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Sealing Ability of Nano-fast Cement *vs.* Mineral Trioxide Aggregate as Retrograde Apical Plugs: An *In-vitro* Microleakage Study

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Introduction: Apical surgery aims to eradicate the apical part of the root and the lesion to enhance the healing. The sealing ability of retrograde filling material is an essential factor affecting the success rate of the surgery. Mineral trioxide aggregate (MTA) is the gold standard of retrograde filling materials, with approved sealing capability and biocompatibility. Newly introduced root repair material with an approved antibacterial effect similar to MTA is Nano-fast cement (NFC) which should be investigated for its sealing ability. This study aimed to evaluate the sealing ability of NFC *vs*. MTA. **Materials and Methods:** Root apices of 48 single-rooted teeth were resected at 90 degrees and were prepared at 3 mm depth. The teeth were randomly divided into 2 experimental groups (*n*=21), negative control group (*n*=3), and positive control group (*n*= 3). MTA and NFC plugs were condensed as retrograde filling material. The samples were evaluated by a modified fluid filtration device for 1 hour. The measurement was conducted at 24 h, 1, and 3 months. Data were analyzed by Friedman Test and Kruskal-Wallis test. **Results:** According to the results, NFC at 3-months interval showed the least microleakage, and MTA had the highest at the baseline. However, the results between the two groups were not statistically significant in all intervals. NFC reached the ideal sealing ability within 1 month, which was reached for MTA after 3 months. **Conclusions:** The results of this *in vitro* study showed that the microleakage value of NFC is comparable to MTA. In light of current findings, NFC shows characteristics of a suitable calcium silicate-based cement. Further clinical researches are needed to introduce the NFC as retrograde apical plug or for other endodontic applications.

Keywords: Fluid Filtration; Microleakage; MTA; Nano-fast Cement; Retrograde Obturation

Introduction

Intraradicular microorganisms are the essential factors of apical periodontitis[1, 2]. Endodontic treatment aims to prevent or eradicate apical periodontitis by cleaning, shaping, disinfecting, and obturation of the root canal system [3-5].

The existence of periradicular radiolucencies or cystic lesions reduces the success rate. Surgical intervention (apicoectomy) may be required for the tight seal between the intraradicular and extraradicular systems [6]. The apicoectomy process consists of root-end resection, followed by pathologic periapical tissue removal and then sealing of the root canal system to eliminate any communication between the oral cavity and the periapical tissues [7].

Many restorative and endodontic materials have been used as retrograde apical plugs, including amalgam, polycarboxylate cement, zinc oxide eugenol (ZOE), composite resins, and glass ionomer cement (GIC). However, disparate disadvantages, such as moisture sensitivity, marginal leakage, and biocompatibility issues, associated with these materials restricted their appliance as retrograde filling materials [8]. Considering all the required features, mineral trioxide aggregate (MTA), introduced by Torabinejad, is used as an apical retrograde during apicoectomy. Today, MTA is a gold standard of materials used for retrograde apical plug [9, 10]. MTA is initially bonded to the root canal walls mechanically. However, chemical bonding occurs by extending the particles [11].

Other materials like Bioaggregate, Biodentine, calcium-enriched mixture cement (CEM), cold ceramic, and bioceramic materials have been developed to overcome some of the disadvantages of MTA, such as prolonged setting time, and difficult handling [12-14].

Studies showed that other introduced materials are efficient in sealing ability, capability to set in the presence of blood, biocompatibility, and bactericidal effects [15, 16].

Researchers at Shiraz University of Medical Sciences introduced a nano-calcium silicate-based cement termed Nano-fast-cement (NFC), which has shown encouraging features such as short setting time followed by reducing the particle size of MTA and easy handling. NFC possesses superior mechanical properties to MTA by adding a multi-walled carbon nanotube, which has no adverse effect on NFC setting time [17]. Compared to MTA, this biocompatible cement has shown similar antibacterial and antifungal efficiency against *Enterococcus faecalis*, *Escherichia coli*, and *Candida albicans* [18]. Another related study evaluating NFC solubility and porosity, showed that both MTA and NFC had similar solubility. NFC had a less porous surface when compared with MTA [19].

Microleakage of a retrograde material is a challenging subject affected by various factors such as obturation techniques, smear layer removal, root resection degree, and depth of root end cavity [16].

Various methods of microleakage assessment have been performed including: dye-leakage, radioisotope, liquid-leakage, bacterial-leakage analysis, SEM, electrochemical, fluid filtration, and computerized fluid filtration method [20, 21].

The computerized fluid filtration technique is reliable compared to linear dye-penetration techniques. The computerized fluid filtration is completely electronic, and the digital air pressure evaluating system is recommended to overcome the limitations of the old methods [22]. Considering all of the mentioned drawbacks, a modified fluid filtration technique was used to measure the microleakage in the current study.

To the best of our knowledge, there is no study evaluating NFC microleakage as retrograde material. Therefore, this study aimed to evaluate the NFC and MTA microleakage as retrograde apical plugs *via* a modified fluid filtration technique.

Materials and Methods

The Ethics Committee of Shiraz University of Medical Sciences approved the study protocol (IR.SUMS.DENTAL.REC.1401.006).

A total of 48 single-rooted human teeth were selected, then autoclaved and stored in normal saline. Teeth with calcification, caries, cracks, fractures, and multiple canals were excluded. Samples were sectioned to 14 mm by using carbide bur in a high-speed handpiece with coolant. The patency of apical foramen was confirmed by K file #15 (Dentsply Maillefer, Ballaigues, Switzerland). Working lengths were determined 1 mm shorter than apical foramen. Cleaning and shaping of all canals were performed using crown down technique by rotary ProTaper system: sx, s1, s2, F1, F2, F3, F4 (Dentsply Maillefer, Ballaigues, Switzerland). After application of each rotary file, the canals were irrigated with 2 mL of 5.25% NaOCl followed by saline. Then canals were dried with paper cones (Endopoints Ltda., Paraiba do sul, RJ, Brazil). Specimens were randomly divided into 4 groups: MTA (n=21), NFC (n=21), positive control (n=3) and negative control (n=3).

The positive control group was obturated and the apex of the negative control group was sealed with wax. Following the lateral condensation technique, NFC and MTA groups were obturated with gutta-percha and AH-Plus (Dentsply, DeTrey, Konstanz, Germany). All the roots except 2mm from the apex were covered with two layers of nail varnish.

Three millimeters of root apices were resected using high-speed handpiece with water coolant at the angle of 90 degrees. Then root end class 1 cavity of 3 mm depth were prepared. The depth of cavities was confirmed by the periodontal probe. The cavities were irrigated with 2 mL of 5.25% NaOCl (Cerkamed, Stalowa Wola, Poland), followed by 17% EDTA (Cerkamed, Stalowa Wola, Poland), and finally rinsed by saline. Root end cavities were dried with paper points (Gapadent Co., Ltd., Tianjin, China). Then MTA (Angelus, Londrina, PR, Brazil) and NFC were prepared according to manufacturer recommendations. Retrograde apical plugs were placed using MTA carriers into the cavities and then packed with pluggers until the cavity was completely filled. The depth and quality of the plugs were confirmed radiographically. Then samples were maintained in an incubator at 37-degree 100% humidity for 48-h. The modified fluid filtration technique was used in this study, which is more reliable and objective compared to the conventional fluid filtration method.

The apex of samples was placed in silicone tubes with an internal diameter of 3 mm and then fixed with cyanoacrylate paste. The silicone tube was connected to a micropipette. Another end of the silicone tube was connected to the water reservoir to inhibit the retrograde movement of water into the gas reservoir. The gas and water reservoir were connected by using a silicone tube. Gas reservoir had barometer to measure the amount of the gas pressure. Followed by, gauge 30 syringe performed induction

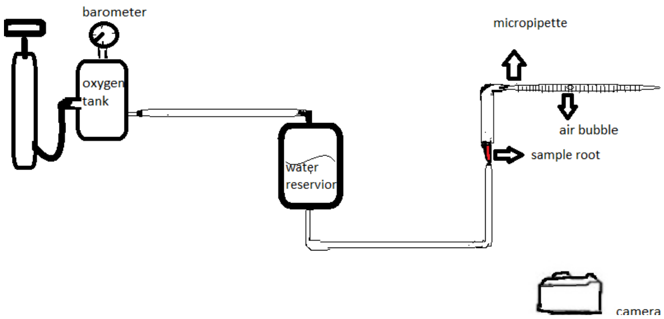

Figure 1. Schematic image of modified fluid filtration method

of approximately 2 mm diameter air bubble. The site of insertion was sealed with nail varnish. The gas pressure of 1.2 bar was applied to the system. The first evaluation of microleakage (mm/h) at baseline was performed after 24 h by measuring air bubble movement in the micropipette in 1-h. The measurements were re-evaluated at 1 and 3 months (Figure 1).

Statistical analysis

Due to violating the normality assumption, the non-parametric Kruskal-Wallis test was used for inter-group comparison. For intragroup evaluation, the data were subjected to the Friedman test. The analyses were performed using SPSS 22.0 software (SPSS, Chicago, IL, USA). The significance level was determined at $P<0.05$.

Results

The samples in the positive-control group exhibited significantly more microleakage compared with the experimental groups. However, the negative control group demonstrated the maximum microleakage value at all three time intervals.

The specimens in the MTA group at 24 h showed the highest microleakage; however, it was not statistically significant compared to NFC. NFC at 3 monthly intervals demonstrated the least microleakage, which was not statistically significant compared to MTA. The results of the fluid filtration test (mm/h) are available in Table 1.

Table 1. Mean (SD) of microleakage (mm/h)

	24 hour.	1 month	3 months
MTA	2.04 (0.63)$^{A,\#}$	1.83 (0.48)$^{A,\#}$	1.66 (0.45)$^{A,\#}$
NFC	2.00 (0.79)^{A,*}	1.52 (0.51)^{A,*}	1.50 (0.35)^{A,*}

MTA: Mineral trioxide aggregate; NFC: Nano-fast-cement
*Uppercase letters denote comparisons between groups at each defined time interval. Equal or common letters denote a lack of statistically-significant difference (P<0.05). (The minimum microleakage values of the groups in each of the times is determined with * symbol.)(The maximum microleakage values of the groups in each of the time intervals is determined with # symbol)*

Discussion

Root canal filling can leak through sealer–filling material and sealer dentin interfaces. Consequently, it may be responsible for root canal treatment failure [16].

Lack of a perfect seal at the interface of the retrograde filling material and cavity margin may lead to failure of apicoectomy due to continuous bacterial leakage from the root canal to periapical tissues resulting in persistent inflammation [16]. Various methods of microleakage assessment have been introduced, including dye-leakage, radioisotope, liquid-leakage, bacterial-leakage analysis SEM, electrochemical, fluid filtration, and computerized fluid filtration method [20, 21].

The fluid filtration method has been proven to be more exact in micro leakage measurement compared to linear dye-penetration techniques. [23] The samples in fluid filtration are not ruined, and measurements of microleakage can be re-evaluated at any time [24]. The computerized fluid filtration technique has some advantages over the conventional one because of being controlled by the computer and digital air pressure adjustments. Furthermore, air bubble movement can be measured with laser diodes under computer control, instead of being visually detected [25].

Modified fluid filtration is a user friendly technique that is recorded by a camera instead of a laser diode and computer. The evaluations can be repeated at any interval, because the samples are not destructed. This method is based on the amount of air bubble movement (mm) recorded in one h using a time laps recorder *via* digital camera.

This study's results showed that NFC microleakage was less than MTA. However, the difference was not statistically significant in all intervals. The reduction of microleakage value in NFC was lower than the reduction rate of MTA within 3-months.

MTA is considered an ideal root-end filling material and has been the gold standard compared to the recently introduced materials [26]. MTA has been selected as the control material in this study due to its excellent sealing ability, biocompatibility, and marginal adaptation [27]. Also, Nepal *et al.* showed a lower microleakage of Biodentine compared to MTA. Indeed, the difference was not statistically significant [26].

In another study performed by Oraie *et al.* evaluating the apical sealing ability of MTA in different liquid to powder ratios and packing methods, the results showed that packing MTA as retrofill apical plug with a plugger or moist cotton pellet made no significant difference in apical dye leakage [28].

A new calcium-silicate-silicate based material named calcium-enriched mixture (CEM) cement has been developed. It has different features than MTA and Portland cement [29] and good biocompatibility [30]. In a study performed by Kazem *et al.*, bacterial and dye microleakage of four different root-end filling materials, including amalgam, Root MTA, White ProRoot MTA (WMTA), and CEM cement was evaluated. CEM cement was not significantly different from conventionally used retrograde filling materials *e.g.*, WMTA [31]. Also, Ghobadi *et al.* declared that Biodentine has the better apical sealing ability as root end-filling material than MTA and CEM cement [32]. Another study by Adl *et al.* evaluating the addition of propylene glycol showed neither a positive nor negative effect on the sealing ability of Angelus MTA and CEM cement [33]. Ramezanali *et al.* evaluated the coronal microleakage of MTA, CEM cement and Biodentine in the orifice region. They demonstrated that the CEM cement and MTA exhibited the least and highest penetration rates in the orifice region, respectively [34]. The difference between their study and other studies was the location of material placement [32].

The Ramazani *et al.* study showed that CEM cement and Biodentine had encouraging results to be used as an alternative to MTA for the repair of furcation perforation in primary molars [35].

Agrafioti *et al.* assessed the sealing ability and microstructure of MTA and Biodentine in various environments. Their results indicated that both materials are proper for application in acidic environments. Exposure of Biodentine to an acidic environment imitates the metabolic environment of bacteria involved in periapical lesions. So, assessing of apical filling materials in this situation is also efficient [36].

According to Ayatollahi *et al.* study, CEM cement provided a considerably better seal than MTA in dry and saliva-contaminated conditions [37].

Another recently developed calcium silicate-based material is Cold ceramic, which is an MTA-like bioceramic [38].

A study by Mokhtari *et al.* compared the marginal adaptation of cold ceramic (CC) and MTA using a scanning electron microscope (SEM). Results declared that the mean interfacial adaptation was better in the CC group. However, differences were not statistically significant. Consequently, both CC and MTA showed similar marginal adaptation [39].

Results of the present study showed an acceptable sealing ability of the NFC as root end-filling material compared to MTA. Due to the importance of microleakage on the success of apical surgeries in the long term and other short-comings of *in vitro* study, further clinical studies are suggested to confirm the appropriate clinical microleakage of NFC.

Conclusions

The present study concluded that NFC showed acceptable sealing ability compared to MTA when used as a retrograde apical plug. It can be a possible candidate among calcium silicate-based materials with similar properties to MTA.

Conflict of Interest: 'None declared'.

References

1. Kakehashi S, Stanley H, Fitzgerald R. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Pathol. 1965;20(3):340-9.
2. GUTMANN JL. Surgical endodontics: quo vadis? EndodTopics. 2005;11(1):1.
3. Hülsmann M, Rümmelin C, Schäfers F. Root canal cleanliness after preparation with different endodontic handpieces and hand instruments: a comparative SEM investigation. J Endod. 1997;23(5):301-6.
4. Siqueira Jr JF, Araújo MC, Garcia PF, Fraga RC, Dantas CJS. Histological evaluation of the effectiveness of five instrumentation techniques for cleaning the apical third of root canals. J Endod. 1997;23(8):499-502.
5. Paredes-Vieyra J, Enriquez FJJ. Success rate of single-versus two-visit root canal treatment of teeth with apical periodontitis: a randomized controlled trial. J Endod. 2012;38(9):1164-9.
6. Krastev B, Filipov I. Periapical Surgery. Epidemiology, indications and contraindications. Review. J of IMAB. 2020;26(2):3114-21.
7. Torabinejad M, Higa RK, McKendry DJ, Ford TRP. Dye leakage of four root end filling materials: effects of blood contamination. J Endod. 1994;20(4):159-63.
8. Saxena P, Gupta SK, Newaskar V. Biocompatibility of root-end filling materials: recent update. Restor Dent Endod. 2013;38(3):119-27.
9. Sousa C, Loyola A, Versiani M, Biffi J, Oliveira R, Pascon E. A comparative histological evaluation of the biocompatibility of materials used in apical surgery. Int Endod J. 2004;37(11):738-48.
10. Orosco FA, Bramante CM, Garcia RB, Bernardineli N, Moraes IGd. Sealing ability, marginal adaptation and their correlation using three root-end filling materials as apical plugs. J Appl Oral Sci. 2010;18:127-34.
11. Sarkar N, 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.
12. Soundappan S, Sundaramurthy JL, Raghu S, Natanasabapathy V. Biodentine versus mineral trioxide aggregate versus intermediate restorative material for retrograde root end filling: an invitro study. J Dent (Teh). 2014;11(2):143.
13. Sadana G, Gupta T, Kaur P, Kaur H, Behl M. Comparative Evaluation of Marginal Integrity of Mineral Trioxide Aggregate and

Biodentine as Retrograde Filling Materials—An In Vitro Study. Current Trends in Diagnosis and Treatment. 2018;2(2).
14. Mozayeni MA, Milani AS, Marvasti LA, Abbas FM, Modaresi SJ. Cytotoxicity of Cold Ceramic compared with MTA and IRM. Iran Endod J 2009;4(3):106.
15. Torabinejad M, Hong C, McDonald F, Ford TP. Physical and chemical properties of a new root-end filling material. J Endod. 1995;21(7):349-53.
16. Yildirim T, Er K, Taşdemir T, Tahan E, Buruk K, Serper A. Effect of smear layer and root-end cavity thickness on apical sealing ability of MTA as a root-end filling material: a bacterial leakage study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;109(1):e67-e72.
17. Sanaee MR, Manesh HD, Janghorban K, Sanaee R, Kooshesh L, Ghahramani Y, Moazami F. The influence of particle size and multi-walled carbon nanotube on physical properties of mineral trioxide aggregate. Mater Res Express. 2019;6(6):065413.
18. Moazami F, Gholami A, Mehrabi V, Ghahramani Y. Evaluation of the antibacterial and antifungal effects of ProRoot MTA and nano-fast cement: an in vitro study. J Contemp Dent Pract. 2020;21(7):760-4.
19. Moazzami F, Rajabzadeh Z, Daneshmanesh H, Ghahramani Y. Evaluation the Solubility and the Porosity of the Nano Fast Cement Comparing to the Mineral Trioxide Aggregate: An in vitro Study. J Dent. 2023;24(1):28-33.
20. Valois CR, Costa Jr ED. Influence of the thickness of mineral trioxide aggregate on sealing ability of root-end fillings in vitro. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;97(1):108-11.
21. Sahebi S, Moazzami F, Dehghan R, Ghahramani Y. The Simultaneous Effect of Apical Resection Angle and Depth of Retrograde Cavity on Apical Microleakage via Fluid Filtration Method. Iran Endod J. 2019;14(4):269-300.
22. Gençoğlu N, Oruçoğlu H, Helvacıoğlu D. Apical leakage of different gutta-percha techniques: Thermafil, Js Quick-Fill, Soft Core, Microseal, System B and lateral condensation with a computerized fluid filtration meter. Euro J Dent. 2007;1(02):097-103.
23. Antonopoulos KG, Attin T, Hellwig E. Evaluation of the apical seal of root canal fillings with different methods. J Endod. 1998;24(10):655-8.
24. Goldman M, Simmonds S, Rush R. The usefulness of dye-penetration studies reexamined. Oral Surg Oral Med Oral Pathol. 1989;67(3):327-32.
25. Oruçoğlu H, Sengun A, Yilmaz N. Apical leakage of resin based root canal sealers with a new computerized fluid filtration meter. J Endod. 2005;31(12):886-90.
26. Nepal M, Shubham S, Tripathi R, Khadka J, Kunwar D, Gautam V, Gautam N. Spectrophotometric analysis evaluating apical microleakage in retrograde filling using GIC, MTA and biodentine: an in-vitro study. BMC Oral Health. 2020;20:1-7.
27. Girish CS, Ponnappa K, Girish T, Ponappa M. Sealing ability of mineral trioxide aggregate, calcium phosphate and polymethylmethacrylate bone cements on root ends prepared using an Erbium: Yttriumaluminium garnet laser and ultrasonics evaluated by confocal laser scanning microscopy. J Conserv Dent. 2013;16(4):304.
28. Oraie E, Ghassemi AR, Eliasifar G, Sadeghi M, Shahravan A. Apical sealing ability of MTA in different liquid to powder ratios and packing methods. Iran Endod J. 2012;7(1):5.
29. Asgary S, Eghbal MJ, Parirokh M, Ghoddusi J, Kheirieh S, Brink F. Comparison of mineral trioxide aggregate's composition with Portland cements and a new endodontic cement. J Endod. 2009;35(2):243-50.
30. Naghavi N, Ghoddusi J, Sadeghnia HR, Asadpour E, Asgary S. Genotoxicity and cytotoxicity of mineral trioxide aggregate and calcium enriched mixture cements on L929 mouse fibroblast cells. Dent Mater J. 2014;33(1):64-9.
31. Kazem M, Eghbal MJ, Asgary S. Comparison of bacterial and dye microleakage of different root-end filling materials. Iran Endod J. 2010;5(1):17.
32. Ghobadi A, Soleymani A, Gholinia H. Comparison of apical microleakage of mineral trioxide aggregate, calcium-enriched mixture cement and biodentine as root end filling materials. Caspian J of Dent Res. 2020;9(2):50-6.
33. Adl A, Sobhnamayan F, Shojaee NS, Azad FT, Bahmani M. Effect of propylene glycol on the sealing ability of mineral trioxide aggregate and calcium-enriched mixture cement apical barriers. Iran Endod J. 2017;12(3):318.
34. Ramezanali F, Aryanezhad S, Mohammadian F, Dibaji F, Kharazifard MJ. In vitro microleakage of mineral trioxide aggregate, calcium-enriched mixture cement and biodentine intra-orifice barriers. Iran Endod J. 2017;12(2):211.
35. Ramazani N, Sadeghi P. Bacterial leakage of mineral trioxide aggregate, calcium-enriched mixture and biodentine as furcation perforation repair materials in primary molars. Iran Endod J. 2016;11(3):214.
36. 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.
37. Ayatollahi F, Tabrizizadeh M, Abad MHB, Ayatollahi R, Zarebidoki F. Comparison of microleakage of MTA and CEM cement apical plugs in three different media. Iran Endod J. 2016;11(3):198.
38. Modaresi J, Hemati HR. The cold ceramic material. Dent Res J 2018;15(2):85.
39. Mokhtari F, Modaresi J, Javadi G, Davoudi A, Badrian H. Comparing the marginal adaptation of cold ceramic and mineral trioxide aggregate by means of scanning electron microscope: An in vitro study. J Int Oral Health. 2015;7(9):7.

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