ORIGINAL ARTICLE

Journal of Research in Dental and Maxillofacial Sciences

DOI: 10.61186/jrdms.10.2.203

Effects of GLUMA Desensitizer and 810 nm Low-Level Diode Laser on Retention of Porcelain-Fused-to-Metal Frameworks Cemented with a Self-Adhesive Resin Cement

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Article History
Received: 28 April 2025
Accepted: 21 May 2025

Abstract

Background and Aim: Dentinal tubules are exposed to the oral environment during preparation of vital teeth for crown restorations, and patients show signs of tooth hypersensitivity. Some treatments have been suggested for dentin hypersensitivity after tooth preparation, such as diode laser (810 nm) irradiation and GLUMA desensitizer. This study aimed to assess the effects of 810 nm diode laser and GLUMA desensitizer on retention of porcelain-fused-to-metal (PFM) frameworks cemented with a self-adhesive resin cement.

Materials and Methods: This in vitro study evaluated 30 intact maxillary first premolars. After tooth preparation with a 0.5 to 0.7 mm finish line above the cementoenamel junction, full metal crowns were cast with a 5 mm diameter ring on their occlusal surface. The specimens were then divided into 3 groups (n=10) of control, 810 nm diode laser, and GLUMA desensitizer. The frameworks were cemented with RelyX U200 self-adhesive resin cement, and their retention was measured by a universal testing machine. Data were analyzed by ANOVA and Tukey post-hoc test (alpha=0.05).

Results: There was no significant difference in retention between 810 nm diode laser (134.96±37.50 N) and the control (138.17±40.81 N) group (P=0.986). However, framework retention in GLUMA desensitizer group (318.59±56.31 N) was significantly higher than that in other groups (P<0.05).

Conclusion: In this in vitro study, GLUMA desensitizer had a significant positive effect while 810 nm diode laser irradiation did no not have any significant effect on retention of PFM frameworks cemented by RelyX U200 self-adhesive resin cement.

Keywords: Dental Prosthesis Retention; GLUMA Desensitizer, Lasers, Semiconductor; Resin Cements

Cite this article as: Hajian Berenjestanaki M, Azizi A, Bazarnoei S, Lawaf S. Effects of GLUMA Desensitizer and 810 nm Low-Level Diode Laser on Retention of Porcelain-Fused-to-Metal Frameworks Cemented with a Self-Adhesive Resin Cement. **J Res Dent Maxillofac Sci. 2025; 10(3):203-209.**

Introduction

Retention is an important parameter in survival and clinical service of prosthetic crowns [1]. The optimal retention for extra-coronal restorations based on the geometrical shape analysis of the prepared teeth depends on factors such as convergence of the walls, magnitude of preparation, roughness of the crown's internal surface, presence of retentive grooves, features of prepared tooth surfaces, and type of cement [2]. Poor retention can lead to complications such as microleakage, formation of secondary caries under crowns, cement wash-out, and eventual failure of the crown [2].

Most patients with fixed restorations on teeth with vital pulp experience discomfort and pain in prepared teeth during the treatment process, and sometimes after restoration placement, which may be due to dentin hypersensitivity [3]. Millions of dentinal tubules are exposed during the tooth preparation of posterior crowns [4]. The increasing prevalence of dentin hypersensitivity after restoration cementation has led to widespread use of desensitizing agents [3]. The suggested treatments for dentin hypersensitivity include sealing of dentinal tubules by calcium phosphate deposition [4], application of potassium nitrate due to its effect on nerve impulses [5], sealing of dentinal tubules through protein deposition [6] using low-power laser for depolarization of nerve fibers and formation of tertiary dentin, and using high-power laser for sealing of dentinal tubules through recrystallization of dentin mineral components [7]. Also, application of adhesive resins, which act as a biological sealer by infiltrating the exposed dentinal tubules and creating a hybrid layer by formation of hybrid resin tags and adhesive side branches, can reduce the permeability of dentinal tubules [4]. Mancuso et al. [8] reported that dentin pre-treatment with GLUMA desensitizer prior to the use of two universal adhesives in self-etch mode could instantaneously increase the bond strength. Jalandar et al. [9] reported that GLUMA desensitizer did not affect crown retention. Kumar et al. [10] stated that laser treatment decreases the self-adhesive cement bond strength.

According to the existing contradictions and limitations of previous research, this study aimed to assess the effects of GLUMA desensitizer and 810 nm diode laser irradiation on retention of metal frameworks of porcelain-fused-to-metal crowns cemented with a self-adhesive resin cement (RelyX U200).

Materials and Methods

This study was an in vitro study (ethics code: IR.IAU.DENTAL.REC97.036). According to a previous study and using PASS 11 software with $\alpha=0.05$, $\beta=0.2$, mean standard deviation of 51.00 N, and effect size of 0.61, the minimum sample size needed for each of the three groups was 10 [11]. Thus, a total of 30 intact, virtually equal-sized maxillary first premolars [10, 11], extracted for orthodontic reasons, were collected and used for this study.

The teeth were placed in 0.1% thymol solution (Sigma-Aldrich, Merck KGaA, Germany) for 48 hours for disinfection, and the remaining tissues around the roots were removed [11-13]. Then, the teeth were prepared by using a milling machine (Degussa, Germany) along the longitudinal axis with a surveyor (Paraline, Dentaurum, Germany) [10, 11, 14]. For this purpose, the teeth were mounted on dental stone molds (Aria Dent, Tehran, Iran) and placed in the milling machine. Round-end tapered diamond bur (Dia-burs, Mani Inc; Japan) was used for occlusal reduction [11]. Chamfer finish line with 0.5-0.7 mm depth was prepared above the cementoenamel junction using a torpedo bur (Dia-burs, Mani Inc; Japan) (Figure 1A) [10, 15]. Also, a 4-mm axial height and 6-degree taper were considered for preparation of all specimens [9, 11]. The teeth were finished using a fine-grit round-end taper diamond bur (Dia-burs, Mani Inc., Japan) and all the line-angles were rounded using abrasive strips (Ceramill Map 400; Amann Girrbach; Germany). Wax patterns with 0.5 mm thickness and 30 µm spacer were designed for each specimen with a software (Dental CAD, Exocad; Germany) (Figure 1B), and wax blocks were carved using a CAD/CAM machine (Ceramill Motion 2, Amann Girrbach; Germany) [14]. Subsequently, a ring with an internal diameter of 5 mm was designed on the occlusal surface of the wax patterns. This ring, which was later cast on the metal framework, was used for jig attachment for retention testing in a universal testing machine (Zwick Z050; Roell Group, Ulm, Germany) (Figure 1C) [11, 14].

Then, the wax patterns (Machinable Wax Block Milling for Dental CAD/CAM System 98 x 10 mm Casting, Shenzhen, China) were invested using high-strength phosphate investment stone (Wirovest, Bego Corp., Germany), and metal frameworks with loops were fabricated by investment casting [11]. The cast metal frameworks were gently placed on the teeth, and marginal integrity and complete seating were checked with fit-checker (GC Corporation, Tokyo, Japan), a dental explorer, and a magnifier to change the ill-fitting crowns [10, 11]. Metal frameworks were then finished using metal finishing stones and burs, and sandblasted using 50 µm aluminum oxide particles (3-Kammer-Sandstrahler typ topStar z 3, Bego; Germany) [10,11]. They were then cleaned in an ultrasonic bath (USG 4000 Ultraschall, Dentaurum; Germany) for 60 seconds [11]. The teeth were then randomly divided into 2 experimental groups and 1 control group. In the first group, GLUMA desensitizer was applied on the surface of 10 teeth with a microbrush and remained for 60 seconds as recommended by the manufacturer. Compressed air was sprayed until the liquid disappeared, and the surface was no longer shiny. The teeth were rinsed with water afterwards [11]. In the second group, 810 nm laser (Simpler, Doctor Smile; Italy) was irradiated on 10 teeth with 0.5 W power for 15 seconds, 3 times in non-contact mode every 24 hours in continuous-wave mode perpendicular to the tooth surface [16]. No treatment was performed for the remaining 10 teeth (control group). In order to achieve equal thickness of the resin cement (RelyX U200, 3M; USA) on all specimens, the cement was mixed according to the manufacturer's instructions [17]. The cemented frameworks were placed on the teeth with finger pressure [11]. Next, a 5-kg constant axial load was applied to each framework for 10 minutes [11, 18]. After 2 minutes, additional cement was removed with an explorer. In order to make sure that the cement was cured, the frameworks' margins were cured by using a light curing unit with a light intensity of 850 mW/cm^2 (LED.D; Woodpecker; China) perpendicularly for 20 seconds at 0.5 cm distance [14]. Next, the specimens were incubated (Kavosh Mega; Iran) at 37°C for 24 hours [11]. Subsequently, the teeth were removed from the stone and grooves were created on their roots in order to mount them in acrylic resin. Subsequently, the specimens were mounted in 25x25x30 mm metal blocks containing auto-polymerizing acrylic resin (Acropars, Iran) perpendicularly 2mm below their cementoenamel junction [11, 19].

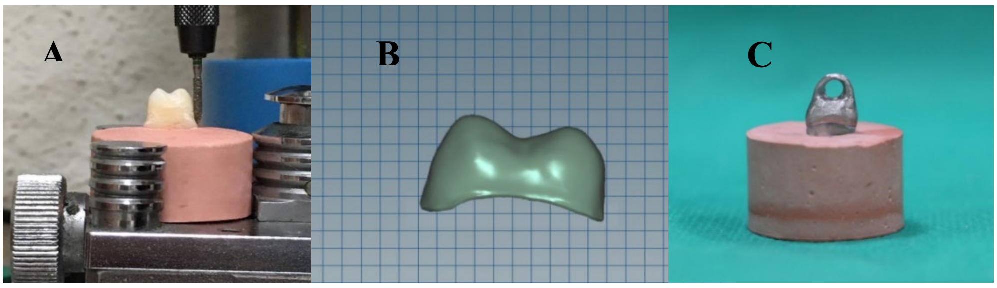

Figure 1. (A) Finish line preparation using torpedo bur. (B) Wax patterns were designed using Exocad software. (C) Ring, cast on the metal framework, was used for jig attachment for retention testing in a universal testing machine

Eventually, the retention test was performed in a universal testing machine (Z050; Zwick/Roell; Germany) and with a custom-made metal jig attached to the upper compartment of the device at a crosshead speed of 0.5 mm/min as recommended by the ADA standards for cement testing [11, 19]. After debonding of the frameworks, the debonded surfaces were evaluated under a stereomicroscope (SMZ800; Nikon, Japan) at x30 magnification to determine the mode of failure, which was categorized into 3 groups [11, 19]:

1. Cohesive failure: More than 75% of the cement remained on the tooth surface.
2. Adhesive failure: Less than 25% of the cement remained on the tooth surface.
3. Mixed failure: Between 25% to 75% of the cement remained on the tooth surface [11].

The Kolmogorov-Smirnov test showed normal distribution of data in the 3 groups (P=0.2). Thus, the obtained retention rates in the 3 study groups were compared using ANOVA, and Tukey's post-hoc test in 2 independent populations using SPSS version 25. P values less than 0.05 were considered statistically significant.

Results

One-way ANOVA showed a significant difference in framework retention among the 3 groups (P<0.05). Pairwise comparisons by the Tukey's test showed that there was no significant difference in framework retention between 810 nm diode laser (134.96±37.50 N) and control (138.17±40.81 N) groups (P=0.986). Framework retention in the GLUMA desensitizer group (318.59±56.31 N) was significantly higher than that in other groups (P<0.05).

The mode of failure in the control group was adhesive in 4 specimens, mixed in 5 specimens, and cohesive in 1 specimen. In the GLUMA group, the failures were cohesive in 6 specimens and mixed in 4. Also, in 810 nm diode laser group, the failure mode was mixed in 4 specimens, and adhesive in 6 specimens.

Discussion

Most patients with fixed restorations of vital teeth experience discomfort in prepared teeth during the treatment and sometimes after restoration placement, which may be due to dentin hypersensitivity [3]. Application of GLUMA desensitizer and photobiomodulation therapy with 810 nm diode laser are two desensitizing treatments to overcome this problem [6]. Hence, considering that these treatments cause changes in the surface characteristics of teeth and also considering the significance of cement bond strength in success of prosthetic treatments, a question arises regarding the effect of GLUMA desensitizer and 810 nm diode laser on retention of metal frameworks cemented with RelyXU200 self-adhesive resin cement. The results of this experimental study demonstrated that the retention rate of the GLUMA group was significantly higher than that of the 810 nm laser and the control groups, and also the retention rate in 810 nm laser group was significantly lower than that in the other two groups. Therefore, within the limitations of this study, the null hypothesis regarding no difference in metal framework retention among the GLUMA, 810 nm laser, and control groups cemented by self-adhesive resin cement (RelyX U200) was rejected. The bond strength of self-adhesive resin cements depends on diverse factors such as the type of dentin, depth of preparation, and tooth surface. Adhesion of self-adhesive resin cements to dentin and some restorative materials is acceptable; while, adhesion to enamel is poor based on bonding characteristics [20]. These cements are characterized by presence of hydrophilic acid monomers that directly adhere to the wet dentin surface [3]. Their ability to bond to the tooth structure depends on the infiltration of monomer into the tooth structure, and formation of a resin-infiltrated layer, which also depends on the presence of hydroxyapatite for adhesion to tooth structure [20]. According to a study by Gaffar [21], RelyX U200 cement has acidic monomers that cause demineralization and tooth infiltration, resulting in micromechanical retention and secondary chemical bonding with hydroxyapatite. The distinctive feature of this cement is the new modified lubricant that has reduced its viscosity and is presumably the reason for the superior bond strength of this cement compared to other cements. Using this lubricant results in better infiltration into the smear layer and better wetting of dentin. In recent years, several studies have investigated the impact of desensitizers on dentin bonding to different cements, including studies by Joudaki et al. [22], Mancuso et al. [8], Elizalde-Hernández et al. [20], Lawaf et al. [11], and Acar et al. [19]. Regardless of the type of cement and type of desensitizer used, limited studies had a methodology similar to that of the present study, including studies conducted by Joudaki et al. [22], Lawaf et al.[11], Acar et al. [19], and Jalandar et al. [9]. GLUMA desensitizer is composed of glutaraldehyde and hydroxyethyl methacrylate (HEMA). Glutaraldehyde causes coagulation of amino acids and proteins in dentinal tubules and is an effective antiseptic, and HEMA can effectively seal dentinal tubules. Qin et al. [23] reported that glutaraldehyde in HEMA could not crosslink with mineralized dentin. It has been reported that glutaraldehyde and HEMA-containing desensitizing agents lead to formation of a collagen-glutaraldehyde layer at the interface between the desensitizing agent and dentin. A chemical bond is formed between the HEMA present in the desensitizer and the collagen-glutaraldehyde complex [23]. Polymerization between the HEMA complex and resin cement, rewetting features of HEMA, buffering capacity of resins, and micro-mechanical bonding between protein plugs formed by GLUMA and resin tags may be possible reasons for escalated retention rates when resin cements are used with GLUMA [4]. Dewan et al. [3] stated that HEMA in GLUMA increases the dentin wettability by the resin cement, which helps to increase the bond strength. Sayed [4] in a systematic review reported that GLUMA obliterates the bulk of dentinal tubules and infiltrates into them as plugs and does not alter the irregularities on the dentin surface. Therefore, it does not decrease the retention of cemented crowns. Another desensitizing treatment evaluated in the present study was irradiation of 810 nm diode laser. In this study, the effect of 810 nm diode laser on the bond strength of RelyX U200 self-adhesive resin cement was investigated. Studies have shown that lasers with a near-infrared wavelength, including 810 nm diode laser, are suitable for application on soft tissues due to greater absorption by hemoglobin, because this property causes cutting, coagulation, and evaporation in soft tissues [24]. Absorption, depending on the wavelength, varies in different tissues. Diode laser in near-infrared wavelengths is absorbed by melanin and other pigments more than dentin [25]. Pandey et al. [26] indicated that the reduction in dentin hypersensitivity can be attributed to the feature of low-power 810 nm diode laser (0.5 W) that acts by bio-stimulation due to the increased production of mitochondrial ATP, raising the threshold of the free nerve endings, providing an analgesic impact due to a surge in beta-endorphin in the cerebrospinal fluid. Alleviation of pain occurs because of the inhibition of cyclooxygenase enzyme, which affects the transformation of arachidonic acid to prostaglandins. Laser irradiation also increases the formation of secondary dentin by odontoblasts in the process of bio-stimulation. In the study by Pandey et al. [26], the mechanism of pain relief by 810 nm laser was due to its effect on the pulp tissue and nerve fibers. However, it did not cause any changes in the mineralized tissues [26]. Thus, their study confirms the results of the present study regarding no significant difference between the laser and control groups. In the present study, irradiation of 810 nm laser with 0.5W power did not have any significant effect on the bond strength of self-adhesive resin cement to metal framework. Considering the impact of pre-treatments such as GLUMA desensitizer on the morphological features of dentin surface, this desensitizing agent can be effective on framework retention.

In the present study, the results demonstrated that GLUMA desensitizer had a positive effect on retention of metal frameworks of PFM crowns cemented with RelyX U200 self-adhesive cement. However, 810 nm diode laser had no effect on retention of metal frameworks of PFM crowns cemented by RelyX U200 self-adhesive cement probably because it has no effect on mineralized tissues. In some cases, there is a possibility of insufficient retention of the framework due to shortness of the teeth or improper preparation design. In such cases, using GLUMA desensitizer with self-adhesive resin cement is recommended to enhance the retention of the framework of PFM crowns.

Conclusion

Considering the limitations of this study, the results showed the positive effect of GLUMA desensitizer on retention of frameworks cemented with RelyX U200 self-adhesive cement. In the current study, 810 nm diode laser had no significant effect on retention of metal frameworks of PFM crowns cemented with RelyX U200 self-adhesive cement.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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