

Effect of Desensitising Laser Treatment on the Bond Strength of Full Metal Crowns: An *In Vitro* Comparative Study

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Abstract:

Background: Dentinal hypersensitivity is a very common complaint of patients undergoing crown and bridge restorations on vital teeth. Of the many desensitizing agents used to counter this issue, desensitizing laser treatment is emerging as one of the most successful treatment modality. However, the dentinal changes brought about by the desensitizing laser application could affect the bond strength of luting cements.

Materials and Methods: Freshly extracted 48 maxillary first premolars, which were intact and morphologically similar were selected for the study. The specimens were divided into two groups, an untreated the control group and a desensitizing laser-treated group, which were exposed to Erbium, Chromium: Yttrium, Selenium, Gallium, Garnet laser at 0.5 W potency for 15 s. Each of the above two groups were again randomly divided into two subgroups, on to which full veneer metal crowns, which were custom fabricated were luted using glass-ionomer and resin luting cements, respectively. Tensile bond strength of the luting cements was evaluated with the help of a Universal Testing Machine. Statistical analysis of the values were done using descriptive, independent samples' test, and two-way ANOVA test.

Results: The tensile bond strength of crowns luted on desensitizing laser treated specimens using self-adhesive resin cement showed a marginal increase in bond strength though it was not statistically significant.

Conclusion: The self-adhesive resin cements could be recommended as the luting agent of choice for desensitizing laser treated abutment teeth, as it showed better bond strength.

Key Words: Crowns, dentinal hypersensitivity, laser, luting cement, tensile bond strength

Introduction

One of the common predicaments experienced by patients undergoing tooth preparation and cementation on vital tooth for crown and bridge restorations is dentinal hypersensitivity.¹

The phenomenon of dentinal hypersensitivity is best explained by Brannstroms hydrodynamic theory, which states that "when exposed, dentinal tubules are stimulated by changes in temperature or osmotic pressure resulting in displacement of tubular fluid. This fluid movement is conveyed to the nerve fibers in the pulp, causing stimulation that is interpreted as pain or hypersensitivity." Vital teeth that are prepared for restorations are at a risk of developing hypersensitivity because a large number of tubules are exposed during the tooth preparation.

When teeth are prepared for complete crowns, approximately 1.2-1.5 mm of tooth structure is removed to ensure appropriate crown contours and adequate occlusal clearance.² Richardson *et al.* reported that approximately 1-2 million dentinal tubules are exposed during an average tooth preparation for a posterior crown.³ Desiccation and frictional heat generated by the preparation also increases the chances of hypersensitivity.⁴

During the procedure of crown cementation, the cement is forced into the patent dentinal tubules before the luting agent sets, and displaces an equal amount of dentinal fluid, thus leading to excessive hydrostatic pressure and resultant irritation of pulpal tissues.^{1,5} The smear layer evident after tooth preparation was demonstrated to be ineffective against luting agent irritation. Before cementation of the final prosthesis dentin can still become sensitive as a result of microleakage of the temporary restoration and the resultant formation of bacterial byproducts.⁶

Oxalates, resin bonding agents, and formulations containing sodium fluoride or potassium ions have been documented to have desensitizing property by blocking the dentinal tubules.⁷ However, the effects of these agents are limited, and the hypersensitivity can recur in the future.⁸ Tooth sensitivity after cementation of crowns, therefore, is a pertinent issue.

The use of low power low potency desensitizing laser treatment before cementation of crowns has shown to occlude exposed dentinal tubules and relieve the hypersensitivity for longer periods than any other desensitizing agents, and this procedure is growing in popularity the world over.⁹ It has been proved by Sipahi *et al.* that application of low-power low-potency desensitizing laser treatment has an effect on the tensile bond strength of full veneer crowns luted with glass-ionomer cement.¹⁰ However, the effect of laser desensitizing treatment on the crown retention, when resin cements are used, has not been documented. This is of importance, because of the growing popularity of these cements due to their better physical and mechanical properties.¹¹

The purpose of this study therefore was to assess, evaluate and compare the effect of desensitizing laser treatment on the bond strength of self-adhesive resin cement to glass-ionomer luting cement.

Materials and Methods

Freshly extracted 48 first premolars of approximately same anatomy selected for the study. The teeth were mounted into a metal jig filled with softened impression compound with the aid of a surveyor, so as to enable the specimen to be mounted parallel to its long axis. Tooth preparation of all the samples is planned. For bringing about standardization in the tooth preparation, it was mandatory for all the specimens to have a uniform taper, uniform length, and width. In order, to obtain uniform taper for the preparation a specially designed clamp was fabricated, which was able to secure a high-speed air-rotor hand-piece to the surveyor. The metal jig with the mounted tooth specimens were secured to the surveying table maintaining parallelism to the floor prior to starting the preparation. A round end tapered diamond bur was used to prepare the occlusal surface of the premolars, to a depth of 1mm below the central groove (Figure 1). The axial reduction of teeth done up to a uniform depth of 1.5 mm with the help of depth-cut diamond bur and tapered chamfer bur.

The surface area of the preparations thus obtained was calculated using a formula for truncated cone,¹² which is described below:

$$\text{Truncated cone area } A_c = 3.141 \times L (r_1 + r_2) \text{ mm}^2$$

$$\text{Flat surface area } A_0 = 3.141 \times r_2^2 \text{ mm}^2$$

$$\text{Surface area of preparation } A_t = A_c + A_0 \text{ mm}^2$$

A_c - Area of axial surface

A_0 - Area of occlusal (flat) surface

A_t - Total surface area

L - Length of the prepared surface, the axial surface

r_1 - Radius of the base of the prepared tooth, i.e. at cervical region

r_2 - Radius of the prepared tooth at the occlusal end

Only the samples with closely matching surface area were selected. The 48 specimens thus selected were then randomly distributed into different groups as follows (Figure 2).

Full veneer metal crown fabrication

Impressions of all the 48 prepared samples were made on a special tray using putty wash impression technique using polyvinyl siloxane impression material. The impressions were then poured in Type IV stone to obtain the master cast following the impression procedure the specimens were stored in isotonic saline.

Wax patterns were made with Type I inlay wax. A loop of approximately 5 mm diameter was then attached onto the occlusal surfaces of the patterns using 0.8 mm thick sprue wax. This loop in the cast metal crown was to engage a hook during the retention testing on the Universal Testing Machine. The wax pattern and dies were then assigned numbers corresponding to the respective prepared specimens so that

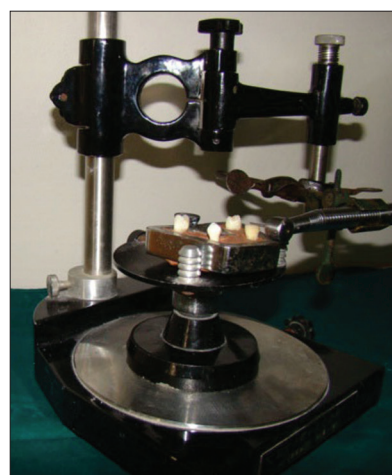


Figure 1: Crown preparation using surveyor.

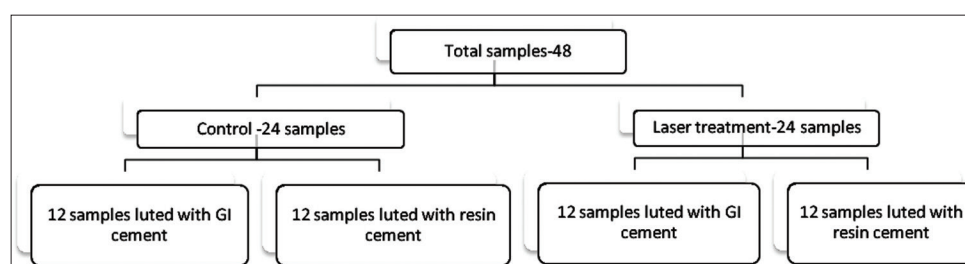


Figure 2: Distribution of samples.

each of the casting can be identified to its respective receptor tooth.

The patterns were sprued, invested and casting done using Nickel-Chromium alloy. Following casting and sandblasting (Figure 3) the sprues were cut, and each casting trimmed, finished, and examined under magnification for any internal surface irregularities. The fit of the completed restorations were verified on the preparations prior to cementation.

Surface treatment of teeth (Application of desensitizing laser)⁹

Prior to cementation of the full veneer metal crowns, the prepared tooth surfaces of the 24 teeth samples, grouped for laser treatment were treated with Erbium, Chromium: Yttrium, Selenium, Gallium, Garnet (Er,Cr: YSGG) laser at 0.5 W potency for 15 s without air or water spray (Figure 4).

After laser application, some of the samples were examined under environmental scanning electron microscopy (E-SEM) for dentinal tubule obliteration (Figure 5).

Cementation of the crowns

The cementation of the crowns was done according to the manufacturer's instructions and was performed by a single operator to prevent interoperator variation. One hour following the cementation procedure, all the samples were stored in an isotonic saline solution for 24 h prior to testing.

Retention testing

The retention testing of all the samples was performed on the INSTRON Automated Universal Testing Machine.

Results

The samples after storage in isotonic saline solution for 24 h, the tensile bond strength of each specimen in the study were tested in a universal testing machine.

Statistical analysis was done with the help of descriptive statistics, Independent samples *t*-test and two-Way ANOVA analysis using SPSS (version 16.0) and Minitab software's (version 11.0) for windows (Tables 1-3, Graph 1).

Discussion

Dentinal hypersensitivity is an age old complaint experienced by patients during the cementation of crown and bridge restorations on vital abutment teeth.¹ Brannstrom in his hydrodynamic theory had stated that, when dentinal tubules are exposed in vital teeth they are stimulated by changes in the temperature or osmotic pressure resulting in displacement of tubular fluid. This fluid movement is conveyed to the nerve fibers in the pulp, causing stimulation that is interpreted as pain or hypersensitivity. The cements used during the luting of the prosthesis bring about these stimuli, resulting in postcementation hypersensitivity.^{1,5,13}



Figure 3: Casted crowns.



Figure 4: Laser application.



Figure 5: Environmental scanning electron microscopy.

Many a tried and tested methods are currently available as dentine desensitizing agents, among which oxalates, resin bonding agents and formulations containing sodium fluoride or potassium fluoride are more commonly used.⁷ However, the effects of these agents are temporary leading to recurrence.⁸

With the advent of lasers into dentistry, desensitizing laser treatment has gained in popularity as an effective means to counter dentinal hypersensitivity. The use of lasers for treating dentinal hypersensitivity was first attempted by Harper *et al.* in 1992.¹⁴

Table 1: Mean tensile bond strength values for glass-ionomer luting cement on specimens with and without laser application.

Group statistics				
Groups	Number of samples	Mean	Std. deviation	Std. error mean
GIC				
Control	12	170.0000	7.51967	2.17074
Laser	12	119.0833	5.35059	1.54458
Independent samples test				
t-test for equality of means				
	t	df	Sig. (two-tailed)	Mean difference
GIC	19.112	22	0.000	50.9167

GIC: Glass Ionomer Cement

Table 2: Mean tensile bond strength values for Self-adhesive resin luting cement on specimens with and without laser application.

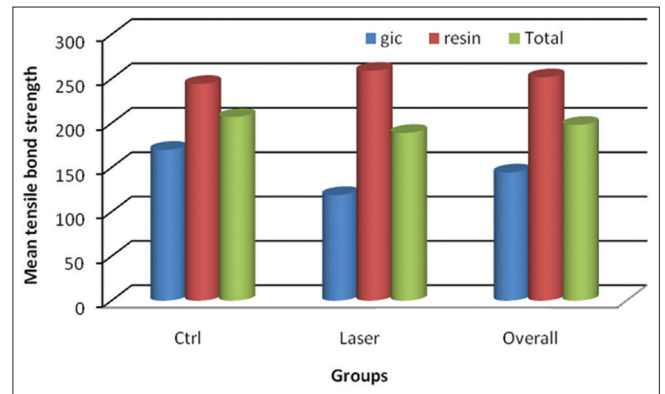
Group statistics				
Groups	Number of samples	Mean	Std. deviation	Std. error mean
SRC				
Control	12	244.3333	11.86541	3.42525
Laser	12	259.1667	5.18448	1.49663
Independent samples test				
t-test for equality of means				
	t	df	Sig. (two-tailed)	Mean difference
SRC	-3.968	22	0.001	-14.8333

SRC: Selfadhesive Resin Cement

Table 3: Results of the 2-Way ANOVA analysis for the mean tensile bond strength of control and experimental groups with Glass ionomer and Self-adhesive resin cement.

Descriptive statistics					
Dependent variable: TBS					
Groups	Mean	Std. deviation	Number of samples		
Control					
GIC	170.0000	7.51967	12		
Resin	244.3333	11.86541	12		
Total	207.1667	39.18925	24		
Experimental					
GIC	119.0833	5.35059	12		
Resin	259.1667	5.18448	12		
Total	189.1250	71.73339	24		
Total					
GIC	144.5417	26.77763	24		
Resin	251.7500	11.72975	24		
Total	198.1458	57.90307	48		
Tests of between-subjects effects					
Dependent variable: TBS					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
GPS	3906.021	1	3906.021	61.794	0.000
GP	137923.521	1	137923.521	2181.981	0.000
GPS* GP	12969.188	1	12969.188	205.175	0.000
Error	2781.250	44	63.210		
Total	2042145.000	48			
Corrected total	157579.979	47			

GPS: Between the groups, GP: Individual group, TBS: Tensile Bonding Strength,
*: Correlation between the groups



Graph 1: Results of the 2-Way ANOVA analysis for mean tensile bond strength of control and experimental groups with Glass ionomer and Self-adhesive resin luting cements.

put forward suggests that when the laser interacts with the dentinal tissue it is absorbed by the water and hydroxyapatite. The laser heats the water causing it to become steam. This expansion during the change of state of water causes cracking of the dentinal tissue. As the steam expands, it also forces the cracked material away from the ablation zone. Since this reaction happens at a rapid pace, it is explosive in nature, and hence it is termed “microexplosion.”⁹ As a result of this micro explosion, dentinal debris similar to a smear layer forms on the surface of the dentin, there by blocking the exposed dentinal tubules. Laser application also lead to decrease in diameter, and size of the dentinal tubules by shrinking it.”¹⁵

An E-SEM study done to understand the tubule-occluding effect of desensitizing laser treatment on prepared dentin surfaces by Sipahi *et al.* observed that the application of desensitizing laser at 0.5 W potency without air and water can be done to reduce hypersensitivity of prepared abutment teeth in prosthodontics.⁹ According to this study, desensitizing laser application causes blockage and reduction in the size of patent dentinal tubules by deposition of dentinal debris created by micro explosion. These observations can raise queries regarding the effect of desensitizing laser application on the bond strength of commonly used luting cements, viz: glass-ionomer and resin cements to treated dentin. Sipahi *et al.* have also observed that the tensile bond strength of glass-ionomer luting cement to the abutment tooth decreased by 15% after laser application.¹⁰

However, there are not many studies currently available on the bond strength of self-adhesive resin cements to desensitizing laser treated teeth. It is imperative to understand the bond strength of self-adhesive resin cement to laser irradiated teeth, as these cements are gaining in popularity as a luting agent due to their improved mechanical and physical properties.¹¹ This study therefore was done to assess and compare the tensile bond strength of crowns luted with glass-ionomer and resin cements to laser irradiated prepared abutment tooth, and control group.

“The precise mechanism of ablation of hard tissues with the Er,Cr:YSGG laser remains unclear. One of the theories

Within the limitations of this study, it was found that laser treatment on dentine appreciably decreased the tensile bond strength of crowns luted with glass-ionomer cements. However, the bond strength of self-adhesive resin cement remained unaffected with a marginal increase in strength, it was not statistically significant. The results of the present study with glass-ionomer cement are concurrent with the findings of a previous study by Sipahi *et al.*¹⁰

The mechanism of adhesion of glass-ionomer cement to dentinal surface is through an ionic bond between negatively charged polyacid chains of the ionomer matrix and the positively charged calcium on the tooth surface.¹⁶ These polyacids also form hydrogen bonds and undergo ion exchange in the collagen and the inorganic components of the tooth structure, particularly to calcium, carboxylate and phosphate ions of the tooth surface.¹⁷ The formation of dentinal debris formed during laser application as observed in SEM picture in this study probably would have interfered with the above mentioned chemical bondage of glass-ionomer cement with the exposed dentinal surface leading to loss of bond strength. The desiccation of collagen fibrils due to laser application may also be another reason, leading to decreased bond strength due to the weak hydrogen bonds and poor ion exchange in the dentinal collagen.¹⁸

The bond strength of the samples luted with self-adhesive resin cements remaining unaffected or showing a marginal increase in bond strength may be due to the following reasons.

- The ability of resin cement to partially decalcify the smear layer and the dentin leading to the formation of short-resin tags into the remaining dentinal tubules after laser application.¹⁹
- Improved chemical bondage due to increased calcium ions on dentinal surface during laser application²⁰ leading to enhanced chelating reactions.²¹

The above observations are in accordance with the study conducted by Yazier *et al.* on the effect of Erbium: Yttrium, Aluminum, Garnet and Neodymium: Yttrium, Aluminum, Garnet laser hypersensitivity treatment parameters on the shear bond strength of self-etch adhesives.²² The exact mechanism behind the bond strength being unaffected or having a marginal increase have to be studied and interpreted further.

The E-SEM pictures of the laser irradiated samples in this study showed that a dentinal smear layer was produced due to microexplosion during laser application, which obliterated the patent dentinal tubules. Some of the dentinal tubules also showed constriction in size due to shrinkage. These findings could be the reason as to how the laser application brings about desensitization. A few micro-cracks were found in some of the samples; possibly due to an accidental increase in duration of

laser exposure.²³ Which reiterates the fact that one has to be judicious while handling and using technology like laser to be an effective tool in dentistry.

From the observation and discussion postulated from this study, it can be concluded that self-adhesive resin cement should be a preferred luting medium to glass-ionomer cement, for abutments, which has undergone desensitizing laser treatment.

The possible mechanism of dentin desensitization brought about by laser treatment could also be studied and understood from the E-SEM pictures of the samples used for the study.

Conclusion

Within the limitations of this *in vitro* study the following conclusions were drawn:

1. Glass-ionomer luting cement showed a statistically significant reduction in the tensile bond strength values after desensitizing laser treatment at 0.5 W for 15 s duration to prepared teeth as compared to the control group.
2. Tensile bond strength of Self-adhesive resin luting cement showed a marginal increase in values after desensitizing laser application, which was not statistically significant.
3. Since combination of Er,Cr:YSGG laser for desensitization of dentin and the self-adhesive resin cement for luting crowns showed a marginal increase in bond strength values after laser application, these crowns could be recommended for luting crowns in laser treated abutments.
4. Scanning electronic microscopic study revealed that application of the Er,Cr:YSGG laser at a power of 0.5 W for 15 s to exposed dentinal surface resulted in obliteration of dentinal tubules and formation of a smear layer formed by dentinal debris, which possibly describes the desensitizing property of lasers.

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