The application of MTA as apical plug for root canal obturation – in vitro study

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SUMMARY
Introduction Prognosis of endodontically treated tooth is directly correlated to the quality of apical obturation. Modern concept of endodontics in particular way points out the quality of apical filling. The aim of this study was to assess the quality of root canal obturation with MTA apical plug using the method of gas (argon) penetration.

Material and Methods Sixty-six freshly extracted single rooted (single canal) teeth were divided into two experimental (30 teeth) and one control group (6). All canals were instrumented using hand and rotary files in step-back technique and copious irrigation of 1%NaOCl. In the first experimental group teeth were obturated using different sealers: Gutta Flow (Roeko), AH Plus (DeTrey), Acroseal (Septodont) and mono gutta-percha cone (10 canals each). In the second experimental group obturation involved 3 mm of MTA-Angelus apical plug while the remaining canal space was filled with the same three sealers as in the first group. The rate of gas permeability by Leak detector-Edwards LD 416 was measured in all teeth.

Results The best seal was found in teeth obturated with Gutta Flow and MTA plug with average diffusion rate of 264.4 sec while the worst quality of obturation was found with Acroseal (178.5 sec-the highest gas permeability). All samples with MTA plug exhibited significantly lower leakage than the samples filled without MTA apical plug.

Conclusion Root canals filled with MTA apical plug exhibited statistically significant lower gas permeability in comparison to the ones filled with sealer and gutta-percha cones only.

Keywords: MTA; sealer; apical obturation; Gutta Flow; calcium silicate; gas permeability

INTRODUCTION
Adequately done endodontic treatment supports and stimulates reparative processes in apical periodontal tissues. Up to date doctrine of endodontic treatment is based on biomechanical canal instrumentation and irrigation [1]. The idea about optimal apical hermetic sealing with biologic properties forced many investigators to find ideal obturation material that could also prevent overfilling [2,3]. This material needed to be biocompatible, adhesive and physico-chemically stable to perform obturation [4,5]. Mineral trioxide aggregate (MTA) material fulfills many of required characteristics [5]. Torabinejad and Asgary were the first ones to use MTA in vitro and then in vivo studies in restorative and endodontic procedures in the nineties of the past century [5]. It was invented to improve and satisfy appropriate hardness, low solubility and short setting time as obturation material. The first dark-gray variant of MTA was mostly based on hydroxyapatite particles [4], similar to the original Portland cement (PC) formulation. It has been examined through the series of physicochemical and biological tests for use in dentistry as cheaper bioactive dentine replacement material besides expensive MTA [5–8]. Up to nowadays, many variants of CS cements showed impressive results as endodontic sealers, pulp-capping agents, apical retrograde fillings [9,10] apical obturation sealers [11,12], perforation healing liners [13], as well as propelling agent during apexogenesis/apexification [12,13]. One of CS preparations, an improved MTA cement, iRoot cement (iR) as root canal sealer is confirmed to kill E. faecalis in bacterial medium [14]. It is considered bioactive material but with high toxicity and certain antibacterial properties [15,16]. Methods for evaluation of apical hermeticity are numerous but diffusion of dye is the one most frequently used, whether by vacuum system or without. Similar methods were used at the end of past century, but with more precision, displaying apical permeability through the function of time [17,18].

The aim of this study was to assess the canal filling hermeticity of MTA apical plug using the method of gas diffusion.

MATERIAL AND METHODS
The study involved sixty-six extracted single-rooted teeth grouped into the two experimental groups of 30 teeth each and one control group of six teeth. The used endodontic sealers were: Gutta Flow (Colthane /Whaledent, Germany), AH Plus (DeTrey, Germany) and Acroseal (Septodont, France). Standardized gutta-percha cones of 2% taper were used for obturation (Pearl Endopia, Pearl Dent Co.). In the first group (A) canals were obturated with single gutta-percha cone and sealer. The second group (B) had canals obturated with apical MTA plug and rest of the canal with gutta-percha and sealer. The roots of teeth had similar diameter and volume of apical portion without any defect along the root. The coronal part of the teeth was removed from the root at the cement-enamel junction using high-speed hand-piece and

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fissure diamond bur enabling direct access to the canal. After the initial patency (Kerr files #10 and #15), preoperative radiograms were performed. Pulp tissue was removed using barbed broach. Working length was determined by insertion of hand file into the canal until it goes out through the apex and then subtraction for 1 mm and taking x-ray. Canals were prepared to the WL (#15 do #40) and then by step-back technique up to the coronal third of canal using copious irrigation (1% NaOCl) and lubricant (Canal +, Septodont, France). Instrumentation was completed with hand Ni-Ti reamers and files (Sybron, Germany).

**Experimental groups**

Upon canal preparation (apical matrix of #40 size) root canals were obturated with three sealers and single gutta-percha cone (groups A1, B1 and C1) or with previously inserted MTA plug by pluggers for vertical condensation (Maillefer, Swiss) and then sealer and gutta-percha cone in the groups A2, B2 and C2. Obturation was performed using Lentulo spiral and guttapercha cones in combination with endodontic sealers: Gutta Flow, Acroseal and AH Plus (DeTray, Germany). Gutta Flow was inserted using dispensing gun (Coltene/Whaledent, Swiss).

Apical plug was 3 mm long where periapical radiographs from two directions confirmed the quality of apical MTA filling (Figure 1). Access cavities were temporary filled with Cavit (Premier, Dental Products, Germany).

Control group involved six canals that were obturated only with gutta-percha cones to show that argon (Ar) is capable of going only through the apical foramen and root canal filling material. The teeth of experimental and control group were kept for 7 days at 37°C in the area of absolute humidity to allow definite hardening of sealers.

**Gas diffusion marking**

Quantification of visual information was done using VegaCam device (Edwards LD, 416, UK) and detector device by added software program (Argon Leak Detector, Edwards, UK). The quality of root canal obturation was assessed using the technique of gas permeability system [18]. Ar concentration was measured using argon-leak detector (Edwards LD 416, UK) [18]. Obturated teeth were fixed in prospecting detectors for stability. Argon gas was introduced by a special micro-cannula placed in the coronal part of canal when the measurement chamber was vaccummed. The time (sec) needed for gas penetration through the apex was measured using the timer [19]. The quality of obturation was expressed as the time interval needed for Ar to penetrate through the apex whereby longer time meant better obturation.

Statistical analysis was performed using ANOVA test for differences between the means of experimental groups using confidentiality level of p=0.01. Newman-Keuls test was used to compare differences between the groups.

**RESULTS**

In the group of teeth that were obturated with apical MTA plug, the lowest gas permeability was shown by combined obturation with Gutta Flow and MTA apical plug (269.4 sec), then AH Plus and MTA plug (258.5 sec) while the highest gas permeability was with Acroseal and MTA plug (255.2 sec). The differences among them were statistically insignificant (p > 0.01) (Table 1, Graph 1).

![Figure 1. X ray of the root canal after the placement of apical filling (plug) using MTA cement](image)

**Graph 1.** Comparative values of the time (sec) required for argon diffusion from coronal part of restoration to the apex (groups of teeth with sealer and gutta-percha without MTA plug and groups with sealer and gutta-percha and MTA plug)

**Table 1.** Average time needed for argon diffusion (sec) throughout the root canal filling

| Material | Sample | Variance | Mean value of Ar diffusion rate (sec) |
|----------|--------|----------|--------------------------------------|
| A1 – Gutta flow | 10 | 21.35 | 186.7 |
| A2 – Gutta flow + MTA | 10 | 27.02 | 269.4 |
| B1 – AH Plus | 10 | 21.85 | 179.9 |
| B2 – AH Plus + MTA | 10 | 41.23 | 258.5 |
| C1 – Acroseal | 10 | 31.24 | 178.5 |
| C2 – Acroseal + MTA | 10 | 33.54 | 255.2 |

F = 0.73, p < 0.01

F = 1.50, p < 0.01

F = 1.87, p < 0.01

F = 1.87, p < 0.01

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In the group of teeth that were obturated with no apical MTA plug, the lowest gas permeability was recorded in Gutta Flow samples (186.7 sec) then AH Plus (179.9 sec) and the highest permeability in the Acroseal paste samples (178.5 sec). The differences among them were statistically insignificant (p > 0.01). The MTA samples showed statistically significant lower argon leakage in comparison to the ones obturated only with sealer and gutta-percha cones without MTA plug (p < 0.05).

**DISCUSSION**

MTA has characteristics of bioactive material and it is known for its use as an apical plug with good physico-chemical properties exhibiting good adherence to dentin, compressive strength and push-out forces [4, 7, 8, 20, 21]. Moreover, its positive biological properties such as biostimulative, osteoconductive and antimicrobial effects have been confirmed either on animal model or in clinical conditions (pulp capping, pulpotomy, root perforations) [4, 6, 7, 8, 19, 20].

Several methods have been used for the evaluation of apical hermeticity such as bacterial penetration [21], electric currency [22], dye diffusion [2] and radioactive agents [23]. Gas permeability method has good value in assessing the quality of canal obturation. Due to the use of different gases in this method (Ar, O\textsubscript{2}, N\textsubscript{2}, CO\textsubscript{2}, noble gases, organic gases), comparison of the results with different gas nature or different experimental models may not be possible [18, 19]. Argon as the noble element was chosen for our study due to its inactivity to endodontic sealers [18, 19]. However, this method only allows assessing overall permeability without showing the path of its diffusion. In addition, combined argon diffusion with optical analysis (XRD and spectrophotometry) could possibly explain physical phenomenon of leakage events [18, 24].

MTA was chosen as most commonly used cement in several investigations [4–9, 15, 25, 26] and due to its biocompatibility, high alkalinity and low solubility [2, 27]. Our satisfying results obtained by MTA-plug could be explained by its low solubility due to water absorption and minimal expansion that was confirmed in several studies [8, 9, 12, 23, 27, 28].

The use of iR as sealer or filler and for reparation of canal-wall perforation presented satisfactory results [27] due to missing alumina particles and resemblance to white MTA. iR is considered appropriate for root canal filling material due to its viscosity [28] and could be used as sealer-filler with or without gutta-percha cones [29].

The advantage of combination of MTA apical plug and sealer over sealer only samples in the current study may be explained by its expansion in the first several hours during setting and water absorption when MTA exposed weight increase around 12% upon submerging for 24 h [30].

Low solubility and good adherence to the canal walls of Gutta Flow and AH Plus paste has been shown in several studies [17, 18, 31, 32]. Our results are consistent with the results of the study of Brackett et al. [33] and Bouillaguet et al. after 12 months follow-up [34]. Bouillaguet et al. explained that in single-cone obturation technique the volume of sealer is higher than the volume of gutta-percha, and this ratio promotes void formation and reduces the quality of seal due to the contraction phenomenon. Use of single-cone technique also allowed comparison of the performance of all materials under relatively standardized conditions. Leakage of AH-Plus may have resulted from inadequate bonding between sealer and gutta-percha cone allowing fluid to flow at the interface. This finding is in agreement with the results from Sagens et al. [29]. Bouillaguet et al. also considered that gun pressure for sealer injection created better adhesion of Guta Flow than AH Plus to the canal walls and consequently lower micro-leakage. Martin et al. based of bacterial canal penetration confirmed better sealability in AH Plus cases than when Guta Flow paste was used as obturation material [35].

Acroseal as calcium-hydroxide based sealer showed inadequate (poor) hermeticity and that finding is also in accordance with several studies [34, 36]. As per Mc Michen et al. AH Plus was more stable than Acroseal that was also confirmed in the current study [37].

The explanation for better apical hermeticity in canals obturated by MTA apical plug than in samples without MTA plug was demonstrated in the study of Guven et al. [38]. They explained this finding by the nanosphere structure of MTA particles that allows the material to penetrate into dentinal tubules and interact with moisture inside the tubules for final setting. This creates mechanical bond with dentin upon setting and renders the material with exceptional dimensional stability. In addition, many MTA brands provided either water or hydro-soluble gel to improve its washout resistance.

Nowadays, more improved MTA-based sealers (BioRoot™-RCS, MTA caps®, iR®, iR- BP Plus-MTA-Fillapex® [27], Biodentine™ [27], Bioaggregate® [38], ProRoot MTA® [39]) are more insoluble than original MTA formula in vivo and in vitro. For their safe clinical use further research is required.

**CONCLUSIONS**

Root canal obturation with different sealers, gutta-percha and MTA apical plug demonstrated significantly lower gas penetration compared to standard technique that included gutta-percha and sealer without MTA plug.

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Primena MTA kao apeksnog čepa u opturaciji kanala korena zuba – in vitro studija

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KRAJAK SADRŽAJ

UVOD

Ustrojstva uspeha endodontskih trećina zuba je u direktnoj korelaciji sa kvalitetom opturisanog endodontskog prostora. Savremena koncepcija endodontskog tretmana poseban akcenat stavlja na kvalitet preparacije i opturacije apektnog dela kanala. Cilj ovog rada je bio da se metodom merenja gasne propustljivosti (argona) proveri kvalitet opturacije kanala korena zuba nakon primene mineral-trioksid agregata (MTA) kao apektnog čepa.

Materijal i metod

U istraživanje je uključeno 66 jednokorenih-jednokanalnih zuba razvrstanih u dve grupe (po 30 zuba), dok je šest zuba korišćeno kao kontrola. Preparacija svih kanala je urađena ručnim instrumentima i primenom step-back tehnike uz obilnu irrigaciju 1% NaOCl. U prvoj grupi zuba je opturacija realizovana silerima uz pomoć gutaperka konusa Gutta Flow-Roeko (10), AH Plus-DeTrey (10) i Acroseal-Septodont (10). Drugu grupu su činili zubi kod kojih je u apektnom delu kanala aplikovan MTA, a potom su kanali ispunjeni primenom tri silera kao u prvoj grupi. Svi zubi iz obe grupe su podvrgnuti metodi merenja brzine gasne propustljivosti pomoću aparata Argon Leak Detector, Edwards LD 416.

Rezultati

Najbolju hermetičnost su pokazali uzorci kanala ispunjeni primenom Gutta Flow+MTA sa prosečnom brzinom gasne propustljivosti 264,4 sek., dok su konvencionalni siler i gutaperk konusi pokazali statistički značajni rastoreo na propustljivosti gasa nego oni u prvoj grupi sa silerom i gutaperkom bez MTA čepa.

Zaključak

Potvrđeno je da je perfuzacija zida kanala, kao lajneri [11] ili ubrzavajući faktor u opturaciji kanala korena zuba, kada se oni ispunjaju silerom i gutaperkom bez MTA čepa. Opturacija kanala sa postavljenim MTA apektnim čepom pokazala je značajno manju propustljivost gasa u poređenju sa uzorcima ispunjenim endodontskim silerom i gutaperka konusima.

Ključne reči: MTA; siler; apektna opturacija; gutaperk; kalcijum-silikat; propustljivost gasa

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Ustrojstva uspeha endodontskih trećina zuba je u direktnoj korelaciji sa kvalitetom opturisanog endodontskog prostora. Savremena koncepcija endodontskog tretmana poseban akcenat stavlja na kvalitet preparacije i opturacije apektnog dela kanala. Cilj ovog rada je bio da se metodom merenja gasne propustljivosti (argona) proveri kvalitet opturacije kanala korena zuba nakon primene mineral-trioksid agregata (MTA) kao apektnog čepa.

Materijal i metod

U istraživanju je korišćeno 66 ekstrahovanih jednokorenih zuba podeljenih u dve eksperimentalne grupe (po 30), dok je šest zuba korišćeno kao kontrola. Kao endodontski sileri su korišćeni: Gutta Flow-Colthane/Whaledent, Germany; AH Plus, De Trey, Germany; Acroseal, Septodont, France za opturaciju. Pri opturaciji su standardizovani gutaperka kočići konicitet 2% (Pearl Endopia, Pearl Dent Co., Vietnam). U grupi A su bili kanali ispunjeni silerom i gutaperka kočićima, a u grupi B oni ispunjeni prvo MTA apektnim čepom, a preostali deo silerom i gutaperka kočićima. Korenovi zubi su bili približno sličnog dijametra i volumena apektne trećine korena bez ikakvog defekta duž korena zuba. Krunični deo zuba je odsečen od korena na gledno-cementnoj granici korišćenjem visokoturažne bušilice i fisurnog dijamantskog svrdla omogućavajući direktn pristup kanalu. Posle inicijalne prohodnosti (Kerr turpije #10 i #15) urađen je preoperativni radiogram. Pulpmo tkivo je uklonjeno pulp-ektirparatorom. Radna dužina za sve zube je određena umetanjem proširivača u kanal i radiografisanjem sa endodontskim proširivačem na 1 mm kraće od anatomskog foramena. Apektna matrica je formirana na tom nivou serijskim proširivanjem #10 do #40, a zatim step back tehnikom do krunične trećine kanala uz obilnu irrigaciju. Za kanalsku instrumentaciju korišćeni su ručni NITI proširivači (Sybron, Germany) uz irrigaciju 1% NaOCl i lubrikant (Canal +, Septodont, France).
Eksperimentalne grupe

Posle apekanske preparacije veličine 40 kanali su opturisani primenom tri silera i gutaperka konusa bilo kao standardna kombinacija (grupe A1, B1 i C1) ili sa prethodno umetnutim MTA čepom kompakterima za vertikalnu kompakciju (Miallefer, Swiss) i grupama (A2, B2 i C2). Opturacija je sprovedena korišćenjem Lentulo spirale i gutaperka konusa kombinovanog sa endodontskim silerom Gutta Flow (Roeco, Germany), Acro seal (Septodont, France) i AH Plus (DeTray, Germany). Gutta Flow siler je aplikovan pšiljotom (Colveine/Whaledent dispensing gun, Swiss). Apeksi MTA čep je bio debljine 3 mm, pri čemu je retrovolearnim snimkom iz dva pravca proven kvalitet ispunja (Slika 1). Pristupni kaviteti su privremeno zatvarani ispunom Cavit (Premier, Dental Products, Germany).

Kontrolnu grupu je činilo šest zuba, kod kojih su kanali opturisani samo gutaperka konusima sa ciljem da pokuša da je argon (Ar) sposoban da prođe samo kroz masu kanalskog ispušta i apeks. Zubi eksperimentalnih i kontrolnih grupa su stajali sedam dana na 37°C u sredini apsolutne vlažnosti da omogući definativno očvršćivanje silera.

Markiranje difuzije gasa

Sistem za kvantifikaciju vizuelnih informacija sastojao se od kamere (VegaCam, Edwards LD 416, UK) i detektorskog uređaja sa odgovarajućim softverskim programom (Argon Leak Detector Edwards LD 416, UK). Kvalitet kanalne opturacije je kontrolisan sa odgovarajućim softverskim programom (Argon Leak Detector Edwards LD 416, UK) i detektorskog uređaja (Argon Leak Detector Edwards LD 416, UK). Zubi su je merena korišćenjem aparata za detektovanje propustljivosti gasa Ar (18). Njegova koncentracija mogla bi slobodno utjecati na druga komponenta reciklažnog procesa.

Uzorci sa MTA čepom pokazali su statistički znatno manju vrednost difuzije Ar u odnosu na grupe čiji su kanali napunjeni samo endodontskim silerom bez MTA čepa (p < 0.01).

DISKUSIJA

Kako se kalcijum-silikatni MTA materijal smatra bioaktivnim materijalom, on je u ovom istraživanju izabran kao apektinski čep jer ispoljava dobre fizičko-hemijske osobine: zadovoljavajuću adherentnost za dentin, pritiska čvrstoća i povoljna sila smicanja i obratno. Ovi autori smatraju da je za lošu adherenciju i veću propustljivost silera AH-Plus (179,9 sek.) i apektinski čep mogla bi se objasniti njegovom ekspanzijom prvih nekoliko sati nakon mešanja i posle primene paste Gutta Flow silera i paste AH Plus. Ova istraživanja potvrđuju i Bracket sa sar. (33), kao i Bourillaguet i sar. (34), ali tek posle 12 meseci. Bourillaguet i sar. (34) smatraju da je kod monokone tehnikhe opturacije zapremina silera mnogo veća od same mase gutaperke pa ovaj nepovoljan odnos utiče na stvaranje zahvata koje često se objašnjava njegovom ekspanzijom, što potvrđuje i drugi radovi (8, 9, 12, 23, 27, 28).

Primena iRoot (iR) cementa za punjenje kanala (kao filer i siler), kao i za reparaciju perforacija korenskog zida, pokazala je zadovoljavajuće rezultate [27] jer on je možda lokalne ispitivanja mešanja i koristeći njegovu biokompatibilnost, visoku alkalnost i slabe rastvorljivosti [27]. Dobri rezultati dobijeni primenom MTA kao apektinskog čepa u našoj studiji mogli bi se objasniti njegovom malom rastvorljivosti usled upijanja vode i neznatnom ekspanzijom, što potvrđuje i drugi radovi [8, 9, 12, 23, 27, 28].

REZULTATI

Dobijeni rezultati su prikazani u Tabeli 1 i na Grafikonu 1. Najbolje rezultate pokazala je kombinacija apektinskog čepa i Gutta Flow silera sa prosečnom brzinom prodora gasa od 269,4 sek., dok je najveća gasna propustljivost uočena posle primene paste Gutta Flow (186,7 sek.), a najveća propustljivost je zabeležena posle same mase gutaperke pa ovaj nepovoljan odnos utiče na stvaranje zahvata koje često se objašnjava njegovom ekspanzijom, što potvrđuje i drugi radovi (8, 9, 12, 23, 27, 28).
koja dozvoljava fluidnu filtraciju na njihovom međuspoju. Oni smatraju da pritisak postolja takođe doprinosi boljoj adherenciji Gutta Flow od paste AH plus pa time i manjoj apenskoj mikropropustljivosti.

Martin RL [35] ispituje bakterijsku penetraciju u kanalima i nalazi bolje zaptivanje silera AH Plus nego kod uzoraka ispunjenih pastom Gutta Flow. On to objašnjava boljim adhezivnim osobinama paste AH Plus.

Acroseal Ca(OH)_2 siler je pokazao u našem eksperimentu neadekvatno odnosno najslabije zaptivanje, što je u saglasnosti sa sličnim studijama [34, 36]. Objašnjenje daju Mc Michen i sar. [37] u vezi sa stepenom rastvorljivosti koji pokazuje da AH Plus ima bolje osobine vezane za nerastvorljivosti od pasti na bazi Ca(OH)_2. Slično tome, i u našem ispitivanju je Acroseal pokazao slabiju apensku hermetičnost u odnosu na AH Plus preparat. Objašnjenje za bolju apensku hermetičnost primećenu kod kanala ispunjenih MTA čepom u odnosu na one opturisane samo silerom i gutaperkom se može naći u studiji Guvena i sar. [38]. Oni smatraju da nanostrukture kod mineral-trioksidnog agregata dozvoljavaju da materijal penetrira u dentinske tubule i interreaguje sa vlagom unutar njih kako bi se ostvarilo završno očvršćavanje. Time se ostvaruje mehanička veza sa dentinom, a materijal poprima izvanrednu dimenzionalnu stabilnost. U tom smislu fabrikovane su razne varijante MTA preparata, koje su se pripremene bilo sa vodom, bilo sa hidrosolubilnim gelom kako bi se poboljšala otpornost na ispiranje.

Danas usavršeni endodontski sileri na bazi MTA presekcije (BioRoot™-RCS, MTA caps®, iR®, iR-BP Plus®, MTA-Fillapex®, Biodentine™, Bioaggregate®, ProRoot MTA®) pokazuju veću otpornost na rastvaranje nego originalni MTA preparat; što pokazuju kako in vivo, tako i in vitro eksperimenti za retrogradno punjenje kanala korena zuba [27, 38, 39]. Za njihovu sigurniju primenu u praksi još uvek nedostaju opsežni klinički rezultati.

ZAKLJUČAK

Dobijeni rezultati su pokazali da je u svim uzorcima u kojima je MTA bio prethodno postavljen kao apesno čep uočena značajna manja difuzija gasa u odnosu na uzorke opturisane standardnom tehnikom opturacije gutaperka kočićima bez apeskog čepa.