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Original Article

Evaluation of Dentin Penetration of Three Different Endodontic Sealers in the Presence and Absence of the Smear Layer

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Abstract

Introduction: A sealer's ability to effectively and stably penetrate the dentinal tubules is an essential factor for selecting an effective root canal obturation material. Evaluation of the sealers' penetration into the dentinal tubules provides valuable data in the endodontic treatment outcome.

Aim: To compare the dentin penetration of AH Plus, Endoseal MTA, and Syntex endodontic sealers in the presence and absence of the smear layer.

Materials and methods: Thirty single-rooted teeth were selected in the present in vitro study and randomly assigned to three experimental groups (n=10). Half of the samples were prepared by removing the smear layer in each group, and the remaining samples were prepared without removing the smear layer. Root canal preparation was carried out with the Perfect Rotary system up to file T3. The root canals were obturated with gutta-percha and AH Plus, Endoseal MTA, or Syntex endodontic sealers. The samples were incubated at 100% relative humidity at 37°C for one week. Each root was sectioned at 2-, 5-, and 8-mm distances from the apex, and sealer penetration depth at each section was determined under a scanning electron microscope (SEM). ANOVA was used to compare penetration depths.

Results: There were significant differences in sealer penetration between the samples with and without smear layer removal in each group. The maximum and minimum sealer penetration was at the coronal and apical sections, respectively. The maximum sealer penetration depths in descending order were observed with AH Plus, Syntex, and Endoseal MTA sealers ($p<0.05$).

Conclusions: Elimination of smear layer increased three sealers' dentin penetration depth, with the deepest penetration for the AH Plus sealer in the coronal section without the smear layer.

Keywords

depth, penetration, sealer, smear layer

INTRODUCTION

The chief aim of endodontic procedures is to eliminate microorganisms from the root canal space mechanically and chemically and prevent re-infection. Microorganisms persist in the accessory canals and dental tubules because these areas protect microorganisms against antimicrobial agents, root canal irrigation solutions, and medicaments.[1-3]

Root canal obturation quality has an essential role in preventing microorganisms' penetration and their products into the periradicular tissues and in treatment success.[4,5] Achieving a hermetic seal has been reported as one of the aims of root canal treatment.[6] Obturation has been defined as the three-dimensional filling of the root canal with materials that have favorable biological and physical characteristics.[7]

Different techniques are used to obturate root canals. The most commonly used root canal obturation technique in the clinic and educational centers is the lateral compaction techniques. Another technique introduced recently is the single cone technique.[6,8]

Various materials have been introduced as the core material for root canal obturation including gutta-percha points, Activ GP, and Resilon although Activ GP system consists of points and sealer. The most commonly used material for root canal obturation is gutta-percha[9], which is the gold standard for root canal obturation materials; however, it cannot provide a three-dimensional seal despite favorable characteristics. Sealers are used with gutta-percha to overcome this problem[1]. Sealers generally seal the space between the core material and the root canal wall; they can also penetrate the accessory canals, resorptive lesions, and all the spaces that are out of reach of the core material.[10] Removal of the smear layer increases the contact area between the sealer and the root canal dentin and increases the penetration of sealers into the dentinal tubules. A sealer's ability to effectively and stably penetrate the dentinal tubules is an essential factor for selecting an effective root canal obturation material.[11] The sealer's penetration into the dentinal tubules is affected by various factors, including smear layer removal, dentin penetrability, sealers flowrate, film thickness, viscosity, root canal obturation technique, setting time, sealer's integrity, capillary action, surface tension and solubility.[1,2,12,13] Sealers' dentin penetration is a critical factor in the endodontic treatment outcome.[14]

AH Plus (Dentsply Sirona, New York) is the most renowned hydrophobic epoxy resin sealer and is used as the gold standard.[15] This sealer consists of two pastes; one paste contains epoxy resins, calcium tungstate, zirconium oxide, silica, and iron oxide pigment; the other one contains amines, calcium tungstate, zirconium oxide, silica, and silicone oil.[16]

Syntex (Cerkamed, Stalowa Wola, Poland) is an epoxy resin-based sealer. It was used in the present study because it is a new sealer from the epoxy resin family.[17]

Endoseal MTA (Maruchi, Korea) is a bioceramic sealer with a pozzolan cement base. It has superb physical and biological characteristics. This product has a premixed and preloaded syringe that facilitates its placement in the root canal. It consists of calcium silicates, calcium aluminates, calcium aluminoferrite, calcium sulfates, radiopacifiers, and thickening agents.[18]

Different techniques are available to remove the smear layer including chemical, ultrasonic, and laser techniques. Although none of the techniques are useful on the entire root canal length, the technique of choice for removing the smear layer is the alternate use of EDTA and NaOCl solutions.[19]

Also, different techniques are used to determine the endodontic sealers' penetration depth in dentin, including scanning electron microscopy, stereomicroscopy, and confocal laser scanning microscopy.[3]

AIM

This study was undertaken to evaluate the dentin penetration of three different endodontic sealers with and without removing the smear layer under a scanning electron microscope (SEM).

MATERIALS AND METHODS

This study was approved by the Institutional Ethics Committee; there is no conflict with ethical considerations (IR.QUMS.REC.1397.415).

In this experimental study, 30 human single-canal maxillary central incisors and mandibular premolars were selected based on inclusion criteria, which consisted of one root canal with a round cross-section, no root curvature, resorption, calcification, cracks, caries, and previous root canal treatment. After removing the residual tissues from the tooth surfaces with a curette, the teeth underwent a radiographic examination before the procedural steps in the buccolingual and mesiodistal directions to confirm one root canal, absence of internal or external resorption signs, calcification, and cracks. The teeth were stored in 5.25% NaOCl solution (Taj, Iran) to control infection and minimize the residual periodontal tissues for 4 hours, and then stored in an 0.5% chloramine solution (Iran Dicus, Iran) for one week before the initiation of the study. The teeth were then transferred into physiologic serum (Shiraz Serum, Iran) one week before the procedural steps to eliminate any interferences.

The tooth crowns were removed at CEJ using a diamond disk in a high-speed handpiece to achieve a standard length of 12 mm[20] for all the samples. A #15 K-file (Mani, Japan) was placed in each root canal, and after the file tip was visible at the apical foramen, the file length was measured. The working length (WL) was determined 0.5 mm shorter than this length. The root canals were prepared with a rotary system (Perfect, China) up to file T3 (equivalent to ProTaper F3 file). The rotary files were replaced with new ones after using them in five root canals. During the root canal preparation, 1 mL of 1% NaOCl (Taj, Iran) was used to irrigate the root canals after each file.

In the groups in which the smear layer was removed, 2 mL of 17% EDTA (META Biomed, South Korea) was used for 3 minutes, followed by 3 mL of 5.25% NaOCl for 1 minute without microbrush. The root canals were then flushed with distilled water[1,21] and dried with #30 paper points (Pumadent, China). Then teeth were randomly assigned to six groups (n=5) as follows:

Group 1: The smear layer was removed, and the root canals were obturated with AH Plus sealer (Dentsply Sirona, New York) and gutta-percha using the lateral compaction technique.

Group 2: The smear layer was not removed, and the root canals were obturated with AH Plus sealer (Dentsply Sirona, New York) and gutta-percha using the lateral compaction technique.

Group 3: The smear layer was removed, and the root canals were obturated with Syntex sealer (Cerkamed, Poland) and gutta-percha using the lateral compaction technique.

Group 4: The smear layer was not removed, and the root canals were obturated with Syntex Sealer (Cerkamed, Poland) and gutta-percha using the lateral compaction technique.

Group 5: The smear layer was removed, and the root canals were obturated with Endoseal MTA sealer (Maruchi, Korea) and gutta-percha using the F3 single-cone technique.

Group 6: The smear layer was not removed, and the root canals were obturated with Endoseal MTA sealer (Maruchi, Korea) and gutta-percha using the F3 single-cone technique.

PSP digital radiography was used to verify the root canal obturation quality (Durr Vista, Germany). In cases where there was a problem with the obturation quality, the problem was resolved if possible; otherwise, the tooth was excluded from the study and replaced by another tooth. Subsequently, gutta-percha was removed from the root canal up to 2 mm below the CEJ with a hot plugger, and the gutta-percha surface was packed. The root canal's 2-mm coronal area was filled with glass-ionomer (GC Gold Label, Japan) with a 2-mm thickness and light-cured for 40 seconds. The samples were incubated at 37°C and 100% relative humidity for one week to ensure sealers' setting (Dorsa, Iran).[22] Then the samples (i.e., the roots) were mounted in a polyester material and prepared for sectioning after 24 hours **(Fig. 1)**. The sections were made horizontally at 2-, 5-, and 8-mm distances from the apex with a 0.2-mm disk (Mecatome T201 A; Presi, Tavernoles, France) at 500 rpm under water cooling.[23] Each section was coded for microscopic evaluation. The samples were placed in an ultrasonic device (Eruonda, Italy) for three minutes to remove the debris and be prepared for microscopic evaluations. The samples were immersed in 17% EDTA (Biomed, South Korea) for 2 minutes, followed by immersion in 5.25% NaOCl for 3 minutes and rinsing with distilled water (15). Finally, the samples were dehydrated and mounted in an aluminum stub and gold-sputtered **(Fig. 2)**. The samples were evaluated under a scanning electron microscope (Vega II x mu, Tescan, Czech Republic) for the penetration of sealers into the dentinal tubules directly by quantitative measurement at ×50–2500 magnification. The sealers' penetration depths were determined at four points in each cross-section (in each area of the surfaces mentioned, the sealers' dentin penetration was evaluated at three levels; therefore, in each tooth section, the penetration was evaluated at 12 points) **(Fig. 3)**. Therefore in each group 15 sections and 180 scenograms were evaluated. Finally, the deepest sealer penetration of each surface was determined at each coronal, middle, and apical section in μm. The operator carrying out SEM evaluations and the statistician were blinded to the study group allocations (a double-blind scheme).

Figure 1. Samples mounting in a polyester material.

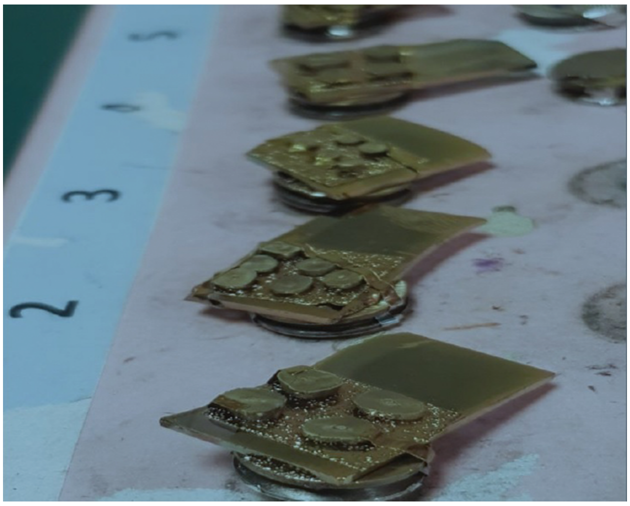

Figure 2. Samples preparation for SEM evaluation.

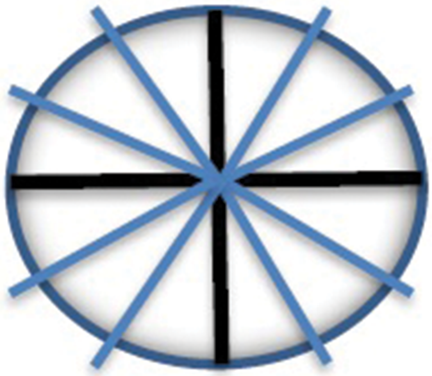

Figure 3. Schematic dividing of root cross-section in 12 areas.

Statistical analysis

Statistical analyses were performed using SPSS-24 software (IBM Corp: Armonk, NY.). The two-way and three-way analysis of variance (ANOVA) was used to evaluate the dentin penetration of three different endodontic sealers with and without removing the smear layer and effects of all the variables on the sealers' penetration depths with a statistical significance level $\alpha < 0.05$.

RESULTS

The mean penetration depths in the AH Plus sealer group in the presence and absence of the smear layer were 358.02±349.89 and 395.31±380.21 µm, respectively. The penetration depths in the Syntex sealer group were 124.68±149.10 and 162.15±165.05 µm, respectively, with 6.39±8.85 and 8.56±9.56 µm in the Endoseal MTA sealer group, respectively **(Figs 4A-C)**.

Two-way ANOVA was used to evaluate the effect of the presence and absence of the smear layer on the sealers' penetration depths. The results showed that apart from the significant differences between the sealers' penetration depths, in all the sealer groups, the mean penetration depth in the groups without the smear layer was significantly greater than in the groups with the smear layer ($p<0.0001$).

Two-way ANOVA was used to evaluate the effect of sections' location (i.e., coronal, middle, and apical thirds) on the sealers' penetration depth. The results showed that apart from the significant difference in penetration depth between the sealers, the mean penetration depths in the coronal third was significantly greater than the middle and apical thirds ($p<0.0001$).

Three-way ANOVA was used to evaluate the effects of all the variables on the sealers' penetration depths **(Table 1)**. The results showed that the effects of all the three variables (sealer type, the presence or absence of the smear layer, and

Table 1. The effect of the sealer types in the presence and absence of the smear layer and the cross-section on the extent of sealer penetration into the dentin

Sealer type	Smear layer	Cross-section	Mean	SD	*p*
AH Plus	with	Coronal	699.73	223.20	<0.004
		Middle	343.04	305.99	
		Apical	31.30	21.18	
	without	Coronal	836.25	256.89	
		Middle	314.04	190.14	
		Apical	35.62	20.54	
Syntex	with	Coronal	279.86	142.57	<0.004
		Middle	82.32	87.97	
		Apical	11.84	10.71	
	without	Coronal	329.11	173.02	
		Middle	138.63	51.91	
		Apical	18.71	13.60	
Endoseal MTA	with	Coronal	14.52	10.82	<0.004
		Middle	4.20	3.48	
		Apical	0.47	0.98	
	without	Coronal	17.59	11.40	
		Middle	5.80	3.43	
		Apical	2.30	2.26	

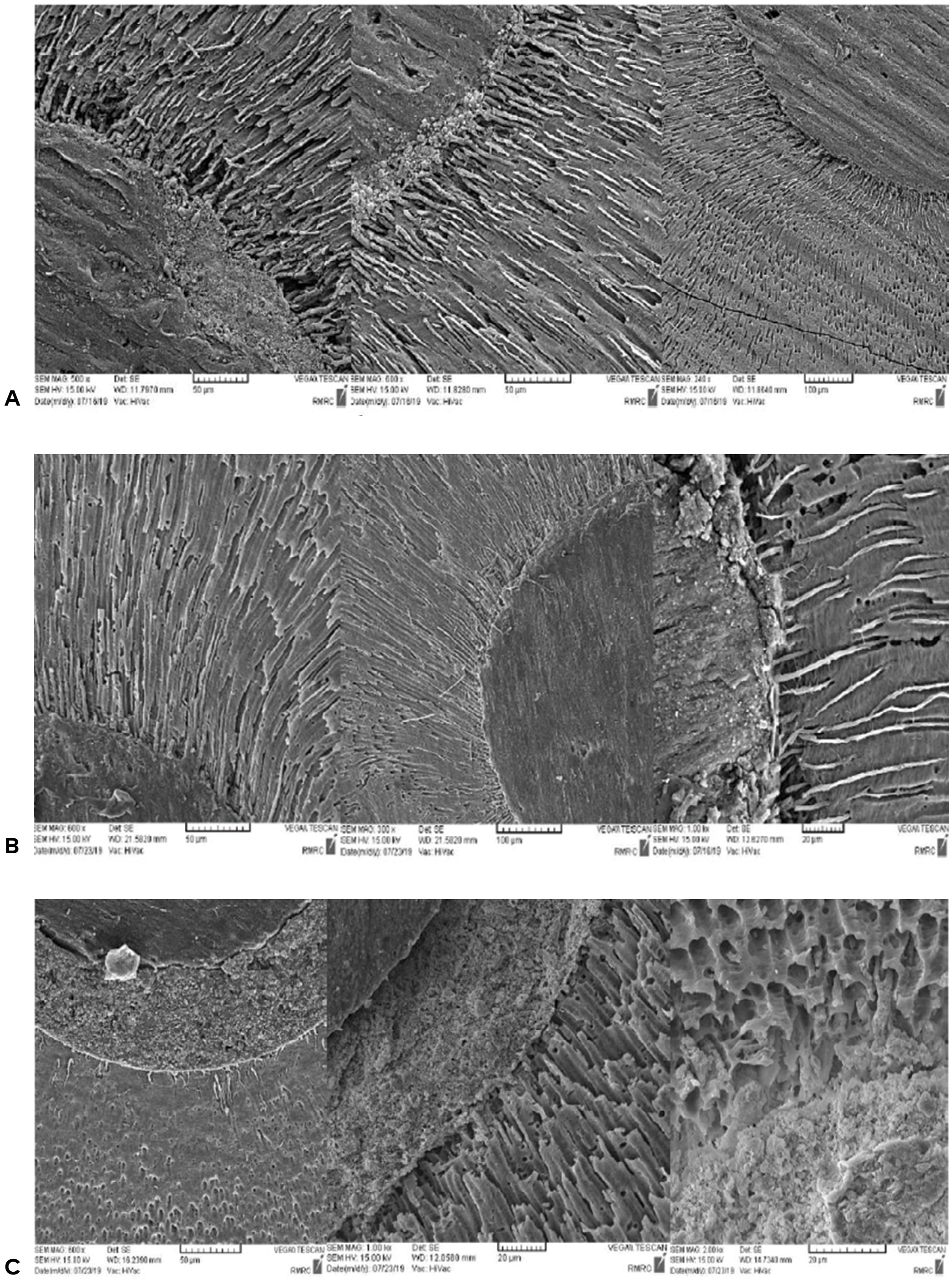

Figure 4. Sealer dentin penetration in the absence of the smear layer in the coronal part with different magnifications. **A**) AH plus; **B**) Syntex; **C**) Endoseal MTA.

the section) on the sealers' penetration depth were significant ($p<0.004$). The coronal section without the smear layer with the AH Plus sealer exhibited the greatest penetration depth.

DISCUSSION

The physicochemical structure of sealers has an essential role in their bond strength, tissue tolerance, and antimicrobial activity. The importance of sealer tags is in their role in increasing the adaptability and retention of the core material to the root canal dentin wall.[1]

Different techniques are used to determine the endodontic sealers' penetration depth in the dentin.[3]

SEM images have many advantages, including accurate observation of sealer penetration into the dentinal tubules, integrity, surface appearance, and accurate measurement of sealers' depth of penetration.[1] SEM observations of teeth have some disadvantages, too. For example, the time-con-

Folia Medica

suming nature of preparation before SEM observation and the high-vacuum condition might lead to the separation of the material from the root canal walls and tooth structure dehydration, resulting in crack formation and artifacts in the samples.[24,25]

In the present study, sample dehydration occurred slowly at room temperature over a few days so that crack formation decreased to a minimum. One of the strengths of the present study was that the Idex analysis was used to identify AH Plus sealer in dentin on SEM images, in which it is possible to evaluate the components of each material using an electron microscope and distinguish each material from the matrix around it.

Some of the reasons for deeper penetration of AH Plus sealer in the study by Sonu were the thixotropic behavior of the sealer, the sealer's integrity, capillary action, and a lack of polymerization stress in the material[1], which can explain the significant penetration of the sealer in the present study.

A higher penetration capacity of resin sealers might be attributed to their physical properties, such as flow, film thickness, surface tension, solubility, viscosity, chemical properties, working time, and setting time.[2]

In a study by Attur et al., too, AH 26 sealer exhibited greater dentin penetration than MTA and ZOE sealers, with less microleakage, consistent with the present study.[11]

Astrit et al. showed that the lateral compaction obturation technique with bioceramic sealer family resulted in deeper penetration than AH 26 sealer, which is different from the present study's results.[24] One possible reason for differences in the results might be the higher flowability of the MTA Fillapex sealer than the Endoseal MTA sealer. Ju Kyung Lee reported that the reason for the higher flowability of MTA Fillapex sealer than other bioceramic sealers is the higher resin-to-MTA ratio in this sealer.[26] Besides, the positive effects of removing the smear layer were different from the present study, i.e., removing the smear layer did not affect AH 26 sealer penetration. The difference in the results might be attributed to differences in the techniques used to remove the smear layer and difference in the methods used to evaluate penetration. In the present study, SEM was used for the evaluation, and in the mentioned study, confocal microscopy was used.[24]

Contradictory reports are available on the removal of the smear layer before root canal obturation. Therefore, further studies are necessary.[19] Although none of the techniques are useful on the entire root canal length, the technique of choice for removing the smear layer is the alternate use of EDTA and NaOCl solutions[19] that was used in the present study.

According to an in vitro study by Rouhani et al., removing the smear layer helps increase the penetration depth of all the sealers[27], consistent with the present study. The sealers' penetration depth in the apical third was significantly less than that in the middle and coronal thirds, consistent with the present study.[1]

Ordinola-Zapata et al., too, reported that the sealers' penetration depth into dentinal tubules was affected by the sealer type and the section's location; the penetration depth decreased toward the apical third.[28] In the study by Huan Chen, the penetration depth significantly decreased in the apical third, consistent with the present study, which might be attributed to the complex anatomy of the apical area and the presence of sclerotic dentin, transparent dentin, and sometimes occluded dentin.[14]

CONCLUSIONS

Comparison of the dentin penetration depth of Endoseal MTA, Syntex, and AH Plus sealers in the presence or absence of the smear layer in vitro showed that the deepest penetration in the absence and presence of the smear layer and at all the sections was observed with the AH Plus, Syntex, and Endoseal MTA sealers in descending order. Besides, the penetration depth of all the sealers at all the sections was higher in the absence of the smear layer than in the presence of the smear layer.

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Disclosure statement

The authors declare that they have no conflict of interest.

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Оценка проникновения в дентин трёх различных эндодонтических силеров при наличии и отсутствии смазанного слоя

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Резюме

Введение: Способность силера эффективно и стабильно проникать в дентинные канальцы является важным фактором при выборе эффективного материала для обтурации корневых каналов. Оценка проникновения силеров в дентинные канальцы дает ценные данные об исходе эндодонтического лечения.

Цель: Сравнить проникновение в дентин эндодонтических силеров AH Plus, Endoseal MTA и Syntex при наличии и отсутствии смазанного слоя.

Материалы и методы: В настоящем исследовании *in vitro* было отобрано 30 однокорневых зубов, которые случайным образом распределены по трём экспериментальным группам (n=10). Половину образцов готовили путём удаления смазанного слоя в каждой группе, а остальные образцы готовили без удаления смазанного слоя. Препарирование корневых каналов проводилось системой Perfect Rotary до файла T3. Корневые каналы обтурировали гуттаперчей и эндодонтическими силерами AH Plus, Endoseal MTA или Syntex. Образцы инкубировали при 100% относительной влажности при 37°C в течение одной недели. Каждый корень был срезан на расстоянии 2, 5 и 8 мм от апекса, и глубина проникновения силера в каждом срезе определялась под сканирующим электронным микроскопом (СЭМ). ANOVA использовался для сравнения глубины проникновения.

Результаты: В каждой группе наблюдались значительные различия в проникновении силера между образцами с удалением смазанного слоя и без него. Максимальное и минимальное проникновение силера было в коронковой и апикальной частях соответственно. Максимальная глубина проникновения силера в порядке убывания наблюдалась у силеров AH Plus, Syntex и Endoseal MTA (p<0.05).

Заключение: Устранение смазанного слоя увеличило глубину проникновения трёх силеров в дентин, при этом самое глубокое проникновение силера AH Plus произошло в коронковой части без смазанного слоя.

Ключевые слова

глубина, проникновение, силер, смазанный слой