Microleakage of new glass ionomer restorative materials in permanent teeth

ABSTRACT

Aim The aim of this in vitro study was to evaluate the microleakage of the new glass ionomers ChemFil™Rock and IonoluxAC in comparison to Fuji IX GP Extra and the composite Aelite™LS Posterior in permanent teeth.

Materials and methods Class V standardised U-shaped cavities were made on a total of 40 freshly extracted teeth and restored with different glass ionomer materials (4 groups of 10 samples each). After thermocycling, the teeth were immersed in 0.5% basic fuchsin for 24h. They were then sectioned in the buccolingual direction. Microleakage was assessed for the occlusal and gingival margins under a microscope at 40x magnification.

Results There were significant differences among the materials used (p=0.000). While there was no dye penetration in the Fuji IX GP EXTRA group, which behaved similarly to the composite resin group, ChemFil™Rock showed less microleakage than IonoluxAC. The Wilcoxon rank test showed no significant differences in the occlusal and gingival scores between the groups (p>0.05).

Conclusions Although cavities filled with a conventional glass ionomer (Fuji IX GP Extra) had significantly less leakage than cavities filled with the new glass ionomers (ChemFil™Rock and IonoluxAC), these results do not reflect all the variables present in vivo conditions. As the in vitro evaluation of new materials does not always reveal their full limitations or possibilities, clinical testing of new systems remains the ultimate proof of effectiveness.

Keywords Microleakage; Restorative materials; New and conventional Glass ionomers cements.

Introduction

Glass ionomer cements (GICs) have been around for over 30 years, but they have undergone a number of improvements in the recent years. Today, the new generation of glass ionomers, sometimes called intermediate restorative materials, may be able to provide better aesthetics, stronger bond and long-term results [Castro and Feigal, 2002, Mather et al., 1995]. The development of GICs has been the subject of several studies due to the many advantages they provide. Conventional GICs have a coefficient of thermal expansion very similar to that of the tooth structure and a low setting shrinkage, and therefore provide good marginal sealing, minimal microleakage at the restoration/tooth interface, and high retention rate [De Moor and Delme, 2010]. Microleakage has been used to evaluate the success of any restorative material used in the oral cavity since it is a major contributing factor to secondary caries and pulpal irritation [Bergenholtz et al., 1982]. Accordingly, there is an interest in finding a restorative material which has better bond characteristics, thus minimising microleakage and reducing the potential for caries development at the tooth surface interface and consequent pulpal irritation [Mclean, 1994]. Microleakage is the main causative factor for the high incidence of secondary caries in the cervical region and accounts for many failed restorations [Baygın et al., 2012]. Microleakage induced by polymerisation shrinkage continues to be a major concern for the clinical longevity of dental restorations. Although improved adhesive systems have been developed, they do not completely prevent microleakage at the enamel and dentin margins [Uctasli et al., 2008]. The relationship between marginal leakage in restorations and type of restorative materials used has been extensively studied both in clinical and laboratory experiments. In the absence of definitive clinical data, laboratory microleakage studies are a well-accepted method of screening adhesive restorative materials for marginal seal.

The objective of this in vitro study was to evaluate and compare the microleakage of new improved glass ionomer restorative materials with a conventional glass ionomer and a composite resin in Class V cavities.

Materials and methods

Sample preparation

Forty intact, caries-free human premolar teeth freshly extracted for orthodontic purposes were selected for the study. The selected teeth were also free from cracks and restorations. The teeth were used in this study after having obtained informed consent from the subjects. After surface debridement with hand scaling instruments, the teeth were cleaned with pumice and...
Microleakage of new glass ionomer restorative materials

stored in 0.1% thymol solution, which was changed to normal saline one week before use. Class V standardised U-shaped cavities (3.0 mm mesiodistal length, 2.0 mm occlusogingival height) were prepared using a water-cooled, high-speed handpiece and fissure diamond burs (Dia-Burs, Mani Inc, Tochigi, Japan) on the buccal surface of the teeth. The depth of the cavity was approximately 1.5 mm, as determined by a periodontal probe. The occlusal margin of the cavity was located on the enamel, and the gingival margin was located on the dentin.

Restorative procedures

The prepared teeth were randomly divided into four groups of 10 teeth and were kept in normal saline solution. Before material placement, the preparations were cleaned with a rubber cup and a slurry of pumice powder. Each group was restored with a different restorative material according to the manufacturers’ instruction and randomly assigned as follows.

- Group I: ChemFil™ Rock Glass Ionomer Restorative Cement.
- Group II: IonoluxAC Conventional Glass Ionomer Cement.
- Group III: Fuji IX GP EXTRA Conventional Glass Ionomer Cement.
- Group IV: Aelite™ LS Posterior Composite Resin.

Table 1 shows the composition and manufacturers of the materials used. All cavities were prepared and restored by the same operator. After placement of the restorative materials, the finishing and polishing steps were performed with abrasive disks (Soflex Disk, 3M ESPE, Minnesota, USA).

Dye penetration test

After placement of the restorations, all teeth were stored in deionised water at 37 °C for 24 hours. The teeth were then subjected to 500 thermal cycles between 5±2º C–55±2º C water baths, with a dwell time of 30 sec and transfer time of 3 sec [Malekipour et al., 2010; Mortazaviet al., 2011; Khier and Hassan, 2011]. After thermocycling, all teeth were stored in distilled water at 37° C for 24h to prevent dehydration.

Preparation of samples for microleakage

Each sample was sealed with two coats of nail varnish, leaving a 1 mm window around the cavity margins. The sealed specimens were then immersed in a 0.5% basic fuchsin for 24 hours. After removal from the dye solution, the teeth were sectioned in the buccolingual direction along the center of the restoration using a slow-speed diamond saw (Isomed 1000  Precision saw, Buehler Ltd, USA) mounted with a diamond wafering blade (6”Dia. X 0.20”Buehler Ltd, USA) under water irrigation.

For each tooth two sections were obtained, corresponding to the occlusal and the gingival margins.

Microleakage measurement

Marginal leakage was evaluated using a conventional dye penetration method. The evaluation of leakage was made with a 3-point severity scale as described by Araujo RM et al. [ 2001] and Munro et al. [ 996] (Table 2). Dye penetration at the enamel and dentin margins of Class V cavities was assessed by compound microscope at magnification of 40x to measure the depth of the dye penetration on the occlusal and gingival margins. Both sections in each tooth were examined and the scores for both the occlusal (enamel) and gingival (dentin) margins were used for data analysis.

Data analysis

Results are expressed as means±standard deviations (SDs). Inter-examiner reproducibility was calculated

### Table 1: Compositions of the materials investigated in this study.

<table>
<thead>
<tr>
<th>MATERIAL TYPE</th>
<th>COMPOSITION</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChemFil™ Rock Advanced Glass Ionomer Cement</td>
<td>Calcium-aluminum-zinc-fluoro-Phosphor-silicate glass, Polycarboxylic acid,</td>
<td>DENTSPLY DeTrey GmbH DeTrey-Str. 1 78467 Konstanz GERMANY</td>
</tr>
<tr>
<td></td>
<td>Iron oxide pigments, Titanium dioxide pigments, Tartaric acid and Water</td>
<td></td>
</tr>
<tr>
<td>IonoluxAC Conventional Glass Ionomer Cement</td>
<td>Polycrylicacid, Fluorosilicate glass, Amines, BHT and Methacrylates.</td>
<td>VOCO GmbH, Cuxhaven, Germany</td>
</tr>
<tr>
<td>Fuji IX GP EXTRA Conventional Glass Ionomer Cement</td>
<td>95% Aluminosilicate glass, 5% Polycrylicacid powder</td>
<td>GC Corporation, Tokyo, Japan</td>
</tr>
<tr>
<td>Aelite™ LS Posterior Composite Resin</td>
<td>EthoxylatedBis-GMA, Glass filler, Amorphoussilica</td>
<td>BISCO, Inc. 1100 W Irving Park Road, Schaumburg, IL 60193 USA</td>
</tr>
</tbody>
</table>

### Table 2: Criteria for microleakage scores at the tooth-restoration interface.

<table>
<thead>
<tr>
<th>SCORE</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No microleakage No dye penetration</td>
</tr>
<tr>
<td>1</td>
<td>Microleakage observed only at the cavity wall of enamel Dye penetration through the cavity margin reaching the enamel or cementum</td>
</tr>
<tr>
<td>2</td>
<td>Microleakage observed at the cavity wall of dentin but not on the cavity floor Dye penetration through the cavity margin reaching the dentin</td>
</tr>
<tr>
<td>3</td>
<td>Microleakage observed on the cavity floor Dye penetration through the cavity margin reaching the cavity floor</td>
</tr>
</tbody>
</table>
using Kappa statistics. Data were statistically analysed using the nonparametric Kruskal-Wallis test. The differences between the occlusal and gingival dye penetration scores for each group were analysed using Wilcoxon’s signed ranks test. The statistical analyses were carried out with the SPSS 16.0 software package (SPSS Inc. Chicago, IL, USA) with a significance level of \( p<0.05 \).

**Results**

Measurements were taken by two examiners independently. Prior to the investigation, calibration of both examiners was undertaken by reading samples. Kappa value for inter-examiner agreement was 0.87 (almost perfect agreement). Distributions of the microleakage scores according to all test groups and margin location, i.e. the occlusal margin (enamel) and the gingival margin (dentin), are shown in Table 3 and Table 4. Among all materials, The Kruskal Wallis test indicated statistically significant differences in microleakage results \( (p=0.000) \). Overall, there was no dye penetration in the enamel or dentin in the Fuji IX GP EXTRA group, which behaved similarly to the composite resin group, while ChemFil™Rock and Ionolux AC showed a higher degree of microleakage. Figures 1–4 show representative microscopic images of the different materials. The arrows show dye penetration. There were no significant differences between the occlusal and gingival scores in the groups \( (p>0.05) \). In the ChemFil™Rock group, gingival margins showed significantly less microleakage than the Ionolux AC group \( (p<0.05) \).

![FIG. 1](image1.png) Representative microscopic image of a tooth of ChemFil™ Rock group with score 1 on the occlusal margin and score 0 on the gingival margin. Original magnification 40x.

![FIG. 2](image2.png) Representative microscopic image of a tooth of Ionolux AC group with score 1 on the occlusal margin and score 2 on the gingival margin. Original magnification 40x.

![FIG. 3](image3.png) Representative microscopic image of a tooth of Fuji IX GP EXTRA group with score 0 on the occlusal margin and score 0 on the gingival margin. Original magnification 40x.

![FIG. 4](image4.png) Representative microscopic image of a tooth of Aelite™ LS group with score 1 on the occlusal margin and score 0 on the gingival margin. Original magnification 40x.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>RESTORATIVE MATERIALS</th>
<th>LEAKAGE SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>1</td>
<td>IonoluxAC</td>
<td>1 5 1 3</td>
</tr>
<tr>
<td>2</td>
<td>ChemFil™ Rock</td>
<td>1 4 0 5</td>
</tr>
<tr>
<td>3</td>
<td>Fuji IX GP EXTRA</td>
<td>10 0 0 0</td>
</tr>
<tr>
<td>4</td>
<td>Aelite™ LS</td>
<td>7 3 0 0</td>
</tr>
</tbody>
</table>

**TABLE 3** Occlusal (enamel) leakage scores.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>RESTORATIVE MATERIALS</th>
<th>LEAKAGE SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>1</td>
<td>IonoluxAC</td>
<td>0 4 3 3</td>
</tr>
<tr>
<td>2</td>
<td>ChemFil™ Rock</td>
<td>4 1 0 5</td>
</tr>
<tr>
<td>3</td>
<td>Fuji IXG PE EXTRA</td>
<td>10 0 0 0</td>
</tr>
<tr>
<td>4</td>
<td>Aelite™ LS</td>
<td>9 0 1 0</td>
</tr>
</tbody>
</table>

**TABLE 4** Gingival (dentin) leakage scores.
Discussion

There have been many experiments involving GICs for assessment of microleakage in Class V preparations. This study measured microleakage of new improved GICs (ChemFil™Rock and Ionolux AC), conventional GIC (Fuji IX GP EXTRA) and composite resin (Aelite™LS) in Class V restorations. One of the main properties of a good restorative material is its ability to resist leakage of bacterial fluid in and around the restoration. Microleakage evaluation is the method most commonly used for assessing the sealing efficiency of a restorative system [Yamamazaki et al., 2006]. In vitro microleakage studies are a valuable means of evaluating clinical restorative materials and techniques on their ability to reduce, and perhaps eliminate, microleakage [Bertrand et al., 2006; Sungurtekin and Oztas, 2010]. This in vitro study was carried out to further investigate microleakage of new GICs in permanent teeth. This means that differences may exist between the restorative materials. The mechanical loading leads to a decrease in bonding performance because of fatigue at the adhesive interface. A consolidated view indicates that various material properties (e.g., thermal expansion, elasticity) seem to play a role in modifying the marginal sealing ability; non-material-related factors (e.g., cavity configuration, application technique, and curing method) have to be taken into account as well. However, this also means that generally predicting microleakage based on some material properties is not possible for Class V cavities [Krifka et al., 2011].

Long-term maintenance of a marginal seal is extremely important for avoiding or at least decreasing clinical problems such as discoloration of margins due to microleakage and secondary caries [Castro et al., 2002]. Microleakage is governed by marginal adaptation of the restorative material to the tooth and is influenced by polymerisation shrinkage and coefficient of thermal expansion. Ideally, filling materials and dental tissues should have identical coefficients of thermal expansion in order to limit leakage at the margins of the restorations [Quo et al., 2002]. To simulate thermal stresses on the tooth restoration interface, microleakage studies usually employ thermocycling of different regimens [Oberholzer et al., 2006; Rosales-Leal, 1997]. In this study, the dynamic environment of the oral cavity was simulated by exposing the GICs and composite resin restored teeth to thermal changes via thermocycling. Thermal cycles ranging between 200 and 1,000 were used in some studies [Bertrand et al., 2006; Sungurtekin and Oztas, 2010]. In the present study 500 thermal cycles were used.

In this study, for the qualitative measurements we measured the degree of microleakage on a 0-3 scale using the same images. Qualitative measurements could be done directly on the microscope without the need for special equipment [Alomari et al., 2011]. Restorative materials are constantly subjected to thermal challenges in the oral environment. Such challenges, if significant, can have unfavorable effects on the restoration margins in terms of the seal between the material and the tooth structure. Dye penetration test was used to assess marginal leakage in this study. It is a widely accepted and generally preferred method because it is readily available, cheap, and non-toxic. In addition, the most effective dye for revealing microleakage - 0.5% basic fuchsin - was used in this study [Sungurtekin and Oztas, 2010]. Heintze et al. [2007], stated the clinical relevance of various in vitro tests, such as the evaluation of microleakage by dye penetration, as problematic. Different results of dye penetration in vitro seem to be affected by many factors and various test methods [Raskin et al., 2001]. Furthermore, the results of sparse comparative studies are varying and a direct correlation between the results of dye penetration studies and the clinical outcome appears to be difficult. Therefore, clinical studies cannot be replaced by in vitro microleakage studies or used to solely predict clinical performance. However, dye penetration may provide an easy, fast, and commonly applied screening method [Bagis et al., 2009; Aschenbrenner et al., 2012].

Class V cavities are located in both dentin/cementum and enamel. Studies have shown that microleakage was greater on the gingival wall than on the occlusal wall. A study by Attar et al. compared microleakages at the occlusal and cervical margins. They reported higher levels of microleakage in the gingival margins in all groups [Attar et al., 2008]. Roebuck et al. [2000] found microleakage in all groups at both the enamel and the dentin margins. They reported that levels of microleakage were statistically insignificant for both enamel and dentin. The extent of microleakage at both enamel and gingival margins is still debatable. This study showed no significant differences in the enamel and gingival scores between groups, which differs from the conclusions of by Thornton et al. [1988] and Tsunekawa et al. [1992], who reported that the gingival margins exhibit greater leakage than the occlusal margins in Class V restorations filled with GICs in vitro.

Castro and Feigal [2002] reported that the Fuji IX GP™, the improved conventional glass ionomer, behaved similarly to the composite resin. When the materials were compared, differences were clearly shown. The light-curing glass ionomer cement (Ionolux AC) showed more leakage than all other groups. The first zinc-reinforced glass ionomer cement (Chemfil™Rock) showed more leakage than Fuji IX GP Extra. However, Fuji IX GP Extra, the conventional glass ionomer, behaved similarly to the composite resin. The results are similar to those of Castro and Feigal [2002], Wilder et al. [2000], and Erdilek et al. [1997], who concluded that composite resins provide a better seal than conventional glass ionomer cements. In the study of Brackett et al. [1995] microleakage of three glass...
ionomer restorative materials, one chemically cured and two light cured, was evaluated and no statistically significant difference was found among the materials. Therefore, the Fuji IX GP Extra may offer some benefits to dental patients, especially children. Fuji IX GP Extra chemically bonds to the tooth structure, has a coefficient of thermal expansion similar to that of the tooth, and is a rechargeable fluoride reservoir.

Some limitations of this study include the lack of an in vivo environment. In vitro studies do not reflect all the variables present in a patient mouth. In addition, to preserve the integrity of samples and to avoid the loss of samples, it is suggested to mount the teeth in epoxy resin prior to sectioning. However, long-term performance has not yet been evaluated. In addition, improved glass ionomer materials may prove to be ideal for methods of minimally invasive caries management offering high strength, chemical adhesion and fluoride release.

Conclusion

To date, no studies have been carried out to investigate and compare the microleakage of the new glass ionomer materials ChemFil™ Rock and IonoluxAC in permanent teeth. Under the conditions of this in vitro study, it can be concluded that: cavities filled with conventional glass ionomer cement (Fuji IX GP Extra) had significantly less leakage than cavities filled with the new glass ionomer cements. And ChemFil™ Rock had similar leakage with Ionolux AC glass ionomer cement in the occlusal margins. Within the limitations of the present study, it can be concluded that microleakage could be prevented entirely by Fuji IX GP EXTRA. Nevertheless, the results of our in vitro study need further clinical investigations.

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References