Wear of resin-modified glass ionomers : an in vitro study

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The purpose of this study was to evaluate the wear resistance and clinical applicability of resin-modified glass ionomer cements as restorative or fissure-sealing materials. The in vitro *wear of resin-modified glass ionomers was compared to conventional glass ionomers, a resin-based sealant, and a composite resin. A three-body wear test (enamel block - polymethylmethacrylate powder - experimental dental material) was performed by 20,000 cycles with a load of 4kgf/cm^2. The depth of wear of the experimental materials was measured and calculated using a computerized laser surface scanner. The glass ionomers generally showed more wear than the resin-based sealant and the composite resin, but there was no difference in wear between resin-modified and conventional glass ionomers. Type III ionomers (used for sealant) showed lower wear resistance than type II ionomers (used for restoration).*
J Clin Pediatr Dent 25(4): 297-301, 2001

INTRODUCTION

The use of glass ionomer cements has become more common in 1990's due to the introduction of light-cured or resin-modified glass ionomer. Since glass ionomer would have the advantages of fluoride release, biocompatibility, and bonding especially with dentin, this material has been widely used as a base material and luting cement. The fluoride rechargeability of glass ionomer materials has also been reported in a recent study by Hatibovic-Kofman *et al.*[1] Due to improvement in physical properties and water-sensitivity when setting, resin-modified types seem to be clinically more useful and convenient than conventional (self-cure) types. In particular, resin-modified glass ionomer for restoration or fissure sealant, for which clinical procedures are relatively simpler and do not use acid-etching and bonding agents, may cover some part of the indications for resin-based materials.

Much research on glass ionomer has been conducted on various aspects including bonding ability, fluoride release and remineralization, basic physical properties, and clinical performance. Since restorative and fissure sealant materials are directly affected by aspects of the intraoral environment such as saliva, food, tooth brushing, and masticatory force, retentive longevity is also an important requirement.

However, most of the studies on clinical evaluations have been short-term[2-8] and only a small number of basic studies have investigated the wear and fracture of glass ionomers.[9-14] Additionally, since some clinical studies[5-8] have already commented on the poorer clinical performances of conventional and resin-modified glass ionomer sealants when compared with resin-based sealants, this study is focused on the wear resistance of resin-modified glass ionomer and a discussion of their clinical applicability and indications.

MATERIALS AND METHODS

The experimental dental materials used in this study were as follows:

1. Fuji II (GC, Tokyo, Japan) — conventional glass ionomer for restoration,
2. Fuji III (GC, Tokyo, Japan) — conventional glass ionomer for sealant,
3. Fuji II LC (GC, Tokyo, Japan) — light-cured resin-modified glass ionomer for restoration,
4. Fuji III LC (GC, Tokyo, Japan) — light-cured resin-modified glass ionomer for sealant,
5. Concise Light Cured White Sealant (3M, St. Paul, MN) — resin-based sealant,
6. Restorative Z-100 (3M, St. Paul, MN) — hybrid type composite resin.

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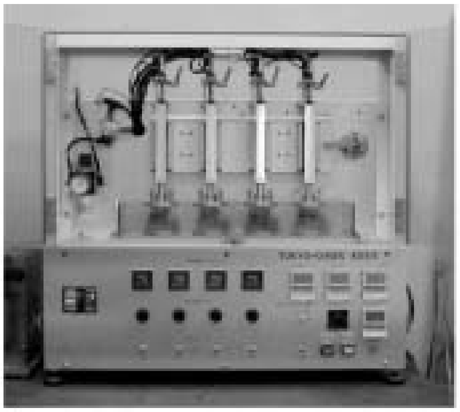

Figure 1. Load cycling tester (TOKYO GIKEN: K554).

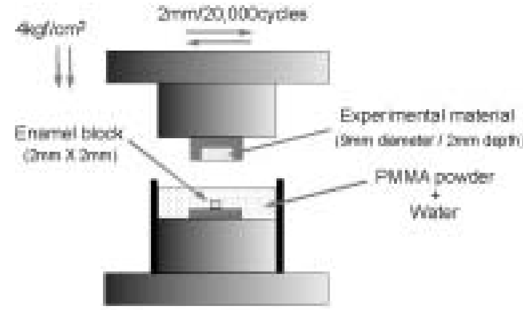

Figure 2. Load cycling and three-body wear test.

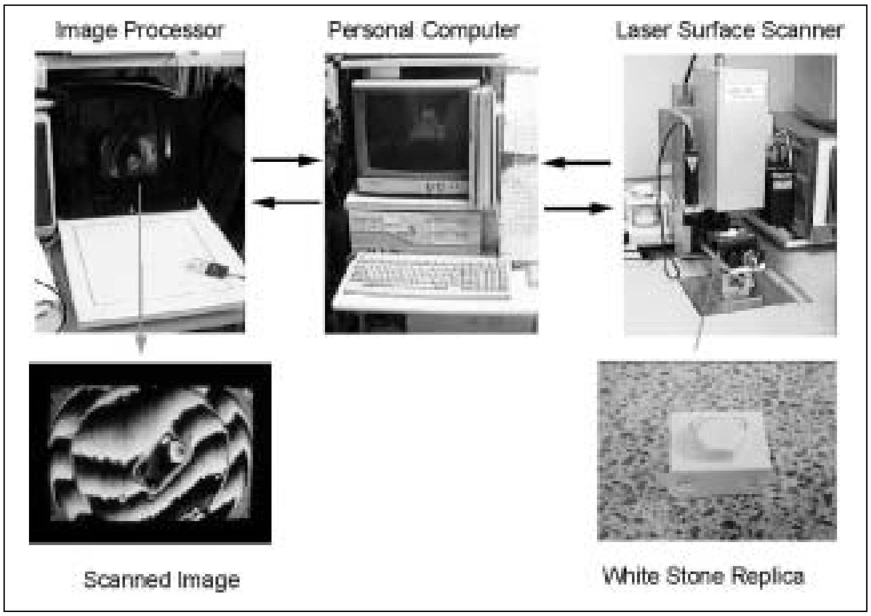

Figure 3. Computerized laser surface scanner.

In the restorative materials for which multiple shades are available, A2 shade was used. Glass ionomer was mixed by a standard powder / liquid ratio for each material, and all materials were filled and cured in standardized metal molds (9mm diameter / 2mm depth) according to the manufacturers' instructions. One hour after curing, the filled surfaces were water polished using silicon carbide papers up to 1000-grit. Four samples were produced for each of the 6 materials.

A three-body wear / load cycling test was performed using a Load Cycling Tester (K554, Tokyo Giken, Tokyo, Japan)(Figure 1). As shown in Figure 2, experimental materials were fixed to the upper mounts and enamel blocks carved from extracted human premolars were fixed to the lower mounts. A slurry of polymethylmethacrylate (PMMA) powder (Orthocrystal, Nissin, and Kyoto, Japan) with water was poured and filled around the lower enamel block as a third medium. The upper mount moved down on the enamel block with a compressive load of 4kgf/cm^2 and slid by 2mm. This movement, which simulated masticatory action, was repeated for 20,000 cycles. The contact area of the enamel block was 2mm square. After the wear test was completed, impressions of the specimens were taken using a vinyl polysiloxane impression material (Exafine, GC, Tokyo, Japan), and white stone (Fujirock, GC, Tokyo, Japan) was poured to make replicas.

The surface of the white stone replica was scanned by a laser surface scanner (XA-100, Ono Sokki, Tokyo, Japan) controlled by a personal computer (PC9801AP2, NEC, Tokyo, Japan), and the scanned image was rendered on the image processor (nexus 6400, Nexus, Tokyo, Japan) (Figure 3). As shown in Figure 4, 20 random reference points from the worn surface were plotted on the scanned image using a X-Y digitizer.

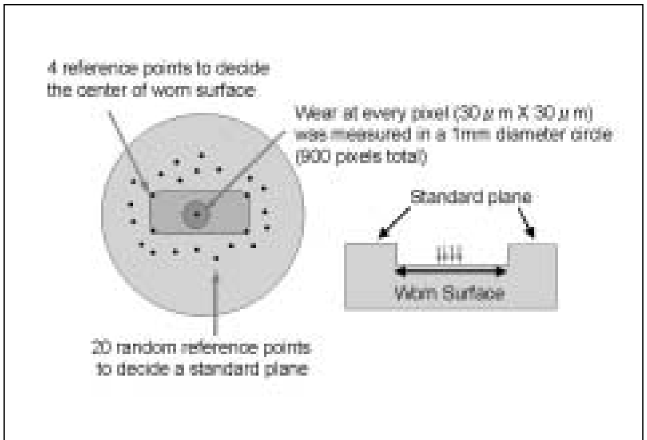

Figure 4. Measurement method for the amount of wear.

These reference points were used to decide a standard plane for measuring the amount of wear. Another 4 reference points were plotted at each corner of the worn surface, and the center of the worn surface was decided. A 1mm diameter circle with a center identical to that of the worn surface was determined. The depth of wear at every pixel (30μm X 30μm) was measured in the circle. Total number of the measurement points was 900 for each specimen. A mean value and standard deviation were calculated for each of the six experimental material groups, and the mean values were compared statistically by Student's t-test. P=0.05 was used as the level of significance.

RESULTS

Table 1 shows the results for each experimental material. Mean values can be categorized as type II group (Fuji II & Fuji II LC), type III group (Fuji III & Fuji III LC), and resin group (White Sealant & Z-100). The type III group showed the most wear followed by the type II group. The resin group showed the least amount of wear. There was no significant difference of wear between the materials in each category (group). These results also showed no difference between the wear resistance of conventional and resin-modified glass ionomer. There was a significant difference in wear between the types of resin-modified glass ionomer (Fuji II LC & Fuji III LC), and the mean wear value of Fuji III was greater than Fuji II. However, no significant difference was found between these conventional glass ionomers, may be because the S.D. value of Fuji III was relatively larger.

DISCUSSION

In the studies of composite resin materials, various kinds of wear tests have been performed *in vitro* to reproduce clinical performance. The amount of wear has also been evaluated using various measurement methods. The three-body wear test in this study modified the method used in our previous study,[15] which evaluated wear and marginal fracture of posterior composite resin. The use of polymethylmethacrylate (PMMA) powder, as a medium, provides an accurate reproduction of the relative wear status of posterior composite resin to enamel.[15] The precision level of the laser-scanned value for Z-axis (depth) is shown to be about ± 3μm, therefore, the relative wear value of the experimental materials can be accurately evaluated. The results of the present study showed that the resin component did not reinforce the wear resistance of glass ionomer, but that the powder / liquid ratio of resin-modified and/or conventional glass ionomer had a greater influence on the wear value.

Peutzfeldt *et al.*[10] reported that resin-modified glass ionomer displayed less surface hardness and *in vitro* wear resistance than conventional glass ionomers and compomers. Momoi *et al.*[13] also found, from a toothbrush-dentifrice abrasion test that the *in vitro* resistance of resin-modified glass ionomer was inferior to that of the conventional acid-base glass ionomer. They discussed that the lower abrasion resistance of the resin-modified products appeared to be related to the lower surface hardness.

However, Iwami *et al.*[14] reported no significant difference in abrasive wear between resin-modified and conventional glass ionomer. Considering the various differences of the experimental conditions including the present study, the *in vitro* wear performance of resin-modified glass ionomer seems to be comparable or inferior to that of conventional glass ionomer and the wear difference between the types of glass ionomer is affected by the powder / liquid ratio.

According to the instructions of the manufacturer, the standard powder / liquid ratio (by weight) of Fuji II is 2.7, Fuji II LC is 3.0, Fuji III is 1.2, and Fuji III LC is 1.4. Although resin-modified glass ionomers have a slightly higher ratio, the type II glass ionomers have more than twice the ratio when compared to type III glass ionomers. This difference would affect the density of the glass cores after setting, and this micro-morphological difference would affect the wear resistance.

Table 1. Mean and S.D. wear values by the three-body wear test

Experimental material	Wear (μm)	S.D.
Fuji II	86	8
Fuji III	154	79
Fuji II LC	85	55
Fuji III LC	157	14
White Sealant	25	12
Z-100 Restorative	23	10

Komatsu *et al.*[12] reported in a study using Fuji IX (conventional glass ionomer for restorative) that a change in the powder / liquid ratio was effective in improving the abrasion resistance. The powder / liquid ratio of Fuji IX was 3.5 high, and the abrasion resistance to toothbrush abrasion test was higher than the conventional glass ionomer (Fuji II), and was similar to the silver-reinforced glass ionomer (Chelon Silver, ESPE, Seefeld, Germany), of which the ratio was 3.8. Watanabe *et al.*[11] reported the similar findings by changing the powder / liquid ratio of three glass ionomers for restorative filling. They also discussed that a higher powder / liquid ratio led to a higher density of glass cores with a narrower inter-core distance and a smaller matrix area, which would improve abrasive wear resistance.

A clinical research by Weerheijm *et al.*[16] on glass ionomers used as fissure sealants reported that the retention rate of the restorative (Fuji IX, GC, Tokyo, Japan) was significantly better than the sealant material (Fuji III) after four and nine months. They discussed that the better performance of the restorative material might be from a higher mechanical strength.

For the longevity of a restorative material, wear resistance is, of course, one of the important requirements. Another is fracture resistance, which would be affected by the strength of the material itself and its ability to bond with tooth material. Futatsuki *et al.*[15] found that the degree of marginal fracture in a composite resin was related to the enamel bonding ability of the material. Therefore, the improved physical strength and bonding ability of resin-modified glass ionomer, which have been reported by many researchers, means they work better than conventional material. Including faster setting time and improved water sensitivity, resin-modified glass ionomer for restoration and sealant would have a better prognosis than a conventional counterparts in the clinical setting.

However, most physical properties and enamel / dentin bonding of resin-modified glass ionomers are inferior to those of resin-based materials. Another result obtained from this study was that glass ionomer materials were generally less wear resistant than resin-based materials. Thus, clinical longevity of resin-modified glass ionomer (for restoration or fissure-sealing) still may not be comparable to that of resin-based materials, although biocompatibility, fluoride release and rechargeability, and simple clinical procedures without etching will be advantageous.

Recently, the new generation of composite resins has simpler and convenient bonding systems, which can be called one-bottle bonding and wet bonding. Another trend of restorative materials is compomer or ionomer-modified composite resin, which has a simplified clinical procedure with a self-etching primer or an adhesive. In the development of new materials and bonding systems for restoratives, indications for each kind of material should be carefully evaluated to provide a better prognosis using a simpler clinical procedures.

ACKNOWLEDGEMENT

The authors would like to express their appreciation to Kiyohito Minematsu, who was a graduate student and developed the measurement program for the computerized laser surface scanner.

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