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# Shear Bond Strength of Resin-modified Glass Ionomer Cements to Er:YAG Laser-treated Tooth Structure

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### Clinical Relevance

Er:YAG laser adversely affected the adhesion of resin-modified glass ionomer cements to tooth structure and cannot be considered an alternative technique to the conventional turbine handpiece.


## SUMMARY

**This study evaluated the effect of Er:YAG laser irradiation of enamel and dentin on the shear bond strength of resin-modified glass ionomer cements (RMGIC). Twenty molars were selected and the roots removed. The crowns were bisected, embedded in polyester resin and ground to plane the enamel or expose the dentin. The bonding site was delimited, and samples were randomly assigned according to the cavity preparation device: I- Er:YAG laser (350mJ/2Hz); II—Carbide bur (control group). They were subdivided according to the restorative material employed: A) Fuji II LC (GC); B) Vitremer (3M). Samples were then fixed to a metallic device where ionomer cylinders were prepared. Sequentially, the molars were stored for 24 hours and subjected to a shear bond strength test (50Kgf at 0.5 mm/minute). Means in MPa were: Enamel—IA) 4.77(± 1.12); IB) 4.36(± 1.50); IIA) 7.70(± 1.53); IIB) 7.34(± 1.52) and Dentin—IA) 3.13(± 1.15); IB) 2.67(± 0.74); IIA) 6.38(± 1.44); IIB) 5.58(±2.09). Data were submitted to statistical analysis by ANOVA. Adhesion for enamel was more efficient than for dentin ($p<0.01$). The cavities prepared with a conventional bur (control group) presented higher bond strength values than those recorded for Er:YAG laser ($p<0.01$). No significant differences were observed between the restorative materials. Based on these results, it was concluded that Er:YAG laser adversely affected**


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**the shear bond strength of RMGIC for both enamel and dentin.**

## INTRODUCTION

Glass ionomer restorative materials have been widely used in restorative dentistry due to several chemical and physical properties, including biocompatibility (Arora & Deshpande, 1998; Shaffer, Charlton & Hermesch, 1998), adhesion to tooth structure (Shaffer & others, 1998; Glasspoole, Erickson & Davidson, 2002), demineralization inhibition (Liberman & others, 1990), fluoride release (Glasspoole & others, 2002), reduced microleakage (Kim, Hirano & Hirasawa, 1998; Chinelatti & others, 2004) and lower polymerization shrinkage (Kim & others, 1998). Nevertheless, glass ionomer cements (GIC) present some clinical limitations, such as prolonged setting time, moisture sensitivity during initial setting, dehydration and rough surface texture, which can hamper mechanical resistance (Liberman & others, 1990; Kim & others, 1998; Pereira & others, 2002; Corona & others, 2003).

In view of these shortcomings, attention has been directed to improving properties and handling characteristics. Among the innovating materials, the role of resin-modified glass ionomer cements (RMGIC) has been highlighted (Wilder & others, 1996; Abdalla & García-Godoy, 1997; Kim & others, 1998; Shaffer & others, 1998; Glasspoole & others, 2002; Chinelatti & others, 2004). The formulation consists of approximately 80% GIC combined with 20% visible light polymerized resin components (Quo & others, 2002). Light-cured RMGICs contain polymerizable monomers and a photo initiator in addition to the traditional GIC formulation and may be finished immediately after light exposure, so that operators can have a longer working time and control the reaction of the setting (Pereira & others, 1998; Quo & others, 2002; Palma-Dibb & others, 2002). Previous investigations (Pereira & others, 2002; Palma-Dibb & others, 2003) demonstrated that the light–activated monomer's reaction results in earlier development of bond strength and higher moisture resistance as compared to chemical reactions found in conventional GICs.

Recently, several studies (Visuri & others, 1996; Dostalová & others, 1978; Ceballos & others, 2002; Apel & others, 2002; Schein & others, 2003; Corona & others, 2003; Monghini & others, 2004; Souza & others, 2004; Trajtenberg, Pereira & Powers, 2004) have focused on investigating the efficiency of Er:YAG laser on the removal of carious tooth substance, surface pretreatment and cavity preparation, searching for an alternative technique to the conventional air turbine handpiece. The Er:YAG laser 2.94 μm wavelength emission coincides with the main absorption band of water (~3.0 μm) and is also well absorbed by OH-groups in hydroxyapatite (Hibst & Keller, 1989). Heat produced by laser irradiation causes instantaneous evaporation of water molecules present in dental crystalline structures and organic components (Hibst & Keller, 1989; Keller & Hibst, 1997). As water vaporizes, it increases pressure within the tissue, leading to multiple micro-explosions (Hibst & Keller, 1989; Visuri & others, 1996; Ceballos & others, 2002; Schein & others, 2003; Souza & others, 2004).

When safety parameter settings are selected, Er:YAG laser effectively ablates dental hard tissues without causing injury to pulp or severe thermal effects to the remaining tooth structure and surrounding tissues (Hibst & Keller, 1989; Hossain & others, 1999; Monghini & others, 2004; Trajtenberg & others, 2004). As a rule, Er:YAG laser irradiation does not demineralize the surface or expose the collagen matrix (Ceballos & others, 2002) but can promote a rough micro-retentive pattern that can facilitate the retention of restorative materials (Visuri & others, 1996; Dostalová & others, 1978; Armengol & others, 1999). Comparing the use of rotary instruments and Er:YAG laser, it was verified that laser irradiation requires at least twice the time for caries removal (Aoki & others, 1998), but its advantages include low noise, pressure, vibration and, in most cases, eliminating the need for local anesthesia (Keller & Hibst, 1997; Dostalová & others, 1978; Aoki & others, 1998).

Despite the effectiveness of Er:YAG laser for enamel and dentin ablation, the literature has shown controversial results as to the effects of lasing tooth structure before bonding restorative materials (Visuri & others, 1996; Kataumi & others, 1998; Martinez-Insua & others, 2000; Ceballos & others, 2002; Glasspoole & others, 2002; Schein & others, 2003; Monghini & others, 2004; Souza & others, 2004; Trajtenberg & others, 2004). Moreover, to date, no reported study has evaluated the effect of this laser on the RMGIC bond strength to dental structures. Therefore, this study assessed the influence of Er:YAG laser irradiation on enamel and dentin in the shear bond strength of resin-modified glass ionomer cements, *in vitro*.

## METHODS AND MATERIALS

Twenty sound human third molars extracted within a six-month period and stored in 0.4% sodium azide solution were selected and cleaned with a scaler and pumice/water slurry in dental prophylactic cups. The roots were sectioned 2 mm over the enamel-cementum junction. The crowns were bisected in a mesiodistal direction at low speed in a sectioning machine (Minitron, Struers A/S, Copenhagen, Denmark) under water cooling, providing 40 halves. The surfaces were identified to avoid the buccal and lingual halves being assigned to the same experimental group. The sections were individually embedded in polyester resin (Milflex Indústria Química, São Bernardo do Campo, SP,

Brazil) using polyvinyl chloride (PVC) cylinders (2.0 cm diameter and 1.0 cm high), with the enamel surfaces facing upward. Following polymerization of resinous material, the specimens were submitted to a polishing machine (Politriz, Struers A/S, Copenhagen, Denmark) and abraded with decreasing grits (#280–#400) of silicon carbide (SiC) paper (Buehler Ltd, Lake Bluff, IL, USA) under water-cooling until the overlying enamel was flattened. Upon completion of the shear bonding tests, the specimens were ground again to obtain dentin surfaces (approximately 1 mm beyond the amelodentinal junction). Viewing the ground surfaces under a 20x magnifier ensured complete removal of the enamel. As a result, the same sample provided both enamel and dentin surfaces. Complementary grinding was accomplished with #600-grit SiC paper for 30 seconds to produce a standardized smear layer.

The surface area for adhesion was delimited using an adhesive tape made by a modified Ainsworth rubber-dam punch to provide holes 3-mm in diameter. This was necessary to ensure that the restorative material was inserted into a defined, secure surface area no larger than the one to be tested.

The specimens were randomly assigned to two groups of equal size (n=20) according to the cavity preparation device: Er:YAG laser irradiation or carbide bur (control group) and subdivided into two additional groups (n=10) according to the restorative material used: Fuji II LC (GC Corp,Tokyo, Japan) or Vitremer (3M Dental Products, St Paul, MN, USA).

Sample surfaces prepared with laser were irradiated by an Er:YAG laser machine (Kavo Key Laser 2, Kavo Corp, Biberach, Germany) adjusted to 12 mm of focal distance, 350mJ of energy and 2Hz of pulse repetition rate, under a 5mL/minute water spray for 20 seconds. The laser beam spot size was 0.63 mm, and a handpiece (2051) with a removable tip attached to a flexible fiber delivery system was used. The remaining samples were prepared with a #56 carbide bur (KG Sorensen, Barueri, SP, Brazil) at high-speed using turbine handpieces (Dabi Atlante, Ribeirão Preto, SP, Brazil) with water/air spray for 10 seconds. New burs were used after every five preparations.

The laser parameter settings utilized in this study were the standard ones recommended for cavity preparation, and the time employed was sufficient to scan all demarcated surfaces.

After cavity preparation, the specimens destined to receive Fuji II LC were conditioned with Dentin Conditioner (GC Corp, Tokyo, Japan) that was applied over the surfaces with a light scrubbing motion for 10 seconds. The specimens were then washed with distilled water for 30 seconds and excess moisture was removed with absorbing paper.

Specimens restored with Vitremer received an application of Primer (3M, St Paul, MN, USA) on the limited surface for 30 seconds. Disposable brush tips were used in order to avoid excess along the edges of the insulating tape, which could compromise the distribution of tensions during the test and, hence, the validity of the results. The surfaces were gently air-dried for 15 seconds and photopolymerized for 20 seconds using a light-curing unit (XL 3000, 3M Dental Products) with an output of 450mW/cm$^2$, with every three samples being checked with a radiometer (NewDent Equipamentos, Ribeirão Preto, SP, Brazil).

All specimens were individually fixed into a clamping metallic device (developed by Houston Biomaterial Research Center) in a way that the embedded dental fragment remained parallel to a flat surface. A bisected Teflon matrix was positioned over the tooth, resulting in a cylindrical cavity with the diameter coincident with the delimited bonding area (∅ 3 mm).

A standard power/liquid ratio was then mixed as specified by each manufacturer. The resultant mixture was injected into the matrix in a single increment using a Centrix injector (Centrix, Shelton, CT, USA) to prevent blister formation and was polymerized for 40 seconds. The matrix was opened and separated, leaving a GIC cylinder (3-mm in diameter x 4 mm high) that adhered to the delimited surface, and the specimens were removed from the clamping device. A complementary 40 second polymerization was accomplished to ensure that the specimens were adequately polymerized. To avoid water loss or uptake, Fuji II LC restorations received a thin layer of Protect It! (Jeneric, Pentron Inc, Wallingford, CT, USA) and, on the Vitremer restorations, Finishing Gloss (3M Dental Products) was applied. In both situations, the glass ionomer protector was light cured for 20 seconds. Details about the tested restorative systems are described in Table 1.

After storage in distilled water at 37°C for 24 hours, samples were placed into an apparatus with an internal shape that corresponds to the shape of the specimens. This configuration was loaded in tension bond using a Universal Testing Machine (MEM-2000, EMIC, São José dos Pinhais, PR, Brazil), at a 0.5

Table 1: *Tested Restorative System*

| Material/Manufacturer | Composition | Powder/Liquid Ratio (g) |
|---|---|---|
| Fuji II LC<br>GC Corporation,<br>Tokyo, Japan | Powder: fluoroaluminosilicate glass, polyacrilic acid.<br>Liquid: water, polyacrilic acid, HEMA | 3.2/1 |
| Vitremer<br>3M Dental Products,<br>St Paul, MN, USA | Powder: fluoroaluminosilicate glass.<br>Liquid: polyalkenoate copolymer, HEMA, water | 2.5/1 |

mm/minute crosshead speed and a 50kgf load cell until fracture. Shear bond strength values were registered in Kgf and transformed into MPa. Averages and standard deviations were calculated, and the data were analyzed by three-way ANOVA, using a factorial design with *substrate, material* and *cavity preparation device* as independent variables.

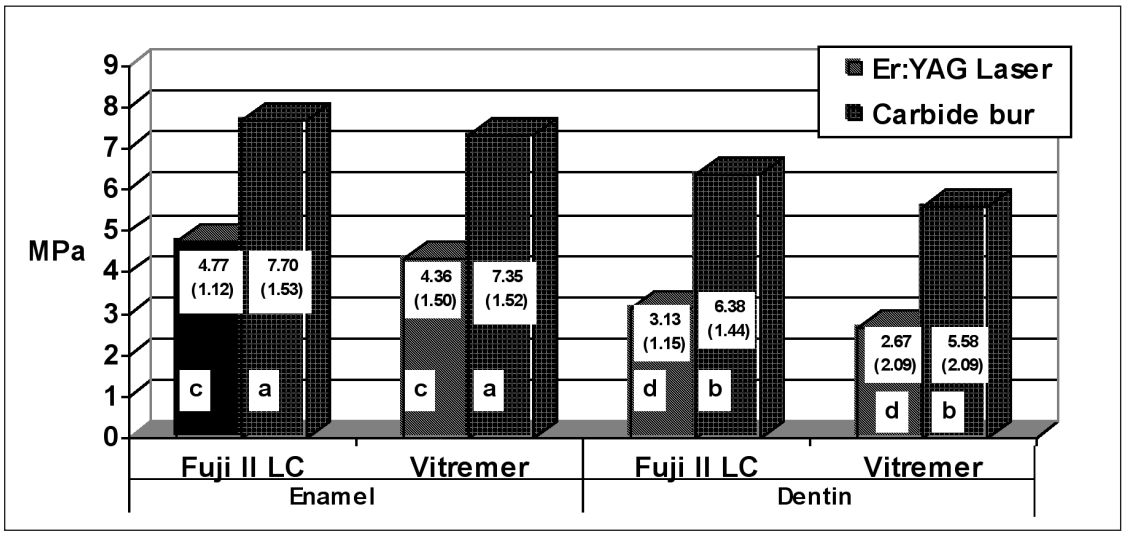


Figure 1. *Mean and standard deviations (MPa) of shear bond strength in each group.*

Fracture types at the surface/restorative material interface were verified under a stereoscopic microscope at 40x magnification. Failure was considered adhesive if it occurred at the substrate/adhesive interface, cohesive if it occurred in the material or the substrate and mixed if it involved both the interface and the material. Bond failure sites were not statistically analyzed.

## RESULTS

The mean values obtained and their respective standard deviations are presented in Figure 1. In general, data analysis disclosed that shear bond strength values were higher for enamel than what was recorded for dentin ($p<0.01$).

There were statistically significant differences when the cavity preparation devices were compared ($p<0.01$). The Er:YAG laser-prepared group displayed the lowest bond strength mean when compared to the conventional turbine handpiece, regardless of the substrate employed (enamel and dentin).

The tested restorative materials (Fuji II LC and Vitremer) showed no statistically significant differences ($p=5.90$) in either enamel or dentin bond strength.

In all samples that were conventionally prepared, irrespective of the restorative system, the predominating type of fracture was cohesive (58%). However, the groups treated with Er:YAG laser exhibited a higher percentage of adhesive fracture (64%), regardless the glass ionomer cement applied.

## DISCUSSION

This study disclosed that the use of Er:YAG laser for cavity preparation may interfere decisively with the adhesion of resin-modified glass ionomer cements (RMGIC) to enamel and dentin. The probable explanation for this result derives from the fact that heating caused by Er:YAG laser irradiation is responsible for structural (Arimoto & others, 1997; Martinez-Insua & others, 2000; Trajtenberg & others, 2004) and chemical (Ceballos & others, 2002; Sasaki & others, 2002; Apel & others, 2002; Camerlingo & others, 2004; Ying, Chuah & Hsu, 2004) alterations to the dental surface. However, several studies report that the heat generated does not propagate into pulp tissue (Hibst & Keller, 1989; Keller & Hibst, 1997; Dostalová & others, 1978; Carmerlingo & others, 2004).

The excessive heat that occurs during cavity preparation may cause denaturation of the collagen network and a decrease in dentin permeability, since their components were covered by gelatinized collagen (Pashley, 1992; Ariamoto & others, 1999; Ceballos & others, 2002). In this regard, Ceballos and others (2002) mentioned that Er:YAG laser irradiation produced a modified superficial layer in which collagen fibers are poorly attached to the underlying substrate, because they lost part of their cross-banding, and the thermal effects could extend into the dental subsurface, thus impairing interdiffusion zone formation. Er:YAG laser irradiation also produced fused areas (Kataumi & others, 1998; Hossain & others, 1999; Martinez-Insua & others, 2000) and may reduce the surface area and pore volume of normal enamel (Ying & others, 2004).

Chemical alterations may occur due to crystal liquefaction, that is, when the tooth is submitted to high temperatures (Sasaki & others, 2002; Camerlingo & others, 2004; Ying & others, 2004). This liquefaction process is caused during quick dental tissue cooling and is responsible for increasing the hydroxyapatite crystals that obliterate surface micropores (Kataumi & others, 1998; Martinez-Insua & others, 2000; Ying &

others, 2004). In addition, it has been reported that Er:YAG laser irradiation modifies the calcium-to-phosphorus ratio, reduces the carbon-to-phosphorus ratio and leads to the formation of more stable and less acid-soluble compounds (Apel & others, 2002) that can hamper the chemical adhesion of ionomeric cements.

Moreover, the Er:YAG laser microblasive process causes vaporization of water and dental organic components, promoting the microexplosive destruction of inorganic substances, resulting in macroscopic and microscopic irregularities (Hibst & Keller, 1989; Visuri & others, 1996; Kataumi & others, 1998; Martinez-Insua & others, 2000; Monghini & others, 2004). Although the microcrater-like appearance and the absence of the smear layer of lased surfaces were described as favorable for adhesion (Visuri & others, 1996; Armengol & others, 1999; Dostalová & others, 1978), the mechanical retention of glass ionomer cements could be compromised, because this material does not have the ideal viscosity and fluidity to penetrate into surface microirregularities.

The adhesive mechanism of RMGIC relies upon a chemical interaction between the carboxylic groups from material and calcium ions from dental substrates associated with the chemical diffusion of polymer into the surface (Swift Jr, Pawlus & Vargas, 1995; Abdalla & García-Godoy, 1997; Pereira & others, 2002). This means that, for optimal performance, ionomeric cement requires intimate contact with a homogeneous tooth surface (Glasspoole & others, 2002; Corona & others, 2003; Chinelatti & others, 2004). As laser irradiation produces a disorganized, indiscriminate destruction of organic and inorganic components (Martinez-Insua & others, 2000; Schein & others, 2003) and influences the availability of calcium ions on dental structure (Delbem & others, 2003), the mechanical and chemical adhesion of RMGIC is inherently affected (Liberman & others, 1990; Corona & others, 2003; Chinelatti & others, 2004). All these events together might be responsible for RMGICs' unfavorable adhesion to irradiated tissue. The higher percentage of adhesive fracture on laser-irradiated groups also confirms this observation.

In this study, enamel presented higher bond strength value than dentin. This was an expected result, since it is well known that adhesion to dentin is more complex than adhesion to enamel (Pashley, 1989; Swift Jr & others, 1995) due to factors such as the dentin tubular pattern, the occurrence of pathophysiological alterations (sclerotic areas) and the increased water content in its composition (Pashley, 1992), which makes this substrate a target for strong interaction with the Er:YAG laser beam (Visuri & others, 1996; Armengol & others, 1999; Souza & others, 2004). In addition, the ion-exchange mechanism may occur strongly on enamel, because of the higher quantity of phosphate and calcium ions on this tissue (Kim & others, 1998).

Despite the differences in formulation, Fuji II LC and Vitremer displayed similar performance in both substrates. These findings corroborate those obtained by Swift Jr and others (1995) in human dentin and findings by Pereira and others (1998) in bovine dentin when a resin bonding system was applied. A possible explanation for such results may be ascribed to similar physical properties, mainly water absorption (Kim & others, 1998) and microhardness (Palma-Dibb & others, 2002). Likewise, an earlier investigation (Wilder & others, 1996) reported that Fuji II LC and Vitremer did not present significant differences in viscosity and surface moistness. Other studies compared Fuji II LC to Vitremer, the latter exhibiting lower bond strength values in enamel (Glasspoole & others, 2002) and dentin (Abdalla & García-Godoy, 1997; Arora & Deshpande, 1998). However, it is difficult to obtain a more appropriate comparison of the results of this study due to the lack of literature reporting the adhesion of glass ionomer cements to laser-irradiated surfaces. Furthermore, the vast variety of current dental materials is a crucial feature to be considered. Depending on the recommended material and bonding protocol, a peculiar interaction pattern with the lased substrate should be expected (Aoki & others, 1998; Trajtenberg & others, 2004).

It seems appropriate to emphasize that, despite the notable advances in dental research, further investigation is necessary to disclose and define the ultimate effect of lasing on dental substrate and its applicability in restorative dentistry, as well as to determine which dental material is more appropriate to promote an optimal bonding to laser-prepared teeth. In addition, the standardization of basic workable laser parameters is required to yield optimal and safe ablation of dental hard tissues.

## CONCLUSIONS

Based on these findings, and within the limitations of an *in vitro* study, it may be concluded that:

- Bond strength values obtained for enamel were higher than those recorded in dentin;
- Conventional bur-prepared samples displayed better adhesion than samples prepared by Er:YAG laser;
- The tested restorative systems (Fuji II LC and Vitremer) showed similar performance, regardless of the substrate employed.

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