EFFECT OF PULPAL PRESSURE ON MICROTENSILE BOND STRENGTH OF SELF-ETCH SYSTEMS TO DENTIN. APPLICATION OF TWO ADHESIVE LAYERS

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Abstract

The first objective of this study was to examine effect of simulated hydrostatic pulpal pressure (PP) on μTBS of Bond Force (BF) (Tokuyama Corp., Tokyo, Japan), applied in a single or double layer. The second objective was to evaluate dentin location influence (superficial and deep) on μTBS.

Flat coronal dentin surfaces of extracted human molars were prepared. Two groups were created with two different conditions of PP. In group A no PP was present (0 cm) during BF application and composite build-up. In group B a PP (20 cm H2O) was present during BF application. Specimens bonded under PP were stored in water at 37C° under 20 cm H2O for 20 min. For both groups BF was applied in single (subgroups A1,B1) or double layer (A2,B2). Flowable resin composite (Estelite Flow Quick Tokuyama Corp., Tokyo, Japan) was used for the build-up. Beams with a 1.0 mm2 area were obtained and stressed to failure using microtensile tester.

Application of two layers of BF showed higher μTBS than single application in all tested conditions. PP was responsible for a statistical reduction in μTBS only when Bond Force was applied in single coat. Superficial dentin showed higher values than deep dentin in all conditions but no statistical differences were found. A highly significant correlation was observed between droplets presence and μTBS results.

The application of a double layer of BF is a clinical requirement to avoid the reduction in μTBS and prevent any interference of pulpal pressure.

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Introduction

The application procedure of a one-step self etch adhesive may take considerably less time compared with their multi-step counterparts, and this may be an important clinical advantage. Unfortunately they exhibit high permeability, resulting in water flow through the adhesive thus, exhibiting a dramatic reduction in bond strength after water storage[1].

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The outward movement of dentinal fluid under a slight positive pulpal pressure may probably permeate polymerized hydrophilic adhesives[2], hindering monomer infiltration into the demineralised collagen matrix contaminating the bonding surface with water.

Pulpal pressure has been reported to influence the surface wetness and to affect the bond strength of different types of DBAs[3] and it is in relationship with remain dentin thickness (RDT). Periotron device was used to measure the surface humidity of dentin samples, supporting the concept that the dentin surface is wet, especially after smear layer removal and under a physiological pulpal pressure[3]. For optimal bonding to dentin, the consequence of outward fluid through the dentinal tubules due to the positive pulpal pressure should be taken into consideration. There have been many bonding studies performed under a simulated hydrostatic pulpal pressure[2,4,5,6]. However, few *in vitro* studies have tested the efficacy of a new all-in-one adhesive under physiological condition (hydrostatic pulpal pressure) when applied in a single or double layer.

The aim of this study was to evaluate the μTBS to deep and superficial dentin bonded with one or two coats of BF bonded and stored under zero and 20 cm H_2O hydrostatic PP. The null hypothesis tested was that positive PP does not affect the bond strength of BF to dentin.

Materials and Methods

Twenty extracted human third molar teeth were stored in 4 °C water for no more than one month. A flat midcoronal dentin disc was prepared by removing the occlusal enamel with a slow-speed diamond saw (Remet, Bologna, Italy) under water cooling. A 180-grit silicon carbide paper was used under running water to create a clinically relevant smear layer on the dentin surface. The root of each tooth was removed below the cement-enamel junction so as to expose the pulp chamber. The pulpal tissue was removed with a small forceps, taking care to avoid touching the pulp chamber walls. A pincer-type caliper was used for measurement of the remaining dentin thickness (RDT) that was between 0.9 and 1.5 mm. Each crown segment was attached to a Plexiglas platform (2 ×2 × 0.5 cm) and sealed with cyanocrylate (ROCKET Heavy DVA, Corona, CA, USA). Each platform was penetrated by a short length of 18-gauge stainless steel tube into a center hole created in a piece of Plexiglas. Each Plexiglas-tooth assembly was attached via polyethylene tubing to 20-ml syringe barrel filled with distilled water in order to produce a hydrostatic pressure of 20 cm H_2O at the dentin surface to be bonded (Group A). In the control group, the barrel remained empty (Group B).

The specimens of the two experimental groups were divided into two subgroups (n = 5) (A1, A2), (B1, B2) according to the number of BF layers applied.

To the first subgroup (A1 and B1) a single layer of BF was applied, thinned with a gentle air spray and light cured for 20 s. In the other subgroup (A2 and B2) a first layer of BF was applied, thinned with a gentle air spray followed by the application of a second layer, thinned once again with air and finally light cured for 20 s.

Finally, a 5 mm-thick resin composite build-up was performed on the resin-bonded dentin surfaces using a light-cured flowable composite (Estelite Flow Quick, Tokuyama Corp., Tokyo, Japan). Each of four 1.5 mm increments was light-cured for 40 s at 600 mW/cm^2 using a halogen curing unit (XL-2500, 3M ESPE, St. Paul, MN, USA). The bonded specimens were stored in water at 37°C for 20 min before testing. The simulated hydrostatic pulpal pressure (0 or 20 cm H_2O) was maintained during storage.

Microtensile Bond Strength Evaluation

After a 20 min storage, all samples (A1, A2, B1, B2) were sectioned perpendicular to the adhesive interfaces into 1 mm-thick slabs using the a diamond saw under water cooling. Each slab was subsequently trimmed to produce resin-dentin beams with a cross-sectional area of 1.0 mm^2 (measured with a digital calliper) at the bonded interface.

Ten teeth were used for each group and ten to twelve beams were obtained from each tooth. The beams were then attached with cyanoacrylate to a testing jig, and loaded in tension with a universal testing machine (Bisco Inc., Schaumburg, IL, USA) at a crosshead speed of 0.9 mm/min. until failure.

Tested specimens were mounted on stubs, sputter coated with gold, and observed with a scanning electron microscope (JSM-5200, JEOL, Tokyo, Japan) for evaluating the failure mode and the morphology the of fracture between dentin and composite build-up. The digitalized SEM images were subjected to quantitative image analysis using a digital slow-scan image recording system (SemAfore, JEOL, Sollentuna, Sweden).

The microtensile bond strength data was analyzed by using a two-way ANOVA to test the effect of the adhesive system and the experimental condition (simulated pulpal pressure or no pulpal pressure) on bond strength.

Results

The μTBS results are summarized in Table I. Bond strength was influenced by the number of BF layers applied and by pulpal pressure during bonding and storage. Pulpal pressure was responsible for a considerable reduction of μTBS, especially when BF was applied in a single layer. The application of two layers of BF showed higher μTBS than the single application in all of the tested conditions. Superficial dentin showed higher bond strength than deep dentin in all tested conditions but no statistical differences were found with respect to deeper dentin.

Microtensile Bond Strength				
Material	**No Pulpal Pressure (MPa) (Group A)**		**With Pulpal Pressure (MPa) (Group B)**	
	Deep dentin	*Superficial dentin*	*Deep dentin*	*Superficial dentin*
BF *One layer* n = 80	17.4 ± 7.0 $_{a,1}$	18.1 ± 7.5 $_{a,1}$	5.7 ± 2.0 $_{b,2}$	6.8 ± 2.9 $_{b,2}$
BF *Two layers* n = 76	23.3 ± 5.8 $_{c,3}$	25.3 ± 3.8 $_{c,5}$	17.2 ± 7.7 $_{a,4}$	20.5 ± 5.6 $_{d,6}$

n = number of tested sticks
For the column "Deep dentin", values with the same lower case letter superscripts are not statistically significant (p > 0.05).
For the column "Superficial dentin", values with the same lower case letter superscripts are not statistically significant (p > 0.05).
For the column "No Pulpal Pressure", values with the same lower case letter superscripts are not statistically significant (p > 0.05).
For the column "Pulpal Pressure during G-BOND application", values with the same lower case letter superscripts are not statistically significant (p > 0.05).

Table I. Microtensile bond strengths (means ± standard deviation) of BF bonded to deep and superficial dentin with and without pulpal pressure application.

Pulpal pressure was able to considerably reduce microtensile bond strength both for deep and for superficial dentin (Table II) but it had a greater influence in deep dentin.

Material	**% change from no PP values (deep dentin)**	**% change from PP values (superficial dentin)**
Bond Force ***One layer***	- 67.2	- 62.4
Bond Force ***Two layers***	- 26.2	- 19

Table II. Percentage of μTBS change in deep and superficial dentin under pulpal pressure.

A highly significant correlation was observed between the presence of droplets inside adhesive layer and μTBS results.

SEM micrographs of BF applied in a single layer did not show the presence of voids inside the adhesive thickness (Figure 1a and 1b).

Figures 1c and 1d micrographs show representative samples of BF applied with pulpal pressure (dentin side). A mixed fracture pattern was observed. Almost the entire adhesive layer was affected by droplets (c). Droplet dimensions varied from 1 to 20 μ.

Figures 1e and 1f show the morphology of the bond surface when BF is applied in two coats in the presence of pulpal pressure. A cohesive failure inside the thickness of the resin composite can be observed (composite side).

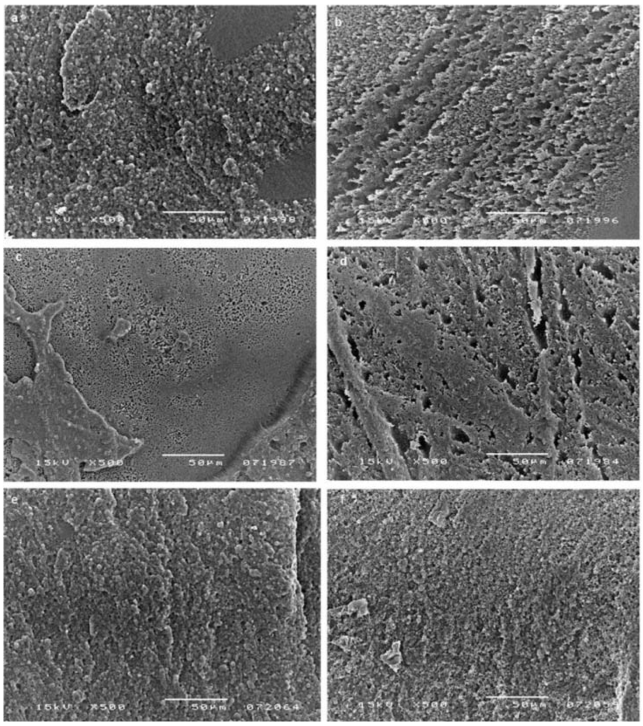

Figure 1. SEM photomicrographs illustrating fractured samples bonded with BF (one layer). a and b micrograph show the morphology of bond surface when BF is applied without pulpal pressure (dentin side). Delamination of the bonding layer were observed. c and d micrographs shows a representative samples of BF applied with pulpal pressure (dentin side). A mixed fracture pattern was observed. Almost the entire adhesive layer was affected by droplets (c). Droplets dimension varying from 1 to 20 μ. e and f show the morphology of the bond surface when BF is applied in two coats in the presence of pulpal pressure. A cohesive failure inside the thickness of the resin composite can be observed (composite side).

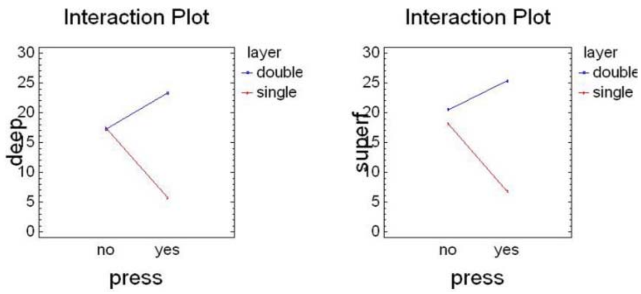

Figure 2. Statistical analysis.

Discussion

In vitro simulated pulpal pressure adversely affected bonding of BF to coronal dentin. Therefore, the null hypothesis that positive pulpal pressure does not affect bond strength of BF must be rejected. The all-in-one self-etching adhesive contains hydrophilic and hydrophobic resin monomers with a high solvent content[7, 8]. The presence of water is essential for providing an ionization medium for self-etching activity[9]. Prior to photopolymerization, the complete elimination of both water and solvents is needed. The role played by volatile solvents (acetone or ethanol) in promoting water displacement from the dentinal surface is well established[10]. Water that permeated dentin under a simulated pulpal pressure may have resulted in the lower achieved under pulpal pressure. When a simulated hydrostatic positive pressure is applied to dentin, an outward fluid flow from the dentinal tubules may occur across the smear layer, resulting in “wet bonding” instead of the recommended dry bonding for which these one-step adhesives are ideally designed. In the specimens bonded without simulated pulpal pressure, the water in the adhesive can be evaporated by an air blast. However, specimens bonded under a simulated pulpal pressure may replace that of evaporated water.

HEMA-based adhesives are prone to hydrolytic degradation, resulting in reduction of their mechanical properties[11]. The study demonstrated that the adhesion of BF may be influenced by simulated pulpal pressure only when a single layer of bonding agent has been applied on dentin surface (Figure 2). The resin-dentin bond achieved with two layers of BF appeared less sensitive to the application of hydrostatic pulpal pressure respect to the application of a single layer. The application of the second layer on the primed dentin may increase hydrophobic layer thickness, prevent the formation of water channels in the adhesive layer after polymerization improving the degree of conversion. Moreover, the second layer may probably fill all the porosities and voids created by the application of first layer and produce a solid layer of resin with a greater and deeper anchorage to the collagen fibers of exposed dentin.

In the present study, deep and superficial dentin were divided because of the different permeability rate and the different orientation of tubules. In fact it is well known that dentin has far more tubules in the deepest area near the pulp than on the surface, close to enamel junction.[12]

Conclusions

Pulpal pressure is responsible for a significantly reduction in bond strength when adhesives are applied in deep dentin. All-in-one adhesive systems are particularly prone to pulpal pressure. The present study showed that the clinical performance of All-in-one adhesive systems could be improved by the application of a double layer before the polymerization. This particular type of application is important especially in deep dentin in which the effect of pulpal pressure is well detectable.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

References

1. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, Van Meerbeek B. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res 2005; 84: 118–132.
2. Sauro S, Pashley DH, Montanari M, Chersoni S, Carvalho RM, Toledano M, Osorio R, Tay FR, Prati C. Effect of simulated pulpal pressure on dentin permeability and adhesion of self-etch adhesives. Dent Mater 2007; 23: 705-13.
3. Prati C, Pashley DH. Dentin wetness, permeability and thickness and bond strength of adhesive systems. Am J Dent 1992; 5: 33-8.
4. Elhabashy A, Swift EJ Jr, Boyer DB, Denehy GE. Effects of dentin permeability and hydration on the bond strengths of dentin bonding systems. Am J Dent 1993; 6: 123-6.
5. Hosaka K, Nakajima M, Monticelli F, Carrilho M, Yamauti M, Aksornmuang J, Nishitani Y, Tay FR, Pashley DH, Tagami J. Influence of hydrostatic pulpal pressure on the microtensile bond strength of all-in-one self-etching adhesives. J Adhes Dent 2007; 5: 437-442.
6. Tao L, Tagami J, Pashley DH. Pulpal pressure and bond strengths of SuperBond and Gluma. Am J Dent 1991; 4: 73-6.
7. Tay FR, Pashley DH. Have dentin adhesives become too hydrophilic? J Can Dent Assoc 2003; 69: 726-31.
8. Van Landuyt KL, De Munck J, Snauwaert J, Coutinho E, Poitevin A, Yoshida Y, Inoue S, Peumans M, Suzuki K, Lambrechts P, Van Meerbeek B. Monomer-solvent phase separation in one-step self-etch adhesives. J Dent Res 2005; 84: 183-8.
9. Schulze KA, Oliveira SA, Wilson RS, Gansky SA, Marshall GW, Marshall SJ. Effect of hydration variability on hybrid layer properties of a self-etching versus an acid-etching system. Biomaterials 2005; 26: 1011-8.
10. Tay FR, Gwinnett JA, Wei SH. Micromorphological spectrum from overdrying to overwetting acid-conditioned dentin in water-free acetone-based, single-bottle primer/adhesives. Dent Mater 1996; 12: 236-44.
11. Ito S, Hashimoto M, Wadgaonkar B, Svizero N, Carvalho RM,

Yiu C, Rueggeberg FA, Foulger S, Saito T, Nishitani Y, Yoshiyama M, Tay FR, Pashley DH. Effects of resin hydrophilicity on water sorption and changes in modulus of elasticity. Biomaterials 2005; 26: 6449-59.
12. Garberoglio R, Brännström M. Scanning electron microscopic investigation of human dentinal tubules. Arch Oral Biol 1976; 21: 355-62.