Shear bond strengths of bulk-fill composite resin to mineral trioxide aggregate

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Abstract

Objectives:

Mineral trioxide aggregate (MTA) show physical and biological properties that can be used as the preservation of pulp vitality and regenerative techniques. The bond strength between MTA and restorative materials has great importance since MTA is often in direct contact with restorative materials. This study aimed to compare the shear bond strength (SBS) of bulk-fill composite resins to MTA.

Materials and Methods:

45 acrylic blocks with central holes (5 and 2 mm in diameter and height, respectively) were prepared and divided into three groups of 15 according to the composites used (Tetric N-Ceram bulk-fill composite resin, Filtek bulk-fill composite resin, Estelite bulk-fill flowable composite resin). The acrylic cavities were filled with ProRoot MTA. After the application of bonding material and proper composite resin samples, the SBS was assessed using a universal testing machine. Data were analyzed through ANOVA. A p-value less than 0.05 was considered statistically significant.

Result:

Bond strength was significantly higher in samples of Tetric N-Ceram bulk-fill composite resin ($P<0.05$). However, there was no significant difference between the two other groups in this regard ($P=0.99$).

Conclusion:

ProRoot MTA and Tetric N-Ceram bulk-fill composite resin showed statistically higher bond strengths, compared to other bulk-fill composite resins.

Keywords: Bulk-fill resin composites, Mineral trioxide aggregate, Shear bond strength.

Introduction

Vital pulp therapy of reversible pulpitis after traumatic injuries or exposure of the pulp due to caries is the treatment of choice in both primary and permanent teeth (1-3). This technique consists of the coronal pulp removal and treatment of the remaining radicular pulp by placing the biocompatible materials to maintain the health and vitality of the dental pulp (1). Mineral Trioxide Aggregate (MTA) is a hydraulic calcium-silicate cement that has been used in vital pulp therapy (4). The MTA is considered a biocompatible and bioactive material that can support cementum regrowth and can induce mineralized tissue formation when comes in contact with dental pulp (5). The suitable materials for coronal restorations over MTA should have the required low condensation forces; therefore, esthetic materials can be used over the pulp capping agents (6).

Recently introduced "bulk-fill" materials that can be inserted into a cavity have become known with larger increments. The implementation of these materials has changed the application procedures and reduced the risk of entrapping air voids between subsequent increments with negative effects on mechanical strength (7). Some of this has a higher fluidity and penetration in cavities; moreover, it leads to the elimination of the factors associated with polymerization stress, such as marginal fractures (8). The bulk-fill composites have lower filler content and larger filler particles (>20μ), compared to conventional composites (6). Therefore, this material class includes low- (flowable) and high-viscosity paste types. Lower filler content decreases the mechanical properties of these materials (9).

The bulk-fill composites attempt to speed up the restoration process by allowing dentists to place materials in increments of 4- or 5-mm thickness (10). This is especially useful for restorations in uncooperative children.

Çolak et al. (11) showed no significant difference between nano-hybrid and bulk-fill composite resin in terms of the clinical performance (retention, marginal discoloration, recurrent caries, marginal adaptation, and postoperative sensitivity) during the 12 months recall period. Since there is no information on the adhesion of bulk-fill materials to MTA, this study aimed to evaluate and compare the shear bond strength (SBS) of bulk-fill materials to MTA.

Material and Methods

A total of 45 cylindrical acrylic resin blocks (1 cm in diameter and 25 cm in height) were prepared in this study. In order to create a completely smooth and horizontal surface, the cylinders were meticulously trimmed in a trimmer. Subsequently, cavities (5 mm in diameter and 2 mm in height) were prepared in the center of the cylinders. They were stored in distilled water for a week in order to minimize the potential subsequent absorption of water from the MTA by the acrylic resin, which could disrupt the setting of MTA.

The ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK, USA) powder was mixed with water according to the manufacturer's instructions in a 3:1 ratio on a glass slab with a metal spatula. In the next stage, the acrylic cavities were filled with MTA and packed with a condenser followed by surface smoothening with a glass slab. The specimens were stored at 100% humidity at 37˚C for 72 h to set the MTA completely. The specimens were divided into three groups of Tetric N-Ceram bulk-fill composite resin (Group 1, Ivoclar Vivadent, Schaan, Liechtenstein, Germany), Filtek bulk-fill composite resin (Group 2, 3M ESPE, St Paul, MN, USA), and Estelite bulk-fill flowable composite resin (Group 3, Tokuyama Dental Corporation, Japan) (Table 1).

Table 1. Characteristics of the composites used

	Composition	Manufacturer
Estelite bulk-fill flowable composite resin	Bisphenol A Di Dimethacrylate, Trietylene Glycol Dimethacrylate, (1-Methylethylidene)Bis(4,1-Phenyleneoxy-2,1-Ethanediyloxy-2 ,1-Ethanediyl) Bismethacrylate, 2-(2h-Benzotriazol-2-Yl)- P-Cresol	Tokuyama Dental Corporation, Japan
*Tetric Evo-Ceram bulk fill Nano-hybrid bulk-fill resin composite	Bis-GMA, UDMA Ba-AL-Si glass, prepolymer filler (monomer, glass filler and ytterbium fluoride), spherical mixed oxide. Filler 79–81 wt.% (including 17% prepolymers)/60–61 vol.%	Kerr, Orange, CA, USA

*Filtek bulk-fill	Bis-GMA, UDMA, Bis-EMA, procrylate resins Ytterbium trifluoride, zirconia, silica (64.5 wt%, 42.5 vol %)	3M ESPE, St. Paul, MN, USA

The surfaces of the MTA samples were etched with 35% phosphoric acid gel for 15 seconds, rinsed with water for 30 seconds, and gently air-dried leaving the MTA surface visibly moist. Following that, a clean micro brush (Microbrush Co, Greyton, WI, USA) was used to apply (Single Bond Universal 3M ESPE, Neuss, Germany) the adhesive to the prepared surfaces of the samples. Subsequently, the adhesive was light-cured for 15 seconds. Transparent molds with 4-mm diameter and height were used to achieve the identical surfaces of the composite resin in all samples. The samples were light-cured for 20 seconds from the top in one stage, and they were kept in a humid environment at the temperature of 37˚C for 24 h to simulate the oral condition.

Furthermore, they were subjected to the SBS test utilizing a universal testing machine (STM-15, Santam, Iran) at a crosshead speed of 0/5 mm/min. The maximum loads at failure were recorded in Newton and were then converted into the Mps. All samples were observed under a stereomicroscope with ×25 magnification to determine the type of failure as either adhesive or cohesive as following:
Adhesive fracture: Failure between MTA materials and composite resin
Cohesive fracture: Failure within MTA materials or composite resin
Mixed fracture: Both adhesive and cohesive failure

After confirmation of the normal distribution of the data with the Kolmogorov Smirnov test and equality of variance among the groups using the Levene test, the two-way ANOVA analysis was applied to determine the interaction effect among the experimental groups. If it was applicable, the post hoc comparison and Games-Howell test were used to compare the SBS results among the groups. A p-value less than 0.05 was considered statistically significant.

Result

Table 2 summarizes the mean±SD of SBS for all groups. Based on the ANOVA results, there is an interaction effect between SBS and type of composite. The results of the Games-Howell test revealed that the SBS values of Tetric N-Ceram bulk-fill were significantly higher when compared with those of the two other bulk-fill composite resins (P<0.05). However, the difference between groups 2 and 3 was not statistically significant in this regard (P=0.990). Moreover, no significant difference was observed between the groups regarding the fracture patterns (P>0.05). Table 3 tabulates the failure modes of the specimens.

Table 2. Mean±SD of shear bond strength in the experimental groups

	Shear Bond Strength (Mpa)	Type of failure mode		
		Adhesive failure	Cohesive failure	Mixed failure
Tetric N-Ceram bulk-fill composite resin	0.861±0.29	0.765±0.12	-	0.915±0.35
Filtek bulk-fill composite resin	0.579±0.24	0.664±0.52	0.588±0.20	0.562±0.22
Estelite bulk-fill flowable composite resin	0.567±0.20	0.490±0.22	0.736±0.1	0.609±0.19

Table 3. Failure modes of the tested materials

	Type of failure mode				
	Adhesive failure-MTA-Composite resin	Cohesive failure-Composite resin	Cohesive failure-MTA	Mixed	P-value
Tetric N-Ceram bulk-fill composite resin	6	0	0	9	.001
Filtek bulk-fill composite resin	2	1	1	11	.001
Estelite bulk-fill flowable composite resin	6	1	0	8	.001

Discussion

The MTA shows physical and biological properties that can be used effectively as the preservation of pulp vitality and regenerative techniques. The bond strength between MTA and restorative materials has great importance since the MTA is often in direct contact with restorative materials. High SBS shows better bonding between two interfaces, provides favorable adhesion, and enhances the retention. Furthermore, the higher SBS provides less microleakage, thereby lowering the subsequent contamination of the pulp tissue that has a critical negative effect on the outcome of treatment procedures (12).

Verma et al. (13) revealed that residual bacteria was a major risk to the success of regenerative procedures, as well as the amount of root growth and dentin associated with the mineralized tissue formed. Recent developments in restorative composite resins have resulted in a greater total depth of cure up to 4 mm due to its higher translucency and greater depth of cure. Bulk application of these composites decreases the treatment time and it is useful, especially for restorations in uncooperative children (6). Only a few studies have tested the SBS of the bulk-fill resin composite to MTA (10, 14).

Mosharrafian et al. (15) compared the push-out bond strengths of the two bulk-fill and one conventional composite to intracanal dentin in primary anterior teeth. They reported similar results in two groups and suggested that bulk-fill composite could be used successfully in primary teeth to decrease the treatment time in children.

Various restoration procedures and the appropriate time of restoration after mixing MTA have effects on the chemical and mechanical characteristics of MTA (16). The authors found that when MTA was etched, the microhardness of the MTA decreased (16). In this study, according to Atabek at al., restorative procedures were postponed 72 h after mixing MTA to achieve optimum physical properties of MTA (17)The differences in the bond strength of resin composite to MTA may be due to various adhesive systems of different generations that have been observed in these studies (18). A universal adhesive was selected to eliminate the composition of the bonding system as a variable.

In the same vein, Doozaneh et al. (19) compared the SBS of a self-adhering flowable composite (SAFC) with resin-modified glass ionomer to MTA and calcium-enriched mixture (CEM) cement. They found that the bond strength of SAFC to MTA and CEM cement was higher than that of the glass ionomer. Moreover, the surface treatment with an all-in-one adhesive before SAFC significantly increased the SBS of SAFC to MTA and CEM cement.

Furthermore, they reported higher bond strength values in most groups, compared to our values, which may be explained by the differences in the type of restorative materials and adhesive system. The sensitivity of MTA to the acidic environment can affect the SBS of the composite resin (16). Accordingly, in the SEM evaluation, the disordered structure, selective dissolution, detachment of filler particles, as well as displacement and dissolution of MTA were observed after the acid etching process (20).

In the present study, statistically significant differences ($P<0.05$) were found when comparing the SBS of Tetric N-Ceram bulk-fill composite resin with that of the two other bulk-fill composites. New types of the photo initiator, such as Ivocerin and Benzoyl Germaniumare are used in the composition of this bulk-fill composite instead of the common type, such as Camphorquinone (6). Filler size, morphologies, and monomer type of the composite resin may affect the mechanical properties (21).

Estelite bulk-fill flowable composite resin displayed lower bond strength to MTA. A contributing factor to the low bond strength of flowable composites may be the lack of compression forces/pressure during placement, which is crucial to prevent open spaces on the interface. Moreover, the particle sizes may influence bond strength (22); however, no significant differences were observed between groups 2 and 3 in terms of SBS to MTA.

Ehlers et al. (23) described the use of low viscosity bulk-fill composite resin without a cover layer in the primary dentition and demonstrated the acceptable clinical performance regarding the expected longevity of primary tooth restorations, even short with 1-2 year observational period studies.

In our study, most of the observed fracture modes were mixed (62.2%) and adhesive failure MTA-composite resin (31.1%). Hursh et al. (24) made a comparison between four bioceramic materials and a dual-cure composite resin regarding the bond strength. According to the results, in the White ProRoot MTA group, 30% and 70% of the samples were adhesive and mixed fractures, respectively.

Similarly, Palma et al. (25) assessed the fracture modes of calcium silicate-based cement in two different restoration protocols (immediately or delayed) and reported a high frequency of cohesive failures within MTA that reflect MTA-low cohesive resistance, compared to a high bond strength value. This result is not in line with the findings in this study. In fact, in the present study, the samples exhibited mixed failures regardless of the restorative material. Several elements could have caused these discrepancies in the example type of restorative material and adhesive system.

Tavarez (26) observed that the microstructure of the composite resins influenced average bond strength values in which a microhybrid resin displays a higher strength, compared to a nanoparticle resin. Bulk-fill resin presented inferior results, compared to the conventional nanoparticle and microhybrid resins in the SBS.

In a similar way, Tulumbaci demonstrated that the bond strength between MTA and composite resin is higher than that between Biodentine and composite, which displayed higher values than those in SBS. The difference can be related to the composition of restorative materials and crosshead speed used. In our study, this corresponding value was estimated at 0.5 mm/min, whereas it was obtained at 1 mm/min in their studies. Some studies show that the crosshead speed influences the results of the SBS tests (27).

The recommended bond strength values to achieve a restoration with no gaps with a proper seal has been reported to be 17-20 MPa (28) which is much higher than those of bulk-fill composite resin to MTA in the present study. Ajami et al. (29) evaluated the SBS of the composite resin and giomer to MTA at different time intervals after mixing MTA. They observed lower bond strength values of 17 MPa, which was consistent with the results of this study. According to a study conducted by Cantekin et al. (14), on the evaluation of the bond strength of methacrylate-based composites, silorane-based composites, and glass ionomer cement to MTA, the SBS values of the MTA with all of these restorative materials did not reach an optimal shear bond value.

The main limitation of the present study was the use of a flat surface with a single interface between the two materials and a lack of evaluation of the effect of dentin in bonding which is present in the clinical setting. Therefore, further studies should investigate the other physical and mechanical properties of bulk-fill composite resin characteristics.

Conclusion

According to the results of this study, ProRoot MTA and Tetric N-Ceram bulk-fill composite resin showed statistically higher bond strengths, compared to other bulk-fill composite resin.

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Conflicts of interest

There are no conflicts of interest regarding the publication of this study.

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