Shear bond strength of different restorative materials to mineral trioxide aggregate and Biodentine

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Abstract

Significance of Study: Mineral trioxide aggregate (MTA) and Biodentine (calcium silicate-based materials) have great importance in dentistry. There is no study comparing the bond strength of Biodentine and MTA for composite, compomer, and compomer or resin-modified glass ionomer (RMGIC). Although many advantages of Biodentine over MTA; in this study, MTA has shown better shear bond strength (SBS) to restorative materials.

Aim: Recently, a variety of calcium silicate-based materials are often used for pulp capping, perforation repair, and endodontic therapies. After those treatment procedures, teeth are commonly restored with composite resin, (RMGIC materials in pediatric dentistry. The aim of this study was to evaluate the SBS of composite resin (Filtek™ Z250; 3M ESPE, USA), compomer (Dyract XP; LD Caulk/Dentsply, USA), and resin-modified glass ionomer (Photac-Fil Quick Aplicap; 3M ESPE, USA) to white MTA and Biodentine.

Materials and Methods: Ninety acrylic cylindrical blocks were prepared and divided into two groups (n = 45). The acrylic blocks were randomly allocated into 3 subgroups; Group-1A: MTA + composite (Filtek™ Z250), Group-1B: MTA + compomer (Dyract XP), Group-1C: MTA + RMGIC (Photac-Fil Quick Aplicap), Group-2A: Biodentine + composite, Group-2B: Biodentine + compomer, Group-2C: Biodentine + RMGIC. The specimens were mounted in Universal Testing Machine. A crosshead speed 1 mm/min was applied to each specimen using a knife-edge blade until the bond between the MTA/Biodentine and restorative material failed. Failure modes of each group were evaluated under polarized light microscope at ×40 magnification.

Results: There was no statistically significant difference between MTA + Composite resin with MTA + Compomer; and MTA + RMGIC with Biodentine + RMGIC (P > 0.05). There were statistically significant differences between other groups (P < 0.05).

Conclusions: The results of the present study displayed that although many advantages of Biodentine over MTA; MTA has shown better SBS to compomer and composite resin materials than Biodentine.

Keywords: Biodentine; mineral trioxide aggregate; shear bond strength

INTRODUCTION

Mineral trioxide aggregate (MTA) was introduced as a retrograde filling material by Lee et al. in 1993. In the last decade, MTA has become a very popular biomaterial, especially in endodontics and pediatric dentistry field, owing to its physical and regenerative properties such as; setting in the presence of blood, saliva, or other biological fluids, low solubility after setting, providing cementum regrowth and a strong barrier for bacterial leakage; inducing mineralized tissue formation, control of bleeding also, great biocompatibility.

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Pulp capping with MTA has gained very popularity because of providing dentinogenesis in human pulp cells.\(^{[5-7]}\) When compared with calcium hydroxide as a pulp capping agent; MTA forms faster, uniform and thicker dentinal bridge, provides less pulp inflammation and bacterial microleakage with lower solubility and better marginal adaptation.\(^{[8,9]}\) However, it has disadvantages such as high cost, long setting time, difficulty in manipulation, low resistance to compression and flow capacity, discoloration of tooth structure, and release of arsenic.\(^{[10]}\)

Recently, a variety of new calcium silicate-based materials have been developed to eliminate the disadvantages of MTA. Biodentine, one of these materials, shows dentine-like mechanical properties and apatite formation after immersion in phosphate solution.\(^{[11,12]}\) Improved properties of Biodentine are good sealing ability, high compressive strength, short setting time, biocompatible with human gingival fibroblasts, bioactivity, and biomineralization.\(^{[13,14]}\)

MTA and Biodentine are often used for pulp capping, perforation repair, and endodontic therapies. After these treatment procedures, teeth are commonly restored with composite resin, RMGIC materials in pediatric dentistry.\(^{[15]}\) The bond strength between calcium silicate-based and restorative materials is one of the main factors for the success of restoration.\(^{[16]}\) There are a limited number of studies comparing the bond strength of Biodentine and MTA.\(^{[17,18]}\) The aim of this study was to evaluate the shear bond strength (SBS) of composite resin (Filtek™ Z250; 3M ESPE, USA), compomer (Dyract XP; LD Caulk/Dentsply, USA) and resin-modified glass ionomer (Photac-Fil Quick Aplicap; 3M ESPE, USA) to MTA (ProRoot MTA, Dentsply, UK) and Biodentine (Septodont, USA).

**MATERIALS AND METHODS**

Three commercial restorative materials and two calcium silicate-based materials were used in this study. The materials are listed in Table 1. Ninety acrylic cylindrical blocks were prepared and in the center of the cylinders, a hole with a 4-mm diameter, and a 2-mm height was created and divided into two groups as MTA and Biodentine (n = 45). MTA and Biodentine were prepared according to the manufacturer’s instructions and placed into the holes. The blocks were coded and covered with a wet cotton pellets. The specimens were stored for 72 h at 37°C and 100% humidity.

The acrylic blocks were randomly allocated into 3 subgroups (n = 15).
- Group-1A: MTA + composite resin (Filtek™ Z250),
- Group-1B: MTA + compomer (Dyract XP),
- Group-1C: MTA + RMGIC (Photac-Fil Quick Aplicap),
- Group-2A: Biodentine + composite resin (Filtek™ Z250),
- Group-2B: Biodentine + compomer (Dyract XP),
- Group-2C: Biodentine + RMGIC (Photac-Fil Quick Aplicap).

In composite resin and compomer groups, adhesive system was applied over MTA and Biodentine surfaces and light cured for 20 s. Then, the restorative materials were placed at the center of MTA and Biodentine surfaces by applying materials into cylindrically shaped plastic tubes with an internal diameter of 2 mm and a height of 2 mm. The specimens were light-cured with a light emitting diode (Elipar Free light 3; 3M ESPE, Seefeld, Germany) for 20s. After the polymerization process, the plastic tubes were removed carefully, and the specimens were stored at 37°C in 100% humidity for 24 h.

**Shear bond strength test**

The specimens were mounted in Universal Testing Machine (Instron Model 8500 Plus Dynamic Testing System-1341 Instron – Instron Corp., Canton, MA, USA). A crosshead speed 1 mm/min was applied to each specimen using a knife-edge blade until the bond between the MTA/Biodentine and restorative material failed [Figure 1]. SBS was calculated as Megapascal (MPa). Failure modes of each group were evaluated by a single operator under polarized light microscope (Euromex, Arnhem, Almanya) at 40× and categorized as following;

- Adhesive fracture: Failure between MTA/Biodentine materials and restorative materials.
- Cohesive fracture: Failure within MTA/Biodentine materials or restorative materials.
- Mixed fracture: Both adhesive and cohesive failure.

**Statistical analysis**

All data were processed using the Statistical Package for the Social Sciences (SPSS) statistical software, version 16 (SPSS Inc., Chicago, IL, USA). Comparison between groups were analyzed using one-way analysis of variance (ANOVA) and Kruskal–Wallis (significance level, P < 0.05).

**RESULTS**

Table 2 shows the descriptive statistics of SBS of each group. The highest and lowest SBS values for groups found to be 40.35 MPa (Group 1a) and 0, 40 MPa (Groups 1c). There was no statistically significant difference between MTA + Composite resin and MTA + Compomer; and between MTA + RMGIC and Biodentine + RMGIC (P > 0.05). MTA + Composite resin, and MTA + Compomer groups showed significantly higher bond strength values than other groups and groups with RMGIC showed significantly lower values (P < 0.05).

The failure modes of the specimens are displayed in Table 3. The adhesive failure modes were mostly observed...
in groups with Biodentine. In groups with MTA, both adhesive and cohesive failure modes were observed.

**DISCUSSION**

MTA and Biodentine have shown excellent success in the various endodontic applications. Therefore, the bond strength between calcium silicate cements and restorative materials has a great importance. High SBS shows better bonding between two interfaces, provides favorable adhesion and enhance retention, also the higher SBS provide less microleakage.

MTA has also been shown that restorative procedures should be deferred for at least 72–96 h after mixing MTA to allow the material to succeed its optimum physical properties. However, Bachoo et al. reported that the initial setting reaction of Biodentine takes approximately 12 min and the provision of full maturation takes 2 weeks–1 month. In the present study, MTA and Biodentine specimens were stored for 72 h, 37°C at 100% humidity to allow complete hardening of the materials.

The bond strength between the restorative materials and the cavity liner is of importance factors for the quality of dental filling treatments. It has been estimated that a bond strength ranging from 17 MPa to 20 MPa may be required to resist contraction forces sufficiently to constitute gap-free restoration margins. According to the results of the present study, only MTA + compomer and MTA + composite resin groups displayed higher values than 17 MPa. It can be concluded that MTA provides sufficient bonding to compomer and composite resin materials.

In the study of Cantekin and Avci, MTA + Composite resin group had a mean bond strength value of 17.7 MPa similar to our study (18.69 MPa). They reported that the reason of high bond strength value may depend on methacrylate-based composite resin have low free-radical monomers and polymerization shrinkage.

In the present study, there were no statistically significant differences between MTA + composite resin (18.69 MPa) with MTA + compomer (21.00 MPa). Similar to our study, MTA and Biodentine have shown excellent success in the various endodontic applications. Therefore, the bond strength between calcium silicate cements and restorative materials has a great importance.

**Table 1: Restorative materials used in this study and their composition, manufacturer, and application details**

| Material                          | Composition                                                                 | Method/Steps for application |
|-----------------------------------|-----------------------------------------------------------------------------|-----------------------------|
| MTA ProRoot MTA (Dentsply Tulsa Dental, USA) | Tricalcium silicate, bismuth oxide, dicalcium silicate, tricalcium aluminate, calcium sulfate dehydrate, or gypsum | Mix powder and liquid in a 1:3 ratio (Biodentine steps) |
| Biodentine® (Septodont, Saint Maur des Fosses, France) | Biodentine Composition                                                       | Light polymerize for 20 s (Biodentine steps) |
| Composite resin Filtek® Z250 (3M ESPE, USA) | Composite Filtek Z250 Composition 0.1-10                                     | Light polymerize for 20 s |
| Compomer Dyract XP (LD Caulk/Dentsply, USA) | Compomer composition                                                         | Light polymerize for 20 s |
| RMGIC (Photac-Fil Quick Aplicap; 3M ESPE, USA) | RMGIC Composition                                                             | Light curing for 20 s |
| Adhesive system (Prime and Bond® NT) | Adeziv system Composition                                                    | Apply 35% phosphoric. Acid etchant for 15 s, Rinse and blot-dry, Apply bond, Allow gentle airstream, Light-cure for 10 s |

MTA: Mineral trioxide aggregate, RMGIC: Compomer or resin-modified glass ionomer, SD: Standard deviation

**Table 2: Shear bond strength values of restorative materials to mineral trioxide aggregate and Biodentine**

| Groups                              | n | Minimum | Maximum | Mean | SD  |
|-------------------------------------|---|---------|---------|------|-----|
| MTA and composite resin             | 15| 4.76    | 40.35   | 18.69| 10.26|
| MTA and compomer                    | 15| 7.66    | 30.67   | 21.00| 6.75 |
| MTA and RMGIC                       | 15| 0.40    | 11.92   | 2.84 | 3.51 |
| Biodentine and composite resin      | 15| 4.57    | 18.12   | 9.34 | 4.08 |
| Biodentine and compomer             | 15| 0.68    | 31.10   | 7.58 | 8.47 |
| Biodentine and RMGIC                | 15| 0.62    | 9.00    | 2.59 | 2.58 |

MDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, BHT: Butylated hydroxytoluene, TMPTMA: Trimethylolpropane trimethacrylate, BIS-GMA: Bisphenol A glycerolate dimethacrylate, Bi-Et-MA: Bisphenol A ethoxylate dimethacrylate, RMGIC: Compomer or resin modified glass ionomer, PENTA: Dipentaerythritol penta acrylate monophosphate, TCB: Carboxylic acid-modified dimethacrylate

**Figure 1:** Schematic modeling of the sample design for shear bond strength testing.
results, Tunç et al. reported no statistically significant difference between MTA and Composite resin (13.22 MPa) with MTA and Compomer (15.09 MPa). However, in the present study, higher bond strength values were obtained than in the study of Tunç et al. The difference may be due to the use of white MTA in their study.

In the present study, RMGIC showed lower bond strength values in both MTA and Biodentine groups. Similarly, Ajami et al. (2013) have reported low bond strength values between RMGIC and pulp capping agents. The low values can be attributed to the lower etching capability of polyacrylic acid resulting from glass ionomer particles. Depending on this, insufficient preparation of the surface and creating the honeycomb pattern may affect bonding between two interfaces.

According to the results of the present study, it was observed that groups with Biodentine showed lower values than groups with MTA. Kaup et al. reported that, in their study, the SBS of Biodentine increased significantly from 2 days to 1 week. Furthermore, Bachoo et al. reported that the initial setting reaction of Biodentine takes approximately 12 min and but the provision of full maturation takes 2 weeks–1 month. Consequently, setting reaction of Biodentine may affect the bond strength between Biodentine and the materials.

When the failure modes of the specimens were evaluated, it was observed that most of the failures were cohesive in groups with MTA, while for groups with Biodentine most of the failures were adhesive type. A general trend was observed that samples with high bond strength showed cohesive failure, but samples with low bond strength showed adhesive failure.

**CONCLUSIONS**

The results of the present study displayed that although many advantages of Biodentine over MTA; MTA has shown better SBS to compomer and composite resin materials when compared to Biodentine. However, more in vivo and in vitro studies are required to further investigate the performance of these materials with restorative materials.

**Table 3: Failure modes of the tested materials**

| Groups                        | Adhesive | Cohesive | Maximum | Total |
|-------------------------------|----------|----------|---------|-------|
| MTA and composite resin       | 4        | 10       | 1       | 15    |
| MTA and compomer              | 5        | 9        | 1       | 15    |
| MTA and RMGIC                 | 6        | 8        | 1       | 15    |
| Biodentine and composite resin| 12       | 0        | 3       | 15    |
| Biodentine and compomer       | 12       | 0        | 3       | 15    |
| Biodentine and RMGIC          | 11       | 1        | 3       | 15    |

MTA: Mineral trioxide aggregate, RMGIC: Composite or resin modified glass ionomer

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**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Lee SJ, Monsef M, Torabinejad M. Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. J Endod 1993;19:541-4.
2. Gandolfi MG, Tedde P, Siboni F, Modena E, De Stefano ED, Prati C, et al. Biomimetic remineralization of human dentin using promising innovative calcium-silicate hybrid “smart” materials. Dent Mater 2011;27:1056-69.
3. Fridland M, Rosado R. MTA solubility: A long term study. J Endod 2005;31:376-9.
4. Cantekin K. Bond strength of different restorative materials to light-curable mineral trioxide aggregate. J Clin Pediatr Dent 2015;39:143-8.
5. Sari S, Sönmez D. Internal resorption treated with mineral trioxide aggregate in a primary molar tooth: 18-month follow-up. J Endod 2006;32:69-71.
6. Tunç D, Olmez A. Clinical long-term evaluation of MTA as a direct pulp capping material in primary teeth. Int Endod J 2008;41:273-8.
7. Min KS, Park HJ, Lee SK, Park SH, Hong CU, Kim HW, et al. Effect of mineral trioxide aggregate on dentin bridge formation and expression of dentin sialoprotein and heme oxygenase-1 in human dental pulp. J Endod 2008;34:666-70.
8. Hakki SS, Bozkurt SB, Hakki EE, Belli S. Effects of mineral trioxide aggregate on cell survival, gene expression associated with mineralized tissues, and biomineralization of cementoblasts. J Endod 2009;35:513-9.
9. Dammashcke T, Stratmann U, Wolff R, Sagheri D, Schäfer E. Direct pulp capping with mineral trioxide aggregate: An immunohistologic comparison with calcium hydroxyde in rodents. J Endod 2010;36:814-9.
10. Paririk M, Torabinejad M. Mineral trioxide aggregate: A comprehensive literature review – Part III: Clinical applications, drawbacks, and mechanism of action. J Endod 2010;36:400-13.
11. File BS. Active biocalcite technology, septodont. Saint-Maur-des-Fossés Cedex: R&D Department. 2010.
12. Goldberg M, Pradelle-Plasse N, Tran X. Emerging trends in (bio) material researches. Biocompatibility or Cytoxic Effects of Dental Composites. Oxford, UK: Coomoor Publishing; 2009. p. 181-203.
13. Han L, Okiji T. Uptake of calcium and silicon released from calcium silicate-based endodontic materials into root canal dentine. Int Endod J 2011;44:1081-7.
14. Laurent P, Camps J, De Moe M, Déjou J, About I. Induction of specific cell responses to a Ca(3)SiO(5)-based posterior restorative material. Dent Mater 2006;22:1486-94.
15. Bayrak S, Tunç ES, Saroğlu I, Eğilmez T. Shear bond strengths of different adhesive systems to white mineral trioxide aggregate. Dent Mater J 2009;28:62-7.
16. Tunç ES, Sönmez IS, Bayrak S, Eğilmez T. The evaluation of bond strength of a composite and a compomer to white mineral trioxide aggregate with two different bonding systems. J Endod 2008;34:603-5.
17. Kaup M, Dammann CH, Schäfer E, Dammashcke T. Shear bond strength of biodentine, Proroot MTA, glass ionomer cement and composite resin on human dentine ex vivo. Head Face Med 2015;11:14.
18. Altunsoy M, Tanner M, Ok E, Kucukyilmaz E. Shear bond strength of a self-adhering flowable composite and a flowable base composite to mineral trioxide aggregate, calcium-enriched mixture cement, and Biodentine. J Endod 2015;41:1681-9.
19. Wang L, Sakai VT, Kawai ES, Buzalaf MA, Atta MT. Effect of adhesive systems associated with resin-modified glass ionomer cements. J Oral Rehabil 2006;33:110-6.
20. Suresh K, Nagarathna J. Evaluation of shear bond strengths of fuji II and fuji IX with and without salivary contamination on deciduous molars – An In vitro study. Arch O Sci Res 2011;1:139-45.
21. Bodanezi A, Carvalho N, Silva D, Bernardini N, Bramante CM, Garcia RB, et al. Immediate and delayed solubility of mineral trioxide aggregate and Portland cement. J Appl Oral Sci 2008;16:127-31.
22. Bachoo IK, Seymour D, Brunton P. A biocompatible and bioactive replacement for dentine: Is this a reality? The properties and uses of a novel calcium-based cement. Br Dent J 2013;214:5.
23. Davidson CL, de Gee AJ, Feilzer A. The competition between the composite-dentin bond strength and the polymerization contraction stress. J Dent Res 1984;63:1396-9.
24. Al-Sarheed MA. Evaluation of shear bond strength and SEM observation of all-in-one self-etching primer used for bonding of fissure sealants. J Contemp Dent Pract 2006;7:9-16.
25. Cantekin K, Avci S. Evaluation of shear bond strength of two resin-based composites and glass ionomer cement to pure tricalcium silicate-based cement (Biodentine®). J Appl Oral Sci 2014;22:302-6.
26. Ajami AA, Jafari Navimipour E, Savadi Oskooee S, Abed Kahnamou M, Lotfi M, Daneshpoooy M, et al. Comparison of shear bond strength of resin-modified glass ionomer and composite resin to three pulp capping agents. J Dent Res Dent Clin Dent Prospects 2013;7:164-8.