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Push-out bond strength of retrograde root-end filling materials in extracted human teeth: calcium enriched mixture cement versus Biodentine

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Abstract

Backgrounds and aim: Root-end filling materials are applied to provide an apical seal in apicoectomy. The purpose of this study was to compare the push-out bond strength of calcium-enriched mixture (CEM) cement and Biodentine in extracted humanbeing teeth.
Materials and Methods: This in vitro, experimental study evaluated 40 extracted sound single-rooted mandibular premolars with mature apices. After disinfection process, the teeth were decoronated to acquire roots with 13 mm length. The root canals were instrumented using hand and rotary files and Gates-Glidden drills and filled using lateral compaction technique. The apical 3 mm of root ends was cut perpendicular to the longitudinal axis of the root. The apical region was prepared to 3 mm depth using the tip of an ultrasonic instrument. The samples were then randomly divided into two groups (n=20) for root-end sealing with CEM cement and Biodentine. To assess the push-out bond strength, the apical end was cut perpendicular to the longitudinal axis of the tooth to obtain circular segments with 2±0.001 mm thickness. The push-out bond strength was determined by a universal testing machine. Data were analyzed using SPSS via chi-square test.
Results: The mean bond strength of Biodentine was significantly higher than that of CEM cement (P=0.001). The maximum and minimum bond strength values were 20 MPa and 14.7 MPa for Biodentine and 13.8 MPa and 11.7 MPa for CEM cement, respectively.
Conclusion: Considering the high push-out bond strength of Biodentine, it can be successfully used as a retrograde root-end filling material in endodontic surgery.

Keywords: push-out bond strength, calcium-enriched mixture cement, tricalcium silicate

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INTRODUCTION

Root canal treatment is performed to prevent apical periodontitis (Ørstavik and Pitt Ford 1998). Despite the recent advances in endodontic treatment, failures still occur. Endodontic surgery, i.e. apicoectomy, is recommended for cases where orthograde endodontic retreatment has failed or is not possible to perform (Dugas et al. 2003). Apicoectomy, also known as periradicular surgery, involves flap elevation, bone removal, root-end resection, cavity preparation at the root-end and application of root-end filling material (Rainwater et al. 2000). Each of the above-mentioned steps has its share in success of endodontic surgery (Gondim et al. 2002, Rainwater et al. 2000).

Different materials are applied as retrograde root-end filling materials in apicoectomy. Zinc oxide eugenol, Intermediate Restorative Material, Super EBA, Cavit, polycarboxylate cement, zinc phosphate cement, glass

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ionomer, mineral trioxide aggregate (MTA), calcium phosphate cement, Bone Cement, and calcium enriched mixture (CEM) cement are among the most commonly used root-end filling materials (Torabinejad and Walton 2009). Root-end filling materials should be non-toxic, non-resorbable, biocompatible, radiopaque, non-carcinogenic and insoluble. They should also be easy to use and capable of providing a hermetic seal (Glickman and Hartwell 2008, Torabinejad and Walton 2009). No root-end filling material meets all the required properties (Torabinejad and Walton 2009). At present, MTA is extensively used as a root-end filling material (Economides et al. 2003, Pelliccioni et al. 2004, Zhu et al. 2000). However, it has shortcomings such as long setting time and difficult handling (Torabinejad and Walton 2009).

CEM cement, introduced in 2006, has optimal biocompatibility, sealing ability, osteoinductive traits and antibacterial activity as good as those of MTA (Asgary et al. 2008b). Also, its physical properties such as low film thickness and optimal flowability are superior to those of MTA. It also has easier handling and shorter setting time than MTA, which make it suitable for use in the clinical setting (Asgary et al. 2008a, 2009). Due to such favorable properties, it is a suitable filling material for root perforation repair and root-end filling (Asgary et al. 2008b).

Biodentine is a calcium silicate-based cement introduced by Septodent in 2009. It has optimal mechanical properties, favorable biocompatibility and excellent bioactivity (Biodentine Active Biosilicate …). It also has a short setting time and easy application (Asgary et al. 2008b). Due to the aforementioned favorable properties, Biodentine is considered as a replacement for dentin in restorative and endodontic treatment procedures of severely damaged teeth (Nikhade et al. 2016). Evidence confirms its superior physical properties such as shorter setting time and easier handling compared to MTA (Biodentine Active Biosilicate …). Moreover, Biodentine has reportedly higher bond strength than MTA (Majeed and AlShwaimi 2017, Nikhade et al. 2016).

Adequate push-out bond strength is imperative for a root-end filling material. Push-out bond strength is defined as resistance of a material against dislodging forces. Microtensile bond strength test is a recently introduced method for assessment of bond strength of dental materials (Armstrong et al. 2010). However, evidence shows that it is not suitable for assessment of bond strength of root-end filling materials due to high rate of unfavorable failures and high variability in test results (Soares et al. 2008). Push-out bond strength test is a modified version of shear punch test, which is believed to be highly suitable for measurement of bond strength of root-end filling materials (Goracci et al. 2004).

Considering the significance of adequate bond strength of root-end filling materials, this study aimed to assess and compare the push-out bond strength of CEM cement and Biodentine retrograde root-end filling materials in extracted single-rooted human teeth.

MATERIALS AND METHODS

This in vitro, experimental study evaluated extracted single-rooted human mandibular premolars. The teeth had straight roots, no cracks or caries and mature apices. Sample size was calculated to be 20 in each of the two groups (a total of 40) assuming 80% study power. The study was accepted in the ethics committee of Qazvin University of Medical Sciences .

The teeth were immersed in 0.5% chloramine T solution for one week for the purpose of disinfection and were then transferred to distilled water according to ISO/TS 11405:200.

In order to standardize the samples, the teeth were decoronated at the cementoenamel junction or further apical using a diamond disc (D&Z, Wiesbaden, Germany) to obtain roots with 13 mm length. Working length was determined by introducing a #10 or #15 K-file into the canal until its tip was visible at the apex; 1 mm was subtracted from this length to determine the working length. The root canals were instrumented using hand and rotary files and Gates-Glidden drills. Final preparation of the apical region was performed using Mtwo rotary system (VDW, Munich, Germany) until reaching #30/0.04 apical size. The coronal region was prepared using #3 Gates-Glidden drill (Dentsply Maillefer, Ballaigues, Switzerland) up to size 80. The canals were rinsed with 2.5% sodium hypochlorite and saline during filing. Patency was maintained using a #10 K-file. The canals were then dried with paper points and obturated with gutta-percha (Meta Biomed Co., Ltd, Cheongju City, Chungbuk, Korea) and AH26 sealer (DENTSPLY, DeTrey, Konstanz, Germany) via lateral compaction technique. The coronal part was sealed with Cavit (3M ESPE, Seefeld, Germany). After storing the samples in an incubator at 37°C and 100% humidity for 72 hours, the apical 3 mm of the root-end was resected at 90° angle perpendicular to the longitudinal axis of the tooth using a long cylindrical diamond bur under water coolant. The samples were then randomly divided into two groups of 20. Before preparing the root-end cavity, apical gutta-percha was removed by a heat carrier by up to 3 mm depth. The root-end cavity was then prepared using the tip of an ultrasonic instrument (Obtura Spartan, Fenton, MO, USA) adjusted at 5 power under water irrigation.

In group 1, CEM cement (BioniqueDent, Tehran, Iran) was mixed according to the manufacturer's guidelines and condensed into the prepared root-end cavity with 3 mm thickness.

In group 2, as instructed by the manufacturer, 5 drops of the respective liquid were added to each Biodentine capsule (Septodont, Saint maur des Foses, France) and the capsule was then put in an amalgamator and mixed for 30 seconds. The mixed Biodentine was then condensed in the cavity with 3 mm thickness.

Immediately after filling of the root-end cavities, radiographs were obtained of the samples to ensure adequate quality of filling and absence of voids. Samples with voids or inadequate thickness of root-end filling were excluded and replaced. The samples were placed in a wet sponge and were then incubated at 37°C and 100% humidity for 72 hours. Next, the apical end of the samples was cut perpendicular to the longitudinal axis of the root using a diamond disc (Mecatome, Presi, France) under water coolant to obtain circular segments with 2.00±0.001 mm thickness. One section of each root was selected and inspected under a surgical microscope at x25 magnification to determine the presence/absence of cracks or fracture lines and measure the lumen diameter to calculate the surface area of the lateral canal wall.

The bond strength was measured using a universal testing machine (Z050; Zwick Roell, Ulm, Germany). The operator was blinded to the group allocation of samples. Load was applied by a piston with 0.7 mm diameter to the center of the side of sample with smaller diameter at a crosshead speed of 0.5 mm/minute. Samples that broke during load application were excluded. Maximum load causing dislodgement of root-end filling material was recorded in Newtons (N) and converted to megapascals (MPa) using the formula below:

$$bond\ strength\ (MPa) = \frac{debonding\ force\ (N)}{surface\ area\ (mm^2)}$$

Data were analyzed using SPSS version 22 (SPSS Inc., IL, USA). Chi-square test was applied to compare the push-out bond strength of the two groups. Level of significance was fixed at 0.05.

RESULTS

The mean push-out bond strength was 17.75±8.31 MPa (range 14.7 to 20 MPa) in the Biodentine and 12.88±5.12 MPa (range 11.7 to 13.8 MPa) in the CEM cement group. According to independent sample t-test, the push-out bond strength was significantly higher in Biodentine group (P=0.001).

DISCUSSION

This study evaluated the push-out bond strength of CEM cement and Biodentine in extracted human teeth. The results showed that the mean push-out bond strength of Biodentine was significantly higher than that of CEM cement (P=0.001).

The ability to provide a strong bond to dentin is among the most important prerequisites for root-end filling materials and plays an important role in success of endodontic surgery. The majority of endodontic failures are related to microleakage of stimuli into the periapical tissue. On the other hand, root-end filling materials should be able to resist dislodging forces such as masticatory forces; this resistance is referred to as bond strength (Sahebi et al. 2016, Vivan et al. 2016).

In the present study, Biodentine and CEM cement plugs were placed as retrograde to better simulate apicoectomy in the clinical setting. Also, the root end region was prepared by an ultrasonic instrument, which is often recommended to provide better retention for root-end filling materials (Bernardes et al. 2007). The results showed superior push-out bond strength of Biodentine compared to CEM cement. This difference can be attributed to different composition of cements (Atmeh et al. 2012). Calcium silicate-based cements form calcium phosphate and apatite-like deposits at the cement-dentin interface and within the dentinal tubules. Also, the biomineralziation ability of these materials is directly related to the calcium ion release, and phosphate release to a lesser extent (Atmeh et al. 2012). The released ions are responsible for the formation of tag-like structures and an intermediate hybrid layer, which is responsible for the formation of physical and chemical bonds (Atmeh et al. 2012, Camilleri et al. 2013).

Biodentine and CEM cement both release high amounts of calcium (Rajasekharan et al. 2014, Ghazvini et al. 2009). However, calcium-silicate based materials provide adequate phosphate ions for the formation of apatite-like compounds using the adjacent tissue fluids (Kim et al. 2015). Our study had an in vitro design and although the root-end filling materials condensed into the root-end cavity remained moist until their setting completed, the in vivo conditions could not be perfectly simulated and further in vivo studies are required to better elucidate this topic.

Calcium silicate-based compounds form hydrated calcium silicate gel when in contact with water. This gel has porosities which are proportionate to the silicate content (Biodentine Active Biosilicate …). Such porosities can be used as a core to provide retention for calcium hydroxide and hydroxyapatite crystals (Li and Roy 1988). Biodentine contains higher silicate content compared to CEM cement (Ghazvini et al. 2009, Tomás-Catalá et al. 2018), which may explain higher bond strength of Biodentine in our study. Saghiri et al. (2013) indicated that the size of particles used in the composition of materials affects their penetration depth into dentinal tubules and consequently their bond strength. Biodentine has a smaller particle size (5 μm) than CEM cement (Rajasekharan et al. 2014). Thus, it has better adhesion to dentin compared to CEM cement (Atmeh et al. 2012, Camilleri et al. 2013). This finding may explain higher bond strength of Biodentine than CEM cement. Majeed and AlShwaimi (2017) assessed strength of the bonding and surface hardness of calcium silicate-based cements. They reported higher bond strength values for Biodentine compared to our study, which may be due to difference in dentinal tubular size because they evaluated the coronal region of the roots. It has been demonstrated that the size of dentinal tubules can affect the penetration depth and adhesion of materials to root canal walls and consequently their bond strength (Pane et al. 2013). Sobhnamayan et al. (2015) evaluated the effect of 2% chlorhexidine on bond strength of CEM cement and showed lower bond strength of CEM cement compared to our study; this difference may be attributed to the larger diameter of the lumen of samples in their study compared to ours. Previous studies have indicated that the diameter of prepared lumens for placement of root-end filling materials has an inverse correlation with bond strength (Chen et al. 2013).

Bond strength of the root-end filling materials to dentinal walls is affected by the presence/absence of smear layer as well (Violich and Chandler 2010). EL-Ma'aita et al. (2013) investigated the influence of smear layer on push-out bond strength of calcium silicate-based root-end filling materials and demonstrated that Biodentine yielded the highest bond strength in presence of smear layer. We did not eliminate the smear layer in our study; nonetheless, Biodentine showed higher push-out bond strength than CEM cement.

Considering the in vitro design of the current study, generalization of results to the clinical setting should be done cautiously. Clinical studies are required to more accurately compare the efficacy of root-end filling materials. Future studies are recommended to compare the push-out bond strength of other commonly used root-end filling materials with Biodentine such as BioAggregate and MTA to find the gold-standard root-end filling material. Also, future studies should also perform other tests such as fluid filtration test to evaluate and compare other important properties of root-end filling materials. Considering the significance of stability and no movement of materials used for perforation repair such as MTA and Biodentine, bond strength tests should also be performed for repaired perforations in other areas such as root furcation.

CONCLUSION

Within the limitations of this study, the results showed higher push-out bond strength of Biodentine than CEM cement when used as retrograde root-end filling material. Thus, it may be successfully used in apicoectomy considering its optimally high push-out bond strength given that its other properties are also favorable.

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