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Original Article

Comparative SEM Study of the Marginal Adaptation of MTA and Biodentine after Apical Resection (In Vitro Study)

Elka Radeva[1], Tsonko Uzunov[1]

[1] *Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University of Sofia, Sofia, Bulgaria*

Corresponding author: Elka Radeva, Department of Conservative Dentistry, Faculty of Dental Medicine, Medical University of Sofia, Sofia, Bulgaria; Email: eradeva90@gmail.com; Tel.: +359 888 319 813

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Abstract

Introduction: Successful periapical surgery requires appropriate root resection, preparation, and adequate sealing.

Aim: The aim of the present study was to assess the marginal adaptation of MTA and Biodentine after apical resection with an Er:YAG laser and a diamond turbine bur using a scanning electron microscope (SEM).

Materials and methods: The crown part of forty-eight extracted single-root human teeth was removed, and the root canal length of 15 mm was standardized. The root canals were prepared using rotary Ni-Ti Revo-S files up to an apical stop – AS40 and filled with MTA Fillapex and gutta-percha points (cold lateral condensation). The teeth are divided into 2 main groups: group 1 (n=24) after apical resection with a turbine bur, ultrasonic preparation of the retrograde cavity at 3 mm depth and retrograde obturation with Biodentine and MTA; group 2 (n=24) after apical resection with an Er:YAG laser, ultrasonic preparation of the retrograde cavity at a depth of 3 mm and retrograde obturation with MTA and Biodentine. A SEM was used for assessment of the marginal adaptation of the material to the root dentin. The data was entered into and analyzed with IBM SPSS Statistics 22.0.

Results: In the group with apical resection with a turbine bur, a statistically significant difference in the gap size between the material and dentin was found in both materials we studied (MTA and Biodentine). The higher mean value was in MTA (1.72 μm), in Biodentine it was 1.08 μm. In the group with apical resection with Er:YAG laser, no statistically significant difference in the gap size between the material and dentin was found in both studied materials: MTA – 1.88 μm, Biodentine – 1.32 μm.

Conclusions: In the present study, MTA and Biodentine showed good sealing capabilities after apical resection. Biodentine displayed better marginal adaptation when resecting the root tip using a turbine bur. The Er:YAG laser-assisted apical resection shows sealing of the open dentinal tubules around the resected root surface.

Keywords

apicoectomy, marginal adaptation, periapical surgery, retrograde cavity obturation

INTRODUCTION

Successful periapical surgery requires appropriate root resection, preparation, and adequate sealing.[1-5] Apical resection can be performed with a diamond/stainless steel burs or a laser. Low-energy lasers are used in endodontics to disinfect the root canal system. The high-energy lasers of the Erbium family are applied in apical resection. Er:YAG lasers (400 mJ, 10 Hz), CO_2 lasers (5 W, CW/SP) and Nd:YAG lasers are used for apicoectomy.

The root apex resection should be at least 3 mm. The apical cavity should follow the course of the root canal and be able to be filled effectively. Ultrasound preparation results in better removal of the contaminant layer compared to preparation with burs.[2,6]

The requirements for the ideal material used in retrograde cavity obturation after apical resection involve: biocompatibility, stability, X-ray contrast, ability to harden in a liquid medium, antibacterial properties, easy handling, hardness, presence of osteoinductive or osteoconductive properties, good adhesion to the canal walls and good apical sealing.[6,7] Taking into account the forthcoming endodontic surgical procedure, obturation of the root canal system needs to be performed with a hard, non-resorbable material. In the past, zinc phosphate cement was used as such while modern endodontics now uses thermoplasticized gutta-percha and epoxy resin sealer.

The modern materials for retrograde obturation are the mineral trioxide aggregate (MTA), Biodentine, intermediate restorative material (IRM), and the ethoxy-benzoic acid (EBA).[8-12]

Although the physical properties and bioavailability of the materials used have been studied in a number of in-vitro and in-vivo studies, the results obtained vary.[13,14] In recent years, various materials such as Biodentine, Endosequence Root repair Material, etc., have been introduced in order to improve the handling qualities and curing time of MTA proven effective.[13] This necessitates making a critical evaluation of their adaptive (sealing) properties regarding radicular dentin by measuring the microgap on a scanning electron microscopy (SEM).

AIM

In the present study, we used SEM to assess the marginal adaption of MTA and Biodentine following apical excision using an Er:YAG laser and a diamond turbine bur.

MATERIALS AND METHODS

We used in the study 48 extracted human teeth: single-root and single-canal teeth with no calcifications in the root canals. The root surfaces of the teeth were cleaned of plaque and stains using a periodontal curette and then the teeth were stored in saline at a room temperature (20°–25°C). The teeth crowns were removed by cutting with a diamond bur of a cylindrical-conical profile. The length of the root canal was made standard – 15 mm.

The root canals were cleaned with 0.5% NaOCl solution and formed using Revo-S rotary Ni-Ti files. An apical stop to AS40 was prepared. The final irrigation was performed with 17% EDTA. Distilled water was used between both solutions. The root canals are filled with MTA Fillapex and gutta-percha points (cold lateral condensation) followed by dividing the teeth into the following groups:

Group 1. After apical resection using a turbine, ultrasound preparation of the retrograde cavity and retrograde obturation: subgroup 1 (n=12) – retrograde obturation with MTA; subgroup 2 (n=12) – retrograde obturation with Biodentine.

Group 2. After apical resection with a laser, ultrasound preparation of the retrograde cavity and retrograde obturation: subgroup 3 (n=12) – retrograde obturation with MTA; subgroup 4 (n=12) – retrograde obturation with Biodentine.

Control radiographs were taken to follow up on the quality of the root canal filling.

In group 1, after filling the root canals, we performed apical resection 3 mm from the root apex using a diamond turbine bur (Komet ISO 806 314 199 514 014) and water-air cooling.

In group 2, the apical resection was performed at 3 mm from the root apex with a laser keeping the following parameters: 300 mJ, 30 Hz. Fotona laser was used for this purpose **(Fig. 1)**.

After apical resection performed with a turbine (n=24) and Er:YAG laser (n=24), the root canals were prepared retrogradely with ultrasonic diamond-coated tip and intensity 7 (Satelec AS 3D, France) **(Fig. 2)** at a depth of 3 mm, with subsequent drying and filling of the retrograde cavities with: Biodentine (n=24: apical resection with a turbine n=12 and apical resection with Er:YAG laser n=12) and MTA (n=24: apical resection with a turbine n=12 and apical resection with Er:YAG laser n=12).

The materials were prepared in compliance with the manufacturer's instructions and applied in retrograde cavities by means of a micro condenser/burnisher. Excess material was removed and the teeth were kept in humid environment (gauze soaked in saline) for 24 hours.

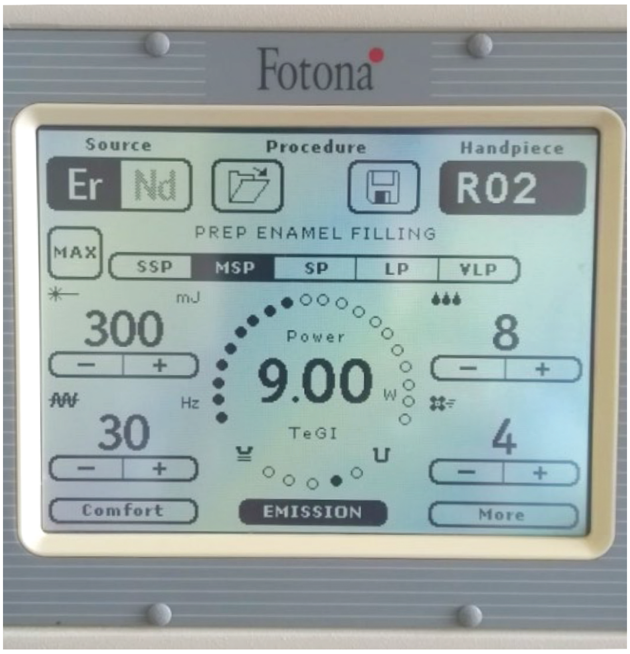

Figure 1. Characteristics of the values used for apical resection with Fotona laser.

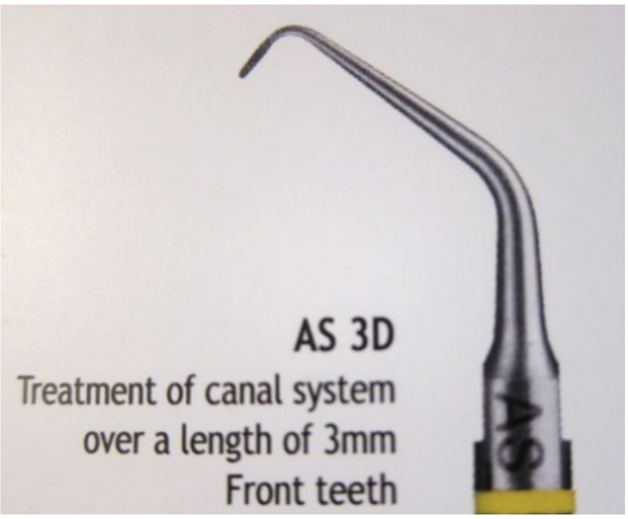

Figure 2. AS3D ultrasonic tip.

A scanning electron microscope (SEM) was used to assess the material adaptation to the root dentin.

In order to visualize SEM, the extracted teeth were treated with 37% phosphoric acid, followed by thorough water washing and drying. They were covered with vacuum powdered gold and prepared for monitoring by CEM. The magnification ×1000 was found to be most suitable for measuring the microgap width in the dentin-material boundary area. Four scanograms were made for each sample in different areas of the gap. Knowing that the length of a marking segment corresponds to 10 μm, the data was recalculated in μm with an accuracy of 0.01 μm.

The data was entered into and analyzed with IBM SPSS Statistics 22.0; it was accepted that the null hypothesis can be rejected at $p<0.05$.

The following methods were used:

1. Variation analysis – to assess the central trend characteristics and data dispersion.
2. Graphic analysis – to visualize the results obtained.
3. Non-parametric Shapiro-Wilk test – to check data distribution normality.
4. Non-parametric Kruskal-Wallis test – to test hypotheses for difference between several unrelated samples.
5. Non-parametric Mann-Whitney test – to test hypotheses for difference between two unrelated samples.

RESULTS

The SEM study revealed the availability of a gap on the border of material/dentin in both materials used but to a different degree **(Figs 3-6)**.

I. After apical resection with a turbine bur, ultrasonic preparation of the retrograde cavity and retrograde obturation

II. After apical resection with a laser, ultrasonic preparation of the retrograde cavity and retrograde obturation

The results shown in **Table 1** and **Fig. 7** indicate that in the groups with retrograde filling:

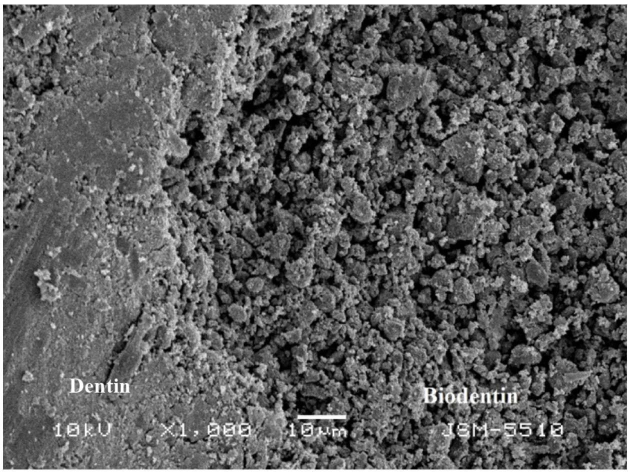

Figure 3. Marginal adaptation of Biodentine (SEM ×1000 magnification).

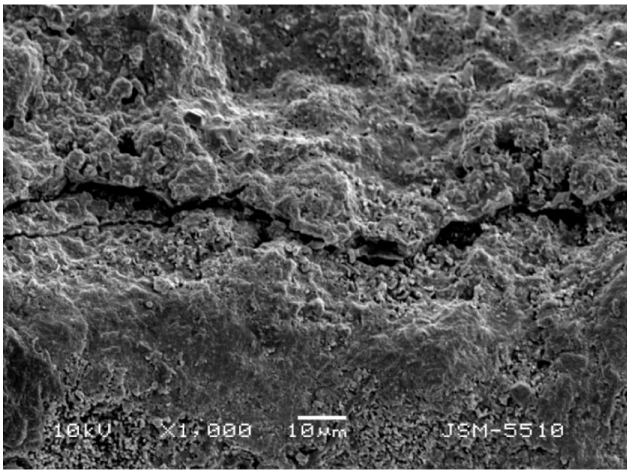

Figure 4. Marginal adaptation of MTA (SEM ×1000 magnification).

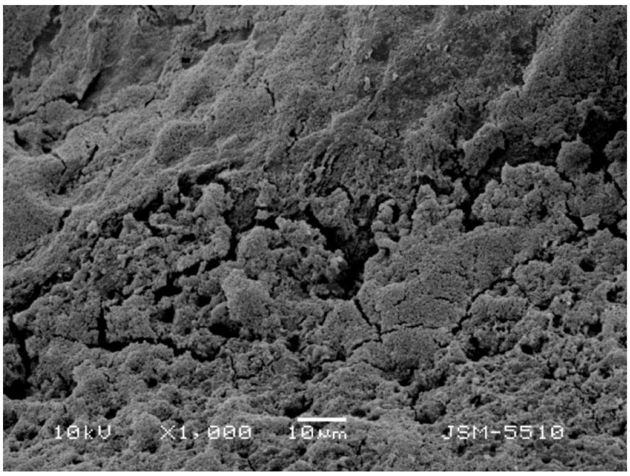

Figure 5. Marginal adaptation of Biodentine (SEM ×1000 magnification).

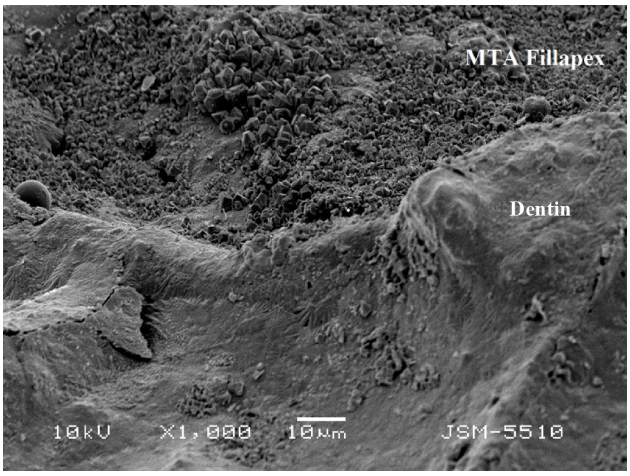

Figure 6. Marginal adaptation of MTA (SEM ×1000 magnification).

- There is no statistically significant difference between the groups with apical resection with a turbine and an Er:YAG laser in terms of the gap size between the material and dentin in both studied materials;
- In the group with apical resection with a turbine, a statistically significant difference in the gap size between the material and dentin was found in both studied materials (MTA and Biodentine). The higher mean value was in MTA – 1.72 µm; for Biodentine it was 1.08 µm;
- In the group with apical resection with an Er:YAG laser, no statistically significant difference in the gap size between the material and dentin was found in both studied materials: MTA – 1.88 µm, Biodentine – 1.32 µm.

The results shown in **Table 2** and **Fig. 8** suggest that in the group with apical resection with a turbine bur, a statistically significant difference in the gap size between the material and dentin was found in both studied materials (MTA and Biodentine). The higher mean value was in MTA – 1.72 µm, while in Biodentine it was 1.08 µm.

In the group with apical resection with an Er:YAG laser, no statistically significant difference in the gap size between the material and dentin was established in both studied materials: in MTA – 1.88 µm and in Biodentine – 1.32 µm **(Table 3**, **Fig. 9)**.

DISCUSSION

The Er:YAG laser removes the contaminant layer by ablation leaving the dentinal tubules open. This laser emits photon flux directed into the middle infrared part of the electromagnetic spectrum. The accompanying laser energy

Table 1. Comparative analysis of the size of gap between the material and dentin in the groups with retrograde obturation

Materials	Apical resection with a high-speed handpiece and a diamond bur			Apical resection with Er:YAG laser			*P*
	n	$\overline{X}$	SD	n	$\overline{X}$	SD	
MTA	12	1.72	1.10	10	1.88	1.04	0.140
Biodentine	12	10.8	0.37	10	1.32	0.45	0.192
p		0.040			0.280		

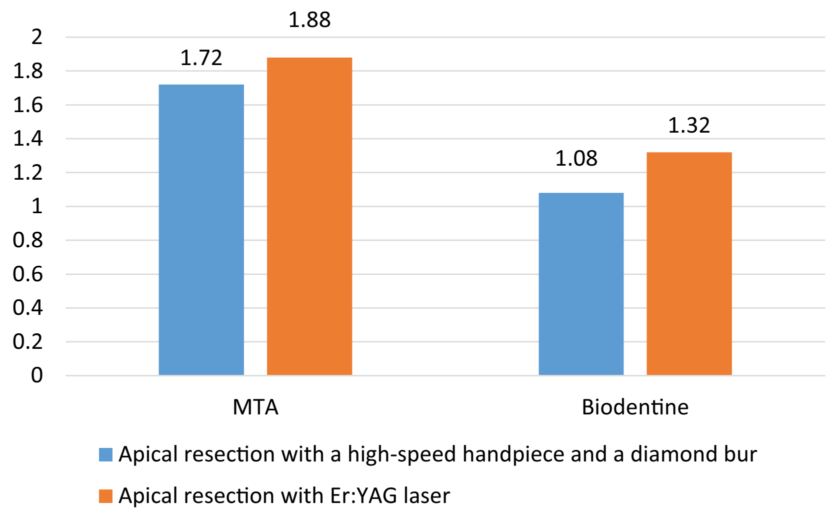

Figure 7. Comparative analysis of the size of gap between the material and dentin in the groups with retrograde obturation after apical resection with Er:YAG laser and a turbine bur.

Table 2. Comparative analysis of the size of gap between the material and dentin in apical resection with a turbine bur

Materials						
MTA			Biodentine			*p*
n	$\overline{X}$	SD	n	$\overline{X}$	SD	
12	1.72	1.10	12	1.08	0.37	0.040

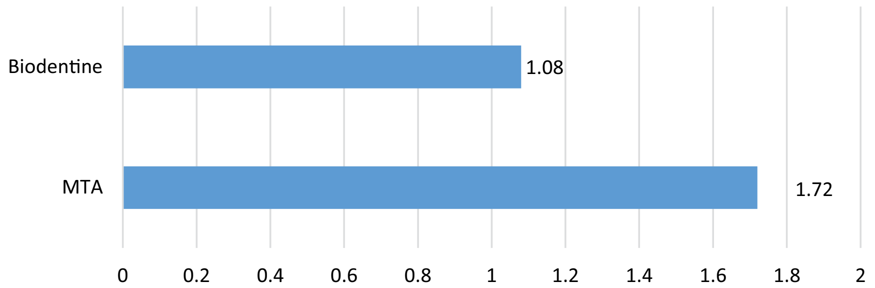

Figure 8. Comparative analysis of the size of gap between the material and dentin in apical resection with a turbine bur.

Table 3. Comparative analysis of the size of gap between the material and dentin in apical resection with Er:YAG laser

Materials						
MTA			Biodentine			*p*
n	$\overline{X}$	SD	n	$\overline{X}$	SD	
10	1.88	1.04	10	1.32	0.45	0.280

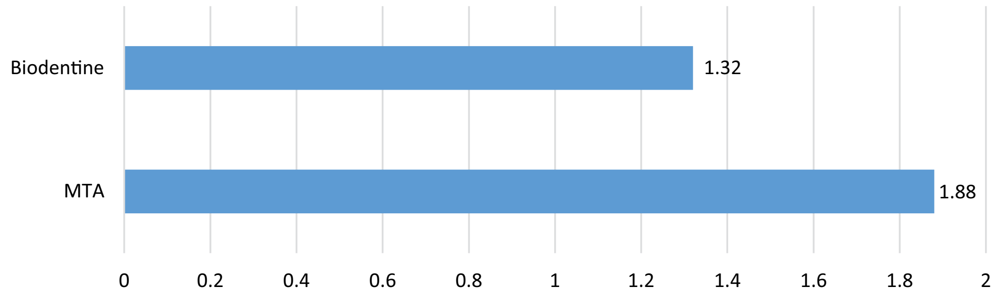

Figure 9. Comparative analysis of the size of gap between the material and dentin in apical resection with Er:YAG laser.

is absorbed by chromophores, transforms into heat energy, leading to expansive evaporation (vaporization). Compared to the diode or CO_2 lasers, overheating the surrounding bone in the removal of granulation tissue after reflection of the flap is the least for the Er:YAG lasers.[15] The laser energy leads to a significant reduction in bacterial load in use, supporting its application in modern practice.[16] Such an action brings about dislocation of tissue structures and ablation, accompanied by a specific "popping" sound.

This laser is appropriate for making incisions in order to reflect the flap. Unlike the CO_2 lasers, where no bleeding is observed, the Er:YAG lasers indicate some bleeding. Using a laser produces a smoother and more homogeneous surface as a result of the occlusion and glazing of the dentinal tubules and the leakage reduction. Thermal ablation with Er:YAG laser is likely to cause dissolution of the mineral components and fusion of amorphous particles without crystallization, thus achieving a clean and smooth surface. The advantages of laser apical resection are as follows: better visibility, contactlessness, lesion removal in a short time by vaporization, hemostasis, lack of vibration or discomfort and postoperative pain reduction.

Grgurevic et al.[17] tested an Er:YAG laser with different apicectomy parameters and found that 380 mJ and 20 Hz had an ablation rate four times higher than 200 mJ and 8 Hz. They found that high-energy lasers were safe when used under water cooling. In vitro Er:YAG laser was studied by Paghdiwala et al.[18] in a previous study and it was found out the obtaining of root surface – smooth, clean, devoid of microflora and charred.

Among the various types of lasers used for apical surgery, the authors identify the Nd:YAG laser to be effective as well.[19,20] However, the Nd:YAG laser creates some inconvenience when used in contact with dentin and cement. This includes craters formation and roughness of melted surface. In vitro studies have shown that such effects can inhibit cell adhesion to irradiated surfaces with subsequent delay of the healing process in vivo. Craters and carbonization are less common in non-contact irradiation. The Nd:YAG laser can reduce dentin leakage by means of its contactless use. Dederich et al. have found that melting and recrystallization of the contaminant layer give a non-porous appearance to the root surface.[20]

Er:YAG lasers allow the reflection of the flap, the removal of granulation tissue and the subsequent resection of the root apex to be performed. Additionally, it gives the possibility of making the final ablation of the adapted soft tissues, reducing the bacterial load and postoperative complications. Thus, the Er:YAG laser provides a faster healing process, reduces operator fatigue and is better accepted by the patient. Stubinger and Pourzarandian have proved histologically that bone healing is faster when an Er:YAG laser is used compared to surgical burr, piezosurgery or a CO_2 laser.[21,22]

Root resection should be at least 3 mm. Thus, 98% of the apical ramifications and 93% of the lateral tubules accounting for endodontic failure are eliminated or reduced. The obturating material should seal the apical tissues, preventing the bacteria release and the diffusion of bacterial products from the root system into the periapex. The criterion for good sealing is the marginal adaptation of the material, which can be best assessed by scanning electron microscopy at different magnifications. Poor marginal adaptation is considered to be able to affect sealing capability and the level of clinical success rate.[23]

Hegde et al.[24] have compared the results obtained after apical resection with a laser and with carbide burs. After SEM was made, the authors reported areas with microgaps potential for apical microleakage after the already performed apical resection. Laser cutting leads to the sealing of dentinal tubules as well as the presence of a smaller amount of contaminant layer compared to bur resection. The authors observed roughness and unevenness at high magnification. The traction of the gutta-percha during laser resection is taken into account as well. Our study has yielded similar results.

There is evidence in the literature that the use of MTA leads to regeneration processes rather than to repair in periapical tissues.[25] The in vivo studies of some authors indicate that retrograde obturation with MTA achieves osteoinductive effects on periapical tissues, which in turn leads to the formation of new bone, root cementum and periodontal ligament.[26] Fridland et al.[27] reported the release of hydroxide ions and presence of high pH in the medium, indicating the bactericidal effect of MTA on microorganisms in the periapical environment.

Over the years the marginal adaptation of various materials used for retrograde sealing has been studied. The microgap between the dentinal walls and dental amalgam studied by Moodnik et al.[28] is in the range of 6-150 µm. Torabinejad et al.[29] have proved marginal adaptation in MTA to be the best compared to dental amalgam, IRM and EVA cement. Soundappan et al.[30] examined the marginal adaptation after cavity preparation of 1 mm and 2 mm in depth. The authors suppose that a 3-mm-deep cavity may compromise the relation between the retrograde obturation material and the gutta-percha. However, MTA excels IRM and Biodentine in a 2-mm cavity and such MTA superiority coincides with the results reported by Torabinejad. In cases of a 2-mm retrograde cavity, they have shown that MTA (0.79±0.20 µm) is superior to IRM and Biodentine (1.44±0.36 µm). In this study, the depth of the cavity was 3 mm, which brings about effective root sealing and leakage prevention.

CONCLUSIONS

In the present study, MTA and Biodentine have shown good sealing capabilities after apical resection. Biodentine showed better marginal adaptation when resecting the root apex using a turbine bur. Er:YAG laser-assisted apicectomy showed sealing of the open dentinal tubules around the resected root surface.

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Conflict of Interests

The authors have declared that there is no conflict of interests regarding the publication of this article.

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Сравнительное SEM – исследование маргинальной адаптации MTA и биодентина после апикальной резекции (исследование *in vitro*)

Елка Радева[1], Цонко Узунов[1]

[1] *Кафедра консервативной дентальной медицины, Факультет дентальной медицины, Медицинский университет – София, София, Болгария*

Адрес для корреспонденции: Елка Радева, Кафедра консервативной дентальной медицины, Факультет дентальной медицины, Медицинский университет – София, София, Болгария; E-mail: eradeva90@gmail.com; тел.: +359 888 319 813

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Резюме

Введение: Успешная периапикальная хирургия требует соответствующей резекции корня, подготовки и адекватной герметизации.

Цель: Целью настоящего исследования было оценить маргинальную адаптацию MTA и Biodentine после апикальной резекции лазером Er:YAG и алмазным турбинным бором с использованием сканирующего электронного микроскопа (SEM).

Материалы и методы: Удалена коронковая часть 48 удалённых однокорневых зубов человека, стандартизирована длина корневого канала 15 мм. Корневые каналы препарированы ротационными Ni-Ti Revo-S иглами до апикального упора AS40 и заполнены MTA Fillapex и гуттаперчевыми штифтами (холодная латеральная конденсация). Зубы были разделены на 2 основные группы: 1-я группа (n=24) после апикальной резекции турбинным бором, ультразвуковой препарации ретроградной полости на глубину 3 mm и ретроградной обтурации Biodentine и MTA; 2-я группа (n=24) после апикальной резекции Er:YAG-лазером, ультразвукового препарирования ретроградной полости на глубине 3 mm и ретроградной обтурации MTA и Biodentine. SEM использовали для оценки маргинальной адаптации материала к корневому дентину. Данные были введены и проанализированы с помощью IBM SPSS Statistics 22.0.

Результаты: В группе с апикальной резекцией турбинным бором выявлена статистически значимая разница в величине зазора между материалом и дентином в обоих изученных нами материалах (MTA и Biodentine). Более высокое среднее значение было у MTA (1.72 μm), у Biodentin оно составило 1.08 μm. В группе с апикальной резекцией Er:YAG-лазером не было обнаружено статистически значимой разницы в размерах зазора между материалом и дентином в обоих исследованных материалах: MTA – 1.88 μm, Biodentin – 1.32 μm.

Заключение: В настоящем исследовании MTA и Biodentine продемонстрировали хорошие герметизирующие свойства после апикальной резекции. Biodentine продемонстрировал лучшую маргинальную адаптацию при резекции верхушки корня турбинным бором. Верхушечная резекция с помощью Er:YAG-лазера показывает герметизацию открытых дентинных канальцев вокруг резецированной поверхности корня.

Ключевые слова

апикоэктомия, маргинальная адаптация, периапикальная хирургия, ретроградная обтурация полости