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Influence of air abrasion preparation on microleakage in glass ionomer cement restorations

LUCIA DA SILVA REIS[1], MICHELLE A. CHINELATTI[2], SILMARA A. M. CORONA[2,*], REGINA G. PALMA-DIBB[2], MARIA CRISTINA BORSATTO[3]
[1]*Graduate Student, Ribeirão Preto School of Dentistry, University of São Paulo, Brazil*
[2]*Department of Restorative Dentistry, Ribeirão Preto School of Dentistry, University of São Paulo, Brazil*
E-mail: nelsoncorona@uol.com.br
[3]*Department of Pediatric Dentistry, Ribeirão Preto School of Dentistry, University of São Paulo, Brazil*

The aim of this study was to assess microleakage in class V cavities prepared by air abrasion or high-speed dental bur and restored with different glass ionomer cements. Sixty bovine incisors were equally divided into 6 groups: I, II and III (preparation by high-speed) and IV, V and VI (preparation by air abrasion). Groups I and IV were restored with Fuji IX; groups II and V with Ketac Molar; and groups III and VI with Vitremer. After 24 h (37 °C), specimens were thermocycled, isolated with nail varnish, immersed in a 0.2% Rhodamine B solution for 24 hours, sectioned longitudinally and analyzed for microleakage using an optical microscope connected to a digital camera and a computer. The images were digitized and a software allowed the quantitative evaluation of microleakage in millimeters. Data were analyzed by Wilcoxon and Kruskal-Wallis tests. It was observed that there were significant differences ($p < 0.05$) between incisal (enamel) and cervical (dentine/cementum) margins, mainly for Ketac Molar; there was no difference ($p > 0.05$) between preparation methods, except for group II (high-speed/Ketac Molar) that showed higher infiltration; regarding the materials, Ketac Molar demonstrated the highest microleakage values ($p < 0.05$), and only Vitremer sealed completely both margins of restorations. It was concluded that air abrasion preparation did not influence microleakage in class V restorations with the employed glass ionomer cements.

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Introduction

The advent of adhesive restorative materials in dentistry has encouraged a trend towards conservation of tooth structure. This has led to investigations into methods of tooth preparation that are an alternative to conventional rotatory methods. Air abrasive technique is one altternative method using a high-speed stream of purified aluminium oxide particles delivered by air pressure [1].

Tooth preparation by air abrasion is reported to eliminate pressure, heat, noise and vibration associated with rotatory instruments, and to reduce pain, allowing preparation with less need for local anaesthesia [2–5]. Cavity preparation by air abrasion also introduces a surface roughening, which seems to be suitable for direct bonding techniques [6]. This fact could possibly improve the sealing ability of adhesive restorative materials.

Loss of seal integrity, often manifested as microleakage, may result in secondary caries, staining and post-operative sensitivity, ultimately leading to clinical failure [7]. Reducing or eliminating microleakage around restorations is an important objective in clinical practice and has resulted in numerous investigations on microleakage in direct restorations with adhesive matherials, such as glass ionomer cements [8–12]. Glass ionomer cements are alternative materials for conservative restoration due to their properties, including adhesion to tooth structure, fluoride release, mild pulpal irritation, lower setting shrinkage, acceptable esthetics, and reduced microleakage [8, 9].

However, there are few studies regarding microleakage in glass ionomer cement restorations placed in cavities prepared by air abrasion. Thus, the present study evaluated *in vitro* the degree of microleakage in class V

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*Author to whom all correspondence should be addressed.

TABLE I Experimental groups

Groups	Cavity preparation	Restorative system
I	High-speed	Fuji IX
II	High-speed	Ketac Molar
III	High-speed	Vitremer
IV	Aluminum oxide air-abrasion	Fuji IX
V	Aluminum oxide air-abrasion	Ketac Molar
VI	Aluminum oxide air-abrasion	Vitremer

cavities prepared by air abrasion and restored with different glass ionomer cements.

Material and methods

Sixty sound bovine incisors extracted within a 6-month period, stored in a saline solution at 4 °C and examined macroscopically for defects in enamel and dentin, were selected for the study. Teeth were carefully cleaned with a hand scaler and a water-pumice slurry in dental prophylactic cups, and randomly assigned to 6 groups of equal size, according to the cavity preparation method and to the restorative glass ionomer cement. The experimental groups are displayed in Table I and the tested glass ionomer cements are in Table II.

Sixty class V cavities were prepared on buccal surfaces with the incisal margin located in enamel and cervical margin in dentin/cementum. The cavity outline was previously traced on surfaces with a marker, to define a uniform size (4 mm mesio-distal width and 3 mm occluso-gingival measurement). The depth of the cavity was approximately 2 mm, calibrated by a premarked periodontal probe.

For air abrasion cavity preparations, the delimited surfaces were prepared with the air-abrasive system Mach 4.1 (Kreativ Inc., Albany, OR, USA), with aluminum oxide particles of 27.5 μm under 60 psi pressure with intensity of 4 g/min at continuous mode, delivered by a 0.011-inch nozzle opening, under a 45 ° angle with the tooth surface. The application distance was standardized using a custom designed apparatus consisting of a moving holder that positioned the handpiece in such way that the aluminium oxide particles stream was delivered at a constant distance of 2 mm from the delimited surface of the specimem. The specimens were fixed with wax at a semi-adjustable base. The operator manipulated the apparatus′ screws in such way that the semi-adjustable base with the specimem was moved in right-to-left and foward-to-back directions, thereby allowing the stream to provide a more accurate application of the entire delimited site. After the stream application, the specimem was removed and the cavity preparation was rinsed for 30 s, then gently dried with oil-free compressed air.

For the conventional method, cavities were prepared using a #245 carbide bur at high-speed handpiece under water spray coolant, and cavity finishing was done with the same bur at low-speed handpiece. The enamel cavosurface bevel was accomplished with a #1195 diamond point.

Cavities restored with conventional glass ionomers (Fuji IX and Ketac Molar) were previously etched with a 40% polyacrylic acid (Durelon Liquid—ESPE Dental AG, Seefeld-Germany) with a light scrubbing motion for 10 s, thoroughly rinsed with a water spray for 30 s and then gently air dried. For teeth restored with the resin-modified glass ionomer cement, a thin layer of Vitremer Primer (3 M Dental Products, St Paul, MN, USA) was applied to the entire surface with a disposable brush and light-cured for 20 s with a visible light-curing unit with a 450 mW/cm^2 output (XL 3000-3 M Dental Products, St Paul, MN, USA).

Cavities were restored with the glass ionomer cements following the manufacturer's instructions. The restorative materials were injected into the cavities in a single increment using a Centrix (Centrix, Shelton, USA) injector to prevent air-entrapment, void or bubble formation. Then, the unfinished conventional glass ionomer cement restorations were coated with a layer of colourless nail varnish, and for resin-modified glass ionomer restorations, Vitremer Finishing Gloss (3 M Dental Products, St Paul, MN, USA) was applied and light-cured for 20 s. Specimens were stored for 24 h in distilled water at 37 °C and then restorations were polished with Super-Snap disks (Shofu Inc., Kyoto, Japan) in a decreasing abrasive order. All cavity preparations, restorations and finishing procedures were performed by a same operator.

The specimens were submitted to a thermocycling regimen of 500 cycles between 5 °C and 55 °C waterbaths. Dwell time was 1 minute, with a 3-s transfer time between baths. In preparation for the dye penetration test, the teeth were superficially dried, the apices

TABLE II Tested glass ionomer cements

Material	Type/Composition	Powder/Liquid ratio	Batch number	Manufacturer
Fuji IX	Conventional high viscosity/Powder: aluminum-fluorosilicate glass, polyacrilic acid. Liquid: water, polyacrilic acid, tartaric acid, polybasic carboxilic acid.	3.6:1	010571	GC Co., Tokyo, Japan
Ketac Molar	Convetional high viscosity/Powder: calcium aluminum-lanthanum-fluorosilicate glass, acrylic acid-maleic acid copolymer. Liquid: acrylic acid-maleic acid copolymer, tartaric acid, water.	3:1	FW 0047716	ESPE/3 M Dental Products, St Paul, MN, USA
Vitremer	Resin-modified/Powder: fluoroaluminosilicate glass. Liquid: polyalkenoate copolymer, HEMA, water.	2.5:1	20010404	3 M Dental Products, St Paul, MN, USA

of all teeth were sealed off with epoxy resin and the entire tooth received two coats of nail varnish, except for a 2-mm window around restoration margins. As the nail varnish dried, the teeth were immersed in distilled water for 2 h, and then immersed in a 50% aqueous silver nitrate solution for 8 h, kept in a light-proof container. Afterwards, the teeth were rinsed thoroughly in tap water and the nail varnish was entirely removed with a sharp instrument.

The specimens were embedded in chemically activated acrylic resin (JET, Clássico, São Paulo, Brazil) and sectioned in a buccolingual direction with a water cooled diamond saw, in a sectioning machine (Minitom, Struers A/S, Copenhagen, Denmark), providing two to three 1.0 mm thick sections for each tooth. Afterwards, the sections were exposed to the light of a photoflood lamp for 20 min to reveal the silver nitrate, which, exposed to light, acquires a dark color, allowing the visualization of the dye-penetrated areas. The sections were initially thinned in a polishing machine (Politriz, Struers A/S, Copenhagen, Denmark) with 180- to 600-grit silicon carbide paper, and then manually smoothed with 1000- to 1200-grit SiC paper to obtain a flat surface and a final thickness of approximately 0.25 mm.

The cuts were identified and carefully fixed on microscopic slides. The margins were analyzed separately; each margin was viewed under a ×5 magnification optical microscope (Axiostar Plus, Carl Zeiss Vision GmbH, München-Hallbergmoos, Germany) connected to a digital camera (Cyber-shot 3.3 MPEG Movie EX, model no. DSC-S75, Sony Corporation, Japan). The images obtained were transmitted to a personal computer and, after digitization, were analyzed by Axion Vision 3.1 software (Carl Zeiss Vision GmbH, München-Hallbergmoos, Germany), which performs a standardized assessment of the tracer agent's extent along the margins and allows a quantitative measurement in millimeters. The depth of the cavity wall and dye penatration along incisal and cervical margins toward the axial wall were determined, and the percentage of dye penetration was calculated. The average of dye penetration for enamel and dentin interfaces were calculated for each group.

Data were subjected to statiscal analysis using Wilcoxon and Kruskall-Wallis tests at 0.05 significance level.

Results

Table III showsthe means of dye penetration and standard deviation at both margins for the experimental groups.

The analysis of the data showed statistically significant difference ($p < 0.05$) between the incisal (enamel) and cervical (dentin-cementum) margins for all groups. As a rule, there was less microleakage in the enamel margins. The materials completely sealed the enamel margins in both techniques of cavity preparation, except for group I (high-speed/Fuji IX) and group II (high-speed/Ketac Molar). At cervical margins, it was observed dye penetration in all groups, except for groups III (high-speed/Vitremer) and VI (air abrasion/Vitremer).

There was no difference ($p > 0.05$) between the preparations carried out with air abrasion and high-speed, except for cavities restored with Ketac Molar, which showed lower degree of penetration ($p < 0.05$) at cavities prepared by air abrasion.

Concerning the three restorative glass ionomer cements, the groups restored with Ketac Molar (II and V) presented the biggest values of dye penetration, being Vitremer the only one to seal completely both margins.

Discussion

The relationship between air-abrasion and microleakage has received limited attention. Few studied have examined microleakage of restored teeth prepared with air-abrasion and they have yielded conflicting results.

The findings of the present study disclosed that the used glass ionomer cements as restorative materials of class V cavities prepared by a aluminum oxide air abrasion system or a high-speed handpiece presented similar behavior, unless for Ketac Molar, that presented the biggest values of infiltration in the cavities prepared by high-speed. The lesser microleakage observed in the cavities prepared by air abrasion and restored with Ketac Molar can be ascribed to the bigger dentine surface roughness produced by the aluminum oxide spurt, providing an increase in the surface area [12, 13].

The resin-modified glass ionomer cement, Vitremer, sealed completely both enamel and dentine/cementum margins of the restorations, no matter what the cavity preparation method. This probably ocurred due to this cement bond to enamel and dentine via the development of ionic crosslinks at the tooth-retoration interfaces, as in the conventional glass ionomer cement adhesion mechanism [14]. Moreover, the pretreatment of dentine, along with the modified composition of glass ionomer liquid, should result in a more intimate contact of cement with tooth structure and an elevated bond strength [15, 16]. Vitremer contains polymerizable monomers such as 2-hydroxyethyl methacrylate

TABLE III Means (%) and standard deviation of dye penetration at enamel and dentin/cementum margins

	High-speed Fuji IX (Group I)	High-speed Ketac Molar (Group II)	High-speed Vitremer (Group III)	Air abrasion Fuji IX (Group IV)	Air abrasion Ketac Molar (Group V)	Air abrasion Vitremer (Group VI)
Enamel	10.96 (±15.5)	15.84 (±32.02)	0 (±0)	0 (±0)	0 (±0)	0 (±0)
Dentin/ Cementum	10.72 (±16.59)	90 (± 31.62)	0 (± 0)	15 (±33.74)	73.33 (±43.88)	0 (±0)

(HEMA) in its composition, and besides a simple mixture of HEMA with a polyalkenoic acid, the later itself is also modified by the attachment of polymerizable methacrylate side groups [8]. In addition, Vitremer uses a primer that improves the wetting of dentine [17].

The similarity between the cavity preparation techniques can be explained due to the surface treatment after the accomplishment of the cavity preparation and previously to the insertion of the materials, which reduce the substrate's surface energy, resulting in a more intimate contact of the cements with tooth structure and an elevated bond strength [18]. It has been suggested from previous studies [19–22] that air-abrasive technology has the potential to prepare tooth bonding surfaces equal to those obtained from acid etching. The application of weak acid solutions, such as polyacrylic acid, for dentinal surface treatment previously to glass ionomer restorations, is strongly advised due to its ability to promote surface cleaning, increase the surface energy and optimize the contact between the material and substrate, by eliminating only the smear on, without demineralyzing dentin or removing smear plugs. Such treatment maintains calcium ions available for chemical reaction with cement, also avoiding the contamination of the restoration by moisture from dentinal fluid [18].

In the present work, the margins located in enamel presented lower values of dye penetration than the margins in dentine for the greater part of the tested groups. Similar findings concerning the marginal sealing were also observed in cavities prepared by air abrasion and compared with high-speed turbine and restored with composite resin [10, 11, 24] and glass ionomer cements [25]. This probably ocurred due to presence of microporosities in the conditioned enamel surface, increasing the area for chemical or micromecanical adhesion, and due to the lesser amount of calcium ions in dentine, which can worsen the adhesion and the marginal sealing [18].

In a previous study [11], it was found severe microleakage at the dentine/cementum margins, and less microleakage was detected at the enamel cavity margins in class V cavities prepared by air abrasion and restored with composite resin bonded with self-etching primers. Some authors [26] stated that microleakage did not occur in enamel for both conventional and air-abrasion cavity preparation methods when the enamel was etched prior to adhesive application.

Aluminum oxide air-abrasion is still in developmental stage compared to the traditional high-speed turbine technique, and may be useful as adjunct or replacement method for some cavity preparation and restorative materials. Studies have yet to establish the adhesive behavior obtained with air-abrasion systems and how it differs from that obtained with conventional techniques. Likewise, additional research should also determine whether any difference is produced by varying particle size or pressure.

Further investigation that focuses on the long-term effects of ultrastructural changes observed in enamel and dentin substrates prepared and treated by air-abrasive systems may lead to improved microleakage prevention as well to more widespread applicability of this technology in clinical practice.

Conclusion

Based on the results obtained in the present work and within the limitation of an *in vitro* study, it is possible to conclude that cavity preparations accomplished either by air abrasion or high-speed techniques and restored with conventional glass ionomer cements (Fuji IX and Ketac Molar) did not present complete marginal sealing, whereas only the resin-modified glass inomer cement (Vitremer) was able to hinder dye penetration; and air abrasion preparation did not influence microleakage in class V restorations with the employed glass ionomer cements.

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