Comparison of Push-Out Bond Strength of Furcation Perforation Repair Materials – Glass Ionomer Cement Type II, Hydroxyapatite, Mineral Trioxide Aggregate, and Biodentine: An *in vitro* Study

Abstract

**Background:** A furcation perforation is mid-curvature opening into periodontal ligament space which is a worst possible outcome in root canal treatment. Perforations should immediately be repaired with a biocompatible material to seal the communication between perforation site and gingival sulcus. **Aim:** The aim of this study was to evaluate the push-out bond strength of glass ionomer cement, hydroxyapatite, mineral trioxide aggregate, and biodentine (BD) when used in repairing furcal perforations with and without blood contamination in permanent molars. **Materials and Methods:** A total of 120 human extracted molars were collected and divided on the basis of perforation repair materials and blood contamination status (*n* = 15). All the materials were subjected to universal testing machine to a load cell from 0 N to 100 KN at a crosshead speed of 1 mm/min. **Statistical Analysis:** The data obtained were subjected to statistical analysis using SPSS version 20.0. Results and **Conclusion:** The push-out bond strength was maximum in BD contaminated with blood and least for the hydroxyapatite contaminated with blood. A significant difference was found between all the perforation repair materials.

**Keywords:** Biodentine, glass ionomer cement, hydroxyapatite, mineral trioxide aggregate, perforation repair, permanent molars

Introduction

Endodontic therapy can often be complex and challenging. Some procedures carry an inherent risk for complication or procedural accidents during access opening, shaping, and debridement. One of these procedural accidents is endodontic perforation that will affect the prognosis of root canal treatment. An endodontic perforation is an artificial opening in the tooth or its root, created by clinician during entry to the canal system or by biologic events such as pathologic perforation or caries, those resulting in a communication between the root canal and periodontal tissue. A furcation perforation refers to a mid-curvature opening into periodontal ligament space which is a worst possible outcome in root canal treatment. Except for resorptive defect or caries, furcation, or root perforations are iatrogenic in nature and one of the key causes of endodontic failure.

Two main techniques, that is, surgical and nonsurgical techniques have been proposed for the repair of such defects. Since surgical procedures for the repair of such defects may lead to pocket formation, thus the nonsurgical methods, especially in inaccessible areas, are advocated. Ideally, perforations should immediately be repaired with a biocompatible material to seal the communication between perforation site and gingival sulcus. Numerous materials have been used for furcal and root perforation repair.

An ideal perforation repair material should provide an adequate seal; be biocompatible, radiopaque, and easy to manipulate; induce osteogenesis; and have adequate strength against which an intracoronal restorative material could be condensed and tolerates a moist environment, etc. Materials such as calcium hydroxide, amalgam, glass ionomer cement (GIC), hydroxyapatite, mineral trioxide aggregate (MTA), and Portland cement are commonly used to manage furcation perforation. GICs are popular in restorative dentistry because

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of their adhesion to dental tissue, based primarily on a chemical interaction. Hydroxyapatite ceramics come very close to fulfilling the criteria for the ideal bone substitute. MTA, a calcium silicate-based material (CSM), is currently the choice of material in perforation repair. It is a bioactive silicate that seals well, even when the cavity is contaminated with blood and proved to have cementogenic properties. Recently, a new CSM-based material has been introduced, that is, Biodentine (BD) promoted as a dentin substitute which can also be used as an endodontic repair material.

Since the teeth are unavoidably subjected to masticatory forces; dislodgement resistance of the repair material plays an important role on the time of the placement of permanent coronal restoration. There are very few studies evaluating the dislodgement resistance of different repair materials sealing the furcal perforations. Thus, the present study was conducted to comparatively evaluate the push-out bond strength of GIC, hydroxyapatite, MTA, and BD in repairing furcal perforations when subjected to blood contamination in permanent molars.

Materials and Methods

The present study was done in the Department of Pediatric and Preventive Dentistry, Surendera Dental College and Research Institute, Sri Ganganagar, Rajasthan, under the Institutional Ethical Committee no. (SDCRI/IEC/2014/19). The study was conducted from September 2014 to November 2016.

A total number of 120 human extracted maxillary and mandibular molars were collected and used in the present study. Teeth free of root caries, no endodontic treatment, and free of cracks were included in the study. After the collection of molars, surface debridement was done with hand scaler, and the teeth were stored in distilled water containing 0.5% thymol crystals, to maintain aseptic condition till they were further used for the study.

The standard endodontic access cavities [Figure 1a] were prepared for all the study groups using ISO size (109/013) straight fissure bur using high-speed water cooled air rotor. Then, all the study samples were marked 4 mm above the pulpal floor and 4 mm below the furcation area with the help of Williams probe and black marker. After that, the samples were decoronated 4 mm above the pulpal floor, and the roots were amputated 4 mm below the furcation using a water-cooled diamond disk attached to mandrel. A perforation was made in the center of furcation area [Figure 1b] from the external surface using an ISO Size (173/016) round bur. All the 120 study samples were placed in the respective plastic containers [Figure 1c], in straight position over the sponge to prevent acrylic to flow over and under the area of perforation, and study molds were prepared [Figure 1d].

After the formation of study molds, the samples were randomly divided into four experimental groups on the basis of the type of perforation repair material (n = 30). Each group was then further subdivided into two subgroups (n = 15) on the basis of blood contamination status. The experimental groups were as follows:

Group I (n = 30): perforation repaired with Glass Ionomer Type II Cement (GC Corporation, Tokyo, Japan.), Group II with hydroxyapatite (Basic Healthcare Products Pvt., Ltd, India.), Group III with MTA Angelus (Angelus, Londrina, Brazil.), and Group IV with BD (Septodont, France). The Subgroup A (n = 15) of all the experimental groups was not contaminated with blood, whereas Subgroup B (n = 15) of all the experimental groups was contaminated with blood.

A wet cotton pallet was placed below the perforation to simulate the clinical situation, as the conditions are always wet in the perforation area. Then, Subgroup B from each experimental group was contaminated with freshly drawn human blood using an applicator tip, immediately before the placement of repair material. The Subgroup A of all the experimental groups was left uncontaminated. All the study samples were repaired using the respective perforation repair materials [Figure 2] followed by the placement of wet cotton pellet and were stored in an incubator for 24 h to allow the materials to fully set.

The specimens were subjected to a load cell from 0 N to 100 KN using universal testing machine at a crosshead speed of 1 mm/min in apical-coronal direction using an endodontic plugger to check the push-out bond strength. The results obtained were subjected to statistical analysis using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA).

Results and Observations

The push-out bond strength of different perforation repair materials of all the study samples was calculated. Table 1 shows the mean ± standard deviation (SD) of push-out bond strength test of all the four study groups with and without blood contamination. The mean ± SD
obtained were as follows: Group IA (28.825 ± 6.184), Group IB (23.194 ± 1.363), Group IIA (18.122 ± 1.459), Group IIB (16.372 ± 1.087), Group IIIA (46.129 ± 4.813), Group IIIB (40.409 ± 4.241), Group IVA (38.944 ± 6.740), and Group IVB (66.279 ± 8.359). The maximum mean value score of push-out bond strength was found for the Group IVB, followed by Group IIIA, Group IIIIB, Group IVA, Group IA, Group IB, Group IIA, and least for the Group IIB. Table 2 shows the intergroup comparison of all the four study groups with and without blood contamination using Paired t-test. A highly significant difference in push-out bond strength scores (P < 0.01) was found between all the study groups except Group IVA versus Group IIIB that showed an insignificant difference (P > 0.05).

Discussion

A perforation, irrespective of location or etiology, hampers the prognosis of endodontic therapy. This mechanical/pathological communication between root canal system and external tooth surface should be sealed with a biocompatible material as soon as possible.[4] The bond strength of perforation repair materials to dentine is important for maintaining the integrity of the seal in the furcation area. A furcation perforation repair material should have adequate strength against which intracoronal restorative material could be condensed safely. To assess bond strength, the push-out test is an efficient and reliable method, where a gradually increasing pressure is applied to the material until debonding occurs.[6]

In Group I, perforation was repaired with Glass Ionomer Type II cement. Various clinical studies have provided evidence of the effectiveness of GIC as a perforation repair material.[2,8,10] In Group II, perforation was repaired with hydroxyapatite being commonly used as the ideal bone substitute. The hydroxyapatite was proved to be successful as a furcation perforation repair material as studied by various authors.[11-13]
In the present study, MTA was used in Group III as perforation repair material. MTA has the property to stimulate the cementoblasts to produce matrix for cementum formation and is biocompatible with the periapical tissues, thus showing a superior sealing ability when used for perforation repair.\[^{[3,13]}\]

A new calcium silicate-based material, (BD) has been used in Group IV as perforation repair material. The study conducted by various authors, proved BD as a favorable material for perforation repair because it is easy to handle owing to its ease of manipulation and a short setting time approximately 12 min.\[^{[5,13-15]}\] It has high alkaline pH and is a biocompatible material.

Push-out bond strength test is a test to measure the interfacial shear strength developed between different surfaces, providing the information about the adhesive property of the material and its resistance of the tested material to dislodgement. According to the various studies, the tubule density is greater in the coronal part than in the furcation area.\[^{[16,17]}\] The difference in the number of tubules may explain why the strongest adhesion is achieved in the most coronal regions. In the presence of a greater number of tubules per mm\(^2\), a stronger bond will be expected, because the adhesion may be enhanced by proper filling of the material. Hence, the force applied to check the push-out bond strength was in apical-coronal direction, to evaluate the dentin bond strength of filling materials.

The push-out bond strength score for BD, contaminated with blood was maximum. According to the study conducted by various authors, it could be attributed to the ability of BD to form tag-like structures, which increased the resistance to dislodgement forces.\[^{[15,18]}\] The biomineralization capacity of BD and the higher uptake of calcium and silicon ions into dentin as compared to MTA could explain the higher bond strength of BD to dentin.

With contamination of blood, the calcium silicate materials form hydroxyapatite crystals at the surface. These crystals might have the potential to increase the sealing ability, especially when formed at the interface of the material with dentinal walls.

The push-out bond strength of MTA-Angelus, uncontaminated with blood was lesser than BD, but more than Glass Ionomer Type II Cement and hydroxyapatite. According to the study conducted by various authors, this could be attributed to a prolonged maturation process because of the formation of passivating trisulfate layer over hydrating crystals of MTA.\[^{[4,19,20]}\] The blood contamination causes fewer hexagonal crystal formation and general lack of needle-like structures in the mature MTA, as they were more rounded and less angular due to which the push-out bond strength of MTA decreases.

The push-out bond strength of Glass Ionomer Type II Cement, contaminated with blood was lesser than MTA and BD. According to various studies, the presence of blood on the perforation walls could adversely affect the chemical bonding and adaptation of the GIC.\[^{[21]}\] No expansion of GIC was noted during the setting reaction of GIC, unlike MTA and BD. The push-out bond strength of Group II (hydroxyapatite) was least among all the study groups. According to a study, it was attributed as hydroxyapatite is granular, has poor adaptability to the walls and does not set easily, thus making the material least suitable perforation repair material.\[^{[21]}\]

Many factors can also affect the perforation repair, including the technique used, the physician's ability and the surface area of perforation which was not determined in the present study.\[^{[9]}\] In the present study, the materials were tested after their setting, which is not the real clinical scenario, where the tooth is immediately subjected to masticatory stresses. Thus, there is a need to conduct more elaborated studies, considering all the relevant limitations.

**Conclusion**

Within the limitations of the study, it was concluded that the push-out bond strength was maximum in BD contaminated with blood, followed by MTA-Angelus uncontaminated with blood, MTA-Angelus contaminated with blood, BD uncontaminated with blood, Glass Ionomer Type II Cement uncontaminated with blood, Glass Ionomer Type II Cement contaminated with blood, hydroxyapatite uncontaminated with blood and least mean value score was found for the hydroxyapatite contaminated with blood.

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**Conflicts of interest**

There are no conflicts of interest.

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