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ORIGINAL RESEARCH

Comparative Evaluation of Push-out Bond Strength of ProRoot MTA, Bioaggregate and Biodentine

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ABSTRACT

Objective: To evaluate the push-out bond strength of Biodentine (BD) in comparison with two available calcium silicate based materials, bioaggregate (BA) and ProRoot MTA (WMTA).

Materials and methods: One hundred and twenty-three root dentin slices of freshly extracted single rooted human teeth were randomly divided into three groups (n = 41) according to the used test material: WMTA, BA, BD. After canal space preparation, the filling materials were placed inside the lumen of the slices. After 72 hours, the maximum force applied to materials at the time of dislodgement was recorded and slices were then examined under a stereomicroscope at ×40 magnification to determine the nature of bond failure. Analysis of variance (ANOVA) test was used to compare means of push-out bond strength. Post-hoc test was then accomplished for multiple comparisons. Chi-square test was used to determine if there is significant association between the type of material and type of failure.

Results: The mean push-out bond strength ± standard deviation in MPa values of WMTA, BA and BD were 23.26 ± 5.49, 9.57 ± 3.45, 21.86 ± 6.9, respectively. There was no significant difference between the means of WMTA and BD (p = 0.566), but the mean of BA was significantly lower than those of WMTA and BD (p = 0.000). Under stereomicroscope, WMTA and BA showed a majority of mixed type of failure than cohesive failure, while BD showed the opposite. No adhesive failure was observed in any specimen.

Conclusion: The findings of the present study imply that the force needed for BD displacement is similar to WMTA and significantly higher than the force required to displace BA.

Keywords: Push-out, ProRoot MTA, Bioaggregate, Biodentine.

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INTRODUCTION

Mineral trioxide aggregate (MTA), a calcium silicate-based cement (CSC) material, was first described in dental literature in 1993[1] and introduced to the market in 1998. It was available in gray color, which was then replaced by white MTA in 2002. According to the material safety data sheet, the ingredients of MTA (ProRoot MTA, Dentsply, Tulsa, OK) are Portland cement, bismuth oxide and gypsum. By weight, Portland cement is the major component of MTA (75%). It is composed of dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite.[2]

Mineral trioxide aggregate has different clinical applications in endodontics, which include repair of root perforations, in vital pulp therapy, as root end filling material and an apical plug for teeth with necrotic pulps and open apexes.[3] These numerous clinical applications of MTA are due to its advantages, which include biocompatibility,[4] osteoconductivity[5] and its effective sealing ability.[6] However, the main disadvantages of MTA are difficulty in handling characteristics,[7] long setting time ≈ 140 minutes,[8] and high cost. To overcome the unfavorable properties of MTA, several new CSCs have been introduced to the market. These materials include bioaggregate (BA) (Innovative BioCeramix, Vancouver, Canada) and biodentine (BD) (Septodont, Saint Maur des Fossés, France) that have the same potential clinical uses in endodontics to those of MTA.

According to the manufacturer booklet, components present in BA are: calcium silicate, calcium hydroxide, hydroxyapatite, tantalum oxide and silicon oxide. Bioaggregate comes in the form of powder and liquid that is mixed to a thick paste-like mixture. The working time of BA is at least 5 minutes. The complete setting time is between 4 and 72 hours. The manufacturing company claims that the difference between MTA and BA that BA is aluminum free, which minimize the toxic effect to human cells. Another difference is that BA contains a significant amount of tantalum oxide instead of bismuth oxide as a radio-pacifier.[9] This material was found to be biocompatible to human PDL fibroblasts,[10] bioactive,[11] has similar antibacterial effect against *Enterococcus faecalis* to MTA.[12] The dislodgment resistance of BA, as a furcation repair material, was found to be inferior to MTA-angelus. However, it was not affected by acidic environment.[13]

Biodentine is a newer calcium silicate-based cement, which has been advertised as a bioactive material. Biodentine can be used as a dentin substitute on crowns and roots. It consists of a powder in a capsule and liquid in a pipette. According to the company scientific file, the powder mainly contains tricalcium and dicalcium silicate, which are the principal component of Portland cement. The liquid contains calcium chloride, which act as an accelerator. The powder is mixed with the liquid in a capsule in the triturator for 30 seconds. Once mixed, the working time of BD is up to 6 minutes with a final set at around 10 to 12 minutes. This new material was proved to be biocompatible to human gingival fibroblasts,[14] bioactive,[15] and has lower setting time when compared to BA.[16] The push-out bond strength of BD is not affected by NaOCl or Chlorhexidine gluconate.[17]

Considering the clinical applications for CSCs, the marginal adaptation and bond strength of these materials with dentin is an extremely important factor in clinical practice. The push-out test aims to assess the bond strength of a restorative material to dentin.[18] To the best of our knowledge, there is no published data comparing the push-out bond strength of the three calcium silicate based endodontic materials; White ProRoot MTA, BA and BD. Therefore, the purpose of this study was to evaluate the push-out bond strength of BD in comparison with two available calcium silicate based materials, BA and WMTA. The tested null hypothesis was that there is no difference in the push-out bond strength of the three different calcium silicate based material.

MATERIALS AND METHODS

Sample Preparation

Freshly extracted, single-rooted teeth, stored in saline, were used in this study. Teeth were embedded vertically in a rubber mold containing epoxy resin (Vertex Orthoplast; Vertex-Dental, Zeist, Netherlands). A mounting device was used to ensure orientation in the long axis of the tooth. The middle third of each root was sectioned, perpendicular to the long axis, into slices with a thickness of 2.0 ± 0.05 mm by using Isomet low speed saw (Isomet; Buehler Ltd, Lake Bluff, NY, USA) with continuous water irrigation. A total of 123 root dentin slices was obtained. For standardization, the canal space of each slice was instrumented with a complete pass of Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland) sizes 2, 3, 4, 5 and 6 to achieve a diameter of 1.5 mm. All samples were rinsed with saline to remove all debris produced. Paper points were used to absorb the liquid present in the canal walls.

The slices were randomly divided into three groups (n = 41) according to the used test material:

- Group A: White ProRoot MTA (WMTA)
- Group B: Bioaggregate (BA)
- Group C: Biodentine (BD).

All three different filling materials were mixed according to manufacturers' instructions, placed inside the lumen of the slices, and condensed using endodontic plugger. A scalpel was used to remove the excess material. Specimens were wrapped in a piece of wet gauze and placed in an incubator at 37°C and 100% relative humidity, for 72 hours.

Push-out Test

The push-out test was carried out using a universal testing machine (Instron testing machine; Model 5965, ITW, MA, USA). The samples were placed on a metal slap containing a central hole to allow a free motion of the plunger with a 1.2 mm diameter, at a constant vertical pressure of a speed of 1 mm/min. The plunger tip was positioned to contact the test material only. The test was carried out until total bond failure. The highest force applied to materials at the time of dislodgement was recorded in newtons. The operator, who made the measurements, was blinded to which sample is matched to which material. The push-out bond strength was calculated in megapascal (MPa) by using the following formula:

$$\text{Bond strength (MPa)} = \frac{\text{Force for dislodgement (N)}}{\text{Bonded surface area (mm}^2\text{)}}$$

Bonded surface area = 2 × p × r × h

where p is the constant 3.14, r is the radius of the root canal, and h is the thickness of the dentin slice in millimeter.

Evaluation of Failure Patterns

After the push-out test, slices were examined under a stereomicroscope at ×40 magnification to determine the nature of bond failure. Each sample was categorized into 1 of the 3 failure modes: adhesive failure that occurred at dentin-material interface, cohesive failure that occurred within the material, or mixed failure, which is the combination of the two failure modes. The operator, who examined the slices, was blinded to which sample is matched to which material.

Statistical Analysis

For dislodgement resistance, Shapiro-Wilk normality test revealed normal distribution; hence one-way analysis of variance (ANOVA) test was used to compare means of push-out bond strength for the three different materials. Post-hoc test was then accomplished using Games-Hawell for multiple comparisons. Chi-square test was used to determine if there

Table 1: Mean and standard deviation for three different materials

	Material	*Mean*	*SD*
Push-out bond strength (MPa)	WMTA	23.2637	5.485
	BA	9.5739	3.45483
	BD	21.8578	6.89735

Table 2: Type of failure within each material in percentage

Material	*Number of specimens*	*Type of failure*	
		Cohesive failure (%)	*Mixed failure (%)*
WMTA	41	36.6	63.4
BA	41	63.4	36.6
BD	41	34.1	65.9
Total	123	44.7	55.3

is significant association between the type of material and type of failure.

The level of significance was set at 0.05. Statistical analysis was performed using SPSS statistical software (version 16; SPSS Inc, Chicago, IL, USA).

RESULTS

Push-out Test

The mean push-out bond strength and standard deviation of each material are presented in Table 1. Analysis of variance test revealed that the mean push-out bond strength ± standard deviation in MPa values of WMTA, BA and BD were 23.26 ± 5.49, 9.57 ± 3.45, 21.86 ± 6.9, respectively.

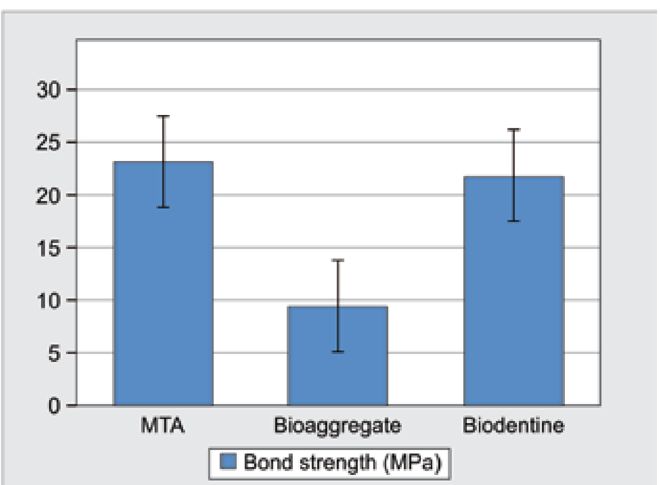
Multiple comparisons between three materials using Games-Hawell test showed that there was no significant difference between the means of WMTA and BD (p = 0.566), but the mean of BA was significantly lower than those of WMTA and BD (p = 0.000) (Graph 1).

Bond Failure Patterns

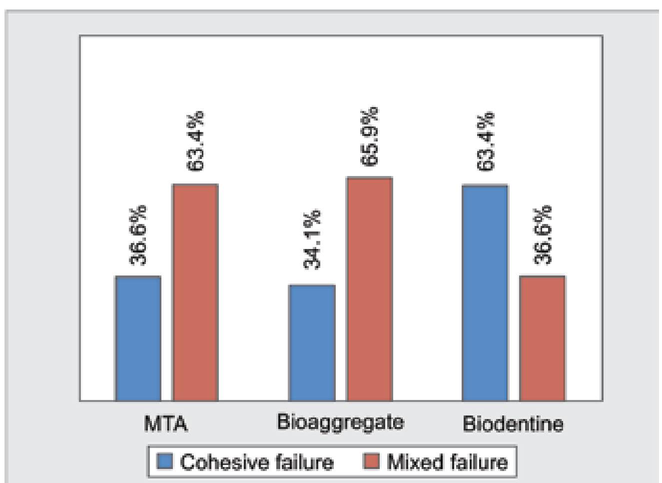
Regardless of the type of material, none of the specimens showed adhesive type of failure (Table 2). Chi-square tests revealed a significant association between the different materials and type of failure (p = 0.013). ProRoot MTA and BA showed a majority of mixed type of failure than cohesive failure, where BD showed the opposite results; cohesive failure more than mixed type (Graph 2).

DISCUSSION

The bond strength of endodontic materials used in perforation repair, vital pulp therapy or MTA apical plug is an important factor in clinical practice. One of the requirements of such material is to persist in place under dislodging forces, such as mechanical stresses resulting from tooth function or operative procedures.[19] Different methods have been used to demonstrate the adhesive properties of dental materials to the surrounding dentin. These include tensile, shear and push-out bond strength test. The push-out bond strength, which was used in this study, has been shown to be efficient, practical and reliable.[19-21] The published literature on the bond strength of both BA and BD is very limited, this study is the first to compare the push-out bond strength between the three CSC materials: WMTA, BA and BD. For standardization, all three materials were tested after an identical period of time had elapsed since mixing. The



Graph 1: The mean push-out bond strength in MPa of three different materials



Graph 2: The percentage of bond failure by material

72 hours interval was deemed sufficient to minimize the effect of the differences in setting time of the individual material.

The results of the present study showed lower push-out bond strength of BA when compared to WMTA. This finding was similar to those obtained in previous studies.[13,22] Furthermore, BD push-out bond strength results were very similar to those of WMTA. A previous study by Guneser et al (2013)[17] showed significantly higher retention in BD than WMTA. The specimens in their study were immersed in various endodontic irrigants for 30 minutes before the placement in incubator. Comparing the push-out bond strength of BD and BA; BA was found to be less resistant to dislodgement forces than BD, no previous study compared the push-out bond strength between these two materials. The higher retention in WMTA and BD groups may be explained by the tag-like structure formed in the adjacent root canal dentin.[23] Bioaggregate is aluminum-free compound.[9] This may explain the lower push-out bond strength in BA. Liu et al[24] indicated that the addition of tricalcium aluminate improves the strength of CSC. Without $Ca_3Al_2O_6$ the strength of the cement may be jeopardized.

In the present study, the bond failure of all three materials was investigated. ProRoot MTA and BA showed a majority of mixed type of failure. The finding regarding WMTA is in agreement with Rahimi et al[25] but disagrees with others who reported failure at the MTA-dentine interface.[20,21] The differences might be attributed to the factors included in their study designs; different acidic[21] or alkaline[20] pH levels. The mixed type of bond failure in WMTA and BA might be explained by the short time of storage before the push-out test.

The bond failure observed in BD group was predominantly within the material itself, which is in accordance with Guneser et al.[17] This mode of failure may have occurred as a result of smaller sized particles that might modify the interlocking of BD within the dentinal tubules. Furthermore, BD forms a tag-like structure along the dentin-material interface.[23]

This *in vitro* method of push-out cannot duplicate the environment that exists *in vivo*. However, the results from this study might provide information that can aid the clinician in the selection of the best material used in clinical practice. Based on the findings of this study, BD showed comparative retention when compared to WMTA. However, it has a shorter setting time, which would be beneficial because it would allow an immediate, safe placement of a final restorative material over it, reduce the number of appointments and also shorten the period when washout of the cement could occur. Biodentine is less expensive than WMTA. This material needs further investigation regarding other physical properties.

CONCLUSION

Within the conditions of the present *in vitro* study, it could be concluded that the force needed for BD displacement is similar to WMTA and significantly higher than force required to displace BA.

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