An *in vitro* evaluation of microleakage in class I preparations using 5th, 6th and 7th generation composite bonding agents

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The intent of this study was to evaluate microleakage of newer generations of dentinal bonding systems of Class I restorations filled with the same resin based composites. Eighty extracted human premolar and molar teeth were randomly assigned to four groups for bonding: the 5th generation bonding system (Optibond Solo), the 6th generation bonding system (Prompt-L-Pop) and the 7th generation bonding system (iBond), and a control group that was used with no dentinal bonding system. Cavities were prepared 3mm in width, 2mm in depth and 2mm in length. Margins of the cavities were chamfered using a high-speed hand piece with water spray and a #1/2 round diamond bur. The cavities were restored with resin based composites after the application of the dentinal bonding systems according to the instructions of the manufacturer. Upon drying of the teeth, two coats of nail varnish were applied covering the surface of the tooth, excluding the tooth-restoration interface. Samples were thermocycled and immersed in methylene blue dye (0.05%). Each sample was sectioned with an Isomet and evaluated, for microleakage using light microscopy under a measuring microscope at 50x magnification

Statitical significance was determined using the Chi-Square Test. Among the three dentinal adhesive systems used in this study the 5th generation outperformed both the 6th and 7th generation bonding systems.

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INTRODUCTION

The most current breakthrough in dental adhesive systems used in composite bonding restorations is the 7th generation bonding system. The claim of the manufacturer is that this bonding system will eliminate mixing and etching, while at the same time accomplishing the priming and the bonding of the dental surfaces. If proven successful, this new system has the ability to greatly simplify the adhesive procedure.

Adhesive dentistry began in 1955, when Buonocore described the acid etching technique on enamel[1]. Since then, a large number of adhesive systems have been introduced in the market as new adhesive methods were developed. Adhesion has been defined as the mechanism that bonds two materials in intimate contact across an interface, and perfect adhesion to dental substances is the main objective.[2] The capacity of clinicians to bond restorative materials to enamel and dentin has fundamentally changed concepts of cavity preparations, orthodontic treatment, caries prevention, and cementation of fixed prostheses.

Adhesion is a process of solid and/or liquid interaction of one material (adhesive or adherent) with another (adherent) at a single interface. This is also called dental bonding. Adhesion is classified as physical, chemical, and/or mechanical bonding. Physical bonding involves Van der-Waals forces, which are forces between molecules of the same substance. They are different than the forces that make up the molecule. For example, these forces can be formed between separate H_2O molecules. Chemical bonding involves bonds between atoms formed across the interface from the adhesive to the adherent. Mechanical bonding is the result of an interface that involves undercuts and other irregularities that produce interlocking of the materials.

After conditioning enamel, an irregular surface is produced and then the low viscosity fluid resin is

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applied that will be pulled into the microporosities of the enamel through capillary attraction. Enamel bonding depends on resin tags becoming interlocked with the surface irregularities created by etching. This is a result of the resin monomers being polymerized. Microtags and macrotags formed are the basis for micro-mechanical bonding. Microtags are more important because of the large numbers and great surface of contact, leading to a strong micromechanical interlocking with the enamel.

Dentin-bonding system involves an unfilled, liquid acrylic monomer mixture, which is placed onto an acid conditioned and primed dentin surface.[3] Acid interacting with dentin, removes the debris layer from the dentin and is responsible for dentinal demineralization to depths of 0.5 to 7.5micrometer, depending on the type, concentration, pH, and viscosity of acid.[4] As opposed to enamel, which is composed of more than 90% of hydroxyapatite, dentin is an intrinsically wet organic tissue penetrated by a tubular maze containing the odontoblastic processes, which communicates with the pulp. Whenever the dentinal surface is prepared with a bur or other instrument, residual organic and inorganic components form a smear layer of debris on the surface. The smear layer fills the entrance of the dentin tubules to form smear plugs, which can decrease dentin permeability by up to 86%.[5] Although the smear layer acts as a diffusion barrier that decreases the permeability of dentin, it also can be considered an obstacle that must be removed so that resin can be bonded to dentin.

Although enamel adhesion is a predictable and established entity in restorative dentistry, an adequate bond to dentin is more difficult to achieve.[2] To overcome this challenge, technological advancement of dentin adhesives has, at this time, involved two trends: the total acid-etching techniques and the self etching primer technique. To interact with the intrinsically moist tissue of dentin, an adhesive system must react under such conditions, therefore hydrophilic primers became part of numerous adhesive systems seeking to secure a strong bond to dentin. Incorporated hydrophilic components are able to dislodge moisture from the conditioned dentin and attain an intimate interaction at the demineralized intertubular and peritubular dentin, creating the hybrid layer, which seems to be essential for an ideal bond to dentin. In principle, the capacity of solvents (acetone and ethanol) included in hydrophilic agents to go after water creates greater interdiffusion to dentin.[6,7]

Self-conditioning adhesives are acidic primers capable of penetrating the aqueous channels formed between the smear layer particles, widening these channels and interacting at the top of the underlying dentin.[8,9] These bonding systems do not remove the smear layer, but make it permeable to the monomers subsequently applied. The rationale behind the action of self-etching agents is the formation of a continuum between tooth surfaces and adhesive material, which is accompanied by the simultaneous demineralization and penetration of resin in enamel and dentin surfaces.[10]

Microleakage is defined as the clinically undetectable passage of bacteria, fluids, molecules, or ions between a cavity wall and the restorative material applied to it, as a result of either difference between thermal expansion coefficients of material-tooth tissue or shrinkage promoted during polymerization.[11] It is a fact, that there does not yet exist a perfect adhesive material, nor a dental material duplicating the physical properties of tooth structure.[12]

The hypothesis is that the 5th generation bonding agent, provided less microleakage in Class I composite restorations in permanent teeth *in vitro* than the 6th and 7th generation bonding agents.

METHODS AND MATERIALS

Eighty sound non-carious human first molars were selected. All teeth were free of clinical cracks, white spots or hypoplasia that might affect acid resistance. From the time of the extraction to the time of the procedure, the teeth were stored in distilled water in room temperature until the start of the process. Teeth were randomly divided into four groups:

- Group #1 was used as the control group, which did not use a dental adhesive system but used Tetric Ceram Microfilled (RBC) for the filling material.
- Group #2 used the 5th Generation adhesive system and Tetric Ceram Microfilled (RBC) for the filling material.
- Group #3 used the 6th Generation adhesive system and Tetric Ceram Microfilled (RBC) for the filling material.
- Group #4 used the 7th Generation adhesive system and Tetric Ceram Microfilled (RBC) for the filling material.

Each tooth was cleaned using a rubber cup and water for 90 seconds. A single operator prepared the class I preparations with a high speed hand piece using water spray and a #330 diamond bur. Preparations were 3mm in width, 2mm in depth and 2mm in length. Margins of the preparations were chamfered using a high speed hand piece with water spray and a #1/2 round diamond bur.

Each adhesive system was used according to the instructions of the manufacturer. The resin composite, Tetric Ceram composite resin was placed incrementally, and each increment was polymerized for 40 seconds with light curing unit of 300mW/cm^2 light intensity (3M Dental). The light was held perpendicular to each increment at a distance of 2mm.

After the specimens were cured and final finishing and polishing was done with finishing diamond burs #555, all samples were put into distilled water for 24 hours. Samples were thermocycled (Model CHCB/ 2050A, Standard Environmental Systems Inc, Totowa, NJ07510) 500 times between two water baths of 5° C → 55° C (one minute in each bath) with a dwell time of 30 seconds each.[6,13] Thermocycling procedures represent a way to accelerate specimen aging and to challenge the marginal seal.[14] Specimens were then stored in distilled H_2O for 72 hrs at room temperature before being tested. Root apices were sealed with a layer of resin composite. All the surfaces of the restored teeth were sealed with two layers of nail varnish leaving a 1mm space after the restoration tooth interface.

Teeth were dried and then immersed in methylene blue solution for 24 hrs. The specimens were rinsed and sectioned vertically and bucco-lingual direction through the center of the restoration with an Isomet (Buechler Ltd, Lake Bluff, IL60044) slow-speed, water-cooled diamond saw. Restorations were evaluated under a measuring microscope at 50x magnification for microleakage of methylene blue along the occlusal margins. The scoring method is following:

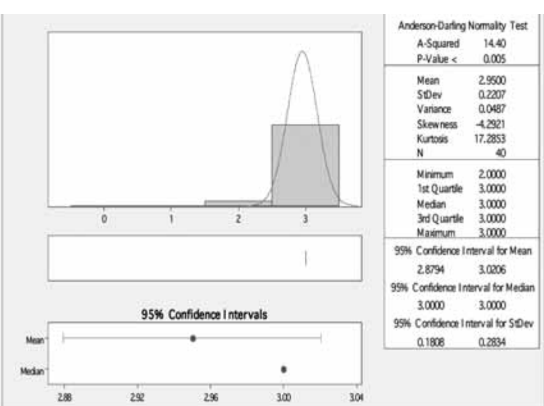
0 = no dye penetration
1= dye reaching 1.0 mm in depth
2= dye reaching beyond 1 mm in depth
3=dye reaching or beyond the axial wall.

Each tooth section was given two values, one for each side of the tooth where the microleakage could be measured.

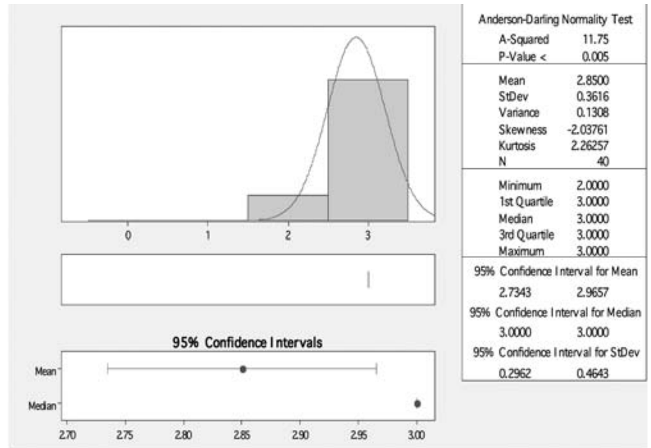
RESULTS

The result data were analyzed using the Chi-Square Test and contingency tables to determine if there were significant differences between the groups. Within each group there were 2 sets of data, side 1 and side 2. Each side from each group was graphically plotted using histograms showing the distribution of values between all groups. The p-value for the histograms is < .005 because the data is normally distributed.

Control Group- Side 1

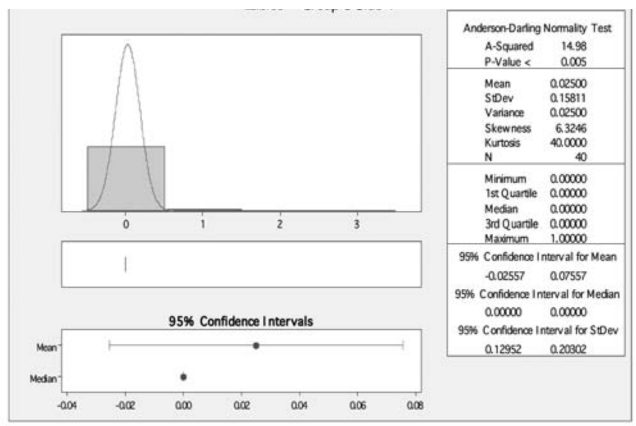


Control Group- Side 2

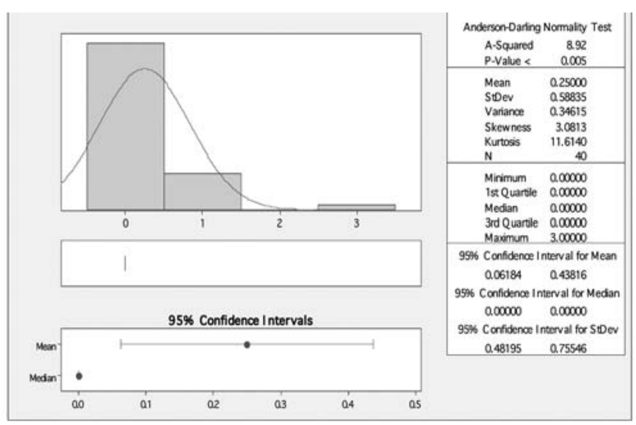


In the Control Group only 8 values for both side 1 and side 2 fell into category 2 (dye reaching beyond 1 mm in depth), while the remaining 72 data points fell into category 3 (dye reaching beyond the axial wall).

5th Generation- Side 1

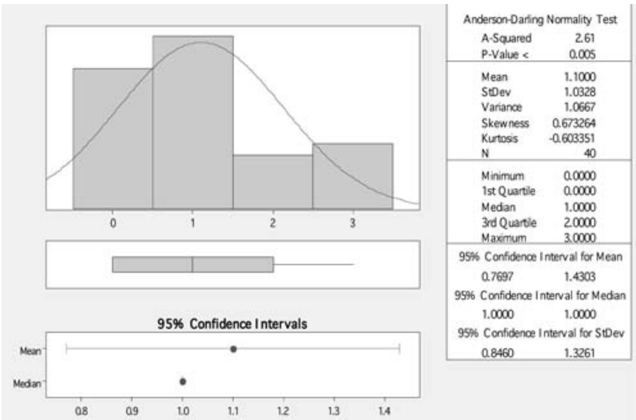


5th Generation- Side 2

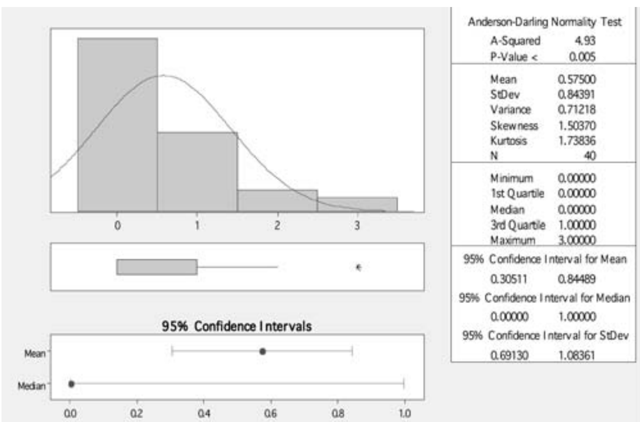


In the 5th Generation bonding system group, 88.75% of samplings showed no dye penetration, 10% had dye reaching 1.0 mm in depth and only 0.0125% had dye reaching or beyond the axial wall.

6th Generation- Side 1

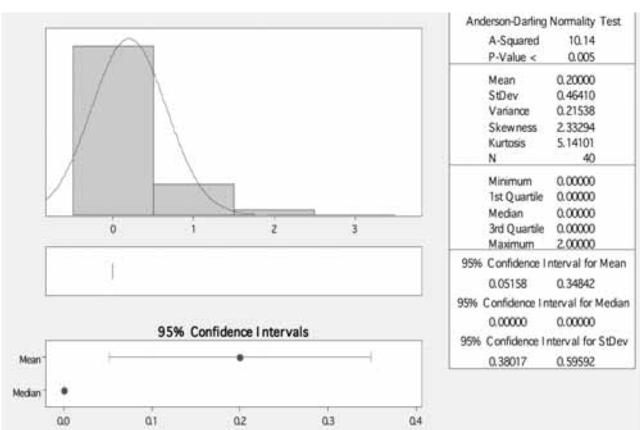


6th Generation- Side 2

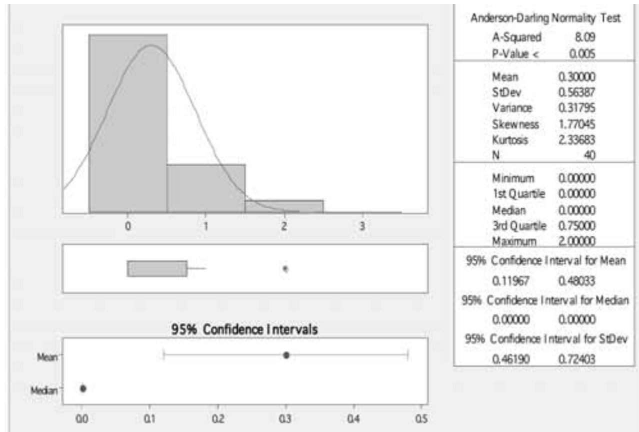


In the 6th Generation bonding system, 46.25% had no dye penetration, 33.75% had dye reaching 1.0mm in depth, 10% had dye reaching beyond 1mm in depth and 10% showing dye reaching or beyond the axial wall.

7th Generation- Side 1



7th Generation- Side 2

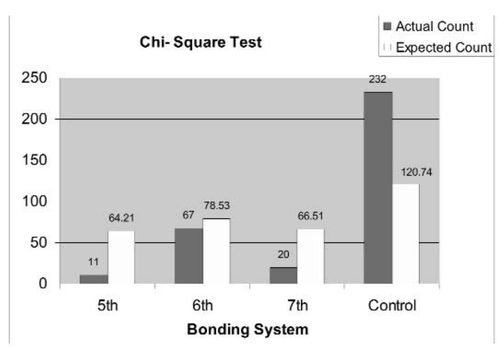


In the 7th Generation bonding system group, 78.75% of the samples had no dye penetration, 3.75% had dye reaching beyond 1mm in depth, and 17.5 % had dye reaching 1.00 mm in depth. There were no samples where dye reached or was beyond the axial wall.

The Chi-Square Test was used to determine which group statistically showed the least microleakage. The worst possible score per group is 240 (80 data points per group X 3 being the worst possible score). The proportion: Sum of Scores/240 was used. Since the P value is below the alpha level, which is set at 95% confidence interval, we can conclude from the contingency table that the sampling error is less than the population error so there is a statistical difference between the groups.

For nominal (categorical) data in which the count of items in each category has been tabulated, the observed frequency is the actual count, and the expected frequency is the count predicted by the theoretical distribution (i.e., Poisson distribution) underlying the data. For the 5th Generation group the actual count was 11, but had an expected frequency of 64.2 therefore having a 44.094% deviation from the expected. The 7th Generation group is the next best with actual being 20, expected frequency count of 66.51 and 32.536% deviation. The 6th Generation group had an actual score of 67, expected frequency count of 78.53 and therefore was only off by 1.694% from the expected frequency. The 6th generation therefore had the most microleakage (Figure 1).

Figure 1



DISCUSSION

The results of the present study show that none of the groups of the newer dentin bonding agents prevented microleakage at the restoration- tooth interface, however the third group (6th generation) showed significantly more microleakage than the other products. None of the adhesive systems studied showed perfect sealing at the restoration-tooth interface.

The most extensive penetration of the dye was observed in the samples treated with the all-in-one dentin bonding agent of the third group. Some authors claim that the absence of fillers in the third group, can explain the poor results in terms of microleakage. Yazici *et al*.[15] stated that there is a possibility that the lack of a separate primer may reduce the infiltration depth or the wettability of dentin adhesives, thereby reducing adhesion and sealing capacity. Moreover, the thickness of the adhesive layer obtained with the filler containing dental bonding systems is higher which improves the ability of the interfaces to maintain adhesion during the critical early stages of polymerization.[16] Etching enamel with non-rinsing conditioners of a pH higher than that of phosphoric acid, remains controversial in the terms of the clinical effectiveness of the conditioners and the durability of the restoration.[17] In this study, the self-etching adhesives did not achieve the same results as the single component adhesives 2nd group (5th generation) using 37% phosphoric acid.

One of the most important advantages of the 6th generation is that it eliminates cross contamination. It consists of conditioner, primer and adhesive in a unique application unit, which allows for easier and faster usage because the need to etch rinse and dry is eliminated.[18]

The 7th generation dental bonding system represents the single bottle all in one adhesives. It eliminates the uncertainty of mixing and multi-step process, which could lead to technique sensitivity. This group performed better than the 6th generation bonding system, however; it was worse than the 5th generation bonding system. This proves that the self-etching systems have minimal technique sensitivity, but still performed weaker than the total etch systems.

The existing one-bottle total-etch adhesives are popular for a number of reasons. They are easy to handle, convenient, and less confusing to the clinician than are multi-step adhesive systems, and not because they improve bonding.[19] Over drying can cause dentin collagen to collapse resulting in closing of the pores in intertubular collagen. This will prevent the monomers to intermingle with the exposed collagen fibers and form a "hybrid layer".[20] One challenge for the operator is to become fully knowledgeable with one bonding system, since new generations of bonding adhesive systems continually get introduced into the marketplace. The recent advances in adhesive dentistry simplify resin bonding leading to a trend towards self etching primer adhesives even though the total-etch systems performance was better.

CONCLUSION

Based on the above research, the following conclusions can be stated:

1. The 5th generation (Group #2) had 88.5% of the samples showing no microleakage.
2. The 6th generation (Group #3) had 46.35% of the samples showing no microleakage.
3. The 7th generation (Group #4) had 78.5% of the samples showing no microleakage.

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