Sealing ability of three different materials to repair furcation perforations using computerized fluid filtration method

Cemre Koç1*, Berna Aslan1, Zuhal Ulusoy2, Hasan Oruçoğlu3

1Department of Endodontics, Faculty of Dentistry, Başkent University, Ankara, Turkey
2Bolu Izzet Baysal Oral Health Clinics, Bolu, Turkey
3Private Practice, Sakarya, Turkey

 ARTICLE INFO
Article History:
Received: 14 March 2021
Accepted: 8 May 2021
ePublished: 25 Aug. 2021

Keywords:
BC-RRM Putty
Endocem
EndoSequence
Fluid Filtration
Furcation
Perforation
MTA

Abstract
Background. The present study aimed to evaluate the sealing ability of three different calcium silicate-based materials in furcation perforations.

Methods. Seventy-six human mandibular molar teeth were selected. Perforations were created in the center of the pulp chamber floor. The experimental teeth were randomly divided into three groups (n = 22). Perforations were repaired with MTA Angelus, Endocem MTA, or EndoSequence BioCeramic Root Repair Material Fast Set Putty (BC-RRM Putty). Microleakage of the different repair materials to be tested was measured by computerized fluid filtration method at 24- and 72-hour intervals.

Results. For each time interval, no statistically significant difference was observed between the groups. For Endocem MTA and BC-RRM Putty groups, the difference between the leakage values measured at both periods was not statistically significant (P > 0.05). However, there was a significant difference for the MTA Angelus group (P < 0.05).

Conclusion. All the calcium silicate-based materials used in the present study showed similar performance in repairing furcation perforations at 24- and 72-hour intervals.

Introduction
A root perforation can be defined as a communication between the root canal system and supporting periodontal tissues of the tooth. The prognosis for teeth with root perforation usually depends on the time elapsed before treatment, size, location, and degree of periodontal damage. When root perforation occurs, it should be repaired as soon as it is made to prevent bacterial contamination, inflammation, and loss of attachment. Also, the location of root perforations is considered a detrimental factor in the treatment prognosis of the affected tooth. Perforation located in the coronal third of the root or the furcation area is more susceptible to apical migration of the gingival epithelium and periodontal pocket formation when compared to perforation in the middle or apical third of the root.1-3

Among various materials described over the years for perforation repair, MTA could be considered a material of choice due to its good biocompatibility and outstanding sealing ability. However, the use of MTA has some disadvantages, such as long setting time, discoloration potential, and difficult handling.4 To overcome these drawbacks, attempts have been made to develop new formulations of calcium silicate-based cements.

Recently, a new pozzolan-based MTA-derived material, namely Endocem MTA (Maruchi, Wonju-si, Korea), has been introduced. Endocem MTA has a short setting time and physical and biological properties comparable to MTA.5 Additionally, it results in less discoloration potential and higher washout resistance than the original form of MTA. Another newly developed premixed calcium silicate-based material is EndoSequence BioCeramic Root Repair Material Fast Set Putty (BC-RRM PuttyBrasseler, Savannah, GA, USA). This material has been shown to be bio compatible, with simple handling properties and a low risk of discoloration.6

Several studies evaluating leakage using various in vitro methods (dye penetration, bacterial, and fluid filtration) have shown that MTA is superior to other restorative materials for perforation repair.7-10 However, to the best of our knowledge, no studies have compared the sealing ability of new commercially available calcium silicate-based materials, Endocem MTA and BC-RRM Putty, with those of MTA Angelus (Londrina, Parana, Brazil) used as a reference material. The present study aimed to compare the sealing ability of Endocem MTA and BC-RRM Putty with that of MTA Angelus to repair furcation perforations using fluid filtration method at two different

*Corresponding author: Cemre Koç, Email: cemrekoc@gmail.com

© 2021 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
time intervals (24 and 72 hours). The first null hypothesis stated that there was no difference between two leakage values measured at 24 and 72 hours for each repair material. The second null hypothesis stated that there was no difference in leakage values measured for three different repair materials at both time intervals.

**Methods**

**Tooth selection and preparation**

Seventy-six three-rooted human mandibular left and right first molar teeth extracted for periodontal, prosthetic, or orthodontic reasons and without any restorations, cracks, or fractures were used. The collected teeth had a dentin thickness of 2.0-2.5 mm at the furcation area to standardize the specimens. All the specimens were decoronated 3 mm above the cementoenamel junction and amputated 3 mm below the furcation area using a diamond saw under water cooling. Access cavities were prepared, and then root canal orifices were located. The canal orifices and the apical end of the roots were etched with 37% phosphoric acid gel (Scotchbond; 3M ESPE Dental Products, St Paul, MN) for 30 seconds, followed by the application of a single-bond adhesive system (Scotchbond; 3M ESPE Dental Products, St Paul, MN) and photopolymerization for 10 seconds. The root canal orifices and the apical end of each root were restored with a composite resin (Filtek Supreme XTE, 3M ESPE) and sealed with cyanoacrylate adhesive (Pattex; Henkel, Dusseldorf, Germany). Sixty-six teeth were randomly divided into three experimental groups (n = 22 for each group) according to the material used for perforation repair: Group 1: MTA Angelus; Group 2: Endocem MTA; Group 3: BC-RRM Putty. The remaining ten teeth served as positive and negative control groups. In the positive control group (n = 5), perforations were created and left unsealed. In the negative control group (n = 5), no perforation was created.

Perforations were created between the root canal orifices at the center of the pulp chamber floor using a #2 round high-speed bur under water cooling. Dentin residues in the perforation area were removed by rinsing with saline solution. The teeth were then placed in saline-soaked sponges in plastic cylinders to simulate clinical conditions. MTA Angelus and Endocem MTA were prepared by mixing the powder and liquid according to the manufacturer’s recommendations. BC-RRM Putty was used as received. The repair materials were then placed in furcation perforation areas using an MTA carrier and condensed with a plugger. A saline-moistened cotton pellet was placed in the pulp chamber. All the teeth were stored at 37°C and 100% humidity for 24 hours to allow the materials to set.

**Fluid filtration method**

Microleakage of the different repair materials to be tested was measured by electronically monitoring the movement of air bubbles in the microsyringe. Microleakage values of all the specimens were measured at 24-72 hour intervals.

**Statistical analysis**

Shapiro-Wilk test was used to determine whether the variables were suitable for normal distribution. Microleakage values were compared with nonparametric Kruskal-Wallis and Wilcoxon tests. The level of significance was set at P < 0.05.

**Results**

In the positive control group, air bubble movement was too rapid to be measured due to the high fluid transport, whereas no fluid transport was recorded in the negative control group.

Mean leakage values of MTA Angelus, Endocem MTA, and BC-RRM Putty at 24 hours were 2.5721, 2.1356, and 1.6463, respectively. Mean leakage values of MTA Angelus, Endocem MTA, and BC-RRM Putty at 72 hours were 1.8112, 1.9955, and 1.4766. Although the highest leakage value was recorded in the MTA Angelus group at 24 hours, no statistically significant difference was observed between the groups (P = 0.052, P < 0.05). Although the highest leakage value was recorded in the Endocem MTA group at 72 hours, no statistically significant difference was observed between the groups (P = 0.519, P > 0.05) (Table 1).

When the leakage values of the three repair materials at 24 and 72 hours were compared within the groups, leakage values measured at 72 hours were lower than those at 24 hours. For Endocem MTA and BC-RRM Putty groups, the difference between the leakage values measured at both time intervals was not significant (P = 0.828 and P = 0.506, respectively; P > 0.05). However, there was a significant difference in the MTA Angelus group (P = 0.001; P < 0.05) (Table 1).

**Discussion**

The present study evaluated the sealing ability of Endocem MTA, BC-RRM Putty, and MTA Angelus at two different time intervals when used as furcation perforation repair materials. For all the materials, lower leakage values were
Obtained at 24-hour measurement than values measured at 72-hour. Only in the MTA Angelus group, significantly low values were found between the two time intervals. Thus, the first null hypothesis tested was partially accepted. All the three materials exhibited a similar ability to seal furcation perforations at 24 and 72 hours. Therefore, the second null hypothesis tested was accepted.

Various methods such as dye, bacteria, protein, radioisotope, and glucose penetration, and fluid filtration have been used in vitro to evaluate the leakage properties of materials. Among the mentioned methods, nondestructive and quantitative testing methods, the fluid filtration method has been reported to be more reliable than other methods. In the dye penetration method, it is not possible to measure the amount of leakage precisely and at different time intervals. In case of bacterial leakage in two-chamber models, potential routes of bacteria and antimicrobial properties of tested material could affect the results. The glucose leakage method is not particularly suitable for evaluating the sealing ability of MTA, Portland cement, and calcium hydroxide, which could directly react with glucose as a tracer. Liquid filtration method was first described by Derkson et al in 1986 to evaluate the sealing ability of temporary filling materials. Then, some modifications were made to the method in the field of endodontics. In the liquid filtration method, the sealing ability of root canal fillings can be evaluated from both apical and coronal aspects, and measurement of the same samples can be repeated at different time intervals because the samples are not destroyed. Therefore, the liquid filtration method was used to evaluate the sealing properties of different materials in the present study. Additionally, a pressure of 2 atm was applied to mimic physiological conditions. Pommel and Camps's study showed that the measurement time should be as long as possible to obtain accurate measurement data. Wu and colleagues study used the data at 3 hours due to uncertain correlation of measurements with clinical conditions. In vitro studies evaluating the sealing properties of the materials were not determined for an optimal period, and the application techniques of the materials or related materials were compared by themselves.

In the present study, the sealing ability of the newly developed MTA derivative materials was evaluated at 24 and 72 hours. There was no significant difference between the leakage values measured at both time intervals. Although all the tested materials have different features, such as adding pozzolan particles (Endocem MTA), consisting of fine particles (BC-RRM Putty), and not containing calcium sulfate (MTA Angelus), they maintain a chemical composition similar to that of commercially available MTA. Thus, they may exhibit similar sealing ability when used as a perforation repair material. Similar to the present study results, another study evaluated the sealing ability and marginal adaptation of calcium silicate-based cements. The authors reported no significant difference in microleakage between the three different calcium silicate-based materials due to the similar compositions of the materials.

Table 1. The analysis of the microleakage values of the groups in terms of the materials and time intervals (μL.cmH₂O.cm².min⁻¹)

| Perforation repair material | Mean 24 h | Median 24 h | Mean 72 h | Median 72 h | Standard deviation 24 h | Standard deviation 72 h | P value |
|----------------------------|-----------|-------------|-----------|-------------|-------------------------|-------------------------|---------|
| MTA Angelus                | 2.5721±   | 1.8112±     | 2.4165±   | 1.6875±     | 1.71±                   | 1.50±                   | 0.001*  |
| Endocem MTA                | 2.1356±   | 1.9955±     | 2.00±     | 2.1250±     | 0.83±                   | 1.02±                   | 0.828   |
| BC-RRM Putty               | 1.6463±   | 1.4766±     | 1.1430±   | 0.8750±     | 1.59±                   | 1.59±                   | 0.506   |

*P<0.05; Wilcoxon test.
References

1. Fuss Z, Trope M. Root perforations: classification and treatment choices based on prognostic factors. Endod Dent Traumatol. 1996;12(6):255-64. doi: 10.1111/j.1600-9657.1996.tb00524.x.

2. Seltzer S, Sinai I, August D. Periodontal effects of root perforations before and during endodontic procedures. J Dent Res. 1970;49(2):332-9. doi: 10.1177/00220345700490022301.

3. Tesis I, Fuss ZV. Diagnosis and treatment of accidental root perforations. Endod Topics. 2006;13(1):95-107. doi: 10.1111/j.1601-1546.2006.00213.x.

4. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review--Part I: chemical, physical, and antibacterial properties. J Endod. 2010;36(1):16-27. doi: 10.1016/j.joen.2009.09.006.

5. Choi Y, Park SJ, Lee SH, Hwang YC, Yu MK, Min KS. Biological effects and washout resistance of a newly developed fast-setting pozzolan cement. J Endod. 2013;39(4):467-72. doi: 10.1016/j.joen.2012.11.023.

6. Alanezi AZ, Jiang J, Safavi KE, Spangberg LS, Zhu Q. Cytotoxicity evaluation of endosequence root repair material. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;109(3):e122-5. doi: 10.1016/j.tripleo.2009.01.007.

7. Hardy I, Liewehr FR, Joyce AP, Agee K, Pashley DH. Sealing ability of One-Up Bond and MTA with and without a secondary seal as furcation perforation repair materials. J Endod. 2004;30(9):658-61. doi: 10.1016/j.joen.20021619.33952.9a.

8. De-Deus G, Reis C, Brandão C, Fidel S, Fidel RA. The ability of Portland cement, MTA, and MTA Bio to prevent through-and-through fluid movement in repaired furcal perforations. J Endod. 2007;33(11):1374-7. doi: 10.1016/j.joen.2007.07.024.

9. Hashem AA, Hassansien EE. ProRoot MTA, MTA-Angelus and IRM used to repair large furcation perforations: sealability study. J Endod. 2008;34(1):59-61. doi: 10.1016/j.joen.2007.09.007.

10. Lodiene G, Kleivmyr M, Bruzell E, Ørstavik D. Sealing ability of mineral trioxide aggregate, glass ionomer cement and composite resin when repairing large furcal perforations. Br Dent J. 2011;210(5):E7. doi: 10.1038/sj.bdj.2011.198.

11. Oruçğolu H, Sengun A, Yılmaz N. Apical leakage of resin based root canal sealers with a new computerized fluid filtration meter. J Endod. 2005;31(12):886-90. doi: 10.1097/01.don.0000164134.79052.b3.

12. Alani AH, Toh CG. Detection of microleakage around dental restorations: a review. Oper Dent. 1997;22(4):173-85.

13. Wu MK, Wesselink PR. Endodontic leakage studies reconsidered. Part I. Methodology, application and relevance. Int Endod J. 1993;26(1):37-43. doi: 10.1111/j.1365-2591.1993.tb00540.x.

14. Garip H, Garip Y, Oruçğolu H, Hatipoğlu S. Effect of the angle of apical resection on apical leakage, measured with a computerized fluid filtration device. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111(3):e50-5. doi: 10.1016/j.tripleo.2010.08.004.

15. Rechenberg DK, De-Deus G, Zehnder M. Potential systematic error in laboratory experiments on microbial leakage through filled root canals: review of published articles. Int Endod J.2011;44(3):183-94. doi: 10.1111/j.1365-2591.2010.01821.x.

16. Shemesh H. Limitations of the glucose leakage model due to reactivity of glucose with MTA. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106(5):626-627. doi: 10.1016/j.tripleo.2008.06.021.

17. Derkson GD, Pashley DH, Derkson ME. Microleakage measurement of selected restorative materials: a new in vitro method. J Prosthet Dent. 1986;56(4):435-430. doi: 10.1002/j.1097-0022-3913(96)90384-7.

18. Pashley DH, Andringga HJ, Derkson GD, Derkson ME, Kalathoor SJ. Regional variability in the permeability of human dentine. Arch Oral Biol. 1987;32(7):519-23. doi: 10.1016/s0003-9969(87)80014-6.

19. van der Sluis IJ, Wu MK, Wesselink PR. An evaluation of the quality of root fillings in mandibular incisors and maxillary and mandibular canines using different methodologies. J Dent. 2005;33(8):683-8. doi: 10.1016/j.jdent.2005.01.007.

20. Wu MK, Wesselink PR, Boersma J. A 1-year follow-up study on leakage of four root canal sealers at different thicknesses. Int Endod J. 1995;28(4):185-9. doi: 10.1111/j.1365-2591.1995.tb00297.x.

21. Lamb EL, Loushine RJ, Weller RN, Kimbrough WF, Pashley DH. Effect of root resection on the apical sealing ability of mineral trioxide aggregate. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003;95(6):732-5. doi: 10.1067/moe.2003.98.

22. Pommel L, Camps J. Effects of pressure and measurement time on the fluid filtration method in endodontics. J Endod. 2001;27(4):256-8. doi: 10.1097/00004770-200104000-00003.

23. De Bruyne MA, De Bruyne RJ, Rosiers L, De Moor RJ. Longitudinal study on microleakage of three root-end filling materials by the fluid transport method and by capillary flow porometry. Int Endod J. 2005;38(2):129-36. doi: 10.1111/j.1365-2591.2004.00919.x.

24. Uyanık MO, Nagaš E, Sahin C, Dağlı F, Cehreli ZC. Effects of different irrigation regimens on the sealing properties of repaired furcal perforations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107(3):e91-5. doi:
25. Agrafioti A, Tzimpoulas N, Chatzitheodoridis E, Kontakiotis EG. Comparative evaluation of sealing ability and microstructure of MTA and Biodentine after exposure to different environments. Clin Oral Investig. 2016;20(7):1535-40. doi: 10.1007/s00784-015-1638-6.

26. Küçükkaya Eren S, Gördüysus M, Şahin C. Sealing ability and adaptation of root-end filling materials in cavities prepared with different techniques. Microsc Res Tech. 2017;80(7):756-62. doi: 10.1002/jemt.22861.

27. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. J Endod. 2005;31(2):97-100. doi: 10.1097/01.don.0000133155.04468.41.

28. Reyes-Carmona JF, Felippe MS, Felippe WT. Biomineralization ability and interaction of mineral trioxide aggregate and white portland cement with dentin in a phosphate-containing fluid. J Endod. 2009;35(5):731-6. doi: 10.1016/j.joen.2009.02.011.