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Surface Treatments that Demonstrate a Significant Positive Effect on the Shear Bond Strength of Repaired Resin-modified Glass Ionomer

D Welch • B Seesengood • C Hopp

Clinical Relevance

The appropriate surface treatment used to repair resin-modified glass ionomer is not well defined. A definitive protocol needs to be established as a guideline for the conservative repair of this material.

SUMMARY

This study examined surface treatment options used to repair resin-modified glass ionomer (RMGI; GC Fuji II LC, GC America). Two hundred forty specimens were equally divided into four different water/temperature cycling environmental conditions. The conditions were 1) five-minute delay, 2) one-week delay with one thermocycle, 3) 500 thermocycles, and 4) 24-hour delay in a dry environment, followed by 500 thermocycles. Within each of the condition groups, the specimens were equally divided again into three different surface treatment groups with 20 specimens in each. The treatment groups comprised A) sanding, B) sanding and acid etch, and C) sanding, acid etch, and dental bonding agent. Our results suggest that RMGI is extremely susceptible to the simultaneous exposure of temperature cycling and water during the first 24 hours. Our main results reflect that 1) during the first five minutes after the initial placement, the surface treatments made no difference in terms of the shear bond strength (NS); and 2) when we weakened the RMGI by exposing it to water and temperature cycling immediately after initial placement, each of the treatments (A<B<C) had a significant incremental increase in bond strength ($p<0.05$). As such, given that a RMGI is partially a composite resin, the surface treatment with a dental bonding agent did have a significant positive

*Dan Welch, PhD, Southern Illinois University School of Dental Medicine, Growth Development and Structure, Alton, IL, USA

Brooke Seesengood, BA, Southern Illinois University School of Dental Medicine, Biology, Alton, IL, USA

Christa Hopp, DMD, Southern Illinois University School of Dental Medicine, Restorative, Alton, IL, USA

*Corresponding author: 2800 College Ave, Alton, IL 62002, USA; e-mail: dwelch@siue.edu

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effect on the micromechanical bond strength of the repair.

INTRODUCTION

Resin-modified glass ionomer (RMGI) restorative materials are generally believed to have advantages over regular glass ionomer, such as reduced sensitivity to moisture contamination,[1] and are often used for Class 3 and Class 5 lesions.[2] Clinically, the retention of RMGIs is favorable, with a failure rate under 3% over the course of 13 years.[3] However, the repair of a previous restoration is sometimes required as a result of the presence of voids, marginal chipping, lack of contour,[2] or color changes. The initial color match may be favorable, but it appears that they may not always be color stable.[3] The benefits of a repair of such minor defects include the preservation of the tooth and a reduction in cost.[4] A longitudinal clinical study conducted by Gordan and others[5] in 2006 indicates that restorations with marginal adaptation and stained margins are better off being repaired rather than replaced. Despite the need for a clear protocol on the noninvasive repair of a RMGI, an appropriate evidence-based approach in the literature has been largely neglected.

In 1998, the first attempt to address this issue was made simultaneously by Yap and others[6] and Shaffer and others.[2] Unfortunately, Yap and others[6] found that none of the surface treatments that they tried demonstrated significantly higher repair bond strength than did the control. Shaffer and others[2] simulated the harsh conditions of the oral environment by thermocycling the specimens 500 times between 5°C and 55°C after the specimens had been stored for two days in 37°C water. With these conditions, they found that the time of repair significantly affected the bond strength of two of the three materials tested.[2] However, water by itself does not seem to affect the strength of RMGIs.[7] In 2000, Yap and others[8] followed their initial research question and found that surface conditioning with maleic acid and resin application gave the highest repair bond strengths for those that were in three and six months of storage. However, in 2010, Maneenut and others[9] found that acid treatment shows little effect on the surface of a RMGI under scanning electron microscopy (SEM) evaluation.

Few articles have explored the repair of RMGI with consideration of surface treatment prior to application and variations in moisture and temperature cycling before the repair process. The results obtained to date have been mixed. In this study, we wish to validate and extend these previous results by examining each of the known factors simultaneously in order to help resolve the inconsistencies and gaps in our knowledge. In essence, a definitive protocol needs to be established as a guideline for the conservative repair of this material.

METHODS AND MATERIALS

Specimens were created using epoxy resin plates with inverted cone recesses (6-mm outer diameter and 5-mm inner diameter). The plates were filled with RMGI (Shade A1), which was purchased in capsule form (GC Fuji II LC, GC Corporation, Tokyo, Japan). The RMGI was mixed for 10 seconds using an amalgamator with the speed set at M3 (Caulk Vari-Mix II-M, Dentsply International, York, PA, USA). For each sample, the RMGI was extruded into the recessed cone, which was supported by a glass slab held underneath. The RMGI was then cured according to the manufacturer's directions with a quartz-tungsten-halogen light for 20 seconds (Optilux 501, Kerr, Danbury, CT, USA) at an intensity of >750 W/cm^2. The glass was removed and the RMGI was examined for the presence of a uniform surface. If satisfactory, the specimens were then placed into 12 respective groups with 20 samples in each group. There were four environmental conditions with one of three surface treatments given to each individual group, for a grand total of 240 specimens (see Figure 1). The environmental conditions were as follows: 1) five-minute delay, 2) one-week delay with one thermocycle, 3) 500 thermocycles, and 4) 24-hour delay in a dry environment, followed by 500 thermocycles. We programmed an environmental testing chamber (Cincinnati Sub-Zero Products Inc, Cincinnati, OH, USA) to either 1) thermocycle once between 5°C and 55°C and then maintain the temperature at 37°C with 95% humidity for one week or 2) thermocycle 500 times between 5°C and 55°C and then maintain the temperature at 37°C with 95% humidity, which required 10 days to simulate the temperature and moisture variations of the oral environment. Each of the four environmental conditions contained three treatment groups, as follows: A) sanded, B) sanded and acid etched, and C) sanded and acid etched, followed by application of a dental bonding agent. The purpose of these groups was to separately assess the impact that each significant factor has on the strength of the material. The sanded samples were abraded

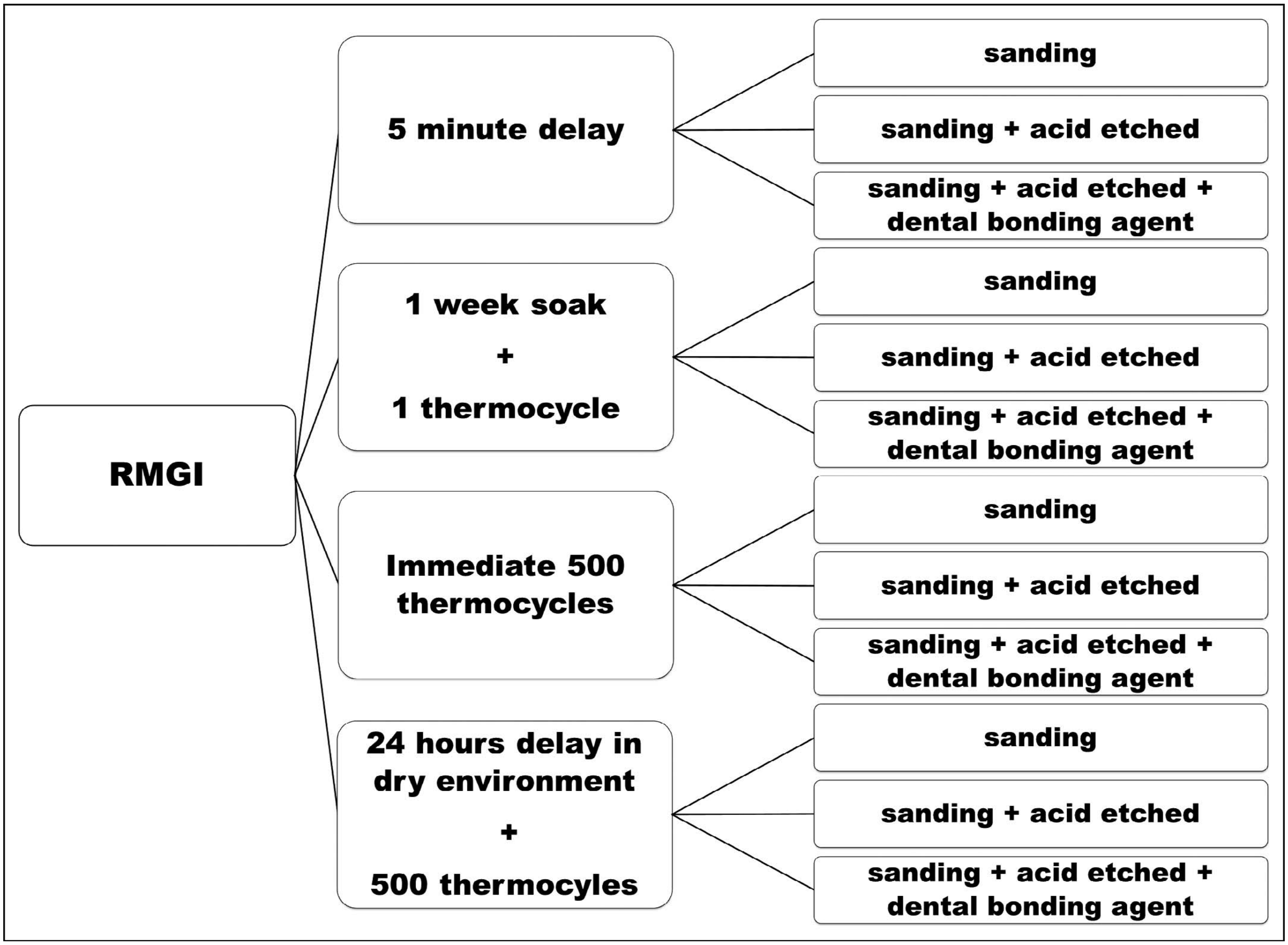

Figure 1. *Two hundred forty specimens were equally divided into four different water/temperature cycling environmental conditions and were equally divided again into three different surface treatment groups (n=20).*

with wet 800-grit silicon carbide paper (Leco, St Joseph, MI, USA) until smooth and then rinsed and dried to insure a uniform matt surface. The coarseness of the 800-grit carbide paper was intended to simulate a typical diamond bur. The acid etchant treatment comprised 37.5% phosphoric acid (Kerr, Orange, CA, USA). The acid etchant was applied for 15 seconds using a disposable applicator brush, and then the samples were rinsed for 15 seconds using water. The dental bonding agent (Optibond Solo Plus, Kerr) was applied for 15 seconds using a disposable applicator brush, air-thinned for three seconds, and then cured with a quartz halogen light for 20 seconds, according to the manufacturer's directions. After the respective treatments, a plastic matrix with a standardized 4-mm-diameter window was placed over the sample, and then a second epoxy resin plate with a window was placed over the plastic to standardize the bonding interface. The two epoxy resin plates were temporarily fixed in place with screws and wing nuts to prevent any movement. The RMGI was then syringed through the window and cured according to the manufacturer's directions. The bonded samples were placed on the universal testing machine (5960 Dual Column Tabletop Instron, Norwood, MA, USA) to test shear bond strength (see Figure 2).

Analysis of variance was used to test the effects of the surface treatments for each environmental condition. Paired *t*-test post hoc comparisons were made, with Bonferroni corrections to control for the probability of false positives, due to multiple com-

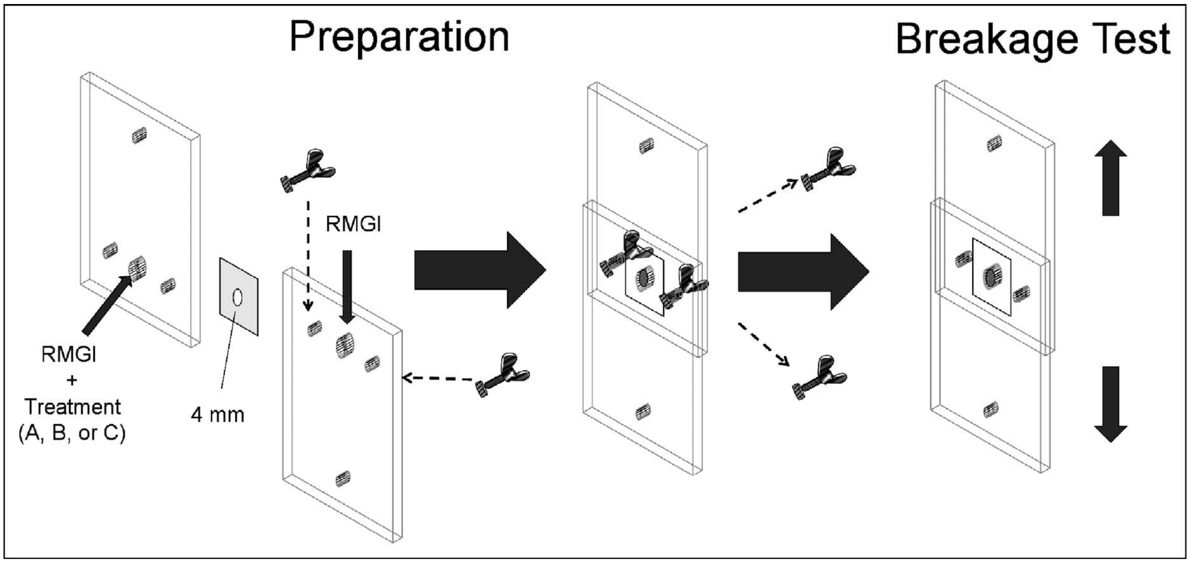

Figure 2. *Flow chart. Diagram demonstrating the sequence from specimen preparation to breakage test.*

parisons. A value of $p < 0.05$ was used to determine statistical significance for this study.

RESULTS

A series of SEM images (13×, 10 kV) were used in our assessment of the breakage (ABT-32, Topcon, Livermore, CA, USA). The mode of failure was documented as A) adhesive failure, B) mixed failure, or C) cohesive failure (see Figure 3). The failure modes of the groups are presented in Table 1. Initially, we compared the specimens that received a sanding surface treatment only for the following conditions: 1) five-minute delay, 2) one-week delay with one thermocycle, 3) 500 thermocycles, and 4) 24-hour delay in a dry environment, followed by 500 thermocycles. We found that the RMGI is extremely susceptible to temperature cycling and water exposure during the first 24 hours ($p<0.05$) (see Figure 4). This was an experimental negative control condition that would not occur in a clinical setting, in which saliva and moisture are always an issue. We did this to evaluate the properties of the material independently and in order to emphasize how important it is to control moisture as much as possible in a clinical setting. We also compared the surface treatments (A-C) for each environmental condition (1-4) (see Figure 5). We found that 1) during the first five minutes, the surface treatments made no difference (NS); 2) when we temperature cycled the specimens once and had them soak in water for one week, those with sanding, acid etch, and dental

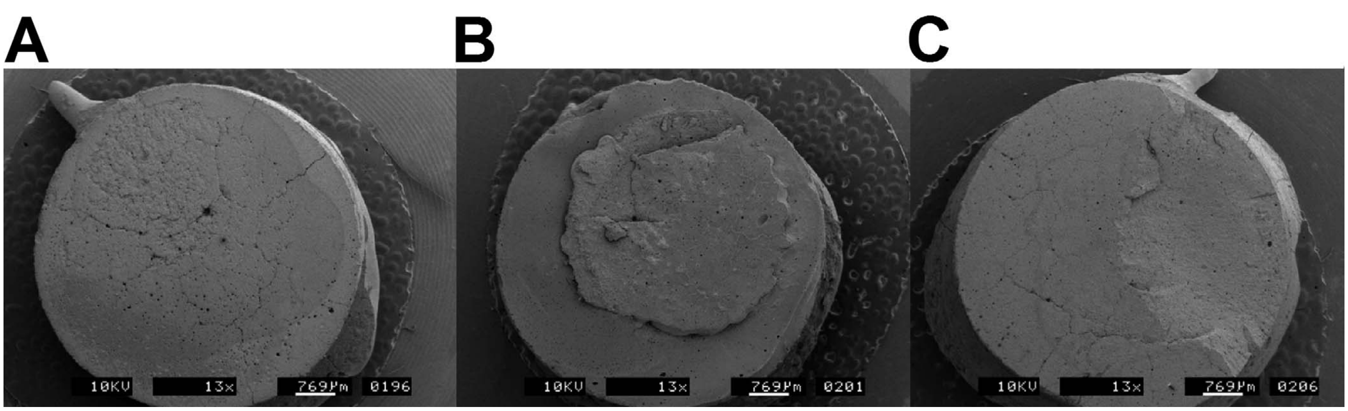

Figure 3. *The mode of failure was documented as (A) adhesive failure, (B) mixed failure, or (C) cohesive failure.*

Table 1: *The Failure Modes of the Groups Are Presented*

Environmental Condition	Surface Treatment	Adhesive	Mixed	Cohesive	n
5 min	sand	9	11	0	20
5 min	sand + acid etch	10	10	0	20
5 min	sand + acid etch + bonding agent	5	15	0	20
1 wk soak + 1 thermocycle	sand	5	7	8	20
1 wk soak + 1 thermocycle	sand + acid etch	4	11	5	20
1 wk soak + 1 thermocycle	sand + acid etch + bonding agent	1	13	6	20
500 thermocycles	sand	13	6	1	20
500 thermocycles	sand + acid etch	16	2	2	20
500 thermocycles	sand + acid etch + bonding agent	7	8	5	20
24-h delay + 500 thermocycles	sand	0	10	10	20
24-h delay + 500 thermocycles	sand + acid etch	6	11	3	20
24-h delay + 500 thermocycles	sand + acid etch + bonding agent	0	6	14	20

bonding agent (C) were significantly stronger than those that were sanded and acid etched (B) ($p<0.05$); 3) when we temperature cycled the specimens immediately, each of the treatments (A<B<C) had a significant incremental increase in bond strength ($p<0.05$); and 4) when we let the samples dry for 24 hours prior to the temperature cycling and water, we also found that all treatments had significant differences in bond strength relative to each other, with the sanding and acid etch being the weakest (B) ($p<0.05$).

DISCUSSION

The main finding of our study was that a dental bonding agent will improve the tensile bond strength between an old and new layer of RMGI but has no significant effect during the first few minutes, while the glass ionomer is still maturing. This verifies and extends previous results in which surface conditioning with maleic acid and resin application gave the highest repair bond strengths for those that were in three and six months of storage.[8] Previous research seems to indicate that the strength of RMGI materials is not affected by early water contact.[7] However, we have demonstrated that temperature cycling and water exposure together during the first 24 hours does in fact weaken the bond (see Figure 4). This is because a RMGI hardens by two separate reactions: 1) a fairly rapid photochemical-initiated polymerization of the resin and 2) a slower acid-base reaction between the glass powder and an organic acid.[10] As such, the physical properties of the glass ionomer depend on the formation of a fairly insoluble polysalt matrix. This matrix takes time to change from being a mostly soluble calcium polyacrylate to a more stable aluminum polyacrylate during the first 24 hours.[11] As an experimental control, we added a fourth condition in which there was a 24-hour delay prior to the water and temperature cycling. These results clearly demonstrate that the vulnerability of the material dissipates after the first day (Figure 3). Clinical application of the results can be interpreted as follows: if repair of a RMGI is necessary on the day of the initial placement, the only surface treatment needed is roughening the surface prior to placement; if repair is necessary more than 24 hours after the initial placement, a bonding agent should be used to strengthen the bond.

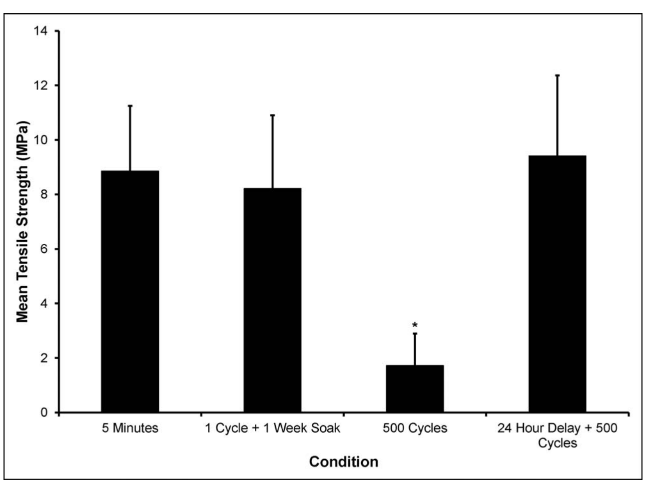

Figure 4. *RMGI is extremely susceptible to temperature cycling and water exposure during the first 24 hours. * = statistically significant difference (p<0.05).*

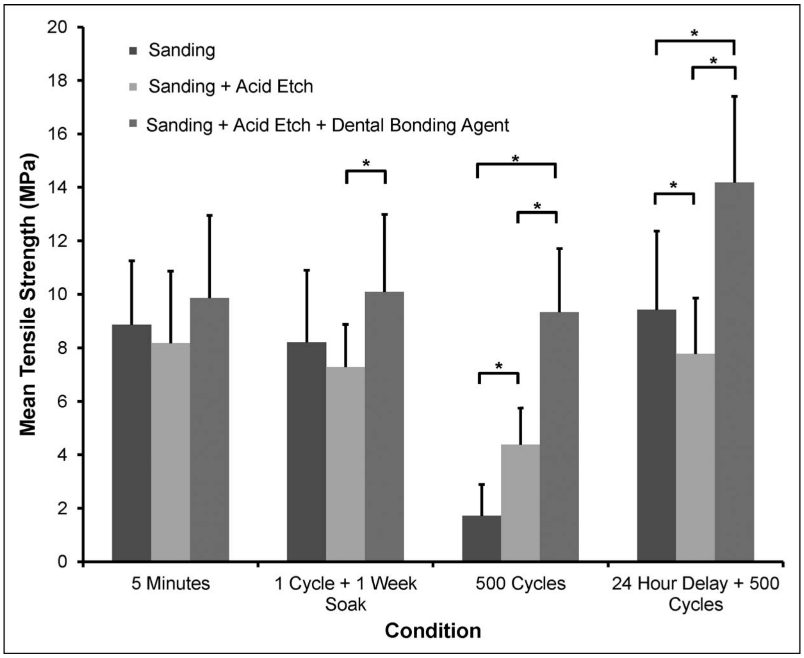

Figure 5. *Comparison of the mean tensile strength (MPa) measurements for the environmental conditions vs surface treatments.*

The focus of this study was to determine the best approach for the clinical situation when RMGI is the chosen material. An example would be a pediatric patient, when the advantages of RMGI (speed/ease of use) overshadow any other undesirable properties of the material. However, composite resin can be used as a viable alternative to repair RMGI in some clinical situations. In fact, other investigators have examined that approach experimentally. We already know that certain factors may affect the bond strength between RMGI and a composite resin.[12] However, the focus of this study is the repair of RMGI using the same material, as an alternative approach.

CONCLUSION

Given that a RMGI is partially a composite resin, the surface treatment with a dental bonding agent did have a significant positive effect on the bond strength of the repair. We believe that the findings of our study increase the chance of a positive clinical outcome for cases that involve the repair of RMGI with the same material.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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