ORIGINAL RESEARCH

Comparative Evaluation of Shear Bond Strength of Resin-modified Glass Ionomer Cement with ProRoot MTA and MTA Angelus

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Abstract

Aim: The aim of the present study was to evaluate the shear bond strength of resin-modified glass ionomer cement with two different types of mineral trioxide aggregate at different time intervals.

Materials and methods: A total of 80 cylindrical blocks were prepared using a self-cure acrylic resin with a central cavity of 4 mm internal diameter and 2 mm height. The prepared samples were randomly divided into two groups ($n = 40$ each) according to the type of MTA cements used (ProRoot MTA and MTA Angelus). Two groups were further sub-divided into four sub-groups of 10 samples each according to the different time intervals. ProRoot MTA and MTA Angelus were placed in the prepared cavity and a wet cotton pellet was placed over the filled cavity. A hollow plastic tube was placed over the MTA surface and resin-modified glass ionomer cement (RMGIC) was placed into the hollow plastic tube and light-cured (Spectrum 800, Dentsply Caulk Milford, DE, USA) according to the time intervals decided. After light curing the plastic tubes were removed carefully and the specimens were stored at 37°C and 100% humidity for 24 hours to encourage setting of MTA. The specimens were mounted in a universal testing machine (ADMET) and a crosshead speed of 0.5 mm/min was applied to each specimen by using a knife-edge blade until the bond between the MTA and RMGIC failed. The data were statistically analyzed using ANOVA, *post hoc* Tukey's *t*-test and Fisher's *t*-test and p-value ≤ 0.5 was considered significant.

Results: For both ProRoot MTA and MTA Angelus there was no statistically significant difference between 45 minutes and 24 hours (p-value ≥ 0.8). For ProRoot MTA, shear bond strength value at 10 minutes were significantly lower than 45 minutes and 24 hours group. However, for MTA Angelus, shear bond strength value at 10 minute was not significantly different from 45 minutes group (p-value ≥ 0.3). For both ProRoot MTA and MTA Angelus shear bond strength value at 0 minute were the least and were significantly lower than 10 minutes, 45 minutes, and 24 hours, respectively (p-value ≥ 0.000).

Conclusion: Resin-modified glass ionomer cement can be layered over MTA Angelus after it is allowed to set for 10 minutes. However, ProRoot MTA should be allowed to set for at least 45 minutes before the placement of RMGIC to achieve better shear bond strength.

Clinical significance: Due to the variety of types of mineral trioxide aggregate cements available in dentistry, it is justifiable to emphasize on different time intervals as it may affect the shear bond strength of restorative cements. Such information is pivotal for the clinicians while using mineral aggregate-based cements that receive forces from the condensation of restorative materials or occlusion, as the compressive strength may be affected due to different time intervals.

Keywords: MTA Angelus, ProRoot MTA, Resin-modified glass ionomer cement, Shear bond strength, Universal testing machine.

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Introduction

Mineral trioxide aggregate (MTA) was first described in the dental scientific literature in 1993 and was given approval for endodontic use by the US Food and Drug Administration in 1998.[1] Till 2002, only gray-colored MTA was available, white mineral trioxide aggregate (WMTA) was introduced to address the esthetic concerns.[2] Since then, WMTA has become gold standard for many endodontic procedures, such as direct pulp capping, pulpotomy, sealing of perforations, and root-end filling after root-end resection.[1,3]

The original formulation of WMTA is manufactured by Dentsply (Dentsply Tulsa Dental Johnson City, TN, USA) and consists of approximately 75 wt% Portland cement, 20 wt% bismuth oxide, and 5 wt% calcium sulfate dihydrate or gypsum. When these components are blended, they produce a mixture of tricalcium aluminate, dicalcium silicate, tricalcium silicate, tetracalcium aluminoferrite, and bismuth oxide. Bismuth oxide is added to the cement as a radiopacifier for dental radiological diagnosis.

Despite its sealing ability and biocompatibility, the prolonged setting time and difficult handling properties of WMTA is one of the

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major drawbacks of its use. The mean setting time of ProRoot MTA is 165 ± 5 minutes, and this behavior is one of the reasons that MTA cannot be applied in a single visit.[4] MTA Angelus (AMTA) (Angelus, Londrina, PR, Brazil) has been introduced as an alternative to WMTA to overcome its prolonged setting time. AMTA is composed of 80% PC and 20% bismuth oxide. In an attempt to reduce the setting time, AMTA eliminates the dehydrated calcium sulfate from the material's composition, and the setting time for AMTA is 14.28 ± 0.49 minutes, which is much lower than WMTA on the basis of previous studies.[5] The literature shows that the physical properties and biocompatibility of WMTA and AMTA are not different significantly, but they differ in setting time and particle size range.[6] A recent study of the particle size of ProRoot MTA revealed a bimodal distribution with 10% of particles below (d10) 1.13 mm, 50% of particles below (d50) 1.99 mm, and 90% of particles below (d90) 4.30 mm. By comparison, MTA Angelus showed a bimodal distribution with much larger particle sizes overall, with the d10 at 4.15 mm, d50 at 12.72 mm, and d90 at 42.66 mm.[7]

Mineral trioxide aggregate used in recently traumatic pulp exposure, perforation, and vital pulp therapy are covered with glass ionomer cement and composite resin immediately. Therefore, the interaction between the MTA and the restorative material may be equally crucial at the junction between the MTA and the dentin. However, the potential of restorative materials to attach to the MTA is not well known. The effect of various restorative procedures on the chemical and mechanical characteristics of MTA and the appropriate time of restoration after MTA placement are issues that have not been evaluated adequately.[8]

Previously ProRoot MTA has shown the lowest shear bond strength to glass ionomer cement and composite resin.[9] The shear bond strength increased up to 5 MPa after 2 weeks. An increase of the shear bond strength values over time was reported which range from 3.03 ± 1.28 MPa after 2 days and between 4.75 ± 1.71 MPa up to 9.0 ± 0.9 MPa after 7 days.[10] The different results of ProRoot MTA may be explained by the different particle size, which affects the penetration of cement into dentinal tubules in tag-like structures leading to a micromechanical anchor. ProRoot MTA has shown that calcium and silicon uptake into dentine leading the formation of tag-like structures.[11]

The effect of surface conditioning on WMTA materials is a fundamental issue for the durability and effectiveness of the composite. Previous studies have demonstrated that conventional glass ionomer cement can be applied over partially set MTA for a single-visit operation with no adverse effects on the MTA's setting.[12] Thus, despite good sealing ability and biocompatibility of MTA, its prolonged maturation process and limited information about the effect of placement time of final restoration on MTA is a major disadvantage and requires consideration in clinical use. Therefore, it seems necessary to evaluate the shear bond strength of resin-modified glass ionomer cement with ProRoot MTA and MTA Angelus at different time intervals of 0, 10, 45 minutes and 24 hours.

MATERIALS AND METHODS

The present *in vitro* study was conducted in the Department of Conservative Dentistry and Endodontics, Ghaziabad, Uttar Pradesh, and institute ethical clearance was obtained prior to the study with number IDST/IERBC/2015-18/13 and was conducted from April 2016 to March 2017 (12 months). Sample size was calculated using G power software with the help of mean and standard deviation obtained from the literature.

Source of support: Nil
Conflict of interest: None

Sample Fabrication

A total of 80 cylindrical blocks having a diameter and a height of 2.5 cm were prepared using a self-cure acrylic resin. A central cavity of 4 mm internal diameter and 2 mm height were prepared in the center of the blocks using an acrylic trimmer. The prepared samples were randomly divided into two groups (*n* = 40 each), group I as ProRoot MTA (PR) and group II as MTA Angelus (MA). Two groups were further sub-divided into four sub-groups of 10 samples each according to the different time intervals, that is, sub-group I-A and II-A at zero minute, sub-group I-B and II-B at 10 minutes, sub-group I-C and II-C at 45 minutes, sub-group I-D and II-D at 24 hours.

Group I-A (PR 0 m): ProRoot MTA was mixed with distilled water according to the manufacturer's instruction and placed in the prepared cavity with plastic filling instrument. A plugger was used to condense the MTA and a wet cotton pellet was placed over the filled cavity. A hollow plastic tube having an internal diameter of 3 mm and a height of 3 mm was placed over the WMTA surface. Resin-modified glass ionomer cement (RMGIC) was mixed according to the manufacturer's instruction and placed immediately into the hollow plastic tube and light-cured (Spectrum 800, Dentsply Caulk, Milford, DE, USA). After light-curing, the plastic tubes were removed carefully and the specimens were stored at 37°C and 100% humidity for 24 hours to encourage the setting of WMTA. Similar procedures were performed using MTA Angelus for group II-A (MA 0 m).

Group I-B (PR 10 m): ProRoot MTA was allowed to set for 10 minutes in a wet condition, respectively. The WMTA surfaces were covered with a wet cotton pellet and a temporary filling (Dentemp, Waldent Alchem, Vasa Denticity Pvt. Ltd, Gurgaon, Haryana, India). Temporary filling and cotton pellets were removed after an interval of 10 minutes using a sharp excavator without touching the WMTA surface and the surface was neither rinsed nor polished. Resin-modified glass ionomer cement was mixed according to the manufacturer's instruction and placed into the hollow plastic tube and light-cured. After light curing, the plastic tubes were removed carefully and the specimens were stored at 37°C and 100% humidity for 24 hours to encourage the setting of WMTA. Similar procedures were performed at different time intervals for group I-C (PR 45 m), group I-D (PR 24 h), and for group II-B (MA 10 m), group II-C (MA 45 m), group II-D (MA 24 h) using MTA Angelus.

Shear Bond Strength Measurement

A single investigator mounted the specimens in a universal testing machine (ADMET Inc, Norwood, USA). A crosshead speed of 0.5 mm/min was applied to each specimen by using a knife-edge blade until the bond between the MTA and RMGIC failed. The values were calculated in newtons and converted into megapascals (MPa) by dividing the peak load at failure with the specimen surface area.

Statistical Analysis

The data was analyzed with IBM SPSS (SPSS Inc, Chicago, version 23.0) using ANOVA One factor analysis followed by *post hoc* analyses using Tukey's *t*-test and to compare the different sub-groups Fisher's *t*-test was used. A significant level of ≤0.05 was considered for the probability value.

RESULTS

Table 1 presents the mean square using one-way ANOVA test in between group and within group of ProRoot MTA with frequency of 171.4 and MTA Angelus with frequency 150.1 that was highly significant ($p < 0.000$).

Table 2 presents the inter-group comparison using *post hoc* analysis using Tukey's test for ProRoot MTA and MTA Angelus in which there was no statistical difference at 45 minutes and 24 hours (for PR 45 m and PR 24 h $p = 0.837$), (for MA 45 m and MA 10 m = 0.304), (for MA 45 m and MA 24 h $p = 0.511$). For WMTA shear bond strength, the value at 10 minutes were significantly lower at 45 minutes and 24 hours group ($p = 0.000$). However, for MTA Angelus shear bond strength value at 10 minute was not significantly different from 45 minutes group. ($p = 0.304$). For both WMTA and AMTA shear bond strength value at 0 minute were the least and were significantly lower than 10 minutes, 45 minutes, and 24 hours. ($p = 0.000$).

Table 3 presents the inter-group comparisons using Fisher's *t*-test in which significant values for both WMTA and AMTA was not observed between (PR 0 m – MA 0 m, *p*-value = 0.236), (PR 45 m – MA 10 m, *p*-value = 0.254), (PR 45 m – MA 45 m, *p*-value = 0.495), (PR 24 h – MA 45 m, *p*-value = 1.0), (PR 24 h – MA 24 m, *p*-value = 0.139) groups, whereas it was highly significant for remaining different time intervals.

Table 1: The mean square in between group and within group of Pro Root MTA and MTA Angelus using one-way ANOVA

ProRoot MTA	*Sum of squares*	*Df*	*Mean square*	*F*	*Sig.*
Between groups	354.041	3	118.014	171.462	0.000
Within groups	24.778	36	0.688		
Total	378.819	39			
MTA Angelus					
Between groups	363.089	3	121.030	150.179	0.000
Within groups	29.012	36	0.806		
Total	392.101	39			

Inference of Results

For both ProRoot MTA and MTA Angelus there was no statistically significant difference between 45 minutes and 24 hours. For ProRoot MTA, shear bond strength value at 10 minutes were significantly lower than 45 minutes and 24 hours group. However, for MTA Angelus, shear bond strength value at 10 minute was not significantly different from 45 minutes group. For both ProRoot MTA and MTA Angelus shear bond strength value at 0 minute were the least and were significantly lower than 10 minutes, 45 minutes, and 24 hours, respectively.

DISCUSSION

Mineral trioxide aggregate is a hydraulic type of cement that sets by reacting with water and is then stable in water. The two most

Table 2: Multiple comparisons using *post hoc* analysis using Tukey's *t*-test for ProRoot MTA and MTA Angelus group

					95% Confidence interval	
(I) Interval	*(J) Interval*	*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
(PR 0 m)	(PR 10 m)	−3.33000*	0.37102	0.000	−4.3292	−2.3308
	(PR 45 m)	−6.97000*	0.37102	0.000	−7.9692	−5.9708
	(PR 24 h)	−7.28000*	0.37102	0.000	−8.2792	−6.2808
(PR 10 m)	(PR 0 m)	3.33000*	0.37102	0.000	2.3308	4.3292
	(PR 45 m)	−3.64000*	0.37102	0.000	−4.6392	−2.6408
	(PR 24 h)	−3.95000*	0.37102	0.000	−4.9492	−2.9508
(PR 45 m)	(PR 0 m)	6.97000*	0.37102	0.000	5.9708	7.9692
	(PR 10 m)	3.64000*	0.37102	0.000	2.6408	4.6392
	(PR 24 h)	−0.31000	0.37102	0.837	−1.3092	0.6892
(PR 24 h)	(PR 0 m)	7.28000*	0.37102	0.000	6.2808	8.2792
	(PR 10 m)	3.95000*	0.37102	0.000	2.9508	4.9492
	(PR 45 m)	0.31000	0.37102	0.837	−0.6892	1.3092
(MA 0 m)	(MA 10 m)	−6.21900*	0.40147	0.000	−7.3003	−5.1377
	(MA 45 m)	−6.93000*	0.40147	0.000	−8.0113	−5.8487
	(MA 24 h)	−7.49000*	0.40147	0.000	−8.5713	−6.4087
(MA 10 m)	(MA 0 m)	6.21900*	0.40147	0.000	5.1377	7.3003
	(MA 45 m)	−0.71100	0.40147	0.304	−1.7923	0.3703
	(MA 24 h)	−1.27100*	0.40147	0.016	−2.3523	−0.1897
(MA 45 m)	(MA 0 m)	6.93000*	0.40147	0.000	5.8487	8.0113
	(MA 10 m)	0.71100	0.40147	0.304	−0.3703	1.7923
	(MA 24 h)	−0.56000	0.40147	0.511	−1.6413	0.5213
(MA 24 h)	(MA 0 m)	7.49000*	0.40147	0.000	6.4087	8.5713
	(MA 10 m)	1.27100*	0.40147	0.016	0.1897	2.3523
	(MA 45 m)	0.56000	0.40147	0.511	−0.5213	1.6413

*The mean difference is significant at the 0.05 level

Table 3: Inter-group comparisons showing p-values using Fisher's t-test at a significance level of $p < 0.05$

Groups	*p-value*	*Observation*
PR 0 m – MA 0 m	0.2369	PR 0 m < MA 0 m
PR 0 m – MA 10 m	0.0000	PR 0 m < MA 10 m
PR 0 m – MA 45 m	0.0000	PR 0 m < MA 45 m
PR 0 m – MA 24 h	0.0000	PR 0 m < MA 24 h
PR 10 m – MA 0 m	0.0000	PR 10 m > MA 0 m
PR 10 m – MA 10 m	0.0000	PR 10 m < MA 10 m
PR 10 m – MA 45 m	0.0000	PR 10 m < MA 45 m
PR 10 m – MA 24 h	0.0000	PR 10 m < MA 24 h
PR 45 m – MA 0 m	0.0000	PR 45 m > MA 0 m
PR 45 m – MA 10 m	0.2543	PR 45 m = MA 10 m
PR 45 m – MA 45 m	0.4952	PR 45 m = MA 45 m
PR 45 m – MA 24 h	0.0322	PR 45 m < MA 24 h
PR 24 h – MA 0 m	0.0000	PR 24 h > MA 0 m
PR 24 h – MA 10 m	0.0416	PR 24 h > MA 10 m
PR 24 h – MA 45 m	1.0000	PR 24 h = MA 45 m
PR 24 h – MA 24 h	0.1398	PR 24 h = MA 24 h

important hydration reactions are those of tricalcium silicate and dicalcium silicate.[13,14] Calcium silicate hydrates and calcium hydroxide are the major products, while the calcium hydroxide is mostly crystalline and able to be detected using X-ray diffraction, the calcium silicate hydrates are primarily amorphous and may exhibit a range of compositions.[15,16] After all of the gypsum is consumed, the tricalcium aluminate reacts with ettringite to form monosulfates.[13,14]

Mineral trioxide aggregate directions for use state that it will set over a period of 4 hours and it should be given a working duration of 5 minutes. Alternatively, the setting time of MTA has been quoted by different researchers as 50 minutes, 65 minutes, 140 minutes, 150 minutes, and 250 minutes.[13,17] Gray AMTA has a smaller bismuth oxide and magnesium phosphate content than gray ProRoot MTA, but a greater calcium carbonate, calcium silicate, and barium zinc phosphate content. Additionally, AMTA has a lower carbon, oxygen, and silica content than gray ProRoot MTA, but a higher calcium content. Additionally, AMTA displayed the absence of iron and the presence of aluminum, as opposed to gray ProRoot MTA, which exhibited the opposite.[5,12,13,18]

The amount of aluminum oxide in AMTA was reported to be more than twice as high that in white ProRoot MTA.[19] De-Deus et al. and Shahi et al. have shown that both gray ProRoot MTA and gray AMTA had a below the limit amount of arsenic in their compositions, whereas the white ProRoot MTA and white AMTA had a higher than permitted amount of arsenic in their compositions.[11,20] In synthetic bodily fluid, AMTA released a lot less chromium than ProRoot MTA.[21]

Some of the physical properties of AMTA, such as setting time and range of particles, are different from those of ProRoot MTA.[22] However, the latter material showed higher alkalinity up to 168 hours after mixing. The amount of calcium ions released in gray AMTA is higher than that in white AMTA up to 72 hours after mixing.[23] White AMTA showed an alkaline pH, lower calcium ion release, as well as lower initial and final setting time compared with PC.[24] According to the manufacturers of AMTA, the absence of dehydrated calcium sulfate lowers the material setting time to 10 minutes. The setting time of AMTA (14.28 ± 0.49 min) is lower than white and gray ProRoot MTA.[25]

Permanent restoration is required following the placement of MTA. Therefore, the bonding between the permanent restoration and MTA has an important role in the quality of filling and treatment outcome. The most used method for the evaluation of adhesive properties of restorative material is the bond strength test. Therefore, shear bond strength test is used in the present study to evaluate the adhesive properties of WMTA and AMTA with RMGIC. Kayahan et al. and Candan et al. evaluated the effect of acid-etching procedures on the physical properties of WMTA and found that acidic surface treatment changed the surface morphology of WMTA.[26,27] The nature of the solvent and the filler content of the adhesive may also influence the bond strength of WMTA to restorative material.[28] Atabek et al. reported that the conditioning procedure and restorative procedure should be postponed from 24 hours to 96 hours after mixing WMTA to allow the material to achieve its optimum physical properties.[2,29] Chang and Alqahtani et al. reported the quality of crystals which is a reaction product of hydrated WMTA was poor in acidic pH compared with alkaline pH.[30,31]

Balla et al., Nandini et al., and Ansari et al. reported that glass ionomer cement layered over the setting WMTA did not affect its further setting, and the calcium salts formed at the interface were restricted to the interface only.[32–34] Kazemipoor et al. and Yesilyurt et al. reported that glass ionomer cement can be placed over WMTA after it is allowed to set for 45 minutes to allow single sitting procedures which was similar to the findings of the current study.[8,35] However, Patil et al. and Eid et al. reported that GIC can be applied over freshly mixed WMTA which seems to decrease with time which was in contrast to the findings of the present study.[13,36]

In the current study, the shear bond strength of WMTA and AMTA with RMGIC was highest for the 24 hours groups and was least for the zero-minute groups. For both WMTA and AMTA there was no significant difference between the 24 hours groups and 45 minutes groups. At the interface, it may be assumed that the COO^- of polyacrylic acid could interact with the calcium of MTA to form calcium salts or the silicate hydrated gel and MTA can condense with the silicate hydrate gel of GIC to form by products. Nandini used laser Raman spectroscopy and established the point that the time intervals at which GIC was layered over MTA did not affect the formation of calcium salts at the interface, and therefore, GIC can be layered over MTA after 45 minutes and does not affect further setting of MTA.[13,33] Kazemipoor et al. and Balla concluded that GIC might be layered over partially set MTA after 45 minutes to enable the clinician to place a permanent restoration in a single-visit procedure which was similar with the findings of the present study.[8,32] Recently, Yesilyurt et al. concluded that there was no significant difference between the two tested groups, that is, 45 minutes and 24 hours in their study and after MTA has been set up for 45 minutes, GIC may be used alternatively which was similar with the findings of the current study.[35]

Significantly lower bond strength was observed in the present study at 10 minutes interval for WMTA. However, for AMTA, significantly higher bond strength values were observed at 10 minutes interval than WMTA. The difference in values may be attributed to the difference in the setting time and compositional difference between both materials. As the setting time of AMTA is 14 minutes, it may have partially set at 10 minutes interval. So, there would be less interference with hydration reaction in the case of AMTA when RMGIC is subsequently placed over it.

At zero minute, the shear bond strength of both AMTA and WMTA was significantly lower than the 10 minutes, 45 minutes, and 24 hours groups. However, according to previous studies, the effect of GIC placement immediately over unset WMTA was transient.[31,36] They stated that RMGIC can be successfully applied on freshly mixed WMTA in a single visit with no expected adverse reaction between the two materials. Nandini et al. also stated that the interaction of calcium salts, at the interface is similar to the interaction of GIC with the tooth structure and does not hamper the setting of GIC.[33] This approach has gained widespread acceptance as a reliable way to examine a significant aspect of a material's *in vitro* performance, so the shear bond strength test has been used in the present study to evaluate the adhesive properties of RMGIC to MTA.[37]

Placement of a definitive restoration after WMTA application requires two visits as per the manufacturer's instruction since WMTA takes 2 hours and 45 minutes to set. The findings of the current study confirmed the previous outcomes regarding placement of RMGIC over unset or partially set MTA. More research should be conducted to investigate how to improve the shear bond strength of RMGIC as an immediate restoration and the possibility of using bonding agents with RMGI to improve its bond strength. Moreover, the clinical performance of RMGIC and MTA should be investigated on larger sample size.

CONCLUSION

Within the limitation of the present study, it can be concluded that shear bond strength value of RMGIC was higher when it was layered over MTA Angelus after it was allowed to set for 10 minutes. However, the shear bond strength value of RMGIC was higher for ProRoot MTA only after when it was allowed to set for at least 45 minutes before the placement of RMGIC.

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