Microleakage Evaluation of Composite Restorations Following Papain-Based Chemo-Mechanical Caries Removal in Primary Teeth

Marwa Abdel Hafez / Mona Elkateb / Sonia El Shabrawy / Amel Mahmoud / Omar El Meligy

Aim: *To evaluate the microleakage of composite restorations following Papain-based chemo-mechanical caries removal compared to the conventional drilling method. The characteristic of the hybrid layer was also studied using scanning electron microscopy.* ***Study design:*** *The sample included thirty freshly extracted and exfoliated primary molars with open proximal carious dentin lesions. Teeth were divided into two equal groups, according to method of caries removal. Following caries removal, cavity preparations were restored with composite resin. After thermocycling, teeth were sealed apically and coated with nail polish except the surface of restorations and the surrounding 1mm. Teeth were immersed in basic fuschin dye solution, then they were sectioned mesiodistally. The extent of dye penetration was detected using a light stereomicroscope. After microleakage test, the resin/dentin interface was examined using scanning electron microscopy.* ***Results:*** *There was no significant difference in the degree of leakage between both groups. In the Papacarie group, longer and numerous resin tags were observed with statistically significant thicker hybrid layer than those following the drilling method. However, there was no significant difference between the diameters of resin tags of both groups.* ***Conclusions:*** *Papacarie does not adversely affect the microleakage of composite restorations and provides a suitable surface for bonding.*

Key words: *Chemo-mechanical Caries Removal, Primary Teeth, Papain gel.*

INTRODUCTION

In view of the need for adopting conservative treatment to preserve sound tooth structure in teeth affected by carious lesions, conventional caries removal may result in excessive loss of sound structure [1, 2] and often induces pain and discomfort [3].

Several methods of caries removal have been proposed and developed as an alternative to the conventional drilling method [4-8]. Chemo-mechanical caries removal (CMCR) has so far been a promising method in pediatric dentistry, especially for anxious or medically compromised patients [9]. It helps to reduce the patient's stress [10], minimize the need of local anesthesia [9] as well as allowing a more selective removal of carious tooth structure [11].

The CMCR involves the chemical softening of carious dentin, followed by its removal with gentle excavation. Its main objective is to eliminate the outer infected layer, leaving behind the affected demineralized dentin that can be remineralized and repaired [11].

Studies have been carried out on the nature of the dentin surface remaining after complete caries removal by CMCR "Carisolv". They noted that the dentin surface left after the CMCR is rough, highly irregular and well suited to bonding with composite or glass ionomer [9, 12].

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Scanning electron microscopic analysis has also shown that "Carisolv" removes the smear layer leaving opened dentinal tubules [13, 14]. Consequently, the dentin becomes more permeable to the penetration of the adhesive system and, the bonding of resin restoration to tooth structure will be enhanced [15].

A stable adhesion between resin restorations and dental structure is fundamental to the clinical success of restorations because an adhesion failure yields poor marginal seal with consequent microleakage [16]. This allows the infiltration of bacteria and oral fluids that may lead to the development of a secondary carious lesion [17]. The results of several studies revealed no significant difference in microleakage of bonded restorations between the conventional and Carisolv CMCR method [18, 19].

Papacarie is a CMCR product consisting basically of papain and chloramine [20], which together are responsible for the Papacarie's bactericide, bacteriostatic and anti-inflammatory characteristics [21]. Papain, the main component of the gel, is a proteolytic enzyme similar to the human pepsin.

Researchers concluded that Papacarie was effective in removing infected dentin, while preserving the deeper layer of affected dentin [22-26]. In addition, Papacarie was easy to manipulate, did not require neither special instruments nor local anesthesia, cheap and comfortable to the patient [20, 27]. Moreover, the results of several studies indicated that the papain-based gel did not interfere with the bond strength of the adhesive restorative materials to sound and demineralized dentin [28-30].

Few studies are available in the literature concerning the effect of papain-based chemo-mechanical system on marginal seal of the adhesive restorations in primary teeth [31]. More investigations are still needed to verify if this method would provide a tooth surface suitable for bonding and marginal seal of resin restorations.

The aim of this study was to evaluate and compare the microleakage of composite restoration following caries removal using a new chemo-mechanical agent (Papacarie) versus the conventional drilling method. In addition, study the characteristic of resin /dentin interface using scanning electron microscope (SEM) following both caries removal methods.

MATERIALS AND METHOD

The Ethical Committee at the Faculty of Dentistry, Alexandria University approved the research protocol.

Thirty exfoliated human primary molars and freshly extracted at time of shedding with proximal carious dentin lesions were selected. All teeth were cleaned from debris and blood stains and kept in distilled water at room temperature, before the restorative and testing procedure.

The teeth were randomly divided using the random bowl technique [32] into two equal groups of fifteen teeth each, according to the method of caries removal. Group I: the experimental group, in which the carious lesions were removed using CMCR agent, Papacarie (Laboratorio Famaceutico Ltda,Sao Paulo (SP)–Brazil). Group II: the control group, in which the carious lesions were removed using conventional drilling method.

Microleakage Test

For group I using the chemo-mechanical method [23]: The Papacarie was applied on the carious lesion for 60 seconds. The softened decayed dentin was scraped away in a pendulum motion with a blunt excavator (Martin. Gebruder Tuttlingen. Germany). The gel was reapplied whenever it appeared cloudy. The procedure was repeated until the gel appeared clear and reached an unchanged light color. The remaining gel was removed with a cotton-pellet soaked in water.

For group II using the conventional drilling method: Cavity preparation has been done using a high speed hand piece under water irrigation with a # 330 bur (SS White Burs, New Jersey) and caries were removed using a sharp excavator. The cavity outline followed the guidelines of conventional cavity preparation for resin restorations [33]. The gingival margin was beveled to enhance resin adaptation and seal. The cavities were checked for remaining caries by visual and tactile sensation using an explorer.

Restorative Procedure [34]

After caries removal by either method, cavities of the two groups were rinsed and dried with oil free compressed air. The wall of the preparation was etched with 35% phosphoric acid (3M Dental Products, St. Paul, MN, USA) for 15 seconds. Then it was rinsed with water spray for 10 seconds and dried using oil-free compressed air for 15 seconds. Two consecutive coats of 3M single bond adhesive (3M Dental Products, St. Paul, MN, USA) were applied to etched enamel and dentin for 15 seconds with gentle agitation using fully saturated brush, followed by gentle air thinning for 5 seconds to evaporate solvents. Visible light (Halogen Light Unit, mega-physik Rastatt/Germany) curing for 10 seconds using a high intensity visible light source was done. 3M light activated composite Filtek Z250 (3M Dental Products, St. Paul, MN, USA) was applied in successive laminated increments to prevent excessive polymerization shrinkage [35, 36]. The first increment, no thicker than 1mm was placed against the gingival floor, using small plastic filling instrument [37]. After complete adaptation, it was light cured. Subsequent increments were placed in thickness no greater than 2 mm in an oblique layering technique. The restoration was cured from the facial and lingual aspects to ensure adequate polymerization throughout the entire restoration [38]. Finishing was delayed for 3 minutes to allow approximately 70% of maximal polymerization to occur during the dark-curing phase following application of the curing light. This is because early finishing of composite resin after placement has been shown to significantly increase microleakage [39]. After that, shaping of occlusal surfaces was accomplished with fine diamonds finishing burs to provide the smoothest surface and minimize trauma-induced microleakage [40, 41]. A final high polish was accomplished using a rubber prophylaxis cup with aluminum oxide polishing pastes. Before rebonding, etching was performed by applying 35% phosphoric acid to all the restoration margins for 10 seconds, rinsed off and then thoroughly dried. The single bond adhesive was applied, thinned with a blotted brush and light cured for 40 seconds [42].

All teeth were stored [43]in distilled water at 37^{0}C inside an incubator unit for 24 hours.

After storage, the teeth were thermocycled [44] in a water bath for 500 cycles using the thermocycling machine, alternating between 5^0 and 45^0 C with a dwell time 20 seconds.

The pulp chamber, root apices and furcations were sealed with intermediate restorative material "IRM" (Dolla Soom, Egypt) and sticky wax (Dentsply International. Milford, USA). Teeth surfaces were coated with three layers of nail polish except the surface of restorations and the surrounding 1mm. Teeth were immersed in 0.5% basic fuchsin solution for 24 hours, then they were removed from the dye solution and washed under running water for half an hour. Teeth were sectioned mesiodistally using a diamond saw through the center of the restoration. Each tooth produced two specimens and the extent of dye penetration was detected using a light stereomicroscope (Olympus stereomicroscope SZ11. Tokyo, Japan) [45].

The following scoring criteria have been used according to Milleding [46]:

0=No microleakage

1=Microleakage along the enamel

2=Microleakage extending beyond the amelodentinal junction

3=Microleakage along the floor of the cavity

4=Microleakage reaching the pulp.

The samples were evaluated for the degree of dye penetration by two independent examiners. The examiners were faculty from Departments of Pediatric Dentistry and Dental Biomaterials, Alexandria University. The examiners scored the degree of dye penetration on an ordinal scale ranging from 0 to 4.

Scanning Electron Microscopic Study

After the microleakage test, seven specimens were selected from each group of different microleakage score.

Materials and Equipments for SEM:

1. For sample preparation: (a) Ethyl alcohol, acetone and amyl acetate; (b) Vacuum desiccator; (c) Jeol coating apparatus (JFC-110 Sputtering Device, Jeol-Japan).
2. For studying the sample: Jeol SEM (JSM-5300 Scanning Microscope, Jeol-Japan).

Specimens were soaked in 6 mol/l Hydrochloric acid (HCl) for 30 seconds to dissolve the mineral component of dentin, followed by immersion in 5% Sodium hypochlorite (NaOCl) for 5 minutes to remove collagen that was not resin protected. Specimens were immersed in ethyl alcohol of serial concentrations, 30%, 50%, 70%, and 90%, 10 minutes each, then in absolute alcohol for one hour for dehydration of the specimens. Then specimens were passed in acetone for 30 minutes for neutralization of ethyl alcohol and complete dehydration. After that, the specimens were placed in amyl acetate for 30 minutes for absorption of acetone and complete dehydration. The specimens were kept in vacuum desiccator containing silica gel to avoid rehydration. The specimens were then mounted on a copper stub using a silver paint. They were placed in the glass-bell jar of the Jeol coating apparatus for 3 minutes to be covered with a thin layer of gold palladium at 200 A^0 (A^0 = Angstrom = 1x10^{-6} mm) that was enough for the scanning procedure without affecting the surface details of the specimens. Then the specimens were placed in the chamber of the Jeol SEM operating at 25 KV to be scanned and photographed. The resin / dentin interface were then examined at magnification (X 3500) and at higher magnification (X 5000) to evaluate the adaptation of hybrid layer, resin-tag formation and the lateral branching. The thickness of hybrid layer (tags' penetration) and the diameter of resin tags were measured using computer calibration linked to the SEM [47].

Statistical Analysis

I. Microleakage Test:

Descriptive statistics for microleakage scores were displayed. Comparison of microleakage scores at the occlusal and cervical locations in the same group as well as between group I (experimental group) and group II (control group) was done using Fisher exact test.

II. Scanning Electron Microscopic Study:

Descriptive statistics for the thickness of hybrid layer as well as the diameter of resin tags were displayed as mean and standard deviation. Comparison of mean values between the experimental group and control group was done using t test.

Significance level was set at 5% level. Statistical Package for Social Sciences Computer Software (SPSS) version 15.0 was used for the statistical analysis.

RESULTS

Microleakage Test

In the present study, 30 exfoliated human primary molars and freshly extracted at time of shedding with proximal carious dentin lesions were used for the microleakage test. After longitudinal sectioning, each tooth produced 2 specimens. The scoring was done according to Milleding scoring criteria [46].

Table 1 shows a comparison of microleakage scores between occlusal and cervical margins in group I (Papacarie group). Statistical analysis was carried out utilizing Fisher exact test. At the occlusal margin, all specimens (100%) treated with Papacarie gel showed score 0 microleakage. Regarding the cervical margin, score 0 was noted in 93.3% of the specimens, while 6.7% (2 out of 30 specimens) revealed score 1 microleakage. There was no statistically significant difference between microleakage scores at the occlusal and cervical margins in group I (Papacarie) with P value = 0.49 NS set at 5% level.

Regarding group II (conventional group); there was no significant difference between occlusal and cervical margins in microleakage scores, which were listed in table 2. No microleakage was observed in group II specimens prepared by the conventional drilling method (100% of the specimens).

Table 3 shows a comparison of microleakage scores between group I (Papacarie) and group II (conventional). Score 0 represents 93.3% of total specimens treated with Papacarie gel. Score 1 microleakage was only detected in 6.7% (2 out of 30 specimens), while no specimens showed scores 2, 3 or 4. Regarding group II (conventional), score 0 microleakage was observed in 100% of specimens. Statistical analysis of the data using Fisher exact test showed no statistically significant difference between group I and group II with P value = 0.49 NS.

Scanning Electron Microscopic Study

The scanning electron microscopic study was done to study the characteristic of the resin/dentin interface (hybrid layer). After microleakage test, 7 specimens were selected from each group according to microleakage scores.

Table 4 shows the thickness of hybrid layer of group I (Papacarie) and group II (conventional method). Table 5 shows the mean and standard deviations of the thickness of the hybrid layer of the two groups. The mean thickness of the hybrid layer in group I (Papacarie group) was 55.35 $\pm$ 12.10 microns, while it was 11.04 $\pm$ 1.83 in group II (conventional method). The statistical analysis of data using t test showed a significant difference between the two groups with P value < 0.0001.

Table 6 shows the diameter of resin tags in microns in group I (Papacarie) and group II (conventional) specimens. Table 7 shows the mean and standard deviations of the diameter of resin tags between the two groups. The mean diameter of resin tags in group I (Papacarie) was 0.79 $\pm$ 0.11 microns, while it was 0.80 $\pm$ 0.11 in group II (conventional method). There was no statistically significant difference between the two groups using t test with P value = 0.79 NS.

In group I, where the teeth have been prepared with Papacarie gel, a well defined hybrid layer and resin tags formation was observed, with intimate adaptation between resin and dentin (figure 1). Multiple lateral branching of resin tags were evident. The thickness of hybrid layer was approximately 43.8-68.6 microns in most specimens presented with score 0 microleakage (figure 2), also multiple long resin tags were seen.

However, the specimens with score 1 microleakage revealed a thinner hybrid layer, the thickness were approximately 42.5 microns (figure 3). Intimate adaptation was noted but fracture of dentin and gaps occurred in some parts of the specimens. The resin tags appeared broken and shorter than those of score 0 microleakage.

SEM of resin/ dentin interface of specimens prepared with conventional bur (group II) revealed thinner hybrid layer than that of group I. It ranged from 9.31 to 14.15 microns (figure 4). Intimate adaptation of hybrid layer and resin tags formation were also seen (figure 5). The lateral branching of resin tags were evident but to a lesser extent than those of group I.

Table 1. Comparison of microleakage scores between occlusal and cervical margins in group I (Papacarie).

Microleakage scores	Occlusal N (%)	Cervical N (%)
Score 0	30 (100)	28 (93.3)
Score 1	0	2 (6.7)
Score 2	0	0
Score 3	0	0
Score 4	0	0
P value of Fisher exact test	0.49 NS	

NS: Not statistically significant

Table 2. Comparison of microleakage scores between occlusal and cervical margins in group II (conventional method).

Microleakage scores	Occlusal N (%)	Cervical N (%)
Score 0	30 (100)	30 (100)
Score 1	0	0
Score 2	0	0
Score 3	0	0
Score 4	0	0
Test of significance	-	

Table 3. Comparison of microleakage scores between group I (Papacarie) and group II (conventional method).

Microleakage scores	Group I Papacarie N (%)	Group II Conventional N (%)
Score 0	28 (93.3)	30 (100)
Score 1	2 (6.7)	0
Score 2	0	0
Score 3	0	0
Score 4	0	0
P value of Fisher exact test	0.49 NS	

NS: Not statistically significant

Table 4. Thickness of the hybrid layer in microns of group I (Papacarie) and group II (conventional method).

Specimen number	Group I (Papacarie)	Group II (conventional)
1	42.50 microns	12.80 microns
2	53.46 microns	10.47 microns
3	66.27 microns	11.30 microns
4	43.80 microns	9.47 microns
5	68.60 microns	9.80 microns
6	44.60 microns	9.31 microns
7	68.21 microns	14.15 microns

Table 5. Comparison of mean hybrid layer thickness in microns between the Papacarie and the conventional method of caries removal.

	Thickness in microns	
	Group I Papacarie	**Group II Conventional**
Min- max	42.50- 68.60	9.31- 14.15
Mean ± SD	55.35 ± 12.10	11.04 ± 1.83
t test	9.58	
P value	<0.0001*	

*: Statistically significant at P≤0.05

Table 6. Diameter of resin tags in microns of group I (Papacarie) and group II (conventional method).

Specimen number	Group I (Papacarie)	Group II (conventional)
1	0.59 microns	0.64 microns
2	0.74 microns	0.71 microns
3	0.74 microns	0.75 microns
4	0.81 microns	0.83 microns
5	0.87 microns	0.86 microns
6	0.88 microns	0.91 microns
7	0.88 microns	0.92 microns

Table 7. Comparison of mean resin tags diameter in microns between the Papacarie and the conventional method of caries removal.

	Diameter in microns	
	Group I Papacarie	**Group II Conventional**
Min- max	0.59- 0.88	0.64- 0.92
Mean ± SD	0.79 ± 0.11	0.80 ± 0.11
t test	0.28	
P value	0.79 NS	

NS: Not statistically significant

Figure 1. A SEM image of the hybrid layer in group I specimen (Papacarie group) of score 0 microleakage showing hybrid layer formation and resin tags (arrows). Note the intimate adaptation between resin and dentin (X 3500). Bar = 5 microns. C = Composite, D = Dentin.

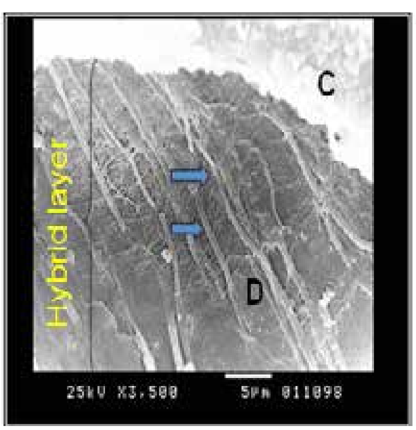


Figure 2. Another SEM image of the hybrid layer in group I specimen (Papacarie group) of score 0 microleakage showing multiple resin tags (arrows). Note the thickness of hybrid layer (X 3500). Bar = 5 microns. C = Composite, D = Dentin.

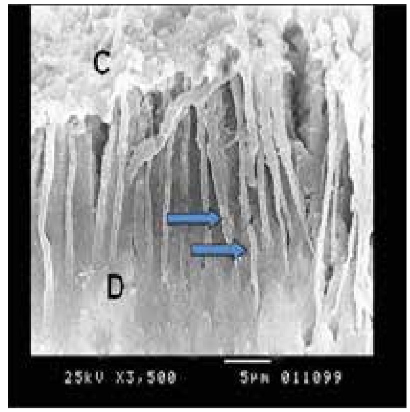


Figure 3. A SEM image of the hybrid layer in group I specimen (Papacarie group) of score 1 microleakage. Note the thinner hybrid layer than that of score 0 specimen. The arrows showing fracture in dentin in some parts of the specimen (X 3500). Bar = 5 microns. C = Composite, D = Dentin.

Figure 4. A SEM image of the hybrid layer in group II specimen (conventional method) of score 0 microleakage showing a well-defined hybrid layer. Note the thinner hybrid layer than that of group I specimens (X 3500). Bar = 5 microns. C = Composite, D = Dentin.

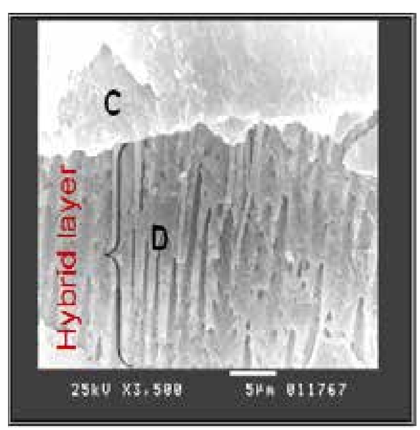
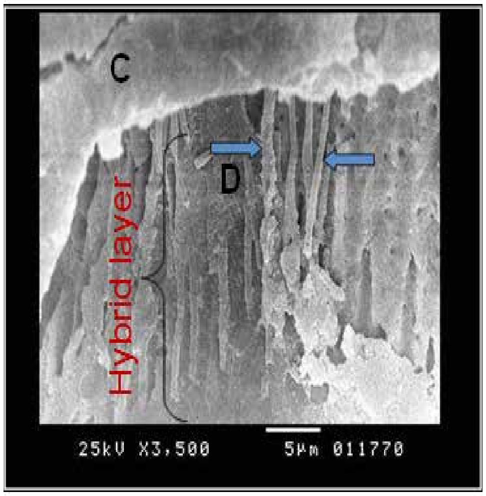


Figure 5. A SEM image of the hybrid layer in group II specimen (conventional method) of score 0 microleakage showing intimate adaptation between dentin and resin. Resin tags (arrows) are evident but to a lesser extent than those of group I (X 3500). Bar = 5 microns. C = Composite, D = Dentin.



DISCUSSION

Microleakage Test

Marginal seal plays a major role in the success of dental restorations. Additionally, proper adhesion between the restorative material and the cavity walls results in good marginal sealing with less microleakage and a longer life of the restoration [48].

The statistical analysis in this present study indicated that there was no statistically significant difference between the microleakage in the two methods of caries removal. These results were in accordance with several previous studies who reported that using the CMCR method appeared to decrease the microleakage [19, 49, 50].

On the contrary, Araujo *et al* [31] suggested that the chemo-mechanical method of caries removal using Papacarie gel compromised the marginal seal of the adhesive restorative material. In addition, they showed that there was no statistically significant difference in marginal leakage at the cervical wall between the Papacarie group and the conventional drilling method. However, there was a statistically significant difference at the occlusal wall between the two groups regarding the degree of microleakage.

In the present study, 93.3% of group I (Papacarie) specimens and 100% of group II (conventional) showed no microleakage (score 0). This may be attributed to the technique followed during cavity preparation and restorative procedures. Also a perfect seal along the resin / dentin interface can be established within demineralized collagen matrix when it is completely infiltrated by adhesive resins [51]. In group II (conventional method), a bevel was done at the gingival margins to enhance the resin adaptation and seal [34]. According to Sturdevant *et al* [52], it has been recorded that the bevel is potential to increase the retention and the marginal seal, as bevels in enamel provide more surface area for acid etching and bonding. During restoration, incremental technique was used in both groups, which was suggested to decrease the marginal leakage [53]. Studies suggested that the incremental technique prevent excessive polymerization shrinkage because the thin increments ensured proper light irradiation [35, 36].

Additionally, the manner of curing used from the facial and lingual aspects might improve the marginal integrity, because this allows the polymerization shrinkage to be directed toward the facial or lingual proximal walls and margins [54, 55]. Also the rebonding has been shown to improve the marginal integrity of composite resin restoration in vitro [56]. Eick and Welch [57] and Lutz *et al* [58] suggested that the finishing procedures are destructive to the composite resin, which may exacerbate the marginal gaps formed during polymerization. So all restoration margins should be rebonded because the low viscosity of the rebonding resin facilitates its penetration in the interfacial gaps and microcracks [59].

In the present study, score 1 microleakage was detected in only two specimens (6.7%) from a single tooth in group I prepared with Papacarie gel. The leakage was observed at the cervical margin in that tooth. This may be attributed to the deep location of the cervical margin gingivally with thin enamel wall. During sample selection, it was difficult to find primary molars with proximal caries without extensive lesions and pulp involvement.

The same results were obtained by Toledano *et al* [60], who found that the microleakage in occlusal margins is less than gingival margins because the enamel interfaces show a better resistance against polymerization shrinkage forces. This resistance will lead to crazing in enamel margins. If shrinkage forces overcome the dentin bond strength, it will produce marginal gap that is usually seen in the gingival margins.

These findings also accord the results of Mousavinenasab and Jafary [43], who reported a more considerable degree of leakage in the gingival than the occlusal margin either in conventional or chemo-mechanical method. Additionally, this was in agreement with Casagrande *et al* [61] who found that cervical enamel-dentin / composite resin interface is more vulnerable to microleakage than other sites of tooth / resin interface. According to Herrin and Berry [62], and Fuks *et al* [63], leakage at the gingival margin was contributed to a combination of factors such as thin enamel, poor adherence of the material at the cervical margin and the difficulty of condensation of the composite to the gingival wall.

Scanning Electron Microscopic Study

The formation of a uniform hybrid layer in all cavity walls becomes fundamental to allow a hermetic sealing of the tooth / restoration interface [64].

In the present study, to assess the characteristic of the hybrid layer after CMCR using the Papacarie gel versus the conventional drilling method, the resin / dentin interfaces were treated with 0.5 N HCl followed by 5% NaOCl to examine the features of the hybrid layer. The hybrid layer was treated with HCl to remove the surrounding mineral allowing its visualization without affecting the acid resistant hybrid layer or resin. NaOCl was used to remove any exposed collagen that was not resin protected [65]. The hybrid layer can be revealed from either sound dentin or resin [66].

In the present study, a significant difference in the thicknesses of the hybrid layer was observed between the Papacarie group (experimental group) and the conventional group (control group). In group I (Papacarie group), the hybrid layer was thicker than that of group II in most specimens, and ranging from 42.5 – 68.6 microns and many evident long resin tags with lateral branching were seen.

Regarding the conventional drilling group, the thickness of the hybrid layer was lower than that of group I ranging from 9.31 – 14.15 microns with few lateral branchings. The two groups showed a well defined hybrid layer and intimate adaptation between resin and dentin with resin tags formation. The results of Kotb *et al* [25] could explain the deeper resin penetration in group I. Following Papacarie treatment; the dentin surface was generally free of smear layer with patent dentinal tubules. A possible explanation of the absence of the smear layer is the presence of chloramines, which tend to chlorinate and dissolve the denaturated organic components leaving opened dentinal tubules [23]. Consequently, the quality of bonding to adhesive material would be increased which in turn decreased the degree of microleakage [67].

The intimate adaptation in group II, could be attributed to the acid etch which removes the smear layer and smear plugs, opening the dentinal tubules, thus increasing dentinal permeability as well as enhancing the quality of bonding between resin and dentin [68]. These results were in accordance with previous studies [51, 66]. Therefore, etching procedures need to be reviewed to ensure optimum adhesion of resin – based materials to dentin.

Also the result of the present study accords with Cehreli *et al* [69], who evaluated a single – bottle adhesive to caries affected human dentin after four different caries removal techniques. They demonstrated that CMCR using Carisolv system revealed the thickest hybrid layer. Moreover, the hybrid layer formed when affected dentin was bonded with the single – bottle adhesive systems was almost twice as thick compared with normal dentin, and this difference in thickness may be due to the reduction or absence of smear layer after treatment with Carisolv [70]. On the other hand, the bur removal of dentinal caries produces a considerable smear layer on the dentinal surface with occluded tubules [49].

In 2005, Hosoya *et al* [71] carried out another study comparing the characteristic of hybrid layer in primary dentin and permanent dentin. It has been demonstrated that the primary dentin had a thicker hybrid layer than permanent dentin after treatment with a CMCR agent (Carisolv).

In the present study, only one specimen with score 1 microleakage at the gingival margin was used to study the characteristic of resin /dentin interface. Intimate adaptation between resin and dentin was observed with fracture in dentin and gaps in some parts of the specimen close to the gingival wall. The resin tags appeared broken and to some extent shorter than those of the other specimens with score 0 microleakage among the Papacarie group. This may be related to the bonding of residual dentin after caries removal at the gingival margin that might contribute to the little micro-mechanical retention [72]. This finding accords with another study done to analyze the voids in Class II composite resin restorations at the axial and gingival walls using SEM. It has been noted that more voids along the tooth / resin interface at gingival wall than the axial wall and this voids resulted in stress concentration and incomplete adhesion to dentin [73].

In the current study, measuring of the diameter of resin tags revealed no statistically significant difference between the experimental group (Papacarie group) and the control group (conventional group). This finding accords with Ceballos *et al* [74] who found that the resin bonding would form resin tags with a diameter similar to that of the dentinal tubules lumen. Brajdic *et al* [75] also reported a similar finding when studying the number, diameter, surface area of exposed dentinal tubules of the human coronal dentin and its influence on dentin hybridization.

On considering the multiple advantages of chemo-mechanical methods for dental caries removal, regarding the patient acceptance and comfort, the adhesive bonding, and the biocompatibility with both soft tissues and restorative materials [76, 77], several studies concluded that the chemo-mechanical approach seems to be a valuable alternative for caries removal especially in pediatric patients [78-81].

So, it appears from the results of the present study that the utilization of Papacarie as a mean for caries removal in opened dentinal lesions has encouraging outcomes. This is a consequence of the marginal adaptation, which supports the clinical results of previous studies [22, 23, 25, 82, 83]. Therefore, this method of caries removal might also be an alternative treatment to realize the new strategies of minimal invasive techniques.

CONCLUSIONS

From the results of the present study, it was concluded that:

1. The use of Papacarie for caries removal does not adversely affect the microleakage of composite restorations.
2. Papacarie treatment influences the characteristics of the hybrid layer (resin/dentin interface) and provides a suitable surface for bonding.
3. Papacarie treatment produces longer and numerous resin tags with thicker hybrid layer than those following the conventional drilling method.
4. The use of Papacarie gel does not affect the diameter of resin tags.

RECOMMENDATIONS

1. Since Papacarie does not affect the microleakage in class II resin restoration, it can be used for caries removal in primary teeth.
2. Further studies are needed to determine the shear bond strength of adhesive restorations following caries removal using Papacarie gel.
3. The effect of acid etching following Papacarie treatment on surface topography and depth of demineralization of dentin has to be determined.

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