BRIEF RESEARCH COMMUNICATION

A Comparative Evaluation of Sealing Ability of Three Root-end Filling Materials at Different Time Intervals Using Novel Fluid Filtration Model: An *In Vitro* Study

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Abstract

Background: Microleakage is one of the major causes of endodontic treatment failure. Many microleakage testing techniques have been introduced through the years, but there has been no agreement as to which technique gives the most accurate results. The objective of this research was to assess the accuracy of fluid filtration when analyzing the apical sealing capability of the aggregate of mineral trioxide, Biodentine, and total putty.

Materials and methods: A sample of 40 human central incisors was collected. The samples were decoronated at cementoenamel junction followed by preparing the canal up to size 80. Using the lateral compaction method, the obturation was done with AH plus sealer. The apical 3 mm root was resected after which ultrasonic retro tips have been utilized to make the retrograde preparation. Apical microleakage evaluation for each of the specimens was performed utilizing the fluid filtration method at specific time intervals, i.e., immediate, 1 week, 1 month, 3 months, and 6 months.

Results: The outcomes of the current study inferred that MTA revealed better apical sealing properties than that of Biodentine and total putty. Overall, comparative analysis of microleakage immediately and post restoration at different time intervals was done using one-way ANOVA '*F*' test that was highly significant, $p < 0.001$. Pairwise comparison was done using Tukey's *post-hoc* test $p < 0.001$.

Conclusion: Thus, the results of the present study conclude that MTA with its superior sealing ability might provide long-term sealing benefits to the root canal system than that of Biodentine and total putty.

Key message: In this study, MTA has shown a better long-term sealing ability as compared to Biodentine and total putty.

In a surgically attempt to repair the tooth, it is necessary to select a material with promising long-term sealing ability, MTA as a root-end filling material can be suggested as a better alternative to the other bioactive materials.

Keywords: Calcium silicate, Fluid filtration, Pemetrexed, Treatment failure.

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Introduction

A three-dimensional obturation is intended for fluid-tight sealing of all communication pathways between the pulpal and periradicular tissues. This type of treatment is designed to cleanse and fill the three-dimensional areas of the root canal system. Nonetheless, the root canal treatment fails due to multiple factors. Such cases are treated either surgically or non-endodontically.[1] Endodontic surgery typically includes preparing of the root end, root resection, and root-end filling.[1,2] Biocompatibility, low toxicity, easily controlled, radiopaque, extremely durable, and adherent to dentin are some of the major qualities that should be possessed by an acceptable root-end filling material.[3] Root canal therapy is desired to seal the root canals apically and coronally in order to prevent the leakage and percolation of the oral fluids and as well as to avoid recontamination of infected canals.[4]

Certain endodontic defects result from the leakage of root canal irritants, which are pathologically implicated.[4] However accomplishment is often challenging due to the complexity of root canal structures, inadequate instrumentation, and the presence of physical barriers. The purpose of apical surgery is to preserve a tooth surgically which is primarily having an endodontic lesion that cannot be treated nonsurgically. Consequently, a detailed clinical as well as radiographic evaluation of the tooth prior to the apical surgery should be carried out in order to decide whether surgical or nonsurgical endodontics should be considered.[4,5]

MTA was primarily created at the Loma Linda University. Previous researchers have witnessed that the MTA was superior with greater marginal adaptation. Studies also showed that the mineral trioxide aggregate has weak properties in handling.[6,7]

Particularly, Septodont (Saint-Maur-des-Fosses, France) has developed a new calcium-silicate restorative material called

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Biodentine.[8] This can be utilized not just as an endodontic repair material but also as dentin replacing material and root-end filling material.[8]

A collection of several putty and paste materials have been made available in recent time. Endo sequence root repair material (ERMM) is available as a paste or putty. Putty can be molded to any shape by hands. Being putty and easy moldability, it provides very good contact with bony tissues, resulting in better healing. It has similar physical properties to MTA once set but has greatly better handling properties.[9] In addition, *in vitro* research shows comparable sealing abilities of MTA as well as Biodentine.[10]

The mechanism of bonding of calcium silicate cement to dentin can be due to a chemical bond or micromechanical.[11] After the placement of MTA, the hydroxyapatite crystals nucleate and grow and fill the microscopic space between MTA and the dentin surface. Initially, this seal is mechanical. Over a period of time, the reaction leads to chemical bonding between hydroxyapatite and dentin. Whereas, Biodentine induces denaturation and permeability of the organic collagen component of interfacial dentin. Recent studies have reported that Biodentine showed the formation of intratubular tags in mineral infiltration zone.[11]

Numerous studies have evaluated the apical sealing ability of root canal fillings using various methods such as dye leakage, electrochemical techniques, bacterial penetration measurement, radioisotope techniques, and fluid filtration techniques.[12] Recently, the acetate peel technique has been introduced which is a simple, inexpensive, and fast method for measuring microleakage. Moreover, peels are stable and can be preserved for further evaluation. However, the peel technique is delicate, which may produce artifacts that can be misinterpreted, which can lead to over-estimation of the result.[13] Three-dimensional techniques such as micro-computed tomography, confocal laser microscope, and optical coherence tomography have been introduced.[13] The present study thus emphasizes the use of the fluid filtration method to assess and compare the microleakage of three regenerative materials: MTA, Biodentine, and total putty.

Materials and Methods

Forty single-rooted maxillary central incisors were used in the study. The selected teeth were evaluated for fractures and surface cracks. Teeth that had fractures and cracks have been excluded. The teeth were decoronated at the cementoenamel junction using a diamond disc (Frank dental) at a perpendicular plane to the long axis of the tooth. Access opening was done using Endo Z bur (Dentsply Sirona). Using ProTaper Universal files (Dentsply Sirona), the canals were prepared up to size F5 followed by a step back to size 80. Irrigation was performed using 5.25% of sodium hypochlorite (Cerkamed), saline (Baxter), and a chlorhexidine (Prevest DenPro) as the final irrigant. Using lateral condensation, the canals were obturated utilizing AH Plus sealer (Dentsply Sirona). The access to the coronal section was sealed through Cavit (3M ESPE). Each root was then resected with an apical 3 mm utilizing a high-speed, tapered fissure bur (SS White). The 3 mm retrograde cavity preparation was performed utilizing the Kim Surgical (KIS) ultrasonic tip (Fig. 1). The teeth were then arbitrarily divided into four different groups and restored. The four groups are as follows:

- Group I – Control
- Group II – MTA (Dentsply Sirona) (Table 1)

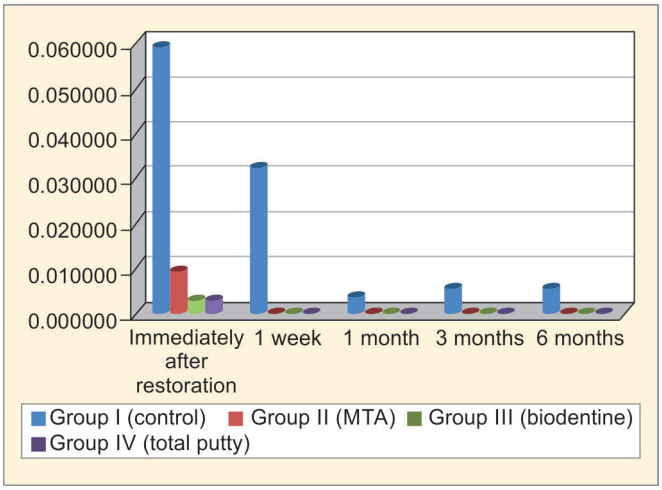

Fig. 1: Overall comparative graphical presentation of the groups at different time intervals

- Group III – Biodentine (Septodont)
- Group IV – Total putty (FKG Dentaire).

Excluding the resected root surface, the outer surfaces of the roots of tooth samples were coated with nail varnish. All the samples were then stored in artificial saliva (Nanochemazone). The apical microleakage of each individual sample was analyzed using a fluid filtration system. This method measures microleakage determined by the air bubble movement that is produced in the apparatus. The study was approved by the ethical committee MCES/EC/432-A/2018.

Microleakage Testing Apparatus (Fluid Filtration Model)

The method involves measuring microleakage by the movement of fluids in the model determined by displacing the bubbles.

The system consists of two segments:

Section A: Composed of tubes, syringes, micropipette, faucet control, pressurized buffer system, and tooth sample
Section B: Composed of a bubble displacement recorder incorporating a digital SLR camera (Canon 1200D) AutoCAD (Autodesk, Inc.)

First, the negative tooth specimens were attached to the three-way control faucet; the control faucet was then closed to the tooth specimen to connect only the micropipette and syringe. In the micropipette, a bubble was formed utilizing a syringe. Following the injection of the bubble into the micropipette, the control faucet was closed against the syringe, ensuring the micropipette was attached to the tooth sample. At the same time, the digital SLR camera was adjusted. The oxygen was gradually released from the oxygen cylinder by means of a pressure adjustment device which was adjusted at 4–6 psi.[14]

Results

The microleakage scores at a different time intervals, i.e., immediate, 1 week, 1 month, 3 months, and 6 months were recorded and analyzed. Results showed that there was a noticeable difference between the materials at all-time intervals, i.e., immediate, 1 week, 1 month, 3 months, and 6 months.

Table 1: Pairwise comparative statistics of microleakage scores recorded immediately and post restoration at different time intervals using Tukey's *post-hoc* test

	Immediately after restoration Mean (SD)	*1 week Mean (SD)*	*1 month Mean (SD)*	*3 months Mean (SD)*	*6 months Mean (SD)*
Group I (Control) vs Group II (MTA)	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$
Group I (Control) vs Group III (Biodentine)	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$
Group I (Control) vs Group IV (Total putty)	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$
Group II (MTA) vs Group III (Biodentine)	$p < 0.001^*$	$p = 0.994$	$p = 0.967$	$p = 1.000$	$p = 0.999$
Group II (MTA) vs Group IV (Total putty)	$p < 0.001^*$	$p = 0.986$	$p = 1.000$	$p = 1.000$	$p = 1.0000$
Group III (Biodentine) vs Group IV (Total putty)	$p = 0.995$	$p = 1.000$	$p = 0.968$	$p = 1.000$	$p = 1.000$

$p > 0.05$, no significant difference; $^*p < 0.001$, highly significant difference

Table 2: Overall comparative statistics of microleakage scores recorded immediately and post restoration at different time intervals using One-way ANOVA '*F*' test

	Immediately after restoration Mean (SD)	*1 week Mean (SD)*	*1 month Mean (SD)*	*3 months Mean (SD)*	*6 months Mean (SD)*
Group I (Control)	0.05921 (0.00238)	0.0324 (0.00431)	0.004 (0.000068)	0.0057 (0.00068)	0.00057 (0.000059)
Group II (MTA)	0.009218 (0.00017)	0.0004569 (0.000093)	0.00011692 (0.000063)	0.0000987 (0.000063)	0.0000907 (0.0000063)
Group III (Biodentine)	0.003015 (0.00024)	0.0002021 (0.000057)	0.0001921 (0.0000188)	0.0001121 (0.000065)	0.0001101 (0.0000086)
Group IV (Total putty)	0.00288 (0.00043)	0.0001278 (0.000027)	0.0001178 (0.000053)	0.0001111 (0.0000085)	0.0001040 (0.000054)
ANOVA '*F*' test	4983.0	554.15	279.11	725.19	888.51
p value	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$	$p < 0.001^*$

$^*p < 0.001$, overall highly significant difference among groups

Microleakage scores recorded immediately after restoration showed that there was a statistically significant difference between control with MTA (0.0092188), Biodentine (0.003015), and total putty (0.00288), $p < 0.001$ (Table 2).

Microleakage scores recorded after 1 week of storage showed that there was a statistically significant difference between control with MTA (0.00045692), Biodentine (0.00020210), and total putty (0.00012783), $p < 0.001$ (Table 2).

Microleakage scores recorded after 1 month of storage showed that there was a statistically significant difference between control with MTA (0.00011692), Biodentine (0.00019210), and total putty (0.00011783), $p < 0.001$ (Table 2).

Microleakage scores recorded after 3 months of storage showed that there was a statistically significant difference between control with MTA (0.0000987), Biodentine (0.00011210), and total putty (0.00010783), $p < 0.001$ (Table 2).

Microleakage scores recorded after 6 months of storage showed that there was a statistically significant difference between control with MTA (0.0000907), Biodentine (0.00011010), and total putty (0.00010483), $p < 0.001$ (Table 2).

Discussion

Sealing capability refers to the ability of the materials to withstand microleakage through the entire material thickness.[15] Insufficient apical seal results in microleakage, which is considered to be the major reason for endodontic surgical failure.[16] Microleakage is characterized by the movement of fluids, bacteria, molecules, or ions between the tooth restoration interfaces.[17] Numerous methodologies have been applied and used for evaluating microleakage. Most recent technologies utilize key variations which include biological, chemical, electrical, physical, or radioactive components, which include the use of colors, radioactive isotopes, air pressure, filtration of water, bacteria, neutron activation analysis, artificial caries, electron microscopy screening, calcium hydroxide, and several other approaches.[18]

The fluid filtration technique is generally utilized in microleakage tests. Such techniques were utilized to assess the sealing properties of various restorative as well as endodontic sealers. This technique thus featured prominently in endodontics for apical or coronary microleakage assessment.[19]

The approach to the filtration of fluids has many benefits compared to other approaches used for microleakage assessment. The advantages include: The samples are not damaged as with dye penetration, no tracer is needed, and no intermediate materials as necessary in bacterial or radioactive studies. In addition, the fluid filtration method gives very precise results because of the automatic recording of very small volumes, thus avoiding any possible operator bias.[20]

Several specific retrograde root-end filling materials were used over the years, including silver amalgam, IRM, glass ionomer, and composite resins. These materials, however, did not meet the requirements for an ideal root-end filling material.[6] Apical ramifications as well as the lateral canals are quite popular near the root tip, resection at the depth of 3 mm suppresses the apical ramifications by 98%, and indeed the lateral canals by 93%.[21] During preparations of root-end cavity, good visualization and easy access are the main criteria for choosing 0°, 30°, or 45° resection angles.[22] Furthermore, angled root-end resection also has the ability to open dentin tubules that might significantly raise the bacterial infection risk rate as well as microleakage possibilities leading to the failings of endodontic surgery. Gagliani et al. and Gilheany et al. in their studies concluded that the microleakage significantly enhanced with enhancement in the angulations of the resected root-end.

Based on the experimental conditions of this *in vitro* test, the findings showed that all of the materials used in this test had microleakage, but MTA showed substantially less leakage than Biodentine and total putty at all time periods.[7] In a study by Nabeel et al., where they compared the sealing ability of Biodentine and Pro-Root MTA, the sealing ability of Pro-Root MTA was better than Biodentine.[23] The results obtained through this study are consistent with studies reported by De Bruyne et al. and Mulla et al.[24,25] and are inconsistent with studies reported by Abualhasan et al. and Mahmoud et al. who concluded that Biodentine showed better clinical results compared with MTA.[26,27]

MTA samples showed more leakage immediately after restoration, but the leakage was reduced over a time period at 1 week, 1 month, 3 months, and 6 months intervals compared with Biodentine and total putty. This shows the impact of wet curing that might retard the setting time, which could be the possible reason for the substantial leakage during the immediate period.[28] Hydration and material setting explain the minimum leakage at later intervals of time (1 and 3 months). MTA's microstructure, elementary makeup, and hydration reaction result in an alkaline pH and release calcium ions in the solution, indicating that it is expected to be bioactive.[29]

Several studies have been reported on MTA drawbacks, including its long setting period.[30] MTA erosion may be caused by persistent exudates or fluid from the tissue. While MTA has shown to exhibit excellent sealing capability, its erosion might prevent the complete sealing of the tooth's retrograde preparation site and thereby ultimately triggers failure.[31] Efforts have been made to resolve MTA's long set period with the use of various additives. While MTA's setting duration with additives is reported to show a shorter time period than that of the original MTA type, the setting time recorded is still too long to represent clinical significance. In addition, different studies have shown that the addition of additives to MTA to speed up the setting time will adversely affect its physical properties.[31]

The outcomes of the present study showed substantially higher leakage of MTA during the initial phase; however, the leakage was gradually reduced over time intervals of 1 week, 1 month, 3 months, and 6 months compared with Biodentine and total putty. However, MTA exhibited superior sealing ability which might provide long-term sealing benefits to the root canal system than that of Biodentine and total putty.

The analysis, thus, witnessed the superior sealing capabilities of MTA. The other two bioactive materials: Biodentine and total putty have also been effective in exhibiting the long-term sealing ability of the root canal system. The three regenerative materials MTA, Biodentine, and total putty provide an adequate seal, cost-effective, dimensionally stable, insoluble, and radiopaque, and allow easy manipulation and placement. These regenerative materials were developed mainly for long-term sealing of the root canal system and also exhibit a bioactive characteristic.

Conclusion

Within the limitations of this research, a long-term evaluation was concluded, and it was possible to compare the sealing capability of root-end filling materials using a fluid filtration model. The relatively high leakage of MTA was observed during the initial period, which might be due to the longer setting time of MTA. Nevertheless, MTA has shown a better long-term sealing capability than Biodentine and total putty. This advancement in MTA's sealing capacity over time could be due to its hydrophilic properties as well as the formation of an interfacial layer between the dentin as well as MTA. The interfacial layer reduces the risk rate of partial percolation as well as increases clinical performance in the longer term. Thus, MTA as a root-end filling material can be suggested as a better alternative to the other bioactive materials. However, more research needs to be carried out both *in vitro* and *in vivo* to assess the suitability of MTA for Clinical implementation.

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