 258.04 ± 150.18 N (6.45 MPa); CCA: 288.501 ± 196.22 N (7.21 MPa). For micromotor, the silicon carbide paper group produced the lowest mean bond strength, and a statistically significant difference was observed among all groups: DM: 64.81 ± 42.71 N (1.62 MPa); CCM: 243.86 ± 110.94 N (6.09 MPa); CM: 51.03 ± 47.95 N (1.27 MPa); SiC: 26.93 ± 14.71 (0.67 MPa). One-way and two-way ANOVA analysis revealed a statistically significant interaction between type of bur and speed used for tooth surface preparation.

When examined under a stereomicroscope (10x), the representative micromorphology of the failure pattern was classified as either adhesive or mixed. There was no remarkable difference in failure patterns among all groups.

DISCUSSION

The use of the adhesive systems in restorative dentistry allows for use of more conservative preparations, a reduction of microleakage in the tooth-restoration interface and the prevention of recurrent caries, marginal discoloration and the reduction of postoperative sensitivity. One of the primary objectives of researchers is to achieve a strong, durable, predictable union between restorative materials and tooth structure. Shear bond strength tests have been the method of choice for testing tooth bonding and are included in the International Organization for Standardization for testing dental materials and adhesives, ISO's TR 11405 (Blomlof & others, 2001).

In a tooth composed of brittle materials, the stresses responsible for failure, called Von Mises stresses, are a combination of the resultant normal stresses and shearing stresses (Yaman, Alacam & Yaman, 1998). Load applied at a 45° angle simulates the effect of high shearing stresses (Yaman & others, 2000). Microtensile tests were not used in this study, because they are not easy to perform, and they are labor intensive, technically demanding, require special equipment, rapid dehydration of small samples occur and it is difficult to measure bond strengths less than 5 MPa (Pashley & others, 1995). A push-out test is more time-consuming and cannot be applied for evaluating enamel bond strength. Plus, there are chances of fracture of adjacent tooth structure during testing (Van Meerbeek & others, 2003).

Shear bond strength values recorded in this study are lower—in the range of 0.67-7.21 MPa. These are the total bond strength values obtained by resin composites to both enamel and dentin surfaces. Bouillaguet and others (2001) reported a bond strength of 18.5 MPa for flat dentin surfaces and a bond strength of 13 MPa for mesioocclusodistal cavities, including both enamel and dentin surfaces. Rosa and Perdigão (2000) observed bond strengths of 18.2 MPa and 23.4 MPa for flat dentin and enamel surfaces, respectively. Perdigão, Baratieri and Lopes (1999) reported bond strengths of 20.5 MPa and 27.0 MPa for flat dentin and enamel surfaces, respectively. These lower values could be attributed to polymerization shrinkage forces with a high C-factor in Class II cavities, a large bonded surface area, more axial dentin permeability and interference by dentinal fluid due to intrapulpal pressure.

Bouillaguet and others (2001) reported a 20% reduction in bond strength in the cavity bonding group as compared to those measured in the flat bonding group. Yoshikawa and others (1999) reported similar results for bulk-filled Class I cavity surfaces. The lower shear bond strength recorded in this study can be explained by the fact that shrinkage forces in Class II cavities have a high C-factor that cannot be relieved by resin flow, resulting in debonding of one or more walls as compared to flat surfaces with a low C-factor (Bouillaguet & others, 2001).

The results of this study are supported by studies by Mitchem and Gronas (1991), who reported a low bond strength of 1 ± 1.3 MPa in tubules full of fluid under pressure as compared to 18.3 MPa in empty tubules. Pioch and others (2001) reported that bond strength using Prime & Bond NT dropped significantly from 14.8 to 8.7 MPa when the dentin of extracted teeth was perfused under intrapulpal pressure (34cm H_2O). The presence of fluid inside the dentinal tubules tends to dilute the dentin conditioner, decrease its potential for demineralization of the intertubular and peritubular dentin and eventually lower bond strength (Perdigão & others, 1996).

The purpose of this study was not to ratify how good the bonds were, but simply to compare the bond strength achieved by different burs at different speeds. Consequently, negative controls (the same burs using the same test methods with no pulpal pressure) were not included.

In this study, all burs in micromotor, except crosscut fissure carbide burs, resulted in significantly lower bond strength than in air rotor. This can be explained by the fact that cutting in micromotor requires a relatively heavy force application and produces vibrations of high amplitude and low frequency (Marzouk, Simonton & Gross, 2001). At low speeds, burs have a tendency to roll out of the tooth preparation, mar the proximal margin of tooth surface and leave micro-cracks. The presence of micro-cracks in the bonding interface may leave flaws that will diminish the bond strength of resin composite to tooth surface.

There was no statistically significant difference in mean bond strength attained by crosscut fissure carbide burs in air rotor and micromotor and between fine grit straight fissure diamond burs and crosscut fissure carbide burs in air rotor. A possible explanation might be that etching may have produced a similar bonding substrate despite of the different types of smear layers created by different cutting instruments.

The lower values of bond strength with fine grit straight fissure diamond burs, compared to crosscut fissure carbide burs in micromotor, can be attributed to more frictional stresses created due to greater contact between the diamond fine grit and tooth surface as compared to a cutting instrument like a carbide fissure bur (Ogata & others, 2001). Watson, Flanagan and Stone (2000) reported no significant differences in subsurface enamel cracking by diamond and carbide fissure burs; however, they reported a slight increase in temperature by frictional heat using diamond burs as compared to carbide fissure burs. Ogata and others (2001) reported a significantly lower bond strength with regular grit diamond burs at high speed as compared to both plain and crosscut fissure carbide burs at low speed using self-etching systems; while in this study, bond strength achieved with a fine grit straight fissure diamond bur was lower than a crosscut fissure carbide bur but significantly higher than a plain fissure carbide bur.

A higher bond strength with a crosscut fissure carbide bur as compared to a plain fissure carbide bur can be attributed to the increased surface area of tooth substrate. The true contact area between the materials involved may be much greater, because of a mechanically rough interface that allows for better infiltration of the bonding resins. The above findings are well supported by Vaysman and others (2003), who reported the highest reduction in etched and bonded dentin permeability by increased surface area produced by extensively serrated carbide burs.

Unlike the results of previous studies, lower bond strengths depicted with silicon carbide abrasive paper in this study might be due to inaccessibility of the instrument and variations in the amount of pressure application during each in Class II cavities.

The ranking of bond strengths from highest to lowest yielded the following results CCA> DA> CCM> DM> CM> SiC. Statistically significant differences existed ($p<0.05$). From these observations, it is clear that both the type of cutting instrument and its speed may affect the shear bond strength of composite-tooth interface, although the crosscut fissure carbide bur produced high bond strength at either speed used. These differences in mean bond strength values were recorded despite of etching with 38% orthophosphoric acid. These findings are in opposition to the study by Ogata and others (2002), who reported no significant difference in bond strength with different burs after phosphoric acid etching, as it completely removed the smear layer created by the different burs. The results of this study warrant further exploration to determine the degree of roughness with different burs after removal of the smear layer.

Lower bond strength exhibited in this study is further supported by the type of failures seen, which is predominantly adhesive and mixed in nature. These types of failure suggest poor bond strengths at the composite-tooth interface and an improvement in the wetting properties or chemical reactions, with the substrate probably being necessary to improve bond strength.

The variations in bond strength results obtained by the different researchers are significant. Standardization of test methods is needed in order to give comparable values that can be used for both guidance to users and further improvement in adhesives. Further research is required, as this study did not take into account the effect of interproximal contacts between teeth, the smooth carbide burs and silicon carbide paper in air rotor, a lack of standardized preparations by fixing the handpiece in a jig, the different types of bonding agents, the effects of temperature changes on restoration, the effects of longevity on the composite restoration and the different types of testing methods.

While significant progress has been made in the area of adhesion and esthetic restorative materials, numerous questions still remain unanswered in the area of adhesive materials. In particular, the confirmation of preliminary laboratory results with controlled clinical research seldom surfaces or is delayed beyond the commercial life of proprietary adhesive systems. Without such data, little confidence in adhesive behavior can be obtained. More importantly, without a thorough understanding of the performance of adhesives *in vivo*, knowledge will never be gained relative to adhesive mechanisms that are necessary to further technology in this area.

CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that shear bond strength values recorded by maintaining the intrapulpal pressure were lower. Groups with bond strengths from highest to lowest were CCA> DA> CCM> DM> CM> SiC. The bond strength achieved with a fine grit straight fissure diamond bur or a crosscut fissure carbide bur in air rotor and a crosscut fissure carbide bur in micromotor was significantly higher than a fine grit straight fissure diamond bur, a plain fissure carbide bur and #600 grit silicon carbide abrasive paper in micromotor. Therefore, both the bur and its speed may affect bonding, although the crosscut fissure carbide burs produced high bond strength at either speed used.

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References

Blomlof J, Cederlund A, Jonsson B & Ohlson N (2001) Acid conditioning combined with single-component and two-component dentin bonding agents *Quintessence International* **32(9)** 711-715.

Bouillaguet S, Ciucchi B, Jocoby T, Wataha JC & Pashley D (2001) Bonding characteristics to dentin walls of Class II cavities, *in vitro Dental Materials* **17(4)** 316-321.

Brännström M, Linden L & Johnson G (1968) Movement of dentinal and pulpal fluid caused by clinical procedures *Journal of Dental Research* **47(5)** 679-682.

Davidson CL, de Gee AJ & Feilzer AJ (1984) The competition between the composite-dentin bond strength and the polymerization contraction stress *Journal of Dental Research* **63(12)** 1396-1399.

Della Bona A & Summitt JB (1998) The effect of amalgam bonding on resistance form of Class II amalgam restorations *Quintessence International* **29(2)** 95-101.

Eick JD, Wilko RA, Anderson CH & Soresen SE (1970) Scanning electron microscopy of cut tooth surfaces and identification of debris by use of the electron microprobe *Journal of Dental Research* **49(6)** 1359-1368.

Eick JD, Johnson LN, Fromer JR, Good RJ & Neumann AL (1972) Surface topography: Its influence on wetting and adhesion in a dental adhesive system *Journal of Dental Research* **51(3)** 780-788.

Erickson RL (1992) Surface interactions of dentin adhesion materials *Operative Dentistry* **(Supplement 5)** 81-94.

Feilzer AJ, de Gee AJ & Davidson CL (1987) Setting stress in composite resin in relation to configuration of the restoration *Journal of Dental Research* **66(11)** 1636-1639.

Gilboe DB, Svare CW, Thayer KE & Drennon DG (1980) Dentinal smearing: An investigation of the phenomenon *Journal of Prosthetic Dentistry* **44(3)** 310-316.

Lopes GC, Baratieri LN, Andrada MAC & Vieira LCC (2002) Dental adhesion: Present state of the art and future perspectives *Quintessence International* **33(3)** 213-224.

Marzouk MA, Simonton AL & Gross RD (2001) *Operative Dentistry Modern Theory and Practice* 1st Indian ed, Ishiyaka Euro America Inc Tokio St Louis.

Mitchem JC & Gronas DG (1991) Adhesion to dentin with and without smear layer under varying degrees of wetness *Journal of Prosthetic Dentistry* **66(5)** 619-622.

Mitchem JC, Terkla LG & Gronas DG (1988) Bonding of resin dentin adhesives under simulated physiological conditions *Dental Materials* **4(6)** 351-353.

Nikaido T, Burrow MF, Tagami J & Takatsu T (1995) Effect of pulpal pressure on adhesion of resin composite to dentin: Bovine serum versus saline *Quintessence International* **26(3)** 221-226.

Ogata M, Harada N, Yamaguchi S, Nakajima M, Pereira PN & Tagami J (2001) Effects of different burs on dentin bond strengths of self-etching primer bonding systems *Operative Dentistry* **26(4)** 375-382.

Ogata M, Harada N, Yamaguchi S, Nakajima M & Tagami J (2002) Effect of self-etching primer vs phosphoric acid etchant on bonding to bur–prepared dentin *Operative Dentistry* **27(5)** 447-454.

Ozok AR, Wu MK & Wesserlink PR (2002) Comparison of the *in vitro* permeability of human dentin according to the dentinal region and the composition of the simulated dentinal fluid *Journal of Dentistry* **30(2-3)** 107-111.

Pashley DH (1984) Smear layer: Physiological considerations *Operative Dentistry* **(Supplement 3)** 13-29.

Pashley DH, Livingstone MJ & Greenhill JD (1978) Regional resistances to fluid flow in human dentin *in vitro Archives of Oral Biology* **23(9)** 807-810.

Pashley DH, Sano H, Ciucchi B, Yoshiyama M & Carvalho RM (1995) Adhesion testing of dentin bonding agents: A review *Dental Materials* **11(2)** 117-125.

Perdigão J, Baratieri LN & Lopes M (1999) Laboratory evaluation and clinical application of a new one-bottle adhesive *Journal of Esthetic Dentistry* **11(1)** 23-35.

Perdigão J, Lambrechts P, Van Meerbeek B, Braem M, Yildiz E, Yucel T & Vanherle G (1996) The interaction of adhesive systems with human dentin *American Journal of Dentistry* **9(4)** 167-173.

Pioch T, Staehle HJ, Schneider H, Duschner H & Dorfer CE (2001) Effect of intrapulpal pressure simulation *in vitro* on shear bond strengths and hybrid layer formation *American Journal of Dentistry* **14(5)** 319-323.

Rosa BT & Perdigão J (2000) Bond strengths of non rinsing adhesives *Quintessence International* **31(5)** 353-358.

Royer MA & Meiers JC (1995) Shear bond strength of resin to acid/pumice micro abraded enamel *Operative Dentistry* **20(4)** 155-159.

Stead WJ, Orchardson R & Warren PB (1996) A mathematical model of potassium ion diffusion in dentinal tubules *Archives of Oral Biology* **41(7)** 679-687.

Summitt JB, Della Bona A & Burgess JO (1994) The strength of Class II composite resin restorations as affected by preparation design *Quintessence International* **25(4)** 251-257.

Van Hassel HJ (1971) Physiology of the human dental pulp *Oral Surgery Oral Medicine Oral Pathology* **32(1)** 126-134.

Van Meerbeek B, De-Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P & Vanherle G (2003) Adhesion to enamel and dentin: Current status and future challenges *Operative Dentistry* **28(3)** 215-235.

Vaysman T, Rajan N & Thompson VP (2003) Effect of bur cutting patterns and dentin bonding agents on dentin permeability in a fluid flow model *Operative Dentistry* **28(5)** 522-528.

Watanabe I, Nakabayashi N & Pashley DH (1994) Bonding to ground dentin by a Phenyl-P self-etching primer *Journal of Dental Research* **73(6)** 1212-1220.

Watson TF, Flanagan D & Stone DG (2000) High and low torque handpieces cutting dynamics, enamel cracking and tooth temperature *British Dental Journal* **188(12)** 680-686.

Yaman SD, Alacam T & Yaman Y (1998) Analysis of stress distribution in a maxillary central incisor subjected to various post and core applications *Journal of Endodontics* **24(2)** 107-111.

Yaman SD, Yetmez M, Turkoz E & Akkas N (2000) Fracture resistance of Class II approximal slot restorations *Journal of Prosthetic Dentistry* **84(3)** 297-302.

Yoshikawa T, Sano H, Burrow MF, Tagami J & Pashley DH (1999) Effects of dentin depth and cavity configuration on bond strength *Journal of Dental Research* **78(4)** 898-905.