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Comparison of Flexural Strength of Mineral Trioxide Aggregate, Calcium-enriched Mixture and BioAggregate

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ABSTRACT

Introduction: The aim of this study was to compare the flexural strength of mineral trioxide aggregate (MTA), calcium-enriched mixture (CEM), and BioAggregate (BA). **Methods and Materials**: In this study, the flexural strength of materials was measured using a 3-point bend test. After being prepared, MTA, CEM, and BA were inserted into the intra-putty molds using amalgam plugger. The specimens were covered with a sponge wetted with synthetic tissue fluid (STF) and incubated for 96 h. They were then subjected to a 3-point bend test using Universal Testing Machine. The Kruskal-Wallis and Mann-Whitney U tests were used to compare flexural strength in groups. In this study, $P<0.05$ was considered as the significant level. **Results**: There were significant differences between the three groups in terms of the flexural strength ($P<0.001$). The mean flexural strength in the BA, CEM, and MTA groups were 27.32±2, 9.09±1.16, and 10.25±1.6, respectively. Pairwise comparison showed significant differences between the three groups. **Conclusion**: This *in vitro* study showed that BA has the highest and CEM has the lowest flexural strength.

Keywords: BioAggregate; CEM Cement; Flexural Strength; Mineral Trioxide Aggregate

Introduction

Mineral trioxide aggregate (MTA) as an endodontic biomaterial has numerous applications [1-3]. These are mainly due to its biocompatibility feature [4, 5], release of calcium hydroxide, optimum sealing ability against bacteria and saliva [6], antibacterial feature [7], ability to set in wet conditions such as the presence of blood or serum [8], having acceptable compressive strength and hardness [9]. Despite these advantages, MTA has some disadvantages such as long setting time, difficult use, and tooth discoloration [10, 11].

Calcium-enriched mixture (CEM) is a new generation of retrograde filling materials with the ability to produce hydroxyapatite [12]. CEM, in addition to proper sealing capability, has good tissue compatibility and studies confirm the regeneration of periradicular tissues following its application [13]. CEM is a hydrophilic cement which is synthesized from various calcium compounds [14]. This cement has the ability to stimulate hard tissue formation, exert antimicrobial effect and create a seal against the entry of microorganisms [15]. Although the clinical applications of this material are as diverse as MTA, its chemical composition is different from MTA [13, 14]. It also showed similar sealing ability to MTA [16, 17]. CEM has the biocompatibility similar to that of MTA and other favorable properties such as shorter setting time, better handling and less tooth discoloration [15, 18, 19]. Cell culture studies showed that this material has cellular toxicity similar to MTA [20], its biocompatibility is better than calcium hydroxide in the treatment of living pulp tissue [21] and the same as MTA [22, 23]. The previous studies showed that some physical characteristics of the CEM, for example film thickness, flow and setting expansion have been optimum and better than MTA [24]. Suitable sealing ability, good biocompatibility and easy application, even in wet cavities, are superior features of this material [22].

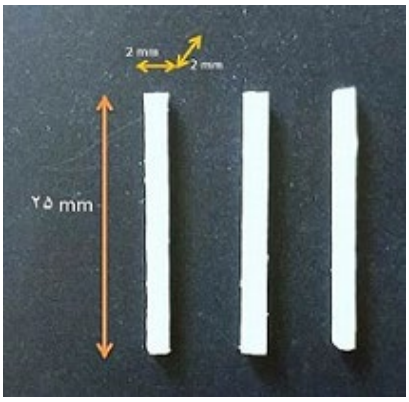

Figure 1. Prepared specimens (2×2×25 mm)

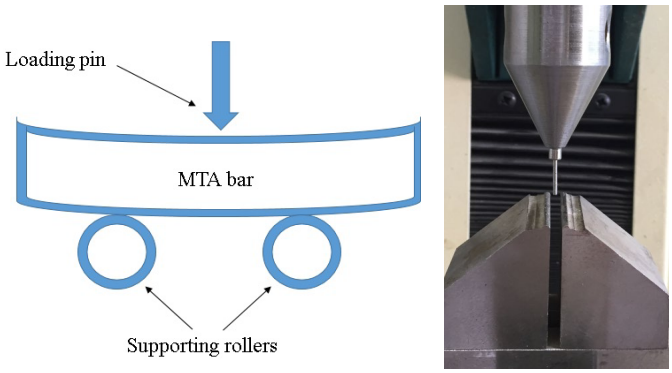

Figure 2. Three-point bend test; the bar is supported by two lower rollers and loaded at the center until crushing and Universal testing machine

BioAggregate (BA) is another endodontic biomaterial recently introduced and approved by the Food and Drug Administration (FDA) of the United States [25]. Root-end filling, perforation repair, and vital pulp therapy are considered among the applications of this material [25]. On the other hand, the basic composition of this material is fundamentally the same as that of MTA, and includes several synthetic particles; for example, calcium silicate hydrate, calcium hydroxide, hydroxyapatite, tantalum oxide and silicon oxide [25].

Flexural strength is one of the important characteristics of MTA. This property becomes more important when the MTA are directly or indirectly exposed to occlusal pressures, for example when MTA is used as pulpotomy material or direct pulp coating or furcal perforation repair. If the clinician wishes to restore the tooth with amalgam, MTA needs to be set first and needs flexural strength greater than the amount of pressure applied when placing amalgam. In these cases, the flexural strength of the MTA should exceed condensation pressure (6-9 MPa) to prevent crushing of the MTA [26]. According to previous studies, the flexural strength of the MTA is about 9-10 MPa [26]. Since there has been no study on the flexural strength of CEM and BA in comparison with MTA, the aim of the present study was to assess this issue.

Materials and Methods

This experimental study was approved by the Research Ethics Committee (IR.TBZMED.REC.1396.257). In this study, 36 specimens were divided into three groups: White MTA (Angelus, Londrina, Brazil), CEM (BioniqueDent, Tehran, Iran) and BA (DiaDent Group International Inc., Burnaby, Canada), with 12 specimens in each group. All tested specimens were prepared according to the ISO 4049 standard [27] for flexural strength testing using the three-point flexural test in the Universal testing machine (Hounsfield testing equipment, Redhill, UK). Considering that there has been no previous study on this subject, the sample size was determined according to the results of a pilot study with three specimens in each group. The sample size was determined to be 9 according to the results of the pilot study, taking into account α=0.05 and 80% power. Considering that the specimens might be excluded during the study, 12 specimens were considered for each group. To prepare the bars, wooden bars (2×2×25 mm) were mounted on a glass slab, and an impression was made using putty impression material (Spidex, Apadanatak, Iran) to achieve 36 molds in putty.

MTA, CEM and BA were prepared according to Manufacturer's instruction. For MTA and CEM, 0.34 gr distilled water was mixed with 1 gr powder. For BA preparation, BioA Liquid vial progressively mix into DiaRoot powder using the spatula for about 2 min. Then, the specimens were transferred into the intra-putty cavities (molds) using an amalgam plugger with minimum pressure. The specimens were later covered with a sponge wetted with phosphate-buffered saline (PBS) as synthetic tissue fluid (STF) and incubated for 96 h. The dimensions of the specimens were measured using a caliper (Figure 1) before the flexural strength testing and then subjected to a three-point bending test (Figure 2). To perform the test, the Universal Testing Machine was used to apply force at a speed of 0.5 mm/min between the bars placed on the support from both sides. The maximum force leading to crushing was recorded, and the flexural strength was calculated according to the formula of $\delta=3Fl/2bd^2$ where F stands for the maximum force leading to crush; l, the bar length; b, the bar width; d, the bar thickness. In this research, flexural strength was performed on three groups based on ISO 6872 [28] and ISO 9917-1 [29]. The Kruskal-Wallis and U-Mann Whitney tests were used to analyze the data using SPSS (Statistical Package for Social Science, SPSS, version 20.0, SPSS, Chicago, IL, USA). In this study, $P\leq0.05$ was considered as the statistically significant level.

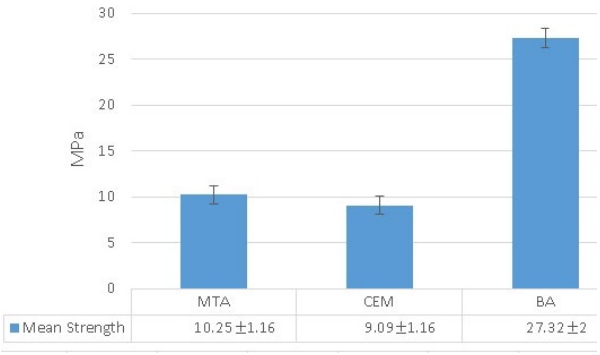

Figure 3. Comparison of flexural strength in three groups (Mean±SD)

Results

The mean flexural strength in the BA, CEM and MTA were 27.32±2 MPa, 9.09±1.16 MPa, and 10.25±1.6 MPa, respectively (Figure 3). The Kolmogorov-Smirnov test showed that the data did not have a normal distribution (P=0.002). Therefore, the nonparametric Kruskal-Wallis test was used to perform the comparisons. The results of this test showed a significant difference between the three groups in terms of flexural strength values (P<0.001). To carry out the pairwise comparison, the U-Mann-Whitney test was used and the results showed significant differences between the three groups. The highest difference was observed in the CEM and BA groups, with BA flexural strength 22.28 MPa greater than that of CEM (P<0.001). The lowest difference was also seen in MTA and CEM, with MTA flexural strength 1.16 MPa greater than that of CEM (P=0.012). Also, the difference between the MTA and BA groups was 17.6 MPa (P<0.001).

Discussion

The purpose of this study was to compare the flexural strength of MTA, CEM, and BA. According to the results of the current study, BA and CEM had the highest and the lowest mean flexural strength, respectively. Additionally, the results of the inter-groups mean comparison demonstrated that there was a significant difference between the three groups in terms of flexural strength levels.

Strength is an important property for restorative materials, which depends on the microstructure and composition of the material, the method of testing the fracture mechanism and the environment [30]. The measurement of compressive and flexural strength is one of the methods to investigate the mechanical properties of restorations [31]. Flexural strength is one of the important characteristics of biomaterials. As mentioned, this property becomes more important when the MTA is placed under occlusive pressures. In these situations, the flexural strength of the MTA should be greater than the load of the amalgam condensation to prevent the crushing of the MTA [32].

Several studies have tried to determine the optimum and mean condensation pressure applied during amalgam placement [33, 34]. Comparing the results of these studies with the flexural strength values obtained in our study shows that theoretically, 96-h set BA has sufficient flexural strength to withstand such condensation forces; however, the strength of 96-h set MTA or CEM is near the condensational forces.

It is not clear whether the flexural strength of MTA or CEM increases over time or when these biomaterials achieve sufficient strength to withstand amalgam condensation forces; however, the results of the available literature on the flexural strength of MTA shows a possible increasing trend over time [35-38].

A study on flexural strength of MTA by three-point bending test reported flexural strength of MTA about 0.93 MPa which is significantly lower the finding in our study. [37]. The difference in material preparation *i.e.* mixing method, environment humidity, the pressure used for condensation, could be the cause of this difference [38]. Also, the incubation time in this study was 24 h while we incubate our samples for 96 h.

In the similar study by Basturk *et al.* [35] with same incubation time (96 h), template size (2×2×25 mm) and cross head speed (0.5 mm/min) reported the ProRoot MTA and MTA Angelus mean flexural strength was 11.27 MPa and 8.73 MPa, respectively. This result is in agreement with our study.

A study on the effect of hydration and setting condition on MTA flexural strength suggested that a moistened cotton pellet be placed on the MTA surface under a temporary restoration; and if possible, to optimize flexural strength, the moistened pellet should remain in place for 24 h [38]. Aggarwal *et al.* [39] found that the BioPure MTAD and EDTA irrigation reduced the flexural strength of MTA and proposed a final flush with distilled water before placement of MTA especially if decalcifying agents are used during the clinical procedures.

All the above-mentioned studies are up to 96 h incubation time; thus, further long-term studies are required to determine the pattern of MTA or CEM cement's strength alteration over time and the time that they obtain sufficient strength.

Within the limitations of the present study, it is advisable to use BA under amalgam restoration; however, when MTA or CEM are used, bonding restorations are preferred that require fewer condensation forces when the tooth is restored before 96 h.

This study was an *in vitro* one with its inherent limitations. For instance, the perforations may have different shapes and sizes, and the biomaterials placed at large perforations may have different thickness in a different part. Therefore, direct extrapolation of the results of the present study to all clinical situations is not appropriate.

Conclusion

It can be concluded that 96-h set BA has the highest flexural strength sufficient to withstand condensational forces; however, the flexural strength of 96-h set MTA and CEM is significantly lower than BA.

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Conflict of Interest: 'None declared'.

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