Class I Gap-formation in Highly-viscous Glass-ionomer Restorations: Delayed vs Immediate Polishing

Masao Irie[*]   Yukinori Maruo[†]   Goro Nishgawa[‡]

Kazuomi Suzuki[**]   David C. Watts[††]

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

[†]Okayama University

[‡]Okayama University

[**]Okayama University

[††]University of Manchester Dental School

2 **Class I gap-formation with highly-viscous glass-ionomer restorations**

3 **minimized by delayed polishing.**

4

5 **RESEARCH MANUSCRIPTS**

6 **Short title**: Delayed polishing technique on Class I restorations

7 **Clinical relevance**: Delaying polishing for one day resulted in improved gap-formation for

8 Class I restoration of highly-viscous conventional and conventional glass-ionomer cements.

9 **Abstract**

10 This *in vitro* study evaluated the effects of delayed *versus* immediate polishing to permit

11 maturation on interfacial gap-formation around highly-viscous conventional glass-ionomer

12 cement (HV-GIC) in Class I restorations together with determination of associated mechanical

13 properties. Cavity preparations were made in occlusal surfaces of premolar teeth. Three HV−

14 GICs were studied (*Fuji IX GP, GlasIonomer FX-II* and *Ketac Molar*) and one conventional

15 glass-ionomer cement (C-GIC, Fuji II, as a control), with specimen sub-groups (n = 10) for

16 each property measured. After polishing, either: (i) immediately (6 min) after setting or (ii)

17 after 24 h storage, the restored teeth were sectioned in a mesio-distal direction through the

18 center of the model Class I restorations. The presence or absence of interfacial-gaps was

19 measured at x 1000 magnification at 14 points (each 0.5-mm apart) along the cavity

20 restoration interface; (n=10; total points measured per group =140). Marginal gaps were

21 similarly measured in Teflon molds as swelling data, together with shear-bond-strengths to

22 enamel and dentin, and flexural strengths and moduli. For three HV-GICs and one C-GIC,

23 significant differences ($p<0.05$) in gap-incidence were observed between polishing (i)

24 immediately and (ii) after one-day storage. In the former case, 80-100 gaps were found. In the

25 latter case, only 9-21 gaps were observed. For all materials, their shear-bond-strengths,

26 flexural strength and moduli increased significantly after 24 h storage.

27

Introduction

29 As a restorative material, conventional glass-ionomer cements (C-GIC) have certain desirable

30 properties. C-GIC include chemical bonding to enamel and dentin substrates, release of

31 anticariogenic fluoride into adjacent hard tissues and a low coefficient of thermal expansion

32 similar to that of dentine.[1,2] However, C-GICs are susceptible to fracture and exhibit low wear

33 resistance. Therefore, these deficiencies have limited their use to areas subject to low

34 masticatory stresses.[2] Because of the low fracture toughness, mechanical strength and

35 brittleness of C-GICs, efforts were made to improve their mechanical properties by the

36 addition of powder.[3-5] Highly-viscous C-GICs (HV-GICs) were developed to overcome

37 early moisture sensitivity and low mechanical properties associated with conventional

38 materials. And then they were designed as an alternative to amalgam for posterior preventive

39 restoration.[1,2] Highly-viscous or high powder-liquid ratio C-GICs, such as Fuji IX GP, Ketac

40 Molar and GlasIonomer FX-II, provide a "condensable" feel and are particularly used for the

41 atraumatic restorative treatment (ART) technique introduced by the World Health

42 Organization (WHO) for use in developing countries.[6, 7] Indications for these cements in

43   general practice are to small Class I cavities, deciduous teeth and long-term temporaries.[2, 8-12]

44   The polishing period is another factor that may influence the seal-ability around a cervical or

45   a cavity restoration. Polishing after storage in water for one day resulted in improved gap

46   formation for cervical restorations or dentin cavities of a resin-modified glass-ionomer cement

47   (RM-GIC) or a C-CGI.[13-17] Due to the structure of RM-GIC or C-GIC and their hydrophilic

48   nature, water sorption and subsequent swelling may lead to partial compensation of the

49   shrinkage. The preservation of sealing around a restoration would benefit most if water

50   sorption and setting shrinkage could proceed simultaneously. However, water sorption occurs

51   only at a later stage compared with setting shrinkage.[18] Currently, no information is available

52   regarding the interfacial-gap formation behavior around Class I restoration of a C-GIC.

53   In the oral environment, C-GICs must also withstand masticatory and parafunctional

54   stresses. And these stresses vary markedly in different clinical situations. Thus, thresholds in

55   mechanical properties needed for success may vary considerably from case to case, with

56   stronger C-GICs being required where greater stresses are anticipated. Flexural test are

57   appropriate to assess the mechanical properties of restorative and luting cements.[9, 13, 16] In

58   previous studies, C-GICs were proposed to improve their marginal seal by enhancement of

59   their flexural strength and bonding ability after 24 h water-storage.[13] Appropriate elastic

60   moduli and proportional limit values are also desirable.[16]

61   The principal aims of the present study, therefore, were: 1) to evaluate both gap-formation

62   integrity around but-joints in model restorations, analogous to Class I restoration of HV-GICs

63   and 2) determination of the early development of their flexural and adhesive properties,

64 compared with those of a C-GIC. An important clinical variable was to be assessed in this

65 connection: namely, the effect on these properties of an immediate *versus* a 24 h -delayed

66 finishing procedure. Hence, a major hypothesis to be tested was that premature finishing

67 would significantly reduce interfacial integrity, relative to delayed finishing. Several

68 additional properties, including shear-bond-strengths, were also to be measured, to further

69 elucidate the effects of water-uptake over 24 h upon intrinsic and interfacial material behavior,

70 and to discriminate between the different material types.

71

72 **Materials and Methods**

73 The basic properties of three HV-GICs and one C-GIC, as a control, are summarized in Tables

74 1. Human premolars, extracted for orthodontic reasons, were used for the experiment. After

75 extraction, each tooth was immediately stored in distilled water at $4^{o}C$ for one to two months

76 before use.

77   Four C-GICs were investigated (Table 1), which were placed according to the

78 manufacturers' instructions. Dentin Conditioner was applied for 20 s, and rinsed with water.

79 Ketac Conditioner was applied for 10 s, and rinsed with water. The cavity was filled with

80 mixed GIC using a syringe tip (Centrix C-R Syringe System, Centrix, Connecticut, USA) and

81 covered with a plastic strip and was stored in an incubator at $37\,^{o}C$ and 100% relative

82 humidity for 4 min after mixing as setting procedure. The restored teeth were then coated with

83 a varnish (Fuji Varnish, GC, Tokyo, Japan).

84

Gap-Formation around Class I restoration:

1. Preparing and Polishing Procedures:

A Class I cavity was prepared in the human premolar surface, having a length of 3.5 mm, a width of approximately 2 mm with a depth of 1.5 mm, using a tungsten carbide bur (200,000-rpm) and a fissure bur (8,000-rpm) under wet conditions (Figure 1). Cavosurface walls were finished to a butt joint. This design differed from a Class I clinical cavity in that cavity corners were geometric-box angles to prepare a constant-volume model. One cavity was prepared in each of 80 teeth; (4 materials x 2 polishing or inspecting times x 10 repeats = 80).   The surfaces of designated restorations were polished immediately after setting, 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 setting in distilled water at $37^{\circ}C$ for 24 h. Then the surfaces of the restorations were polished, as described above.

2: 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) (Figure 1). The number of gaps in each position was totaled and expressed as a sum for each sample.[14, 15, 17]

Marginal Gap in Teflon Cavity

Since Teflon does not react with GICs, it was used as a mold to measure the degree of setting

shrinkage (immediately after setting) and any hygroscopic expansion (after 1-day storage in

water) of the GICs. Each prepared Teflon mold (n = 10), with a depth of 1.5 mm and a

diameter of 3.5 mm, was placed on a silicone oil-coated glass plate, and filled with GIC using

a syringe tip, then covered with a plastic strip until set. The sum of the maximum gap-width

and the opposing gap width (if any) was expressed as the marginal gap in the Teflon cavity.

Shear Bond Strengths to Enamel and to Dentin

Wet grinding of buccal surfaces was performed with up to 1000 grit silicon carbide abrasive

paper until a flat enamel or superficial dentin area of at least 4 mm in diameter was exposed.

The surface was pretreated as described above. A split Teflon mold with a cylindrical hole

(diameter, 3.6 mm; height, 2 mm) was clamped to the prepared enamel or dentin surface. The

Teflon mold was filled with various restorative materials using a Centrix syringe tip (Centrix

C-R Syringe System, Centrix, Connecticut, USA). It was covered with a plastic strip and the

material was hardened by light irradiation, as described above. For each material, 10

specimens were prepared. Prepared specimens were secured in a mounting jig. At a time of

either 6 minutes from start of mixing procedure, or after 24 h water-storage, the shear force

was transmitted by a flat (blunt) 1 mm broad shearing edge making a 90° angle to the

direction of the load (or the back of the load plate). The shear force was applied (Autograph

DCS-2000, Shimadzu, Kyoto, Japan) at a cross-head speed of 0.5 mm/min. The stress at

127 failure was calculated and recorded as the shear-bond strength. The failed specimens were

128 examined under a light microscope (x 4; SMZ-10, Nikon, Tokyo, Japan) to determine the total

129 number of adhesive failure surfaces.[16]

130

131 **Flexural strength and flexural modulus of elasticity.**

132 Teflon molds ($25\times2\times2$ mm) were used to prepare flexural specimens (n=10 /group). Each GIC

133 was setting as described above. Flexural properties were measured, both immediately after

134 setting and after 24 h storage, using the three-point bending method with a 20 mm-span and a

135 load speed of 0.5 mm/min (5565, Instron, Canton, MA, USA) outlined in ISO 9917-2 (1996)

136 and the flexural modulus was calculated (Software Series IX, Instron, Canton, MA, USA).

137

138   All procedures, except for cavity preparation, were performed in a thermo-hygrostatic room

139 kept at 23 ± 0.5 ^{o}C and 50 ± 2 % relative humidity. Ten specimens were made for each material,

140 storage period and property investigated. The results were analyzed statistically using the

141 Mann-Whitney U test, Tukey Test (non-parametric),[14 - 17, 19] Tukey Test, *t*-Test, or Fisher Exact

142 Test (Sigmastat 3.1, Systat software, Inc., Point Richmond, CA).

143

144 **RESULTS**

145 Table 2 summarizes the interfacial gap formation observed in the Class I with three HV-GICs

146 and a normal C-GIC (as a control), when the specimen was polished immediately after

147 light-activation and after delayed polishing. For all materials, the sums of gaps were

148   significantly fewer with delayed polishing, compared to immediate polishing.

149   Table 3 summarizes the marginal gap width between the four GICs and Teflon molds under

150   two conditions. The two columns represent the linear (diametral) setting shrinkage-strain

151   immediately after setting and after one-day storage. The data for polishing after one-day

152   storage was significantly better compared with that for polishing immediately. With

153   immediate and after one-day stages, the values of Fuji IX GP and GlasIonomer FX-II were

154   significantly less than for Fuji II.

155   Tables 4 summarize the shear bond strength to the enamel surface and the mode of fracture,

156   respectively. Immediately after setting, the value of shear bond strength of Ketac-Molar was

157   significantly less than that of the normal C-GIC (Fuji II). However there was no difference

158   between the four GICs after one-day storage. The data for polishing after one-day storage

159   were significantly better compared with that for polishing immediately. For all groups, no

160   significant differences in fracture mode were observed between immediate and 24 h.

161   Tables 5 summarize the shear bond strength to the dentin surface and the mode of fracture,

162   respectively. Immediately after setting, the value of shear bond strength of Fuji IX GP and

163   Ketac-Molar were significantly less than that of Fuji II. It was not significantly different

164   between the three C-GICs, except GlasIonomer FX-II, after one-day storage. The data for

165   polishing after one-day storage were significantly better compared with that for polishing

166   immediately. For all groups, no significant differences in fracture mode were observed

167   between immediate and 24 h.

168   All materials showed significantly higher flexural strengths after 1 day than immediately

169   after setting (Table 6).

170   Table 7 summarizes the flexural modulus under two conditions. The tendency of results

171   was similar to the flexural strength, increasing after storage. All materials showed

172   significantly higher value than when the specimens were measured immediately after setting.

173

174   **DISCUSSION**

175   This study used a model cavity for the geometry of typical Class I cavities. This only

176   approximates the Class I morphology and is not the typical morphology for a C-GIC, but has

177   the advantage of a constant volume, reproducible geometry that is beneficial for an in vitro

178   scientific study.

179   This study demonstrated that polishing of four GICs should not be performed immediately

180   after the filling and setting procedure but should be delayed to a later time to prevent

181   interfacial gap-formation between the material and the Class I cavity. In contrast to the

182   marginal gap of approximately 80-100 gaps when the specimen was polished immediately

183   after setting, the gap was near zero when the specimen was polished after storage in water for

184   1 day. The GICs shrink during the setting reaction, so interfacial gaps form as the adhesion

185   between tooth-cavity and glass-ionomers does not resist the shrinkage-stress.[13, 20, 21] However,

186   after 1-day water storage the shrinkage-stresses of the materials are effectively compensated

187   for or even converted into expansion-stress due to water uptake and swelling.[1,2,, 4, 18] Water

188   absorption of C-GICs reportedly affects cavity adaptation and reduces microleakage.[3, 13]

189   Although the hygroscopic expansion may not be enough to compensate for the setting

– 9 –

190 shrinkage, it plays an important role in reducing the shrinkage caused by the cement setting

191 reaction and thus improves the interfacial gap-formation in the restoration.[14, 15]

192   The marginal gap measured using the Teflon mold showed a similar pattern, with respect to

193 the polishing condition, to that obtained using the Class I restoration, as mentioned above. The

194 marginal gap observed even after the specimen was stored in water for 1 day indicated that the

195 hygroscopic expansion did not fully compensate for the setting-shrinkage.

196   The bond-strength, flexural-strength and flexural-modulus of 1-day storage were

197 significantly higher than those measured immediately for the all C-GICs, and

198 inter-relationships have been reported previously.[3, 13, 22] As expected, cements show higher

199 bond and mechanical strengths when fully set than during the setting reaction. Also the pH, an

200 index of the extent of the hardening reaction for GICs, gradually increases for 24 hours.[1, 2, 23]

201 Therefore it can be presumed that completing of the setting reaction of a GIC requires at least

202 24 hours.

203   After 1-day storage a HV-GIC (Fuji IX GP) performed significantly better than its

204 corresponding conventional C-GIC (Fuji II). Increasing powder-liquid ratio is the main reason

205 for improving these results, as the two C-GICs are otherwise very similar. This improvement

206 is achieved by a reduction in the glass particle-size. However GlasIonomer FX-II and Ketac

207 Molar Aplicap did not clearly show this pattern. This may be explained by differences in

208 density, distribution or content of the powder, and the polyacrylic or maleic acid concentration

209 or molecular weight of polyacrylic or maleic acid of the liquid. A number of variations led to a

210 HV-GIC with improved physical properties.[24]

211   Investigating interfacial gap-formation after 24 h storage, for C-GICs, had value, as was

212   also found in studying various types of restorative filling materials.[13-17] The greater interfacial

213   integrity of GICs resulted from harmony between: good bond-strength, low setting shrinkage

214   or possibly some hygroscopic expansion. With HV-GICs it is thus generally advisable to

215   adjust of occlusion immediately after initial setting and perform a final contouring and

216   finishing by delayed polishing procedure. And, it is thought that a HV-GIC is the most useful

217   and significant restorative material for some pediatric or geriatric patients.

218   A more extensive approach to the evaluation of sealing efficacy with C-GICs would require

219   longer-term durability testing or load-cycling.

220

221 **References**

222 1. Tosaki S & Hirota K (1994) Current and future trends for light cured systems, In Hunt PR,

223   ed *Glass ionomers: The next generation ─Proceedings of the 2nd international symposium on*

224   *glass ionomers* Philadelphia 35-46.

225 2. Davidson CK & Mjor IA (1999) *Advanced in Glass-Ionomer Cement* Quintessence

226   Chicago 15-50.

227 3. Irie M & Nakai H (1987) The marginal gap and bonding strength of glass ionomers *Dental*

228   *Materials Journal* 6(1) 46-53.

229 4. Wilson AD & McLean JW. *Glass-Ionomer Cement* Quintessence Chicago, 1988 57-72.

230 5. Guggenberger R, May R & Stefan KP (1998) New trends in glass-ionomer chemistry.

231   *Biomaterials* 19(6) 479-483.

232 6. Frencken J Phantumvanit P & Pilot T (1994) Manual Atraumatic Restorative Treatment

233 Technique of Dental Caries. 2nd ed. Groningen: WHO Collaborating Center for Oral Health

234 Services Research University of Groningen.

235 7. Frencken JE, Songpaisan Y, Phantumvanit P & Pilot T (1994) An atraumatic restorative

236 treatment (ART) technique: evaluation after one year. *International Dental Journal* 44(5)

237 460-464.

238 8. Mount GJ (1995) Some physical and biological properties of glass ionomer cement.

239 *International Dental Journal* 45(2) 135-140.

240 9. Peutzfeldt A (1996) Compomers and glass ionomers: Bond strength to dentin and

241 mechanical properties *American Journal of dentistry* 9(6) 259-263.

242 10. Tyas MJ, Anusavice KJ, Frencken JE, & Mount GJ (2000) Minimal Intervention dentistry

243 – a review. FDI Commission Project 1-97 *International Dental Journal* 50(1)1-12.

244 11. Yip H-K, Smales RJ, Yu C, Gao X-J & Deng D-M (2002) comparison of atraumatic

245 restorative treatment and conventional cavity preparations for glass-ionomer restorations in

246 primary molars: one-year result *Quintessence International* 33(1) 17-21.

247 12. Yu C, Gao X-J, Deng D-M, Yip H-K & Smales RJ (2004) Survival of glass ionomer

248 restorations placed in primary molars using atraumatic restorative treatment (ART) and

249 conventional cavity preparations: two-year results *International Dental Journal* 54(1) 42-46.

250 13. Irie M & Suzuki K (2000) Marginal seal of resin-modified glass ionomers and

251 compomers: Effect of delaying polishing procedure after one-day storage *Operative Dentistry*

252 25(6) 488-496.

253 14. Irie M & Suzuki K (2002) Effect of delayed polishing on gap formation of cervical

254 restorations *Operative Dentistry* 27(1) 59-65.

255 15. Irie M, Tjandrawinata R & Suzuki K (2003) Effect of delayed polishing on Interfacial gap

256 formation of Class V restorations *Operative Dentistry* 28(5) 554-561.

257 16. Irie M, Suzuki K & Watts DC (2004) Marginal and flexural integrity of three classes of

258 luting cement, with early finishing and water storage *Dental Materials* 20(1) 3-11.

259 17. Irie M, R Tjandrawinata, Suzuki K & Watts DC (2006) Root-surface gap-formation with

260 RMGIC restorations minimized by reduced P/L ratio of the first increment and delayed

261 polishing *Dental Materials* 22(5) 486-497.

262 18. Feilzer AJ, Kakaboura AI, de Gee AJ & Davidson CL (1995) The influence of water

263 sorption on the development of setting shrinkage stress in traditional and resin-modified glass

264 ionomer cements *Dental Materials* 11(3) 186-190.

265 19. Conover & Iman RL (1981) Rank transformations as a bridge between parametric and

266 nonparametric statistics *Amer Statistician*   35(3) 124-129.

267 20. Feilzer AJ, de Gee AJ & Davidson CL (1988) Curing contraction of composites and glass

268 ionomer cements *Journal of Prosthetic Dentistry* 59(4) 297-300.

269 21. Sidue SK (1994) Marginal contraction gap formation of light-cured glass ionomers

270 *American Journal of Dentistry* 7(2) 115-118.

271 22. Irie M & Nakai H (1988) Mechanical properties of silver-added glass ionomers and their

272 bond strength to human tooth *Dental Materials Journal* 7(1) 87-93.

273 23. Anusavice KJ (1996) *Phillips' science of dental materials* 10th ed. WB Saunders Co.,

274   Philadelphia 565-566.

275   24. Guggenberger R, May R. & Stefan KP (1998) New trends in glass-ionomer chemistry

276   *Biomaterials* 17(6) 479-483.

277

278

279

286

287

288

289   **Caption to Figure**

290   Figure   Class I restoration and each measurement location for gap-formation.

291   E: Enamel substrate, D: Dentin substrate, G: Glass ionomer restorative material
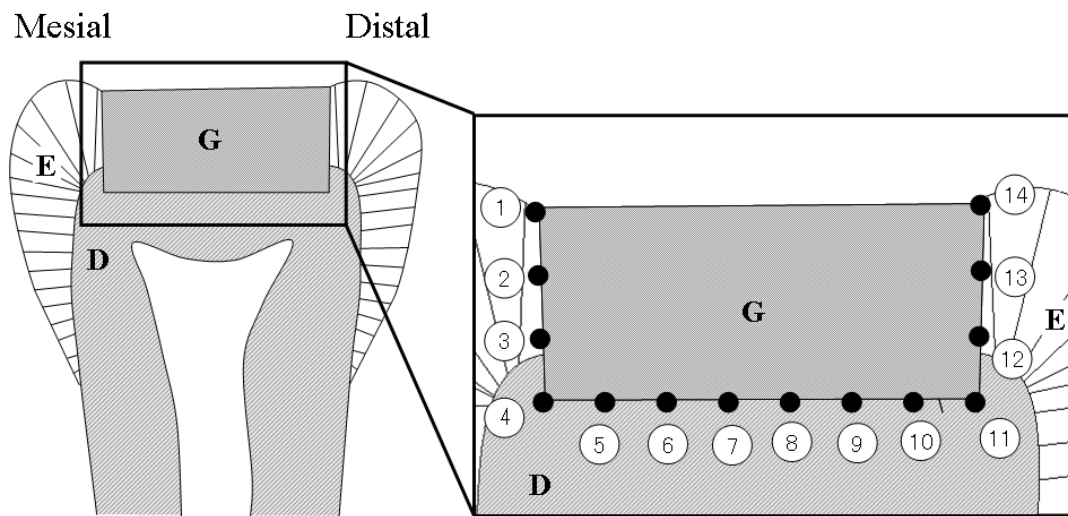
Table 1   Restorative Materials and conditioner agents investigated

Material	Manufacturer	Batch No.	Powder/Liquid, Components, Surface treatment
Restirative materials			
Fuji IX GP	GC Corp. Tokyo, Japan	P: 0404301 L: 0404301	3.6 P: fluoroaluminosilicate glass L: copolymer of acrylic and maleic acids, polybasic carboxylic acid, water
GlasIonomer FX-II	Shofu Corp.	P: 120304 L: 050302	2.6 P: fluoroaluminosilicate glass L: copolymer of acrylic acid and tri-carboxylic acid, water
Ketac Molar Aplicap	3M ESPE AG Seefeld, Germany	169574	Precapsulated P: fluoroaluminosilicate glass L: polycarbonic acid, tartaric acid, oligomers, water
Fuji II (as a control)	GC Corp. Tokyo, Japan	P: 0309091 L: 0309121	2.7 P: fluoroaluminosilicate glass L: copolymer of acrylic and maleic acids, polybasic carboxylic acid, water
Conditioner agents			
Dentin Conditioner	GC Corp. Tokyo, Japan	151021	Polyacrylic acid, water. Apply with brush 20 seconds - rinse - gently dry 5 seconds
Ketac Conditioner	3M ESPE AG Seefeld, Germany	00026	Polyacrylic acid, water Apply with brush 10 seconds - rinse - gently dry 5 seconds

Table 2   Effect of polishing time on gap formation around Class I restoration

Restoration	Number of specimens showing gaps														Sum
	Medial				Bottom							Distal			
Polishing time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Fuji IX GP															
Immediate	10	5	2	4	2	1	7	7	7	3	7	6	9	10	**80** (NS) [*] a[#] S[**]
After one-day storage	2	0	0	0	0	1	1	0	0	0	0	0	0	5	**9** (S) b
GlasIonomer FX-II															
Immediate	9	5	4	4	2	5	6	5	7	7	7	3	6	10	**80** (NS) a S
After one-day storage	5	0	0	0	0	1	0	0	0	0	1	0	0	5	**12** (NS) b
Ketac Molar Aplicap															
Immediate	10	6	6	5	6	5	7	9	5	7	8	9	6	10	**99** (NS) c S
After one-day storage	4	0	0	2	0	1	0	2	2	1	4	2	0	3	**21** (NS) d
Fuji II (as a control) Immediate	10	5	4	4	5	7	10	10	6	3	7	6	7	10	**94** S
After one-day storage	7	0	0	2	0	2	1	1	0	2	1	0	1	4	**21**

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

[*] : vs. Fuji II (Man-Whitney U-Test, S: Significant difference, NS: Not significant difference, alpha=0.05)

[#] : Means with the same letters were not significantly different by Tukey test. (p>0.05, non-parametric[14 - 17, 19]).

[**] : Immediate vs. After 1-day storage (Man-Whitney U-Test, S: Significant difference, alpha=0.05)

Table 3　Effect of polishing time on marginal gap-width in the Teflon mold (micrometer).

Restoration	Mean (S.D.)		p value*
	Immediately	After one-day storage	
Fuji IX GP	**14.3** (2.3) (S) [#]	**9.3** (2.2) (S)	<0.001
GlasIonomer FX-II	**14.3** (3.5) (S)	**9.5** (1.7) (S)	<0.05
Ketac Molar Aplicap	**17.0** (2.4) (S)	**11.8** (3.0) (NS)	<0.001
Fuji II	**20.0** (3.3)	**12.9** (3.0)	<0.001

N=10,　Diameter in Teflon mold: 3.5 mm.　[*]: *t*-test.

[#] : vs. Fuji II (*t*-test, S: Significant difference, NS: Not significant difference, p>0.05)

Table 4　Shear bond strength to enamel surface (MPa) immediately after setting and one-day storage.

Restoration	Mean (S.D.)		p value[*]
	Immediately	After one-day storage	p value[#]
Fuji IX GP	**2.50** (0.64) a b	**8.29** (1.87) c	<0.001
	0 / 2 / 8 [**]	0 / 3 / 7	NS
GlasIonomer FX-II	**2.78** (0.58) a	**8.41** (1.52) c	<0.001
	0 / 0 / 10	0 / 0 / 10	NS
Ketac Molar Aplicap	**1.83** (0.53)　b	**5.99** (2.90) c	<0.001
	0 / 8 / 2	0 / 7 / 3	NS
Fuji II (as a control)	**2.93** (0.90) a	**6.44** (1.97) c	<0.001
	0 / 2 / 8	0 / 3 / 7	NS

[*]: t-test.　[#]: Fisher Exact test.　NS: Not significantly different ($p > 0.05$)

[**]: Number with each fracture mode, adhesive failure at the bonding site / mixed failure / cohesive failure, N=10

Means with the same letters were not significantly different by Tukey test. ($p > 0.05$).

Table 5   Shear bond strength to dentin surface (MPa) immediately after setting and after one-day storage.

Restoration	Mean (S.D.)		p value[*]
	Immediately	After one-day storage	p value[#]
Fuji IX GP	**1.38** (0.55) a	**8.80** (1.12) c	<0.001
	0 / 0 / 10[**]	0 / 0/ 10	NS
GlasIonomer FX-II	**2.12** (0.45) b	**5.45** (1.03) d	<0.001
	0 / 0 / 10	0 / 0 / 10	NS
Ketac Molar Aplicap	**1.42** (0.59) a	**7.17** (1.99) c d	<0.001
	0 / 0 / 10	0 / 0 / 10	NS
Fuji II (as a control)	**2.20** (0.67) b	**8.59** (2.00) c	<0.001
	0 / 0 / 10	0 / 0 / 10	NS

[*]: t-test.   [#]: Fisher Exact test.   NS: Not significantly different (p>0.05)

[**]: Number with each fracture mode, adhesive failure at the bonding site / mixed failure / cohesive failure, N=10

Means with the same letters were not significantly different by Tukey test. (p>0.05).

Table 6   Flexural strength (MPa) immediately after setting and after one-day storage.

Restoration	Mean (S.D.)		p value[*]
	Immediately	After one-day storage	
Fuji IX GP	**1.83** (0.79) a	**29.18** (5.39) b	<0.001
GlasIonomer FX-II	**1.70** (0.53) a	**17.29** (1.87) c	<0.001
Ketac Molar Aplicap	**1.89** (0.88) a	**19.33** (5.38) c	<0.001
Fuji II (as a control)	**2.00** (1.59) a	**15.33** (2.07) c	<0.001

[*]: t-test,   N=10

Means with the same letters were not significantly different by Tukey test. (p>0.05).

Table 7　Flexural modulus (GPa) immediately after setting and after one-day storage.

Restoration	Mean (S.D.)		p value[*]
	Immediately	After one-day storage	
Fuji IX GP	**1.30** (0.34) a	**14.54** (1.97) b	<0.001
GlasIonomer FX-II	**1.82** (0.43) a	**12.63** (1.92) b	<0.001
Ketac Molar Aplicap	**1.98** (0.95) a	**14.43** (4.34) b	<0.001
Fuji II (as a control)	**1.57** (1.01) a	**12.63** (4.10) b	<0.001

[*]: *t*-test,　N=10
Means with the same letters were not significantly different by Tukey test. (p>0.05).