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Full Length Research Paper

Effect of different light curing systems on the shear bond strength of resin-modified glass ionomer cement and polyacid-modified composite resin

Oya Bala, Hacer Deniz Arisu*, Bagdagul Helvacioglu Kivanc and Sara Samur

University of Gazi, Faculty of Dentistry, Department of Operative Dentistry and Endodontics, Ankara, Turkey.

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The aim of this study was to determine *in vitro* shear bond strength of resin-modified glass ionomer cement (RMGIC) and polyacid-modified composite resin (PMCR) polymerized with conventional halogen light curing unit (LCU) or light emitting diode (LED). Twenty-four mandibular molar teeth were used. Enamel was removed from buccal and lingual surfaces of the teeth to expose superficial dentin. Teeth were embedded in acrylic resin molds. Plastic rings were placed on the buccal and lingual-exposed superficial dentin. The teeth were then randomly divided into four groups. The study groups were designed as: Group A: PMCR, polymerized with conventional halogen LCU, Group B: RMGIC, polymerized with conventional halogen LCU, Group C: PMCR, polymerized with LED LCU, Group D: RMGIC, polymerized with LED LCU. The shear bond strength for each specimen was measured with a universal testing machine at a cross-head speed of 0.5 mm/min. Data were analyzed with ANOVA and Turkey tests at a preset of 0.05. Values in Group 1 were significantly lower than in Groups 2, 3 and 4 ($p < 0.05$). There was no significant difference between Groups 2, 3 and 4 ($p > 0.05$). The shear bond strength values of LED LCU were significantly higher than that of halogen LCU ($p < 0.05$). The shear bond strength values of RMGIC were significantly higher than that of PMCR ($p < 0.05$).

Key Words: Resin modified glass ionomer cement, polyacid modified resin composite, halogen, light emitting diode, shear bond strength.

INTRODUCTION

Glass ionomer cements (GIC) have been widely used in restorative dentistry, and have some advantages such as fluoride release (Burke et al., 2006), adhesion to tooth structure (Glasspoole et al., 2002) and biocompatibility (Shaffer et al., 1998). However, these materials have some clinical limitations, such as prolonged setting time, moisture sensitivity during initial setting, dehydration, and rough surface texture, which can hamper mechanical resistance (Pereira et al., 2002). Resin-modified glass-ionomer and polyacid-modified composite restoratives have been developed to overcome the problems of moisture sensitivity and low initial mechanical strengths typical for conventional glass-ionomers. Polyacid- modified resin composites (compomers) claim to combine the mechanical and esthetic properties of composites with the fluoride-releasing advantages of conventional glass-ionomer cements (Wiegand et al., 2007). In addition to the conventional GIC formulation, resin-modified glass ionomer cements (RMGICs) contain polymerizable monomers and photo initiators (Hickel et al., 2001). Resin-modified glass-ionomers were basically formed by adding methacrylate components to the polyacrylic acid, which are polymerizable by light-curing supplementing the fundamental acid-base reaction (Wiegand et al., 2007). The setting reactions of these cements begin after mixing two components and undergo setting through an acid-base reaction. Light exposure causes the creation of cross-bonds between polymeric chains and simultaneous polymerization of methacrylate (Burke et al., 2006), so the setting reaction can be controlled, which gives the operator a longer working time (Algera et al., 2006; Cho et al.,1999).

Polyacid-modified composite resins, known trivially as

*Corresponding author. E-mail: hdenz@yahoo.com, hacer@gazi.edu.tr. Tel.: + 90 532 6461244, + 90 312 3802405. Fax: +90 312 2239226.

compomers, are a group of aesthetic materials for the restoration of teeth damaged by dental caries (McLean et al., 1994). Polyacid-modified resin composites consist of conventional macromonomers also used in composites, such as Bisphenol-Glycidyldimethacrylate or urethane dimethacrylate. Compomers contain additional monomers that differ from those in conventional composites, which contain acidic functional groups. These materials combine glass polyalkenoate components with polymerizable composite resin (Geurtsen et al., 1999; Kwon et al., 2002) . The filler glass is identical to the ion-leachable glass fillers used in conventional glass-ionomer cements but in smaller sizes as known from composites. Initial setting is performed by light-activated polymerization which is followed by an acid-base reaction that arises from sorption of water (Wiegand et al., 2007). PMCRs subsequently absorb water, which results in ionization of the monomers and the production of hydrogen ions with light-curing. Compomers are similar to composite resins in that they are fundamentally hydrophobic, though less than conventional composite resins. They are set by a polymerization reaction, and only once set do the minority hydrophilic constituents draw in a limited amount of water to promote a secondary neutralization reaction (Eliades et al., 1998). They lack the ability to bond to tooth tissues (Martin et al., 1997; Moodley and Grobler, 2003), so require bespoke bonding agents of the type used with conventional composite resins (Moodley and Grobler, 2003) , and their fluoride release levels are significantly lower than those of glass ionomer cements (Shaw et al., 1998; Grobler et al., 1998) and resin modified glass ionomer cements (Paradella et al., 2008; Pin et al., 2005).

Halogen light curing units (LCUs) are commonly used for polymerization of both RMGICs and PMCRs. However, the bulb, reflector and filter of halogen LCUs degrade over time due to the operating temperatures and the large quantity of heat generated, resulting in a reduction of the curing effectiveness of halogen LCUs over time (Barghi et al., 1991).

Light emitting diode (LED) technology has been improved for light curing dental materials in order to overcome the drawbacks of the halogen LCUs (Mills, 1995). Rather than a hot filament, junctions of doped semiconductors are used in LED LCUs, and they have an expected life span of several thousand hours without significant degradation of light flux over time. LEDs require no filter to produce blue light (Mills et al., 2002) and they also produce less heat, so it may have lower potential for gingival and pulpal irritation (Leonard et al., 2002).

There are several studies concerning the application of LED LCUs on polymerization of composite resins (Mills et al., 2002; Bala et al., 2005a; Bala et al., 2005b; Jandt et al., 2000). These studies reported that the performance of LED LCUs was clinically satisfactory and had sufficient irradiance to polymerize composite resins.

There are some studies evaluating the effect of light curing units on the mechanical properties of RMGIC (Alpöz et al., 2008; Cefaly et al., 2006; Sfondrini et al., 2006) but there is little knowledge about the effect of LED LCU on the shear bond strength of RMGICs.

The aim of this study, therefore, was to evaluate and compare the effect of two LCUs (halogen or LED) on the shear bond strength of RMGIC and PMCR to dentin, *in vitro*.

MATERIALS AND METHODS

Twenty-four freshly extracted noncarious human mandibular molar teeth were cleaned from tissue remnants and stored in distilled water with thymol (0.002%).

Buccal and lingual enamel surfaces were removed with a diamond fissure bur under water coolant to expose superficial dentin. The exposed dentinal surfaces were ground under water coolant with a series of wet silicon carbide discs (# 600, 800, 1000, 1200) to achieve a flat dentin surface. Teeth were embedded into convenience cylinders with acrylic resin up to 2 mm apical of the cemento-enamel junction. Plastic rings (2 x 5 mm) were placed horizontally to the flattened buccal and lingual surfaces using modelation wax for the equal dimensional applications. The teeth were then randomly divided into four groups of six teeth with 12 application surfaces.

In Group 1, the dentin surfaces were etched (Caulk 34% Tooth Conditioner Gel, Dentsply DeTrey GmbH; Konstanz, Germany) for 15 s, rinsed for 20 s and gently dried. Prime and Bond NT (Dentsply DeTrey GmbH; Konstanz, Germany) adhesive was applied to the dentine surface for 20 s and gently air dried for 5 s. The adhesive was polymerized for 10 s with a halogen LCU (Hilux Ultra Plus, Benlio lu; Ankara, Turkey). The irradiance of halogen LCU was 600 mW/cm^2 with a wavelength of 450 - 520 nm. Light intensity was measured by means of a radiometer (Hilux Curing Light Meter, Benlio lu; Ankara, Turkey). PMCR (Dyract Extra, Dentsply DeTrey GmbH; Konstanz, Germany) was dispensed from the compule directly into the plastic rings and polymerized for 20 s according to the manufacturers' instructions.

In Group 2, the dentin surfaces were conditioned with cavity conditioner (GC Corporation; Tokyo, Japan) for 20 s, rinsed for 15 s, and left moist, according to the manufacturer's recommendations. RMGIC (Fuji II LC, GC Corporation; Tokyo, Japan) was mixed according to the manufacturers' instructions as 1 scoop of powder to 2 drops of liquid and inserted into the plastic rings and polymerized for 20 s with halogen LCU as used in Group 1.

In Group 3, the teeth were prepared as in Group 1 and polymerized for 20 s with a LED LCU (Elipar Free Light, 3M-ESPE Dental Products; St Paul, USA). The irradiance of LED LCU was 400 mW/cm^2, with a wavelength of 440 - 490 nm. Light intensity was measured by means of a radiometer (Elipar Free Light, 3M-ESPE Dental Products; St Paul, USA). LED LCU was used in a standard mode (full light intensity during the complete exposure cycle).

In Group 4, the teeth were prepared as in Group 2 and polymerized for 20 s with LED LCU as used in Group 3.The compositions of the tested materials are shown in Table 1.

The prepared specimens were immersed in distilled water at 37°C for 24 h and then subjected to thermocycling for 500 cycles between 5 $\pm$ 2°C and 55 $\pm$ 2°C water with a 15 s dwell time per bath and transfer time between baths was 5 s (Gale et al., 1999).

The shear bond strength for each specimen was measured using a universal testing machine (Shimadzu Co.; Kyoto, Japan) at a cross -head speed of 0.5 mm/min until fracture and the values of bond strength were recorded in MegaPascals (MPa).

The data were submitted to a one-way analysis of variance (ANOVA) and Tukey tests at a preset , value of 0.05.

Table 1. The composition of the tested materials.

Material	Composition	Batch no.
Fuji II LC GC Corporation, Tokyo, Japan	Powder: fluoroaluminosilicate glass, polyacrylic acid Liquid: water, polyacrylic acid, HEMA	0605261
Dyract Extra Dentsply DeTrey GmbH, Konstanz, Germany	TCB resin, polymerizable resins, strontium-fluoro-silicate glass, strontium fluoride, initiators/stabilizers	0601000745

Table 2. Shear bond strength values of the groups (n = 12) (arithmetic means and standard deviations).

Groups	Means	Standard Deviations
Group 1	3.78	±1.22
Group 2	6.41	±2.13
Group 3	7.02	±2.87
Group 4	7.72	±3.02

RESULTS

The mean shear bond strength values (MPa) and standard deviations are given in Table 2.

Lowest mean value (3.78 MPa) was observed in Group 1, which was significantly different from Groups 2 ($p = 0.025$), 3 ($p = 0.016$) and 4 ($p = 0.008$). There was no significant difference between Groups 2, 3 and 4 ($p > 0.05$). For curing units, the mean MPa values of groups polymerized with LED LCU were significantly higher than that of groups polymerized with halogen LCU ($p = 0.005$). For restorative materials tested, the mean MPa values of RMGIC were significantly higher than that of PMCR ($p = 0.045$).

DISCUSSION

If the bond strength to tooth surfaces is analyzed *in vitro*, different methods are available. The shear bond strength test has been widely used for determining the bond strength of dental materials to tooth structures (Tay et al., 2001). A possible advantage of the shear bond strength test is that, this method when compared to the microtensile is easy to perform (Lührs et al., 2009).

In this study, the effectiveness of LED LCU and halogen LCU on bonding of PMCR and RMGIC to dentin was compared. The shear bond strength values of tested groups varied between 3.78 and 7.72 MPa.

Data published on bond strengths for a given material often vary widely. This wide variance in data may be attributed to the variables inherent at the dentin surface, such as water content, the presence or absence of smear layer, dentin permeability, orientation of the tubules relative to the surface, and differences in the *in vitro* test design (Marshall et al., 1993). Studies have shown that bonding to superficial dentin is more successful than bonding to deep dentin (McCabe et al., 1992; Yoshikawa et al., 1999). In the present study, the teeth were ground only to expose superficial buccal and lingual dentin surfaces but the bond strength values were lower than those obtained from previous studies (Chitnis et al., 2006; Prabhakar et al., 2003; Almuammar et al., 2001). This may be attributed to the differences in the *in vitro* test design. Chitnis et al. (2006) measured the bond strength values of RMGIC and PMCR to enamel. Prabhakar et al. (2003) used primary teeth and Almuammar et al. (2001) used occlusal dentin surfaces for the shear bond test.

In the present study, the lowest shear bond strength value (3.78 MPa) was observed in PMCR (Dyract Extra) polymerized with halogen LCU, while the highest (7.72 MPa) was observed in RMGIC (Fuji II LC) polymerized with LED LCU. This finding may be due to the differences between the bonding mechanisms of the two materials.

Ideally, adhesive monomers should fully penetrate the demineralized dentin to create a hybrid layer at the resin dentin interface (Paul et al., 1999). This procedure should both improve the sealing ability and increase the bond strength between restorative material and dental tissue (Guzmán- Armstrong et al., 2003). The bonding mechanism of PMCRs involves hybrid layer formation like bonded resin based composites. They lack the ability to bond to tooth tissues and so they have to be applied with a dentin-bonding agent for sufficient adhesion onto the surfaces of the cavity (Cortes et al., 1993; Fritz et al., 1996; Moodley et al., 2003). Dyract Extra is based on a Sr/Al glass and anhydrous urethane dimethacrylate (UEDMA) system containing an acid monomer, tetracyano benzene (TCB). The addition of glass ionomer components to conventional resin composites reduces the physical properties of PMRCs (Chitnis et al., 2006).

The adhesive mechanism of Fuji II LC 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 (Pereira et al., 2002; Lin et al., 1992). This mode of bonding varies greatly from acid etching with phosphoric acid, when the tooth is demineralized, therefore reducing the calcium content. The appropriate protocol is to clean the tooth surface before bonding but not to demineralize it (Chitnis et al., 2006). Chitnis et al. (2006) compared the bond strength between GIC, RMGIC, PMCR and a resin-based composite and found that resin-based composite and RMGIC had significantly higher shear bond strength than GIC and the PMCR. Prabhakar et al. (2003) compared the shear bond strength of resin-based composite, PMCR and RMGIC in both primary and permanent teeth and observed in the case of primary teeth that RMGIC exhibited significantly higher shear bond strength as compared to PMCR and resin-based composite. On the contrary, Almuammar et al. (2001) stated that PMCR had higher shear bond strength than GIC and RMGIC, but less than resin-based composite.

Adequate polymerization of light curing materials depends on the light source intensity, wavelength, exposure duration, size, location and orientation of the tip of the source, and shade, thickness and composition of the material (Leonard et al. 2002; Dunn et al., 2002). It is known that adequate polymerization may also enhance mechanical properties like shear bond strength (Asmussen, 1982).

In the present study, the bond strength values of PMCR polymerized by LED LCU were significantly higher than when polymerized by halogen LCU. Although there was not a statistically significant difference between the shear bond strength values of RMGIC polymerized with LED and halogen LCU, the shear bond strength values of LED LCU were higher than that of halogen LCU. This can be attributed to the wavelength of LED LCU of approximately 470 nm, which corresponds to blue light and matches the peak absorption of the camphorquinone photoinitiator. The number of photons emitted by LED LCU was higher than that emitted by halogen LCU (Neumann et al., 2005).

Okte et al. (2005) reported that PMCRs could be effectively polymerized by LED LCU in 20 s, especially in children, so that LED LCU could be used as an alternative for polymerizing PMCRs in children or in large cavities. There has been no study evaluating the shear bond strength to dentin of RMGIC polymerized with LED LCU. Therefore, we could not compare the results of RMGIC polymerized with LED LCU. Further studies are needed regarding RMGIC polymerized with LED LCU, especially in primary teeth.

Conclusion

Within the limitations of this *in vitro* study, it may be concluded that:

- The lowest shear bond strength values were obtained with PMCR polymerized with halogen LCU and the highest values with RMGIC polymerized with LED LCU.

- Polymerization with LED LCU significantly improved the shear bond strength values of PMCR.

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