Original Article

Comparison of diode laser with maleic acid and ethylenediaminetetraacetic acid on smear layer removal from root canals: A scanning electron microscope study

Shahnaz Nabi, Riyaz Farooq[1]

Department of Conservative Dentistry and Endodntics, Government Dental College and Hospital, [1]Department of Conservative Dentistry and Endodontics, Government Dental College, Srinagar, Jammu and Kashmir, India

ABSTRACT

Aim: The aim of the study was to evaluate the effect of diode laser with maleic acid andethylenediaminetetraacetic acid (EDTA) on smear layer removal from root canals.

Materials and Methods: A total of 160 mandibular premolars were decoronated to the working length of 12 mm and prepared with ProTaper gold rotary files up to size F3. Group 1 canals were irrigated with 1 ml of 17% EDTA, followed by 3 ml of 3% sodium hypochlorite (NaOCl). Group 2 canals were initially irrigated with 0.8 ml of 17% EDTA, the remaining 0.2 ml was used to fill the root canals, and diode laser application was done. Group 3 canals were irrigated with 1 ml of 7% maleic acid, followed by 3 ml of 3% NaOCl. Group 4 canals were irrigated with 0.8 ml of maleic acid and remaining 0.2 ml was used to fill canal (total 1 ml) and activated by diode laser, followed by 3 ml of 3% NaOCl. Scanning electron microscope examination of the canals was done for the remaining smear layer at the coronal middle and apical third levels.

Results: Maleic acid with and without diode laser had the least smear layer scores.

Conclusion: Diode laser with maleic acid performed significantly better than EDTA.

Keywords: Diode laser, ethylenediaminetetraacetic acid, maleic acid, root canal irrigants, scanning electron microscope

INTRODUCTION

The basic aim of root canal treatment is to clean and disinfect the root canals as thoroughly as possible and to eliminate debris and microorganisms to achieve perfect obturation and hermetic seal without leakage. However, during preparation and instrumentation of the root canals, an amorphous, irregular layer is formed on the root canal walls' smear layer. Various chemicals, ultrasonics, and lasers, in combination or alone, have been evaluated for the removal of smear layer with varying results.[1-3] Sodium hypochlorite (NaOCl), 1%–5.25% concentration as an irrigant, is widely used in root canal treatment as it is bactericidal and has the ability to dissolve organic tissues but noneffective in removing the smear layer.[4,5] Decalcifying solutions used for removing smear layer include phosphoric acid, citric acid, maleic acid, ethylenediaminetetraacetic acid (EDTA), and a mixture of tetracycline isomer, an acid, and a detergent.[6,7] Lasers have also been used to remove smear layer, such as argon laser,[8] neodymium-doped yttrium aluminum garnet,[9] CO_2 laser,[10] erbium-doped yttrium aluminum garnet,[3] and diode.[11] Maleic acid is used as an acid conditioner in adhesive dentistry.[12] This mild organic acid is found to remove the

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Address for correspondence: Dr. Shahnaz Nabi,
Department of Conservative Dentistry and Endodontics, Government Dental College and Hospital, Srinagar, Jammu and Kashmir, India.
E-mail: drshahnaznabi@gmail.com

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smear layer from the surface of the teeth.[13] Ballal *et al*. have shown that smear layer removal from the apical third of the root canal was performed better using 7% maleic acid than EDTA.[14] Currently, a final irrigation sequence with a chelating agent, EDTA and NaOCl, is being used to remove the inorganic and organic components of the smear layer.[15] This study evaluates the efficacy of smear layer removal from the root canals using diode laser with EDTA and maleic acid during endodontic therapy.

MATERIALS AND METHODS

A total of 160 adult human noncarious mandibular premolars were taken for the study. Inclusion criteria included single-rooted teeth with straight, patent roots and fully formed apices and whose initial apical size was 15 as determined by inserting a 15 number K file. Teeth extracted for periodontal and orthodontic reasons. Standard radiographs were taken in buccolingual and mesiodistal directions of each tooth after being held in a custom-made jig to determine the degree of canal curvatures, and only those teeth with straight canals and canal curvatures $<10°$ were included in the study.

Sample preparation

The teeth were stored in 10% formalin solution till they were used for the study. The root surfaces were cleaned and then decoronated using a diamond disc under water irrigation to obtain a standardized root length of 12 mm. After standardization, the working length of specimens was determined by deducting 1 mm from the length of the #15 K-file after it was passively placed in the canal until the tip of the instrument visibly penetrated the apical foramen. Apices of the roots were sealed with sticky wax to simulate the clinical conditions, and root canal instrumentation was initiated with ISO hand files up to #20, followed by ProTaper gold rotary files up to size F3 (Dentsply/Tulsa Dental, Tulsa, OK, USA). Two milliliters of 3% NaOCl (KMC Pharmacy, Manipal, Karnataka, India) was used as an irrigant after every instrument change. The irrigants were delivered with a disposable syringe, and a 30-G Max-I-Probe needle was placed 1 mm short of the working length. Finally, 3 ml of 3% NaOCl was used to flush out the debris from the root canals, followed by a rinse with 3 ml of distilled water to terminate any action of the solvents remaining in the canal. A constant total volume of 15 ml of NaOCl was used as irrigant for each root canal during the study.

Grouping of samples

After biomechanical preparation, the samples were divided into the following six different groups of twenty specimens each.

- Group 1 (EDTA) – Root canals were irrigated with a final flush of 1 ml of 17% EDTA for 1 min, followed by 3 ml of 3% NaOCl
- Group 2 (diode + EDTA) – The root canals were initially irrigated with 0.8 ml of 17% EDTA for 40 s; the remaining 0.2 ml was used to fill the root canals as the canal volume dictated so, and diode laser application was done for 20 s. For laser application, a 200-μm, 970 ± 15 nm, power max 1.5 W fiberoptic tip was introduced into the root canal up to the working length; the laser was activated in continuous mode and gently withdrawn from the root canal to the coronal region with a helicoid movement and reintroduced to the apex for a total laser irradiation cycle of 20 s. This was followed by 3 ml of 3% NaOCL
- Group 3 (maleic acid) – The root canals were irrigated with 1 ml of 7% maleic acid, followed by 3 ml of 3% NaOCl
- Group 4 (diode + maleic acid) – The root canals were irrigated with a final flush of 0.8 ml of maleic acid, and the remaining 0.2 ml was kept in the canal and activated by a diode laser, followed by 3 ml of 3% NaOCl. The root canals were finally flushed with 5 ml of distilled water to terminate the action of the irrigating solutions dried and prepared for scanning electron microscope (SEM) examination.

Scanning microscope examination

The teeth were grooved along the buccal and lingual planes by using a diamond disc at low speed. The roots were then split longitudinally with a bi-beveled chisel and a mallet. One-half of each root was selected, depicting the entire root canal length, and prepared for SEM examination. The selected samples were progressively dehydrated using graded concentrations of aqueous ethanol (70%, 80%, 90%, and 100%) for 24 h at each concentration. After dehydration, the samples were placed in a vacuum chamber and sputter coated with a 30-nm gold layer. The dentinal wall of the root canals was examined at coronal, middle, and apical thirds at a magnification of ×1000 for the presence or absence of smear layer and patency of dentinal tubules. Photomicrographs of the root canals were taken at coronal, middle, and apical levels (4 mm each) for scoring individually in a calibrated single-blinded manner according to the rating system developed by Gutmann *et al*.[16] [Table 1].

Data were analyzed using one-way analysis of variance using the SPSS version 20 (IBM Corp, Armonk, NY, USA) and *post hoc* tests ($P < 0.05$).

RESULTS

At the coronal third level, Group 3 followed by Group 4 had the least smear layer scores with no significant difference

between them. This was followed by Group 2 and Group 1 with a significant difference between Group 3 and Group 1 [Figure 1]. At the middle third level, Group 3 followed by Group 4 had the least smear layer scores with a significant difference between Group 3 and Group 1 [Figure 2]. This was followed by Group 2 and Group 1 with a significant difference between them. The highest smear layer scores were observed in Group 1 and Group 2 [Table 2]. At the apical third level, the lowest smear layer scores were observed in Group 3, followed by Group 4, Group 2, and Group 1, with a significant difference between them [Figure 3].

DISCUSSION

The outcome of this research revealed that 7% maleic acid was better in the removal of smear layer than 17% EDTA and diode laser combination in the coronal, middle, and apical thirds of the root canal with a significant difference. In the middle third, maleic acid and EDTA diode combination was equally effective without any statistical difference between them. This is in agreement with other studies.[17,18] A larger canal diameter in the coronal and middle third exposes the dentin to a higher volume of irrigants, allowing a better flow of the solution and hence, improving the efficacy of smear layer removal.[19] In Group 2 and Group 4, the choice of the power 1.5 W in continous wave (CW) parameter settings used in this study was based on the results of the study by Alfredo *et al*.,[20] who demonstrated that these parameters yielded a temperature rise at approximately 10°C, which does not exceed the limit supported by the periapical tissues.[21] Twenty seconds' time application was used according to the study by Marchesan *et al*.[22] In Group 2 and Group 4, the smear layer was removed from the root canals; the dentinal tubules were obliterated mostly at the middle and apical levels. The results were similar to the study of Faria *et al*.[23] who found absence of smear layer and partially obliterated dentinal tubules after the application of 980-nm diode laser on root canals irrigated with 1% NaOCl plus 17% EDTA.

In Group 1, the root canal surfaces were clean and free of smear layer in the coronal and middle third, whereas the apical third showed scattered areas with smear layer. No significant difference in smear layer scores was recorded

Table 1: Gutmann rating system for remaining smear layer scores

Remaining smear layer scores	Scoring criteria
1	Little or no smear layer; covering <25% of the specimen; most tubules were visible and patent, or almost complete laser melting
2	Little to moderate or patchy mounts of smear layer; covering 25-50% of the specimen; many tubules were visible and patent, or laser melting
3	Moderate amounts of scattered of aggregated smear layer; covering 50%-75% of the specimen; minimal to no tubule visibility or patency, or scattered laser melting
4	Heavy smear layer covering >75% of the specimen; no tubule orifices were visible or patent; or no visible laser melting

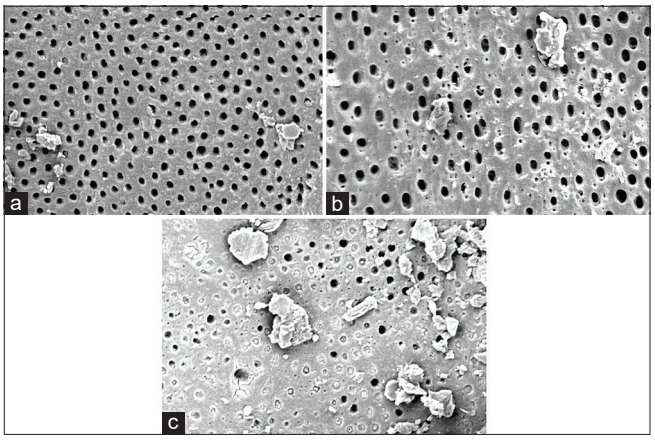

Figure 1: Coronal (a), Middle (b) AND Apical (c) SEM images of group 2

Table 2: Comparison of remaining smear layer scores among various groups

Groups	Coronal			Middle			Apical			Overall		
	Mean difference	*P*	Significance	Mean difference	*P*	Significance	Mean difference	*P*	Significance	Mean difference	*P*	Significance
Group 1 versus Group 2	0.15	0.012	NS	0.15	0.012	NS	0.55	0.0040	S	0.30	0.13	NS
Group 1 versus Group 3	0.25	0.005	S	0.30	0.002	S	0.80	0.001	S	0.55	0.004	S
Group 1 versus Group 4	0.15	0.06	NS	0.25	0.005	S	0.65	0.002	S	0.40	0.005	S
Group 2 versus Group 3	0.10	0.065	NS	0.15	0.06	NS	25	0.005	S	0.25	0.005	S
Group 2 versus Group 4	0	0.01	NS	0.10	0.065	NS	0.10	0.065	NS	0.10	0.065	NS
Group 3 versus Group 4	0.10	0.065	NS	0.05	0.12	NS	0.15	0.06	NS	0.15	0.06	NS

NS: Nonsignificant; S: Significant

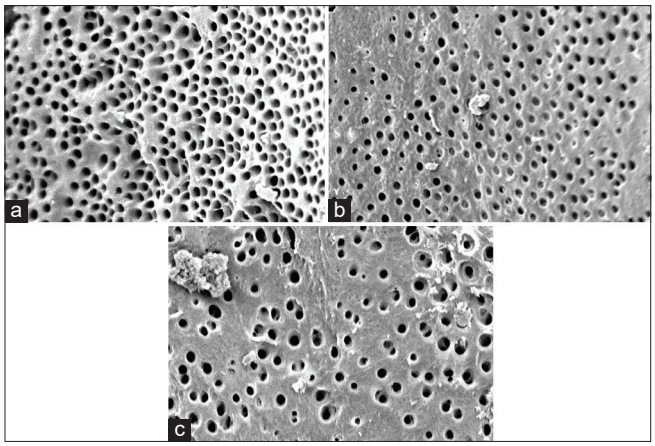

Figure 2: Coronal (a), Middle (b) AND Apical (c) SEM images of group 4

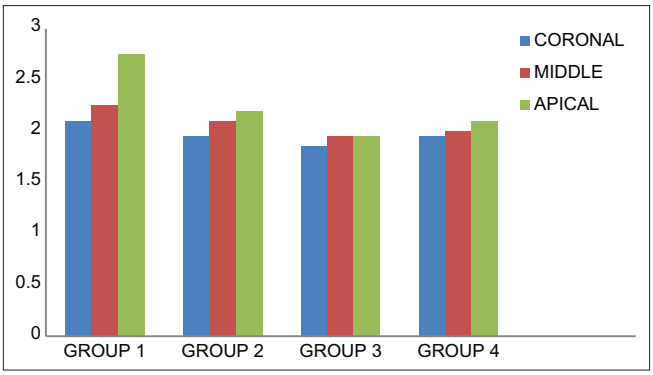

Figure 3: Remaining smear layer scores among various groups

at the coronal and middle levels; however, higher smear layer scores were recorded at the apical level which was not significant in comparison to the coronal third. The results were statistically nonsignificant in comparison to Group 3 and Group 4.[24] The combinations of diode and EDTA and diode and maleic acid performed better than EDTA alone in removing the smear layer, suggesting that the incorporation of diode laser with EDTA might prove beneficial in increasing the ability of EDTA to remove the smear layer by enhancing its interaction with the root canal walls, particularly in the apical regions. The diode laser used alone proved to be effective than EDTA in the apical regions in removing the smear layer; however, the difference was not significant. Diode laser is shown to be capable of removing the smear layer as it is designed to emit light over numerous wavelengths in continuous or pulsed mode.[25] In endodontics, the wavelengths used are of 800–980 nm range. These lengths are poorly absorbed by water. These lasers provide deeper access and penetration (500 μm) as compared to irrigating solutions (100 μm).[26] The irradiation by laser results in vaporization of smear layer and opening of dentinal tubules, thereby increasing the potency of EDTA and maleic acid. The 200-μm tip used provided greater penetration to the apical third of the root canals and greater removal of the smear layer.[27] The outcome of this research revealed that 7% maleic acid was better in the removal of smear layer than 17% EDTA and diode laser combination. This might be related to the differences in surface tension between 17% EDTA (0.0783 N/m) and 7% maleic acid (0.06345 N/m).[23] EDTA is a chelating agent effective at a neutral pH and thus is independent of a high hydrogen ion concentration to cause decalcification. A decrease in pH in dentin is due to the exchange of calcium by hydrogen, which is responsible for a reduced efficacy of EDTA over time.[28] Maleic acid has a better demineralizing effect within a shorter period as it is highly acidic.

CONCLUSION

The removal of smear layer is deemed as an important area for the complete disinfection of the root canal system. Within the limitations of the current study, all the tested groups were able to remove the smear layer from the prepared root canals to different degrees. Maleic acid alone or its combination with diode laser showed significantly better smear layer removal than EDTA alone. Diode laser could be a good addition to the armamentarium used for smear layer removal and along with its bactericidal effects on the root canal microbes could increase the success rate of endodontic therapy. Seven percent maleic acid as a final irrigant is highly efficacious for the removal of smear layer when used in the apical third of the root canal system.

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Conflicts of interest

There are no conflicts of interest.

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