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Microtensile Bond Strength of Two Bioactive Restorative Materials to Sound Dentin: (In-Vitro Study)

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Abstract

This study investigated the microtensile bond strength of Giomer compared to Resin-Modified Glass Ionomer Cement (RMGIC). Sixteen sound molars were utilized. Following dentin exposure on both buccal and lingual surfaces, each tooth crown was sectioned vertically, creating two test specimens per tooth. The buccal halves received RMGIC restorations, while the lingual halves received Giomer restorations. After storage in distilled water, each half was embedded in self-cure acrylic resin, with the bonded surface facing upwards. A custom-made Teflon mold facilitated the restoration placement for both materials. Following restoration procedures, the specimens underwent thermocycling and were then sectioned using an isomet saw to obtain beam-shaped specimens with a bond area of approximately 1mm². To minimize the effect of variations within a specimen, four to six beams were collected from each. The bond strength test was conducted immediately after sectioning. Results revealed that Giomer exhibited a significantly higher bond strength compared to RMGIC. In conclusion, this study suggests that Giomer offers superior bond strength to dentin when compared to RMGIC.

Keywords: Giomer, RMGIC, Microtensile bond Strength, Bioactive Materials

Introduction

Dental caries, a widespread disease affecting a large portion of the global population, is characterized by a dynamic interplay between demineralization and remineralization processes driven by sugar-metabolizing biofilms. (1) While various restorative materials exist to address carious lesions, glass ionomer (GI) cements stand out for their bioactivity and ability to promote dentin remineralization through fluoride release and uptake. However, GI materials suffer from drawbacks such as limited mechanical strength, increased solubility, and poor aesthetics. (2)

To overcome these limitations, researchers have developed novel hybrid biomaterials that combine the advantages of composites with the bioactive properties of glass ionomers. Resin-modified glass ionomer cements (RMGICs) and Giomers are prime examples of such advancements. (3)

RMGICs combine the resin composite's improved aesthetics and strength with the continued presence of the acid-base reaction from GI during curing. Despite this advancement, RMGICs still fall short of the aesthetics and strength offered by pure resin composites. Giomers, on the other hand, represent a promising alternative. These resin-based restorations incorporate pre-reacted glass particles (PRG) within the resin matrix. The PRG can be either surface-pre-reacted (S-PRG) or fully pre-reacted (F-PRG). The pre-reaction process involves treating fluoroaluminosilicate glass with polyalkenoic acid, which creates a hydrogel that is then frozen and dried into a xerogel. This xerogel is subsequently milled and silanized to form the final PRG fillers. Notably, F-PRG releases more fluoride due to the complete reaction of the glass particle, but this comes at the cost of faster degradation. Conversely, S-PRG releases not only fluoride but also additional ions like aluminum, strontium, silicon, boron, and sodium, contributing to the remineralization process. (3)(4)

Introduced in 1994, the Microtensile Bond Strength (µTBS) test has become a cornerstone in dental materials research. This versatile and robust technique evaluates the bond strength between dental materials, especially adhesive systems, and dentin bonding agents. The process involves sectioning teeth into thin slabs containing the bonded interface and subjecting them to controlled tensile forces. This allows for multiple measurements per tooth, minimizing variability and providing a more comprehensive understanding of bond performance. The µTBS test's strength lies in its ability to investigate various factors influencing bond strength, such as dentin type, chosen adhesive system, and the bonding protocol itself. While limitations exist, including potential technique sensitivity and its static nature (not reflecting the dynamic forces encountered in the mouth), the µTBS test remains invaluable. By effectively assessing bond strength, it plays a crucial role in advancing adhesive materials, ultimately leading to improved clinical outcomes for patients. (5)

A comprehensive literature review failed to identify a definitive value for optimal Giomer bond strength. To address this gap in knowledge, this in vitro study aims to evaluate the microtensile bond strength of two bioactive restorative materials, RMGI and Giomer. The null hypothesis is that there will be no significant difference in microtensile bond strength between these two materials.

Materials & Methods

The materials used in this study can be categorized as follows:

Restorative Materials:

- Beautifil II *(Shofu Inc., Japan)*: A nano-hybrid Giomer restorative material
- Fuji II LC *(GC Corp, Japan)*: A light-cured Resin-modified glass ionomer cement

Adhesive System:

- FL-BOND II *(Shofu Inc., Japan)*: A two-step self-etch Giomer adhesive.

Conditioner:

- Cavity conditioner *(GC Corp, Japan)*: A mild polyacrylic acid glass-ionomer conditioner.

Devices:

- Elipar™ Deep Cure-L *(3M, Germany)*: LED curing light unit.
- CapMix™ *(3M, Germany)*: Capsule Mixing Device.

Sample Size Calculation:

A power analysis was conducted using G*Power software (version 3.1.9.7) to determine the appropriate sample size for the microtensile bond strength testing. The analysis was based on a previous study by Kutulu et al. (2019). (6) aiming for 80% power ($\beta = 0.2$) to detect a medium effect size ($d = 1.53$) using a two-sided statistical test with an alpha (α) level of 0.05. This analysis determined a total sample size of 16 specimens per group.

Sample Selection:

This in vitro study was approved by the Research Ethical Committee of the Faculty of Dentistry at The British University in Egypt. Sixteen sound, permanent molar teeth were collected from individuals aged 25-35 years. Each tooth was subsequently used to create two test specimens. Following extraction, the teeth were cleaned to remove debris, scaled to eliminate calculus, and remaining periodontal tissue, and polished with a fine, fluoride-free pumice and soft rubber cups.

Teeth were examined using a 6x magnification dental loupe (Univet, Italy) for any caries, micro-cracks, enamel or dentin defects, existing restorations, or sealants, for which they were excluded from the study if found. The chosen teeth were disinfected by a 0.5% chloramine T solution at 4°C for 48 hours. (7) After disinfection, the teeth were thoroughly rinsed and stored in fresh, distilled water at 4°C and utilized within one month of extraction. (8)

Sample Preparation:

A single operator employed a water-cooled, diamond-embedded blade *(XL 12205; Benetec, London, UK)* at low speed to section each tooth vertically along its long axis, from the occlusal surface towards the cervix. This sectioning removed enamel and exposed dentin on both the buccal and lingual crown surfaces. The exposed dentin was then polished with 320-grit silicon carbide paper for one minute under continuous water irrigation, mimicking the smear layer that would be generated clinically during dentin cavity preparation. Finally, the molars were stored in distilled water at 4°C until the restorative materials were placed.

Following sectioning along the long axis, each tooth was further divided mesiodistally into separate "buccal" and "lingual" halves. Two-thirds of the root on each half was then removed using a low-speed diamond disc under water-cooling in a micro-slicing machine. To facilitate bonding and testing, each half was positioned horizontally, with either the buccal or lingual surface facing upwards, within a custom-made cylindrical mold. This mold was filled with a self-curing acrylic resin (1.5cm x 2cm) to securely embed the dentin surface. Before the acrylic fully set, the specimens were carefully positioned within the mold to ensure proper alignment. Once the acrylic polymerized at room temperature, the resulting blocks were removed from the mold and inspected for any irregularities.

Restoration Placement:

Half of each tooth was designated for a specific restorative material: the buccal halves received RMGIC restorations (Fuji II LC), while the lingual halves received Giomer restorations (Beautifil II). A custom-made Teflon mold (4mm thick, 5mm diameter) ensured consistent placement for both materials. All procedures strictly followed the manufacturers' instructions.

For the RMGIC restorations (R1 group), the dentin surface was first conditioned with Cavity Conditioner for 10 seconds, rinsed, and dried. The Fuji II LC capsule was then activated and mixed for 10 seconds using a designated capsule mixing device (3M™ CapMix™). The material was then applied in two vertical increments of 2mm each within the mold using a applicator gun (TPC Capsules Applicator Gun). A ball burnisher was used to condense the material, followed by light-curing for 20 seconds with a designated LED curing unit (Elipar™ Deep Cure-L).

For the Giomer restorations (R2 group), the FL-Bond II adhesive system was used. A microbrush applied the primer to the dentin surface for 10 seconds, followed by air-thinning with oil-free air. Subsequently, a bonding agent was applied evenly with another microbrush and light-cured for 10 seconds using the same LED curing unit. Finally, Beautifil II was placed in two vertical increments of 2mm each within the mold using a plastic instrument and ball burnisher. Each increment was light-cured for 10 seconds according to the manufacturer's recommendations.

Thermocycling:

After restoration placement, the specimens were stored in distilled water at room temperature for 24 hours. Subsequently, they underwent a thermocycling through submerging the specimens in distilled water and cycling them between 5°C and 55°C for a total of 5,000 cycles. (9)

Microtensile Bond Strength Testing:

Following thermocycling, the specimens were sectioned using a diamond disc under water-cooling in a low-speed micro-slicing machine. This sectioning process, performed along both the occluso-cervical and mesiodistal planes, aimed to create beam-shaped specimens with a bond area of approximately 1mm². To minimize the influence of regional variations within a specimen, four to six beams were obtained from each. The microtensile bond strength test was then performed immediately after sectioning using a µTBS Instron Universal testing machine. (8)

Results

The results of this study are shown in table 1. Giomer (R2) (29.85±2.67) (MPa) had a significantly higher bond strength than RMGI (R1) (25.79±2.81) (MPa) (p=0.010) to dentin.

Table (1): Intergroup comparisons, mean and standard deviation values of micro-tensile bond strength (MPa) for different restorative materials.

	Material		**p-value**
	RMGI (R1)	**Giomer (R2)**	
Micro-tensile bond strength (MPa) (Mean±SD)	**25.79±2.81**	**29.85±2.67**	**0.010***

*; Significant (*p*<0.05) ns; non-significant (p>0.05).

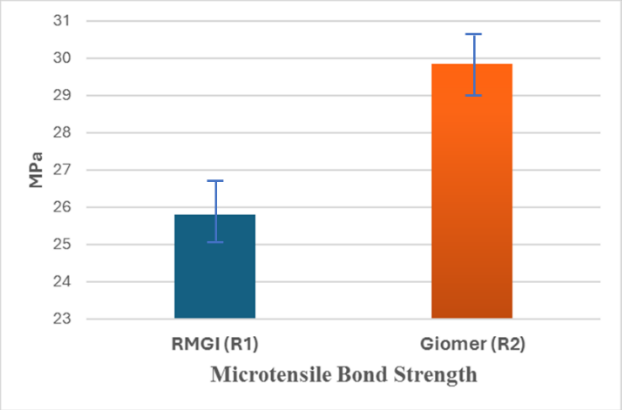

Figure (1): Bar chart showing mean and standard deviation (error bars) values for micro-tensile bond strength (MPa) for different restorative materials (A).

Discussion

RMGIC surpasses conventional glass ionomer cements (GICs) in clinical performance due to enhanced physical and mechanical properties. This improvement stems from the incorporation of resin materials. These resins contain methacrylate monomers, vinyl-modified polyalkenoic acid, and photo-initiating systems like camphorquinone, enabling light-cured restorations.

RMGICs achieve micromechanical adhesion by allowing resin infiltration of the dentin exposed after polyacrylic acid (PAA) conditioning. Additionally, they form a chemical bond through ionic interactions between carboxyl groups within the RMGIC and residual calcium ions present in the tooth structure. These advancements contribute to superior fracture and wear resistance, improved moisture resistance, and ultimately, better clinical performance compared to conventional GICs. (11)(12) Based on this, this study used RMGI as comparator to the Giomer.

A novel family of materials called Giomers is newly produced with a goal to combine the greatest qualities of glass-ionomers with composite resins, such as strong mechanical resistance, carious lesion resistance, and aesthetics. Giomers, which combine aesthetics with the potential for a polished surface and strong mechanical resistance, are among the most recent advancements in the field of fluoride-releasing dental materials. (13)

To simulate the degradation experienced by dental restorations in the mouth, the specimens underwent thermocycling. They were cycled in distilled water for 5,000 cycles between 5°C and 55°C, with dwell times of 50 seconds at each temperature and 10-second transfer times. This protocol followed the recommendations by Eliasson and Dahl (2020) (9) and it was found that 5000 cycle is equivalent to period of 6 months of intraoral physiological aging. (13)(14)(15)

The microtensile bond strength (µTBS) test, pioneered by Sano et al., has become the gold standard for evaluating dental adhesive systems. This method surpasses traditional macro-shear bond tests in several ways. Firstly, µTBS utilizes small, beam-shaped specimens. This design promotes a more uniform distribution of stress during testing and allows researchers to obtain multiple measurements from a single tooth. This translates to increased accuracy and reduced data variability. Secondly, the µTBS test offers the unique ability to assess bond strength at various locations within a cavity, including areas of healthy or compromised dentin. This versatility has proven invaluable in the development and refinement of dentin adhesives. While the µTBS test is a static measure of bond strength, it has significantly advanced the field by enabling researchers to compare the effectiveness of different adhesives when bonding to various dentin conditions. (10) Consequently, this study adopted the μTBS test to evaluate the bond strength of the materials under investigation.

Based on the findings, the null hypothesis which stated that there would be no significant difference in microtensile bond strength between Giomer and RMGIC restorations was rejected. Our results align with previous studies conducted by Keskin et al. (8) , Feiz et al. (16) , and Ayres et al. (17). The superior bond strength observed with Giomer can be attributed to the presence of surface pre-reacted glass ionomer particles (S-PRG). These S-PRG particles contribute to the formation of hard structures that enhance adhesion to the tooth substrate. Additionally, the inclusion of 4-META hydrophobic monomers facilitates a strong bond with the remaining hydroxyapatite crystals in dentin. Furthermore, 4-META releases silicon, which promotes the formation of additional hydroxyapatite. Finally, the silicon particles within Giomer are thought to adsorb onto the dentin surface, creating sites that promote the nucleation of hydroxyapatite crystals, ultimately leading to enhanced adhesion to the tooth structure. (18)

Conclusion

Within the limitations of this study, it can be concluded that Giomer has a superior bond strength to dentin than RMGIC.

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