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Original Article

Effect of the of Zeolite Containing Silver-Zinc Nanoparticles on the Push out Bond Strength of Mineral Trioxide Aggregate in Simulated Furcation Perforation

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ABSTRACT

Statement of the Problem: Recently, zeolite has been regarded to improve the properties of dental materials such as mineral trioxide aggregate (MTA).

Purpose: The aim of the present study was to evaluate the effect of incorporating zeolite/silver/zinc (Ze/Ag/Zn) composite at 2 wt% to MTA powder on the push-out bond strength in simulated furcation perforations.

Materials and Method: Furcal perforations, measuring 1.3 mm in diameter and 2 mm in height, were simulated in 40 human mandibular first molars. The samples were allocated to two groups (n=20) based on the material used for the repair of perforations. In the group 1, MTA and in the group 2, MTA plus Ze/Ag/Zn (2%) was used. The samples were incubated at 37°C for 1 week. Then the universal testing machine was employed to measure bond strength. The resistance of materials to dislodgment was recorded in MPa. Data were analyzed using t-test. Statistical significance was set at $p< 0.05$.

Results: The push-out bond strength in the group 1 (6.40±1.98 MPa) was significantly higher than that in the group 2 (2.1±0.6 MPa) with $p= 0.001$.

Conclusion: Under the limitations of the present study, it can be concluded that incorporation of Ze/Ag/Zn at 2 wt% to MTA powder had a negative effect on the push-out bond strength.

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Introduction

Root and crown perforations are considered as some of the procedural errors during root canal treatment [1]. In order to achieve favorable prognosis, perforations should be repaired as soon as possible by employing an appropriate biomaterial. Mineral trioxide aggregate (MTA) has been reported to be a suitable biomaterial in the field of endodontics for the repair of perforations regarding its favorable properties such as good sealing ability, tissue compatibility, and the ability to induce cementogenesis and osteogenesis [2]. A material, which is used for the repair of perforations, particularly in perforation of furcal floor, should have proper resistance against dislodgment. In other words, it should form a proper bond with the dentinal wall in the perforation area. This is because the forces resulted from the placement of the restorative material and the occlusal forces (being consistently exerted on the material over time) might displace the material and interfere with the sealing ability [1, 3-4].

MTA has a long setting time and difficult handling [5-6]. One of the measures taken to improve the physico-chemical properties of MTA is to incorporate materials into its power or liquid [7].

In recent studies, focus has been on zeolite concerning the improvement of dental materials properties [8-11]. Zeolite is the crystalline structure of aluminosilicate and it has porous molecular structure; several ions such as zinc and silver are embedded in these pores [10]. Incorporation of silver-zeolite into MTA increased its solubility, resulted in the release of calcium, and decreased its setting time. Apparently, mixing with a 2 wt% ratio yielded better results compared to mixing with 0.2 wt% ratio [10]. Furthermore, incorporation of silver-zeolite into MTA increased its antibacterial activity against *E. faecalis, S. aureus,* and *C. albicans* [11-13]. The study conducted by Samiei *et al.* [14] revealed that incorporation of 2% wt Ze/Ag/Zn to the MTA decreased the compressive strength but did not present any cytotoxic effect.

A review of the literature in relation to the push-out bond strength of MTA brought up no studies on the effect of Ze/Ag/Zn composite. The aim of the present study was to evaluate the effect of incorporating this composite at 2 wt% into MTA powder on the push-out bond strength of MTA in simulated furcation perforation.

Materials and Method

Tooth selection, preparation of samples and simulation of perforations

A total of 40 mandibular first molars were selected based on the inclusion criteria, which consisted of the absence of root fusions and morphological or size anomalies, absence of carious lesions in the furcation area and negative history of previous root canal treatment. All teeth were extracted because of periodontal or orthodontic reasons and the relevant informed consents were obtained. After the soft tissues were removed, the teeth were transferred into 0.5% chloramine-T solution. The teeth were decoronated with a diamond disk (SP 1600 Microtome, Leica, Nu Block, Germany) with water coolant at level of cementoenamel junction. Then they were mounted in acrylic resin molds in a manner to leave 3 mm of the furcation area out of the acrylic resin in order to provide a space for placing the gelatin sponge (Geltamp, Roeko-Coltène/Whaledent, Langenau, Germany), which would serve as a matrix to pack materials for the repair of the perforated furcal area. A round bur (#1/2, Dentsply Maillefer, Ballaigues, Switzerland) was angulated perpendicular to the furcation floor and parallel to the long axis of the tooth to create perforations. Moreover, #1 to #4 Peeso reamers (Dentsply Maillefer, Ballaigues, Switzerland) were used to enlarge the perforation up to 1.3 mm in diameter. The heights of the walls of the perforated area were measured by using a periodontal probe to reach a height of 2 mm in all the samples. The samples in which the height of dentin at the perforated area was less than 2 mm were excluded. The extra dentin in each sample with greater dentin thickness was removed by using a disk. All the samples were irrigated with normal saline to remove the subsequent debris.

Preparation of Ze/Ag/Zn

HZSM-5 zeolite was prepared in the laboratory. Zinc nitrate, and $AgNO_3$ were procured from Merck (Merck, Darmstad, Germany). The powder form of ZSM-5 was modified by liquid phase ion exchange (LPIE), using Ag^+ and Zn^{2+} cations. First, Ag^+-ZSM-5 was prepared through a 24-h ion exchange with a solution consisting of 10 g of ZSM-5 and 300 mL of silver nitrate (1M) at room temperature. Then to prepare Ag^+ and Zn^{2+}-ZSM-5, 10 g of Ag^+-ZSM-5 were added to 300 mL of zinc nitrate solution (5M). After each exchange process, the modified zeolite suspension was filtered and washed with copious amounts of deionized water. Synthesized nanoparticles were characterized by scanning electron microscopy MRIA3-FEG-SEM (Tescan, Brno, Czech) and transmission electron microscopy (Zeiss LEO 912 Omega).

Repair of perforations

The samples were assigned to two groups (n=20) based on the type of the material used for the repair of perforation. In the group 1, MTA (Angelus, Londrina, Paraná, Brazil) and in the group 2, a mixture of MTA with 2 wt% of Ze/Ag/Zn was used for perforation repair. In both groups, the powder and liquid were mixed at a ratio of 3:1. To place the materials in the perforation area, gelatin sponge was placed under the furcal area. The materials were transferred to the area with a carrier and packed with a condenser with an appropriate size. Then the gelatin sponge was removed and to simulate the clinical conditions, cotton pellets impregnated with phosphate-buffered saline solution, was placed under the furcal area and cotton pellets impregnated with normal saline solution were placed on the furcal floor area on the perforation repair materials. The samples were incubated in a closed container at 37°C for one week.

Push-out test

The samples were subjected to a push-out test with the use of a universal testing machine (H5K-S; Hounsfield Test Equipment, Surrey, England). A force was inserted to the restorative materials in the perforated area at a crosshead speed of 0.5 mm/min in the apical direction parallel to the tooth long axis by using a cylindrical bar (1.1 mm in diameter) until the material was dislodged. The maximum force before dislodgment was recorded in Newtons (N) and converted to mega Pascal (Mpa) by dividing it to the bond surface area, which calculated using this equation:

Bonded surface area= the diameter of the perforated area × 3:14× height of perforation

Statistical analyses

After calculation the means and standard deviations of bond strengths, t-test was used to compare the dislodgment resistance between the study groups. Statistical significance was defined at $p< 0.05$. SPSS (SPSS version 18.0, SPSS, Chicago, IL, USA) was used for data analysis.

Results

The push-out bond strength (6.40±1.98 MPa) in the group 1 was significantly higher than that in the group 2 (2.1±0.6 MPa) with p=0.001. The failure type was mixed type (cohesive and adhesive).

Discussion

The results showed a significant decrease in push-out bond strength in the presence of such a composite. Since no similar study was available in the literature, the results of the present study could not be compared with those of other studies. Evaluation of the structure of zeolite indicates the presences of voids in its framework, which can house water molecules and ions such as silver and zinc [10]. A possible mechanism for decreasing the dislodgment resistance, by considering the porous structure of zeolite, is a disturbance in the hydration and crystallization processes of MTA by the composite above, because it is possible for the water molecule to enter its structure and exit the hydration process.

In the present study, Ze/Ag/Zn composite was incorporated into MTA powder at 2 wt%. This weight percentage has the best effect on solubility, release of calcium ions, antimicrobial activity, and setting time of MTA based on the results yielded by previous studies [10, 13]. A review of the literature in relation to the use of zeolite in combination with various elements such as silver and zinc in the dental field indicates its positive antimicrobials effect. The cytotoxicity of endodontic sealer with 2 wt% of silver-zeolite is similar to that of glass-ionomer and is less than that of AH26 [8-9, 11].

In the present study, the push-out bond strength was used to evaluate resistance against displacement, which is a reliable test for such a purpose based on the results of previous studies [1, 3, 15]. The push-out test uses a shearing stress at dentin–material interfaces, with various variables that are considered as the confounding factors during the push-out test such as the ratio of the diameter of the plunger to the dimension of the prepared root canal. Based on the results of previous studies, the effect of this confounding factor is minimal when the diameter of the plunger is 70–90% that of the root canal [15-16]. In the present study, the 1.3-mm diameter of the perforation area and the diameter of the plunger was 1.1 mm. To avoid the contact with the walls of the perforation area, the plunger was placed perpendicular to the sample surfaces.

After condensing the MTA, the gelatin sponge was removed and a cotton pellet impregnated with phosphate-buffered saline solution was placed under the furcal area to simulate the clinical situation. In the clinical situation, the bio mineralization of MTA occurs in the presence of phosphate ions in the interstitial fluid. Moreover, the resistance of MTA to displacement is influenced by the presence of phosphate-buffered saline solution [17-18].

Evaluation of the structure of zeolite indicates the presence of voids in its framework, which can house water molecules and ions such as silver and zinc [10]. In the present study, incorporation of Ze/Ag/Zn composite to MTA resulted in a significant decrease in its push-out bond strength. Considering the porous structure of zeolite, a possible mechanism would be the disturbance in the hydration and crystallization processes of MTA by the composite above since it is possible for water molecules enter its structure and exit the hydration process.

Under the clinical conditions, apart from the type of restoration material used to repair the furcal area, other factors such as the presence of hemorrhage, inflammation and the resulted acidic environment can affect the setting process and bonding of the material to the dentinal wall in the perforated area [3, 19-20]. These issues were not concerned in the present study, therefore, it might be considered as one of the limitations of the present study.

The condensation force for amalgam is 5.5–9.17 MPa, depending on the type of amalgam [3]. The results of the present study showed that MTA resistance to displacement one week after being placed in the area was in this range; however, this did not happen when combination of MTA/composite was used.

Conclusion

Under the limitations of the present study, despite the favorable effect of incorporating Ze/Ag/Zn into MTA powder on the properties evaluated in previous studies, resistance to displacement is affected negatively and this combination is not recommended in the repair of furcal perforations.

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Conflict of Interest

None declared.

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