Effect of Spherical Silica Filler Addition on Immediate Interfacial Gap-formation in Class V Cavity and Mechanical Properties of Resin-modified Glass-ionomer Cement

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The aim of this study was to investigate how the addition of silanized spherical silica filler (SF) would influence the formation of summed, immediate interfacial gaps in Class V tooth cavities. Resin-modified glass-ionomer cement (RMGIC) is usually used for Class V restorations. As such, the following aspects of RMGIC were examined in correlation with summed interfacial gaps in the tooth cavity: setting shrinkage of cement in the Teflon mold, as well as mechanical properties in terms of compressive strength, diametral tensile strength, and flexural strength.

Spherical silica filler was added to the RMGIC powder (Fuji II LC EM). For comparison purpose, untreated spherical silica filler (UF) was added too. When compared with the control (i.e., original RMGIC mixed with manufacturer-recommended powder/liquid ratio), the addition of SF significantly decreased the formation of summed interfacial gaps in Class V cavities in the immediate condition. In particular, addition of 10 wt% SF increased the compressive strength by 56%, while diametral tensile strength was increased by 28% and flexural strength by 26%.

Key words: Resin-modified glass-ionomer cement, Silanized spherical silica fillers, Immediate condition

INTRODUCTION

It was reported that in resin-modified glass-ionomer cements (RMGICs) is found the best of both glass-ionomer cements (GICs) and resin composites. From GICs, RMGICs acquire the inherent adhesion and cariostatic properties of GICs. From resin composites, RMGICs acquire the command setting behavior, as well as good mechanical properties and wear resistance. As a result, when compared with conventional GICs, RMGICs have been characterized as having a longer working time with rapid set, improved appearance and translucency, as well as higher early strength and higher bond strength to enamel and dentin.

Endowed with these advantageous properties, RMGICs therefore have less microleakage than conventional GICs. Furthermore, the rapid setting of RMGIC is an advantage for color stability, as water no longer inhibits the setting reaction by the time photopolymerization is completed.

In previous studies, it was reported that the addition of spherical silica filler to a RMGIC powder improved the flowability or workability of the cement — based on the latter’s rolling performance. Silanization of filler depends on siloxane bridge (Si-O-Si) formation between the silica surface and the silane molecule and addition of silanized spherical silica fillers (SF) to RMGIC has been shown to yield good results after 24 hours: increased compressive strength, diametral tensile strength and flexural strength, and reduced water uptake. Further, it was shown that SF improved the mechanical properties of RMGIC more than untreated spherical silica fillers (UF). Indeed, SF addition also reduced the immediate marginal gaps in tooth cavities and setting shrinkage of RMGIC in the Teflon mold by 63%.

However, the effect of SF addition on interfacial gap-formation in Class V restorations, where RMGICs are usually used, has not been studied. It is usually recommended that restorations be polished after 24 hours. However, for practical reasons, dentists seldom or never do that. As a matter of fact, most practitioners would polish the restoration once it is cured or set. In this immediate condition, the mechanical strength of restorative materials is weaker than that after one-day storage. Moreover, the polishing technique or surface protector also influence microleakage and interfacial gap-formation at this condition.

Against this background, it is important to study and evaluate the mechanical properties of restorative materials in the immediate condition and their influence on immediate interfacial gap-formation in restorations.

In the present study, the first hypothesis was that the addition of SF to RMGIC would reduce immediate interfacial gap-formation in Class V cavities.
The second hypothesis was that the addition of spherical silica filler would significantly increase the immediate mechanical properties of RMGIC since these properties correlate with interfacial gap-formation.

MATERIALS AND METHODS

Materials

Material used in this study was Fuji II LC EM (Powder Lot No. 0507201, Liquid Lot No. 0507141, GC Corp., Tokyo, Japan) with a recommended powder/liquid ratio (P/L) of 3.0. The powder was fluoroalumino silicate glass, and the liquid was composed of methacrylic acid ester, polyacrylic acid, and water.3

Silanized spherical silica filler (GC Corp., Tokyo, Japan), which had an average particle diameter of 0.3 μm with γ-methacryloxypropyl trimethoxysilane (γ-MPTS) (KBM 503, Shin-Etsu Chemical Co., Tokyo, Japan), was prepared as previously described.20

RMGIC powder was modified by initially mixing it with either SF or UF at different weight percentages (5 wt%, 10 wt%, and 20 wt%) before mixing it with Fuji II LC EM liquid. Prepared cement powders were described as SF5, SF10, SF20, UF5, UF10, and UF20 — hence indicating the type of filler added and filler content in weight percentage. Both the mixing time and preparation time were 30 seconds each. As for the P/L ratio, each one was chosen based on the maximum compressive strength value of cement as given in a previous study.18 In the present study, the CONTROL and BASE specimens served as controls. For CONTROL, Fuji II LC EM was mixed with P/L=3.6 (the P/L ratio at which maximum compressive strength was achieved); for BASE, it was P/L=3.0 (manufacturer’s recommended P/L). SF5, SF10, and SF20 were mixed with P/L ratios of 4.0, 4.4, and 4.0 respectively; while UF5, UF10, and UF20 were mixed with P/L ratios of 4.4, 4.4, and 4.0 respectively.

A visible light curing unit (New Light VL-II, GC Corp., Tokyo, Japan; irradiated diameter: 10 mm) was used for activating the specimens, and close contact was ensured between exit window of the lamp and a celluloid strip (Universal Strips, Shofu Corp., Kyoto, Japan) that covered the specimen. Using a radiometer (Demetron/Kerr, Danbury, CT, USA), light intensity was checked and maintained at 450 mW/cm².

All procedures, except for cavity preparation and mechanical testing, were performed in a thermostatic room maintained at 23±0.5°C and 50±2% relative humidity.

Interfacial gap-formation in Class V cavity

Human premolars, extracted for orthodontic reasons, were used for gap measurement in Class V tooth cavities. After extraction, the teeth were stored immediately in distilled water at about 4°C for a maximum period of three months before use. Since occlusal dentin tends to give a lower bond strength than proximal or buccal dentin24,25, and that dentinal tubule orientation and location significantly influence mechanical strength test results,24,25 buccal enamel and dentin surfaces were used in this study.

Ten human premolars for each material were prepared. A round Class V cavity on the buccal region of each tooth was prepared with a tungsten carbide bur (200,000 rpm) and a fissure bur (8,000 rpm) under wet conditions to a depth of 1.5 mm with a diameter of 3.5 mm. Cavity preparation was placed 1.0 mm above the cementoenamel junction (CEJ), and cavosurface walls were finished to a butt joint. One cavity was prepared in each tooth, and its dimensions were measured using a vernier caliper (U39818, Mitutoyo, Kawasaki, Japan). Each cavity was treated with a Cavity Conditioner (Lot No. 0405271, GC Corp., Tokyo, Japan) for 10 seconds according to manufacturer’s instructions, rinsed thoroughly with distilled water, air-sprayed, and filled with the material using a syringe tip (Centrix C-R Syringe System, Centrix, Shelton, CT, USA).

Covered with a celluloid strip (Universal Strips, Shofu Corp., Kyoto, Japan), the material was light-cured for 20 seconds. Surfaces were polished immediately after light activation. Excess filling material was removed by wet grinding with a carbide bur and thorough rinsing with distilled water. Then, the 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 60044, USA). The presence or absence of marginal gaps was inspected at 14 points (each 0.5 mm apart) under a traveling microscope (1000 X, Measurescope, MM-11, Nikon, Tokyo, Japan). A point with no gap would be assigned a 0 value, while 1 indicated the presence of gap. The overall sum of 14 points examined (Fig. 1) for each tooth specimen was calculated and expressed as the sum of each sample.20,21

Compressive strength measurement

All specimens were mixed within 30 seconds using a plastic spatula on a mixing pad, syringe-loaded into a cylindrical Teflon split mold (with a depth of 6.0 mm and diameter of 3.0 mm), covered with a glass plate and clamped. Specimens were light-cured for 60 seconds on each side, with due consideration to the thickness of the glass plate and the specimens. Then, they were removed from the mold and tested immediately. Ten specimens were prepared for each material. The compressive strength was measured using a universal testing machine (Autograph DCS-2000, Shimadzu, Kyoto, Japan) with a cross-head speed of 0.5 mm/min as outlined in ISO 7489-1986, with a...
maximum external force of 200 kgf.

**Diametral tensile strength (DTS) measurement**

Samples for DTS test were also prepared in the cylindrical Teflon split mold (height = 3.0 mm, diameter = 6.0 mm). Light curing and testing procedures were the same as those described for compressive strength measurement. Ten samples were prepared for each type of material.

*Flexural strength measurement*

Rectangular samples for flexural strength test were prepared in a Teflon split mold with internal dimensions of $25 \times 2 \times 2$ mm. After mixing within 30 seconds using a plastic spatula on a mixing pad and syringe-loaded, the mold was covered with a glass plate and clamped. The samples, 10 for each type of material, were light-cured for 60 seconds at three overlapping sites. To measure flexural strength, the three-point bending method was used with a 20-mm span and a load speed of 0.5 mm/min (5565, Instron, Canton, MA, USA) as outlined in ISO 9917-2 (1996), and the flexural modulus thereby calculated (Software Series IX, Instron, Canton, MA, USA).

**Statistical analysis**

Results of mechanical measurements were analyzed statistically using ANOVA and Tukey’s test with the level of significance set at 0.05. Differences among interfacial gap-formation in Class V cavities were compared statistically using non-parametrical t-test\(^{16,28}\). Correlations among setting shrinkage in the Teflon mold\(^{16}\), sum of interfacial gaps, and mechanical strength results were analyzed using a SigmaPlot 8.0 program (SPSS, Chicago, IL, USA).

**RESULTS**

**Summed interfacial gap-formation in Class V cavity**

Table 1 presents the effect of spherical silica fillers on summed interfacial gaps observed in Class V tooth cavities. The summed interfacial gap-formation of all SF-added RMGICs was about 75% that of the BASE or less. The summed interfacial gap-formation of SF10 was 58% that of the BASE or 75% that of the CONTROL; with UF5, it was 61% higher than the BASE.

**Table 1 Immediate interfacial gap-formation in Class V cavity**

<table>
<thead>
<tr>
<th>Material (P/L)</th>
<th>Material Type</th>
<th>Number of specimens showing gaps</th>
<th>Cervical</th>
<th>Sum*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coronal</td>
<td>Axial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1      2   3  4</td>
<td>5  6  7  8  9  10</td>
<td>11  12  13  14</td>
</tr>
<tr>
<td>SF5 (4.0)</td>
<td>Silanized</td>
<td>7      6  4  6</td>
<td>3  4  4  3  3  7  6</td>
<td>9  6  7  10</td>
</tr>
<tr>
<td>SF10 (4.4)</td>
<td>Silanized</td>
<td>5      4  3  6</td>
<td>5  3  3  3  5  5</td>
<td>5  5  4  7</td>
</tr>
<tr>
<td>SF20 (4.0)</td>
<td>Silanized</td>
<td>5      7  5  4</td>
<td>5  5  4  7  6  7</td>
<td>7  5  5  8</td>
</tr>
<tr>
<td>UF5 (4.4)</td>
<td>Untreated</td>
<td>6      1  4  4</td>
<td>6  6  4  5  4  3</td>
<td>6  4  5  8</td>
</tr>
<tr>
<td>UF10 (4.4)</td>
<td>Untreated</td>
<td>4      2  4  8</td>
<td>4  8  5  3  6  5</td>
<td>5  4  4  8</td>
</tr>
<tr>
<td>UF20 (4.0)</td>
<td>Untreated</td>
<td>10     2  5  6</td>
<td>5  7  5  4  5  7</td>
<td>7  3  6  7</td>
</tr>
<tr>
<td>CONTROL</td>
<td>Untreated</td>
<td>7      7  8  6</td>
<td>6  3  5  4  4  6</td>
<td>8  6  6  8</td>
</tr>
<tr>
<td>BASE</td>
<td>Untreated</td>
<td>10     5  7  9</td>
<td>8  6  6  8  7  8</td>
<td>9  9  8  9</td>
</tr>
</tbody>
</table>

SF: Silanized spherical silica filler added to Fuji II LC EM
UF: Untreated spherical silica filler added to Fuji II LC EM
CONTROL: Fuji II LC EM mixed at P/L=3.6
BASE: Fuji II LC EM mixed at P/L=3.0

*specimens per measuring point, N=10; Total number of measuring points (1-14) =140

*: Identical letters indicate no significant differences among the materials analyzed using non-parametric t-test (p>0.05).
that of the BASE or 79% that of the CONTROL. These two materials were significantly the smallest among all the test materials. All materials, except SF5, SF20 and UF 20, also showed significant differences when compared with CONTROL (p<0.05). However, there were no significant differences among SF10, UF5, and UF10; or among UF5, UF10 and UF20. The BASE material presented the worst performance – with statistical significance too – among all the materials. In all the materials and at all measured points, there were no differences among the observed gaps for all the three regions (Coronal, Axial, and Cervical by Mann-Whitney U Test, \( \alpha = 0.05 \)). On the overall, it was about four to eight gaps at each measured point.

The summed interfacial gap-formation of all materials showed a similar tendency to the values of gaps at each measured point. A significant linear correlation is demonstrated significant correlations with compressive strength and the sum of interfacial gaps in Class V cavity of all 10 specimens. A significant linear correlation is shown between the two results (n=8, \( r=0.88, p<0.001 \)).

![Setting shrinkage in the Teflon mold](image)

Fig. 2 Setting shrinkage in the Teflon mold\(^{19} \) and the sum of interfacial gaps in Class V cavity of all 10 specimens. A significant linear correlation is shown between the two results (n=8, \( r=0.88, p<0.001 \)).

Table 2 presents the compressive strength measurement results. All SF and UF specimens, except UF20, showed compressive strength values 22 to 34% higher than that of CONTROL. All RMGICs added with spherical silica filler, except UF20, showed significantly higher compressive strength values than that of either CONTROL or BASE. As for SF-added RMGICs, SF10 showed the highest compressive strength value (173.1 MPa). Compared with BASE, the addition of 10 wt% SF increased the compressive strength by 56%. Similarly, the compressive strengths of SF5, SF20, and UF10 were approximately 40% higher than that of BASE, while UF5 showed a 50% increase. For both CONTROL and UF20, only a 16% increase in compressive strength was observed when compared to BASE.

Table 2 also shows the DTS measurement results. It can be seen that there were significant differences between the DTS value of BASE and those of spherical silica filler-added RMGICs (p<0.05). The addition of 10 wt% SF caused a significant increase in DTS by 28%, \( i.e., \) from 20.4 MPa (BASE) to 26.1 MPa. However, there were no significant differences among the DTS values of CONTROL (23.1 MPa) and those of spherical silica filler-added RMGICs, except with SF10. The DTS value of SF10 was 13% higher than that of CONTROL, while the DTS value of CONTROL was 13% higher than that of BASE. In Fig. 3, the sum of interfacial gaps in Class V cavities showed a significant correlation with both compressive strength (\( r=0.87, p<0.001, n=8 \)) and DTS (\( r=0.81, p<0.01, n=8 \)). In other words, a RMGIC with a smaller sum of interfacial gaps in a Class V cavity showed higher compressive and diametral tensile strengths. Similarly, setting shrinkage in the Teflon mold\(^{19} \) demonstrated significant correlations with compressive strength (\( r=0.92, p<0.001 \)) and DTS (\( r=0.88, p<0.01 \)).

As for rela-

<table>
<thead>
<tr>
<th>Material</th>
<th>P/L</th>
<th>Compressive strength (MPa)</th>
<th>Diametral tensile strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF5</td>
<td>4.0</td>
<td>158.3±10.9(^{a,b} )</td>
<td>24.8±2.5(^{e} )</td>
</tr>
<tr>
<td>SF10</td>
<td>4.4</td>
<td>173.1±9.7(^{a} )</td>
<td>26.1±2.3(^{e} )</td>
</tr>
<tr>
<td>SF20</td>
<td>4.0</td>
<td>157.1±9.3(^{a} )</td>
<td>24.1±3.3(^{e} )</td>
</tr>
<tr>
<td>UF5</td>
<td>4.4</td>
<td>167.0±7.9(^{ab} )</td>
<td>23.3±1.7(^{e} )</td>
</tr>
<tr>
<td>UF10</td>
<td>4.4</td>
<td>158.6±7.6(^{ab} )</td>
<td>24.6±2.4(^{e} )</td>
</tr>
<tr>
<td>UF20</td>
<td>4.0</td>
<td>129.2±5.6(^{c} )</td>
<td>22.2±2.6(^{e} )</td>
</tr>
<tr>
<td>CONTROL</td>
<td>3.6</td>
<td>128.8±5.8(^{c} )</td>
<td>23.1±1.2(^{e} )</td>
</tr>
<tr>
<td>BASE</td>
<td>3.0</td>
<td>111.0±7.9(^{a} )</td>
<td>20.4±1.2(^{e} )</td>
</tr>
</tbody>
</table>

Abbreviations as listed in Table 1
N=10
Identical letters indicate no significant differences according to Tukey’s test (p>0.05)
tion between compressive strength and DTS, it is shown in Fig. 4 that a RMGIC with a weaker compressive strength showed a weaker DTS.

**Flexural strength and flexural modulus of elasticity**

Table 3 presents the results of flexural strength and flexural modulus measurements. On the whole, except with UF20, the flexural strengths of spherical silica filler-added RMGICs and CONTROL increased by about 5 to 30% compared to that of BASE. In particular, the flexural strengths of SF5, SF10, UF5, and CONTROL were significantly higher than that of BASE \( (p<0.05) \), with SF5 exhibiting the highest value at 39.9 MPa. Flexural modulus of CONTROL and those of spherical silica filler-added RMGICs were 24 to 68% higher than that of BASE. However, the flexural moduli of SF5 and SF10 were 24% and 35% higher than that of CONTROL respectively, with SF10 exhibiting the highest flexural modulus at 5.67 GPa. No linear correlation was observed between the summed interfacial gap formation and flexural strength \( (r=0.20, p>0.50, n=8) \).

**DISCUSSION**

In this study, it was shown that in the immediate condition, the addition of spherical silica filler significantly reduced the formation of summed interfacial gaps in RMGIC as well as the latter’s mechanical strength. It was reported that the addition of spherical silica filler to a RMGIC powder improved the flowability or workability of the cement—based on the latter’s rolling performance. Further, SF—whereby silanization of filler depends on siloxane bridge \( (\text{Si-O-Si}) \) formation between silica surface and silane molecule—has been shown to improve the mechanical properties of RMGICs \(^{13,14,16}\). These improvements occurred due to one or the combination of the following reasons. First, the SF- or UF-added RMGIC was mixed with a higher P/L. It has been shown in previous studies \(^{13,14}\) that a higher P/L resulted in a smaller sum of interfacial gaps in the tooth cavity, and at the same time imparted a

![Fig. 3](image-url)  
**Fig. 3** Correlation of sum of interfacial gap-formation in Class V cavity with mechanical strength \( (n=8) \). Each fitting curve gives a linear correlation that is significant with compressive strength \( (r=0.87, p<0.001) \) and diametral tensile strength \( (r=0.81, p<0.01) \).

![Fig. 4](image-url)  
**Fig. 4** Significant correlation between compressive strength and diametral tensile strength \( (n=8, r=0.89, p<0.001) \).

<table>
<thead>
<tr>
<th>Material</th>
<th>P/L</th>
<th>Flexural strength (MPa)</th>
<th>Flexural modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF5</td>
<td>4.0</td>
<td>39.9 (2.9)(^a)</td>
<td>5.20 (0.53)(^k)</td>
</tr>
<tr>
<td>SF10</td>
<td>4.4</td>
<td>38.9 (2.3)(^a)</td>
<td>5.67 (1.06)(^k)</td>
</tr>
<tr>
<td>SF20</td>
<td>4.0</td>
<td>32.2 (2.5)(^b)</td>
<td>4.45 (0.32)(^l)</td>
</tr>
<tr>
<td>UF5</td>
<td>4.4</td>
<td>34.7 (2.2)(^b)</td>
<td>5.12 (0.97)(^l)</td>
</tr>
<tr>
<td>UF10</td>
<td>4.4</td>
<td>30.9 (2.4)(^c)</td>
<td>4.43 (0.51)(^l)</td>
</tr>
<tr>
<td>UF20</td>
<td>4.0</td>
<td>24.9 (2.3)(^c)</td>
<td>5.10 (0.48)(^l)</td>
</tr>
<tr>
<td>CONTROL</td>
<td>3.6</td>
<td>35.9 (2.5)(^b)</td>
<td>4.19 (0.54)(^l)</td>
</tr>
<tr>
<td>BASE</td>
<td>3.0</td>
<td>30.8 (1.2)(^c)</td>
<td>3.37 (0.28)(^m)</td>
</tr>
</tbody>
</table>

Abbreviations as listed in Table 1
Identical letters indicate no significant differences among the materials according to Tukey’s test \( (p>0.05) \).
greater mechanical strength to the GIC. The second reason is that silica fillers do not shrink; hence the higher the amount of fillers, the smaller would be the shrinkage\(^{25}\). Therefore, the reduced sum of interfacial gaps in the immediate condition and the significantly improved mechanical strength of RMGIC could be attributed to the above-mentioned reasons.

By examining the setting shrinkage in the Teflon mold\(^{20}\), it was found that this could be used to predict the sum of interfacial gaps in tooth cavities since there was a linear correlation between the values\(^{30}\). Previously, it was shown that the size of gaps (in \(\mu\)m) has a linear correlation with the setting shrinkage in the Teflon mold\(^{20}\). In this study, the summed-up amount of interfacial gaps, which was obtained by summing up the interfacial gaps formed in all the 10 specimens at each measuring point, also had a significant correlation with the setting shrinkage in the Teflon mold (Fig. 2). Although the marginal gaps in tooth cavities were remarkably eliminated after 24 hours\(^{16,17,20}\), stress development in RMGICs – due to cement setting – starts immediately after light irradiation commences\(^{31}\). It should be noted that in RMGICs, shrinkage occurs for both the polymerization reaction of the monomers as well as the acid-base reaction, depending on the timing of light activation\(^{12}\). In this study, light activation started within two minutes after mixing, hence only shrinkage due to polymerization reaction took place. Nonetheless, a little shrinkage of the acid-base reaction might have taken place, although it should be completely blocked by the polymer network\(^{15,20}\). This is because when light activation is omitted or delayed, shrinkage due to acid-base reaction will expressively take place during this period. Besides, if the composition comprises a catalyst to speed up the polymerization of the monomers, there would be a contributory shrinkage effect due to the chemically initiated polymerization reaction\(^{12}\).

Setting or curing shrinkage, especially in Class V cavities, may exceed the bond strength and create interfacial gaps that contribute to restoration failure\(^{12,20}\). As shown in this study, the sum of interfacial gaps formed had a significant correlation with compressive strength and DTS (Fig. 3). Table 4 shows the relations between the five measured properties and the eight powder/liquid ratios of RMGIC used in this study. It was shown that four relations were significantly correlated, except for the case of flexural strength. In turn, these correlations are shown in Figs. 2, 3, and 4. In other words, improved mechanical properties of RMGIC were achieved by using power/liquid ratios higher than that recommended by the manufacturer. Although the case of flexural strength did not show a significant correlation, the significant effect of spherical silica filler addition was clearly demonstrated.

The results of this study underscored the need for a further study on the characteristics of spherical silica filler-added RMGICs. Although it was shown that the addition of SF up to 20 wt% increased the mechanical strength, the addition of 10 wt% SF was the most effective in improving the immediate compressive strength and diametral tensile strength, whereas flexural strength was significantly improved by a mere addition of 5 wt% SF. The addition of SF or UF also increased the flexural modulus of RMGIC, which represents material stiffness. It was speculated that the higher immediate flexural modulus value was due to the higher immediate polymerization of the material\(^{25}\).

While silanization is important for fillers, it seemed that the addition of 5 wt% UF gave a promising result in terms of compressive strength. However, more UF addition would reduce the strengthening effect in the immediate condition, as it was so shown after 24 hours in a study with P/L ratio at maximum workability\(^{13}\). This was because many cracks originated from bubbles along the filler-resin interface\(^{32}\). Against this background, a filler-matrix coupling agent serves to enhance the physical properties of RMGICs, and thereby allow for adequate wetting and dispersion of the fillers within the considerably more hydrophobic resin matrices, although it does depend on the hydrophobicity of the silane coupling agent\(^{33}\).

In terms of directions for the scope of future study, the authors’ view is that interfacial integrity in tooth cavities is of paramount importance. This is because the long-term functioning of resin-based restorations depends on it. Nevertheless, interfacial crevices may arise from shrinkage stress, thereby leading to imperfect bonding because the fracture planes will not fit together as perfectly as before\(^{12}\).

Table 4 Linear regression correlations between the five measured properties and the eight P/L ratios of RMGIC used in this study

<table>
<thead>
<tr>
<th>Relationship between each measured property and eight P/L ratios used for RMGIC</th>
<th>r</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of marginal gaps in Class V cavity</td>
<td>0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Setting shrinkage in Teflon mold</td>
<td>0.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>0.90</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Diametral tensile strength</td>
<td>0.79</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>0.20</td>
<td>&gt;0.50</td>
</tr>
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</table>

N=8
Besides material characteristics, the success of a RMGIC restoration cannot be separated from environmental factors. Water, as the major component of saliva, plays a major role in filler-matrix bond failures in resin-based matrices\(^{12,30}\). It causes filler elements to leach out and induces filler-matrix debonding failures. As a result, the strength of matrix material is reduced because debonded fillers may act as stress concentrators and significantly multiply the number of potential crack growth sites. Moreover, water has a plasticizing effect on the matrix\(^{12,30}\). Therefore, to ensure that spherical silica filler addition does more good than harm, a long-term study in a wet environment seems inevitable.

CONCLUSION

In the immediate condition, the addition of spherical silica fillers – especially silanized ones – to RMGICs led to a significant decrease in summed interfacial gap-formation in Class V cavities. At the same time, either compressive strength or diametral tensile strength was increased too. In this connection, this study revealed that summed interfacial gap-formation was correlated to either compressive strength or diametral tensile strength. In terms of flexural properties, the addition of 5 or 10 wt% silanized spherical silica fillers to RMGIC powder increased the flexural strength and flexural modulus of RMGIC remarkably.

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