In Vitro Study on the Sealing Ability of Mineral Trioxide Aggregate

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The success of an endodontic material depends on its sealing ability, as most post-treatment endodontic disease usually occur due to marginal leakage in the apical area of the root canal. The aim of our study is to evaluate the sealing ability of a Mineral Trioxide Aggregate-based endodontic sealer (ProRootMTA), compared to other frequently used materials, on extracted human teeth, using a dye penetration leakage test. The results showed a significant difference ($p<0.01$) between ProRoot MTA and the other two sealers.

Keywords: MTA, apical seal, marginal leakage, dye penetration

An ideal endodontic material would have a series of qualities, such as adherence to tooth structure, efficient apical seal, stability in tissue fluids, antibacterial effect, induce mineralization, dimensionally stable, non-resorbable, radiopaque, and biocompatibility[1-3]. A number of materials have historically been used in endodontic treatments, but unfortunately, none of these have been able to satisfy the total requirements of an ideal sealer [4, 6]. Mineral trioxide aggregate (MTA) is a biomaterial derived from Portland cement that has been investigated for endodontic applications since the early 1990s. MTA has demonstrated to be highly biocompatible in contact with periapical tissues and able to form hydroxyapatite when exposed to physiologic solutions. Two forms of MTA materials are avaible: the traditional gray MTA (GMTA) and white MTA (WMTA), the letter being introduced in 2002 as ProRoot MTA (Dentsply Endodontics, Tulsa, OK, USA) for esthetic considerations. It contains less iron, aluminum, and magnesium oxides than GMTA [7-9]. In experimental and clinical investigations MTA has demonstrated many advantages: inhibition of bacterial infection, biological lock of root canals through periapical cement formation in root perforations and apical development of a hard tissue barrier [3-8].

The aim of this in vitro study is to evaluate the sealing ability of ProRoot MTA material on extracted human teeth using dye penetration leakage test. For comparison we had used other sealers frequently used in every day dental practice, AH Plus and Endomethasone. The null hypothese tested was that there were no differences in the apical sealing ability measured in root canals filled with gutta-percha and these three endodontic materials.

Experimental part

We selected a number of 45 single-rooted human extracted teeth, divided into three experimental groups, each containing a number of 15 teeth. The root canals were prepared by standardized technique with manual endodontic files (fig. 1) and then filled by cold lateral condensation of gutta-percha cones and one of the sealing materials (ProRoot MTA, AH Plus or Endomethasone). The sealers were prepared according to the manufacturer's instructions. ProRoot MTA white containing tricalcium silicate, dicalcium silicate, bismuth oxide and calcium sulfate was prepared by mixing one spoonful of powder with one drop of distilled water, to obtain a sandy consistence.

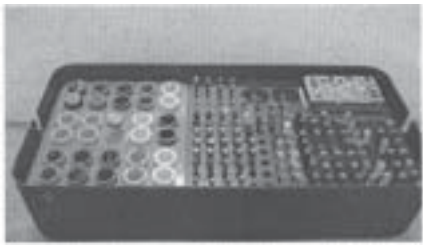

Fig. 1. The endodontic tray used to prepare the root canals

AH Plus is an epoxy resin presented in a paste-paste system that are mixed together in equal cuantities: Paste A-epoxy resin, calcium tungstate, zirconium oxide, silica and iron oxide and Paste B- adamantine amine-N, N-dibenzyl – 5 oxononane-diamine-1,9,TDC-diamine, calcium tungstate – zirconium oxide, silica-silicone oil.

Endomethasone was prepared mixing the powder (bismuth carbonate, barium sulfate, sodium borate anhydrous) with the liquid (4-allyl-2-methoxyphenol) in the given proportion. The teeth were prepared for the dye penetration leakage test after 48 h, for the complete setting of the endodontic materials, during this interval being stored in deionized water at 37^{0}C. The whole tooth except 3-4 mm around the apex was covered with two layers of nail polish and after that placed with the apical third in methylene blue solution for 24 h, long enough for the dye to penetrate all the gaps and irregularities between the root filling material and the dentinal walls. Then a longitudinal section was made along the root using a double face diamond disk under copious irrigation with water, obtaining two slices per tooth. The marginal leakage evaluation was done using scores and linear measurements. The prepared teeth for dye penetration test are presented in figure 2.

Fig. 2. Teeth prepared for dye penetration test

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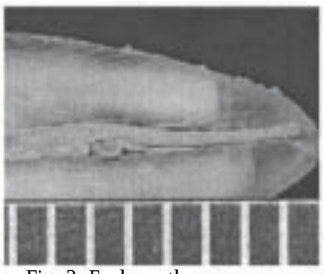

Fig. 3. Endomethasone case with 6.5 mm of dye penetration (score 3)

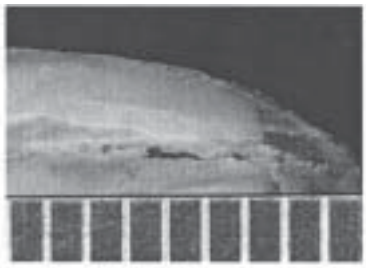

Fig. 4. Apical leakage in a case of AH Plus with 1.2 mm dye penetration (score 2)

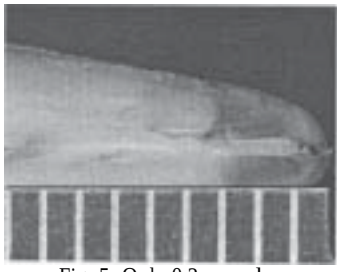

Fig. 5. Only 0.2 mm dye penetration in a case filled with ProRoot MTA (score 1)

The extension of dye penetration along the apical part of the root filling was evaluated according to the following scores: **0** – no dye penetration, **1** – less than 1mm, **2** – between 1.0-2.0 mm, **3** – over 2.0 mm dye penetration. For the linear measurements we used a dental operating microscope with a 10 fold magnification. The three examiners were calibrated and each slide was evaluated individually, finally the differences in readings being resolved by consensus.

The variance analyses Kruskal – Wallis test and the Dunn test ($p<0.05$) were used for the score method. For the linear measurements readings we used ANOVA and Student test for comparison among the groups ($p<0.05$).

Results and discussions

The evaluation was made after longitudinal sectioning of the teeth from each study group and under magnification (x 25) provided by a dental operating micro scope, based on evaluation of 28 slices filled with ProRoot MTA and Endomethasone and 25 with AH Plus.

In figures 3-5 we present suggestive cases from each study group. In figure 3 is presented an Endomethasone case, with 6.5 mm of dye penetration, which represent score 3.

Figure 4 shows apical leakage in a case of AH Plus with 1.2 mm dye penetration, which represent score 2.

Only 0.2 mm dye penetration in a case filled with ProRoot MTA, which represent score 1, is shown in figure 5.

The scores and procentual marginal leakage measurements are presented in table 1 and 2.

Based on the linear measurements, the average size of dye penetration varied between 6.5 mm (Endomethasone) and 0.0 mm ProRoot (MTA) in the three studied groups. The range of linear measurements, mean values and standard deviations are presented in table 3.

All the tested materials showed dye leakage and the statistical analysis of the results by one way-ANOVA test demonstrated a highly significant difference between the study groups. The best results were obtained when ProRoot MTA was used as a root canal sealer, when the marginal leakage had a mean value less than 1mm. The results showed a significant difference ($p<0,.01$) between ProRoot MTA and the other two materials.

The periapical tissue repair depends on the complete filling of the root canal system and its hermetic sealing by means of physically and biologically compatible materials, which is the primary goal of the endodontic treatment [10]. A successful endodontic treatment is achieved by cleansing, shaping and filling the root canal space for healing to occur. The main cause for failure is the lack of seal of the root canal filling (apical and coronal leakage), as un-removed microorganisms can trigger a periapical inflammatory response.

Mineral trioxide aggregate (MTA) is mainly composed of tricalcium and dicalcium silicate; it has a chemical composition similar to Portland cement, but containes lower amounts of heavy metals [11, 12]. MTA is used primarily to seal lateral root perforations and as a root-end filling material. It has been demonstrated that MTA is a bioactive material that produces calcium hydroxide, which is released in solution and induces formation of hydroxylapatite structures in simulated body fluid. Newer developments of MTA include its use as a root canal sealer.

The hydration reaction of MTA produces mainly calcium silicate hydrate and calcium hydroxide. Dreeger et al [13] reported that the calcium ions released from the cement diffused through the dentinal tubules and reacted with phosphate ions in the tissue fluids and yield calcium phosphate. Usually this will incorporate other ions and matured into carbonated apatite. Calcium silicate hydrate, calcium hydroxide and carbonated apatite form the interfacial layers between the MTA and radicular dentin which is responsible of the good sealing ability of MTA [14]. The success of an endodontic material may largely depend on its sealing ability, as most post-treatment endodontic disease is thought to occur due to tissue and other materials in uncleaned and/or unfilled areas of the root canal system that egress into the surrounding tissues [15-16]. In comparison to traditional endodontic sealers, in case of using MTA as an apical restoration, furcation repair, and in the treatment of immature apices, it has been reported a similar or less microleakage of fluids and microorganisms

Table 1
SCORE METHOD READINGS AND MEAN VALUES FOR THE STUDY GROUPS

Material	Score 0	Score 1	Score 2	Score 3	Mean value
ProRoot MTA	7	19	2	0	0.85
AH Plus	2	3	16	4	1.23
Endomethasone	0	4	6	18	2.91

Table 2
PROCENTUAL MICROLEAKAGE MEASURED IN THE STUDY GROUPS

Material	Score 0	Score 1	Score 2	Score 3
ProRootMTA	25%	67.86%	7.14%	-
AH Plus	8%	12%	64%	16%
Endomethasone	-	14.29%	21.43%	64.28%

Table 3
RESULTS OF DYE PENETRATION TEST IN THE STUDY GROUPS (MILLIMETERS)

Study group	Dye penetration	Mean value	Standard Deviation
ProRoot MTA	0.0-0.8	0.6	0.16
AH Plus	1.2-3.5	2.6	0.21
Endomethasone	5.2-6.5	5.8	0.35

along the restoration-tooth interface [17-20]. In order to obtain the highest degree of quality during endodontic therapy, it is important to dental practitioners to understand that besides materials and techniques, an important role in long-time success is played by ergonomics and posture mechanics, especially today, when the dental operating microscope is largely used by dental specialists [21].

The method of scores is largely used for experimental studies but it offers only a qualitative evaluation; we used also a linear measurement method that showed also a significant difference between the study groups. Neither of the methods are ideal but these results show the sensibility of the analysis method used, which demonstrated the superiority of ProRoot MTA in sealing ability of the root canal, compared to the other two materials.

Conclusions

Based on the results of our in vitro study, ProRoot MTA demonstrated a superior sealing ability compared to the other two endodontic sealers. The second best sealer was AH Plus, followed by Endomethasone, which showed the highest rate of dye leakage beyond the root filling.

Further clinical studies are needed in order to confirm the sealing ability of MTA based sealers in vivo, as the filling conditions regarding the presence of necrotic tissues or body fluids might interfere with the quality of endodontic restoration.

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