In vitro wear of Ionofil Molar AC quick glass-ionomer cement

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Abstract

Aim: The aim of this study was to evaluate the three-body wear-resistance of one type of restorative glass-ionomer cement (GIC).

Materials and Methods: Specimen including conventional GIC (Ionofil Molar AC Quick: IMACQ), hybrid ionomer (Fuji II LC), and composite resin (Heliomolar) were tested in a wearing machine. In this machine, a 6 kg load was applied via pressable chromium-cobalt bar at 5,000, 10,000, 20,000, 40,000, 80,000, 120,000 cycles. Specimen weight was measured by an electronical weight balance before and after each cycle. Data were analyzed using one-way analysis of variance (ANOVA) followed by a t-test, and a paired t-test at $P \leq 0.05$.

Results: The highest weight loss has been found in Fuji II LC, then in GIC IMACQ and the least wear rate has been reported in heliomolar composite in all cycles except 120,000 cycles. In 120,000 cycles, the highest weight loss was seen in GIC IMACQ, then Fuji II LC, and finally heliomolar composite. There was a statistically significant difference in weight loss between GIC IMACQ and heliomolar composite ($P=0.001$).

Conclusion: The wear rate of GIC IMACQ was between those of heliomolar composite and Fuji II LC glass ionomer in all cycles except 120,000 cycles. The most important advantage of this new-generation glass ionomer is its good manipulability and also high wear-resistance compared to the hybrid ionomer. Therefore, it is suggested that it can be used as restorative material in class I restorations in primary teeth.

Keywords: Glass-ionomer cement, ionofil molar AC quick, wear

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Nowadays patients expect esthetic and longevity from their anterior and posterior teeth restorations. The long-term success of a restoration depends not only on easy application and correct techniques but also on the creation of a biocompatible restoration with acceptable physical and mechanical properties. [1]

Wear-resistance is one of the most important properties of all direct dental restoratives. However, only resin composite among tooth-colored dental materials has been used for high wear and high stress-bearing sites such as class I and II cavity restorations. [2][3][4]

On the other hand, resin composites still have their own significant drawbacks, such as polymerization shrinkage, postoperative sensitivity, relatively high thermal expansion coefficient, and allergic reactions. [5][6]

Efforts have been made to find an alternative that can reduce the disadvantages of resin composites. Glass-ionomer cements (GICs) have been considered to be a suitable candidate. [2]

Conventional GICs have been regarded by dentists because of adhesion to tooth structure, releasing fluoride, good biocompatibility, minimal microleakage, and similar coefficient of thermal expansion to tooth structure. [1][2]

In spite of all modifications of GICs, there are still some technique sensitivity problems. Problems like mixing considerations, sensitivity to moisture during initial setting reaction, low primary mechanical strengths, and poor wear-resistance need to be considered; therefore, their use should be limited to certain low-wear and low stress-bearing areas, such as class III and V cavities in high caries risk patients. [2][7]

Resin modification of GICs was designed to produce physical properties similar to those of the basic features of the conventional GICs, so the resulting resin-modified glass ionomer (RMGIC) exhibits many advantages of both resin cements and GICs. Although these materials showed improved mechanical strength, extended working time, etc., but their lower wear-resistance has limited their use in high-wear sites such as class I and II restorations. [2][6][7]

Efforts have been done to improve the wear-resistance of GICs such as incorporation of silver or amalgam particles and the addition of montmorillonite clay filler but none of the above has shown great improvement in wear-resistance. [2]

Recently, a new encapsulated conventional GIC has been introduced. Ionofil Molar AC quick (IMACQ) is a novel, high viscous conventional GIC, and its manufacturer claims that this material can be used in high wear and high stress-bearing sites such as class I cavities in permanent molars. [8]

The purpose of this in vitro study is the evaluation of the wear rate of IMACQ in comparison to heliomolar composite and Fuji II LC RMGIC.

Materials and Methods
Description of wear testing machine

In this in vitro experimental study the wear rate was measured. The wear test was performed in P.D.B wearing machine (Pajoohesh Dandanpezheshki Babol, Babol, Iran) that simulates occlusal wear. It is a compression-cycling motion system in which the specimens are moved rotationally and has the ability of three-body wear. This apparatus utilizes an electric motor which transfers load to the specimens. It has several parts: Pneumatic system, abrading bar, and contact force station. Different parts of this machine are illustrated in [Figure 1]. The pneumatic system forces a constant stress of 3 N/mm² with the use of predetermined 6 kg load to the specimens. This load is adjustable with a pneumatic barometer. The specimens were placed in a contact force station which contains a brass mold for insertion of the specimens. The cylindrical abrading bar is made up of chromium-cobalt and the samples of restorative materials were subjected to wear testing against circular, flat-ended chromium-cobalt abrading cylindrical bar 1.98 mm² circular contact area at 1-2.5 cycles/sec with artificial saliva (Biotene, USA) as lubricant. This apparatus also includes a built-in counter for automatic shut-off after a predetermined number of cycles.

Figure 1: P.D.B wearing machine

Click here to view

Materials and specimen preparation

For this study, Fuji II LC hybrid ionomer (GC corporation, Tokyo, Japan), ionofil molar AC quick conventional glass ionomer (Voco, Germany), and heliomolar composite (Vivadent, Liechtenstein) were used [Table 1]. Therefore, from each group six cubic specimens were fabricated in customized brass mold (10 mm length × 10 mm width × 2 mm depth).

Table 1: Tested materials specifications

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Cat. no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuji II LC</td>
<td>GC Corporation, Japan</td>
<td>80198</td>
</tr>
<tr>
<td>Hybrid-ionomer</td>
<td>Voco, Germany</td>
<td>603064</td>
</tr>
<tr>
<td>Ionofil molar AC</td>
<td>Vivadent, Liechtenstein</td>
<td>541592</td>
</tr>
</tbody>
</table>

Composite specimens were then light polymerized through the glass slide using high power intensity (750 mw/cm²) of Astralis 7 light-curing unit for 40 seconds. It was polymerized incrementally.

Fuji II LC hybrid ionomer specimens were prepared by this light-curing unit too. Powder and liquid were mixed together according to the manufacturer's recommendation and polymerized by the same technique, time- and light-curing unit mentioned above.

After activation in the AC activator (Voco, Germany) for 2 seconds, ionofil molar AC quick capsules were mixed in a capsule mixer (4000-4500 oscillations/min) for 10 seconds and then the material was inserted in brass mold by AC applicator (Voco, Germany) and after placement, a glass slide was placed on the surface of specimens for 5 minutes.

After preparation of specimen, related letters and numbers were put beneath of each specimen
by round burs ¼ and specimens were then immersed in Biotene artificial saliva (Include, USA) at room temperature for 10 days.

The specimens were removed from the artificial saliva, dried with absorbent paper, and weighed in analytical scale with an accuracy of up to 0.1 mg (Sartorius ED224s, Sartorius AG, Germany).

**Wear testing and measurements**

After specimens were placed in the wear machine, they were abraded in 5,000, 10,000, 20,000, 80,000, and 120,000 cycles respectively at the center and their weights were measured after each cycle by an analytical scale.

For each specimen, the weight was measured seven times in the analytical scale as previously described. The mass loss due to wear was calculated as the difference between the mass of each specimen before and after wearing.

**Statistics**

The data were analyzed by one-way analysis of variance (ANOVA), t-test, and paired t-test at \( P \leq 0.05 \) with SPSS 15 software.

**Results**

The weights of 18 samples before and after each wear cycle were measured and the mean weights of all tested groups before and after different wear cycles are compared in Table 2, Table 3, and Table 4.

<table>
<thead>
<tr>
<th>Wear cycles</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialene water</td>
<td>0.4322</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 5,000 cycles</td>
<td>0.4302</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 10,000 cycles</td>
<td>0.4202</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 20,000 cycles</td>
<td>0.4101</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 80,000 cycles</td>
<td>0.4012</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 120,000 cycles</td>
<td>0.3923</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Click here to view Table 2: Mean weight of Fuji II LC RMGI specimens before and after different wear cycles in grams

<table>
<thead>
<tr>
<th>Wear cycles</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialene water</td>
<td>0.4012</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 5,000 cycles</td>
<td>0.3992</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 10,000 cycles</td>
<td>0.3891</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 20,000 cycles</td>
<td>0.3791</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 80,000 cycles</td>
<td>0.3692</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 120,000 cycles</td>
<td>0.3593</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Click here to view Table 3: Mean weight of heliomolar specimens before and after different wear cycles in grams

<table>
<thead>
<tr>
<th>Wear cycles</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialene water</td>
<td>0.4012</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 5,000 cycles</td>
<td>0.3992</td>
<td>0.0001</td>
<td>0.003</td>
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<tr>
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<td>0.3692</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
<tr>
<td>After 120,000 cycles</td>
<td>0.3593</td>
<td>0.0001</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Click here to view Table 4: Mean weight of ionofil molar AC quick glass-ionomer specimens before and after different wear cycles in grams

Moreover, the mean weight loss of groups in all cycles is measured and compared. In all wear cycles except 120,000, the most weight loss was observed in Fuji II LC RMGI, then IMACQ GI, and then heliomolar composite, respectively, but in 120,000 wear cycles this trend was
In 5000 wear cycles, only the heliomolar composite showed significantly less substance loss than Fuji II LC RMGI ($P=0.005$).

In 10,000 cycles, the differences of weight loss between Fuji II LC and IMACQ ($P=0.025$) and between Fuji II LC and heliomolar composite ($P=0.002$) were statistically significant, while no statistical difference was observed between IMACQ and heliomolar composite ($P=0.379$).

In the 20,000, 40,000, and 80,000 wear cycles, the weight loss differences between Fuji II LC and heliomolar composite ($P=0.005$ for 20,000 cycles, $P=0.006$ for 40,000 cycles and $P=0.002$ for 80,000 cycles) and also between IMACQ GI and heliomolar composite was statistically significant ($P=0.023$ for 20,000 cycles, $P=0.016$ for 40,000 cycles, and $P=0.002$ for 80,000 cycles); however no statistical difference was detected between IMACQ GI and Fuji II LC ($P=0.744$ for 20,000 cycles, $P=0.882$ for 40,000 cycles).

In 120,000 wear cycles, IMACQ GI has shown significantly more weight loss than Fuji II LC and heliomolar composite ($P=0.013$ and 0.001), but no statistically significant difference was observed between Fuji II LC and heliomolar composite ($P=0.402$).

**Discussion**

In the present study IMACQ GI exhibited less wear than Fuji II LC RMGI from 5000 to 80,000 cycles and more wear than heliomolar composite in all wear cycles. Several studies showed that resin-modified glass ionomers possess more wear compared to conventional glass ionomers. Pelka *et al.* compared three body wears of conventional glass ionomer, resin modified glass ionomer, and composite resin. In their study, Photac Fil, a resin modified glass ionomer, showed a lower wear resistance than composite and conventional glass-ionomer cement. Peutzfeldt *et al.* determined in vitro wear of glass-ionomer cements and composites in comparison to a resin composite. The results showed that resin-modified glass-ionomer cement has the most and composite has the least wear rate which is in accordance with the result of this study. [9,10]

Besides, Zhao *et al.* evaluated in vitro wear of an experimental glass ionomer, Fuji II LC resin-modified glass ionomer, and a resin composite and concluded that their experimental glass ionomer has higher wear than resin composite and less than Fuji II LC that can support the results of this study. [11]

IMACQ is a highly viscous conventional glass ionomer that can be used as a restorative material. One reason for higher wear of Fuji II LC RMGI in comparison to IMACQ GI is probably due to the differences in matrix formation. The matrix of IMACQ conventional GI
consists of an ionically cross-linked polyalkenoate network resulting from an acid-base reaction. The cements of Fuji II LC RMGI have a similar cross-linked polyalkenoate network, but these are entangled with HEMA polymer chains. The greater wear reported by resin-modified material may indicate that the coherence of filler particles embedded in the interpenetrating matrices of polyalkenoate and polymer is inferior to that of the particles in the conventional matrix. [7]

This may be due to the partial replacement of the rigid polyalkenoate network by the flexible polymer chains. The increased deformation of the surface imposed by the load of mastication, as simulated in the wear machine, can lead to the formation of subsurface microcracks in the ionic cross-linked polyalkenoate matrix with the subsequent loss of coherence and these phenomena can exacerbate the wear process in resin-modified glass ionomer. [7]

Another explanation is that IMACQ GI is encapsulated and provides consistent mixes if prepared based on the manufacturer's guide considering the powder to liquid mixing ratio where the mixing technique and times are standardized. However, Fuji II LC RMGI is not encapsulated and is mixed with hand. Hand mixing has been reported to introduce operator-induced variability due to the inaccurate dispensation of the powder and liquid constituents using the scoop and dropper bottle system. [8][12][13] The volume of the powder dispensed utilizing a scoop can be changed due to the variable powder packing density achieved on filling. [12][13][14] The scoop and dropper bottles frequently dispense inaccurate volumes of the liquid due to the variation in the angle and position at which the bottle is held and the pressure applied to squeeze a drop. As a result, the functional characteristics normally associated with hand-mixed cements prepared at the manufacturers' recommended powder to liquid mixing ratios are rarely achieved in clinical practice. [12][13][14]

Wear of tooth hard tissues and restorative materials under clinical conditions is a complicated phenomenon in contrast to the other mechanical and physical properties of materials. [3] As we know, to be a clinically durable dental restorative material especially for posterior restorations, the material must be wear resistant. There are some common wear mechanisms, including abrasion, attrition, adhesion, chemical degradation, and fatigue; among them abrasion is the most common wear process encountered during the chewing cycle. Abrasion is caused by frictional surface interactions with toothbrush, toothpaste, food bolus, and fluid components during chewing. There can be two types of abrasive wear, two and three body. These two types of wear are considered to be an important mechanism of occlusal material loss with dental restoratives. [2][6]

In this in vitro study a three-body wearing machine (P.D.B.) was used. This machine is made according to an apparatus that Yap et al. in 2002 used for the wearing test. In their study they utilized stainless steel abrading bar with a 1 mm^2 contact surface and 1.6 N force. They believed that stainless steel can provide standard contact stress on specimens so in this study we used a chromium-cobalt abrading tool because the hardness of chromium-cobalt is similar to enamel and it can simulate oral conditions. Sabri oral simulating posterior composite wear test apparatus is another type of wearing machine that is similar to our machine. Besides, Alaghehmand et al. used the same P.D.B. wearing machine for evaluation of the wear rate of dental composite in 2006. [4][6][15][16]

In the current study, IMACQ GIC has shown the highest wear rate in comparison to Fuji II LC RMGICs and heliomolar composite in 120,000 cycles. IMACQ is an encapsulated conventional glass ionomer. Although Mount recommended capsulation as being the ideal
method of dispensing glass ionomer, however, the increased viscosity of IMCQ compared to Fuji II LC may introduce an additional variable into the mixing process. Voids could be introduced during mixing and it was proposed to trap on filling the mould with encapsulated restorative material. It was possible that further large porosities, namely air bubbles, may have been trapped in and produced internal porosity, which exposed to the wear surface in 120,000 cycles. Zhao et al. used the OSHU wearing machine with the abrasion force of 20 N in 70,000 cycles. Because most studies of wear rates were performed in less than 100,000 cycles we could not compare the wear results of our survey in 1,200,000 cycles with other studies. [17] [18]

From the results of this in vitro study, the wear rate of IMACQ is between those of heliomolar composite and Fuji II LC in all cycles except 1,200,000 cycles. This new material is popular because of the ease of placement and acceptable wear rates, but further studies are still required to evaluate other mechanical and physical properties of this material.

Conclusion

IMACQ is a kind of immediately packable glass-ionomer cement and can be used for semipermanent class I posterior fillings (2 or 3 years) and it is particularly suitable for cases where cost is a concern and for patients allergic to methacrylate.

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References


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Figures

[Figure 1], [Figure 2]

Tables

[Table 1], [Table 2], [Table 3], [Table 4]