

RESEARCH ARTICLE

Comparative Evaluation of Microleakage in Restored Primary Molars using Conventional and Chemomechanical Removal of Carious Tissue: An *in vitro* Study

¹Avula JS Sankar, ²Charishma Birra, ³Sujatha Bandi, ⁴Mahesh Chinta, ⁵Sridevi Enuganti, ⁶Sridhar Mukthineni

ABSTRACT

Background and objective: Microleakage of restored teeth can be considered as a major contributing factor for the occurrence of tooth discoloration, secondary caries, deterioration of restorative material, postoperative tooth sensitivity, and pulpal irritation. The objective of this study was to compare the microleakage of primary molars restored with conventional glass-ionomer cement (GIC) and Giomer after caries removal using conventional cavity preparation (CCP) and chemo-mechanical caries removal (CMCR) techniques.

Materials and methods: Sixty extracted carious human primary molars were randomly assigned into three groups of 20 each based on the method of caries removal: Group A: CCP technique; group B: CMCR using Papacarie gel; and group C: CMCR using Carisolv gel. Each group was further divided into two of 10 teeth each according to the restorative material used – conventional GIC (Fuji II) and Giomer (Beautifil II). The restored teeth were thermocycled, immersed in methylene blue dye, sectioned, and examined under stereomicroscope to elicit the dye penetration scores.

Results: The results demonstrated that none of the restorative materials were free from microleakage. In Fuji II samples highest microleakage scores were noticed in group A (2.09) followed by group B (0.64), and least in group C (0.27), which were statistically significant. However, in Giomer samples no statistical significant difference in microleakage scores was noticed among the three groups.

Conclusion: Chemo-mechanical caries removal technique showed less microleakage when compared to CCP technique and the marginal sealing ability of Giomer was superior to conventional GIC.

Keywords: Carisolv, Chemo-mechanical caries removal technique, Microleakage.

How to cite this article: Sankar AJS, Birra C, Bandi S, Chinta M, Enuganti S, Mukthineni S. Comparative Evaluation

of Microleakage in Restored Primary Molars using Conventional and Chemomechanical Removal of Carious Tissue: An *in vitro* Study. J Contemp Dent 2016;6(2):108-113.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

The main goal of a pediatric dentist is to provide comprehensive dental treatment to child patients by initiating minimally invasive procedures and thereby installing positive dental attitude in them. However, restoration of a decayed tooth in a child patient is considered more difficult with conventional method as the pain/discomfort during drilling and sound of the hand piece will trigger the anxiety. Moreover, drilling results in rapid and excessive removal of tooth structure and may cause harmful thermal/pressure effects on the pulp. Hence, an alternative technique was developed to overcome these limitations by using the chemo-mechanical caries removal (CMCR) agents.

This technique of using CMCR agents in patient is user-friendly, which acts by causing further degradation of the partially degraded collagen in the infected dentin, without affecting the normal dental tissues. Chemomechanical caries removal agents were first introduced by Habib et al in 1975 using 5% sodium hypochlorite, which is a nonspecific proteolytic agent. As sodium hypochlorite was found to be corrosive in healthy tissue, Goldman et al introduced GK-101 for removal of dental caries in 1976 which was marketed from 1985 by the name of Caridex system. Despite its effectiveness, Caridex had certain limitations like short shelf life, requirement of large volume of solutions along with a special pump and long working time.¹

Ericson et al² in mid-1990 introduced Carisolv as a successor to Caridex, which was a huge success in the field of dentistry. However, certain drawbacks like high cost, short shelf life, and requirement of customized instruments have been reported.² In 2003, Bussadori et al³ developed a new CMCR agent, which was launched in 2005 under the brand name Papacarie. Papain is the basic component of this product which is responsible for its bactericidal, bacteriostatic, and anti-inflammatory characteristics.³

¹Professor and Head, ²Ex Postgraduate Student, ³Professor
⁴Senior Lecturer, ^{5,6}Reader

^{1-3,5,6}Department of Pedodontics and Preventive Dentistry, Sibar
Institute of Dental Sciences, Guntur, Andhra Pradesh, India

⁴Department of Pedodontics and Preventive Dentistry, Panineeya
Institute of Dental Science and Hospital, Hyderabad, Telangana
India

Corresponding Author: Avula JS Sankar, Professor and Head
Department of Pedodontics and Preventive Dentistry, Sibar
Institute of Dental Sciences, Guntur, Andhra Pradesh, India
Phone: +919346550646, e-mail: saisamata@gmail.com

The conventional GICs have many attractive features, such as minimal removal of sound tooth substance due to chemical adhesion to the tooth structure, good biocompatibility, slow fluoride release, and color almost similar to that of the tooth. However, there are few disadvantages like susceptibility to moisture contamination or dehydration during early stages of setting, slow rate of setting, low fracture toughness, and poor wear resistance.⁴ In the continuing quest for improved glass-ionomer like restorative materials, Giomer was introduced which comprises inorganic filler particles (multifunctional glass filler and surface prereacted glass filler based on fluoro boro alumino silicate glass) and organic-resin matrix (bisphenyl-A glycidyl dimethacrylate/triethylene glycol dimethacrylate resin) having the properties of fluoride release and recharge of glass-ionomer cements (GIC) in addition to the excellent esthetic properties, along with ease of polishing, outstanding radio-opacity, wear resistance, and strength characteristics of resin composites.⁵

The most common cause for failure of the restorative materials is microleakage at the tooth-restoration interface. It is a major contributing factor to tooth discoloration, secondary caries, postoperative hypersensitivity, and pulpal irritation. Thus, the present *in vitro* microleakage study was conducted on primary molars restored with two restorative materials (conventional GIC and Giomer) following caries removal by conventional and CMCR methods (Papacarie and Carisolv).

MATERIALS AND METHODS

Sixty extracted carious primary molars with open cavities (diameter ≥ 2 mm) and accessible to hand instruments were collected which were extracted for reasons like over retention, unwilling to undergo restorative treatment, or as a part of orthodontic treatment. The teeth with the presence of cracks, multisurface caries lesions, pulpal involvement, and developmental anomalies were excluded. The selected teeth were cleaned with universal scaler no. 11 and stored in distilled water with few thymol crystals added to it until use.

The teeth were divided into three groups of 20 teeth each depending on the method of caries removal advocated as: Group A: Conventional cavity preparation; group B: Using Papacarie gel (F & A Laboratory Formulations Ltd, Brazil); and group C: Using Carisolv gel (Medi Team Co., Sweden).

In group A specimens, the carious tissue was removed by conventional method using carbide straight fissure bur (No. 330) in high-speed hand piece under water spray. Complete caries removal was verified by visual (absence of any discoloration) and tactile examination (smooth passage of explorer and absence of a catch or tug back sensation).

In group B, teeth with carious lesions were filled with Papacarie gel. After 30 seconds when the gel turned turbid, the softened carious dentin was scraped away using a sterile spoon excavator in pendulum movement. The procedure was repeated as many times as necessary, until the color of the gel remained unchanged or the cavity appeared vitreous.

In group C, Carisolv gel was dispensed into the carious lesion and allowed to act for 30 seconds. The infected tissue was removed with specialized manual instrument supplied by the manufacturer. The procedure was repeated until the gel remained unclear. The cavities were considered caries free using visual inspection and probing.

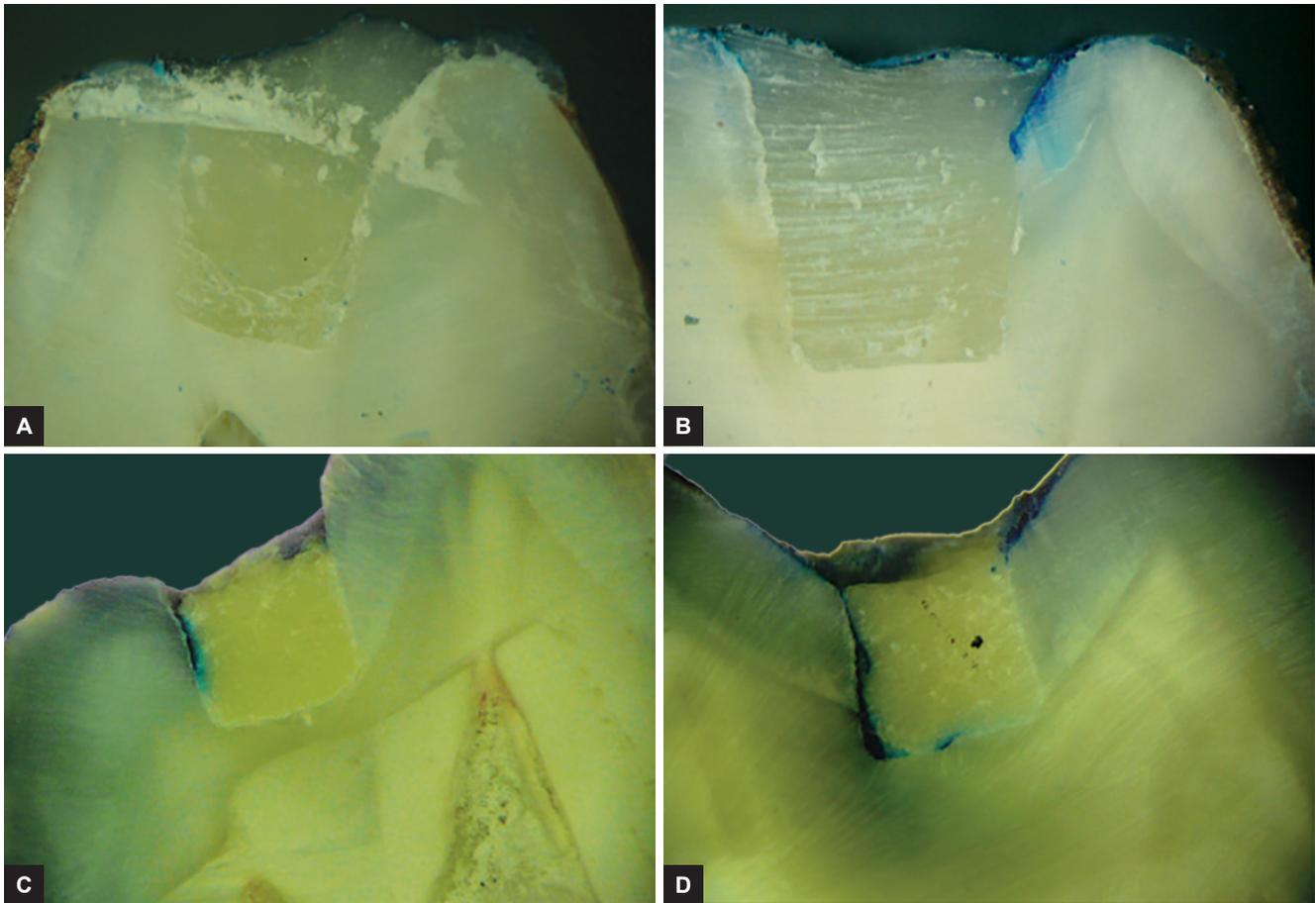
After completing the caries removal, cavities were cleaned with sterile cotton pellets, washed and dried in all the groups. Each group was further divided into two subgroups of 10 teeth each according to the restorative material used: Conventional GIC (Fuji II, GC Corporation, Tokyo, Japan) and Giomer (Beautifil II, Shofu Dental Corporation, Osaka, Japan).

Ten teeth in each group were conditioned with 10% poly acrylic acid for 20 seconds, rinsed with water, and dried with cotton pellets. Test material I (Fuji II) was mixed at 2:1 ratio (P:L) with agate spatula using folding method. The mixed material was placed into the prepared cavity using a cement carrying instrument, which were further protected with petroleum jelly to avoid desiccation.

The remaining sample teeth (n=10) in all the groups were etched with 37% phosphoric acid gel for 10 seconds, rinsed with water, and air dried. Using an applicator tip, a coat of bonding agent was applied and light cured for 20 seconds. Further, these cavities were restored with test material II (Beautifil II) in incremental manner and light cured for 30 seconds (as per the manufacturer's instructions).

The teeth were coated with nail varnish except for 1 mm around the restoration margins. All the specimens were subjected to thermocycling at a temperature of 5 and 55°C ($\pm 1^\circ\text{C}$) for 100 cycles with a dwell time of 30 seconds. Later the teeth were immersed in 1% methylene blue dye for 24 hours. After removal from the dye, the varnish coating was removed with acetone solution and the teeth were thoroughly rinsed with water and dried with tissue papers.

The specimens were mounted on acrylic resin blocks and the teeth were sectioned buccolingually with the help of safe sided diamond disk in a slow-speed micromotor. Photo micrographs of the cut sections were observed under stereo microscope at 20 \times magnification. The degree of microleakage was evaluated by the amount of dye penetration from occlusal margin to the base of cavity and scoring was given according to the evaluation criteria put



Figs 1A to D: Stereomicroscope and photomicrographs at 20× magnification

forth by Castro and Feigal (2002)⁶ (Figs 1A to D). As the whole procedure was carried out by a single operator, a second investigator randomly evaluated the specimens and gave scoring for the same. As the interexaminer variability was not statistically significant, the values given by the first investigator were only considered. The scores thus obtained were tabulated and subjected to statistical analysis (Kruskal-Wallis H test and Mann-Whitney U test).

RESULTS

The present *in vitro* study was designed to know the degree of microleakage at the tooth-restoration interface. The cavity preparation protocols followed were conventional and two different CMCR methods. The two restorative materials compared in this study were conventional GIC (Fuji II) and Giomer (Beautifil II).

In test material I (Fuji II), there was statistically significant difference in microleakage between three groups with group A (2.09) showing highest microleakage followed by group B (0.64) and least in group C (0.27) whereas test material II (Beautifil II) showed no significant difference among the three groups (Table 1). When both the materials were compared, the mean microleakage scores with conventional GIC were significantly higher compared to Giomer (Table 2).

Table 1: Pairwise comparison of microleakage of three groups in tested materials

Group	Fuji II		Beautifil II	
	Mean±SD	p-value	Mean±SD	p-value
A	2.09±1.22	0.008*	0.18±0.40	0.748
B	0.64±0.67	Significant	0.27±0.47	Not significant
A	2.09±1.22	0.002*	0.18±0.40	0.748
C	0.27±0.47	Significant	0.27±0.47	Not significant
B	0.64±0.67	0.243	0.27±0.47	1.000
C	0.27±0.47	Not significant	0.27±0.47	Not significant

*Statistically significant if p < 0.05; HS: Highly significant

Table 2: Mean values of microleakage for tested materials

Material	N	Mean±SD	p-value
Fuji II	30	1.0±1.17	0.03*
Beautifil II	30	0.26±0.44	Significant

DISCUSSION

In the present era, with better understanding of the caries process, the concept of extension for prevention has taken an “U” turn and became prevention of extension with maximum focus on conservation of portion of dental hard tissues though demineralized but uninfected. This became a possibility with the advent of new caries removal techniques and adhesive restorative materials.

Caries excavation has traditionally been performed according to mechanical principles using drills and sharp-edged hand instruments. But this method cannot judge the amount of carious dentin to be removed due to lack of objective clinical markers. It also causes discomfort, pain, and often needs administration of local anesthesia. Chemo-mechanical caries removal was developed to overcome these barriers. The main advantageous properties of CMCR agents include tissue-specific action (able to differentiate between infected and affected dentin), effective removal of smear layer, and less traumatic for the patient. Chemo-mechanical caries removal gels promote dissolution of predegraded collagen of carious lesion without affecting adjacent healthy tissues (chemical action) followed by removal of this softened carious tissue by gentle excavation (mechanical action) which avoids pain stimuli.⁷ The mode of caries removal may affect the quality of bonding of restorative material to the tooth structure to a considerable extent. Henceforth, conventional caries removal technique and CMCR gels (Carisolv and Papacarie) were compared in this laboratory study.

The Carisolv system consists of a gel with sodium hypochlorite and amino acids along with special hand instruments. Even though sodium hypochlorite is a non-specific deproteinizing agent, the capability to selectively remove carious dentin was attributed to the buffering effect of the amino acid mixture, originally intended to reduce the aggressiveness of sodium hypochlorite on sound dentin and to enhance disrupting effect on degenerated collagen within carious dentin.⁸ The chlorination affects the secondary or quaternary structure of collagen by breaking hydrogen bonding, which would soften this carious tissue and reduce the pressure required for removal of infected dentin.⁹ The chloride present in the gel does not seem to be able to interact with collagen fibrils of sound dentin since they are protected by mineral crystals.¹⁰

Another CMCR agent used in this study was papain-based gel, i.e., Papacarie which means "eating caries." Papain is a proteolytic enzyme with bactericidal, bacteriostatic, and anti-inflammatory characteristics. The main advantage of this new enzyme based gel is that it can be more specific by digesting only denatured collagen (after the triple helix integrity is lost) than the sodium chlorite-based agents.¹¹ Flindt¹² demonstrated that papain acts only on infected tissues because they lack plasmatic antiprotease called AI antitrypsin, which is only present in sound tissues and inhibits protein digestion. The absence of AI antitrypsin enzyme in infected tissues allows papain to break the partially degraded molecules. In addition to papain, Papacarie also contains chloramines which are mainly used to chemically soften the carious dentin. Carisolv being most commonly used,

efficient and time tested; this material was selected for the present study to compare its efficacy.

Restoring carious teeth is one of the major treatment needs in pediatric dentistry. Even though conventional GIC is reasonably a good dental restorative material for child patients, new versions of improved GIC's were developed by adding other materials with more desirable properties, one such development was Giomer. Giomer has unique feature of a stable surface prereacted glass core (S-PRG) that is coated with an ionomer lining in a resin matrix which allows for protection of the glass core from moisture, giving it long-term esthetics and durability with fluoride ion release and recharge.^{13,14} Hence, these two restorative materials (conventional GIC and Giomer) were chosen in the current study.

The parameter intended to assess in the present study was microleakage at the tooth-restoration interface as it is one of the important factors affecting the longevity of restoration. Most of the restorative materials show varying degree of marginal leakage which originates in several circumstances, i.e., dimensional changes from mismatch between the coefficient of thermal expansion of the tooth and restorative material or between the elastic modulus of the tooth and the restorative material, lack of adaptation between the restoration and tooth structure that may result from polymerization shrinkage of the restorative material.¹⁵

Microleakage can be assessed by various methods like radioisotopes, dyes, air pressure, neutron activation analysis, bacterial penetration, pH changes, and scanning electron microscopy, but dyes and radioisotopes are the most commonly used. Several dye penetration studies have been performed using methylene blue, india ink, basic fuchsin, crystal white as well as flourescin.¹⁶ In this study, the dye used as a measure of microleakage was 1% methylene blue because it can penetrate better than other solutions due to its size that is smaller than the smallest bacteria, easy for handling and inexpensive.¹⁷⁻¹⁹ Since the *in vitro* studies do not reflect all the variables present in patient mouth, thermocycling was done to mimic intraoral environment to some extent. Specimens were thermocycled 100 times since more than 100 cycles have been shown to be unnecessary.²⁰

The results of this study demonstrated that none of the tested materials were absolutely free from microleakage, but conventional GIC exhibited significantly more microleakage than Giomer ($p=0.03$). It could be due to PRG particles present in Giomer which exhibit a stable glass ionomer hydrogel that surrounds an inner fluoridated glass core.²¹ The glass ionomer phase of the PRG filler surface has the ability to form an ion exchange bond with the inorganic component of dentin that results in resin-dentin bonds more resistant to hydrolytic breakdown.^{22,23}

Ferriera et al²⁴ obtained more microleakage scores with conventional GIC in their study which was attributed to the reduced setting time of glass ionomer that does not allow proper flow of the material and consequently disrupts the marginal seal. In addition to that, increased solubility and porous nature of this material are important factors which might promote the potentiality to microleakage. The granulated texture of glass ionomer viewed under the stereomicroscope confirmed its high microleakage scores in a study conducted by Gupta et al.²⁵ Another study by Mali et al²⁶ also observed maximum microleakage for Fuji II than composite and compomers whereas Walse and Hembree²⁷ established minimum microleakage with GIC contradicting the results of the present study.

Among all the tested groups, group A exhibited highest microleakage, when conventional GIC was used, the probable reason for this could be formation of smear layer during CCP which would interfere with the adhesion of restorative material. Use of conventional burs has resulted in smooth and regular dentin surface with a smear layer and is expected to form weaker bonding with adhesive systems.²⁸ Tanumihraja et al²⁹ and Banomyong et al³⁰ reported that the chemical bonding of glass ionomer is not greatly influenced by conditioning of the dentin surface. The less aggressive poly alkenoic acid of glass ionomer cleans the tooth surface, removes the smear layer only up to 0.5 to 1 µm depth without denuding hydroxyapatite.³¹ But when Giomer was used for the same method of cavity preparation there was less microleakage which might be referred to removal of smear layer using acid etchant and application of bonding agent that facilitates adhesion of material to the tooth structure.

Irrespective of the material used, group C exhibited least microleakage, the probable reason might be that Carisolv created a change in the structure and morphology of dentin surface, which affected the sealing of margins and reduction of the micropermeability. Studies proved that following the use of Carisolv on the dentin surface, there was no sign of a smear layer and dentin tubules had opened completely and showed unclear porosity, which is similar to the microscopic pattern following the use of phosphoric acid, which in turn increases surface energy, improves wetting potential, and thereby increasing the adhesiveness of the material to the tooth structure.^{10,32-35} The results of the present study were in accordance with the study conducted by Maru et al³⁶ which concluded that CMCR gels showed less microleakage due to more irregular and rougher surfaces with modified smear layer than conventional rotary preparation. On the contrary, Mousavinasab and Jafary³⁷ have found that Carisolv failed to remove

the smear layer and patent dentin tubules were not visible.

Group B demonstrated significantly less microleakage compared to group A. It was shown that Papacarie removes the smear layer completely and exposes dentinal tubules similar to total etch technique.³ Bertassoni and Marshall³⁸ resolved that Papacarie promotes superficial degradation of collagen fibrils independent of a preceded partial degradation due to bacterial action. So, the irregular surfaces observed in Papacarie-treated cavities could provide a suitable surface for superior adhesion and less marginal leakage in group B samples. Out of the two CMCR gels tested, Carisolv was found to be better than Papacarie, even though the difference was not significant which might be due to the more aggressive proteolytic action of hypochlorite present in the Carisolv.

Along with the advantages like conservation of tooth structure, reduction of pain and stress, CMCR technique has some disadvantages like longer working time than drilling and complaints of bad smell and taste by few patients with Carisolv.^{3,39,40} The CMCR agents are still not in a position to replace rotary instruments as they cannot remove the enamel overlying the caries or access to small/interproximal carious lesions, still they can be used as a viable alternative to conventional technique in specific situations.

Certain limitations of this study include the use of natural lesions where standardization of the variables like shape of the lesion, location, depth, type, consistency, and the activity status is not possible. In addition, the carious lesions in extracted teeth may respond differently to excavation than the teeth in function since an outward flow of fluid has been reported in *in vivo* dentin which is partly ameliorated by using freshly extracted teeth. Since the teeth in laboratory studies were not subjected to mechanical stress, occlusal wear, and other biological factors, long-term clinical studies are required to critically evaluate the relevance of these *in vitro* studies.

CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions could be drawn:

- When compared to CCP, CMCR technique has proved to be superior.
- Out of the two CMCR agents used, the microleakage scores were less with Carisolv than Papacarie.
- Irrespective of the method followed for caries removal, Giomer was proved to be efficient in maintaining good adhesion to the tooth structure when compared to conventional GIC.

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