ORIGINAL RESEARCH

Assessment of Effectiveness of Erbium:Yttrium–Aluminum–Garnet Laser, GentleWave Irradiation, Photodynamic Therapy, and Sodium Hypochlorite in Smear Layer Removal

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Abstract

Aim and objective: To compare the effectiveness of erbium:yttrium–aluminum–garnet laser, GentleWave irradiation, photodynamic therapy (PDT), and sodium hypochlorite in smear layer removal and dentin permeability with a scanning electron microscope (SEM).

Materials and methods: Seventy-five recently extracted single-rooted teeth (maxillary second premolars) were randomly divided into 5 groups of 15 each. Group I teeth was the control group in which conventional root canal preparation (RCP) [17% ethylenediaminetetraacetic acid (EDTA)] was done without laser irradiation, group II teeth underwent RCP and GentleWave™ treatment, group III teeth were subjected to Er:YAG laser irradiation, group IV uses low-level 660 nm (PDT), and group V samples were irrigated with 5.25% NaOCl. All samples were viewed under the SEM. Images at the coronal, middle, and apical part of the root canal were obtained at ×1000. A scoring system for smear layer removal and debris removal scoring was used for analysis.

Results: Smear layer removal was significantly higher at different points (coronal, middle, and apical area) in group I, followed by V, IV, II, and group III in declining order ($p < 0.05$). Intercomparison between the groups at different points indicates a significant difference in smear layer removal score between group I and group V at coronal, middle, and apical third. The result was not significant at coronal third and middle third, between group I and V, II and III, II and IV. The result was not significant at apical third between I and V, II and III, and II and IV ($p < 0.05$). Ethylenediaminetetraacetic acid and sodium hypochlorite are effective in smear layer removal followed by the Er-YAG laser technique.

Conclusion: Ethylenediaminetetraacetic acid and NaOCl are effective in smear layer removal. Er:YAG laser-activated RCP was comparatively efficient in cleaning the smear layer and opening dentinal tubules.

Clinical significance: Er:YAG laser-activated RCP was comparatively efficient in cleaning the smear layer and it can be used for effective removal of smear layer for clinical usage.

Keywords: Dentinal permeability, Laser, Photodynamic therapy, Smear layer.

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Introduction

The smear layer is a layer of mineral and organic debris that is produced when hand or rotary files are used during mechanical preparation. It is made up of <0.5–15 μm sized particles as seen under a scanning electron microscope (SEM).[1] McComb and Smith[2] first identified smear layer in the year 1975 and found it to be remnants of dentin, dead or vital pulp tissues, odontoblastic processes, and bacteria.[3]

The smear layer has a superficial layer that covers the dentin surface and a smear plug that occludes the dentinal tubules. It has been observed that it cannot be removed by irrigation with sodium hypochlorite (NaOCl).[2] Because the smear layer is mainly composed of dead necrotic pulp, and bacterial products, some researchers suggested the removal of the smear layer. It is further suggested that these end products can provide a medium for bacterial growth, their multiplication, and penetration into deep dentinal tubules.[4]

It has been observed that the presence of a smear layer reduces the adaptation of gutta-percha to canal walls despite good condensation. Various endodontic instruments such as NiTi instruments are not efficient enough to clean flattened root canals.[5] Sodium hypochlorite (NaOCl) agent (0.5–5.25%) is routinely used as irrigating solutions in endodontics. Despite its superior antimicrobial activity and tissue dissolving capacity, it is not as effective in removing the smear layer.[6] A 15–17% of ethylenediaminetetraacetic acid (EDTA) can be used for smear layer removal. Neodymium:yttrium–aluminum–garnet (Nd:YAG) and carbon dioxide (CO_2) lasers were found to be efficient in disinfecting

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and cleaning the root canal and lateral dentinal tubules. Their use can lead to significant removal of the smear layer.[7]

Photodynamic therapy (PDT) using low-level laser irradiation is another method of removal of microorganisms. In PDT, light-sensitive compounds are used against microorganisms which leads to a photochemical reaction that generates free radicals and singlet oxygen, resulting in rupturing of bacterial cell walls and destruction of the microorganisms.[8] The GentleWave™ System cleans the root canal system through the generation and propagation of various physiochemical mechanisms such as sound waves.[9]

The present study was conducted to compare the effectiveness of erbium:yttrium–aluminum–garnet laser, GentleWave irradiation, PDT, and sodium hypochlorite in smear layer removal and dentin permeability with the SEM.

Materials and Methods

This *in vitro* study was done in the Department of Conservative Dentistry and Endodontics Institute of Dental Science, Bhubaneswar, Odisha. The study comprised of 75 recently extracted single-rooted teeth (maxillary second premolars) in the department of endodontics. The study was started after obtaining ethical approval from the institutional ethics committee. Inclusion criteria were caries-free teeth extracted for orthodontic treatment purpose, fully developed teeth, and teeth with no restoration, fractures, cracks, and developmental defects. Exclusion criteria were carious, fractured, dilacerated, and partially developed teeth.

All teeth were subjected to ultrasonic scaling to remove debris and were stored in 0.8% normal saline. All teeth samples were sectioned at CE junction and working length was recognized using a 10k file. Biomechanical preparation of teeth was done using NiTi file systems and irrigation was done using 17% EDTA (5 mL) for 1 minute followed by 5.25% NaOCl (5 mL) and distilled water (2.5 mL). Teeth were randomly divided into 5 groups of 15 each. Group I teeth was the control group in which conventional root canal treatment (17% EDTA) was done without laser irradiation, group II teeth underwent root canal preparation (RCP) and GentleWave™ treatment cycle which consists of 3% NaOCl for 5 minutes, distilled water for 30 seconds, 8% EDTA for 2 minutes, and distilled water for 15 seconds. Group III uses a low-level 660 nm AsGaAl (arsenide, gallium, aluminum) laser applied for 5 minutes using a continuous wave red laser diode unit (Photon Lase III, Brazil) (600 nm wavelength, width 10 nm, 100 mW power, and 12 J energy). Group IV teeth underwent RCP followed by Er:YAG laser irradiation with continuous rotational movement at the orifice of each root canal for 30 seconds (2,940 nm wavelength, 1.8 W energy, 100 mJ pulse rate, 18 Hz frequency). Group V samples were irrigated with 5.25% NaOCl.

Roots were sectioned vertically into two equal parts and both halves were used for the study, then dehydrated for 1 hour with 50, 80, 90, and 100% ethanol solution. Gold plating with a 15–20 nm gold-palladium layer was done and all samples were viewed under the SEM. Images at the coronal, middle, and apical part of the root canal were obtained at ×1000.

Scoring system for smear layer removal was used for analysis according to Dhawan et al.'s study;[10] score 1 was designated to no smear layer with patent dentinal tubules orifice, score 2 showed a small amount of smear layer with few opened dentinal tubules, score 3 was given to the occurrence of homogeneous smear layer along almost the entire canal wall with the presence of few opened dentinal tubules, score 4 showed the presence of homogeneous smear layer covering entire root canal wall with no open dentinal tubules, and score 5 designated thick, homogeneous smear layer covering the entire root canal wall.

Two independent endodontists participated in the study and assessed photographs and scoring. The mean of their results was finally taken into account. Results thus achieved were statistically evaluated after entering the data into MS Excel sheet using SPSS version 21.0. Kruskal–Wallis test was used for inter- and intragroup comparison. The level of significance was labeled below 0.05.

Results

Table 1 shows the distribution of samples based on the type of agent used for irrigation. Each group comprised of 15 samples. Table 2 shows that mean ± SD smear layer removal score at coronal third was 1.82 ± 0.64, 1.24 ± 0.44, 1.14 ± 0.34, 1.34 ± 0.28, and 1.70 ± 0.46 in groups I, II, III, IV, and V, respectively. There was a significantly higher score in group I followed by groups V, IV, II, and III ($p < 0.05$). The mean ± SD smear layer removal score at middle third was 2.10 ± 0.68, 1.46 ± 0.54, 1.20 ± 0.48, 1.52 ± 0.42, and 2.04 ± 0.54 in groups I, II, III, IV, and V, respectively. There was a significantly higher score for smear layer removal in group I followed by groups V, IV, II, and III ($p < 0.05$). Similarly, the mean ± SD smear layer removal score at apical third was 2.52 ± 0.72, 1.54 ± 0.58, 1.22 ± 0.42, 1.72 ± 0.32, and 2.16 ± 0.72 in groups I, II, III, IV, and V, respectively. There was a significantly higher score in group I followed by groups V, IV, II, and III ($p < 0.05$).

Intercomparison between the groups at different points indicates a significant difference in smear layer removal score between group I and group V at coronal, middle, and apical third. The result was not significant at coronal third and middle third, between group I and V, II and III, II and IV. The result was not significant at apical third between I and V, II and III, and II and IV ($p < 0.05$) (Table 3).

Table 1: Distribution of samples in different groups

Groups	*Group I*	*Group II*	*Group III*	*Group IV*	*Group V*
Agent used	17% EDTA (control)	GentleWave laser	PDT	Er:YAG laser	5.25% NaOCl
Number	15	15	15	15	15

Table 2: Assessment of smear layer removal score in different groups

Smear layer score	*Group I*	*Group II*	*Group III*	*Group IV*	*Group V*	*p value*
Coronal	1.82 ± 0.64	1.24 ± 0.44	1.14 ± 0.34	1.34 ± 0.28	1.70 ± 0.46	0.001
Middle	2.10 ± 0.68	1.46 ± 0.54	1.20 ± 0.48	1.52 ± 0.42	2.04 ± 0.54	0.004
Apical	2.52 ± 0.72	1.54 ± 0.58	1.22 ± 0.42	1.72 ± 0.32	2.16 ± 0.72	0.001

Kruskal–Wallis *U* test, significant, $p < 0.05$

Table 3: Intergroup comparison of mean smear layer removal score in different groups

Intergroup comparison		*Coronal*	*Middle*	*Apical*
Group I	Group II	0.021	0.042	0.002
Group I	Group III	0.007	0.007	0.001
Group I	Group IV	0.025	0.046	0.003
Group I	Group V	1.02	1.00	0.914
Group II	Group III	1.00	1.00	0.814
Group II	Group IV	0.124	0.146	0.614
Group II	Group V	0.014	0.052	0.001
Group III	Group IV	0.051	0.032	0.004
Group III	Group V	0.013	0.015	0.001
Group IV	Group V	0.020	0.036	0.001

Kruskal–Wallis *U* test, significant, $p < 0.05$

Table 5: Intergroup comparison of mean debris removal score in different groups

Intergroup comparison		*Coronal*	*Middle*	*Apical*
Group I	Group II	0.381	0.502	0.008
Group I	Group III	0.146	0.078	0.003
Group I	Group IV	0.312	0.523	0.002
Group I	Group V	0.125	0.325	0.092
Group II	Group III	1.00	1.00	1.00
Group II	Group IV	1.242	1.342	0.324
Group II	Group V	0.124	0.052	0.005
Group III	Group IV	0.348	0.531	0.009
Group III	Group V	0.142	0.340	0.002
Group IV	Group V	0.112	0.214	0.070

Kruskal–Wallis *U* test, significant, $p < 0.05$

Table 4: Assessment of debris removal score in different groups

Debris removal score	*Group I*	*Group II*	*Group III*	*Group IV*	*Group V*	*p value*
Coronal	1.62 ± 0.54	1.34 ± 0.46	1.16 ± 0.32	1.46 ± 0.42	1.58 ± 0.48	0.18
Middle	1.78 ± 0.42	1.42 ± 0.52	1.24 ± 0.46	1.52 ± 0.58	1.62 ± 0.52	0.071
Apical	1.92 ± 0.30	1.36 ± 0.46	1.20 ± 0.44	1.68 ± 0.56	1.76 ± 0.60	0.001

Kruskal–Wallis *U* test, significant, $p < 0.05$

Table 4 shows that mean ± SD debris removal score at coronal third was 1.62 ± 0.54, 1.34 ± 0.46, 1.16 ± 0.32, 1.46 ± 0.42, and 1.58 ± 0.48 in groups I, II, III, IV, and V, respectively. There was a higher score in group I followed by groups V, IV, II, and III, however, the difference was nonsignificant ($p > 0.05$). The mean ± SD debris removal score at middle third was 1.78 ± 0.42, 1.42 ± 0.52, 1.24 ± 0.46, 1.52 ± 0.58, and 1.62 ± 0.52 in groups I, II, III, IV, and V, respectively ($p > 0.05$). The mean ± SD debris removal score at apical third was 1.92 ± 0.30, 1.36 ± 0.46, 1.20 ± 0.44, 1.68 ± 0.56, and 1.76 ± 0.60 in groups I, II, III, IV, and V, respectively. There was a higher score in group I followed by groups V, IV, II, and III, however, the difference was nonsignificant ($p > 0.05$).

Intercomparison between the groups at different points indicates a significant difference in debris removal score at apical third between group I and group II (Table 5). In the middle third, a significant difference was found between group I and group III ($p < 0.05$).

It was found from the present study that, using different agents, smear layer removal at coronal, middle, and apical was effective. On intergroup comparison with the SEM, groups I and III are effective in smear layer removal and dentin permeability.

Discussion

The smear layer contains bacteria and their end products produced by instrumentation in infected root canals. The smear layer has a negative influence on the sealing ability of obturated canals.[8] It is further observed that the use of rotary instruments may push the debris deeper into dentinal tubules. Antibacterial irrigants are capable of removing debris as well as smear layer. Therefore, the complete removal of the smear layer is of paramount importance. Irrigants like NaOCl improve the cleaning ability of root canals.[9] Research has shown that a combination of EDTA and NaOCl partially removes the smear layer; moreover, the apical portion of the root canals remains uncleaned. Various methods such as ultrasonic devices, laser activation, and irradiation were found to increase the efficiency of low-volume chelating agents. Laser therapy such as Nd:YAG, Er:YAG, Argon, CO_2, chromium-doped yttrium, scandium, gallium, and garnet lasers are promising in removing the smear layer.[10,11]

Erbium–yttrium–aluminum–garnet (Er:YAG) lasers produce invisible infrared light at a wavelength of 2.940 nm which is idyllic for absorption by hydroxylapatite and water. The main mechanisms of interaction between the lasers and biological tissues are photothermic, photoacoustic, and photochemical. In recent researches, lasers have been advised as a substitute technique for disinfecting root canals and smear layer and debris removal. During laser use, water is used as an intracanal medium to ensure the effectiveness of the laser. In the erbium laser mechanism, they are thought to remove the smear layer by the generation of shock waves through the activation of water, and the formation of vapor bubbles.[12] Bolhari et al. concluded that EDTA and NaOCL are effective in removing the smear layer as compared to 2.78 μm Er,Cr:YSGG laser.[12]

Gutmann[13] in their study advocated that after removal of the smear layer, there was a good adaptation of thermoplastic gutta-percha to canal walls even if the sealer was present. Another point that opposes the importance of the smear layer is that it leads to poor sealing due to failure of adaptation of root filling materials with canal walls. Few suggested that the smear layer may be the reason for marginal leakage as it prevents sealer adaptation to the canal walls. According to others, as the permeability of dentin is reduced by the smear layer, it may help slow down the seepage of microorganisms into dentinal tubules. The present study was conducted to compare erbium:yttrium–aluminum–garnet laser, GentleWave irradiation, PDT, and sodium hypochlorite in smear layer removal and dentin permeability with the SEM.

In this study, we included 75 recently extracted single-rooted teeth (maxillary second premolars) which were divided into 5 groups of 15 each depending on the type of irrigation used (17% EDTA in group I, GentleWave™ in group II, Er:YAG laser in group III, PDT in group IV, and NaOCl in group V). Dhawan et al.[10] compared the efficacy of erbium:yttrium–aluminum–garnet and diode laser irradiation in smear layer removal in 30 single-rooted human teeth which were distributed into three groups depending on the type of irrigation used. It was found that Er:YAG laser was found to be more effective in smear layer removal at coronal, middle, and apical third as compared to diode laser and 17% EDTA. Debris removal score of Er:YAG was better than EDTA and group II diode laser. In contrast to this, in our study, EDTA and NaOCL are effective compared to other groups, and Er:YAG was comparatively effective.

Moon et al.[14] found that activation with a 1320 nm Nd:YAG laser with NaOCl or EDTA for sealer penetration into dentinal tubules was found to be much better than NaOCl. Chopra et al.[15] found that 17% EDTA alone was not effective in removing the complete smear layer especially in the apical third of the root.

A combination of both instrumentation and irrigation helps in cleaning the endodontic space. There is a difference in debris removal efficacy of endodontic instruments because of their specific flute design. Takeda et al.[16] found that because of the complexity of root canal and the presence of tortuous canals, there is inadequate volume and penetration of the solution into the apical portion of the canal, thus the cleaning action of the EDTA solution was less efficient near the apex leading to increased smear scores.

In contrast to our results, several other researchers oppose the concept of smear layer removal, but they believe that the smear layer can improve the ability by adaptation of root filling materials with canal walls. It was stated that the smear layer acts as a protective diffusion barrier and decreases the dentin permeability.[1,17,18]

Lacerda et al.[19] evaluated changes to dentin morphology and permeability with PDT in 40 single-rooted teeth which were divided into two groups: GI—not exposed to PDT (control), and GII—pretreated with toluidine blue photosensitizer and irradiated with AsGaAl laser diode. The results showed a significant difference between GI and GII ($p = 0.001$). The apical leakage was significantly higher in GII than in GI. They concluded that the use of a low-level laser (PDT) reduced the smear layer, opened the dentinal tubules and permeability of the apical dentin. A study by Chan et al.[20] found that GentleWave showed better efficacy in debris removal compared with continuous ultrasonic irrigation.

The limitation of the present study is a smaller sample size, and it is an *in vitro* study. Since results may vary from *in vitro* to *in vivo* conditions, hence further *in vivo* studies are required on larger sample size.

Conclusion

Intercomparison between the groups at different points indicates a significant smear layer removal score with EDTA and sodium hypochlorite groups. All tested agents are effective in smear removal at coronal, middle, and apical third, however, it was found that Er:YAG laser-activated RCP was comparatively efficient in cleaning the smear layer and opening dentinal tubules.

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