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The Evaluation of Shear Bond Strength of Different Restorative Composite Resins and Glass Ionomer Cement to White Mineral Trioxide Aggregate: An in Vitro Study

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ABSTRACT

Aim: The aim of this study is to evaluate & compare the shear bond strength of different restorative composite resins and glass ionomer to white mineral trioxide aggregate.

Method: Forty specimens of White MTA were condensed into cavities prepared in acrylic blocks and divided into four groups (ten each). In group one, Adper single bond (two-step 'total- etch adhesive') bonding agent and Z250 composite, in group two Xeno V one component self-etching adhesive bonding agent and CeramX Mono composite, in group three Vertise flow flowable composite and in group four Glass ionomer cement were placed over White MTA. The shear bond strength was measured in the universal testing machine and the results were analyzed by one-way analysis of variance test.

Result: Adper single bond 2 and Z250 composite had higher shear bond strength values than Xeno V and Ceram.X Mono composite, Vertise flow, GIC and the difference was statistically significant ($p<0.05$).

Conclusion: The placement of composite Z250, used with Adper single bond, over White MTA as final restoration may be appropriate. Because of the variations in the composition and properties of different dentin adhesives and resin composites, different results were obtained. Further investigations with different materials, different combinations and larger sample size are required.

Keywords: Adper single bond, Z250, Xeno V, Ceram.X Mono, Vertise flow, Glass ionomer cement, Shear bond strength.

INTRODUCTION

Dental pulp is the living 'heart' of the tooth and its preservation is paramount in conservative dentistry. The consequences of pulp exposure from caries, trauma or operative misadventure can be significant, often requiring either root canal therapy or extraction of the tooth. An alternative to these procedures is pulp capping, which involves the placement of a medicament over an exposed pulp or residual caries, with the intention of maintaining pulp vitality. Few of the recent materials which were tried as direct pulp capping agents are Mineral Trioxide Aggregate (MTA), bonding agents and bioglass. [1]MTA is a biocompatible material and consists of fine hydrophilic particles that set even in the presence of moisture. [2] MTA requires longer setting time and exact time taken to set varies between different studies. According to Torabinejad and colleagues[3] the setting time of grey mineral

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trioxide aggregate is 2 hours and 45 minutes (±5 minutes). [4] To overcome this disadvantage, recently White MTA has become commercially available as White MTA Angelus with a final setting time of 15 minutes. When used as a pulp capping material, MTA requires additional visits because of its long setting time. To complete the final restoration in a single visit, a material that is compatible with MTA can be applied over partially set MTA. Therefore, it is important to identify materials that can be applied over MTA that can allow for immediate final restoration placement. The material that would be placed over MTA as final restoration is an important factor for long term adhesion of restorative materials to White MTA.

The concept of adhesive restoration has been essentially the most noteworthy development in ever progressing science.[5] Composite resins have been widely used as final restorative materials because of their superior physical properties. Three mechanisms of adhesion are currently in use with modern adhesives. The most valid way to evaluate the quality and efficacy of adhesion of materials is doing controlled clinical trials. [6]Adequate shear bond strength is required to resist contraction forces sufficiently to produce gap-free restoration margins. [7,8,9]

In this study White MTA (ANGELUS) was chosen as a direct pulp capping material on to which many different composite materials like Z 250, Ceram.X mono, Vertise Flow and Glass ionomer Cement were used in combinations with various different bonding agents like Adper single bond 2 and Xeno V or alone (Vertise flow and Glass ionomer cement).

The aim of the present study was to evaluate & compare the shear bond strengths of composites Z250 (3MESPE), Ceram.X-mono (DENTSPLY), Vertise Flow (KERR) and Glass ionomer cement (GC Fuji IX) restorative materials to White MTA (ANGELUS). Shear bond strength was tested using the universal testing machine. [7]

MATERIALS AND METHOD

This study was conducted to evaluate & compare the shear bond strength of different restorative Composite resins and Glass ionomer cement to White MTA. 40 acrylic blocks were prepared using aluminium tubes, having internal diameter 1 cm, 2.5 cm height and 1.2 cm width. When acrylic resin was in the dough stage, a calibrated steel rod was placed into the soft acrylic resin to create a standard cavity with dimensions of 6 mm diameter and 2 mm in height. Steel rod was removed upon setting of the acrylic resin. The depth of the cavity was confirmed using a periodontal probe. The same was repeated to prepare the rest of the samples.

White MTA was mixed according to the manufacturer's instructions in a 3:1 powder liquid ratio. The mixed white MTA was carried in an MTA gun and filled in each of the prepared acrylic blocks up to the entire depth of 2mm . The filled white MTA was then covered with a wet cotton pellet and a temporary filling material Cavit – G (3M ESPE). The specimens were then stored at 37^0C with 100% humidity in an incubator for 24 hours to simulate oral environment. The specimens were randomly divided into four groups of 10 specimens each.

GROUP A: A Two-step 'total-etch adhesive' (37% phosphoric acid, Adper Single Bond 2, and Z250 composite.

GROUP B: One component self-etching adhesive (Xeno V) and ceram.X mono composite .

GROUP C: Vertise flow (flowable composite).

GROUP D: Type IX GIC .

Bonding Procedure:

Group A: 10 blocks of Group A White MTA surface were etched for 15 seconds with 37% phosphoric acid etching gel rinsed with water for 10 seconds, and excess water was removed by blotting with absorbent paper. Over the etched White MTA surface, Adper single bond 2 adhesive was applied in 2 consecutive coats and light cured for 40 seconds. Composite resin(Z250) was placed and light cured with a QHL75 curing light for 40 seconds.

Group B: Over 10 blocks of Group B White MTA surface, Xeno V was applied in 2 consecutive coats and light cured for 10 seconds. The composite resin (Ceram.X Mono) was light cured with a QHL75 curing light for 40 seconds.

Table 1: Mean, SD and other summary statistics according to study groups (A,B,C and D) with respect to the shear bond strength values.

Groups	N	Mean	Std.Dev.	Coefficient of Variation
Group A (Z250)	10	13.12	0.88	6.71
Group B (CeramX)	10	11.05	0.94	8.51
Group C (Vertise flow)	10	11.03	0.95	8.61
Group D (GIC)	10	8.27	0.7	8.46

Table 2: Comparison of four groups (A, B, C and D) with respect to shear bond strength (in MPa) by one way ANOVA.

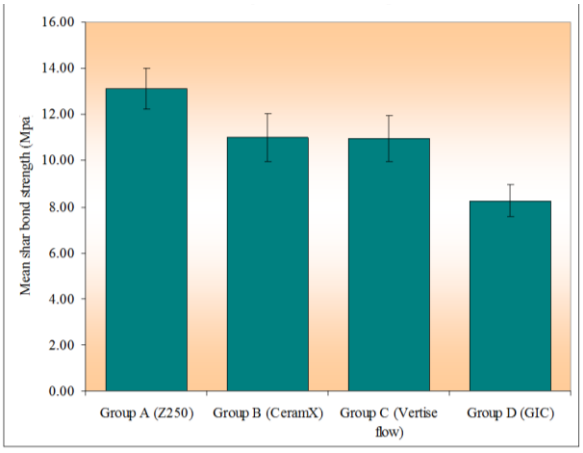
Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	P-value
Between age groups	3	118.5510	39.5170	47.4733	0.0000*
Within age groups	36	29.9666	0.8324		
Total	39	148.5176			

*p<0.05

Table 3: Pair wise comparison of four groups (A, B, C and D) with respect to shear bond strength (in MPa) by Scheffe's post hoc test.

Groups	Group A (Z250)	Group B (CeramX)	Group C (Vertise flow)	Group D (GIC)
Mean	13.12	11.05	11.03	8.27
Group A (Z250)	-			
Group B (CeramX)	0.0001*	-		
Group C (Vertise flow)	0.0001*	0.9999	-	
Group D (GIC)	0.0000*	0.0000*	0.0000*	-

*p<0.05



Graph 1: Comparision of four groups (Z250, CeramX, Vertice flow and GIC) with respect to shear bond strength.

Group C: Over the 10 blocks of Group C White MTA surface, flowable composite (Vertise Flow) was syringed and light cured with a QHL75 curing light for 40 seconds.

Group D: Over 10 blocks of Group D, 10% polyacrylic acid was used to condition White MTA surface. The glass ionomer cement mix was condensed and allow it to set for 2 minutes 20 seconds.

MECHANICAL TESTING FOR SHEAR BOND STRENGTH:

The specimens were secured in a holder placed on the platform of the universal testing machine. All the samples of Group A, B, C and D were assessed for shear bond strength. The shear bond strength in Mega Pascals (MPa) was calculated from the peak bond at failure divided by the specimen surface area using the formula:

$$\text{Shear bond strength} = \frac{\text{Load}}{\text{Area}} \text{ MPa}$$

This procedure was done for all the specimens. The data obtained was subjected to One way Analysis of Variance (ANOVA) and Scheffe's post hoc test.

RESULTS

From the results of the table1:

1. Group A had highest mean values as compared to Group B, C and D.
2. Group B had similar mean values as to that of Group C but higher than Group D and lower than Group A.
3. Group C had similar mean value as that of Group B but higher than Group D and lower than Group A.
4. Group D had the least mean values as compared to other three Groups.

From the results of table 2, it can be seen that the difference between four groups (A, B, C and D) is statistically significant with respect to shear bond strength ($F=47.4733$, $p<0.05$) at 5% level significance. It means that, the shear bond strength is significantly higher in Group A (Z250) followed by Group B (CeramX), Group C (Vertiseflow) and Group D (GIC).

Further, the pair wise comparison of four groups (A, B, C and D) with respect to shear bond strength by applying the Scheffe's post hoc test was used and the results are presented in the following table.

The table 3 shows the inter group comparison and the associated p values:

1. The Group A (Z250) and Group B (CeramX) differ significantly in their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is higher in Group A (Z250) as compared to Group B (CeramX) ($p<0.05$).
2. The Group A (Z250) and Group C (Vertise flow) differ significantly in their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is higher in Group A (Z250) as compared to Group C (Vertise flow) ($p<0.05$).
3. The Group A (Z250) and Group D (GIC) differ significantly in their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is higher in Group A (Z250) as compared to Group D (GIC) ($p<0.05$).
4. The Group B (CeramX) and Group C (Vertise flow) do not differ significantly with their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is similar in Group B (CeramX) and Group C (Vertise flow) ($p>0.05$).
5. The Group B (CeramX) and Group D (GIC) differ significantly in their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is higher in Group B (CeramX) as compared to Group D (GIC) ($p<0.05$).
6. The Group C (Vertise flow) and Group D (GIC) differ significantly in their shear bond strength at 5% level of significance. It means that, the mean shear bond strength is higher in Group C (Vertise flow) as compared to Group D (GIC) ($p<0.05$).

DISCUSSION

Exposure of the pulp can occur during caries excavation, deep cavity preparation, trauma etc. Maintaining the vitality of pulp by direct pulp capping procedure (vital pulp therapy) depends on the choice of pulp capping material, pre-existing inflammation of pulp and ability to obtain good coronal seal. An ideal pulp capping material should be nontoxic, non-carcinogenic, non-genotoxic, biocompatible with the host tissues, insoluble in tissue fluids and dimensionally stable. Furthermore, the presence of moisture should not affect its sealing ability; it should be easy to use and be radiopaque for recognition on radiographs. [8]

Clinical trials are the most valid way to evaluate the quality and efficacy of adhesion of materials. The most common method to evaluate adhesive properties of restorative materials is bond strength assessment. Therefore, shear bond strength test has been used in this study to evaluate

the adhesion between White MTA angelus and different composite materials such as Z250, Ceram.X Mono, Vertise Flow and Glass ionomer cement. It has been estimated that bond strength of 17 to 20 MPa may be required to resist contraction forces sufficiently to produce gap-free restoration margins. [7] When used for vital pulp therapy, Varghese et al. showed that MTA had more complete bridging and caused very little or no inflammation compared to the severe inflammation caused by calcium hydroxide. The authors concluded that MTA gives a more predictable and positive response in vital pulp therapy. [9] In the present study MTA was chosen as the direct pulp capping material, because MTA induces hard tissue formation and has dentinogenesis effect, due to its alkaline pH. Dentinogenic potential of the pulpal cells is favoured by the regulatory effect of pulp treated with MTA in production of osteocalcin, alkaline phosphatase and interleukin 6 & 8.[10]

Tziafas et al observed a homogeneous zone of crystalline structures that was initially found along the pulp-MTA interface, where as pulp cells, showing their cytologic and functional state, were arranged in close proximity to the crystals. In addition, the important role of the fibronectin- rich zone, which is formed on to crystalline structures has been observed along the pulpal side of MTA. [10]

Two-step etch and rinse adhesive or total-etch adhesive (Adper single bond 2) and Z250 composite are some of the most popular and commonly used adhesive-resin composite combinations. It is a total-etch moist bonding adhesive containing 10% of 5 nm colloidal filler. It has a wide range of applications that includes bonding of direct composite restorations, procedures involving porcelain, Bonded amalgam, root surface desensitization. [11] Hence they were chosen for testing as group A in this study. According to SEM evaluation by Lee et al(2004) [12] the surface morphology of MTA after acid etching procedure created a selective loss of matrix around crystalline structures that resulted in a uniform honey comb etched pattern without penetrating deeply or removing substantial amount of the cement.[13] The acids etch procedure created notable structures such as plate-shaped and laminated crystals on the MTA surface. This finding is in accordance with Namazikhah et al., although in their study MTA samples were exposed to butyric acid for 4 days and not the phosphoric acid of the present study. [13]

This differential etching pattern is an essential characteristic for achieving satisfactory bond to the resin restorations.[13] Accordingly, it would appear that the combined MTA-composite restoration could provide a reliable chemical bond to dentine, as well as have the potential for micromechanical bonding of the composite to MTA surfaces (Sarkar et al. 2005, Yan et al.2006, Tunc et al. 2008). [14,15,7] In this study it provided a good micro mechanical bonding with MTA with shear bond strength of 13.13 MPa which is comparatively higher than the other groups.

Two-step etch and rinse adhesive or total-etch adhesive (Adper single bond 2) and Z250 composite performed significantly better than one component self-etch adhesive (XenoV) and Ceram.X mono composite, a self adhering flowable composite Vertise flow and Glass ionomer cement.

In group B, one component self etching adhesive Xeno V containing etchant, primer, bonding agent (all in one bottle) with a P_H < 2 was used [5]. No separate etching and rinsing steps are needed; thus operating time and number of steps are decreased. Xeno V contains bifunctional acryl resin, alkyl sulfonic acid (etchant and wetting aid), acrylic acid, Camphorquinone (photoinitiator system), butylated benzenediol (stabilizes monomer during storage), water (solvent for the resins and etch promoter), tert-butanol (solvent for the resins and mild stabilizer).[16] One component self-etch adhesive Xeno V and Ceram.X mono composite fared worse than Group A. It had better bond strength values than that of Vertise flow; but the difference was not statistically significant.

In group C was used Vertise Flow which is a self adhering flowable composite. It contains GPDM (Glycerol phosphate dimethacrylate) resin monomer. Prepolymerized particles of barium glass filler (size 0.7 µm, 1 µm, 10 – 40 nm), nano sized colloidal silica and 40 nm nano sized Yetterbium fluoride constitute the fillers of Vertise flow. [17] In Vertise flow there is no separate bonding application step, thus simplifying the direct restorative procedure. For this reason, Vertise flow may be considered as the beginning of the 8th

generation of dental adhesive system. [63] According to the manufacturer the bonding mechanism is primarily based on the chemical bond between the phosphate functional group of GPDM monomer and calcium ions of the tooth. A micromechanical bond resulting from an interpenetrating network between Vertise Flow polymerized monomers and dentin collagen fibers also contributes to adhesion.[18]

The results of group A are consistent with Tunc et al and clinically significant with P value of (< 0.05) compared to the other 3 groups. In the present study the difference between different resin composites with different bonding systems. i.e., group A, group B, group C, group D are statistically significant with P value (< 0.05) when group A was compared to the other groups B, C, and D.

The group B has shown lower shear bond strength than group A and the strength of the bond is significant statistically ($p<0.05$) compared to group A. The lessened shear bond strength may be because of the resultant interfacial structure which is hydrophilic thus more prone to hydrolytic degradation. [19] The residual amount of adhesive solvent is present within the interfacial structure which will directly weaken the bond integrity. [19,20] The suboptimal performance of self-etching adhesives: (1) the combination of acidic hydrophilic and hydrophobic monomers into a single step may compromise polymerization of the adhesive, (2) the inherent low strength of the adhesive polymer, and (3) the lower degree of polymerization of the resin monomer because of a major solvent/oxygen inhibition effect during light activation of these materials. [21,22]

The self etching adhesives consists of adhesive resin, basically one or more carboxylic groups or phosphoric acid esters grafted over adhesive resin, hence they do not require a separate acid etching step. [23] They come under smear layer dissolving dentin bonding agents. This bonding agent needs to be investigated for long term stability of the bond between MTA and Xeno V. Although there is no smear layer dissolving action on MTA, the shallow etching could have contributed to weak bond between MTA – XenoV and Cerem.X Mono, thus responsible for low shear bond strength in group B. Tay et al in their study concluded that single bottle adhesives behave as permeable membranes because of lack of more hydrophobic resins resulting in post-operative sensitivity and there may be hybrid layer degradation. [24]

The group C Vertise flow has shear bond strength of 10.28 MPa which is comparable with group B self-etching dental adhesive and there was no statistically significant difference. Although manufacturer claims that Vertise Flow had improved physical properties compared to the other flowable composites, they are not generally recommended as standalone restorative materials especially in cavities with high stress occlusal function. [18,25,26,27]

The group D GIC is a high strength posterior restorative conventional, self-curing glass ionomer cement. Its chemical setting allows single-step placement with out layering and it has excellent, long-lasting marginal seal. [28] One of the two possible following reactions can occur at the MTA-Glass ionomer cement interface. The COO^- of the polyacrylic acid could interact with the calcium of the MTA to form calcium salts. The silicate hydrate gel of the MTA could condense with the silicate hydrate gel of the Glass ionomer cement to form by products. [29] Given the high percentage of mineral oxides in White MTA of the porous surface of MTA, Glass ionomer cements would be expected to bond strongly to White MTA. [30,31] Because the interaction may be by the formation of calcium salts, which is similar to interaction of glass-ionomer cement with the tooth structure, it is assumed that the setting of glass-ionomer cement is also not hindered by combining with MTA.[29]

An in vitro study conducted by Nandini et al reported that conventional Glass ionomer cement can be layered over partially set MTA for a single-visit procedure and that the setting of MTA proceeds unhindered when layered with glass ionomer. [29] In such a procedure, Ballal et al reported their observations on a Glass ionomer cement layered upon partially set MTA. The setting of both materials was unaffected, and the glass ionomer cement showed no signs of dehydration. [32]

Glass ionomer cement differs significantly with its shear bond strength at 5% level of significance when compared to group C, A, B. ($P<0.05$). The mean shear bond strength between

MTA and Glass ionomer cement in the present study is 8.27 MPa which is lower compared to the other groups tested. Two-step etch and rinse adhesive or total-etch adhesive Adper single bond 2 and Z250 composite can be proposed as the material of choice for a permanent restoration when MTA is used as a direct pulp capping agent.

CONCLUSION

Under the conditions of this study, the following conclusions can be drawn:

1. Two-step etch and rinse adhesive or total-etch adhesive (Adper single bond 2) and Z250 composite performed significantly better than one component self-etch adhesive (Xeno V) & Ceram.X mono composite, self adhering flowable composite Vertise flow and Glass ionomer cement in terms of shear bond strength.

2. One component self-etch adhesive (Xeno V) and Ceram. X mono composite i.e. Group B performed better than Group C viz. Vertise Flow. But the difference was very slight and not statistically significant. Both the groups showed better shear bond strength than Group D Glass ionomer cement.

3. Although Glass ionomer cement was expected to bond strongly to MTA, given that MTA has mineral oxides on the surface, the results were contrary to expectations. Glass ionomer cement fared the worst and displayed the least shear bond strength among all the materials tested.

4. The values of Ceram.X mono and Vertise flow are lower compared to that of Z250. With these restorative materials likely to be used in the future by more and more dentists, these materials need to be further investigated for improvement of shear bond strength with MTA.

MTA has made a place for itself in dentistry. Therefore, the bond strength and adhesion of restorative materials to it certainly needs more investigation in the future.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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