Journal of Dentistry and Oral Hygiene Vol. 3(4), pp.57- 60, April 2011
Available online at http://www.academicjournals.org/JDOH
ISSN 2141-2472 ©2011 Academic Journals

Full Length Research Paper

Using electric current during dentin bonding agent application and its effect on microleakage under simulated pulpal pressure conditions

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Accepted 21 February, 2011

The use of electric current during application of etch-and-rinse adhesive systems has been recently introduced to decrease microleakage. This study investigated the effects of an electric field produced by an experimental device for the application of a two-step etch-and-rinse adhesive on moist dentin surface. Sixty freshly extracted human premolars were used for this study. In order to simulate real conditions, the pulpal pressure was set to 35 cm H_2O for all the specimens. The teeth were divided into two groups: Group N1: Etch-and-rinse system (Single bond) applied with electric current, and group 2: Etch-and-rinse system (Single bond) applied without electric current Specimens were prepared for dye penetration test. The data were analyzed using the Kruskal-Wallis and Mann-Whitney U tests. The results showed that group 1 demonstrated the least microleakage scores compared to group 2. As a result of these findings, it could be concluded that using electric current for applying adhesive systems had a statistically significant effect on reducing microleakage.

Key words: Dental bonding systems, electric current, micrileakage.

INTRODUCTION

Despite the recent developments in adhesive dentistry to reduce the number of working steps and to simplify the clinical procedure, bonding to dentin and complete sealing of the exposed dentinal surfaces remain problematic (Nakabayashi and Pashley, 1998) and the new simplified adhesives do not produce better results in *in vitro* tests (Munck et al., 2005) or improve clinical efficacy (Tay and Pashley, 2003).

Different modifications to the application protocols of these simplified etch and rinse adhesives have been reported. They include the application of multiple layers (Hashimoto et al., 2004; Pashley et al., 2002) enhanced solvent evaporation (Hashimoto et al., 2005) and prolonged curing time (Cadenaro et al., 2005). All dentin adhesives are currently applied mechanically to tooth structures using either disposable sponges or brushes. An adhesive application protocol, based on the use of an electric signal to enhance monomer infiltration in dentin, has been introduced .This technique utilizes an electric field to enhance resin infiltration into the demineralized collagen matrices of acid-etched dentin (Pasquantonio et al., 2007).

Bonding to dentin and complete sealing of the exposed dentinal surfaces is troublesome also because of the highly hydrated and complex nature of the tissue. Dentin tubules constitute 20 to 39% of dentin, and the fluid within them represents 22% of dentin volume (Mjor and Nordahl, 1996). The fact is easily overlooked in the design of most *in vitro* studies in which the effect of pulp pressure on the bonding interface is not considered.

This study investigated the effects of an electric field produced by an experimental device for the application of one two-step etch-and-rinse adhesive on moist dentin surface. In order to simulate real conditions, the pulpal pressure was set for all the specimens. The null

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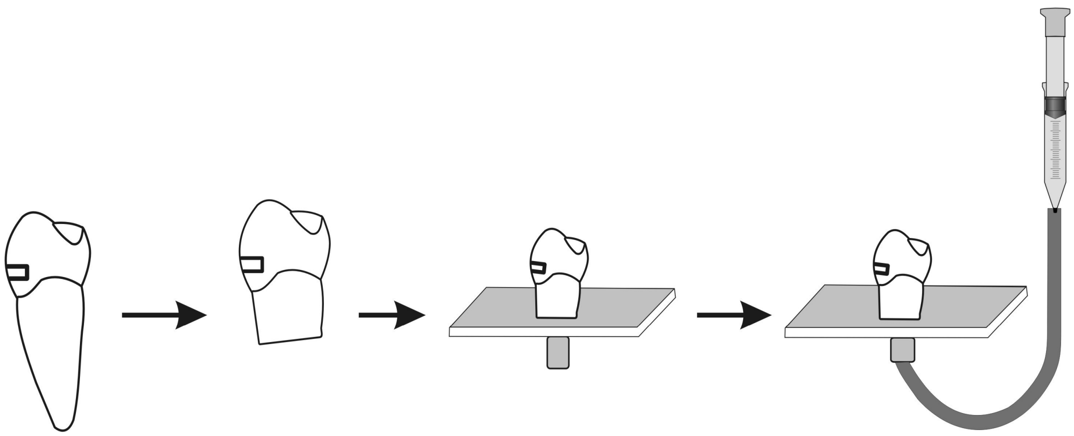

Figure 1. Schematic showing how crown segments were created, attached to plexiglass and how fluid permeability was measured under 35 cm H_2O pressure.

hypothesis was that there is no difference in the microleakage between a conventional mechanical adhesive application technique and the use of an electric impulse assisted adhesive application technique under simulated pulpal pressure condition.

MATERIALS AND METHODS

Sixty freshly extracted, caries free human premolars were selected. The teeth were cleaned thoroughly to remove both hard and soft deposits and were kept in distilled water at 4°C for 24 h. Class v cavities were prepared, with the gingival margin 1 mm below the CEJ, using a # 4 round bur (Brasseler, Savannah, GA, USA) with a high speed handpiece and copious amounts of water. The preparations were standardized at 4 mm long, 3 mm wide and 2 mm in depth and placed in the facial surfaces of each tooth. A 0.5 mm width bevel was placed on the enamel margins. The apical half of each tooth was removed. Pulp tissue was removed by means of endodontic K-files (# 20) taking care to avoid touching the pulp chamber walls. The pulp chambers were then irrigated with 2.5% sodium hypochlorite solution (NaOCl) for 30 s followed by immersion in distilled water for 30 min to neutralize the effects of NaOCl . All of crown segments were luted with cyanoacrylate (Zapit, DVA, Anaheim, CA, USA) to a Plexiglas plate through which an 18-gauge stainless steel tube had been inserted. This tube permitted communication with the pulp chamber and was attached to an empty 20 ml plastic syringe barrel which was 10 cm height. The barrel was filled with distilled water and raised 25 cm from tooth level, in order to produce a pressure of 35 cm H_2O at the dentine surface to be bonded (Figure 1).

Each prepared tooth was then etched with phosphoric acid (Ultra-etch 35%, Ulteradent, South Jordan, UT USA) for 15 s, rinsed for 20 s, and then gently blown to remove excess water, being careful to maintain a moist surface. Then the teeth were randomly divided into two groups. Thirty teeth were assigned to each group.

In group I, the adhesive (Single Bond, 3M ESPE, St Paul, MN, USA) was applied using the experimental electric device (Multifrequency current source, Iran) which created an electric potential difference between the dentin substrate and the adhesive applicator tip. The electric applicator was used with a continuous brushing motion. The device induced an electric flow over 15 µA throughout the adhesive interface during the application procedure.

In group II, the adhesive was applied in the same manner, but with the electric generator switched off. A single blind study design was used, in which the operator performing the bonding procedure was not aware of the operating state of the electrical device (that is, switched-on mode or switch-off mode).

The adhesives were then light activated for 20 s at 600 mW/cm^2 using a Quartz-Tungsten-Halogen light (coltolux 50, coltene/Whaledent Inc,Cuyahoga Falls OH,USA). Prior to this stage, the curing light was tested with a curing radiometer (coltene/Whaledent Inc,Cuyahoga Falls OH,USA) and the output intensity was maintained at 600 mW/cm^2 throughout the restorative procedures. One increment of microhybrid resin composite (Valux Plus A2, 3M ESPE, St Paul, MN, USA) was placed over the bonded dentin surface and polymerized for 40 s. The restorations were finished wet immediately using sof-lex disks (3M ESPE, St Paul, MN, USA).

The teeth were stored in distilled water for 24 h at 37°C before thermocycling which comprised 1000 cycles (20 s in a 55°C water bath, followed by 20 s in a 5°C water bath, with a dwell time of 5 s). An acid-resistant varnish (nail polish) was applied to all surfaces of the teeth except for 1 mm adjacent to the restoration margins. All specimens were then immersed in 0.2% basic fuschin for 24 h at 37°C, and then washed in running water. The teeth were embedded in epoxy resin blocks then sectioned buccolingually through the center of the restoration with a diamond disk (KG Sorensen Ind Com Ltd, São Paulo, Brazil) at low speed.

Dye penetration at the gingival margin was examined using a stereomicroscope at 40× and scored according to the following criteria: 0 = no dye penetration; 1 = Dye penetration that extended up to ⅓ of the preparation depth; 2 = Dye penetration greater than ⅓, up to ⅔ of the preparation depth; 3 = Dye penetration extending to the axial wall; 4 = Dye penetration past the axial wall (Figure 2).

RESULTS

Table 1 shows microleakage scores for the two groups. Statistical analysis was performed utilizing the Kruskal-Wallis followed by a Mann-Whitney test. When comparing the two groups, the Wilcoxon Rank test showed less dye penetration in group I in which bonding agent was applied to dentin by the electric-current-assisted application technique ($p = 0.047$).

Figure 2. Diagram of microleakage evaluation criteria.

Table 1. Microleakage scores for the two groups.

	Score 0	Score 1	Score 1	Score 2	Score 3	Score 4	# Total
Group I: With electric current	6	9	9	6	7	2	30
Group II: Without electric current	3	6	6	5	10	6	30

DISCUSSION

The results of this study require rejection of the null hypothesis that there is no difference in the microleakage between a conventional mechanical adhesive application technique and the use of an electric impulse assisted adhesive application technique under simulated pulpal pressure condition. That is, using electric current for applying the etch and rinse adhesive (Single Bond) had a significant effect on reducing microleakage compared to the conventional application technique.

In vitro studies examining the microleakage are useful but most are not done under *in vivo* conditions, that is, the teeth are non-vital and are not subjected to pulpal pressure. In the present study, the entire evaluation was carried out under simulated pulpal pressure and the teeth were submitted to thermocycling to obtain a condition as similar as possible to the *in vivo* conditions.

Interpretations of the better microleakage results that accompanied the use of an assisted electric field may be explained with hypotheses: Since single bond contains HEMA (Hydroxy ethyl metacrylate),acrylic acid copolymer and itaconic acid which are polar components, it is speculated that this adhesive may interact with the electric field generated by the electric device used in this study. Polyalkenoic acid polymers contain ionisable carboxylic acid groups.

Thus, iontophoresis may enhance the movement of ions across dentin (Pashley et al., 1978). This should be related to a faster rate of impregnation as ionic monomers are moving across the dentin with increasing ion mobilities that are caused by the imposed electrical gradient (Padula et al., 2003). Furthermore, because they are charged particles, these monomers are physically attracted by the electric field, thus increasing the flow which is revealed by the reduced microleakage when applying the bonding agent with electric device. The difference in electric potential between the adhesive and etched dentin could have also enhanced the penetration of adhesive monomers due to a biophysical modification of the organic matrix, or could have enhanced the wettabiliy of the etched dentin surface, thereby improving the spreading of the adhesive.

Several devices that rely on the tooth's electrical properties are used in dentistry. Electronic root apex locators (Sunada, 1962), pulp vitality tester (Daskalov et al., 1997) and early caries lesion detectors (Huysmans et al., 1995) are some of the tested devices. Since dentin is not a pure capacitor or resistor, the flow of electricity depends upon the relative humidity of the environment (Krizaj et al., 2004). Etching of the surface and subsequent exposure of the organic matrix in a wet environment increase the electric flow by reducing resistance (Eldarrat et al., 2003). Furthermore in our study, the use of simulated pulpal pressure condition further increased the fluid flow to the bonding interface. Thus, to ensure consistency of results, we subjected all teeth to the same electrical experimental conditions, regardless of the tooth dimensions. The experimental electric device was adjusted to electrical values that are compatible with *in vivo* use (Rizaj et al., 2004).

It is worth mentioning that the intrinsic wetness of dentin and the perfusion of fluid from the pulp chamber should be considered when bonding to deep dentin. The density of water-filled dentin tubules and hence intrinsic water content of dentine increases with dentin depth (Pashley, 1991) and these factors may increase the microleakage and affect the longevity of the restoration. Several investigations have also demonstrated the sensitivity of various bonding systems to pulpal pressure. Outward fluid flow from dentinal tubules in the mouth might contribute to a more rapid degradation of resin-dentin bonds *in vivo* (Ciucchi et al., 1995; Toledano et al., 2003).

In conclusion, this study represents an attempt in reducing microleakage that is associated with the use of an electric impulse assisted application technique for the bonding of one etches and rinse adhesive to acid etched dentin. The use of simulated pulpal pressure is a further step toward simulation of *in vivo* condition.

Conclusions

The results of this *in vitro* study which was performed under simulated pulpal pressure showed that using electric current for applying the etch and rinse adhesive system (Single Bond) have a significant effect on reducing microleakage.

Further *in vivo* studies should be carried out to confirm that an electric device is effective in improving longevity of resin-dentin bonds through reducing the microleakage *in vivo*.

ACKNOWLEDGEMENT

This report is part of a project, financially supported and approved by the Research Deputy of Ahwaz Jundishapour University of Medical Sciences, Iran for which authors would like to thankfully acknowledge.

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