Comparative evaluation of effect of chloroquick irrigating solution on push-out bond strength of endoseal mineral trioxide aggregate and endosequence root repair material when used as furcal perforation repair material: An *in vitro* study

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**Abstract**

**Aim:** The purpose of this study was to comparatively evaluate the effect of Chloroquick irrigating solution on push-out bond strength of Endoseal mineral trioxide aggregate (MTA) and endosequence root repair material (ERRM) when used as furcal perforation repair materials.

**Materials and Methods:** Forty human extracted mandibular molars were collected. A standardized endodontic access cavity was prepared in 40 samples, and intentional perforation of 1.32 mm in diameter was created on the pulpal floor. Teeth were randomly divided into four groups: Group A: EndoSeal MTA with irrigation, Group B: ERRM with irrigation, Group C: EndoSeal MTA without irrigation (Control group), and Group D: ERRM without irrigation (Control group). The samples were subjected to universal testing machine then examined under a stereomicroscope at × 40 to determine the nature of the bond failures.

**Results:** EndoSeal MTA with Chloroquick irrigating solution irrigation showed the highest push-out bond strength (MPa) with a statistically significant difference among all the groups (*P* = 0.003). The majority of the samples exhibited cohesive and mixed types of failures.

**Conclusion:** Chloroquick irrigating solution irrigation has no adverse effect on the push-out dentin bond strength of Endoseal MTA and ERRM.

**Keywords:** Chloroquick irrigation; endoseal mineral trioxide aggregate; endosequence root repair material; furcal perforation; push out bond strength

**INTRODUCTION**

In endodontic practice, while performing the root canal treatment, procedural accidents such as furcal perforation may occur and affect the prognosis of root canal treatment, which accounts for at least 9.6% of endodontic failures in endodontic treatment. American Association of endodontists Glossary of endodontic terms defines perforation as a mechanical or pathologic communication between the root canal system and the external tooth surface. Successful management of furcation perforations...
poses a challenge for a clinician. The perforation normally occurs in the cervical area of anterior teeth, furcation area of posterior teeth, as a result of the length of the bur being used.\textsuperscript{[2]} An ideal perforation repair material should be biocompatible, not affected by blood contamination, easy manipulation and placement, not extruded during condensation, bactericidal, provide an adequate seal, cost-effective, dimensionally stable, should be unaffected by the presence of moisture, induce bone formation and healing, radiopaque, induce mineralization, cementogenesis.\textsuperscript{[3]}

A wide variety of materials have been suggested for perforations repair, but most preferred are mineral trioxide aggregate (MTA), Biodentine.\textsuperscript{[4,5]} Solanki \textit{et al}. stated that MTA has improved marginal adaptation due to the absence of a gap between MTA and dentin and the possible expansion of the cement on the setting, so it becomes an ideal material for furcal perforation repair.\textsuperscript{[6]}

A new injectable calcium-silicate-based root canal sealer-Endoseal MTA (Maruchi, Wonju, Korea) was developed, which has slow setting time, excellent sealing ability, dimensional stability, insolubility, and biocompatibility and which can be used for root canal filling and root perforation repair.\textsuperscript{[7]}

Recently, Endosequence root repair material (ERRM) (Brasseler, USA) have been developed as a hydrophilic, insoluble, radiopaque, and aluminum-free material, ready to use, premixed bioceramic material recommended for perforation repair, apical surgery, apical plug, and pulp capping.\textsuperscript{[8]} In a study by Jeevani \textit{et al}. Endosequence showed better sealing ability when compared to MTA and Biodentine as furcation repair materials.\textsuperscript{[9]}

After repairing the furcal perforation, the clinician continues with root canal treatment, which causes unavoidable contact of various irrigants with the material, which may affect the bond strength and sealing ability of the repair material.\textsuperscript{[10]} Recently, a new formulation of 18% etidronic acid, 5% NaOCl, has been commercially available as “Chloroquick.” It is a One-step solution, which is a combination solution of stabilized sodium hypochlorite solution with buffer and HEDP with detergent and system activator.\textsuperscript{[11]}

There are very few studies evaluating the dislodgement resistance of different repair materials sealing the furcal perforations.\textsuperscript{[12]} To assess the bond strength, the push-out bond test has been shown to be efficient, practical, and reliable.\textsuperscript{[13]} Thus, the present study was designed to comparatively evaluate the effect of Chloroquick irrigating solution on push-out bond strength of Endoseal MTA and ERRM when used as Furcal perforation repair materials.

The null hypothesis (H0) considered for this study was there was no difference in the effect of Chloroquick irrigating solution on push-out bond strength of Endoseal MTA and ERRM when used as Furcal perforation repair materials.

**MATERIALS AND METHODS**

Forty freshly extracted human permanent first and second mandibular molars with closed apex and completely distinct roots were selected. Teeth with cracks, caries, or resorption were excluded from the study.

**Samples preparation**

Forty teeth were selected according to inclusion and exclusion criteria by clinical examination and dental operating microscope under ×40 for this study. Teeth were disinfected in 0.5% chloramine T trihydrate solution for 1 week and cleaned. The samples were stored in the normal saline solution until used for the study. The teeth were decoronated 3 mm coronal to the cemento-enamel junction using a diamond disk. A standardized endodontic access cavity was prepared by Endo access bur followed by Endo-Z bur with using high-speed hand piece with air-water coolant.

**Perforation preparation**

Intentional perforation was created on the pulpal floor by using a high-speed long shank round carbide bur no. 2 such that it should be between the mesial and distal orifices with air-water coolant. Then, #100 K (Mani) file was used to enlarge the perforation size and get a standardized perforation diameter of 1.32 mm at D 16 of #100 [Figure 1]. The chamber was flushed with water to clear the debris and dried. Teeth were mounted in acrylic molds, leaving a 3-mm space beneath the root bifurcation for the placement of a gelatin sponge (Spongostan, UK) that would act as a matrix on which the repair materials to be tested are packed and simulate the periodontal apparatus at the experimental site (furcation area).

The sample size was calculated using the Microsoft Excel and Statistical Package for the Social Sciences (SPSS) software version 22 (IBM Corp, Armonk, NY), assuming a = 0.05 and a power of 80%. The calculated sample size was 10 for each group.

Teeth were randomly divided into four groups (n = 40):

- **Group A**: EndoSeal MTA with irrigation (n = 10)
- **Group B**: ERRM with irrigation (n = 10)
- **Group C**: EndoSeal MTA without irrigation (control group) (n = 10)
- **Group D**: ERRM without irrigation (control group) (n = 10).
In Group A and C, EndoSeal MTA material was compacted in perforation site with hand pluggers and burnished with a ball burnisher to remove excess material and improve adaptation according to the manufacturer’s directions.

In Group B and D, ERRM was compacted in perforation site the same as placed in Group A and C according to the manufacturer’s directions. The wet cotton pellet was placed over the perforations and all the samples were stored in an incubator at 37°C for 24 h to allow the materials to fully set and for simulating clinical conditions.

After repair of the perforation site, biomechanical preparation was done in Group A, B. Pulp tissues and debris were removed. Working length was determined by 10 K-files, and all the canals were enlarged. During preparation, the root canal was irrigated with 3 ml of Chloroquick irrigating solution per canal, using 25G beveled needle and finally flushed with 5 ml of distilled water. For Group C, D, a moist cotton pellet was placed over each test material without any irrigation and allowed to set in an incubator at 37°C for 48 h before the push-out test.

**Push-out test (primary objective)**

Push-out bond strength was measured using a universal testing machine (Instron). After the experimental periods, the samples were placed on the metal slab containing central hole to allow free motion of plunger with a 1 mm diameter, at a constant vertical pressure of speed 1 mm/min. The plunger tip was positioned to contact the tested material only. The maximum load applied to the filling material was recorded in Newton.

**Failure mode analysis (secondary objective)**

Teeth were examined under a stereomicroscope (Labomed) at ×40 magnification to determine the failure mode. Modes of failure were defined as follows:

1. Cohesive: failure was entirely within the material
2. Adhesive: failure was at the material/dentin interface
3. Mixed failure: This is the combination of the two failure mode.

The examiner for testing push out bond strength, stereo-microscope sample was blinded.

**Statistical methods**

Collected data were analyzed for Push-out Bond strength (MPa) using one-way analysis of variance test. *Post hoc* Tukey test was used to determine if there is a significant association between the type of failure and the irrigation for each material. Statistically significant differences were set at *P* < 0.05.

**RESULTS**

**Push-out test**

The mean values of push-out bond strength (MPa) values of the experimental and control groups are presented in Table 1. Comparison of Push out Bond strength (MPa) shows that the mean value of Group A (18.942) is highest, followed by Group B (13.496), Group D (9.601) least in Group C (9.544) with a statistically significant difference (*P* = 0.003). *Post hoc* Tukey test shows that the difference between Group A and Group B is NOT statistically significant (*P* = 0.055). The difference between Group A and C, between GROUP A and D, is statistically significant (*P* < 0.001). Irrespective of the Chloroquick irrigating solution and protocols, Endoseal MTA yielded significantly higher push-out bond strength than ERRM (*P* < 0.05).

**Nature of bond failure**

It was found that in Group A, B, and D maximum number of samples showed a mixed type of failure, whereas in Group C cohesive failure [Table 2]. Representative microscopic images of specimens with an adhesive, a cohesive and a mixed type of bond failure are shown [Figure 2]. The majority of the samples exhibited cohesive and mixed types of failures.

**DISCUSSION**

A perforation should be sealed with suitable biocompatible material as soon as possible. In the present study, to assess the adhesion of dental materials push-out bond strength was used to evaluate the resistance to dislodgment, which is a reliable technique based on previous studies.

An ideal furcal perforation repair material should adhere to the dentin walls and resist dislodging forces such as
tooth flexion during function and mechanical forces of condensation of restorative materials over the repair site.\textsuperscript{13}

All samples, irrespective of setting time or contamination status, had shown a dislodgment resistance more than the average force recorded by Lussi \textit{et al.} during amalgam condensation (3.7 ± 1.3 MPa and 2.2 ± 0.9 MPa) which were extensively used as the post-repair permanent material.\textsuperscript{16} The other permanent materials like glass ionomer cement, composite core materials require less force for the compaction after the furcal repair material is placed. An important point to be noted is that 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.

The prognosis of perforations depends on the location, size, and time of contamination of the lesion. The location of furcal perforations at the level of the epithelial attachment and crestal bone suggested a guarded prognosis. Furthermore, the size of a perforation represents another important factor in determining the success of the repair procedure; larger the size poor the prognosis. Some authors

Table 1: \textit{Post hoc} Tukey test

| Dependent variable | Comparison group | Compared with | Mean difference | SE  | \( P \) |
|--------------------|------------------|---------------|----------------|-----|-------|
| Force of dislodgment \((n)\) | Group A | Group B | 42.4250000 | 13\(<0.00193\) | 0.012 |
| | | Group C | 69.7270000* | 13\(<0.00193\) | \(<0.001\) |
| | | Group D | 69.3800000* | 13\(<0.00193\) | \(<0.001\) |
| | Group B | Group C | 27.302 | 13\(<0.00193\) | 0.172 |
| | | Group D | 26.955 | 13\(<0.00193\) | 0.181 |
| | Group C | Group D | -0.347 | 13\(<0.00193\) | 1 |
| Push-out bond strength (MPa) | Group A | Group B | 5.446 | 2.055762 | 0.055 |
| | | Group C | 9.3980000* | 2.055762 | \(<0.001\) |
| | | Group D | 9.3410000* | 2.055762 | \(<0.001\) |
| | Group B | Group C | 3.952 | 2.055762 | 0.237 |
| | | Group D | 3.895 | 2.055762 | 0.248 |
| | Group C | Group D | -0.057 | 2.055762 | 1 |

*Significant \( P \) value: \( P<0.05 \); Statistically significant; \( SE \): Standard error

Table 2: Chi-square test for comparison of the categorical fracture types

| Fracture mode | Group A | Group B | Group C | Group D | Total |
|---------------|---------|---------|---------|---------|-------|
| Adhesive; count, \( n \) (%) | 3 (30.0) | 1 (10.0) | 2 (20.0) | 3 (30.0) | 9 (22.5) |
| Cohesive; count, \( n \) (%) | 3 (30.0) | 4 (40.0) | 5 (50.0) | 3 (30.0) | 15 (37.5) |
| Mixed; count, \( n \) (%) | 4 (40.0) | 5 (50.0) | 3 (30.0) | 4 (40.0) | 16 (40.0) |
| Total; count, \( n \) (%) | 10 (100.0) | 10 (100.0) | 10 (100.0) | 10 (100.0) | 40 (100.0) |

Figure 2: Bond failure under stereomicroscopic images (x40) of representative samples showing: (a) endoseal mineral trioxide aggregate (a1) adhesive; (a2) cohesive; (a3) mixed failure, (b) endosequence root repair material (b1) adhesive; (b2) cohesive; (b3) mixed failure

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suggest the use of an internal matrix to avoid the extrusion of the sealing material and consequent peri-radicular tissue inflammation.\textsuperscript{[17]} In the present study, perforations were induced by a #2 long shank carbide round bur from the pulpal floor to furcation area. This resulted in perforations of almost 1.32 mm in diameter. The prognosis of the tooth with furcation diameter 1–1.5 mm is better than those having much bigger perforation diameter sizes.\textsuperscript{[20]}

The effect of furcation perforation size on the efficacy of restorative material is still undetermined. Some studies claimed that tooth size in relation to perforation size directly affects the prognosis, whereas some other studies reported no association between the two variables.\textsuperscript{[18]} To avoid extrusion of the repair material into surrounding periodontal structures for the success of a perforation repair, internal matrices such as calcium sulfate, hydroxyapatite, collagen, demineralized freeze-dried bone, and Gelfoam\textsuperscript{®} (Pfizer) have been suggested (Clauder, Shin, 2009).\textsuperscript{[17]}

ERRM is a new bioceramic material which is delivered as a premixed product in low viscosity paste form dispensed from a syringe, fast-set, ready-to-use. Moisture is required to harden and set. Working time is more than 30 min and setting time is 20 min to 2 h depending upon its viscosity. It has an alkaline pH (pH-12.5), biocompatible, and antibacterial properties. It contains Nanosphere particles, which allow the material to penetrate into the dentinal tubules, moistened by dentin liquid and produces a mechanical bond on setting.\textsuperscript{[8]}

In the present study, push-out bond strength of Group D is 9.601 MPa and for Group B, it is 13.496 MPa, which is not statistically significant ($P = 0.248$). Possible promising result of higher push-out bond strength in ERRM could be due to its greater adherence to dentinal walls, which is in accordance with the study done by Shokouhinejad et al. in 2013, in which they concluded that push-out bond strength values of ERRM were higher when compared to MTA.\textsuperscript{[19]} It has been reported that the presence of zirconium oxide in the composition of ERRM might also result in higher bond strength of ERRM.\textsuperscript{[23]}

Alsubait et al. stated that the push-out bond strengths of ProRoot MTA and ERRM were significantly increased after exposure to 2.5% NaOCl in the early setting phase.\textsuperscript{[19]} In the present study, ERRM with Chloroquick irrigating solution showed less push-out bond strength than EndoSeal MTA with Chloroquick irrigating solution. It is important to point out that there were no previous studies to directly compare the values of dentin bond strength of Endo-Seal with ERRM when used as furcal perforation repair material after exposure of Chloroquick irrigating solution.

In the present study, push-out bond strength of Group A is 18.942 MPa and for Group C, it is 9.544 MPa, which is statistically significant ($P < 0.001$). Calcium silicate is a base material of EndoSeal MTA, which has a comparable chemical composition to that of MTA. In addition, Khatib et al., in their study, stated that according to the manufacturer, it presents outstanding flowability, which may be associated with the penetration of material into dentinal tubules, anatomic irregularities, or accessory canals and therefore increasing the sealing ability and bond strength.\textsuperscript{[20]}

Results of the present study demonstrated that when Chloroquick irrigating solution was used as irrigation, had the adequate push-out values and that can be explained by the comparatively shorter irrigation time of 2–3 min during root canal treatment and due to minimum contact of the irrigation solutions on the coronal surface of the perforation repair material.

To our knowledge, the mode of bond failure of ERRM and EndoSeal MTA has not been investigated in other studies. Bond Failure mode for ERRM, ERRM with chloroquick irrigating solution and EndoSeal MTA with chloroquick irrigating solution was mainly mixed. EndoSeal MTA without irrigation showed a cohesive type of failure.

The cohesive bond failure observed in EndoSeal MTA group, which may be explained by the larger particle size of MTA. This affects the penetration of cement into dentinal tubules.\textsuperscript{[21,22]} The smaller particle size and uniform components might have a role in the better interlocking of ERRM with the dentin, which finally causes cohesive failure inside the cement.\textsuperscript{[23]}

**CONCLUSION**

Within the observations of the present *in vitro* study, it could be concluded that Chloroquick irrigating solution had no adverse effects on EndoSeal MTA and ERRM, while it improved the push-out bond strength. Further studies are required to evaluate the effect of Chloroquick irrigating solution on other properties of new CSCs, including sealing ability, before clinical use.

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**Conflicts of interest**

There are no conflicts of interest.

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