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Original Research Article

Comparative Evaluation of Push-Out Bond Strength and Bond Failure Mode of Ortho MTA and ProRoot MTA

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Abstract: The aim of this study was to compare the push-out bond strength (PBS) and bone failure mode of Ortho mineral trioxide aggregate (MTA) and ProRoot MTA in root dentin. Forty extracted single-rooted human canine teeth were selected in this experimental study and the canal space of each dentin slice was enlarged with Gates Glidden burs to achieve a diameter of 1.3 mm. Midroot dentine was horizontally sectioned into 2-mm-thick slices. The samples were randomly divided into two groups (n=20) with a thin layer placement of Ortho MTA and ProRoot MTA, and then incubated at 37°C, 100% humidity for 24 hours (h). PBS (Mpa) and the bond failure mode were evaluated after 10 minutes (min) and 4 h using a universal testing machine and a stereomicroscope (×10), respectively. Data were analyzed using the Kruskal-Wallis test and K2 test. The mean PBS values of Ortho MTA were less than ProRoot MTA. The main failure mode after 10 min was cohesive type for both materials, while the dominant failure mode after 4 h was adhesive type in Ortho MTA and cohesive type in ProRoot MTA. Failure bond mode was irrelevant to the kind of tested materials and time assessments.

Keywords: Bond strength, Calcium Silicate Cement, Mineral Trioxide Aggregate, Ortho MTA, Push-Out Bond Strength, Push-Out Test.

INTRODUCTION

Mineral trioxide aggregate (MTA), a calcium silicate cement, has been widely used in various endodontic treatments. Despite the favorable results, there are some disadvantages of ProRoot MTA such as difficult handling properties and tooth discoloration (Marconyak *et al*., 2016), therefore new clinically useful materials are developed (Ertas *et al*., 2014).

Ortho MTA (BioMTA, Seoul, Republic of Korea) was introduced as an alternative to ProRoot MTA to overcome the drawbacks, recently. It is claimed that Ortho MTA has an antibacterial effect in orthograde obturation. The bioactive characteristic of Ortho MTA by releasing calcium has some advantages; neutralizing the apical part of the root canal, forming an interfacing hydroxyapatite layer that prevents microleakage, and inducing regeneration of the apical periodontium (Mousavi *et al*., 2018). Two microns granularity of Ortho MTA powder with its biocompatibility and bioactivity effect improve sealing ability of this material even in moisture or blood contamination (Park, 2016).

Some studies compared these two types of MTA materials from different aspects. Ortho MTA has the same composition as ProRoot MTA with the exception of calcium sulfate lack (Kang *et al*., 2015). In comparison with ProRoot MTA, the main composition of Ortho MTA is tricalcium silicate with less heavy metal (Ahmed Rahoma et al., 2018). Compositions of these two MTA materials are described in Table 1.

Table 1: Characteristics of Two MTA Tested Materials

Material	Manufacturer	Compositions of Tested Material	Content (wt%)
ProRoot MTA (Kang *et al*., 2015)	Dentsply, Tulsa, OK	Calcium Oxide (CaO) Silicon Dioxide (SiO2) Bismuth Oxide (Bi2O3) Aluminium Oxide (Al2O3) Magnesium Oxide (MgO) Sulphur Trioxide (SO3) Ferrous Oxide (FeO)	44.2 21.2 16.1 1.9 1.4 0.6 0.4
Ortho MTA *(Kang et al*., 2015)	BioMTA, Seoul, Korea	Tricalcium Silicate (3CaO.SiO2) Dicalcium Silicate (2CaO.SiO2) Tricalcium Aluminate (3CaO.Al2O3) Tetracalcium Aluminoferrite (4CaO.Al2O3.Fe2O3) Free Calcium Oxide (Free CaO)	76.3 11.8 8.0 0.8 0.7

Despite the long setting time of ProRoot MTA, the setting time of OrthoMTA is 180 sec, in addition, easy handling of Ortho MTA with OrthoMTA carrier is an advantage *(Khedmat et al*., 2018), while in another study, the two tested materials showed setting times longer than 5 hours (Kim *et al.*, 2014). When it comes to comparing the tooth discoloration potential, studies showed no significant difference between tooth Ortho MTA and ProRoot MTA materials in the presence of blood, although a significantly greater color change was observed OrthoMTA specimen (Shokouhinejad *et al*., 2016). It was demonstrated that the expression of osteopontin, a bone mineralization market and noncollagenous proteins in mineralized tissues, was significantly higher in ProRoot MTA rather than that of Ortho MTA (Kim *et al*., 2014). In an evaluation of OrthoMTA and ProRoot MTA, similar antibacterial activity was reported against three assessed anaerobic endodontic bacteria (Fusobacterium nucleatum, Porphyromonas gingivalis, and Prevotella intermedia) (Khedmat *et al*., 2018).

Endodontic materials may be exposed to dislocating condensational forces during restoration placement or masticatory forces (Reyes-Carmona *et al*., 2010). Therefore, resistance to these dislocating forces and bond strength of endodontic materials are among the important factors for a successful treatment (Ertas *et al*., 2014).

The mean push-out bond strength (PBS) values of ProRoot MTA were reported significantly higher than that of AH Plus and MTA Fillapex (Sönmez *et al*., 2013). Also, it was recorded that ProRoot MTA had significantly higher PBS when it was compared to MA Angelus and CEM cement (Ertas *et al*., 2014). In 24-h samples of a comparative study, ProRoot MTA showed significantly less PBS than Biodentine and MTA Plus. PBS of all samples increased during the time of 24-h to 7 days (Aggarwal *et al*., 2013). Another study showed the least PBS amount for white ProRoot MTA in comparison with Biodentine and Neo MTA Plus (Aktemur Türker *et al*., 2017). The least PBS values with the dominant failure mode of adhesive type was exhibited in ProRoot MTA when compared to Biodentine, Cem Cement, and ERRM (Yazdi *et al*., 2017). A similar PBS was observed between Biodentine and w ProRoot MTA which were significantly higher than bioaggregate. White ProRoot MTA is reported to have a majority of mixed type of failure than cohesive failure without any adhesive failure when compared to bioaggregate and Biodentine (Alsubait *et al*., 2014). While another study showed a higher PBS and predominantly adhesive failure in Biodentine and ProRoot MTA samples compared to BioAggregate in coronal and apical root dentin, and ProRoot MTA had a significantly difference PBS from Biodentine in coronal root dentine (Majeed & AlShwaimi, 2017). The PBS of bioaggreagte and MTA was reported significantly lesser than that of ERRM, without any significant difference between MTA and bioaggregate. The main bond failure mode was mixed for MTA and Bioaggregate (Shokouhinejad *et al*., 2013). A similar PBS was exhibited in MTA Angelus, ProRoot MTA, and Biodentine with predominantly mixed bond failure in MTA materials (Stefaneli Marques *et al*., 2018). Similar PBS was shown between Ortho MTA, MTA Angelus, and ProRoot MTA in root dentin (A. Rahoma *et al*., 2018).

Due to no abundant information about the comparison of PBS between Ortho MTA and ProRoot MTA, the purpose of this in vitro study was to evaluate the PBS values and bond failure mode of these two dental materials.

MATERIAL AND METHODS

Specimen Preparation

This experimental study has been approved by the Ethics Committee of Azad University, Dental Branch, Tehran, Iran. Forty recently extracted human canine teeth with approximately similar length and buccolingual diameter were selected for this in vitro study. Mesiodistal and buccolingual radiographs were taken to verify the single root canals of the teeth.

Disinfection was provided by immersing the teeth in 5.25% sodium hypochlorite for 1 hour and storing them in normal saline until use. An ultrasonic scaler (Varios 970; NSK Kanuma-shi, Tochigi, Japan) was used to remove debries and stains, then the teeth were polished with a rubber cap, pumice paste, and water.

Decoronataion of the teeth 1mm below the cemento-enamel junction was performed using a diamond disk. Teeth were instrumented using Gates-Glidden drills (Dentsply-Maillefer, Ballaigues, Switzerland) in size #2 through #5 to 1.3 mm preparation. A low-speed water-cooled diamond saw (Isomet; Buehler, USA) was used to achieve two-mm thick sections from the roots. Midroot dentine of the teeth was sectioned horizontally and species were divided into two groups randomly (n=20) according to the root end filling material; Ortho MTA (BioMTA Seoul, Korea), and ProRoot MTA (Dentsply Tulsa Dental, Konstanz, Germany). The tested materials were manipulated according to the manufacturers' instructions, gently condensed into the dentin discs without vigorous pressure and the excess materials were trimmed using a scalpel. Specimen were wrapped in sterile gauze moistened with distilled water. The samples were randomly divided into four groups (n=10) with a thin layer placement of Ortho MTA (for two groups) and ProRoot MTA (for two groups) then incubated at 37º C and 100% humidity.

Push-out Bond Strength (PBS) Assessment:

PBS test was done by a universal testing machine (Z050; Zwick/Roell, Ulm, Germany). After 10 minutes, one of the Ortho MTA groups and one group from ProRoot MTA were placed on a custom metal slab with a center hole in order to free piston removal. The same process was performed for the other two remained groups after 4 hours (Primary setting time of MTA).

The pressure downward force at a constant speed of 1 mm/min was applied on the specimen. This was continued until the removal of root filling materials from the canal and occurrence of total bond failure, then the force was recorded in Newton (N). The bond strength in MPa was calculated following this formula:

$$\text{Bond Strength (MPa)} = \frac{\text{Debonding force (N)}}{\text{Bonded surface area (mm}^2\text{)}}$$

Bonded surface area = 2πrh, which;
π = 3.14 (constant),
r = the radius
h= the thickness of root dentin section (mm)

Failure Mode Evaluation:

Bond failure type was evaluated using a stereomicroscope (Leica M125C, Leica Microsystems, Wetzlar, Germany) at ×10 magnification and categorized in one of the following three groups; failure in the common surface between MTA and dentin (adhesive type), failure within MTA (cohesive type), and combination of adhesive and cohesive failures (mix failure).

***Statistical Analysis*:**

Data of PBS in study groups were statistically analyzed with the Kruskal-Wallis test. Data obtained from bond failure modes were analyzed using the K2 test with SPSS software (ver:22). The isgnificance level was set at P-value < 0.05.

RESULTS

Push-Out bond strength (PBS) of tested groups:

The mean±SD of PBS for MTA groups were 0.24 ±0.12 (10 min) and 0.45±0.27 (4h). The mean±SD of PBS in Ortho MTA group were 0.20 ±0.14 and 0.19±0.09 after 10 min and 4h, respectively. Kruskal-Wallis test showed a statistically significant difference between the two groups according to the PBS at different times (P=0.048<0.05) (Figure 1).

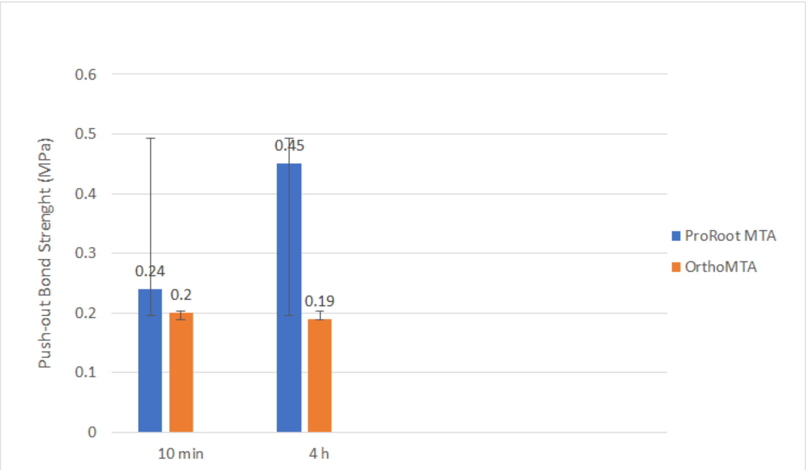

Fig 1: Mean push-out bond strength of tested materials

Failure modes Analysis:

The bond failure type of the two materials of this study is shown in Table 2. The main failure mode after 10 min were cohesive for both materials, while after 4h, the dominant failure was adhesive type in Ortho MTA and cohesive type in ProRoot MTA (Figure 2). Failure bond mode was irrelevant to the kind of tested materials and time assessments (P=0.283>0.05).

Table 2: Distribution of Failure Mode in Each Subgroup

Materials Time		**Bond Failure Mode**			
		Mixed	**Cohesive**	**Adhesive**	**Total**
Ortho MTA	4 hours	3 (30%)	1 (10%)	6 (60%)	10 (100%)
	10 minutes	4 (40 %)	5 (50%)	1 (10%)	10 (100%)
Pro Root MTA	4 hours	3 (30%)	6 (60%)	1 (10%)	10 (100%)
	10 minutes	2 (20%)	8 (80%)	0	10 (100%)
P value: 0.283					
P<0.05, K2 test, as appropriate					

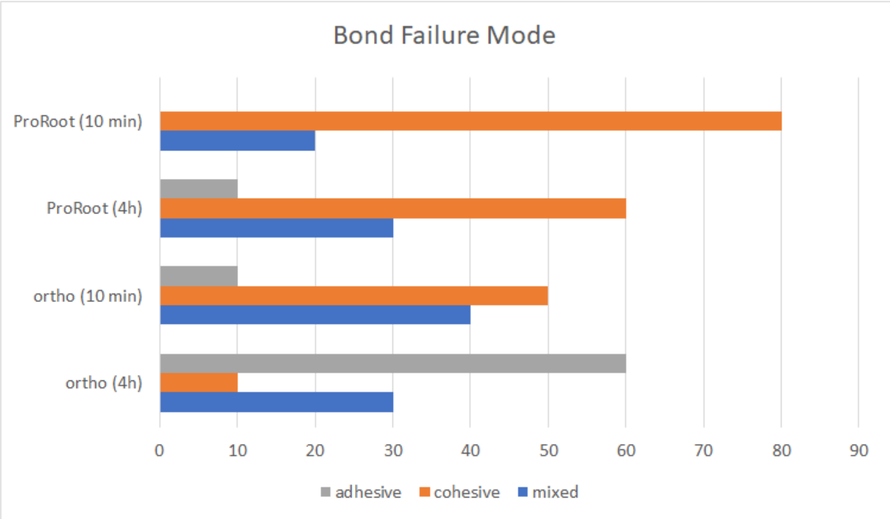

Fig 2: Bond Failure Mode of Ortho MTA and ProRoot MTA after 10 min and 4h

Discussion

We found that PBS values of ProRoot MTA in this study increased from 0.24±0.12 to 0.45±0.27 over the time evaluation which was similar to previous studies which could be due to biomineralization ability of the bioceramic cements (Gancedo-Caravia & Garcia-Barbero, 2006).

According to the results of the current study, we observed that Ortho MTA had lower PBS than that of ProRoot MTA. This was not inconsistent with a previous study by Rahoma et al. (A. Rahoma *et al.*, 2018). They compared the push-out bond strength of three types of mineral trioxide aggregate materials; OrthoMTA, MTA-Angelus, and ProRoot MTA in root dentin. Although MTA-Angelous had relatively lower PBS, no statistically significant difference was observed between the tested groups.

A two-week evaluation by Orhan Eo *et al.*, (Orhan *et al.*, 2019) showed that the mean±SD amount of PBS for OrthoMTA was 15.08 ± 4.17MPa in the middle root area. They also claimed that adhesive-type of failure was the most bond failure mode in OrthoMTA samples in the middle root. In the present study, we showed a PBS of 0.19±0.09 MPa after 4h with the dominant failure mode of a cohesive type after 10 min, and adhesive type after 4h. The difference in failure types might be related to different evaluation periods.

Komabayashi & Spangberg (Komabayashi & Spångberg, 2008) explained that two factors of size and shape of bioceramic cement particles affected adhesive properties to the dentin substrate. Mjor *et al.*, (Mjör *et al.*, 2001) showed the dentin tubule diameter ranges of 2µm-5µm, so smaller particles are able to penetrate the tubules (Komabayashi & Spångberg, 2008). The median of the particle size of OrthoMTA is 2µm (Eid *et al.*, 2013; Mohammadi *et al.*, 2014) whereas, the particle size of ProRootMTA ranges between 1.5-10 µm (Chang, 2018). Previous studies showed that short and long tags of dental materials could seal the dentin tubules and orifices (Komabayashi & Spångberg, 2008). Therefore, different sealing abilities and bond strength with various sizes of particles can be expected.

Al-Haddad et al. (Al-Haddad *et al*., 2020) examined the bond strength of OrthoMTA and iRoot SP and showed that cohesive failure was the prominent failure mode in all groups, but there was no association between failure mode and tested materials. The mentioned results are similar to our study.

Majeed *et al*., (Majeed & AlShwaimi, 2017) showed that the majority of ProRoot MTA (85%) samples had an adhesive-type bond failure which is in contrast to the results of the current study. Turk and Fidler (Turk & Fidler, 2016) demonstrated no predominant failure mode for the MTA group.

According to a 24-hour bonding evaluation by Orhan et al. (Orhan *et al*., 2021), OrthoMTA showed a higher push-out bond strength than that of ProRoot MTA on root dentin. Mixed-type failure mode was the most common type of failure in both OrthoMTA and ProRoot MTA samples.

Some factors including thickness of cement, powder/liquid ratio, humidity and pH of enviroment, and pressure force of condensation may affect MTA bonding characeristics (Parirokh *et al*., 2018). This can partially explain the contrast of bond failure type in MTA materials of different studies.

Within the limitations of this in vitro study, it can be concluded that ProRoot MTA showed higher PBS than that of Ortho MTA. Considering the higher PBS of ProRoot MTA, it might be still a clinical choice for endodontic treatments despite its high price and less availability. More studies are suggested to evaluate the PBS of these two materials in a longer time.

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