International Journal of Advanced Biotechnology and Research (IJBR)
ISSN 0976-2612, Online ISSN 2278–599X,
Vol-8, Issue-3, 2017, pp1636-1642
http://www.bipublication.com

Research Article

Comparison of Shear Bond Strength of Resin-Modified Glass Ionomer and Resin Composite to Mineral Trioxide Aggregate and Bioceramic Root Repair Material

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ABSTRACT

Background and aims: Present study was designed to compare the shear bonding strength of composite resin and resin-modified glass ionomer (RMGI) to mineral trioxide aggregate (MTA) and BioCeramic root repair material (BC RRM) at different intervals.

Materials and methods: In this experimental study, 80 teflon molds were prepared and divided into 8 groups (n=10 each) and filled with MTA-Angelus (groups 1, 2, 3 and 4) or BC RRM-fast set putty (groups 5, 6, 7and 8). The pulp capping materials were covered with a wet cotton pellet. Composite resin and RMGI restorations were then placed on the samples after recommended setting time (groups 1,2, 5 and 6) or after 24 hours (groups 3, 4, 7 and 8). Shear bond strength was assessed using universal testing machine. Three-way ANOVA and two-way ANOVA were used to determine the effect of the pulp cap materials, restorative materials and time on shear bonding strength. To compare the bond strength based on each different variable, T-test was used. Statistical significance was set at $\alpha<0.05$.

Results: Bond strength in composite samples was significantly higher compared to RMGI samples ($p<0.001$). In MTA groups there was no statistically significant difference between two time intervals in bond strength of pulp cap material to composite ($p = 0.98$) and RMGI ($p = 0.32$). In BC RRM groups, the difference between two time intervals in bond strength of pulp cap material to composite ($p = 0.89$) and RMGI ($p = 0.73$) was not also significant. The bond strength of composite to MTA and BC RRM was not significantly different at recommended setting time ($p = 0.81$) or after 24 hours ($p = 0.65$). It was also shown that the bond strength of RMGI to BC RRM was significantly higher than MTA at recommended setting time ($p = 0.002$), however the difference between two pulp cap materials after 24 hours was not significant ($p = 0.08$).

Conclusion: Regarding shear bond strength to pulp cap materials, resin composite was shown to be superior to RMGI. The shear bond strength of RMGI to BC RRM was higher than MTA at recommended setting time.

Keywords: Composite resin, resin-modified glass ionomer, MTA, BC RRM, shear bond strength

INTRODUCTION

Direct pulp capping is the process of placing a biocompatible material on a normal pulp that exposed accidentally during trauma or caries removal. An effective pulp capping material should be biocompatible, stimulating the formation of a dentin bridge, provide a biological seal and prevent bacterial leakage (1). Materials like calcium hydroxide and mineral trioxide aggregate (MTA) have been used for this purpose. At present, MTA is the most indicated material for pulp capping. The major components of MTA are tricalcium silicate, dicalcium silicate, tricalcium aluminate, bismuth oxide (radiopaque agent), and calcium sulfate dehydrate(2).MTA has demonstrated many of the desired properties such as low solubility(3), ability to set in a wet environment,setting in the presence of blood, prevention of bacterial leakage, and biocompatibility(4, 5). However, it has some limitations, such as difficult handling and long setting time (6). As an alternative, MTA-Angelus with reduced setting time of 14.28 ± 0.49 minutes (7) has been produced by elimination of the dehydrated calcium sulfate from the material's composition (8).

In an attempt to improve the properties of MTA and overcome its shortcomings, BioCeramic Root Repair Material (BCRRM) has been introduced. According to the manufacturer, BC RRM is composed of calcium silicates, zirconium oxide, tantalum oxide, monobasic calcium phosphate and fillers. It is manufactured as a premixed product in both moldable putty and preloaded syringe paste to provide a consistent material and improve handling.Previous studies showed that BC RRM is biocompatible (9, 10) and bioactive(11). To reduce the setting time, recently BC RRM fast set putty has been introduced. According to the manufacturer it has the same characteristics as BC RRM Putty and BC RRM Paste but with shorter setting time (20 minutes).

Pulp capped teeth have to be sealed by restorative materials. Resin composites and glass ionomer cements have gained considerable attention in restorative dentistry because of their esthetic properties. Using of glass ionomer (GI) as liner is common because of its chemical bond to dental structure and its fluoride release (12). Resin modified glass ionomers (RMGI)are used as liners in sandwich technique to reduce microleakage under resin composite restorations (13).

Success of direct pulp capping procedures is directly related to the control of bacterial leakage(14). Pulp exposurein a sterile environment can be followed by forming a dentinal bridge (15, 16). However, in presence of bacterial leakage, pulp disease and finally pulp necrosis are inevitable. Therefore, a proper bond between the restorative material and the pulp capping agent is importance because in the absence of a proper seal, bacterial penetration into the pulp will occur and the pulp capping procedure will fail (14).

Since previous studies have not evaluated the bond strength of the newly introduced BC RRM fast set putty to commonly used restorative materials, we evaluated the shear bond strength of RMGI and composite, as restorative materials and BC RRM and MTA Angelus, as pulp capping materials allowed to set for two different times,recommended setting time by the manufacturer and 24 hours.

MATERIALS AND METHODS

1. Preparation of samples

In this in vitro study, 80 teflon molds were prepared and then in the center of the cubic molds, a hole with a 3-mm diameter and a 2-mm height was created. The molds were divided into eight experimental groups:

- In groups 1 and 2: MTA-Angelus (Angelus, Londrina, PR, Brazil) was prepared according to manufacturer's instructions, placed with a carrier in central holes and condensed with a condenser and flattened with spatula. MTA was then covered with a wet cotton pellet and stored at 37°C for 15 minutes(recommended setting time).

- In groups 3 and 4:after placement of MTA-Angelus, the pulp capping material covered with a wet cotton pellet and stored at 37°C for 24 hours.
- In groups 5 and 6: premixed BC RRM-fast set putty (TotalFill, FKG, Switzerland)placed in central holes and condensed with a condenser and flattened with spatula. BC RRM was then covered with a wet cotton pellet and stored at 37°C for 20 minutes (recommended setting time).
- In groups 7 and 8: after placement of BC RRM, the pulp capping material covered with a wet cotton pellet and stored at 37°C for 24 hours.

The storage time for each experimental group was measured from the beginning of mixing procedure.

2. Bonding procedure

In groups 1, 3, 5 and 7, after storage time, the cotton pellet was removed and material surface was etched for 15 seconds with 35% phosphoric acid etching gel (vococid, voco, Germany) and rinsed with water for 20 seconds and then dried with oil-free air syringe for 5 sec. Two consecutive layers of bonding material (Solobond M, Voco, Germany) were then applied onto the surface, gently air-dried for 5 seconds and light-cured for 10 seconds with a LEDlight curing unit (bluephaseC8, IvoclarVivadent). The accuracy of light output was checked using a radiometer. Resin composite (Grandia. Voco, Germany) was filled into a cylinder-shaped plastic mold with an internal diameter of 3 mm and a height of 2 mm. Upon filling, the mold was placed on the prepared surface of the sample and the composite was condensed. Then, molds were light cured for 20 seconds from top and the lateral sides.

In groups 2, 4, 6 and 8, after storage time, RMGI (Ionolux, Voco, Germany) powder was mixed with specific liquid on a glass slab with a plastic spatula, placed in plastic molds and light-cured for 40 sec. Samples were storedat 37°C for 24 hours to simulate the oral condition.

3. Shear Bond Strength Measurement

The shear bond strength of the samples was measured using a universal testing machine (Z050, Zwick/Roell, Ulm, Germany). A force of 1.0 mm/min was applied to the samples using the knife-edge blade of the machine. Shear bond strength was measured in MPa by dividing the highest amount of force to the surface area of the samples.

All samples were observed under stereomicroscope at ×40 magnification to determine the mode of bond failure as adhesive, cohesive or mixed.

To evaluate the effect of acid etching on pulp cap materials, we prepared three samples of both MTA and BC RRM. One sample of each material was not etched after setting, one sample was etched by 35% phosphoric acid immediately after recommended setting time (15 min for MTA and 20 min for BC RRM) and one sample was etched after 24 hours following material placement. Then analysis of the surface elemental composition of each material prior and after etching was done using X-ray energy dispersive analysis (EDX).

4. Statistical analysis

Three-way ANOVA and two-way ANOVA were used to determine the effect of the pulp cap materials, restorative materials and time on shear bonding strength. To compare the bond strength based on each different variable, T-test was used.Statistical significance was set at $\alpha<0.05$.

RESULTS

The results of three way ANOVA and two way ANOVA showed no interaction between pulp cap materials, restorative materials and time on shear bonding strength ($p < 0.05$).

Table 1 demonstrates mean shear bond strength of the studied samples. In both MTA and BC RRM groups, the mean shear bond strength of composite to pulp cap materials was significantly higher than RMGI at both time intervals ($p < 0.001$).In MTA groups, there was no statistically significant difference between two time intervals (15 minutes and 24 hours) in bond strength of pulp cap material to composite ($p = 0.98$) and RMGI ($p = 0.32$). In BC RRM groups, the difference between two time intervals (20 minutes and 24 hours) in bond strength of pulp cap material to composite ($p = 0.89$) and RMGI ($p =$

0.73) was not also significant. The results of our study revealed that the bond strength of composite to MTA and BC RRM was not significantly different at recommended setting time (p = 0.81) or after 24 hours (p = 0.65). It was also shown that the bond strength of RMGI to BC RRM was significantly higher than MTA at recommended setting time (p = 0.002), however the difference between two pulp cap materials after 24 hours was not significant (p = 0.08).

Table 1. Mean shear bond strength of studied samples in MPa

Pulp cap material	Restorative material	Time	Bond Strength (mean ± SD)
MTA	Composite	15 min	18.48 ± 1.82
		24 hrs	18.5 ± 1.53
	RMGI	15 min	4.65 ± 0.96
		24 hrs	5.09 ± 0.96
BC RRM	Composite	20 min	18.7 ± 2.09
		24 hrs	18.81 ± 1.49
	RMGI	20 min	6.14 ± 0.85
		24 hrs	5.98 ± 1.2

Inspection of samples under stereomicroscope revealed that all the failures in composite groups were cohesive (inside the pulp cap material), but the failures in RMGI groups were predominantly adhesive (between RMGI and pulp capping material).

EDX analysis

For MTA Angelus samples, EDX analysis showed Carbon, Oxygen, Silicon, Calcium, Strontium and bismuth. For BC RRM samples, the analysis showed Carbon, Oxygen, Silicon, Calcium, Zirconium and Tungsten. There were no considerable changes in surface elemental composition of both pulp capping materials prior and after etching by phosphoric acid (table 2 and 3).

Table 2. Elemental composition of MTA Angelus obtained by X-ray energy dispersive analysis (EDX) in atomic concentration

	without etching	etching after 15 minutes	etching after 24 hours
Carbon	19.53	18.96	20
Oxygen	60.39	60.71	60.65
Silicon	0.72	0.78	0.69
Calcium	18.86	19.01	18.1
Strontium	0.38	0.38	0.44
Bismuth	0.12	0.16	0.12

Table 3. Elemental composition of BC RRM obtained by X-ray energy dispersive analysis (EDX) in atomic concentration

	without etching	etching after 20 minutes	etching after 24 hours
Carbon	16.48	17.52	14.85
Oxygen	58.55	58.72	61.81
Silicon	0.59	0.64	0.59
Calcium	24.03	22.74	22.6
Zirconium	0.26	0.28	0.35
Tungsten	0.09	0.1	0.07

DISCUSSION

We designed the present study to evaluate and compare the shear bond strength of RMGI and resin composite to MTA and BC RRM. Inrestorative procedures that involve a pulp exposure, conservative treatment modalities such as pulp capping should be used to preserve pulp vitality by using biocompatible products as a strong barrier against bacterial microleakage(1).Preserving pulpal health and

proper seal during this procedure is essential. MTA is the most popular pulp capping agent. However, other biocompatible materials such as BioCeramics have gained attention recently.

After pulp capping, tooth should be restored and often resin composites are the first choice especially in the esthetic zone. However, incases with insufficient enamel around preparation, RMGI can be used as an alternative restorative material.The bond between pulp capping agents and resin composite or RMGI plays an important role in sealing properties of the restoration and finally in the treatment prognosis(17). Therefore, bond strengths of RMGI and composite to MTA and BC-RRM surfaces were investigated in the present study.

In our study, the mean shear bond strength of composite to pulp cap materials was significantly higher than RMGI at both time intervals ($p < 0.001$). This result is in accordance with Ajami et al (18) who reported a significantly higher shear bond strength of resin composite compared to RMGI to MTA. The higher shear bond strength of composite to pulp capping materials can be due to the fact that the 35% phosphoric acid provides a clean surface and creates a honey comb pattern on the samples, increasing micromechanical bond, hence high bond strength as a result of micromechanical bond to composite(18).In a previous study the effect of acid etching procedure on physical properties of MTA has also been studied with scanning electron microscopy demonstrating that during etching,superficial gel-like amorphous structures and needle-shaped crystals that were seen in non-etched samples were removed. This selective removal of matrix from around of crystals withoutsubstantial loss of MTA cementduring etching procedureleads to a relatively uniform honeycomb pattern that provides desirable surface for bonding of resin materials (19).The lower bond strength in RMGI samples could be due to lack of etching by phosphoric acid with regards to the surface preparation and creating the honeycomb pattern. The bond between RMGI and the tested pulp capping materials must be mostly chemical, with insignificant effect of micromechanical bonding.

The results of EDX analysis in our study showed that there were no considerable changes in surface elemental composition of MTA and BC RRM prior and after etching by phosphoric acid, therefore the resin composite restoration could be placed over MTA or BC RRM without any concern about adverse effect of acid etching on surface composition of pulp capping materials.

Bond strength values ranging from 17 to 20MPa may be required to resist contraction forces and produce gap-free restoration margins(20-22).Our results demonstrated that all the samples in resin composite groups reached the optimal shear bond to pulp capping agents while the samples in RMGI groups failed to reach to the optimum.

Placement of restoration as soon as possible after pulp capping is recommended provide an effective seal, which is essential for success of the treatment. In our study there was no significant difference between two time intervals in shear bond strength of restorative materials to either MTA or BC-RRM. This result is in accordance with the results of the EDX analysis which showed that there were no considerable changes in surface elemental composition of BC RRM and MTA following etching procedure by phosphoric acid after recommended setting time or after 24 hours. This result is important because it provides the possibility to complete the final restoration in a single visit after placement of either MTA or BC RRM.This result is in accordance with Yesilyurt et al (23) who reported no significant difference between bond strength of GI cement to MTA that had set for 45 minutes versus 72 hours.

Based on the results of our study the bond strength of composite to MTA and BC RRM was not significantly different at recommended setting time or after 24 hours. In RMGI groups however the bond strength of restorative material to BC RRM was significantly higher than MTA at recommended setting time; after 24 hours the bond strength to BC-RRM was still higher than MTA however the difference was not significant

(p = 0.08). Considering the chemical bonding between RMGI and pulp capping materials, this difference between MTA and BC-RRM might be because of difference in chemical composition of these two materials which makes the chemical bonding between BC-RRM and RMGI stronger. Since the bonding between resin composite and pulp capping material is micromechanical, the difference in chemical composition does not affect the bonding procedure and shear bond strength of MTA and BC-RRM to composite was not significantly different.

In the current study, all the failures in composite groups were cohesive inside the pulp cap material. This can imply that the bond strength to composite is higher than the cohesive strengths of the pulp cap materials.The failures of RMGI groups in our study were predominantly adhesive. It can be inferred that the bond strength between RMGI and substrate was lower than the cohesive strength of the materials. In line with this observation, previous research (18) has shown that almost all failures between resin composite and MTA and also two other pulp cap materials were of cohesive type, while type of the failures were mostly adhesive between RMGI and substrates.

We suggest future studies to focus on the effect of different bonding systems on shear bond strength of composite resin to these pulp cap materials. We also suggest further studies to assess the need for acid etching for bonding of composite to either MTA or BC RRM.Further studies assessing the effect of acid etching on physical properties of BC RRM is also recommended.

CONCLUSION

Based on the results of this experimental study, it can be concluded that shear bond strengths between composite and pulp cap materials (MTA and BC RRM) were significantly higher than those of RMGI. The shear bond strength of RMGI to BC RRM was higher than MTA at recommended setting time, however the difference was not significant after 24 hours.

ACKNOWLEDGEMENTS

The authors would like to thank the Dental Material Research Center of Babol University of Medical Sciences for the time and material supplements for the laboratory procedures.

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