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Masao Irie*
Kazuomi Suzuki‡

Rosalina Tjandrawinata†
David C. Watts**

*Okayama University, mirie@md.okayama-u.ac.jp

†Okayama University

‡Okayama University

**University of Manchester

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Root-surface gap-formation with RMGIC restorations minimized by reduced P/L ratio of the first increment and delayed polishing.

Masao Irie^{1*}, Rosalina Tjandrawinata¹, Kazuomi Suzuki¹, David C. Watts²

¹Department of Biomaterials, Okayama University Graduate School of Medicine and Dentistry,
Okayama, JAPAN

²The University of Manchester, School of Dentistry, Manchester, United Kingdom.

Short title: Incremental techniques on root surface restorations

***Corresponding author details:**

Masao Irie,

Department of Biomaterials, Okayama University Graduate School of Medicine and Dentistry,
2-5-1 Shikata-cho, Okayama 700-8525, JAPAN

Phone: +81-(0)86-235-6668, Fax: +81-(0)86-235-6669

E-mail: mirie@md.okayama-u.ac.jp

Abstract

Objectives: This *in vitro* study evaluated the effect on interfacial gap-formation around resin-modified glass-ionomer (RMGIC) root surface restorations with (a) variations in powder/liquid ratio (P/L) of the first increment of an incremental procedure, compared with a bulk restoration technique, and (b) delayed *versus* immediate polishing, to permit maturation.

Methods: Cavity preparations were placed in premolar teeth on upper facial root surfaces. Two RMGICs were studied (*Fuji II LC* and *Vitremer*), with their associated conditioner or primer, applied with an incremental technique. The P/L ratio of the first increment was reduced to fractional (normalized) values between 0.2 – 1.0 of the manufacturers' recommended P/L, and the manufacturers' P/L was used for the second increment. Control groups were bulk filled. After polishing, either: (i) immediately after light-activation or (ii) after 24 h storage, the restored teeth were sectioned in a buccolingual direction through the center of the restoration and the presence or absence of marginal gaps was measured at x 1000 magnification at 14 points (each 0.5-mm apart) along the cavity restoration interface; (n=10; total points measured per group =140).

Results: For both RMGICs, significant differences ($p < 0.05$) in gap-incidence were observed between polishing (i) immediately and (ii) after one-day storage. In the former case, 30-70 gaps were found, with or without the incremental technique. In the latter case, only 2-14 gaps were observed. With fluid mixes (normalized P/L ratios between 0.3 – 0.6) for the first increment, gap-formation was greatly reduced, especially with *Fuji II LC*.

Significance: To minimize gap formation, more fluid mixes could be used especially with *Fuji II*

LC to give improved adaptation to the dentin. Secondly, whenever possible, polishing should be delayed on the final increment to permit maturation and minimize mechanical disruption of both increments.

Keywords: Resin-modified glass-ionomer cement; Interfacial gap formation; Root surface restoration; Incremental technique; Shrinkage.

Introduction

Cervical restorations may be created with both conventional glass-ionomer cement (CGIC), and resin-modified glass-ionomer cement (RMGIC) [1-8]. CGICs have several beneficial properties, such as physicochemical bonding to the tooth substrate, fluoride release and uptake and tooth color. However, they also demonstrate brittle fracture, erosion and wear in the oral environment [9]. To reduce these deficiencies, RMGICs were developed. These cements have a dual setting reaction consisting of an acid-base reaction and a photochemical polymerization process. The final set materials have a complex structure in which glass particles are sheathed in a matrix consisting of two networks - one derived from the glass ionomer, the other from the resin [10,11]. In these dual-setting systems, the resin reinforcement provides higher mechanical strength [12-14] and higher bond strength to tooth surfaces, compared with CGICs. Thus RMGIC materials may exhibit improved marginal seal and reduced interfacial gap formation by hygroscopic expansion [13, 15] and improved bonding ability after 24 h water-storage [13, 16, 17].

One drawback of RMGICs or restorative resins is their polymerization shrinkage [13, 17] which may be reduced by an incremental technique. Recently, a new incremental technique has emerged where a flowable composite is used as the first increment in the proximal boxes of direct Class II restorations. The reduced filler loading of flowable composites compared with their hybrid analogs leads to enhanced flow and reduced elastic modulus [18]. These two characteristics have been speculated to counteract gap formation by increasing adaptation and by forming a stress-absorbing layer [18-20].

The magnitude of gap-formation with a composite in a butt-joint cavity may be determined by 1) the adhesion forces between the restorative material and cavity walls, 2) the shrinkage-strain (or stress) of the restorative materials and 3) its viscosity or ability to flow [21]. Along with the adhesive system used, polymerization shrinkage and flow were found to be significant determinants of gap formation around resin composite [22]. In the initial stage of setting, when a restorative material still adheres to the cavity walls, the shrinkage-strain may be released as a flow of material from the free surface. Comparing restorative materials with the same volumetric shrinkage, but with different fluidity, the flow from the free surface will decrease with decreasing fluidity of the restorative material and consequently give an increased contraction at the margin. In the case of RMGIC mixes, the powder/liquid ratio is expected to have an effect both on fluidity and polymerization-shrinkage magnitudes, and thereby on interfacial gap-formation.

In this study, the effects on *in vitro* interfacial gap-formation around root surface restorations using RMGICs were investigated for (a) various P/L ratios of the first increment of an incremental restorative procedure and (b) 1-day-delayed *versus* immediate polishing. The hypothesis tested was that gap-formation with RMGIC restorations would be critically dependent upon both factors.

Materials and Methods

Human premolars, extracted for orthodontic reasons, were used for the experiment. After extraction, each tooth was immediately stored in distilled water at 4°C for one to two months before use. 3.5 mm diameter cylindrical-cavity preparations were placed in the facial root surface, using a tungsten carbide bur (200,000-rpm) and a fissure bur (8,000-rpm) under wet conditions, to a depth of 1.5 mm. The preparation was placed parallel to the cemento-enamel junction, extending 1.0 mm below the cemento-enamel junction (Figure 1), and so was completely bordered by cementum or dentin. Cavosurface walls were finished to a butt joint. One cavity was prepared in each tooth.

Two RMGICs were investigated (Tables 1 and 2), which were placed according to the manufacturers' instructions, except for further variations in P/L ratio. Dentin Conditioner was applied for 20 s, and rinsed with water. Vitremer Primer was applied for 30 s, air dried and light cured for 20 s. The cavity was filled with mixed RMGIC using a syringe tip (Centrix C-R Syringe System, Centrix, Connecticut, USA) and covered with a plastic strip and hardened. Each increment and the bulk of *Fuji II LC* or *Vitremer* were exposed to a visible light source (New Light VL-II, GC, Tokyo, Japan; irradiated diameter: 8 mm) with irradiation time of 20 s or 40 s, respectively. Close contact was ensured between the exit window of the lamp and the plastic strip. The light irradiance was checked immediately before each application of restorative material, using a radiometer (Demetron/Kerr, Danbury, CT, USA), and was maintained at 450 mW/cm². The restored teeth were then coated with a varnish (Fuji Varnish, GC, Tokyo, Japan). All procedures, except for cavity preparation, were performed in a

thermo-hygrostatic room kept at 23 ± 0.5 °C and 50 ± 2 % relative humidity.

Incremental Procedure

Restorative material was applied to designated cavities with an incremental technique, as illustrated in Figure 1. Normalized P/Ls of the first increment of *Fuji II LC* were 0.22, 0.33, 0.47, 0.60, 0.73, 0.87 and 1.0, respectively and the P/L of the second increment was constant (3.0). Normalized P/Ls of the first increment of *Vitremer* were 0.24, 0.40, 0.56, 0.72, 0.88 and 1.0, respectively, and the P/L of the second increment was constant (2.5). Approximately half the cavity was filled with the first increment. As a control, the bulk method was applied.

Storage and Polishing Procedures:

The surfaces of designated restorations were polished immediately after light curing, with abrasive points (Silicone Mide, Shofu, Kyoto, Japan) while rinsing with distilled water in an effort to avoid desiccation and breakdown. The other designated specimens were stored after light curing in distilled water at 37°C for 24 h. Then the surfaces of the restorations were polished, as described above.

Inspection Procedures

Each tooth was sectioned in a buccolingual direction through the center of the restoration with a low-speed diamond saw (Isomet, Buehler Ltd., Lake Bluff, IL). The presence or absence of marginal gaps was measured at 14 points (each 0.5-mm apart) along the cavity restoration interface (n=10; total points measured=140) using a traveling microscope (X1,000, Measurescope, MM-11, Nikon, Tokyo, Japan). The number of gaps in each position was

totaled and expressed as a sum for each sample [17].

For each material and incremental restorative procedure, 20 specimens (10 specimens for immediate polishing; and 10 specimens for 1-day-delayed polishing) were made. In total, 300 tooth cavities were prepared for this study (*Fuji II LC*: (7 P/Ls + one bulk) X 20 repeats (polishing immediately after light curing: 10 specimens and polishing after one-day storage: 10 specimens); *Vitremer* (6 P/Ls + one bulk) X 20 repeats (polishing immediately after light curing: 10 specimens and polishing after one-day storage: 10 specimens). The results were analyzed statistically using the Mann-Whitney U-Test and the Tukey Test (Non-parametric) [23, 24].

Results

Table 3 summarizes the interfacial gap formation observed in the root surface restorations with *Fuji II LC* at various normalized powder/liquid ratios of the first increment, when the specimen was polished immediately after light-activation. In the coronal and cervical regions, the sums of gaps were not significantly different for the various P/Ls of the first increment, and also not significantly different compared to the bulk method. In the axial region, when the normalized P/Ls of first increment were 0.33, 0.47 and 0.6, the sums of gaps were 10-11 and were significantly smaller than for the bulk method. Considering totals for all regions, when the normalized P/Ls of the first increment were 0.33, 0.47 and 0.60, the observed sums were 27-30 gaps, which was significantly less than with the bulk method. However, the sums of gaps were not significantly different for the remaining P/Ls of the first increment. The surface locations: 1 and 14 (Figure 1), showed a high incidence of gaps, for this condition. The variation of sums-of-gaps with normalized P/L ratio for increment 1 is shown in Figure 2.

Table 4 summarizes the corresponding data for gap-formation of *Fuji II LC* observed in the restorations after delayed polishing. In the coronal plus cervical regions, the sums of gaps were not significantly different among all P/Ls of increment 1, and also not significantly different from the bulk method. In the axial region, for normalized P/Ls of 0.33, 0.47 and 0.60, only 0-2 gaps were observed, which was significantly less than for the bulk method. No significant differences were observed between the sums-of-gaps for three other P/Ls. Considering totals for all regions, for normalized P/Ls of 0.33, 0.47 and 0.60, the sums-of-gaps were only 2, again significantly less than for the bulk method (Figure 2). The surface locations: 1 and 14, showed

almost no gaps for this condition.

Table 5 compares the sums-of-gaps with *Fuji II LC* restorations with various P/Ls, for immediate *versus* delayed polishing. In the coronal plus cervical regions, gaps were significantly fewer with delayed polishing, compared to immediate polishing. For sums-over-all-regions, gaps were also significantly fewer with delayed polishing, compared to immediate polishing.

Table 6 summarizes the incidence of gap-formation with *Vitremer* restorations after immediate polishing, and Table 7 the corresponding data for delayed polishing. The variation of sums-of-gaps with normalized P/L ratio for the first increment is shown in Figure 3. For delayed polishing, the gap-incidence remained low with all P/L ratios, but with immediate polishing the gap-incidence declined from a high value (*circa* 65) to a more moderate – but still unacceptable value (*circa* 35) as P/L was reduced in the more fluid mixes.

Table 8 compares the sums-of-gaps with *Vitremer* restorations with various P/Ls, for immediate *versus* delayed polishing. For sums-over-all-regions, gaps were also significantly fewer with delayed polishing, compared to immediate polishing.

Discussion

This study used cylindrical cervical cavities as a model for the geometry of clinical cervical cavities. This only approximates the clinical morphology, but has the advantage of a constant, reproducible geometry that is essential for a scientific study.

The results show that using low P/Ls (similar to a luting type), as the first increment, significantly reduces gap formation, especially with *Fuji II LC*, at both axial and all-interfacial regions, with immediate polishing. It was proposed that the incidence of gap-formation of a resin-composite in a cavity is determined by 1) the adhesion forces between the restorative material and cavity walls, 2) the size of the volumetric contraction of the restorative materials and 3) its viscosity or ability to flow [21]. In the initial stage during setting, when the restorative material still adheres to the cavity walls, the shrinkage will be released as a flow of restorative material from the free surface. When the shrinkage-stress, in a vector direction from the tooth substrate wall to the center of the restorative materials, exceeds the strength of bonding, steadily increasing gap-formation will occur along the cavity walls, as long as the setting process continues. Comparing the restorative materials with different fluidity, through reduced P/L of the first increment, the flow from the free surface will increase by increasing fluidity of the restorative material and - other factors being equal - will give decreasing shrinkage-strain at the interfacial gap in the cavity base. However, a low P/L also tends to produce increased setting-shrinkage, which tends to aggravate gap-formation. In this study, enhanced setting-shrinkage may have had a negative effect on gap-formation and a limiting

effect on the gap-reducing capacity of the lowest P/Ls of RMGIC. That could explain the upturn in gap-incidence at a normalized P/L of 0.2 seen in Figure 2. However, because the manufacturers' recommended P/L mixture of RMGIC was used for the second increment, the net result of the counteracting effects was generally favourable, giving overall reductions in gap-incidence.

As noted in the introduction, other factors resulting from the low P/L (similar to a luting type) of the first increment may contribute to this favorable effect: the reduced elastic modulus may provide the material with a certain stress-absorbing ability [18-20]. The use of a more flexible intermediate layer between the root dentin and the second increment (reducing the P/L for RMGICs) is commonly referred to as the elastic wall concept [25].

Nevertheless, delaying polishing for 24 h was the main reason for reduced gap-incidence at both axial and all-interfacial regions [13, 17]. One reason for this reduction with storage-period may have been hygroscopic expansion of the RM glass ionomers. As soon as the adhesion of a restoration is disturbed by the shrinkage-stress during setting, subsequent swelling by water sorption will seldom give perfect closure. A mismatch between the surface of the cavity wall and the opposing surface of the restoration, due to the dimensional changes of the restorations, almost always prevents this. After 24 h water storage the shrinkage-stresses of the materials are effectively compensated for or even converted into expansion-stress due to water uptake and swelling [26]. This effect is reported for water-uptake by the RMGIC matrix forming a poly-HEMA complex [10]. In addition, CGIC forms a hydrogel of calcium and aluminum polyacrylates by water-uptake [9]. Water absorption of RMGICs reportedly affects

cavity adaptation and reduces microleakage [13, 24, 27]. Although the hygroscopic expansion may not be sufficient to totally cancel gap-formation arising from setting-shrinkage, it helps to reduce the necessity for an incremental technique in root surface restorations.

Cements are expected to show higher bond and mechanical strengths when fully set rather than during the setting reaction. Previous suggestions have been made that tooth-bonding ability increases with maturation of the glass-ionomer/tooth-substrate interaction during water-storage, and that the cohesive strength of the cement itself improves with the setting process [13]. The pH, an index of the degree of the hardening reaction of set glass ionomer, is reported to be lower at the initial stage (until 30 min) regardless of the type of cement, that is, CGICs or RMGICs. The pH value of the set cement gradually increases for 24 h [28, 29]. Therefore, it can be presumed that completing of the setting reaction of an RMGIC or CGIC requires 24 h. Thus, 24 h are required until an RMGIC or a CGIC has adequate mechanical strength, which has a close relationship with the bond strength [13]. RMGIC has a dual setting reaction: one is light-initiated cross-linking of methacrylate groups similar to the setting of light-cured resin composites, and the other is an acid-base reaction similar to that of a CGIC [10, 11].

The gap-incidence at the critical material-dentin surface was greatly when the incremental method was used *and* specimens polished after 24 h water-storage. The incremental method was unable to prevent gap-formation in coronal and cervical regions when polishing and inspection took place immediately after light curing, because of the imperfectly-developed bonding capacity to tooth substrate at that stage [13, 17].

For both *Fuji II LC* and *Vitremer* restorations, the total gap-incidence with the low P/L incremental method, with immediate polishing, was still significantly greater than with the bulk method *plus delayed polishing*. Nevertheless, a significant reduction in gap-incidence could still be achieved by the low-P/L incremental method additional to that attained via the delayed polishing method.

A reduced gap-incidence for both axial and total regions of root-surface restorations was achieved with *Fuji II LC* compared to *Vitremer* (cf: Figures 2 and 3). Previously it was found that the marginal gap-widths due to shrinkage, in both tooth cavities or Teflon molds, of *Vitremer* was significantly greater than that for *Fuji II LC*, after 1-day storage [13]. Also the interfacial gap-formation around Class V restorations of *Vitremer* was more than that of *Fuji II LC*, after one-day storage [30]. These results are consistent with the present study, where *Vitremer* showed more gaps than *Fuji II LC*.

The restorative materials examined in the present study should preferably not be polished at the placement appointment, but at a subsequent appointment [13, 17].

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Captions To Figures

Fig. 1 Root surface restoration and each measurement location for gap-formation.

E: Enamel substrate, D: Dentin substrate

I: First layer, II: Second layer

Fig. 2: Variation of the total interfacial gap-incidence with the normalized P/L ratio of the first increment of *Fuji II LC*, for both immediate and delayed (24 h) specimen polishing conditions.

Fig. 3: Variation of the total interfacial gap-incidence with the normalized P/L ratio of the first increment of *Vitremer*, for both immediate and delayed (24 h) specimen polishing conditions.

Figure 1

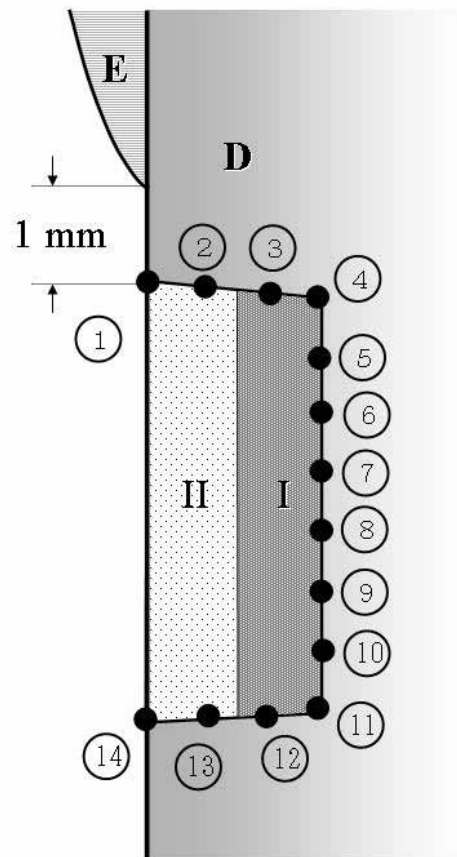


Figure 2

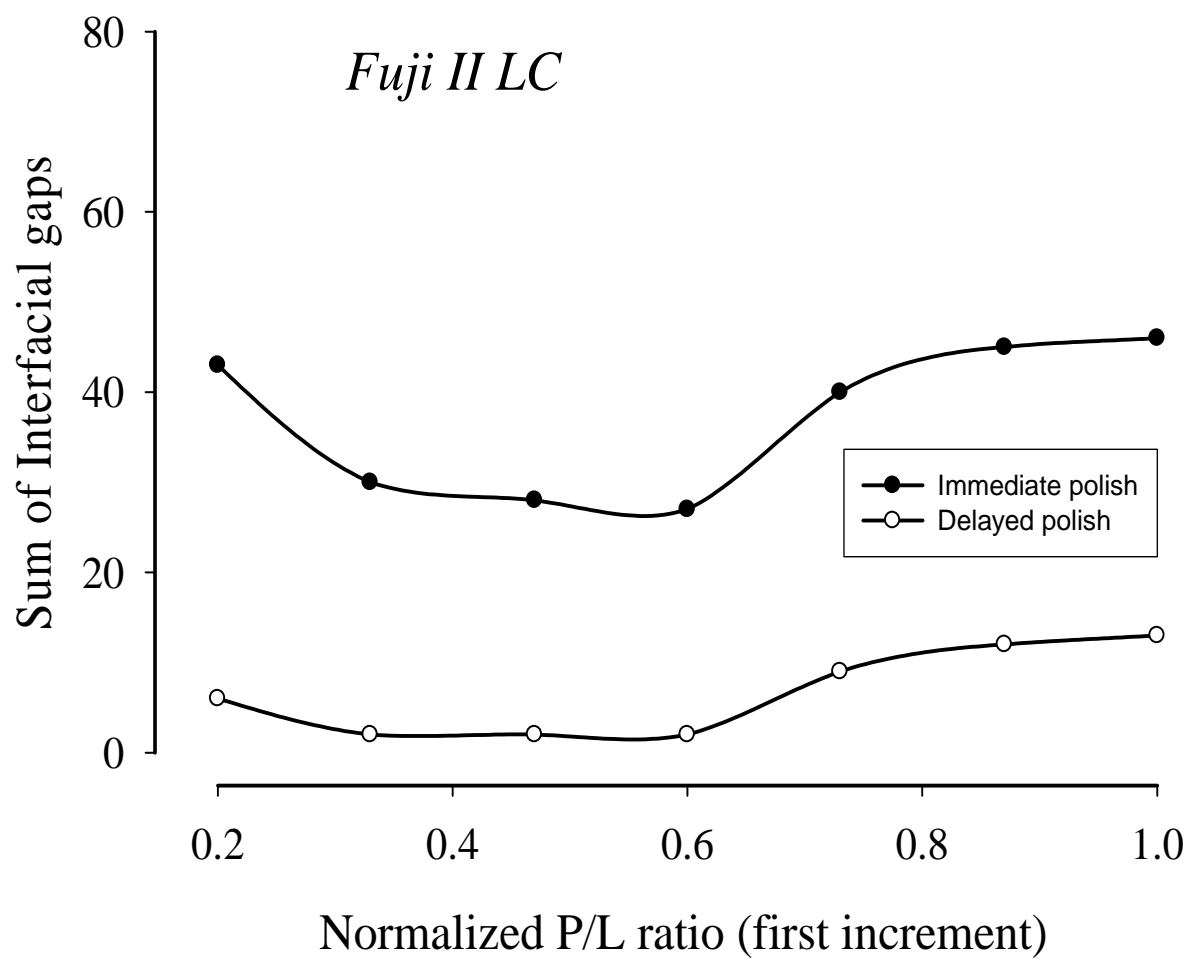


Figure 3

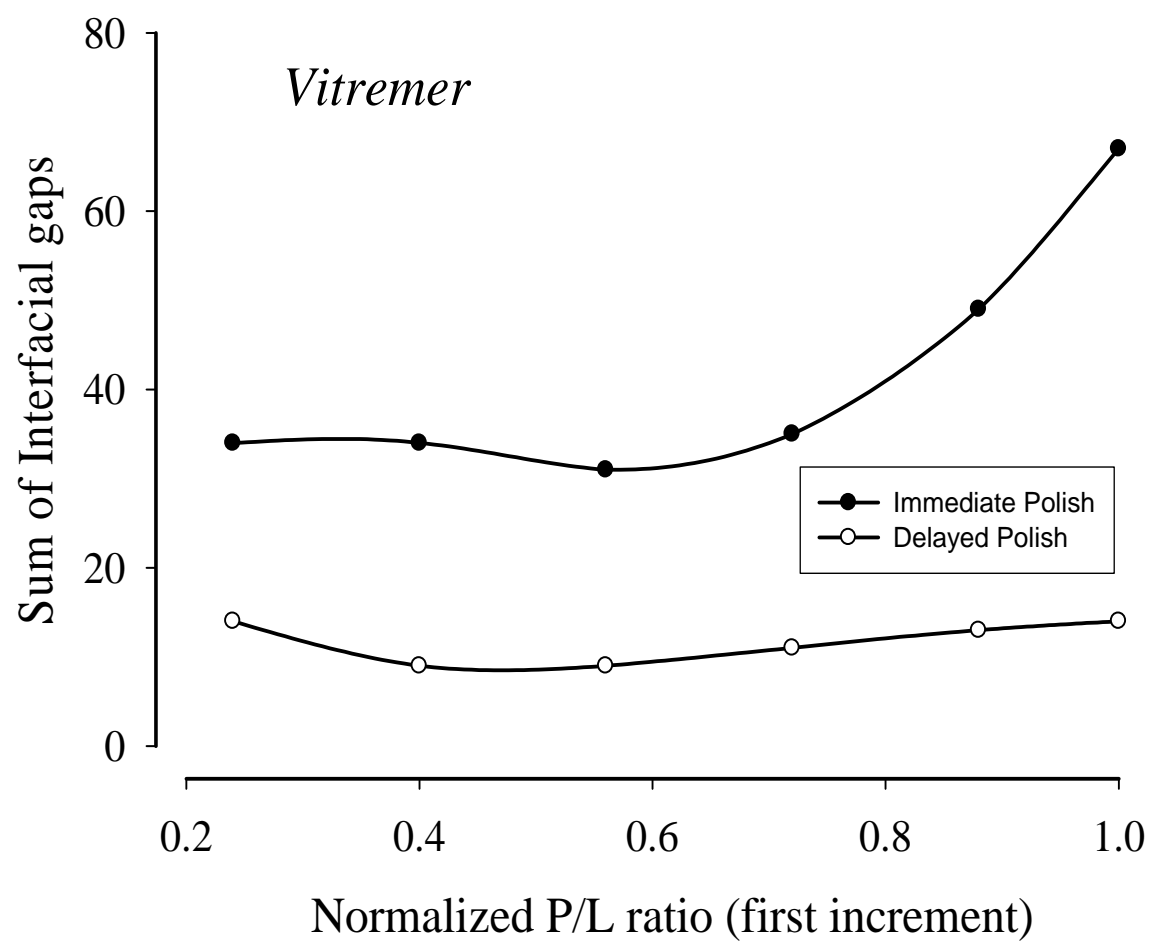


Table 1: Restorative Materials investigated

Material	Manufacturer	Batch No.	Powder/Liquid, Components
Fuji II LC	GC Corp. Tokyo, Japan	P: 211241 L: 140551	3.0 P: fluoroaluminosilicate glass L: copolymer of acrylic and maleic acid HEMA, water
Vitremer	3M ESPE St. Paul, MN, USA	P: 34 L: 311	2.5 P: fluoroaluminosilicate glass L: polyalkenoate copolymer, HEMA, water

Key: HEMA, 2-Hydroxyethyl methacrylate

Table 2: Conditioner/Primer agents investigated

Material	Manufacturer	Batch No.	Components and surface treatment
Dentin Conditioner	GC Corp. Tokyo Japan	151021	Polyacrylic acid, water. Apply with brush 20 seconds rinse gently dry 5 seconds
Vitremer Primer	3M ESPE St. Paul, MN USA	36	HEMA, maleic acid in aqueous solution, ethyl alcohol Apply with brush 30 seconds gently dry 5 seconds light cure 20 seconds

Key: HEMA, 2-hydroxyethyl methacrylate;

Table 3: Effect of normalized powder/liquid ratio of the first layer (incremental method) on interfacial gap-formation around *Fuji II LC* restorations, polished immediately after light-activation.

	Number of specimens showing gaps														Sum		
	Coronal				Axial					Cervical					Coronal	Axial	Total for all
	1	2	3	4	5	6	7	6	9	10	11	12	13	14	Coronal	Axial	Total for all + Cervical
Normalized P/L ratios Incremental method:																	
0.20	7	0	0	2	5	4	3	3	3	5	4	0	0	7	20 (NS)*a #	23 (NS) b	43 (NS) c
0.33	7	0	0	3	1	3	2	2	1	2	2	0	0	7	19 (NS) a	11 (S) b	30 (S) c
0.47	7	0	0	2	1	3	2	3	0	1	3	0	0	6	18 (NS) a	10 (S) b	28 (S) c
0.60	6	0	1	2	2	3	2	1	1	1	2	0	0	6	17 (NS) a	10 (S) b	27 (S) c
0.73	6	0	1	1	2	2	4	4	3	4	6	1	0	6	21 (NS) a	19 (NS) b	40 (NS) c
0.87	7	1	0	2	4	3	4	6	4	2	3	1	1	7	22 (NS) a	23 (NS) b	45 (NS) c
1.0	7	1	3	4	3	5	2	3	3	1	5	2	0	7	29 (NS) a	17 (NS) b	46 (NS) c

Bulk method	7	0	0	2	4	5	2	4	5	5	5	0	0	8	22	25	47

N=10 (total measuring points, 1 – 14 = 140)

*: vs. Bulk method (Mann-Whitney U-Test, S: Significant difference, NS: No significant difference, alpha=0.05)

#: Values with the same letters were not significantly different by Tukey Test (p>0.05, non-parametric [23, 24]).

Table 4: Effect of normalized powder/liquid ratio of the first layer (incremental method) on interfacial gap-formation around *Fuji II LC* restorations, polished after one-day storage.

	Number of specimens showing gaps														Sum		
	Coronal				Axial					Cervical					Coronal	Axial	Total for all
	1	2	3	4	5	6	7	6	9	10	11	12	13	14	Coronal	Axial	Total for all + Cervical
Normalized P/L ratio Incremental method:																	
0.20	0	0	0	1	0	0	1	1	2	1	0	0	0	0	1 (NS)* a #	5 (NS) b	6 (NS) de
0.33	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1(NS) a	1 (S) b	2 (S) e
0.47	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2 (NS) a	0 (S) b	2 (S) e
0.60	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0(NS) a	2 (S) b	2 (S) e
0.73	0	0	0	1	2	2	0	1	1	1	1	0	0	0	2 (NS) a	7 (NS) bc	9 (NS) de
0.87	0	0	0	1	1	3	1	1	2	2	1	0	0	0	2 (NS) a	10 (NS) c	12 (NS) d
1.0	0	0	0	0	1	1	4	1	1	3	2	0	0	0	2 (NS) a	11 (NS) c	13 (NS) d

Bulk method	0	0	0	3	3	3	3	2	2	2	0	0	0	0	3	15	18

N=10 (total measuring points, 1 – 14 = 140)

*: vs. Bulk method (Mann-Whitney U-Test, S: Significant difference, NS: No significant difference, alpha=0.05)

#: Values with the same letters were not significantly different by Tukey Test (p>0.05, non-parametric [23, 24]).

+: P/L=3.0

Table 5: Effect of immediate *versus* delayed polishing techniques on interfacial gap-formation around *Fuji II LC* restorations.

Sum of the interfacial gaps for all ten specimens: Incremental method:									
Normalized P/L ratios	Polishing immediately			Polishing after one-day storage			Alpha value*		
	Coronal + Cervical	Axial	All	Coronal + Cervical	Axial	All	Coronal + Cervical	Axial	All
0.20	20	23	43	1	5	6	S	S	S
0.33	19	11	30	1	1	2	S	S	S
0.47	18	10	28	2	0	2	S	S	S
0.60	17	10	27	0	2	2	S	S	S
0.73	21	19	40	2	7	9	S	S	S
0.87	22	23	45	2	10	12	S	NS	S
1.0	29	17	46	2	11	13	S	NS	S

Bulk method	22	25	47	3	15	18	S	NS	S

N=10 (measuring points, 1 – 14 = 140)

*: Significantly different by Mann-Whitney U-Test between the two sums (S: Significant difference, NS: No significant difference, alpha=0.05)

Table 6: Effect of normalized powder/liquid ratio of the first layer (incremental method) on interfacial gap-formation around *Vitremer* restorations, polished immediately after light-activation.

	Number of specimens showing gaps														Sum		
	Coronal				Axial					Cervical					Coronal	Axial	Total for all
	1	2	3	4	5	6	7	6	9	10	11	12	13	14	Coronal	Axial	+ Cervical
Normalized P/L ratio Incremental method:																	
0.24	6	1	0	3	0	1	2	3	3	2	1	2	3	7	23 (NS)*a #	11 (S) c	34 (S) e
0.40	6	0	0	2	1	2	3	2	3	3	5	0	0	7	20 (NS) a	14 (S) c	34 (S) e
0.56	7	0	0	2	3	1	3	3	1	1	3	1	0	6	19 (S) a	12 (S) c	31 (S) e
0.72	6	1	1	2	2	3	2	2	3	3	3	0	0	7	20 (NS) a	15 (S) c	35 (S) e
0.88	8	2	1	3	2	2	4	4	4	2	5	3	1	8	31 (NS) a	18 (S) c	49 (NS) e
1.0	8	2	2	4	4	5	6	5	6	5	4	5	3	8	36 (NS) b	31 (NS) d	67 (NS) f

Bulk method	9	2	2	2	7	8	6	7	5	4	2	2	1	9	29	37	66

N=10 (total measuring points, 1 – 14 = 140)

*: vs. Bulk method (Mann-Whitney U-Test, S: Significant difference, NS: No significant difference, alpha=0.05)

#: Values with the same letters were not significantly different by Tukey Test (p>0.05, non-parametric [23, 24]).

Table 7: Effect of normalized powder/liquid ratio of the first layer (incremental method) on interfacial gap-formation around *Vitremer* restorations, polished after one-day storage.

	Number of specimens showing gaps														Sum		
	Coronal				Axial					Cervical					Coronal	Axial	Total for all
	1	2	3	4	5	6	7	6	9	10	11	12	13	14	+ Cervical		
Normalized P/L ratio Incremental method:																	
0.24	0	0	0	1	0	0	1	1	2	1	3	0	0	5	9 (NS)* a #	5 (S) b	14 (NS) c
0.40	0	0	0	3	0	1	0	0	0	3	1	1	0	0	5 (NS) a	4 (S) b	9 (S) c
0.56	1	0	0	0	0	2	1	0	0	1	4	0	0	0	5 (NS) a	4 (S) b	9 (S) c
0.72	3	0	0	0	1	1	1	2	3	0	0	0	0	0	3 (NS) a	8 (NS) b	11 (S) c
0.88	1	0	0	2	1	0	0	1	2	1	3	0	0	2	8 (NS) a	5 (S) b	13 (NS) c
1.0	1	0	0	2	1	1	0	1	1	2	4	0	0	1	8 (NS) a	6 (NS) b	14 (NS) c

Bulk method	0	0	0	3	2	2	0	4	2	6	2	0	0	2	7	16	23

N=10 (total measuring points, 1 – 14 = 140)

*: vs. Bulk method (Mann-Whitney U-Test, S: Significant difference, NS: No significant difference, alpha=0.05)

#: Values with the same letters were not significantly different by Tukey Test (p>0.05, non-parametric [23, 24]).

Table 8: Effect of immediate *versus* delayed polishing techniques on interfacial gap-formation with *Vitremer* restorations.

Sum of the interfacial gaps for all ten specimens: Incremental method:									
	Polishing immediately			Polishing after one-day storage			Alpha value*		
Normalized	Coronal	Axial	All	Coronal	Axial	All	Coronal	Axial	All
P/L ratio	+ Cervical			+ Cervical			+ Cervical		
0.24	23	11	34	9	5	14	S	S	S
0.40	20	14	34	5	4	9	S	S	S
0.56	19	12	31	5	4	9	S	S	S
0.72	20	15	35	3	8	11	S	S	S
0.88	31	18	49	8	5	13	S	S	S
1.0	36	31	67	8	6	14	S	S	S

Bulk method	29	37	66	7	16	23	S	S	S

N=10 (measuring points, 1 – 14 = 140)

*: Significantly different by Mann-Whitney U-Test between the two sums (S: Significant difference, NS: No significant difference, alpha=0.05)