Original Article

Stereomicroscopic Evaluation of Sealing Ability of Three Different Furcal Perforation Repair Materials: An *In vitro* Study

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Abstract

Background: The choice of sealing material is a crucial factor that influences the outcome of endodontic treatment. **Aim:** The purpose of this study was to compare the sealing ability of mineral trioxide aggregate (MTA) Angelus, Endocem MTA, and NeoPutty MTA when used as furcal perforation repair materials. **Materials and Methods:** A total of 45 mandibular molars were used. Root canal treatment was carried out following which standardized furcal perforations were made. The specimens were randomly divided into three groups of 15 teeth each. Group A-Furcal perforation repair by means of MTA Angelus, Group B-Furcal perforation repair using Endocem MTA, and Group C-Furcal perforation repair by NeoPutty MTA. Following the repair procedure, the pulp chambers and access openings were filled with temporary restorative material and immersed in 1% basic fuchsin dye for 24 h. The teeth were sectioned longitudinally and the linear dye penetration was measured using a stereo-microscope. **Results:** The one-way analysis of variance (ANOVA) revealed a statistically significant difference among the groups ($F = 16.15$, $P < 0.001$). On calculating the depth of leakage to the total length of the perforation, it was observed that the mean leakage was 32.83% in Group I, 52.92% in Group II and the lowest, 16.35% in Group III. The ANOVA test reveals a statistically significant difference among the groups ($F = 15.92$, $P < 0.001$). Comparing the depth of dye penetration of dye, 33.3% of the Group I samples showed ≥50%, 49%–25%, and <25% dye penetration. Although 56.7% of Group II samples showed ≥50% dye penetration, whereas 63.3% of Group III showed <25% dye penetration. **Conclusion:** The present study indicated that NeoPutty MTA had the least dye penetration followed by MTA Angelus and Endocem MTA.

Keywords: *Furcation defect, mineral trioxide aggregate, repair material*

Introduction

The integrity of natural dentition is important for maintaining full function as well as natural esthetics.[1] Root canal treatment is a dental procedure in which the diseased or damaged pulp of a tooth is removed and cleaned and the canal spaces are filled with biologically inert materials and sealed.[2] Any change in the harmony needs a dental therapy, especially an endodontic therapy. During endodontic procedure, a clinician may come across different procedural accidents, which can affect the prognosis of the treatment and among which perforation of root canal system is one.[1] Such perforations create connection between the pulpal and periodontal ligament space through the pulpal floor.[3]

According to ingle, an endodontic perforation is an artificial opening in the tooth or its root created by the clinician during entry to the canal system or by a biological event such as pathological resorption or caries resulting in a communication between the root canal and periodontal tissue.[4] Perforations are considered as one of the principal cause of failure in endodontics following obturation and can constitute up to 9.6% of all uneventful cases.[3] The creation as well as the detection of perforation cannot only be distressing but also thoroughly change the treatment plan and prognosis of the tooth. If perforations are left unrepaired, it will lead to the entry of bacteria creating endodontic-periodontal lesions.[2] Healing of periodontal tissue happen properly when defects are closed than those left open.[4]

A furcal perforation can be treated by nonsurgical or a surgical approach. The surgical method is least preferred due to difficulty in obtaining accessibility for repair and it often leads to loss of attachment, pocket

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formation, and periodontal furcation involvement. Hence, a minimally invasive nonsurgical method through coronal access is recommended for furcal perforation repair.[5] A variety of materials have been employed to repair furcation perforations such as reinforced zinc oxide eugenol, calcium hydroxide, glass ionomer cement (GIC), bioaggregate, composite resin, biodentine, mineral trioxide aggregate (MTA), platelet rich plasma, platelet-rich fibrin, and others.[6]

MTA, introduced to endodontics by Torabinejad in 1993, is derived from Portland cement and has been implemented successfully in repair of lateral root and furcal perforations, apexogenesis and as a vital pulp capping agent.[7] MTA is calcium silicate-based cement and is one of the most widely used repair materials due to its excellent biocompatibility, marginal adaptation, and low cytotoxicity. However, it has some drawbacks such as long setting time, discoloration, difficult handling and applicability, wash out of MTA newly placed in repair area during subsequent irrigation procedures, etc.[8]

In order to overcome the drawbacks, many researchers have attempted to develop fast setting MTA or its derivatives. MTA Angelus was launched in 2002 and has various improved properties. It sets within 15 min of being prepared.[9] Recently, MTA-derived pozzolan cement (Endocem, Maruchi, Wonju, Korea) was introduced in the endodontic market. Endocem sets quickly without the addition of chemical accelerator and also shows lower cytotoxicity with osteoclast-like cells. Instead, it incorporates small particles of pozzolan cement to improve the surface contact with the mixing liquid and provides rapid setting.[10] The addition of pozzolan is beneficial in terms of compressive strength and durability that is mostly associated with pozzolanic reaction in which calcium hydroxide is consumed to produce calcium silicate hydrate and calcium aluminate hydrate products.[8]

NeoPutty is a new fast setting premixed bioactive bioceramic MTA that has been introduced recently to the market.[11] It is made up of an extremely fine, inorganic powder of tricalcium/dicalcium silicate in a water-free organic liquid. It has radiopacity due to the presence of tantalum oxide and is color stable and nonstaining. It is meant to solidify *in vivo* when the surrounding tissues' moisture content is present. It possesses good handling properties and favorable consistency to be placed easily and precisely to the perforated area. It has excellent biocompatibility and bioactive properties that help in healing of huge interradicular lesion as well as periodontal healing of the defect related to the perforation.

The purpose of the present study was to compare and evaluate the sealing ability of MTA Angelus with the newer fast setting MTA, Endocem MTA and NeoPutty MTA available in the market when used to repair the perforation created in the pulpal floor of extracted human permanent molars in a simulated clinical situation.

Since there are limited literature available on the sealing efficacy of recently introduced MTA derivatives, regarding furcation repair, this study has been formulated testing the same.

Materials and Methods

A total of 45 extracted human mandibular permanent molar teeth with nonfused and well-developed roots, no caries or cracks were used in this study. The specimen were removed of calculus and soft-tissue tags using ultrasonic scaling and were stored in saline solution until used. Before use, the specimen were washed with water. Teeth were then mounted in polyvinyl siloxane impression material. A standardized endodontic access opening was made in each tooth. Orifices of canals were negotiated and modeling wax were placed over each canal orifice. A #2 round carbide bur was used to create perforation in the center of floor of pulp chamber using a high-speed water coolant handpiece. The area was dried with compressed air and the teeth were then randomly allocated to three groups with 15 samples in each:

- Group A (n = 15): Repair of perforation with MTA Angelus
- Group B (n = 15): Repair of perforation with Endocem MTA
- Group C (n = 15): Repair of perforation with NeoPutty MTA.

Each repair material was mixed according to the manufacturer's instructions and was packed into the perforation defect to the level of pulpal chamber floor. The roots were moistened with cotton pellet inertly to simulate the clinical situation during the repair process. After 24 h, the access cavity was filled with temporary restorative material. All the teeth were coated homogeneously with two subsequent layers of varnish leaving a space of 1 mm around the margin of perforation so that dye can penetrate only through the perforation area. All specimens were dipped for 24 h in 1% basic fuchsin dye. Teeth were rinsed under tap water to remove dye residues. Then, teeth were split buccolingually with round disk bur. In all individual sections, the value of dye leaked from outer margins of the perforation cavity to the pulpal floor level was calculated.

Testing

The maximum amount of dye penetrating along both buccal and lingual walls from either mesial and distal walls was recorded using the stereomicroscope. The length of perforation wall (dentin-cementum thickness) and the linear leakage of dye penetration from each section were measured in millimeters. The ratio of linear leakage of dye penetration to the perforation wall length was expressed as percentage [Figure 1]. They were categorized as having penetrated ≥50%, 49%–25% and <25% of the total length, based on the percentage of depth of dye penetration.

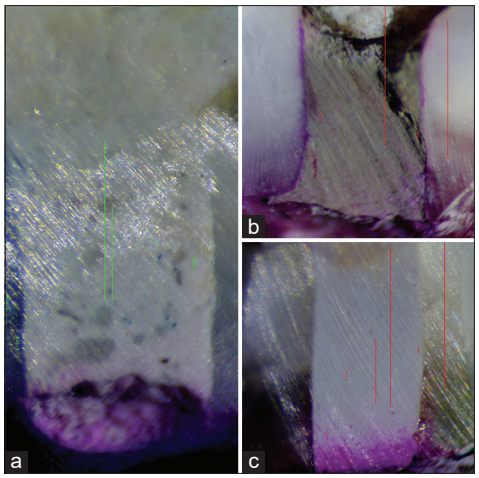


Figure 1: Stereomicroscopic images showing dye penetration of three materials (a) MTA Angelus (b) Endocem MTA (c) NeoPutty MTA. MTA: Mineral trioxide aggregate

Statistical analysis

The results were analyzed using the descriptive statistics and making comparisons among various groups. Data were summarized as mean ± SE (standard error of the mean). Quantitative (Discrete) data were compared by the analysis of variance test and *post hoc* Tukey's pairwise comparison test and Chi-square test. The significance level was taken as $P < 0.05$ indicating statistically significant association. All the analyses were done using the SPSS Software 23.0 (IBM, Armonk, New York, United States).

Results

Table 1 and Graph 1 show the maximum length of linear leakage in Group II with a standard deviation of 0.89 mm. It was observed that the intergroup comparison of linear leakage of Group II and Group III showed a mean difference 0.997, as shown in Table 2. Based on the percentage of dye penetration, Group II showed maximum mean penetration of 52.92%, whereas Group III showed minimum mean penetration of 16.35% which is summarized in Table 3 and Graph 2. On comparing Group I to Group III which revealed a mean difference of 16.480% (SE = 6.49) with a *P* value of 0.034 which is summarized in Table 4 and Graph 3. It was observed that comparing depth of penetration of dye Group I showed 33.3% of samples each for ≥50%, 49%–25% and <25%.Group II showed 56.7% of samples with ≥50% of dye penetration. Group III showed 19 samples with 63.3% of dye penetration which is summarized in Table 5 and Graph 4.

Discussion

The principal goal of endodontic treatment is to eliminate the microbes and seal the root canal system effectively.[3] The success of the furcation repair is always dependent on the effectiveness of the seal between the root canal and the periodontal ligament. This can be accomplished by a suitable material which should prevent the microleakage and communication between the tooth and periodontal ligament. To obtain success, the perforation repair material should ideally result in formation of new bone, periodontal ligament and cementum.[12] Another prognostic factor in the management of a furcation perforation is the time lapse between its occurrence and repair. Therefore, immediate repair of perforation in furcal area is important for endodontic success. However, extensive bleeding from the perforation site would restrict the clinician from immediate sealing with conventional restorative materials.[5]

MTA has become one of the most widely studied endodontic materials for furcation repair.[13] There are several studies that have demonstrated its excellent sealing ability. MTA has become very popular as a perforation repair material due to its excellent biocompatibility. It is evidenced to have a favorable biologic response, minimal

Table 1: Mean linear leakage in each group

Group	Linear leakage, mean±SD
Group I (MTA Angelus)	0.74±0.61
Group II (Endocem MTA)	1.49±0.89
Group III (Neoputty MTA)	0.49±0.59
ANOVA	F=16.15, P<0.001

SD: Standard deviation; MTA: Mineral trioxide aggregate; ANOVA: Analysis of variance

Table 2: *Post hoc* paired comparison of linear leakage (average)

Group pair	Linear leakage		
	Mean difference	SE	*P*
Group I versus Group II	0.748	0.18	<0.001
Group I versus Group III	0.248	0.18	0.366
Group II versus Group III	0.997	0.18	<0.001

SE: Standard error

Table 3: Mean percentage of dye penetration in each group

Group	Percentage of dye penetration, mean±SD
Group I (MTA Angelus)	32.83±24.16
Group II (Endocem MTA)	52.92±30.39
Group III (Neoputty MTA)	16.35±19.76
ANOVA	F=15.92, F<0.001

SD: Standard deviation; MTA: Mineral trioxide aggregate; ANOVA: Analysis of variance

Table 4: *Post hoc* paired comparison of average percentage of dye penetration

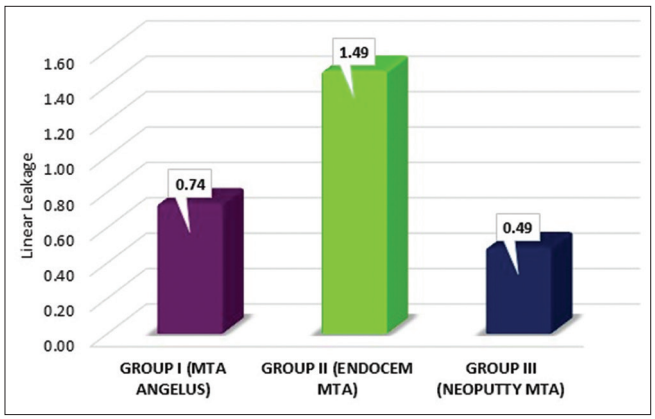
Group pair	Percentage of dye penetration		
	Mean difference	SE	*P*
Group I versus Group II	20.000	6.49	0.007
Group I versus Group III	16.480	6.49	0.034
Group II versus Group III	36.570	6.49	<0.001

SE: Standard deviation

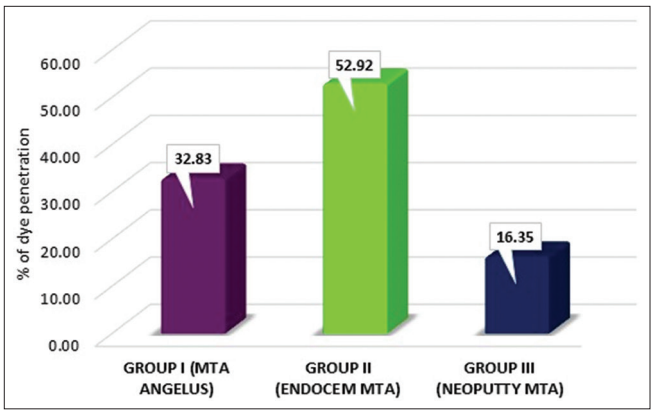
Table 5: Comparison of depth of penetration between the three experimental groups

Depth of penetration	≥50%, *n* (%)	49%–25%, *n* (%)	<25%, *n* (%)	Significance
Group I (MTA angelus)	10 (33.3)	10 (33.3)	10 (33.3)	χ^2=17.30, *P*=0.002
Group II (Endocem MTA)	17 (56.7)	6 (20.0)	7 (23.3)	
Group III (Neoputty MTA)	3 (10.0)	8 (26.7)	19 (63.3)	

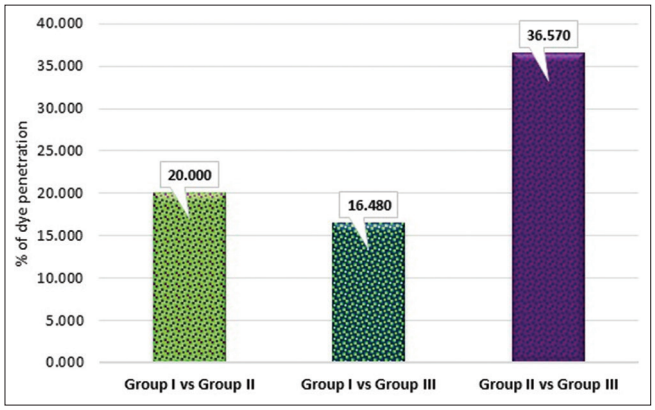
MTA: Mineral trioxide aggregate



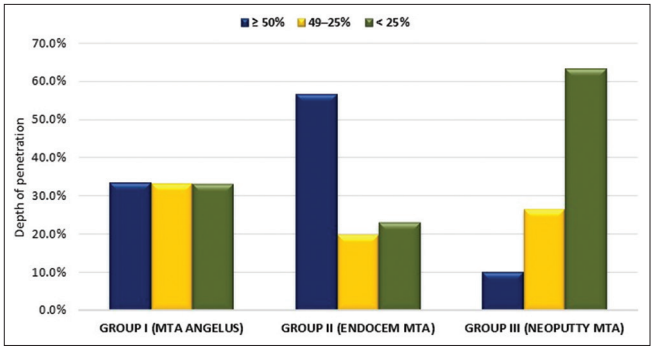
Graph 1: Comparison of linear leakage among the three experimental groups



Graph 2: Comparison of percentage of dye penetration among the three groups



Graph 3: Intergroup comparison of percentage (%) of dye penetration



Graph 4: Comparison of depth of penetration between the three experimental groups

toxicity and pulpal irritation, mild periapical inflammation, nonmutagenicity, cell adherence and growth, increased levels of alkaline phosphatase and osteocalcin, interleukin production (IL-6 and IL-8), periodontal ligament attachment, cementum growth, and promote dentinal bridge formation. One of the properties which make MTA as a material of choice is its ability to set in the presence of moisture. Despite its advantages, MTA may be inconvenient to use because the manufacturer's directions require that it be covered by a wet cotton pellet and left for at least 3–4 h to set.[5]

NeoPutty MTA is a new fast-setting premixed, ready-to-use, and bioceramic material used in endodontic procedures. It is designed to overcome some drawbacks of traditional MTA materials, such as the difficulty in handling and mixing the powder and liquid components and the long setting time. Premixed tricalcium silicate-based putties have the advantages of being easy to handle, premixed, hydrophilic, and offer immediate placement of the final restoration.

Various leakage models have been described in studies to assess the ability of materials to seal furcation perforations including fluid infiltration, dye penetration, bacterial leakage models, dye extraction, air pressure method, radio isotope method, electrochemical method, metal solution tracers, and reverse diffusion.[14] Dye penetration technique is one of the most common methods due to its easy performance and does not require sophisticated materials.[4]

The sealing adaptability was evaluated by measuring the gap (in μm) between the pulpal floor and the material used for the furcal repair. The quality and durability of the interface is a key factor for the survival of a restorative material in clinical conditions. In addition, the marginal adaption and the intimate contact with the surrounding material (dentin and dental material) are the determinative features.[15]

Till date, no research has compared the sealing ability of conventional MTA to these novel MTA formulations. Hence, this study compares the sealing ability of MTA Angelus, Endocem MTA and NeoPutty MTA when used to repair furcation perforations using dye penetration method.

In the present study, comparative evaluation among three groups revealed that Group III (NeoPutty MTA) had least amount of dye penetration compared to Group I (MTA Angelus) and Group II (Endocem MTA).

The improved sealing ability of NeoPutty could be due to the presence of extremely fine, inorganic powder of tricalcium/dicalcium silicate in a water free organic liquid. Bioactive material NeoPutty releases calcium and hydroxide ions from the surface, promoting the formation of hydroxyapatite to ensure bioactive sealing.

Till date, no studies are reported evaluating dye penetration with NeoPutty MTA for furcation perforation repair. However, Al-Homaidhi[11] performed a study to measure the shear bond strength of SAFC and RMGIC with NeoPutty and concluded that bond strength of SAFC was higher than that of RMGIC. Hence, SAFC was recommended for use with NeoPutty instead of RMGIC. A higher shear bond strength shows better bonding between the two interfaces and increases retention, which results in lesser microleakage.

Group I (MTA Angelus) even though it was not fully effective in preventing dye penetration, it was better as compared to Group II (Endocem MTA).

The result of this study is similar to Sadullah *et al*.[16] who performed an *in vitro* study to evaluate the sealing ability of MTA and Ketac Molar Easymix and found that MTA resulted in significantly less dye leakage than Ketac Molar Easymix using volumetric measurement method.

Among all the three groups, Group II showed maximum amount of dye penetration. Endocem MTA consists of small particles of pozzolan cement to increase the surface contact with the mixing water and provide rapid setting. Endocem MTA released a significantly smaller amount of Ca2+ as compared to MTA. This may be attributed, at least in part, to the consumption of calcium hydroxide during the pozzolanic reaction, because the progress of the pozzolanic reaction reduces the amount of free calcium hydroxide produced during hydration reaction which hinders precipitation and causes surface disintegration leading to loss of marginal adaptation. The exact reason behind the poor sealing property of Endocem MTA is still not clear.

Koç *et al*.[17] conducted a study to compare the sealing ability of MTA Angelus, Endocem MTA, or EndoSequence BioCeramic Root Repair Material Fast Set Putty (BC-RRM Putty) and concluded that all materials showed similar behavior in preventing microleakage at both time intervals (24 and 72 h).Only MTA Angelus showed significantly better sealing ability at 72 h compared to 24 h.

These results emphasize the importance of selecting an appropriate MTA material to achieve optimal sealing outcomes in endodontic procedures, with NeoPutty MTA exhibiting the most promising results in minimizing dye penetration compared to MTA Angelus and Endocem MTA. This may be due to the shortcomings of MTA such as difficulty in handling, slow setting reaction that might contribute to leakage, surface disintegration leading to loss of marginal adaptation, bonding to dentin.

In endodontic dentistry, choosing the correct repair material is one of the primary variables that determine its success. Microleakage is one of the factors that affect the performance of the material in the oral cavity. Therefore, it can be concluded from the study that NeoPutty MTA is superior to MTA Angelus and Endocem MTA.

Conclusion

From the results of the present study, it can be concluded that NeoPutty showed lesser microleakage compared to MTA Angelus and Endocem MTA and may be a good alternative to MTA in sealing the furcal perforations in permanent molars, thereby increasing the life of the tooth.

Limitations

Every study has its own limitations with a scope for further investigations.

Laboratory studies attempt to reproduce clinical situations but do not entirely reflect variables encountered with the *in vivo* performance of the materials. The main limitation of the present study relates to the relevance of the *in vitro* studies, in predicting the clinical performance of the materials being tested. However, the present study was aimed at comparative evaluation of microleakage among the available MTA materials-MTA Angelus, Endocem MTA, and Neoputty MTA which can indicate the probable clinical performances.

- Dye penetration test did not take into account the three-diamensional microleakage occurring under the tested restorations
- The materials when tested *in vitro* fail to simulate the dynamic intraoral thermal changes induced by routine eating and drinking.

Future scope of the study

The present study was conducted in *in vitro* conditions, so further *in vivo* studies are needed to generalize and confirm the results obtained in the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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