In vitro wear rates of tooth-colored direct restoratives

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Purpose: To evaluate the wear resistance of resin-modified glass-ionomer cements and compomers for light loading using an in vitro wear simulation machine.

Materials and Methods: Materials tested included Vitremer, Fuji II LC, Advance, Dyract, and Spectrum TPH resin composite (control). Cylindrical Class I cavities were prepared on occlusally flattened human molars, and the cavities were restored with the respective materials according to the manufacturers' instructions. Six specimens for each material were used for an *in vitro* three-body wear testing, and the wear depth was measured with a profilometer on epoxy replicas after 60,000, 120,000, 180,000, and 240,000 cycles. The data were statistically analyzed by ANOVA and Scheffe's test.

Results: The wear rates of all materials gradually decreased after 60,000 cycles. Advance exhibited the highest wear value at every testing interval, and the TPH control showed the lowest value. The wear values of Vitremer and Fuji II LC were nearly twice that of Dyract at each testing interval. There were significant differences in wear values among all materials, except between Vitremer and Fuji II LC at the 180,000 and 240,000 intervals.

Conclusion: Based upon the results within the range of respective materials tested, it can be concluded that the compomer is significantly more wear resistant than the resin-modified glass-ionomer cements but less wear resistant than the resin composite. **(Int Chin J Dent 2003; 3: 82-90.)**

Clinical Significance: The wear resistance of the resin-modified glass-ionomer cements and compomer seem to be insufficient even for the stress bearing area of anterior teeth.

Key Words: tooth-colored filling material, wear resistance, wear simulator.

Introduction

As restorative materials, conventional glass polyalkenoate (ionomer) cements have many desirable properties such as fluoride release, similar thermal expansion to dentin, and chemical adhesion to tooth substrates. On the other hand, they also have several disadvantages including moisture sensitivity and low mechanical properties. They are considered unsuitable restorative materials for stress-bearing areas, such as occlusal surfaces due to their low wear resistance. They are mainly indicated for restoring cervical lesions, class III cavities, and primary teeth. Resin-modified glass-ionomer cements and polyacid-modified resin composites (compomers) have been developed to improve the handling property and to overcome problems of the conventional glass-ionomer cements including moisture sensitivity and low mechanical strength, while maintaining some of their clinical advantages. They have become popular alternative materials for the conventional glass-ionomer cements among clinicians.

Several *in vitro* studies have reported that the physical properties of resin-modified glass-ionomer cements and compomers are better than those of conventional glass-ionomer cements,[1-3] but they provide little information concerning the wear resistance of these materials. Other studies have reported that resin-modified glass-ionomer cements and compomers have lower wear resistance than resin composite materials.[4-7] Some clinical studies have reported satisfactory clinical performance of compomers in anterior restorations.[8-11] Thus, resin-modified glass-ionomer cements and compomers are suitable restorative materials for permanent anterior teeth. However, these previous studies provide little information concerning the use of these materials for class III and IV restorations. It is necessary to investigate the wear of these materials during loading, since lingual or incisal surfaces of anterior teeth are considerably stressed by antagonist teeth.

This study evaluated the wear rates of three kinds of resin-modified glass-ionomer cements, a compomer, and a resin composite by using an *in vitro* three-body wear testing machine under the loading.

Materials and Methods

The materials used in this study are presented in Table 1. The resin-modified glass ionomer cements used were Vitremer (3M/ESPE, St. Paul, MN, USA), Fuji II LC Capsule (GC Corp., Tokyo, Japan), and Advance (Dentsply/Caulk, Milford, DE, USA). Vitremer is a hand mixing and tri-cure type. Fuji II LC Capsule is a mechanical mixing and dual-cure type. Advance is a chemical-cure type. The compomer used was Dyract (Dentsply/DeTrey, Konstanz, Germany), and Spectrum TPH resin composite (Dentsply/Caulk) was used as a control.

Table 1. Materials used.

Material	Trade name	Manufacturer	Lot number	Main composition
RMGI	Vitremer	3M/ESPE St. Paul, MN, USA	Powder: 455 Liquid: 429	Fluoro-alumino-silicate glass Polycarboxylic acid, HEMA, Water
RMGI	Fuji II LC Capsule	GC Corp. Tokyo, Japan	250141	Fluoro-alumino-silicate glass, Polycarboxylic acid, HEMA, Water
RMGI	Advance	Dentsply/Caulk Milford, DE, USA	Powder: 9504201 Liquid: 9505221	Fluoro-alumino-silicate glass Polycarboxylic acid, HEMA, Water,
Compomer	Dyract	Dentsply/DeTrey Konstanz, Germany	C9408103	UDMA, TCB, Strontium-fluoro-silicate glass
Composite	Spectrum TPH	Dentsply/Caulk Milford, DE, USA	9505032	Bis-GMA, Colloidal silica, Barium-alumino-borosilicate glass

Caries-free extracted human molars were used in this study. First, tooth cusps were removed by wet grinding with 600-grit silicon carbide paper to obtain a flat occlusal enamel surface. A cylindrical Class I cavity (4 mm diameter and 2 mm depth) was prepared on the occlusal surface of each tooth, and the cavities were restored with the respective materials according to manufacturers' instructions (Table 2). After storage in 37˚C distilled water for 48 hours, the restored surface was finished and polished by wet-grinding with 800-grit silicon carbide paper. Six specimens were prepared for each material, and each completed specimen was fixed onto a stainless cup with acrylic resin.

Table 2. Restoration procedures for each material.

Material	Restoration procedures
Vitremer	Apply Vitremer Primer (30 s), Dry (15 s), Light cure (20 s), Mix powder and liquid (30 s), Fill the mixture of Vitremer, Light cure (40 s)
Fuji II LC Capsule	Apply Dentin Conditioner (20 s), Dry (10 s), Mix powder and liquid using GC capsule mixer CX-I (8 s), Fill the mixture of Fuji II LC, Light cure (40 s)
Advance	Mix powder and liquid (15 s), Fill the mixture of Advance
Dyract	Apply De Trey Conditioner 36 (15 s), Water spray (5 s), Blot dry, Apply Prime&Bond (20 s), Gently air dry, Light cure (10 s), Apply second layer of Prime&Bond, Gently air dry, Light cure (10 s), Fill Dyract paste, Light cure (40 s)
Spectrum TPH	Apply De Trey Conditioner 36 (15 s), Water spray (5 s), Blot dry, Apply Prime&Bond (20 s), Gently air dry, Light cure (10 s), Apply second layer of Prime&Bond, Gently air dry, Light cure (10 s), Fill Spectrum TPH paste, Light cure (40 s)

The mounting was completed so as the flat occlusal surface was parallel to the plane of the flat polyacetal stylus. A three-body wear test was employed on the surface of the restorations using an *in vitro* wear simulator developed by our department (Fig. 1). The cylindrical stylus (20 mm diameter) slides 10 mm horizontally against the flat occlusal and rises 45 degree at the end of each stroke (Fig. 2). It moves back to the original position and repeats the stroke. This stroke simulates the movement of mastication. The specimens were covered with a slurry of poly(methyl methacrylate beads) (Ostron II, GC Corp.) and poppy seeds (1:1 volume ratio), and relatively light load (4.9 N) was continuously applied at a rate of 120 contacts per minute for up to 240,000 cycles. After every 60,000 cycle, a replica of the worn surface was prepared with a polyvinylsiloxane impression material (Exafine, GC Corp.) and an epoxy resin (Stycast 1266/A, Aplestik Co., Atsugi, Japan). The worn surface of each restoration was then scanned by a profilometer (Surfcom 470A, Tokyo Seimitsu Co., Tokyo, Japan) along two planes perpendicular to each other. The wear depth of the restoration was determined by measuring the deviation between enamel and worn material (Fig. 3). The mean depth of wear for each material was measured on the respective profilometric tracings and recorded as the wear value. The data were statistically analyzed by analysis of variance (ANOVA) and Scheffe's test. After determining the wear values of the restorations, some replicas were randomly selected for scanning electron microscopic examination. They were mounted on aluminum stubs and sputter coated with platinum/palladium (Hitachi E 101, Hitachi Co., Tokyo, Japan). Surface texture and filler/matrix interface of worn surfaces were evaluated with a scanning electron microscope (SEM, Hitachi S-800, Hitachi Co.)

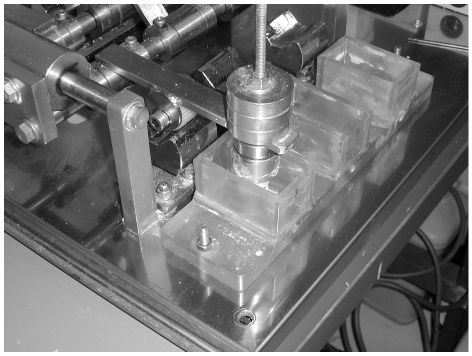

Fig. 1. *In vitro* wear simulator.

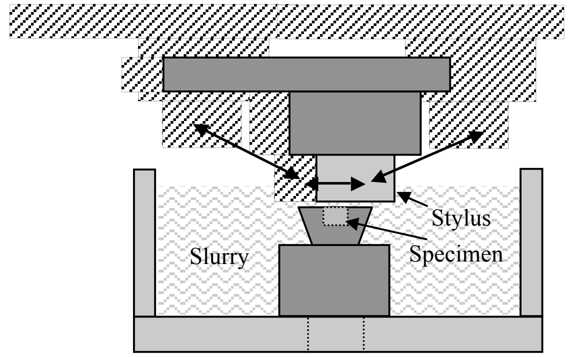

Fig. 2. Schematic diagram of the movement of the stylus.

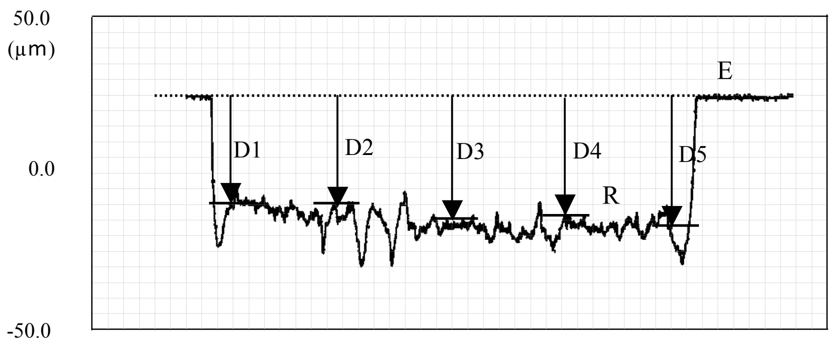

Fig. 3. Typical profilometric tracing of a specimen after three-body wear. E: Enamel surface, R: Resin composite surface, D1-5: Five different wear depth measurements.

Results

The wear rates of all materials are presented in Fig. 4. All of them exhibited gradual decreases after 60,000 cycles. Advance demonstrated the largest, and the Spectrum TPH resin composite showed the smallest wear value at every testing interval. The wear values of Vitremer and Fuji II LC were nearly twice of that for Dyract at each testing interval. The wear value of Vitremer was similar to that of Fuji II LC. The mean wear depths of all materials are presented in Table 3. There were no significant differences among the wear values of Vitremer, Fuji II LC, and Dyract at 60,000 cycles, but the wear value of Dyract became significantly lower than those of Vitremer and Fuji II LC after 120,000 cycles. There were no significant differences between the wear values of two resin-modified glass ionomer cements, Vitremer and Fuji II LC, at any testing interval. Spectrum TPH resin composite exhibited significantly higher wear resistance compared to the other materials at 180,000 and 240,000 cycles, while Advance demonstrated significantly lower wear resistance than the other materials for all time intervals.

Typical SEM photographs of the respective materials after 240,000 cycles are presented in Fig. 5. The view of entire restoration was presented at low magnification, and the surface texture was visualized at high magnification. SEMs of Vitremer showed that the enamel walls were fairly exposed at the cavity margin due to loss of material. Protruding core particles and small defects due to the exfoliation or plucking-out of the particles were confirmed. Air voids could also be observed on the worn surface of Vitremer.

The loss of Fuji II LC increased progressively with the number of wear cycles. Protruding large core particles and small defects was seen on its worn surface. SEMs of Advance showed substantial loss of material after 240,000 cycles. The worn surface texture of Advance at low magnification was rougher than that of Fuji II LC. Under high magnification, the worn surface texture of Advance was similar to that of Fuji II LC, except for the presence of air voids.

The surface texture of worn Dyract was smoother than that of Vitremer, Fuji II LC, and Advance. It was quite different from those of the resin-modified glass-ionomers but very similar to that of Spectrum TPH resin composite.

The SEMs of Spectrum TPH demonstrated less material loss and smoother surface texture compared to the other materials. However, this material also showed protruded small-sized particles and small defects caused by the exfoliation of filler particles.

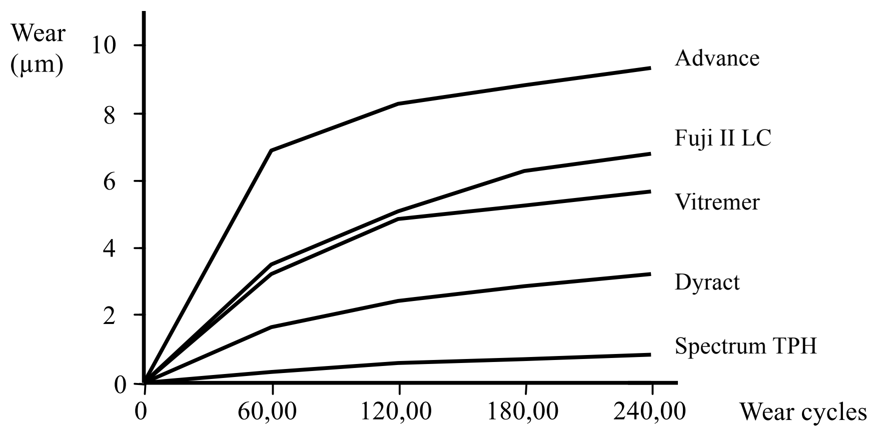

Fig. 4. Comparison of the wear rates for the materials tested.

Table 3. Wear testing results in μm.

Cycles	60,000 Mean	SD		120,000 Mean	SD		180,000 Mean	SD		240,000 Mean	SD	
Spectrum	2.9	0.7	a	5.5	2.0	c	6.8	2.7		8.0	2.6	
Dyract	16.2	5.5	a, b	23.8	7.9	c	28.3	6.2		31.7	6.0	
Vitremer	31.8	9.6	b	48.2	6.5	d	52.5	8.0	e	56.1	8.6	f
Fuji II LC	35.2	12.6	b	50.6	6.5	d	62.4	6.1	e	67.7	7.0	f
Advance	68.5	27.1		82.5	24.5		87.7	22.8		92.9	21.1	

Groups identified by the same letters are not statistically different ($p>0.05$).

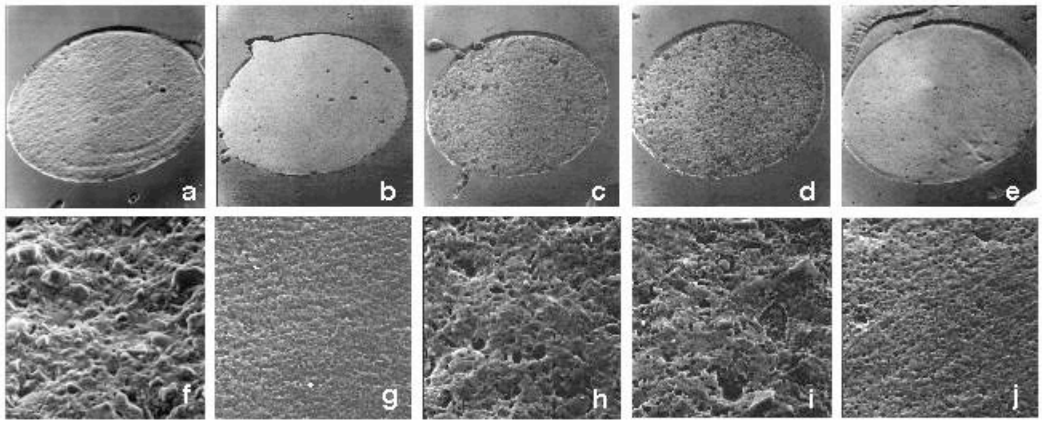

Fig. 5. Typical scanning electron micrographs of the respective materials tested at 240,000 cycles.
(a), (f): Fuji II LC, (b), (g): Spectrum TPH, (c), (h): Vitremer
(d), (I): Advance, (e), (j): Dyract
a-d: overall view, x20. e-h: magnified view, x500.

Discussion

Glass-ionomer cements have several advantages including fluoride release, chemical adhesion to tooth substances, ease of use, and good biocompatibility. The physical properties of glass-ionomer cements, however, are not as good as those of resin composites.[1] Recently, resin-modified glass-ionomers have been developed by adding resin monomer components to the composition of the conventional glass-ionomer. The composition of compomers more closely resembles resin composites than glass-ionomer cements. The physical properties of these restorative materials have been improved by the resin component. Some studies have reported the physical properties of resin-modified glass-ionomers and compomers.[1-3] Kimura et al. reported that the compressive strength and the flexural strength of the compomer tested were significantly higher than those of resin-modified glass-ionomers, but significantly lower than those of resin composites.[3] Attin et al. reported that the physical properties of resin-modified glass-ionomers and compomers were inferior to those of hybrid resin composites.[2] It is speculated that the wear resistance of these restorative materials is also improved by adding resin monomer components. The results of this study revealed that the wear value of Dyract was nearly half of those for Vitremer and Fuji II LC, but the wear resistance of Dyract was significantly lower compared to Spectrum TPH resin composite. Based upon the results, the compomer tested seemed to have superior wear resistance than resin-modified glass-ionomer but inferior wear resistance than resin composite.

Several studies have investigated the wear resistance of resin-modified glass-ionomers and compomers.[4,5] de Gee et al. evaluated in vitro wear rates of occlusal contact-free areas for conventional glass-ionomers, metal-reinforced glass-ionomers, and resin-modified glass-ionomers and reported that the resin-modified glass-ionomers had significantly smaller wear rates than the conventional glass-ionomers at every stage.[4] The results of their study are similar to the results of our study. Pelka et al. compared two-body and three-body wear of glass-ionomers, visible light cured glass-ionomers, and resin composites.[5] The results of these in vitro wear tests showed that the visible-light-cured glass-ionomer had lower wear resistance than the resin composite. Momoi et al. examined the *in vitro* toothbrush abrasion of resin-modified glass-ionomers and reported that the wear resistance of resin-modified glass-ionomers was inferior to that of the conventional acid-base glass-ionomers.[12] Their studies showed counter findings to other studies in that the resin-modified glass-ionomers exhibited superior wear resistance than the conventional glass-ionomer cements. Several clinical studies have reported findings that the wear resistance of resin-modified glass-ionomers and compomers was inferior to that of resin composites.[6,7] Duke et al. examined the clinical performance of a representative resin-modified glass ionomer in cervical abrasions and root caries in adults, and the results of their clinical trial showed the resin-modified glass-ionomer to be inferior to conventional resin composite in terms of color stability and loss of anatomic form or wear.[6] Folwaczny et al. used an optical three-dimensional laser scanning device to investigate the substance loss of cervical restorations of four tooth-colored restoration materials including a resin composite, a compomer, and two resin-modified glass-ionomers *in vivo*.[7] They concluded that the resin-modified glass-ionomers and the compomer demonstrated a distinctly higher wear rate over time in comparison to the resin composite. The results of these clinical studies were much the same as the results of this study.

In vitro wear values of resin composites subjected to 400,000 cycles with Leinfelder's three body wear simulator are comparable to the clinical wear data of resin composite restorations evaluated after a two-year study[13] and a three-year study.[14] In Leinfelder's wear simulator, a flat-planed polyacetal stylus is vertically loaded onto the restored surface under a load of 75 N.[15] In the wear simulator used in this study, 4.9 N load was vertically applied onto the restored surface. There are several differences in vertical loading and stylus movement between Leinfelder's and our machine, but the concept for the simulation is quite similar.

A number of studies have suggested that the wear resistance of resin composites is affected by filler size and amount.[16-22] Microfilled resin composites generally exhibit excellent resistance to generalized wear or three-body wear,[18,19] whereas, resin composites containing large-sized fillers offer low resistance to generalized wear.[16] The SEM examinations of the worn surfaces of the materials tested in the present study showed that Vitremer, Fuji II LC, and Advance protruded large alumino-silicate glass cores. The worn surface texture of Dyract, on the other hand, was quite different from that of the resin-modified glass-ionomers but similar to that of Spectrum TPH resin composite, which was smoother than the other materials. Thus, the large-sized core particles may be responsible for the lower wear resistance of the resin-modified glass-ionomers.

The property of the matrix is also an influencing factor for the wear resistance. The differences in the matrix components among the materials tested might have a large effect on wear resistance.

Conclusion

Based upon the results within the range of respective materials tested, it can be concluded that the compomer is significantly more wear resistant than the resin-modified glass-ionomer cements but less wear resistant than the resin composite. Therefore, it is suggested that the compomer and resin-modified glass-ionomers tested are not recommended for anterior restorations when the materials used for stress bearing areas including lingual and incisal surfaces.

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