



## Permeability Evaluation after Decay Removal in Primary Teeth with Current Caries-excavation Techniques

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### ABSTRACT

**Aim:** The goal of the study was to evaluate the effect of caries removal by three various methods on the permeability of class II composite resin restorations in primary molar teeth.

**Materials and methods:** Forty-five recently extracted primary molars were randomly assigned to three groups for three different methods of caries removal; group 1-mechanical, group 2-caries detector dye, and group 3-Carisolv (n = 15). After that, class II cavities in all groups were restored with the adhesive (Opti Bond Solo Plus) that was applied according to the manufacturer's instruction and a posterior composite (Herculite XRV), which was used incrementally. After 24 hours the samples were thermocycled in water for 500 cycles between 5 and 55°C with a dwell time of 30 sec. Permeability was assessed by the fluid filtration method. The data were analyzed using the ANOVA test while study groups were compared with Tukey test for statistically significant differences at a 5% significance level.

**Results:** The evaluation of tested groups indicated that the highest (0.80) and least (0.37) mean of permeability was observed in group 2 and 3 respectively. Significant difference was revealed among the tested groups ( $p = 0.045$ ). The comparison of Carisolv and caries detector dye groups indicated a statistically significant difference ( $p = 0.037$ ). There was not any significant difference between Carisolv or caries dye in the conventional group.

**Conclusion:** Using the chemomechanical and staining methods for caries removal had no more detrimental effect on permeability than the conventional technique. However, caries detection dye for caries removal could be more harmful than chemomechanical method.

**Clinical significance:** None of the current caries-excavation techniques could eliminate permeability in class II composite resin restorations. Furthermore, staining methods do not have an adverse effect on sealing ability in comparison to the conventional technique.

**Keywords:** Carious dentin, Caries detector, Fluid filtration, Permeability.

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### INTRODUCTION

In the light of the modern concept of minimal-invasive dentistry concept, the macro-retentive principals of cavity preparation have been replaced by limited carious excavation of dentin.<sup>1</sup> Caries-excavation techniques include; mechanical, hand excavation, laser, air-abrasion, air-polishing, sonoabrasion, ultrasonication and chemo-mechanical methods in which each has their own advantages and disadvantages.<sup>2,3</sup> In the mechanical method, which uses a bur and high-speed dental handpiece, it is necessary to administer an anesthetic injection, so young children often are uncooperative and afraid of the injection and in some cases these children may avoid dental treatments.<sup>3</sup> In the mechanical method of caries elimination, the removal of infected and affected dentin is done simultaneously. Today, chemomechanical systems are being used as a caries removal process, so there are fewer traumas with selective removal of decayed tissue.<sup>4</sup> This technique is suitable for fearful and anxious children who do not agree with a local injection and for the removal of deep caries, since it has less pain and worry in comparison to conventional methods. In addition, we do not have adverse effects on teeth pulp due to pressure, heat and excess removal of healthy teeth structure, but this process takes more time.<sup>1-8</sup> In this method, only infected dentin is removed, and so we can prevent the elimination of the affected dentin inner layer, which has the capability to remineralize and is thus better to preserve.<sup>9-11</sup> During the removal of caries in the clinic, the observation technique is based on indentifying the color of the caries and searching by using an explorer to evaluate carious dentin.<sup>12</sup> Color change is only considered as a reliable method in chronic caries and is not a reliable method for removing infected dentin. Using materials that are able

to identify caries and therefore resulting in its selection removal can be very helpful to enhance the capabilities of dental students in caries removal and aid in maintaining the healthy tooth tissue. First, chemical materials were applied to identify and remove carious dentin by using 0.5% fuchsin in propylene glycol. Later, due to the carcinogenic potential of fuchsin, it was replaced by 1% red acid to identify infected caries dentin in need of removal.<sup>4</sup> Caries detector dye is used to increase eye observation power.<sup>13</sup> In this method, only the stained and infected dentin is removed. As a result, we can avert the unnecessary removal of inner layers of the decayed dentin, which has the capability to remineralize and is thus better to preserve.<sup>14</sup> Although sound human dentin has the standard tissue for bonding assessment, but clinically the relevant substrate remaining exhibits mixed chemical and mechanical characteristics and includes caries-affected, caries-infected, sclerotic, eroded and sound dentin.<sup>5</sup> The ultimate goal of a bonded restoration is to attain an intimate adaptation of the restorative material with the dental substrate. Considering the fact that permeability or microleakage is the largest obstacle to reach ideal restoration and all resin-based materials experience shrinkage and create some stresses on the border of restored teeth, leading to the existence of gaps that can be areas for the transition of bacterium and molecular fluids and ions.<sup>15</sup> Permeability evaluation around the margins of restorations is a popular and simple way of assessing the adhesive system in a laboratory condition. The fluid filtration method, which is suitable for longitudinal studies, is an exact quantitative technique and so was used in this study.<sup>16,17</sup> Considering that caries detector dye and Carisolv may have a negative effect on the sealing ability due to its participation or penetration dyes and various components in dentinal tissues, the goal of this study was to evaluate the permeability of composite resin restorations after caries removal by three methods: mechanical, caries detector dye and Carisolv using the fluid filtration method. The null hypothesis of the research was that there is no difference in permeability and microstructural interfaces among different carious dentin removal techniques.

## MATERIALS AND METHODS

In this laboratory study, 45 primary molar teeth that had proximal caries with unexposed dental pulp were collected and stored in an aqueous 1% chloramine solution at room temperature for no longer than 3 months after extraction. The teeth were randomly divided into three groups and class II cavity was prepared for them (n = 15). In the first group, the carious enamel tissue was removed by a fissure bur (No. 0.0ss White Burs, Inc., Lake Uloucl, NJ, USA) placed in a turbine with water-air cooling and then the

carious dentin were removed by a round bur with a low speed. The benchmark for caries removal, in this method, was the color examination of remaining dentin and the stiffness of dentin during palpation with a blunt explorer. The caries removal process continued until the hard dentin was felt by the blunt explorer. In the second group, the guide for caries elimination was the caries detector (Kurary, Osaka, Japan) dye solution. This was conducted by placing one drop of this solution for 10 seconds on the carious dentin. Any color change was accurately eliminated. This stage continued until the dentin was no longer colored by the detector and the sharp probe sensed hard dentin. After assurance of the caries removal, the entire cavities were rinsed with water and dried. In the third group, the caries were eliminated by Carisolv gel (Mediteam, Detaluueckling I, Goteborg AD). This system was accessible by two plastic tubes and in order to activate the gel, the two tubes had to be connected to each other and the material inside had to be homogenized. This stage had to be done immediately before application. The prepared mixed gel was transferred to a suitable dish and a portion of it was placed on the carious dentins by a special hand instrument recommended by the manufactures, in such a way that all the carious dentins were covered by the gel. After 30 seconds, the softened dentins were eliminated by a special instrument. Carisolv gel, before being applied to the caries dentins, was completely clear, however, it became dark and opaque by debris during the process of caries excavation. The process of removing caries by Carisolv gel continued until the gel remained clear and the probe reached hard dentin. After the complete removal of caries, the cavities were rinsed and dried and a total etch adhesive system, Opti Bond Solo Plus (Kerr Mfg Co), was applied into the cavity based on manufactured guidelines and then A3 shade of resin composite, Herculite XRV (Kerr Mfg Co), was placed incrementally. Each layer was light-cured for 20 seconds (Optilux 500 and Demetron-Kerr) at an intensity of 500 mW/cm<sup>2</sup>. The materials used and their compositions are shown in Table 1. All composite resin restorations were polished and the samples were stored in distilled water at 37°C for 24 hours. Next, the teeth were placed in a thermocycling machine and thermocycled (500 cycles), each bath duration was 30 seconds and the interval between the two stages was 10 seconds. The hot bath temperature was 55 ± 2°C and the cold bath temperature was 5 ± 2°C.

### Measurement of Permeability

This system is based on the evaluation of liquid transportation in the specimen, which was calculated from the movement of bubbles. The fluid must be pressed firmly to move through the specimen and as a result move the

bubble. An oxygen tank with a manometer (for precise adjustment of pressure) should be used. A plastic tube must be connected to the oxygen source and the end part should be connected to an erlen. Two holes must be created on the lid, one for oxygen input and the other for the emersion of fluid. A plastic tube was connected to a three-valve tube by a  $0.5 \times 2$  cm long latex pipe. A syringe was connected to the lower side of the three-valve tube to make an air bubble through the micropipette. The upper side was connected to the specimens. The cyanoacrylate glue had to be smeared on all of the system connections (Inter Lock, Japan) and multiple layers of Para film strips were used to cover all of them (Parafilm 'M'; Laboratory film, Chicago, IL). These strips seal the connections in the tube and ensure a strong connection. Next, the observation unit, including a digital camera (Nikon D.90), must be connected to professional software (Photoshop 10.0) to measure the amount of bubble movements.

### Crown Segment Preparation

A diamond disk, which was mounted on a low-speed handpiece, was used to section the roots from the crowns to 2 mm below the cementoenamel junction (CEJ). The pulpal soft tissue was removed and the area washed with a saline solution. A plexiglass surface was used as the base of the final crown segments as mentioned previously.<sup>17</sup> One air bubble, as small as 1 to 2  $\mu$ l, was entered into the system by a microsyringe and its movement inside the micropipette (25  $\mu$ l) was recorded as a sign of liquid movement. All of the tubes, pits and syringes were filled with distilled water under 23.9 cm/H<sub>2</sub>O or 23.4 psi pressure. The camera was zoomed and focused on the macrograph to produce a sharp image. After opening the main oxygen tank for exact pressure ratio during the experiment, the digital camera started capturing the steps. Data were saved to the PC Hard Disk and the bubble movement was evaluated by Photoshop

software. From each study group, one sample was selected randomly and prepared to electronic scanning microscope (LEO 1450 VP and 35 KVP, Germany). Data were analyzed by the ANOVA and Tukey tests.

## RESULTS

The mean permeability and standard deviation in each group of the study and significance value of the ANOVA test has been displayed (Table 2).

The result of the one-way variance analysis test showed that the permeability mean for various groups was statistically significant ( $p = 0.045$ ). For pair comparison to determine the groups different from the point of view in permeability, the Tukey post hoc test was used and the outcomes are shown in Table 3.

**Table 3:** Pair comparisons of mean microleakage among tested groups

Significance level	Mean difference	Comparison
G1 vs G3	0.26	0.25
G1 vs G2	0.16	0.58
G2 vs G3	0.43	0.037

The Tukey test results indicated that the permeability amount in groups 2 and 3 are significantly different ( $p = 0.037$ ).

Scanning electron micrographs of samples in each group were obtained from interfaces between buccal, lingual, gingival walls and composite resin restorations, which are illustrated at 3000  $\times$  magnification in Figures 1 to 3.

## DISCUSSION

In this study, permeability was assessed with different methods of caries excavation on class II cavity preparation. Applying Carisolv to the preparation produced the least permeability. It seems that using Carisolve on the dentin

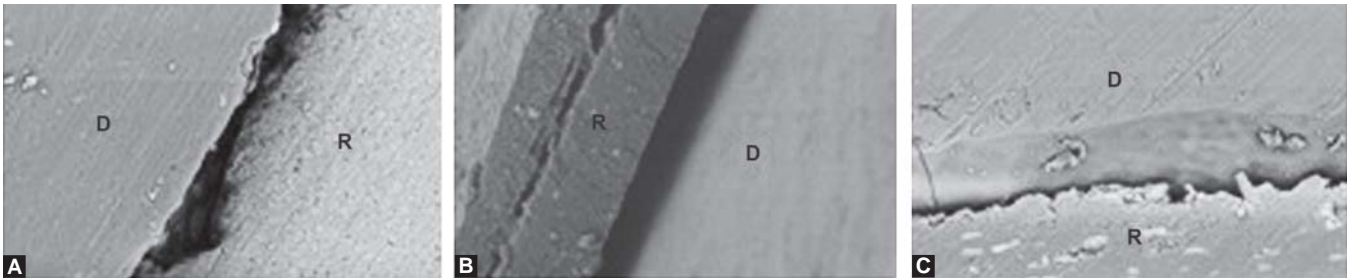
**Table 1:** Materials and their compositions used in the study

Name of material	Composition	Manufacturer
Caries detector dye	1% acid red 52 solution in propylene glycol	Kurary, Osaka, Japan
Carisolv gel	NaOCl-based gel	Mediteam, Detaluueckling I, Goteborg, AD
Opti Bond Solo Plus	Ethyl alcohol 20-25, alkyl dimethacrylate resins 55-60 Barium aluminoborosilicate glass 5-10 Fumed silica (silicon dioxide) 5-10 Sodium hexafluorosilicate 0.5-1	Kerr Corporation, Orange, CA
Herculite XRV	Bis-GMA/TEGDMA, filler load 79% wt	Kerr Corporation, Orange, CA

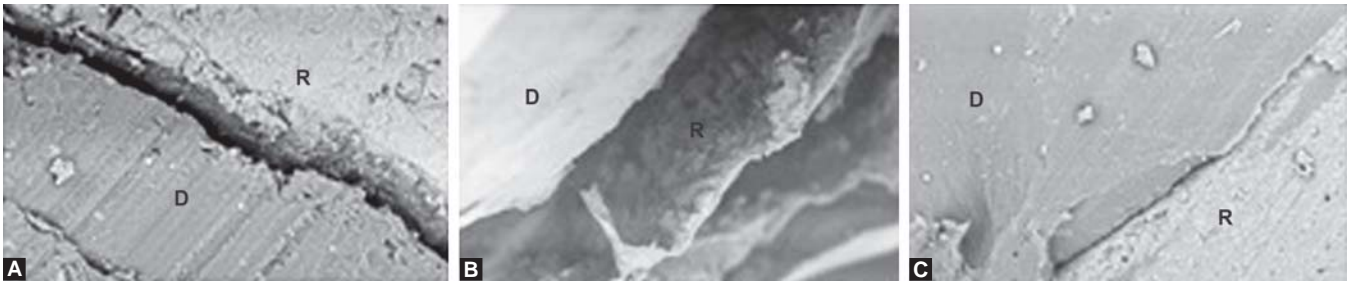
**Table 2:** Mean value of microleakage within experimental groups and ANOVA test result

Study case groups	Number	Leakage mean (Mean $\pm$ SD) ( $\mu$ L min <sup>-1</sup> cm H <sub>2</sub> O-1)	ANOVA test result
Group 1 (Conventional)	15	0.64 $\pm$ 0.16	0.045
Group 2 (Caries detection dye)	15	0.8 $\pm$ 0.39	
Group 3 (Carisolv)	15	0.37 $\pm$ 0.24	

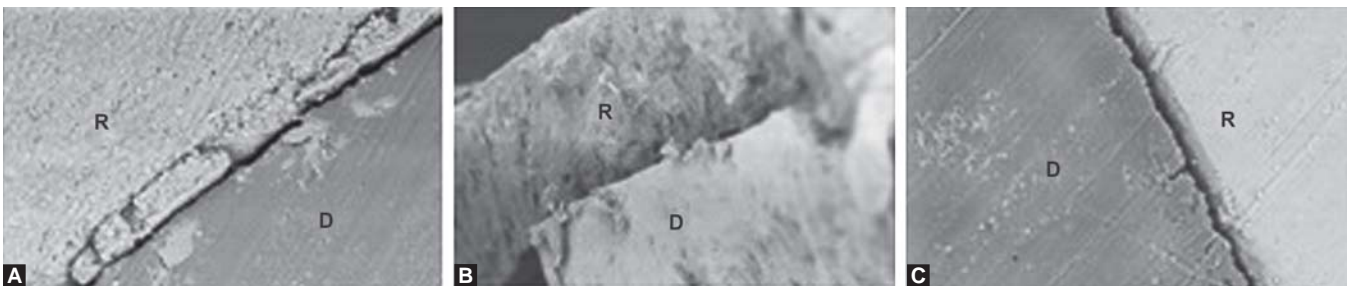




**Figs 1A to C:** Interface microstructure beside the buccal wall of a class II cavity of group 1 (A), group 2 (B), group 3 (C), dentin D: composite restoration; R: 3000x



**Figs 2A to C:** Interface microstructure beside the gingival wall of a class II cavity of group 1 (A), group 2 (B), group 3 (C), dentin D: composite restoration; R: 3000x



**Figs 3A to C:** Interface microstructure beside the lingual wall of a class II cavity of group 1 (A), group 2 (B), group 3 (C), dentin D: composite restoration; R: 3000x

surface created a change on the structure and morphology of it, which could affect the sealing of margins and reduction of the micro permeability within the hybrid layer of resin bonded dentin. Some researchers stated that after using Carisolv on the dentin surface, there was not any sign of a smear layer and dentin tubules had opened completely and showed unclear porosity, which is similar to the dentin microscopic pattern following the use of phosphoric acid, increases dentin surface energy and improves wetting potential.<sup>18-23</sup> These issues cause the increase of material adhesiveness to the dentin. Also, by using Carisolv, the thickness of formed hybrid layer increased, which is the result of the reduction or removal of the smear layer and increasing the depth of dentin demineralization.<sup>15,20,24</sup> The effect of Carisolv is stronger on primary dentin teeth than permanent dentin teeth.<sup>25</sup> This is an indication of Carisolv having greater impact on the demineralization depth and the hybrid layer thickness of primary dentin teeth. The smear

layer provides a path for permeability through very small channels (nanochannels) in its thickness, where in these channels the increase of permeability and the reduction of micromechanical restoration adherence occur, so the smear layer should be removed.<sup>26</sup> Also we suggested, Carisolv causes the effective removal of carious dentin, thereby exposing sound and efficient dentin for the bonding procedure. The dentin bonding receptiveness depends on a large extent to the caries excavation method employed.<sup>27</sup> In other studies, it has been discovered that the hybrid layer created after caries removal by Carisolv was thicker than the formed hybrid layer after using the bur.<sup>20,24</sup> More thickness of the hybrid layer and nonexistence of the smear layer following Carisolv use on dentin surface, which was briefly mentioned, can justify the results of the present study, that the least amount of permeability was observed in the Carisolv group. In a previous study, bond strengths obtained with both etch-and-rinse and self-etching adhesives to dentin

from which caries was excavated with Carisolv were even found to be similar to that of sound dentin.<sup>19</sup> Studies have indicated that after cavity preparation by the bur, the smear layer has formed and has firmly adhered to dentin surfaces. This layer prevents bonding of resin to the dentin; therefore, in order to have adequate bonding to dentin, this layer should be removed before restoration, wherein this action is commonly practiced by etching the dentin surface for a short period of time.<sup>20,21,24</sup> In one study that was done on bond strength of glass polyalkenoate to dentin after chemo-mechanical methods, it was evident that this bond strength to dentin after chemomechanical methods and the usage of a conditioner after bur usage was almost similar and was higher than bond strength only after bur use.<sup>18</sup> Similar to another study, which showed permeability in permanent teeth for cavity preparation of composite restoration, if Carisolv was used it would have been less than the mechanical method.<sup>28</sup> We used a total-etch system for bonding procedure and found no significant difference in microleakage between using the mechanical and Carisolv method for cavity preparation. The effect of caries removal by Carisolv and the bur on dentin adhesion was evaluated and it has been concluded that there was a significant difference on bond strength between the two methods if acid etch was not used. The use of Carisolv showed stronger bonding; however, if acid etch was used, then there was not any difference in the bond strength of the two methods.<sup>22</sup> Similar to our study, we did not observe any difference between permeability of Carisolv and bur methods, although there is not a complete correlation between bond strength and permeability outcomes. In another study, caries detector dye was used to show caries, which did not have any effect on the leakage of tooth colored materials.<sup>29</sup> This finding is contrary to our study. In our study, the difference in permeability which uses caries dye and the Carisolv method was statistically significant. The reason for the difference between our study and the previous study can be due to the type of materials, operator skills, sample teeth used, the method of measuring permeability and the type of cavity prepared. A study by Demarco et al<sup>30</sup> showed that the use of dyes to expose caries could reduce tensile bond strength of composite and compomer of healthy dentin. The authors stated that this reduction could be caused by the remaining dye in the dentin, even after washing and etching of the teeth. This finding is similar to our study, although Demarco measured tensile bond strength. Electron microscopic evaluation of samples indicates a better conformity of composite restorations with buccal, lingual, and gingival walls of the cavity in the third group in comparison to the second group in the current study, which confirms permeability findings.

## CONCLUSION

With regarding to the limitations of this study, it was concluded that caries excavation with Carisolv or the caries detector dye system compared to the bur did not show any difference on sealing ability. Considering the advantages of using these materials in pediatric dentistry to reduce pain and stress and to preserve the tooth structure, Carisolv is recommended, especially for children. Additionally, staining methods can be useful as a technique to increase the ability of dental students and new dentists to identify carious dentin. However, Carisolv should be preferred over the caries detector dye method.

## CLINICAL SIGNIFICANCE

None of the current caries-excitation techniques could eliminate permeability in class II composite resin restorations. Moreover, staining methods do not have an adverse effect on sealing ability in comparison to the conventional technique.

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