Original Article

Comparative evaluation of shear bond strength and modes of failure of five different reinforced glass ionomer restorative cements to TheraCal LC: An *in vitro* study

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Abstract

Aim: The aim of the study is to evaluate and compare the shear bond strength (SBS) and modes of failure of different reinforced glass ionomer cement restorative materials such as GC IX, GC Gold Label 2 LC, Amalgomer CR, Equia Forte, and Secure Core Z to TheraCal LC.

Methodology: A total of 50 acrylic blocks, each containing a cylindrical hole in the center were prepared from self-cure acrylic resin and randomly divided into five groups and restored, namely Group A - TheraCal LC + GC Fuji IX, Group B - TheraCal LC + GC Gold Label 2 LC, Group C - TheraCal LC + Amalgomer CR, Group D - TheraCal LC + Equia Forte, and Group E - TheraCal LC + Secure Core Z. All the specimens were stored in artificial saliva at 37°C for 24 h before testing. The statistical tests used for the analysis of the result were: one-way ANOVA, Tukey multiple comparison test, and the Chi-squared test, and $P < 0.05$ is considered as the level of significance.

Results: Equia Forte showed the highest SBS, while GC type IX showed the lowest SBS with TheraCal LC.

Conclusion: Equia Forte can be the restorative material of choice when TheraCal LC is used as a base materials for better clinical efficacy.

Keywords: Equia Forte; reinforced glass ionomer cement; TheraCal LC; vital pulp therapy

INTRODUCTION

Therapeutic strategies focused on pulp preservation are important when managing vital teeth with deep caries and an exposed pulp. Vital Pulp Therapy (VPTs); however, are not new, with indirect and direct pulp capping procedures being described as a therapy for carious teeth for over a century.[1] According to the "American Association of Endodontics," vital pulp therapy (VPT) is defined as "techniques which are means of preserving the vitality and function of dental pulp after injury resulting from trauma, caries or restorative procedures."[2-4] The protective resistance to mastication forces compared with a root-canal-filled tooth is an important benefit for the preservation of vital pulp.[5,6] Caplan *et al*. reported that the survival rate of endodontically treated teeth (89.6%) is not as good as vital teeth (98.5%), especially in molars.[7] Therefore, the vitality of pulp should be preserved if possible.

Historically, vital pulp therapy was carried out using calcium hydroxide but was not widely accepted due to unpredictable results such as unsatisfactory adherence to

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dentin, dissolution over time, and multiple tunnel defects in dentine bridges.[8,9] Calcium silicate materials such as Mineral trioxide aggregate (MTA) and Biodentin are bioactive materials which release ions needed to stimulate dentin bridging and are superior to calcium hydroxide cement. However, MTA exhibits many drawbacks such as difficult handling and long setting time.[10] Whereas Biodentin showed weak micromechanical bonding to the restoration due to its water-based chemistry. To overcome this limitation, a light-curable resin-modified tricalcium silicate cement TheraCal LC (Bisco, Inc., Schaumburg, IL, USA) was introduced as a pulp capping material.[11]

TheraCal LC is a new light-curing, resin-modified, tri-calcium silicate-based material designed for use as direct and indirect pulp capping as a protective base/liner under composites, amalgams, cement, and other base materials. As opposed to other tricalcium silicate-based materials, TheraCal LC contains polymerizable methacrylate monomers, included to achieve a bond to composite resins and dentin.[12] After the light-cure of TheraCal LC, the material's high physical properties and low solubility permit immediate placement of the final restorative material (Scientific Catalogue of TheraCal LC, 2012).[13]

The quality and durability of the bond between pulp capping material and restorative material are of clinical significance in terms of longevity and predictability of final restoration.[14] Resin composites and glass ionomer cement (GICs) are very popular restorative materials in dentistry. Many previous studies demonstrated good bond strength of composite over GIC. However, curing shrinkage of overlying composite can cause stresses in the bond strength between the liner and composite.[15,16]

Conventional GICs have certain properties which make them useful as a restorative material of choice. However, some deficiencies such as moisture attack during the initial setting period, long setting and maturation time, short working time, low fracture toughness, and lower wear resistance have limited their use to areas which are not subjected to masticatory stresses.[17] The physical and mechanical properties of GIC improved by various manufacturers by incorporating various modifications in the basic formulation of GIC cement.

Although many previous studies have evaluated the bond strength of calcium silicate material over composite and GICs, there are limited data available regarding the bond strength of TheraCal LC to various reinforced glass ionomer restorative materials. Therefore, in this study, the evaluation of shear bond strength (SBS) of different reinforced GIC restorative materials such as strontium-based GIC (GC IX), resin-modified GIC (GC Gold Label 2 LC), ceramic-reinforced GIC (Amalgomer CR), glass hybrid technology-based GIC (Equia Forte), and zirconia-reinforced GIC (Secure Core *Z*) to resin-modified calcium silicate material (TheraCal LC) was done.

METHODOLOGY

The investigation was performed after ethical approval from the institute's research ethics committee (ref. SDKSDCH/IEC/PG/011/2021). A total of 50 acrylic blocks, each containing a cylindrical hole in the center with a depth of 2 mm and an internal diameter of 5 mm, were prepared from self-cure acrylic resin [Figure 1a]. TheraCal LC was dispensed from a syringe into the blocks in increments of 1 mm. Each 1 mm increment was then light-cured with a light-emitting diode curing lamp (Elipar Freelight S10, Woodpecker, China) for 20 s. After the second increment, a glass slab was placed on the top of the block to obtain the standardization of the sample surface and then light cured with a light-emitting diode curing lamp for 20 s [Figure 1b]. These 50 samples were randomly divided into five groups, namely Group A - TheraCal LC + GC Fuji IX, Group B - TheraCal LC + GC Gold Label 2 LC, Group C - TheraCal LC + Amalgomer CR, Group D - TheraCal LC + Equia Forte, and Group E - TheraCal LC + Secure Core *Z*.

Technique for placement of restorative material

GC Fuji IX, GC Gold Label 2 LC, Amalgomer CR, and Secure Core *Z* are available in powder and liquid form while Equia Forte is available in capsule form. They were mixed according to the manufacturer's instructions. The plastic cylinder was placed over the TheraCal LC in the acrylic block. Cement was transferred to the plastic cylinder using a suitable instrument [Figure 1c]. For Equia Forte, the mixed restorative cement was immediately dispensed within 10 s into a plastic cylinder placed on each specimen light curing was done for 20 s. After the setting of the material [Figure 1d], the plastic cylinder was removed carefully. All the specimens were stored in artificial saliva (Wet Mouth, ICPA Health Products Ltd, Mumbai, India) at 37°C for 24 h before testing.

Measurement of shear bond strength

Each specimen was mounted in a universal testing machine and subjected to a shearing force using a knife-edge blade at a crosshead speed of 1 mm/min [Figure 1e]. The load at a mode of failure was recorded in newtons, and the bond strength was calculated in megapascals (MPa) by dividing the load at failure by the adhesive surface area (mm^2).

Failure modes were evaluated by a single operator under a stereomicroscope at ×10 magnification [Figure 1f-h] and classified as follows:

- Adhesive failure (failure within the bonding interface of TheraCal LC and the restorative materials)

- Cohesive failure (failure within TheraCal LC or failure within restorative material)
- Mixed failure (a combination of adhesive and cohesive failure of TheraCal LC or restorative material).

Statistical analysis

Analysis of the data was done using the descriptive and inferential statistics. The statistical tests used for the analysis of the result were: one-way ANOVA, Tukey multiple comparison test, and the Chi-squared test. The software used in the analysis was SPSS (IBM, United States) 24.0 and Graph Pad Prism 7.0 version, and $P < 0.05$ is considered as the level of significance.

RESULTS

Table 1 shows the mean SBS value of all the five groups. Group D (TheraCal LC + Equia Forte) showed the highest SBS followed by Group C (TheraCal LC + Amalgomer CR), while Group A (TheraCal LC + GC Fuji IX) showed the lowest SBS.

Table 1 shows the comparison of modes of failure among the five groups. Adhesive mode of failure was present in 50% of samples of Group A, 80% of Group B, 60% of Group C, 20% of Group D, and 40% of Group E. Mixed mode of failure was present in 50% of samples of Group A, 20% of Group B, 60% of Group D, and 40% of Group E. Cohesive mode of failure was present in 40% of samples of Group C and each 20% samples of Group D and Group E. By using the Chi-square test, statistically significant difference was found in mode of failure among the samples of five groups ($\chi^2 = 17.82$, $P = 0.022$).

DISCUSSION

The primary objective of restorative dentistry is to preserve the pulpal health of vital teeth. In recent years, vital pulp therapy (VPT) has received considerable attention in dentistry, especially in endodontics. Guan *et al.* have shown that permanent teeth with irreversible pulpitis caused by caries in young patients were successfully treated with VPT.[18]

To overcome the limitations of calcium hydroxide, MTA and Biodentin, a light-curable resin-modified tricalcium silicate cement TheraCal LC (Bisco, Inc., Schaumburg, IL, USA)

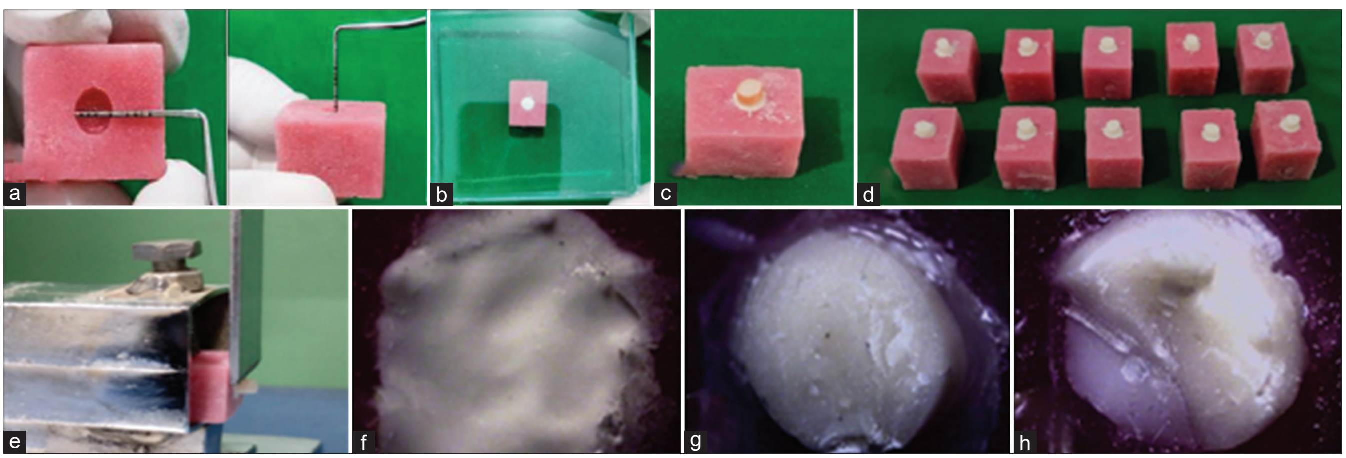

Figure 1: (a) Acrylic block with hole in the center, (b) Placement of glass slab for standardization of sample surface, (c) Placement of cement into plastic cylinder, (d) Final set material, (e) Shear bond strength testing using universal testing machine, (f-h) Failure modes under a stereomicroscope at ×10 magnification. (f) Adhesive failure, (g) Cohesive failure, (h) Mixed failure

Table 1: Comparison of shear bond strength and mode of failure (using Chi-squared test) among samples of five groups

Group	Descriptive statistics							
	n	Mean	SD	SE	95% CI for mean		Minimum	Maximum
					Lower bound	Upper bound		
Group A	10	0.98	0.51	0.16	0.61	1.35	0.05	1.86
Group B	10	5.69	1.82	0.57	4.38	6.99	2.18	8.44
Group C	10	7.24	4.20	1.32	4.23	10.25	0.97	12.71
Group D	10	8.25	4.67	1.47	4.90	11.60	1.00	15.53
Group E	10	6.80	4.69	1.48	3.44	10.16	1.68	17.49

Mode of failure	Group A, *n* (%)	Group B, *n* (%)	Group C, *n* (%)	Group D, *n* (%)	Group E, *n* (%)
Adhesive	5 (50)	8 (80)	6 (60)	2 (20)	4 (40)
Mixed	5 (50)	2 (20)	0	6 (60)	4 (40)
Cohesive	0	0	4 (40)	2 (20)	2 (20)
Total	10 (100)	10 (100)	10 (100)	10 (100)	10 (100)

χ^2=17.82, *P*=0.022. SD: Standard deviation, CI: Confidence interval, SE: Standard error introduced (in 2011) as a pulp capping material.[9,19] Makkar *et al*. found that TheraCal LC exhibited less interfacial microleakage and better sealing ability as a pulp capping agent than MTA and Biodentin.[14] Deepa *et al*. showed that TheraCal LC achieved adequate bond strength to withstand contraction forces from overlying composite resin due to the presence of a resin matrix, and composite restoration can be placed immediately over, completing the procedure in a single appointment.[11]

The clinical success of restorative materials within the oral cavity depends upon a good adhesion with a dentinal surface as well as with the base material to resist various dislodging forces.[20,21] SBS is the ratio of maximum load to debond the specimen (newton-N) to the cross-sectional area (mm^2) of the bonded interface using a universal testing machine. It assumes much importance to the restorative material clinically because the major dislodging forces at the tooth restoration interface have a shearing effect. The bond between light cure MTA (TheraCal LC) with overlying restoration is of pivotal importance for the success of vital pulp therapy (VPT). Therefore, higher SBS implies better bonding of the material.

In the present study, Group D (TheraCal LC + Equia Forte) showed the highest SBS among all the experimental groups. A thorough search of the literature and electronic databases revealed no other published study evaluating the SBS of Equia Forte to TheraCal LC. Hence, the results of the present study could not be compared, and therefore provide important information about the bond strength of Equia Forte to TheraCal LC.

In the present study, a statistically significant difference was found in SBS between Group A (TheraCal LC + GC IX) and Group D (TheraCal LC + Equia Forte) (P = 0.0001). The results are in accordance with the study conducted by Francois *et al.*[22] which showed a significantly higher SBS of Equia Forte when compared to type IX GIC. They observed that for indirect restorations, Equia Forte can be used in synergy with the immediate dentin sealing technique to provide high bond strength values and low postoperative sensitivity and avoid bacterial contamination during the temporization phase.

In the present study, Group B (TheraCal LC + GC Gold Label 2 LC) exhibited lesser SBS than Group D (TheraCal LC + Equia Forte). However, a statistically significant difference was not found. These results are similar to the study conducted by Duman *et al*.,[23] in which they concluded that Equia Forte showed the highest SBS with Medcem pure Portland cement than resin-modified GIC. In the present study, Group C (TheraCal LC + Amalgomer CR) and Group E (TheraCal LC + Secure Core *Z*) exhibited slightly less SBS than Group D (TheraCal LC + Equia Forte). However, a statistically significant difference was not found. A literature search was done and to the best of our knowledge, no literature is available on the comparison of SBS of Amalgomer CR and Secure core *Z* to TheraCal LC and the comparison of SBS of Equia Forte and Secure core *Z* to TheraCal LC.

The comparison of a mode of failure among five groups was evaluated using the Chi-squared test. A statistically significant difference was found in adhesive, cohesive, and mixed types of failure between five groups (χ^2 = 17.82, P = 0.022). A higher number of adhesive failures observed in Group B (TheraCal LC + GC Gold Label 2 LC) may indicate that a strong bond was not formed between TheraCal LC and GC Gold Label 2 LC. A higher number of cohesive failures were observed in Group C (TheraCal LC + Amalgomer CR). This result is in accordance with the study conducted by Cengiz and Ulusoy,[12] in which RMGIC and TheraCal LC showed a high frequency of adhesive failures. Thus, in the present study, the highest SBS is observed in TheraCal LC + Equia Forte group with a prevalence of mixed types of failure.

The present study was performed with an effort to simulate the clinical conditions and achieve standardization. However, *in vitro* conditions do not completely reflect *in vivo* conditions. However, *in vitro* experimental studies provide a more easily reproducible and reliable means for comparison of SBS and modes of failures of different reinforced GIC to TheraCal LC.

Moreover, different study protocols and testing methods, the amount of force applied by the universal testing machine, and the time duration for which it is applied may account for this variability in reported values. Consequently, it would be difficult to accurately compare results. Therefore, further investigations using comparable methodology should be done to be able to directly compare results.

Limitations of this study

Only 10 samples were tested in each group, therefore a greater number of samples should be tested in further studies to increase the power of the study. Forces applied intraorally vary in magnitude, speed of application as well as direction, whereas the forces applied to the teeth in this study were at constant speed and direction and increased continuously till fracture.

CONCLUSION

Within the limitations of this study, the results exhibited that TheraCal LC with Equia Forte had the highest SBS and lowest with TheraCal LC and GC Fuji IX . Failure mode was a predominantly adhesive failure in all the experimental GIC with TheraCal LC. The present study suggests that

Equia Forte can be the restorative material of choice when TheraCal LC is used as base materials for better clinical efficacy.

Clinical relevance

The introduction of novel dental biomaterials, supported by acceptable scientific evidence, has led to increased application of the VPT technique in recent years. Many modifications and reinforcements are made in GIC to increase its properties. Equia Forte, a GIC with glass hybrid technology could be used with TheraCal LC when compared with other reinforced GICs in case of VPT.

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Conflicts of interest

There are no conflicts of interest.

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