

Effect of Condensation Pressure on Microleakage of Mineral Trioxide Aggregate

Seyed Mohsen Jalalzade¹ Elham Khoshbin² Seyed Abdolkarim Tabatabaei^{*3}
Ghassem Ansari⁴

¹Endodontist, Mashhad, Iran.

²Dept. of Endodontic, Dental School, Hamedan University of Medical Sciences, Hamedan, Iran.

³Post Graduate Student, Dept. of Pedodontics, School of Dentistry, Shahid Beheshti University of Medical Science, Tehran, Iran.

⁴Dept. of Pedodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Abstract

Objective: The aim of this study was to assess the effect of condensation pressure on microleakage of mineral trioxide aggregate (MTA).

Methods: This in vitro experimental study was conducted on 55 sound single-rooted straight-canal extracted human teeth. The teeth were sectioned at the cemento-enamel junction (CEJ) and at 3 mm above the root apex. The roots were mounted in putty. Samples were then divided into three experimental groups (n=15) and positive and negative control groups (n=5). After filing of the root canals to file #50, white ProRoot MTA paste was prepared according to the manufacturer's instruction and applied to the canals using condensation pressure of 0.44, 3.22 and 8.88 Mpa in groups one to three, respectively. After a 48-hour setting time, each root was connected to the fluid filtration system to measure microleakage. The mean microleakage rate of the groups was calculated and compared using one-way ANOVA and least significant difference test.

Results: The mean microleakage with condensation pressure of 0.44, 3.22 and 8.88 MPa was 1.70×10^{-4} , 1.17×10^{-4} and 0.48×10^{-4} $\mu\text{L}/\text{minute}$, respectively. One-way ANOVA showed that the mean microleakage rate was significantly different among the groups ($P < 0.05$). The lowest microleakage was observed in condensation pressure of 8.88 MPa.

Conclusion: Within the limitations of this study, the results showed that increase in condensation pressure decreased the rate of microleakage.

Key words: Dental Leakage, Mineral Trioxide Aggregate, Pressure

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*Corresponding Author:
Tabatabaei SA.
E-mail:
Abdolkarim_t@yahoo.com.

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Introduction

Evidence shows that post-treatment microleakage is the most important cause of failure of endodontic treatment (1,2). Therefore, an appropriate root end filling material is essential in order to seal the apex. An ideal root end filling material must be biocompatible and have high sealing ability in order to prevent the leakage of stimulants from the root canal system into the periradicular tissues. To date, various root-end filling materials have been tested for this purpose among which, MTA has shown a high success rate (3,4).

Torabinejad et al. (3) introduced MTA in 1993. At present, MTA is successfully used for furcal and root perforation repair and as a pulp-capping agent for vital pulp therapy. It is also used for single-session apexification and root end filling (5,6). With a pH of 12.5, MTA contains hydrophilic particles, which set in presence of moisture (7). The main ingredients of MTA powder include tri-calcium silicate, di-calcium silicate, tri-calcium aluminate and tetra-calcium aluminoferrite (3,8). Primary setting time of MTA is four hours and during the first 72 hours following its setting, its bond strength to dentine increases significantly

(7). It also creates an effective seal and prevents bacterial penetration through the tooth-restoration interface (8,9). It has been shown that MTA creates a strong seal in presence of blood and moisture, which is highly favorable in cases of difficult isolation. It has been shown that the sealing ability of MTA is higher than that of amalgam and equal or higher than that of Super-EBA (7).

Vizgirda et al. (10) in 2004 compared the sealing ability of MTA with laterally compacted gutta percha plus sealer and high temperature thermo-plasticized gutta percha with sealer in extracted teeth. They showed that gutta percha might create a better apical seal when compared to MTA, which was attributed to difficult handling of MTA (10). Various techniques have been suggested to overcome the problems related to placing MTA including manual and ultrasonic techniques.

Aminoshariae et al. (7) in 2003 reported that manual compaction of MTA provided a better adaptation to the walls and created fewer voids than the ultrasonic technique. Yeung et al. (5) in 2006 compared the quality of compaction of MTA root canal fillings in manual compaction versus the manual compaction plus indirect ultrasonic technique, and concluded that the latter method provided a denser MTA in both straight and curved root canals.

Basturk et al. (11) in 2014 evaluated the effect of mechanical and manual mixing on the flextural strength and porosity of MTA. They concluded that mechanical mixing did not have a significant advantage over manual mixing in terms of flextural strength and total porosity. Nekoofar et al. (8) in

2007 studied the effect of condensation pressure on some physical properties of MTA. They showed that condensation pressure adversely affected the strength and hardness of MTA. It is believed that the condensation pressure of MTA directly influences its sealing ability. Literature indicates that MTA condensation pressure has a significant effect on MTA sealing ability and consequently MTA microleakage; however, the magnitude of this impact is not well known (8). Since apical leakage is considered as one of the most important causes of endodontic treatment failure, finding solutions to decrease leakage can increase the success of endodontic treatment. Based on the current available literature, there is a gap of information on the effect of condensation pressure on MTA microleakage. Therefore, the aim of this study was to assess the effect of compaction forces on microleakage of MTA as a root end filling material.

Methods

This in vitro experimental study was conducted on 55 extracted human permanent single-rooted teeth. Teeth with straight root canals, no calcification, no carious lesions or cracks were included. Sample size was calculated to be 15 in each group based on a previous study (10) and using sample size calculation formula taking into account %85 power of study.

Condensation pressure was considered as a continuous quantitative independent variable. Microleakage was considered as a quantitative dependent variable with

continuous scale and reported in micro liter per minute.

The teeth were radiographed to ensure absence of cracks or root calcifications. They were then washed with 2.5% sodium hypochlorite solution (IPPC, Tehran, Iran). The samples were then stored in saline (IPPC, Tehran, Iran) to remain hydrated. A water-cooled, high-speed handpiece with a long #008 fissure bur (Diaswiss, Bern, Switzerland) was used to cut the crown at the CEJ and the root at 3 mm above the apex. Root canals were then filed, irrigated and shaped by passing the file 2 mm beyond the sectioned level using stainless steel files up to number 50 (Mani, Kiyohara, Japan). For the purpose of standardization, a #40 nickel titanium rotary file (Mani, Kiyohara, Japan) was introduced into the canal (16mm) with 0.06 taper, as retrograde. Root canals were then cleaned and irrigated with 15cc normal saline. The roots were wrapped in moist gauze until obturation. They were then mounted in putty to simulate spongy bone.

The teeth were divided into three test groups of 15. Two extra groups (n=5) were also considered as positive and negative controls. In the positive control group, each tooth was filled with a gutta-percha cone (number 70) while in the negative control group, the teeth were filled with wax. The two control groups were used to calibrate the device.

White ProRoot MTA (Dentsply Tulsa Dental, Johnson City, TN, USA) was mixed with distilled water according to the manufacturer's instructions (powder to liquid ratio of 3 to 1)(12,13). Mounted specimens were placed on a digital scale

(Germany) with an accuracy of 0.01g to calibrate the scale for each root piece (Figure 1).



Figure 1- Teeth mounted in putty on digital balance

The MTA was packed into the root canals by an endodontic plugger (#4, Dentsply Maillefer, OH, USA) with a cross-section of 0.8 mm exerting the following forces:

Group A: 35 ± 5 g Group B: 255 ± 5 g Group C: 710 ± 5 g

Load was converted to Megapascals for the purpose of easy comparison with other reported values. These values were recorded at 0.44 MPa for group A, 3.22 MPa for group B and 8.88 MPa for group C, respectively (8).

All samples were placed on a digital scale for more precise checking of the implemented force. Samples were then radiographed to ensure absence of voids. Attempts were made to create 4mm thickness of apical plug in all samples (9,12,14).

Moistened cotton balls were placed on top of the MTA plug in each specimen. The teeth were then removed from the impression material and wrapped in moist gauze. All filled root pieces were kept in ambient room temperature in moist gauze with 100% moisture for 48 hours to allow complete setting of MTA. Each specimen was then connected to a fluid filtration system designed for this study in order to assess the microleakage. Samples were fixed to an acrylic plate at the CEJ section (Figure 2).

The plate had a 28-gauge needle to connect to fluid filtration system with pressure set at 30 Psi. A period of 15 minutes was allowed for widening of the pipe and stabilization of conditions. The rate of bubble flow was recorded for 10 minutes. To make the results comparable with those of other studies, the values were divided by 21020 to obtain the microleakage value in micro-liter per minute in pressure of one centimeter of water. The average rate of readings of liquid microleakage was compared among the groups after one minute (9,15). The fluid filtration system was built based on a study by Derekson et al, in 1986 (16).



Figure 2- Tooth fixed to an acrylic plate

The collected data were analyzed using Kolmogorov-Smirnov (normality) test. Since the data were found to have normal distribution, one-way ANOVA was used for data analysis. Pairwise comparisons were carried out using the least significant difference test to find the differences in level of microleakage between the groups.

Table 1- Descriptive statistics of microleakage rates in the three groups with different condensation pressures

Force	Mean	Standard deviation	Minimum	Maximum
35g(0.44 MPa)	1.70×10^{-4}	1.21×10^{-4}	0.00	4.76×10^{-4}
255g(3.22MPa)	1.17×10^{-4}	1.16×10^{-4}	0.00	1.76×10^{-4}
710g(8.88MPa)	0.48×10^{-4}	1.41×10^{-4}	0.00	1.43×10^{-4}

Discussion

The clinical use of MTA is increasing in various fields of dental profession (17). Optimal properties including biocompatibility, sealing ability and

Result

The positive control group showed high levels of microleakage. The negative control group showed no microleakage. The highest level of mean microleakage was 1.70×10^{-4} and was seen in group A while the lowest microleakage was 0.48×10^{-4} seen in group C (Table 1, Figure 3).

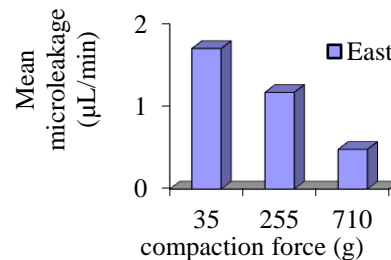


Figure 3- Descriptive statistics of microleakage rates in the three groups with different condensation pressures

One-way ANOVA showed that there was a significant difference in microleakage among the tested groups ($P=0.001$). Significant differences were noted in the microleakage level between groups A and B ($P=0.03$) and groups A and C ($P=0$). Similar differences were observed in the microleakage level between groups B and C ($P=0$).

The lowest microleakage rate was seen in group C.

induction of pulp regeneration have been reported for MTA (18). Also, MTA has long been used as apical plug due to optimal sealing ability and relatively short curing time (17). A newly developed material known as calcium-enriched mixture is

believed to have almost similar properties to those of MTA when it comes to sealing ability (9). The current study was conducted on apical plugs 4mm in thickness similar to a previous study (8).

Despite long-term use of various methods of microleakage assessment including dye penetration and bacterial leakage techniques, fluid filtration technique has been used more extensively for this purpose (9,15,16). The fluid filtration technique enables quantitative measurement and volumetric assessment of microleakage over a period of time and is a non-destructive method that allows repeated evaluation of microleakage in the same sample. This technique also provides a positive pressure, which helps to eliminate the problem caused by air or fluid entrapment in dye penetration method (19).

The current results showed that the mean microleakage of MTA decreased by an increase in condensation pressure. The current findings also revealed that there was a significant difference in the rate of MTA microleakage with various condensation pressures (0.44, 3.22 and 8.88 MPa). The decrease in microleakage following an increase in condensation pressure could be attributed to maximum marginal adaptation of MTA, decreased formation of voids and less shrinkage following MTA polymerization. It could also be noted that as the condensation force increased, polymerization speed decreased, which in turn resulted in maximum marginal adaptation and reduced polymerization shrinkage (7).

Mandava et al. (20) in 2015 evaluated microleakage around retrograde filling materials and showed that MTA had significantly less microleakage than Biodentine and light-cure glass ionomer

cement. This may be due to the formation of hydroxyapatite-like crystals at the interface of material and canal wall, which result in superior adhesion and lower microleakage. Absence of MTA shrinkage and optimal sealing ability due to forming chemical bonds to the intra-canal dentin might be other reasons for low microleakage (21). It appears that lower microleakage of MTA supports its reliable use in the clinical setting.

Kumbuloglu et al. (22) in 2004 and Piwowarczyk et al. (23) in 2007 stated that lower microleakage was due to higher forces preventing unfavorable shrinkage. It is believed that unfavorable shrinkage increases microleakage and decreases the bond strength. Higher forces reduce such unfavorable shrinkage and yield lower microleakage rates.

Improved adaptation of MTA to the walls is considered as another reason for lower microleakage due to manual compaction. Aminoshariae et al. (7) in 2003 tested the extent of MTA adaptation to the walls of plastic tubes simulating root canals. They indicated that manual compaction led to better adaptation of MTA to tube walls and fewer voids than the ultrasonic method (7). The same may apply when working on teeth, and better adaptation may be achieved by manually packing the MTA into the root canals.

To the best of authors' knowledge, no previous study was found on the effect of condensation pressure on microleakage of MTA. Thus, we compared our findings with those of studies on the effects of compaction forces on physical properties of MTA. Yeung et al. (5) in 2006 concluded that ultrasonic forces cause MTA to become denser in both direct and curved root canals.

Nekoofar et al. (8) in 2007 concluded that condensation pressure affected the strength and hardness of MTA, in such a manner that higher compaction forces caused lower microhardness rates. It is probable that condensation pressure rate changes the molecular distance between water molecules and MTA particles and causes changes in the hydration process, which in turn may cause changes in the ideal powder to water ratio. This can also play a role in microleakage. Condensation pressure rate may also affect air entrainment and the number of voids formed within the material bulk. Nekoofar et al. (8) were in favor of lower condensation pressure while the current study showed that lower forces caused higher microleakage. It is noteworthy that the probability of tooth breakage should be taken into account as well, although there were no cases of breakage in the current study.

Vizgirda et al. (10) in 2004 showed that gutta-percha created a better apical seal than MTA. A probable cause of weaker seal provided by MTA could be the higher forces required for placing and compacting MTA in root canal apical region. The results of the current study also showed that exerting higher forces to compress MTA would lead to lower microleakage rates and showed the positive effect of compaction on decreasing leakage. Also, the role of expertise and skills of the operators should not be overlooked since clinicians have a greater experience in working with gutta percha compared to MTA.

Adequate sample size was the strength of the current study. Also, this study assessed the effect of compaction forces on microleakage of MTA, which has not been well evaluated before. However, the current study had an in

vitro design. Oral environment cannot be well simulated in vitro; thus, generalization of in vitro findings to the clinical setting must be done with caution.

The current study showed that higher compaction forces further decreased the microleakage of MTA but did not completely eliminate it. Thus, future studies should focus on other measures to minimize microleakage. Moreover, it should be kept in mind that compressive forces cannot exceed a certain limit since they may result in fracture. Thus, finding the optimal compaction force to minimize microleakage without increasing the risk of tooth fracture can be an interesting topic for future studies. Last but not least, factors affecting the microleakage of MTA in the clinical setting should be investigated in future studies.

Conclusion

It seems that within the limitations of this study, increasing forces for condensation of MTA decreased the microleakage of root canals. There was a significant difference among the groups tested in favor of higher condensation pressure.

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Conflict of Interest: “None Declared”

References:

1. Siren EK, Haapasalo MP, Ranta K, Salami P, Kerosuo EN. Microbiological finding and clinical treatment procedures in endodontic cases selected for microbiological investigation. *Int Endod J.* 1997 Mar;30(2):91-5.
2. Siqueira JE. Aetiology of root canal treatment failure: why well-treated teeth can fail: *Int Endod J.* 2001 Jan;34(1):1-10.
3. Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root end filling material. 1993 Dec;19(12):591-5.
4. Yildirim T, Tasdemir T, Orucoglu H. The evaluation of the influence of using MTA in teeth with post indication on the apical sealing ability. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009 Sep;108(3):471-4.
5. Yeung P, Liewehr FR, Moon PC. A quantitative comparison of the fill density of MTA produced by two placement techniques. *J Endod.* 2006 May;32(5):456-9.
6. Singh P, Paul J, Al-khuraif AA, Vellappalley S, Halawany HS, Hashim M, et al. Sealing ability of mineral trioxide aggregate, calcium phosphate cement, and glass ionomer cement in the repair of furcation perforations. *Acta Medica (Hradec Kralove).* 2013;56(3):97-103.
7. Aminoshariae A, Hartwell GR Moon PC. Placement of mineral trioxide aggregate using two different techniques. *J Endod.* 2003 Oct;29(10):679-82.
8. Nekoofar MH, Adusei G, sheykhrezae MS, Hayes SJ, Bryant ST, Dummer PM. The effect of condensation pressure on selected physical properties of mineral trioxide aggregate. *Int Endod J.* 2007 Jun;40(6):453-61.
9. Moradi S, Disfani R, Lomee M, Naghavi N. Effect of root resection on of sealing ability of orthograde apical plugs of mineral trioxide aggregate and Calcium enriched mixture. *J Dent (Tehran).* 2014 Jul;11(4):447-54.
10. Vizgirda PJ, Liewehr FR, Patton WR, McPherson JC, Buxton TB. A comparison of laterally condensed gutta-percha, thermoplasticized gutta-percha, and mineral trioxide aggregate as root canal filling materials. *J Endod.* 2004 Feb;30(2):103-6.
11. Basturk FB, Nekoofar MH, Gunday M, Dummer PM. Effect of various mixing and placement techniques on the flexural strength and porosity of mineral trioxide aggregate. *J Endod.* 2014 Mar;40(3):441-5.

12. Parirokh M, Torabinejad M. Mineral Trioxide aggregate: a comprehensive literature review part I: chemical, physical and antibacterial properties. *J Endod.* 2010 Jan;36(1):16-27.
13. Olmez A, tuna D, Ozdogan YT, Ulker AE. The effectiveness of different thickness of mineral trioxide aggregate on coronal leakage in endodontically treated deciduous teeth. *J Dent Child (Chic).* 2008 Sep-Dec;75(3):260-3.
14. Torabinejad M, Parirokh M. Mineral trioxide aggregate: a comprehensive literature review part II: leakage and biocompatibility investigations. *J Endod* 2010 Feb;36(2):190-202.
15. Garip H, Garip Y, Orucoglu H, Hatipoglu 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 Mar;111(3):e50-5.
16. Derekson GD, Pashly DH, Derekson ME. Microleakage measurement of selected restorative materials, a new invitro method. *J Prosthet Dent.* 1986 Oct;56(4):435-40.
17. Torabinejad M, Ung B, Kettering JD. In vitro bacterial penetration of coronally unsealed endodontically treated teeth. *J Endod.* 1990 Dec;16(12):566-9.
18. Inoue S, Yoshimura M, Tinkle JS, Marshall FJ. A 24-week study of the microleakage of four retrofilling materials using a fluid filtration method. *J Endod.* 1991 Aug;17(8):369-75.
19. Goldman M, Simmonds S, Rush R. The usefulness of dye-penetration studies re-examined. *Oral Surg Oral Med Oral Pathol.* 1989 Mar;67(3):327-32.
20. Mandava P, Bolla N, Thumu J, Vemuri S, Chukka S. Microleakage evaluation around retrograde filling materials prepared using conventional and ultrasonic techniques. *J Clin Diagn Res.* 2015 Feb;9(2):ZC43-6.
21. Reyhani MF, Yavari H, Ghasemi N, Rahimi S, Barhaghi MH, Mokhtari H, et al. Comparing the Coronal Seal of Different Thicknesses of MTA with Gutta-Percha After Post Space preparation. *ScientificWorldJournal.* 2015;2015:708639.tyz.
22. Kumbuloglu O, Lassila LV, User A, Vallittu PK. A study of the physical and chemical properties of four resin composite luting cements. *Int J Prosthodont.* 2004 May-Jun;17(3):357-63.
23. Piwowarczyk A, Bender R, Ottl P, Lauer HC. Long-term bond between dual-polymerizing cementing agents and human hard dental tissue. *Dent Mater.* 2007 Feb;23(2):211-7. *Epub.* 2006 Feb; 21.