

## Repairability of resin-modified glass-ionomer and polyacid-modified resin composite cements

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عادة ما تحتاج حشوات الأسنان إضافات و إصلاح . و لقد أظهرت الدراسات السابقة إمكانية عمل ذلك بدرجات متفاوتة من النجاح مع مواد الاسمنت الزجاجي المتأمن . و كذلك مادة الراتنج المركب . ولقد هدفت هذه الدراسة لبحث ذلك في مواد أخرى كالراتنج المعدل والراتنج المركب المعدل متعدد الاحماض الغير معروفة حتى الآن . و لقد تم استخدام أربعة أنواع من المواد و هي : مادة الـ Fuji 1X ، الـ Fuji 11 LC ، الـ Vitremer ، والـ Dyract . و تمت عليها التجارب في حالتين مختلفتين و هي الاصلاح بسعد عشر دقائق أو بعد سبعة أيام . تم تجهيز العينات المطلوبة من كل مادة للمدة المحددة ثم تقطيعها ، ثم تم تهيئة الاسطح المقطوعة قبل إضافة الخليط الحديد من المادة لاصلاح العينة . بسعد سبعة أيام من الاصلاح تم اختيار مقاومة الالتواء لكل عينة و مقارنتها مع العينات الأخرى و التي عمرها سبعة أيام و لم يتم تقطيعها ثم فحص السطوح و الأجزاء المقطوعة تحت المجهر الإلكتروني . دلت نتائج هذه التجارب على أن عينات الـ Dyract التي لم يتم إصلاحها هي الأكثر صلابة و عينات الـ Fuji 1X هي الأقل صلابة و أن مقاسومة الالتواء في العينات التي تم ترميمها هي دائماً أقل قوة ممن لم يتم ترميمها مع أن هذه الاختلافات غير واضحة إحصائياً بالنسبة لمادة الـ Fuji 11 LC و هي الوحيدة الغير حساسة لعمر العينة عند الترميم . كما أظهرت نتائج التحليل المجهر باستخدام المجهر الإلكتروني للأجزاء المكسورة أن فشل الترميم لهذه المواد كان فشلاً في التلاصق أو التماسك و يعتمد ذلك على طبيعة المادة تحت الفحص . يستنتج من هذه الدراسة أن مادة الـ Fuji 1X و الـ Dyract لهما قدرة محدودة للإصلاح ، و لكن يمكن عمل الاصلاح سريراً لحشوات الـ Fuji 11 LC أو الـ Vitremer .

Restorations often need additions or repairs. Previous studies have shown that this is possible with varying degrees of success with composite as well as with conventional glass-ionomer cements, but the facility for repair of the new hybrids is not known. The objective of this study was to investigate the repairability of resin-modified glass-ionomer and polyacid-modified resin composite cements using two periods of aging prior to repair. Four different materials were used, Fuji IX, Fuji II LC, Vitremer and Dyract, under two different conditions of (1) repair after ten minutes or (2) seven days. Beam specimens of each material were prepared, aged and sectioned. The cut surfaces of the material were pretreated before newly mixed material was added to repair the specimen. Seven days after the repair was made, the flexural strength of the specimen was determined and compared to that of the seven days old unsectioned specimen. The fractured surfaces were viewed under the scanning electron microscope (SEM). Of the unrepaired specimens, Dyract had the highest flexural strength (MPa = 90.0) and Fuji IX the lowest (MPa = 18.1) ( $P < 0.01$ ). The flexural strengths of the repaired specimens were always lower than those of the unrepaired specimens, although for Fuji II LC these differences were not statistically significant ( $P > 0.05$ ). Only the Fuji II LC specimens were insensitive to age of specimen when repaired. SEM analysis of the fracture surfaces showed either adhesive or cohesive failure depending upon the material under examination. Under the conditions of this study, Fuji IX and Dyract showed only a limited facility for repair, but a clinically viable repair or addition could be made on a Fuji II LC or Vitremer specimens.

### Introduction

**G**lass-ionomer cement (GIC), with its fluoride release and adhesion to both dentine and enamel,<sup>1</sup> is now widely used as an aesthetic restorative material. However, the mechanical properties of the GIC, particularly its tendency towards brittle failure, are such that its applications are generally limited to non-load bearing sites in the oral cavity.<sup>1</sup>

In the late 1980s, the resin-modified glass-ionomer cements (RMGICs) were introduced. These materials, which combine the properties of conventional glass-ionomer with that of composite resin, were developed with the intention of providing materials with improved mechanical properties, while maintaining the fluoride release and adhesion to tooth substance of conventional GIC.<sup>2</sup> An RMGIC has two setting

reactions, the acid-base reaction of the conventional GIC and the polymerisation of the resin system.

Polyacid-modified resin composite (compomer) is also described as the combination of glass-ionomer and composite properties. This material sets by a light-cured polymerisation of its resin components. The manufacturers claim that, as the set cement absorbs water, an acid-base reaction is initiated between the acid groups on the compomer resin and the acid-degradable glass filler which enables the release of fluoride from the cement.<sup>2</sup>

The recognized mechanical weaknesses of conventional GIC have also led more recently to the development of the small particle sized condensable materials. Fuji IX was the first aesthetic condensable material to be introduced. It was developed for use with the Atraumatic Restorative Technique,<sup>3</sup> a minimally invasive technique that requires its restorative material to be both adhesive and fluoride releasing. Under

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such circumstances, repairability would also be a distinct advantage.

Over-finishing during replacement and fracture or erosion during clinical use can lead to the need for repair (or replacement) of any direct restorative material, and generally repair of the filling is preferred to its complete removal and replacement. Previous studies have investigated the repairability of both the resin composite<sup>4,7</sup> and conventional GIC.<sup>8</sup> Although there is some potential for chemical interaction between the new and repaired layers of composite, it is generally thought that the repair strength of the composite resin, quoted as about 60% of the whole specimen, is due to mechanical interaction between two layers of material.<sup>4,5</sup> The old composite surface is generally cleaned with phosphoric acid to achieve this. By contrast with appropriate pretreatment, glass-ionomer cements have been shown to have repair strengths that are not significantly lower than those of the whole specimen.<sup>8</sup> The repair strength of the glass-ionomer is probably both chemical and mechanical origin.

The newer aesthetic materials, particularly GICs and RMGICs also have the potential for both chemical and mechanical union of repaired specimens. Previous studies on RMGICs have indicated that repair of these materials is possible.<sup>9-12</sup> However, there appears to be a general decrease in repair bond strengths with aging and therefore, the immediate clinical repair is preferable and delayed repaired is not recommended.<sup>10,12</sup> This study investigated the repairability of four aesthetic restorative materials using only their supplied adhesives or conditioners for pretreatment of the surface requiring repair and using two periods of aging prior to repair.

### Materials and Method

The restorative materials selected for use in this study are listed in Table 1. Dyract was provided in an encapsulated form and could be syringed directly into the mould, whereas the other materials had to be hand-mixed. For the latter, the components were weighed out and then mixed to a paste according to their manufacturers' instructions.

Beam specimens (2 mm thick, 2 mm wide and 25 mm long) were prepared by one investigator using stainless steel split mould. A glass slide was positioned over the material and light figure pressure applied to expel the excess material. The

**Table 1.** Materials and conditioners used in the study

Material	Composition	Conditioner
<b>Fuji IX</b> A conventional GIC Manufacturer: GC Corporation	<u>Powder</u> Fluoroaluminosilicate glass <u>Liquid</u> Polyalkenoic acid and water	---
<b>Fuji II LC</b> A resin-modified GIC Manufacturer: 3M	<u>Powder</u> Fluoroaluminosilicate glass <u>Liquid</u> Copolymer of acrylic acid and maleic acid HEMA (2-Hydroxy-ethylmethacrylate) Water Camphorquinone Activator	GC dentine conditioner - 35% polyacrylic acid.
<b>Vitremer</b> A resin-modified GIC Manufacturer: GC Corporation	<u>Powder</u> Fluoroaluminosilicate glass <u>Liquid</u> Polycarboxylic acid and Monomer	3M Vitremer primer- contains HEMA (2-hydroxy-ethylmethacrylate)
<b>Dyract</b> A polyacid-modified resin composite Manufacturer: Dentsply DeTrey	UDMA Resin TCB Resin Strontium fluorosilicate glass	Dyract PSA Prime / Adhesive - contains adhesion - promoting monomers and a fluoride compound in acetone solvent

specimens of Fuji II LC, Vitremer and Dyract were then light-cured\* for the time as recommended by the manufacturers. A patch curing technique was employed to ensure that the entire specimen was sufficiently cured. A weight block was placed on top of the glass slide, and then the mould assembly was placed in an incubator at 37°C for either 1 hour or 10 minutes. After the maturation time the specimens were removed from their moulds. The one-hour matured specimens were then placed in distilled water and stored at room temperature (37°C ± 1°C) until required for testing. The ten-minute matured specimens were sectioned prior to pretreatment and subsequent repair.

The study consisted of three parts:

1. The determination of the flexural strength of whole specimens 7 days after their preparation.
2. The determination of the flexural strength of specimens repaired when 7 days old and stored for 7 days after the repair was done.

\* Euromax, DeTrey Dentsply, Konstanz, Germany

3. The determination of the 7-day flexural strength of specimens repaired 10 minutes after preparation.

A minimum of ten specimens of each material was prepared for use in each part of the experiment. Some of the prepared specimens fractured upon removal from the mould and these were excluded from the study.

When required for strength testing the specimens were removed from their storage water, and their dimensions measured to an accuracy of  $\pm 0.001$  mm. The width and depth of each specimen were measured with a micrometer gauge at three different points and the mean of the three measurements was recorded. The specimens were then subjected to a three-point load test using a testing machine\*\* at a crosshead speed of 0.1 mm/min. The maximum load at failure was recorded and the flexural strength of the specimen calculated. Where appropriate, the results were analysed using Mann-Whitney non-parametric statistics and two-way ANOVA. Where the results were significant, a *t* test was performed.

Samples of the fracture surfaces selected at random from the specimens (3 from each group) were viewed under a scanning electron microscope (SEM)\*\*\*. The specimens were allowed to desiccate slowly prior to sputter coating with gold-palladium. The surfaces were then viewed in the microscope at an accelerating voltage of 15 kV.

### Preparation of the Repaired Specimens

At the selected times (either 10 minutes or 7 days) after preparation, the whole specimens were placed onto a jig and mechanically sectioned into two equal parts using a slow diamond cutting wheel<sup>†</sup> operating at a speed of 200 rpm. This created a clean-cut surface. The cut surface of the specimen was then treated with the appropriate adhesive or conditioner depending upon the manufacturers' instructions.

The conditioners used were GC Dentine Conditioner for Fuji II LC, 3M Vitremer primer for Vitremer and Dyract PSA primer for Dyract. The manufacturers' instructions for use were followed for each treatment. Consequently no conditioning treatment was used for Fuji IX. For Fuji II LC, the dentine conditioner (a solution of polyacrylic acid)

was applied to the surface for 20 seconds. The surface was then rinsed and dried. For the Vitremer samples, the primer was applied to the cut surface for 30 seconds after which time the excess solvent was removed using a 3-in-1 air syringe for 5 seconds. The surface was then light-cured for 20 seconds. Similarly for Dyract, the primer was applied to the cut surface and left undisturbed for 30 seconds. Excess solvent was removed using an air syringe for 5 seconds and then the surface was light-cured for 10 seconds.

After the appropriate treatment, the half specimen was replaced into the mould and a new mix of the same material was applied to the cut surface. Again, an excess of the materials were placed into the mould and a glass slide was placed over the mould in order to expel the excess material. The additional material was light-cured according to manufacturers' instructions and then stored in the incubator as described earlier. After 1 hour, the repaired specimens were removed from the mould, placed in distilled water and then stored at room temperature (37<sup>o</sup>) until required for testing.

### Results

The results of this study are summarized in Tables 2 and 3.

The Fuji IX specimens were very brittle and, despite careful handling, a large number of them fractured before loading in the flexural strength-measuring device.

Of the control specimens, Dyract had a flexural strength (90 MPa) that was significantly higher than that of the other materials under test ( $P < 0.01$ ). There was no significant difference between the measured strengths of the Fuji II LC (41 MPa) and Vitremer (40 MPa) control specimens ( $P > 0.05$ ) and these materials were in turn both significantly stronger than the Fuji IX (18 MPa) control specimens ( $P < 0.01$ ). Of the specimens repaired after 7 days, only the Fuji II LC specimens showed no statistically significant decrease in flexural strength ( $P > 0.05$ ) after repair compared with the control. Vitremer showed a statistically significant decrease in flexural strength ( $P < 0.05$ ) on repair at 7 days, whereas both Fuji IX and Dyract showed highly significant decreases in strength after repair at 7 days when compared to their control values ( $P < 0.01$ ).

Those specimens repaired after 10 minutes showed no statistically significant difference in

\*\*Hounsfield 200 N Universal Testing Machine, Croydon, UK

\*\*\*Cambridge Instruments 90B, Cambridge, UK

†Testbourne Ltd, Basingstoke, UK

**Table 2.** Flexural strength of control and repaired specimens (MPa)

	Control			10 minutes repair			7 days repair		
	<i>n</i>	Mean (SD)	Median	<i>n</i>	Mean (SD)	Median	<i>n</i>	Mean (SD)	Median
Fuji II LC	12	40.7 (18.5)	34.6	12	35.5 (7.7)	36.1	9	33.2 (6.4)	35.0
Fuji IX	12	18.1 (8.1)	17.9	10	4.8 (6.5)	2.0	12	8.0 (8.2)	6.2
Dyract	15	90.0 (10.9)	86.9	10	30.4 (11.6)	27.9	8	20.0 (5.0)	20.3
Vitremer	13			10	16.9 (5.2)		12	28.5 (8.7)	28.9

**Table 3.** Flexural strength of the repaired specimens as a percentage of their control values

	10 minutes	7 days
Fuji II LC	87%	82%
Fuji IX	27%	44%
Dyract	34%	22%
Vitremer	42%	71%

These specimens repaired differ 10 minutes

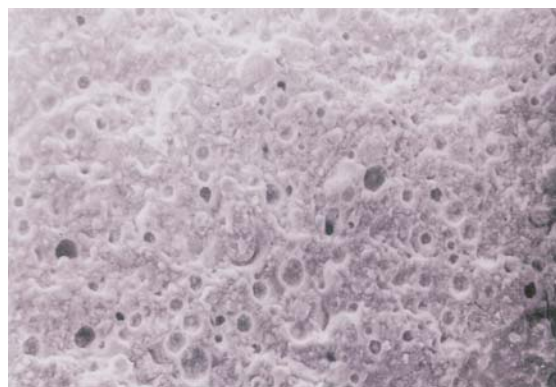
measured flexural strength between the repaired and the control specimens for the Fuji II LC specimens ( $P > 0.05$ ). All the other materials were highly significantly weaker than the control material when repaired at 10 minutes ( $P < 0.01$ ).

When the strengths of the two sets of repaired specimens for each material were compared, it was found that for both Fuji II LC and Fuji IX, the time of repair had no effect on the measured strength ( $P > 0.05$ ) (Table 3). In contrast, the Dyract 10-minute repaired specimens were significantly stronger than the 7-day repaired specimens ( $P < 0.05$ ). The 7-day repaired specimens of Vitremer were highly significantly stronger than the 10-minute repaired specimens ( $P < 0.01$ ).

When the two-way ANOVA analysis was performed and the interaction effects appeared significant, then the material was tested for each time period using a *t* test analysis. The results of this analysis showed that Fuji II LC had no statistically significant difference in its flexural strength between the three treatment time periods ( $P > 0.05$ ). Whereas Fuji IX showed a significant difference in the flexural strength between the control and 10 minutes-repaired specimens, and the control and 7 days-repaired specimens ( $P < 0.01$ ). Both Dyract and Vitremer showed a highly statistical significant difference in the flexural strength between all pairs of time period ( $P < 0.01$ ).

### Scanning Electron Microscope Results

Scanning electron micrographs of the fracture surfaces of examples of the control specimens showed two types of surface. The samples of Fuji IX, Fuji II LC and Vitremer were rough with irregularly shaped glass particles visible on the surface. A large number of spherical holes were also visible, although fewer of these were seen in the Vitremer fracture surfaces than were seen in those for Fuji IX and Fuji II LC. An example of the spherical holes is seen in Figure 1 which showed the fracture surface of a Fuji IX control specimen. In contrast, the surface of the Dyract samples was far smoother and more homogeneous (Figure 2). There were far fewer holes on the surface and those which were present, were irregular in shape.



**Fig. 1.** Micrograph of fracture surface of Fuji IX control specimen at 15 KV (500X).

Visual examination of the fracture surfaces of the repaired specimens showed the occurrence of adhesive, cohesive and mixed adhesive/cohesive failures. Figure 3 showed the fracture surface of a Dyract specimen repaired after 10 minutes. The striations on the surface were caused when the original specimens was sectioned prior to repair.



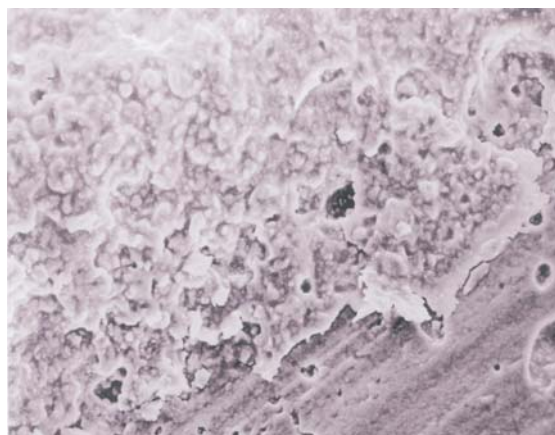
**Fig. 2.** Micrograph of fracture surface of Dyract control specimen at 15 KV (500X).



**Fig. 3.** Micrograph of fracture surface of Dyract specimen repaired after 10 minutes at 15 KV (500X).

Such striations were apparent on all the Dyract specimens indicating that they had all failed adhesively.

All the Vitremer samples inspected showed cohesive failure, the cut surface was not apparent. Similarly, samples of Fuji II LC and Fuji IX showed cohesive failure for the specimens repaired at 7 days but mixed cohesive/adhesive failure for the specimens repaired at 10 minutes. Figure 4 showed the fracture surface of a specimen of Fuji IX repaired at 10 minutes. The original cut surface was clearly visible in the bottom right hand corner of the micrograph, whereas fracture within the bulk of the material can be seen in the rest of the picture. Any cracks observed in the SEM pictures are due to the desiccation of the specimens required prior to observation under the electron beam.



**Fig. 4.** Micrograph of fracture surface of Fuji IX specimen repaired after 10 minutes at 15 KV (500X).

### Discussion

The flexural strength of the materials used in this study was determined using a three-point loading configuration. The four-point loading configuration is usually preferred for flexural strength determination because it is less sensitive to surface defects in the specimen under test.<sup>13</sup> However, the three-point configuration was favoured for use in this study, which is a harder test for repaired specimen, because it places the repair site under direct load. The shear bond test may be the best to examine the bond strength, but the study was designed to compare the results obtained with similar studies.<sup>8,14</sup>

Considering the control unrepaired specimens, Dyract was the strongest material tested. Similar results had been described in previous investigations which described its properties as resembling those of resin composite rather than those of a glass-ionomer material.<sup>14</sup> In fact the figures obtained are similar to that of a microfine composite.<sup>4,5</sup> The control specimens of the two RMGICs (Vitremer and Fuji II LC) were similar in strength but significantly weaker than the Dyract. Again, the results obtained relative to Dyract are in concurrence with previously published data.<sup>11,14-16</sup> The conventional GIC (Fuji IX) was the weakest material tested in this study. Its low strength, lower than that measured for other conventional materials, was surprising, given its claims for broader applicability. However, it should be noted that Fuji IX was a very difficult material to handle and the prepared specimens were very brittle with a tendency to premature fracture.

The scatter in results obtained in this study, although comparable with those in earlier studies, is quite high. This is perhaps a reflection of the difficulty associated with the preparation of flexural strength beam specimens. Three of the materials under investigation required hand-mixing. This can lead to variations in the powder to liquid ratio that the materials are mixed at, but more importantly it led to a significant incorporation of air into the cement paste.<sup>17</sup> The incorporated air could be seen as spherical voids in the fracture surfaces of the cement (Figure 1). It was observed that Vitremer, the easiest of the three materials to mix, showed the fewest voids of the three hand-mixed materials and its control strength had the lowest standard deviation of the three hand-mixed materials (28% of the mean value compared to 45% for both Fuji IX and Fuji II LC). Dyract, the only encapsulated material, showed no such spherical voids (Figure 2) and had the lowest standard deviation (at 12% of the mean value) of the four materials under test. The irregular non-spherical holes visible in the fracture surfaces of the different materials indicated where filler particles have been plucked from the matrix during fracture.

The specimens that were to be repaired were sectioned into two pieces using a slow diamond-cutting wheel. The cut surface was then treated with the material's appropriate conditioner or adhesive as recommended for use by the manufacturer. To form the repaired specimen, the new cement paste was packed against the conditioned surface of the cut sample. This was difficult to achieve particularly with the very viscous hand-mixed materials, which could not be syringed into the mould, and may be a source of some of the variability in their results. This could explain the apparent cohesive/adhesive failure which occurred. It is also possible that the high viscosity material was not fully adapted to the conditioned surface.

The Fuji II LC showed the best repair. There was no significant difference in strength between the control unrepaired specimens and those which had been repaired either at 10 minutes (87% of the control strength) or 7 days (82% of the control strength). The result of this study are consistent with those of previous studies<sup>9,10,12</sup> although it was suggested that immediate repair bond strength is better than delayed repair.<sup>10,12</sup> The cut surface of the Fuji II LC was treated with GC

conditioner, a solution of polyacrylic acid and this may well have produced an active surface on which chemical interaction could occur. Jamaluddin and Pearson<sup>8</sup> found that polyacrylic acid alone was not a very effective pre-treatment for the conditioning of glass-ionomers and the effects were material-dependent. It is likely that conditioning of the surface with polyacrylic acid simply removes any smear layer present on the cut surface. Consequently, any mechanical interaction achieved between the old specimen and new material was likely to be due to the presence of voids in the surface for repair. The removal of any smear layer on the cut surface would also facilitate the chemical interactions. The SEM results for Fuji II LC showed that specimens repaired at 7 days failed cohesively whereas the specimens repaired after 10 minutes showed mixed adhesive/ cohesive failure. The observation of cohesive failure combined with the high flexural strengths of the repaired specimens indicated that there was a significant interaction between the old and new section of the repaired specimen.

In contrast the strength data for Vitremer indicated that it did not possess a similar facility for repair under the conditions used in this study. The specimens repaired at 10 minutes were highly significantly weaker than the controls with a mean strength which was only 42% of that of the control materials. The specimens repaired at 7 days were stronger than those of 10 minutes but still significantly weaker, with a mean value of 71% of that of the control specimens. This finding is contrary to other previous data where this material showed no significant difference in bond strength between control and repair specimens and repair was not affected by time.<sup>10</sup> The variations may, to some extent, be explained by difference in specimens preparation, storage and ageing regimes. The primer used on the cut surface of Vitremer contains both polyacrylic acid (modified by the addition of pendant unsaturated groups) and HEMA. The polyacrylic acid in the primer would, as previously stated, have only a limited etching effect on the cement surface, but both forms of chemical interaction should be possible on the cleaned surface. However, the protocol for this conditioner stated that it should not be rinsed off and so instead the liquid was air dried and then light-cured. This would cause the formation of a crosslinked layer of polyacrylic acid and HEMA on the cut surface of the cement. In consequence,

the potential for acid-base interaction between the old and new materials would be reduced, but the observation of cohesive rather than adhesive failure at the fracture surface indicated that interaction had taken place between the old cement and new material. If a polymerisation reaction was responsible for the interaction, it could be expected that the specimens repaired at 10 minutes would be significantly stronger, because of the potential presence of free radicals and a higher concentration of unreacted species in the relatively immature cement. Instead, the results for Vitremer indicated that the 7-day repaired materials were stronger. This behaviour may be attributed to the on going acid-base reaction within the cement. The reduced porosity observed for the specimens of this lower viscosity cement would also restrict the potential for mechanical interaction between the old cement and the new material. Although the compositions and comparative amounts of glass-ionomer and polymerisation reaction in Fuji II LC and Vitremer are likely to be different, these are unlikely to be the major cause of the observed difference in behaviour. Instead, the different pretreatments prescribed for use are the most likely causes for the differences in repairability.

In this study, Fuji IX did not demonstrate the facility for repair. The mean strength of specimens repaired at 10 minutes was only 27% of that of the control; at seven days, the strength of the repair had improved but was still highly significantly weaker at only 44% of that of the control. These findings are contrary to the previous findings of Jamaluddin and Pearson.<sup>8</sup> It should however be noted that in the earlier study,<sup>8</sup> a conditioner was used on the cut surface before the repair was performed. The conditioner would have removed the smear layer from the cut surface of the cement and allowed the newly exposed glass particles to interact with the fresh cement. When the surface is not cleaned, the fresh material can only interact with the smear layer present and the repair strength may depend upon how tightly the smear layer is held on the cut surface of the old material.

The nature of Fuji IX may also have contributed to its performance. It is very stiff when mixed at the manufacturer's recommended powder to liquid ratio. The paste was not easy to handle and was therefore difficult to pack onto the cut surface of the cement. For any chemical interaction to take place the polyacid in the new material would

have to react with the glass exposed in the sectioned half of the specimen. To achieve this, good adaptability would have been essential, but the handling of the material seemingly militated against this. It is worth considering the use of a primer/conditioner of PAA as this may well enhance the bond by initiating the surface reaction on the old glass. The repair strengths achieved could therefore be expected to be due to mechanical interlocking as a result of the new material filling the air holes. However, the SEM analysis of the fracture surfaces showed a mixture of adhesive and cohesive failure, which indicated that some level of interaction had occurred. The slightly lower strength of the 10-minute repair may be attributed to poor maturation of the material.

Dyract also showed a minimal facility for repair under the conditions used in this study. The repaired specimens were always statistically highly significantly weaker than the controls ( $P < 0.01$ ). The strength of the 10-minute specimens was only 34% of the control, whereas the specimens repaired at 7 days were even weaker at only 22%. This is in agreement with previous work done on the bonding of new composite to old composite.<sup>18</sup> However, other recent studies showed that repair is possible but its bond strength is affected by the method of surface conditioning and time.<sup>11,16</sup> Another work<sup>4</sup> also showed that although repaired specimens had lower strength, the bond between mature and new composite filling material may be durable and adequate for clinical service, and that least viscous materials gave significantly stronger bonds than more viscous brands. However, the low repair strengths achieved in this study would suggest that addition of new Dyract to an old cement would not be clinically acceptable. In this study, Dyract was used with the PSA Primer/Adhesive, which formed a thick film over the surface of the material. It is clear that the early repair was substantially better than that repaired at 7 days. This suggested that there may be unconverted monomer components available at 10 minutes, but not in a more mature specimen, which reacted with the adhesive and the newly packed material. The micrograph (Figure 3) of the fractured surface shows the structure of a cut surface but there appears to be a thin layer of new material over the surface, indicating some degree of cohesive failure and hence some interaction. In contrast, the 7-day repaired specimen failed adhesively and there was no evidence of new

material attached to the surface. It is questionable whether it is a failure at the adhesive/old material interface or the adhesive/new material area. However, the fact that some degree of cohesive failure occurred at 10 minutes suggested that the greater the maturity of the material, the poorer are the chances of repair.

### Conclusion

Within the limitations of the study design, it was concluded that

1. The two RMGICs showed different facilities for repair. Whilst Fuji II LC demonstrated that it was repairable and was insensitive to the time at which the repair was made, all the repaired samples of Vitremer were significantly weaker than the controls.
2. Fuji IX and Dyract showed limited facilities for repair.
3. With regards to the clinical implications of these findings, it seems that although there was a reduction in strength after addition of freshly mixed to aged RMGIC materials, it would appear clinically practical to make an addition. In contrast, the Dyract materials did not appear to be capable of any significant bond strength between new and aged materials under the test conditions described in this study.

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