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Comparative evaluation of microleakage of a carbomer/ fluoroapatite-enhanced glass-ionomer cement on primary teeth restorations

ABSTRACT

Aim *Carbomer cement represents a novel glass-ionomer which gradually mineralises into fluoroapatite. Purpose of this study was to evaluate microleakage around restorations in deciduous teeth made with composite resin, conventional glass-ionomer cement, resin-modified glass-ionomer cement and carbomer/ fluoroapatite-enhanced glass-ionomer cement.*
Materials and methods *A group of 40 primary upper canines, primary upper and lower molars was divided into 4 groups (n=10). Class I cavities were prepared by diamond cylindrical bur at high speed and were restored with a composite resin (Group 1), with a glass-ionomer cement (Group 2), with a resin-modified glass-ionomer cement (Group 3) and with a carbomer/ fluoroapatite-enhanced glass-ionomer cement (Group 4). Hard tissue's bonding involved, in the case of composite resin a total etch bonding procedure, and in glass ionomers the use of their respective primers. Restorations were finished and polished. A 24-hour water storage was followed by thermocycling (1500 cycles, 5°C – 36°C – 55°C – 36°C with a dwell time of 15 seconds) and dye penetration test with immersion in 5% methylene blue for 24 hours. In order to assess the degree of microleakage longitudinal cuts were produced by means of a microtome at 0.5 mm and at 1 mm from the restoration margin, and photographs were taken with a stereomicroscope at 100X. Microleakage was classified according to the number of surfaces and the depth at which dye penetration was observed. Data were analysed with ANOVA and post-hoc analysis was performed with Bonferonni test ($p<0.05$).*
Results *Statistical analysis exhibited no significant statistical difference between Group 2 and Group 3 ($p>0.05$). Statistical difference was exhibited between Group 3 and Group 4 ($p<0.01$), with Group 4 exhibiting lower microleakage values. Group 1 exhibited the lowest mean microleakage values and statistical difference in comparison with all groups ($p<0.001$). Group 4 exhibited the lowest microleakage values among the cements.*
Conclusion *Superior marginal integrity is achieved in restored primary teeth when composite resin is used. If the clinical case suggests the use of a glass-ionomer cement, carbomer/fluoroapatite-enhanced glass-ionomer cement is prefered in terms of microleakage.*

Keywords *Basic sciences; Fluoroapatite; Microleakage; Restorative dentistry/dental materials.*

Introduction

As caries accounts for a major problem concerning primary teeth, successful restorations are every clinician's objective. Marginal quality of the restoration is regarded as the cornerstone of success and long-term preservation. Poor marginal adaptation which may result in microleakage, destroys the restoration both biologically leading to secondary caries and sensitivity, and aesthetically by color absorption, staining and discoloration of the restoration. A minimal degree of leakage can be tolerated and not cause a reaction. But in some cases it can become the source of postoperative pain and recurrent caries and lead to restoration failure [Pashley, 1996].

Restorations in primary teeth are usually fabricated with composite resins and glass-ionomer cements (GIC). However, favourable clinical properties of GICs, such as fluoride release, adhesion to tooth structure, coefficient of thermal expansion (Wilson, 1989), biocompatibility, antibacterial effect [Davidovich et al., 2007] and enamel remineralisation [Bynum and Donly, 1999] has made the material famous among paediatric dentists, especially in cases with high caries risk [Souchois and Vieira, 2012] or in atraumatic restorative techniques (ART) [Davidovich et al., 2007]. Besides the advantages of GICs, polymerisation shrinkage of composite resins and its subsequent phenomena, such as cusp deflection, gap formation and microleakage, play an important role in material selection [Pfeifer et al., 2008]. On the other hand, compromised mechanical properties, water solubility and surface wear have also been listed as disadvantages in GIC restorations. In order to overcome these drawbacks and take advantage of the favourable characteristics of composite resins, such as mechanical strength, resin-modified glass-ionomer cements (RMGIC) were developed. RMGIC are hybrid materials, consisting of a ionomer and of a resinous phase, and exhibiting properties closer to glass-ionomers or to composite resins, depending on which phase prevails over the other during setting [Yelamanchili and Darvell, 2008]. Following the latest trends in hard tissues management, a new glass carbomer cement has been introduced, which besides superior mechanical properties, matures rapidly to form a durable restoration and claims to be able to mineralise into fluoroapatite [van Duinen et al., 2004] or hydroxyapatite [Zainnudin et al., 2012]. In organic chemistry, a carbomer is an expanded molecule obtained by insertion of a C2 unit into each bond of a given molecule, replacing single and double bonds with alkyne and allene bonds consecutively [Remi Chauvin, 1995]. The glass carbomer material is a patented GIC (US Patent Application 20060217455), consisting of: a) dialkyl-siloxane- and b) acidically-treated glass powder enhanced with nanosised particles and fluoroapatite as secondary fillers and of polyacrylic acid as a liquid as conventional GICs. The addition of fluororapaitite fillers is based on previous *in vivo* studies by van Duinen et al. [2004], who demonstated that glass-ionomer is chemically transformed into fluoroapatite-like tissue in primary teeth. This property makes the material essential for Class I restorations, where fissure caries is a problem. Nanosised powder fillers improve mechanical properties, such as flexural strength [Gorseta et al., 2009] or microhardness [Gorseta et al., 2010; Menne-Happ and Ilie, 2013]. Despite the fact that it does not contain a resinous phase, manufacturer suggests warming with a polymerisation unit, in order to produce a strong and stable surface, immediately after placement.

Since there is no published clinical data on carbomer cements and literature is scarce, laboratory testing provides important information on the properties and clinical use of the material. Moreover, no detailed comparative *in vitro* studies concerning microleakage around restorative materials in primary teeth have been reported up to date. Consequently, the purpose of the present study was to evaluate microleakage exhibited by a carbomer/fluoroapatite-enhanced glass-ionomer cement in comparison to a composite resin, a GIC, and a RMGIC in Class I restorations in primary teeth. The null hypothesis was that there is no difference in microleakage exhibited by a composite resin, a GIC, a RMGIC and a carbomer/fluoroapatite-enhanced glass-ionomer cement, around Class I restorations in primary teeth.

Material	Synthesis	Type	Bonding Agent	Filler / Particle Load	Delivery and Handling
Tetric EvoCeram (Ivoclar Vivadent, Schaan, Liechtenstein)	Matrix: Dimethacrylates, additives, catalysts, stabilizers, pigments Filler: Barium glass, ytterbium trifluoride, mized oxide, prepolymers	Nanohybrid Composite Resin	Excite (Ivoclar Vivadent, Schaan, Liechtenstein)	82.5% w/w 68% v/v	Syringe
Ketac Molar (3M, ESPE Dental Products, St. Paul, Minn, USA)	Powder: calcium, aluminium-lanthanum-fluorosilicate glass, acrylic acid-maleic acid copolymer. Liquid: acrylic acid-maleic acid copolymer, tartaric acid, water	Glass-Ionomer Cement	(none)	(not mentioned)	Hand-mixing in powder / liquid ratio 3:1
Ketac N100 (3M, ESPE Dental Products, St. Paul, Minn, USA)	Aqueous component: Deionised water Methacrylate component: Blend including HEMA Polyalkenoic acid component: VBCP (methacrylate modified polyalkenoic acid or copolymer Vitrebond), FAS nanomers (fluoroaluminosilicate glass) forming nanoclusters	Resin Modified Glass-Nanoionomer Cement	Ketac N100 Nano-Ionomer Primer (3M, ESPE Dental Products, St. Paul, Minn)	69% w/w, 56% w/v	Hand-mixing standard quantity of paste / paste used with clicker dispenser
Glass Fill (GCP)	Powder: fluorosilicate glass treated with poly(dialkylsiloxane) having terminal hydroxyl groups, wherein the alkyl groups contain 1 to 4 carbon atoms, fluoroapatite particles Liquid: aqueous acid solution (polyacrylic acid and an inorganic acid). Carbomer / fluoroapatite-enhanced glass-ionomer cement(none) 50% vol. Capsules primed and mixed, used with a universal capsule gun	Carbomer / fluoroapatite-enhanced glass-ionomer cement	(none)	50% vol.	Capsules primed and mixed, used with a universal capsule gun

TABLE 1 Characteristics of tested materials.

Materials and methods

Tooth collection and cavity preparation

A group of 40 freshly extracted primary teeth (upper canines, primary upper and lower molars) were collected from a private dental office and were checked for caries or fractures under magnification, then stored in physiological saline in a refrigerator (4-5°C) for a maximum period of 30 days. Standardised Class I cavities (2 mm width x 2.5 mm depth) were prepared by a single, calibrated operator using a cylindrical standard-grit (106-125μ) diamond bur (SR-13, Dia-Burs, Mani Inc, Japan) under continuous air-water spray. No beveled edges were made in enamel in cavities that would be filled with the cements, but a slight bevel was prepared for the cavities which would be restored with composite resin.

Placement of the restorations

Teeth were randomly divided into 4 groups (n=10) and were immediately restored by the same operator using a composite resin, a GIC, a RMGIC and a carbomer/fluoroapatite-enhanced glass-ionomer cement, according to the manufacturer's instructions. Groups were as follows.

- Group 1: composite resin (Tetric EvoCeram, Ivoclar-Vivadent, Schaan, Liechtenstein).
- Group 2: GIC (Ketac Molar Easy Mix, 3M, ESPE Dental Products, St. Paul, Minn).
- Group 3: RMGIC (Ketac N100, 3M, ESPE Dental Products, St. Paul, Minn).
- Group 4: carbomer/fluoroapatite-enhanced glass-ionomer cement (GCP Glass Fill, GCP Dental, Vianen, Netherlands).

Composition of the tested materials is reported in Table 1. In case of the etch and bond procedure (Group 1), enamel etching with 37% phosphoric acid (Total Etch, Ivoclar-Vivadent, Schaan, Liechtenstein) was performed for 60 seconds, followed by dentine etching for 30 seconds. The acid was rinsed off with water spray for 20 seconds and the tooth surface dried with a slight draft of air for 2 seconds, from an air syringe held 20 cm away from the tooth. Bonding agent (Excite, Ivoclar-Vivadent, Schaan, Liechtenstein) was applied to enamel and dentine with a brush for 5 seconds. After application, bonding agent was thinned while excess solvent was blown with a light air from an air syringe. Polymerisation of the adhesive layer was performed for 20 seconds with Radii Plus (SDI) light curing unit (1500mW/cm^2). Consequently, composite resin was placed in shade A2. Composite resin placement was performed in two diagonal increments. Each increment was separately placed, condensed and formed with a "ward-type" composite resin instrument and was then polymerised for 40 seconds.

In restorations with the cements, matching primer was applied beforehand, while no etching took place. In Group 2, teeth were air dried with a slight draft of air for 2 seconds, from an air syringe held 20 cm away from the tooth and Ketac Conditioner (3M, ESPE Dental Products, St. Paul, Minn) was applied with a brush and was allowed to react with the smear layer for 10 seconds. Then it was thoroughly rinsed off with water spray for 20 seconds and tooth was dried with a slight draft of air for 2 seconds from an air syringe held 20 cm away, allowing for a matt shiny appearance of the cavity. GIC was mixed with a plastic spatula at a 3:1 powder/liquid ratio and the cavity was filled within 1 minute. Restoration was shaped and the cement was allowed to set. Ketac Glaze (3M, ESPE Dental Products, St. Paul, Minn), a hydrophobic, protective varnish, was applied to the surface of the restoration with a brush, was thinned with a slight draft of air from the air syringe and was polymerised for 20 seconds. Further shaping was conducted after 4.5 minutes of initial setting. A thin layer of Ketac Glazed was re-applied following the same instructions.

In Group 3 teeth were air dried with a slight draft of air for 2 seconds, from an air syringe held 20 cm away from the tooth and Ketac N100 Nano-Ionomer Primer (3M, ESPE Dental Products, St. Paul, Minn) was placed with a fiber tip for 15 seconds to prepare semi-dry cavity surfaces and was replenished as needed to assure surfaces were kept wet during the application time. Tooth was dried with a slight draft of air for 10 seconds resulting in primed shiny surfaces. Primer was polymerised for 10 seconds. Consequtively, Ketac N100 (3M, ESPE Dental Products, St. Paul, Minn) in shade A2 was mixed from the paste/paste dispenser and placed in the cavity within 1 minute. RMGIC was allowed to set for 1 minute after placement and was polymerised for 20 seconds. Immediately after polymerisation, restoration surface was shaped.

In Group 4 teeth were air dried with a slight draft of air for 2 seconds, from an air syringe held 20 cm away from the tooth. No primer or conditioner was used. GCP Glass Fill (GCP Dental, Vianen, Netherlands) in shade A2 was applied. The restorative material capsule was activated according to the directions and was mixed at a high-frequency mixer (Rotomix, 3M-ESPE) for 15 seconds and dispensed with a universal capsule gun. The cavity was filled continuously during 30 seconds while keeping the nozzle within the material, to avoid bubble formation. GCP Gloss (GCP Dental, Vianen, Netherlands) was applied with a sponge applicator in order to protect moisture and dessication during warming. After that, the restoration surface was roughly modeled within the working time of 1 minute and 15 seconds. Then the restoration was warmed with a curing unit for 60 seconds. Further surface shaping was conducted after 4 minutes of setting.

Surface anatomy was roughly produced for all groups, though it was preferred to overfill the cavity in order to avoid any area at the enamel margins being left uncovered. The occlusal surfaces were grossly contoured and all cavosurface margins were polished using Soflex discs (3M, ESPE Dental Products) in successive roughness. Restorations were finished with One-Gloss silicon tips (Shofu Inc, Kyoto, Japan) in low speed and specimens were stored in physiological saline for 24 hours. Thermocycling for 1500

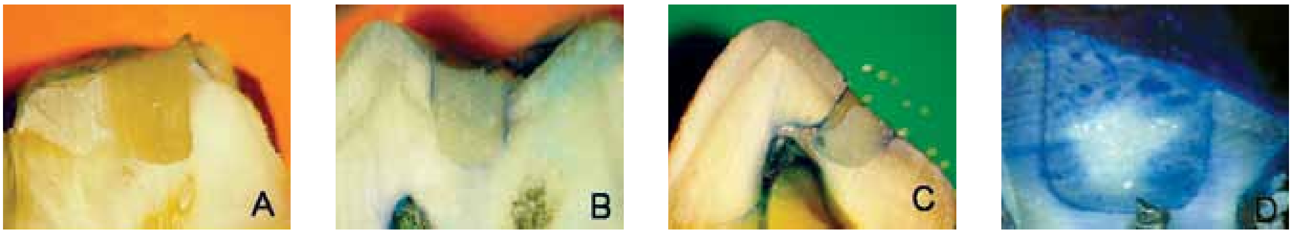

FIG. 1 Representative microleakage digital photos from the stereomicroscope. A: Group 1, Composite Resin; B: Group 2, GIC; C: Group 3, RMGIC; D: Group 4, Glass Carbomer.

cycles (5°C - 36°C - 55°C - 36°C / dwell time 15 seconds / transfer time 5 seconds) followed, in order to simulate the thermal changes taking place in the oral cavity.

Dye Penetration Test

Teeth apices were covered with sticky wax and teeth were then covered with two layers of nail varnish with the exception of the restoration area and an area 1 mm around it, in an effort to exclude dye penetration from another point other than the occlusal margin of the prepared cavities, which might lead to false positive results. Consecutively, teeth were immersed into a 5% aqueous solution of methylene blue, in order to produce a visible staining where microleakage would occur. Teeth were removed from the dye after 24 hours, washed off under tap water for 5 minutes, dried with sterile gauges and air from the air syringe and immediately proceeded to the microtome for sectioning. Two parallel, longitudinal, mesio-distal cuts followed, resulting in 3 slices for each specimen. The first cut was made 0.5 mm away from the restoration margin in the mesio-distal direction, while the second cut was made 1 mm away from the same point, using a low speed diamond saw under water irrigation.

Microscopy / Dye penetration scores

photographsofeachcutweretakenatastereomicroscope under a 100X magnification. Microleakage was classified according to the number of surfaces and the depth at which dye penetration was observed, by a single examiner, blinded to the material and the technique and different from the one who performed the preparation and restoration of the teeth. Microleakage was measured as a continuous track of dye along the axial or pulpal cavity walls (Fig. 1). Digital image analysis was used in order to obtain detailed measurements. Measurements were performed at 3 slices for each specimen, resulting in a total number of six recordings per specimen. Mean score was calculated for each slice and then mean score was calculated for each specimen. Classification of dye penetration scores is the following:

- 0) No dye penetration.
- 1) Dye penetration <1/2 of the length of the axial wall.
- 2) Dye penetration >1/2 of the length of the axial wall.
- 3) Dye penetration <1/2 of the length of the pulpal wall.
- 4) Dye penetration >1/2 of the length of the pulpal wall.

Statistical analysis

Normality was checked with Shapiro Wilk ($p>0.05$). Microleakage scores for each experimental group were normally distributed. Homogeneity of Variances was checked with Levene's test ($p<0.001$). Since microleakage was assessed in scores, non-parametric tests were used for analysis. Statistical analysis was performed using one-way ANOVA to explore whether significant differences existed among restorative materials used, followed by post-hoc Bonferroni test to determine differences among specific comparisons. Statistical analysis was conducted with SPSS 20.0 for Windows software (SPSS Inc, Chicago, IL, USA). Statistical significance was set at $p<0.05$. Microsoft Word and Excel have been used to generate graphs, figures and tables.

Results

Representative photographs depicting microleakage along the tooth-restoration interface are presented in Figure 1. Results are reported in Figure 2 and Table 2. Mean and standard deviation of microleakage degree for each material was as follows.

- Group 1 (1, 0.01).
- Group 2 (3.8, 0.36).
- Group 3 (3.59, 0.7).
- Group 4 (3.08, 0.72).

There was no specimen that exhibited no microleakage at all. No outliers were present. Microleakage ranking was as follows: Group 1 < Group 4 < Group 3 < Group 2. However, statistical ranking observed was as follows: Group 1 < Group 4 < Group 2 = Group 3. Specific comparisons exhibited statistically significant differences between most of the groups. Table 2 summarises the results of the multiple comparisons between the groups.

Discussion

The null hypothesis was partially accepted, as comparison between GIC and RMGIC exhibited no statistical difference in terms of microleakage ($p=0.924$). Multiple comparisons between composite resin, glass carbomer, GIC and RMGIC (with the exception mentioned above) demonstrate varying differences, emphasising the effect of the type of restorative material on marginal sealing.

The present results indicate that glass carbomer exhibits lower microleakage values than GIC and agree with the existing literature [Cehreli et al., 2013; Gorseta et al., 2009b]. However, only the study by Cehreli et al.. [2013] used primary teeth, but both have exhibited no statistical significance between glass carbomer and GIC, in contrast to the present study which is performed with primary teeth and has exhibited statistical significance for the same groups (Table 2). Both materials are glass-based, but glass carbomer has a finer structure, allowing for less matrix between the glass particles and increasing the reactive surface between the molecules. These characteristics may improve the acid-base setting reaction, resulting in stronger consistency avoiding fluid absorption and expansion. On the contrary, when glass carbomer is used as a sealant, it exhibits worse microleakage results in comparison to GIC and composite resins [Chen et al., 2009]. The explanation of this difference may lay upon differences between dental tissues of permanent and primary teeth, on the fact that occlusal sealing lacks cavity preparation while only enamel takes part in bond formation and on lower viscosity of restorative glass carbomer, which may in turn have a potential effect on the chemical bond strength. In lack of other comparable studies on primary teeth and taking into consideration their Aforementioned morphological characteristics, the statistical significance between most of the compared material groups, highlights the importance of material choice in primary teeth restorations. Although a dye penetration set up alone cannot explain the exact reasons for this finding, it may be speculated that superior sealing performance of glass carbomer can be associated with the formation of an apatite layer, greater than 500 μm, which expands into the restoration and increases bond strength between the restorative material and enamel [van Duinen et al., 2004; Zainnudin et al., 2012]. It has been generally reported that apatite-enriched cements achieve higher bond strength to both enamel and dentin [Glavina et al., 2009; Moshaverinis et al., 2008; Lucas et al., 2003]. Hypothetically, another possible explanation for the supremacy of glass carbomer against ionomer cements could be an adjacent coefficient of thermal expansion with enamel, allowing the material and tooth substances to expand and shrink at the same rate thus avoiding microgap formation. However, there is no such data up to date for glass carbomers.

A single microleakage study cannot predict clinical behavioUr, however glass carbomer, complying with ADA directive 27 for permanent, posterior restorations, exhibits improved characteristics against ionomer cements [Glavina et al., 2009; Gorseta et al., 2010], which defend its use in clinical practice. Mechanical characteristics, such as compressive strength or flexural strength have an indirect impact on marginal sealing, after occlusal loading of the restoration during mastication. Carbomer technology relies on the fabrication of molecules of bigger size and of same symmetry. Higher molecular weight cements exhibit enhanced strength, but studies are limited to molecular weight of the liquid part of a GIC [Wilson et al., 1977]. Following the same trend, increased molecular weight of the carbomer molecule may explain the mechanical characteristics of the glass carbomer. Enhancement of conventional GIC with fluoro- or hydroxyapatite particles produces promising materials in terms of mechanical properties [Gorseta et al., 2009; Moshaverinia et al., 2008; Lucas et al., 2003]. It is also recommended by the manufacturer to warm the glass carbomer cement with a high-energy polymerisation unit for 60 s after placement. Warming of GICs has been proved to improve mechanical properties of the cement [Kuter et al., 2013], however temperature may increase up to 60o especially when longer curing times are suggested. It has been shown that 2.5 mm-thick glass carbomer cement presents sufficient thermal insulation during the application of a LED curing unit

Statistical significance was noted between the following groups	No statistical difference was noted between the following groups
Group 1 + Group 2 (p<0.001)	Group 2 + Group 3 (p=0.924)
Group 1 + Group 3 (p<0.001)	
Group 1 + Group 4 (p<0.001)	
Group 2 + Group 4 (p<0.001)	
Group 3 + Group 4 (p=0.002)	

TABLE 2 Comparisons of statistical significance in tested groups.

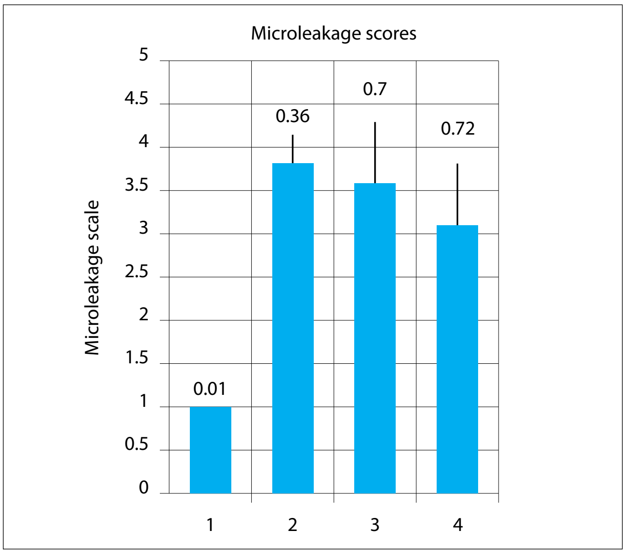

FIG. 2 Mean microleakage scores and standard deviations (over each column) arranged by type of material. 1: Group 1, Composite Resin, 2: Group 2: GIC, 3: Group 3: RMGIC, 4: Group 4, Glass Carbomer

[Cabral et al., 2013]. It is demonstrated that the amount of heat is directly associated with the quality of setting of the glass carbomer material, having a positive effect on microhardness values [Gorseta et al., 2010; Menne-Happ and Ilie, 2013] and making the material surface resistant to moisture, therefore maintaining marginal seal. The reason why heat application is so efficient is the addition of an organic carbon chain in the glass carbomer, which provides greater strength and transparency. This transparency optimizes heat penetration, having also an effect on aesthetic appearance and on sensitivity to acid attack.

Dye penetration is the most popular evaluating method in microleakage studies, because it provides a simple, relatively cheap, quantitative, and comparable method of evaluating marginal sealing. Existence of microleakage *in vitro* does not necessarily predict *in vivo* restoration failure, due to secondary caries. Even though a threshold marginal gap size for clinical failure of the restorations has not been established [Jokstad et al., 2001], restorations with marginal defects exhibit postoperative sensitivity and fail more frequently [Hayashi and Wilson, 2003]. No comparative studies of *in vitro* microleakage of glass carbomers have been reported up to date. In the absence of definitive clinical data and in spite of the limiting aspects of in vitro studies, microleakage was chosen in this study because of its long-term report in literature, as a measure by which the performance of a restorative material can be predicted. Among different methods employed, measurement of dye penetration on sections of restored teeth is the most commonly used technique [Raskin et al., 2003]. In the present study, six measurements were made per specimen, in order to increase reliability [Raskin et al., 2003]. This technique was combined with digital image analysis in order to obtain objective, quantitative results.

In order to mimic intraoral conditions, restorations were thermocycled, using body temperature (37°C) as transition from lower to higher temperatures. Thermal aging affects microleakage values although it has never been demonstrated that cyclic testing is relevant to clinical failures [Gale and Darvell, 1999]. However it has been shown that thermocycling increases microleakage due to consecutive volumetric changes of the restorative material [Asmussen and Jorgensen, 1978].

Light-polymerised, coating protective agents were used for GIC and glass carbomer, as they have been demonstrated to provide an effective surface protection and improve marginal sealing [Hotta et al., 1992]. Ketac Glaze is a dimethylene diacrylate, light-cured varnish, while GCP Gloss is a carbon-silicon fluid, which moistens the surface during modeling and prevents desiccation of the material while warming with the LED curing device. Since literature reports the creation of "fracture lines" on the surface of glass carbomer in absence [Cehreli et al., 2013] or decrease of the amount of the coating agent [Chen et al., 2010], in the present study the protective agent was reapplied after shaping and contouring. Although the manufacturer does not provide specific information on how coating agent of the glass carbomer acts, it is demonstrated by the present study and by literature that it is more effective in terms of microleakage than the coating agent of a GIC [Cehreli et al., 2013]. Resinous materials of Groups 1 and 3 were tested unsealed as per manufacturer's instructions. Unlike polyalkenoic materials, a hydrophobic polymer network is formed after polymerization, maintaining the surface integrity and providing adequate resistance against microleakage. This is demonstrated in the results of the present study, where Group 1, corresponding to composite resin, exhibited the lowest microleakage scores. RMGIC was expected to follow, however resinous and ionomer phase within the material act antagonistically and the final characteristics of the RMGIC depend on which phase is formed on expense of the other [Yelamanchili and Darvell, 2008].

Adding to the unpredictable nature of RMGIC, resinous materials (therefore resinous phase of RMGIC as well) are subject to polymerization shrinkage and its side effects. When shrinkage stress is stronger than the bond strength, the tooth-restoration interface can fracture causing a 0.17 μm gap in enamel- and a 20 μm gap at the dentine-material interface, resulting in loss of seal integrity, which will allow microleakage [Kidd, 1976]. Since Class I resin restorations exhibit a higher C-factor [Pfeifer et al., 2008], they show worse behavior in terms of polymerisation shrinkage, Class I cavities were chosen in order to challenge the resinous materials of the study. However, results indicate that composite resin restorations provide superb marginal seal in primary teeth (Fig. 1, 2). Within the limitations of the present study it has been demonstrated that composite resins can seal more effectively than GIC, RMGIC or glass carbomer. Generally resin bonding agents combined with resin-based restorative materials are able to provide the best total marginal seal in primary teeth [Guelman et al., 2004]. The application of a bonding agent with a distinct etching step [Owens and Johnson, 2007], combined with the incremental diagonal placement of the composite material into the cavity [Braga et al., 2005], results in fabrication of a stable and durable bond. Issues arise after a few years, by the time the formed bond will start to desintegrate as a result of water take up and matrix-metalloproteinases action [Pashley et al., 2011]. Microleakage in primary teeth, is influenced by the presence of a bevel [Swanson et al., 2008]. In the present study, placement of a slight bevel in specimens restored with composite resin eliminates the possibility of etching enamel prisms in any other direction than vertically. As for GICs it is proven that the microporosities in the conditioned enamel surface, increase the chemical [Wilson 1989] and micromechanical adhesion leading to lower microleakage when the margins are located in enamel [Glaspoole et al., 2002]. According to this study, complete marginal sealing cannot be achieved with GICs, especially in primary teeth [Guelmann et al., 2004]. As shown in Figure 2, conventional GIC, demonstrated higher microleakage values compared to RMGIC, owing to the sensitivity and solubility of GIC, including the area of the margins. Despite the fact that a protective surface agent against dilution had been applied on top of GIC restoration, it seems that resinous reinforcement of RMGIC provides better resistance against leakage. Difference between GIC and RMGIC was not statistically significant (Table 2). RMGICs are materials middling between composite resins and GIC [Yelamanchili and Darvell, 2008], being closer to glass-ionomers concerning microleakage, according to the results of the present study (Fig. 2). Microleakage owes to the fact that the extent of polymerisation shrinkage forces generated at the interface between RMGIC and the tooth surface are stronger than the chemical bond between the ionomer phase of the cement and tooth structure. This, results in elimination of any retention gained through chemical adhesion, thus opening a pathway to microleakage.

Conclusions

Within the limitation of the conducted in vitro study and results obtained, the following can be concluded.

- The sealing performance of restorations in primary teeth is greatly influenced by the material chosen.
- In primary teeth restorations, the use of an adhesive system and a resinous restorative material results in better marginal seal.
- Glass carbomer permits easier and quicker application in paediatric patients, with the same effectiveness as GIC and RMGIC, since no dentine conditioning process prior to restorative material placement is needed.
- The differences in marginal sealing between GIC and RMGIC are of little significance.

References

› Braga RR, Ballester RY, Ferracane JL. Factors involved in the development of polymerization shrinkage stress in resin-composites: a systematic review. Dent Mater 2005;21(10):962-70.
› Bynum AM, Donly KJ. Enamel de/remineralization on teeth adjacent to fluoride releasing materials without dentifrice exposure. ASDC J Dent Child 1999;66:89-92.
› Cabral RJ, Zaya LM, Mazzola I, Molina GF, Frencken J. Thermal insulation of restorative cements for ART heated with LED. IADR General Session 2013, ABSTRACT No. 480
› Chen X, Cuijpers V, Fan M, Frencken J. Microleakage of two new glass-ionomer-based sealant materials assessed using micro-CT. IADR PAPF-APR 2009, ANSTRACT No. 114
› Davidovich E, Weiss E, Fuks AB, Beyth N. Surface antibacterial properties of glass ionomer cements used in atraumatic restorative treatment. J Am Dent Assoc 2007;138:1347-1352.
› Glasspoole EA, Erickson RL, Davidson CL. Effect of surface treatments on the bond strength of glass ionomers to enamel. Dent Mater 2002;18(6):454-62.
› Glavina D, Gorseta K, Negovetic-Vranic D, Skrinjaric I. Enamel shear-bond strength of glas carbomer after heating with three polymerization units. Int J Paed Dent 2009;19(Suppl. 1):1-65, p.41.
› Glavina D, Gorseta K, Negovetic-Vranic D, Skrinjaric I. Retentrion od glass carbomer sealant after 6 months of clinical trial. IADR General Session 2010, ABSTRACT No. 138475.
› Gorseta A, Negovetic Vranic D, Glavina D, Skrinjaric I. Effects of polymerisation unit on the flexural strength of glass carbomer. Int J Paed Dent 2009;19(Suppl. 1):66-170, p. 75
› Gorseta A, Glavina D, Skrinjaric I. Microleakage of newly developed nano ionomer and glass ionomer cement restoration. CED-IADR 2009b, ABSTRACT No. 115.
› Gorseta A, Glavina D, Negovetic Vranic D, Skrinjaric I. Microhardness of the new developed glass carbomer cement. IADR General Session 2010, ABSTRACT No. 138573
› Guelmann M, Bookmyer KL, Villalta P, Garcia-Godoy F. Microleakage of restorative techniques for pulpotomized primary molars. J Dent Child 2004;71(3):209-11.
› Hayashi M, Wilson NH. Marginal deterioration as a predictor of failure of a posterior composite. European Journal of Oral Sciences 2003;111:155-162.
› Hotta M, Hirukawa H, Yamamoto K. Effect of coating materials on restorative glass-ionomer cement surface. Oper Dent 1992;17:57-61.
› Jokstad A, Bayne S, Blunck U, Tyas M, Wilson N. Quality of dental restorations. FDI Commission Project 2-95. International Dentistry Journal 2001;51:117-158.
› Kidd EAM. Microleakage: a review. J Dent 1976;4:199-206.
› Kuter B, Eden E, Yildiz H. The effect of heat on mechanical properties of glass ionomer cements. Eur J Paed Dent 2013;14(2):90-4.
› Lucas ME, Arita K, Nishino M.Toughness, bonding and fluoride-release properties of hydroxyapatite-added glass ionomer cement. Biomaterials 2003;24(21):3787-94.
› Moshaverinia A, Ansari S, Moshaverinia M, Roohpour N, Darr JA, Rehman I. Effects of incorporation of hydroxyapatite and fluoroapatite nanobioceramics into conventional glass ionomer cements (GIC). Acta Biomater 2008;4(2):432-40.
› Owens VM, Johnson WW. Effect of single step adhesives on the marginal permeability of Class V resin composites. Oper Dent 2007;32:67-72.
› Pashley DH. Dynamics of the pulpo-dentin complex. Crit Rev Oral Biol Med 1996;7(2):104-33.
› Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, Tezvergil-Mutluay A. State of the art etch-and-rinse adhesives. Dent Mater 2011;27(1):1-16.
› Pfeifer CS, Ferracane JL, Sakaguchi RL, Braga RR. Factors affecting photopolymerization stress in dental composites. J Dent Res 2008;87(11):1043-47.
› Raskin A, Tassery H, D' Hoore W, Gonthier S, Vreven J, Degrange M, Dejaou J. Influence of the number of specimens on reliability of in vitro microleakage evaluations. Am J Dent 2003;6:207-10.
› Remi Chauvin. Carbomers. I. A general concept of expanded molecules. Tetrahedron Letters 1995;36(3):397-400.
› Souchois MW, Vieira RS. Effect of a glass ionomer cement and a fluoride varnish on cross-sectional microhardness values of artificial occlusal caries: in vitro study. Indian J Dent Res 2012;23(6):732-7.
› Swanson TK, Feigal RJ, Tantbirojn D, Hodges JS. Effect of adhesive systems and bevel on enamel margin integrity in primary and permanent teeth. Pediatr Dent 2008;30(2):134-40.
› Van Duinen RN, Davidson CL, De Gee AJ, Feilzer AJ. In situ transformation of glass-ionomer into an enamel-like material. Am J Dent 2004;17:223-227.
› Wilson AD, Crisp S, Abel G. Characterization of glass-ionomer cements. 4. Effect of molecular weight on physical properties. J Dent 1977 ;5(2):117-20.
› Yelamanchili A, Darvell BW. Network competition in a resin-modified glass-ionomer cement. Dent Mater 2008;24(8):1065-9.