

Comparison of 980 nm Diode Laser and Q-Mix Solution Alone and in Combination on Removal of Smear Layer from Root Canal Surface; a Scanning Electron Microscope Study

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Abstract

Aim: The aim of this study was to compare the efficacy of 980 nm diode laser and QMix 2in1 solution (DENTSPLY Tulsa Dental Specialties) alone and in combination, for smear layer removal from the root canals.

Background: Smear layer is an amorphous layer formed on root canal walls following instrumentation. This layer should be removed as it can harbor bacteria and bacterial products and prevents the penetration of intracanal medicaments into the dentinal tubules. Irrigation agitation techniques have been proposed recently to remove smear layer from root canals more efficiently. The diode laser has the potential for irrigant activation and studies are needed to establish their efficacy for smear layer removal especially from apical thirds of canals.

Methods: Forty extracted single-rooted permanent human teeth were used. Root canals were prepared to full working length using manual K-files (MANI) till 40K. Prepared teeth were divided into four groups (n=10): Group 1, no irrigation; Group 2, QMix 2in1 solution; Group 3, diode laser; Group 4, QMix 2in1 in combination with a diode laser. The roots were split longitudinally and prepared for scanning electron microscopic (SEM) investigation. The split roots were examined for remaining smear layer at the coronal, middle, and apical portion of each canal under a scanning electron microscope (JSM5910, JEOL, Japan) at 1000x magnification.

Results: Smear layer removal was scored according to Guttman rating system for remaining smear layer scores (Gutmann et al.). Diode laser in combination with QMix solution had the least smear layer scores.

Conclusions: Diode laser irradiation in combination with QMix 2in1 solution effectively removes smear layer from apical thirds of root canals.

Key Words: Lasers, Endodontics, Biofilm(s), Scanning electron microscopy (SEM), Dentin, Debridement

Introduction

Smear layer is a heterogenous amorphous layer spread on root canal walls following instrumentation [1]. This layer consists of two confluent components. A thin superficial layer 1-2 μm thick overlying the root canal walls and a deeper layer extending into dentinal tubules [2,3]. It can prevent penetration of intracanal medicaments into the dentinal tubules and interferes with the close adaptation of obturation materials to root canal walls; the smear layer should be removed [4].

Irrigants are used to remove smear layer from root canal walls, however, no single irrigants can remove both the organic and inorganic components of this layer. Conventionally used root canal irrigants include sodium hypochlorite (NaOCl), ethylene-diamine-tetra-acetic acid (EDTA) and chlorhexidine.

QMix 2in1 (Dentsply Tulsa Dental, Tulsa, OK, USA) solution is recently developed root canal irrigants. It contains a chelating agent, an antimicrobial agent and a surfactant in a premixed formulation [5]. This irrigating solution is a single solution used as a final rinse after NaOCl for root canal disinfection and removal of smear layer. It has shown to be less aggressive than 17% EDTA as it causes less demineralization of intact dentine collagen. It is also an effective antimicrobial agent providing 99% bacterial reduction in the root canals [6].

Traditional Irrigation techniques used to mechanically remove the debris from root canals involve syringe and needle to flush out the debris. The needle is inserted to the apical 1/3rd of the root canal and irrigant is injected, thereby removing the debris. It has been shown that conventional syringe irrigation transmitted solutions go no more than 0-1.1 mm beyond the needle tip [7]. It has been shown that a large amount of debris remains in the root canal irregularities after the use of conventional syringe irrigation [8,9].

Due to morphological complexities of root canals such as curvatures, lateral branches, and apical ramifications, up to 50% of canal walls may remain un-instrumented during preparation, which results in insufficient debridement [10]. Irrigation agitation techniques have been proposed recently to remove smear layer from root canal walls. Diode laser irradiation produces agitation of irritants and can improve the smear layer removal ability from the apical third of root canals.

Laser-activated irrigation supplements the conventional endodontic cleaning procedures and has shown superior cleaning of the canal walls [11,12]. The present study will be conducted to validate the previous findings regarding the efficacy of diode laser 940-980 nm wavelengths in removing the smear layer from the root canal walls especially the apical one-third. The diode laser has a broad range of wavelengths however 940-980 nm wavelengths are found to be most suitable for the intraoral application. This wavelength has

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relatively superior water absorption in near-infrared range and has shown potential for irrigant activation.

The parameters used in this study are designed to allow adequate thermal relaxation and avoid excessive temperature rise that could cause detrimental effects on periradicular tissues. Diode laser, when used at these parameters, induce agitational effects in irrigant solutions thus activating the solution' [13,14]. Both the 940 and 980 nm produce the agitational effects as observed in previous literature [15].

Previous studies have shown better smear layer removal by laser activation of EDTAC solution especially from the apical thirds of root canals [16]. EDTAC dissolves the calcium from the dentinal surface and results in the formation of soluble precipitates. These precipitates can be washed out of the canals during irrigation. Penetration of EDTAC remains limited in lateral and accessory canals.

Q-mix solution, when used in combination with Erbium laser, showed significantly improved smear layer removal especially from apical thirds of root canals [17]. The present study aims to evaluate the effect of Diode laser activation on Q-mix solution for smear layer removal. This study will aid in better understanding of diode laser interaction with Q-mix solution.

Rationale

The removal of smear layer formed during mechanical preparation ensures a canal free from debris and bacteria. Although various irrigants have been used for this purpose, no single solution has shown the ability to remove both organic and inorganic components of the smear layer. Q-mix 2in1 (DENTSPLY, Tulsa dental sp.) is a newer solution developed to overcome this problem. The diode laser has shown to produce agitation of irritants and remove the smear layer especially from the apical 1/3rd of root canals [18].

This study will explore the most effective method for removal of smear layer.

Materials and Methods

Study design: a comparative study

A sample size of 40 teeth was calculated using G Power 3.0. Forty extracted single-rooted human teeth were selected according to the inclusion criteria after the ethical approval obtained from the Islamabad Medical and Dental College Institutional review board. The inclusion criteria were; single-rooted teeth with fully formed apices and straight canals. Selected teeth were examined radiographically and visually.

Sample

Sample size: A sample size of 40 extracted single-rooted teeth is calculated using the G Power 3.1 sample size calculator at:

1. Level of significance: 10%
2. Power of test: 80%

Anticipated population proportion

1. Average percentage reduction of smear layer after irradiation with diode laser: 97.99%
2. Average percentage reduction of smear layer after Q-mix irrigation: 81.9%

Inclusion criteria

Single-rooted teeth with fully formed apices and straight canals

Exclusion criteria

1. Single-rooted teeth with multiple canals
2. Teeth with radiographic evidence of
 - a) Calcifications and other intracanal obstructions
 - b) Internal Resorption
 - c) Previous endodontic treatment
3. Teeth with root caries

Data collection tools

1. Scanning electron microscope (30KV Scanning Electron Microscope JSM5910, JEOL, Japan)
2. Guttman criteria of smear layer scoring

Data Collection Procedure

Preparation of teeth

1. Extracted teeth obtained from patients were cleaned from tissue debris mechanically and placed in 10% Formalin solution till further use
2. Preoperative X-rays were taken to exclude any abnormality as per exclusion criteria
3. Teeth were decoronated at the cemento-enamel junction (CEJ), using a Marathon high-speed motor and handpiece with metal cutting discs
4. Working lengths were established by inserting a #10 K file (Mani) into the tooth till it appears at the apical foramen and subtracted 1 mm from this length
5. The canal was shaped using a step back technique till #50 K file (Mani) size with #40 K as Master file
6. 3% NaOCl was used for irrigation after each successive instrument
7. The coronal 3rd of the root canal was flared using #2, #3, #4 Gates Glidden drills (Mani) with step back technique
8. Apical foramen of the teeth was sealed using coats of clear nail polish and teeth were allowed to dry overnight in the open air
9. The selected prepared teeth were randomly divided into four groups (ten teeth for each group):
 - a) Group (I): control group
 - b) Group (II): Q-mix 2in1 group
 - c) Group (III): Diode laser group
 - d) Group (IV): Diode laser in combination with Q-mix group

Experimental procedure

1. After instrumentation,
 - a) Group (I): irrigated with normal saline
 - b) Group (II): irrigated with 1 ml Q-mix 2in1 for 20 sec for 2 cycles
 - c) Group (III): irradiated with 980 nm diode laser using 3 Watts power in pulsed mode with 200 μ sec Ton and 400 μ sec T off for 20 sec for 2 cycles as described in *Table 1*. The fiber optic tip was inserted 1 mm short of working length and moved outwards in slow helicoidal movements.
 - d) Group (IV): irrigated with 1 ml of Q-mix solution and irradiated with a diode laser at same settings with the solution still within the canal
2. Teeth of all 4 groups were then flushed with 1 ml of distilled water to remove any residual debris within the canal

Table 1. 980 nm diode laser parameters used for smear layer removal from root canal surfaces.

Manufacturer	Medelux Co. Ltd
Model Identifier	DD-10
Year Produced	2015
Number and Type of Emitters (laser or LED)	Laser
Wavelength and bandwidth [nm]	980 nm
Pulse mode (CW or Hz, duty cycle)	Pulsed
Beam spot size at target (cm ²)	
Irradiance at target (mW/cm ²)	9500 Mw/
If pulsed peak irradiance (mW/cm ²)	
Exposure duration (sec)	20
Radiant exposure (J/cm ²)	0.48 J/cm ²
Radiant energy (J)	
Number of points irradiated	1 canal per tooth
Area irradiated (cm ²)	
Application technique	Non-contact
Number and frequency of treatment sessions	2 applications
Total radiant energy over entire treatment course (J)	

Preparation for SEM

1. The specimens of all groups were kept in individual vials containing 50% alcohol until they were prepared for scanning electron microscopy
2. Two longitudinal shallow grooves were made on the buccal and palatal/lingual aspects of each tooth by a disc so that the grooves did not penetrate the root canal
3. The teeth were separated by gentle strokes using mallet and chisel
4. Dehydration was performed using a series of ethanol concentrations in increasing order from 60% to 100%, and the specimens were left in each concentration for three hours



Figure 1. Split roots mounted on stub with double sided carbon tape.



Figure 2. Mounted roots being sputtered with gold-palladium mixture.



Figure 3. Specimen after sputtering and ready for scanning electron microscopy.

5. The specimens were then air dried in a drying machine for 24 hours
6. Specimens were mounted on SEM holder by double sided carbon tape *Figure 1*
7. Then the specimens were spattered using a gold-palladium mixture using SPI-MODULE™ sputter coater *Figures 2 and 3*

SEM analysis

SEM assessment was made by using Scanning Electron Microscope (JSM5910, JEOL, Japan) *Figure 4*.



Figure 4. 30KV Scanning Electron Microscope JSM5910, JEOL, Japan.

The surface topography of the four groups was examined and the results were recorded photographically. Photomicrographs were taken at 1000x magnification.

Smear layer scores for each tooth was recorded at coronal, middle and apical 3rd of roots according to Guttman scoring system [18,19] in a single-blind manner.

Statistical Analysis

Two observers independently evaluated the SEM images three times with 1-week interval without knowledge of the previous results. To validate the subjective findings Cohen's kappa was used to measure intra-observer and inter-observer agreement as shown in *Tables 2-4* respectively.

The differences between the remaining smear layer scores of each group were analyzed and compared using the Kruskal Wallis test. Statistical analysis was performed using IBM SPSS 20 software (IBM SPSS Inc, Chicago, IL). A significance level of 0.05 was used.

Table 2. Intra-rater reliability for rater 1.

Group	Coronal 1/3 rd	Middle 1/3 rd	Apical 1/3 rd
Measure of agreement (Kappa)	0.86	0.895	0.866

Table 3. Intra-rater reliability for rater 2.

Group	Coronal 1/3 rd	Middle 1/3 rd	Apical 1/3 rd
Measure of agreement (Kappa)	0.895	0.828	0.966

Table 4. Intra-rater reliability for rater 2.

Group	Coronal 1/3 rd	Middle 1/3 rd	Apical 1/3 rd
Measure of agreement (Kappa)	0.93	0.897	0.9

Anticipated Ethical Issues

Safe disposal of the specimen.

Results

Remaining smear layer scores were calculated at the coronal, middle and apical thirds of root canals as shown in *Tables 5 and 6*. According to Guttman et al. [18,19].

Table 5. Mean ranks of the four groups showing remaining smear layer score according to Guttman criteria after treatment with Diode laser; Qmix 2in1 solution, and combination of QMix diode laser.

Groups	Mean Ranks		
	Coronal 3 rd	Middle 3 rd	Apical 3 rd
G1 Control	34.75	34.9	35.05
G2 QMix	24.5	25.3	25.5
G3 Diode Laser	10.7	10.9	11.25
G4 Diode laser with Qmix	12.05	10.9	10.2

Table 6. Guttman rating system for remaining smear layer score.

Score	Criteria
1	Little or no smear layer; covering <25% of the specimen; dentinal tubules visible and patent
2	Little to moderate or patchy mounds of smear layer; covering between 25% to 30% of the specimen, many dentinal tubules visible and patent
3	Moderate amounts of scattered or aggregates of smear layer; covering between 50% to 75% of the specimen; minimal to no dentinal tubules visible and patent
4	Heavy smear layer covering over 75% of the specimen surface; no dentinal tubules visible or patent

Data were analyzed and compared using the Kruskal Wallis test. Statistical analysis was performed using IBM SPSS 20 software (IBM SPSS Inc, Chicago, IL) with ($p < 0.05$).

The result of the remaining smear layer score in four groups is presented in *Tables 2 and 3*. The distribution of four groups

of smears layer scores are shown in *Figure 5*. The final scoring data of all groups is attached as *Table 4*.

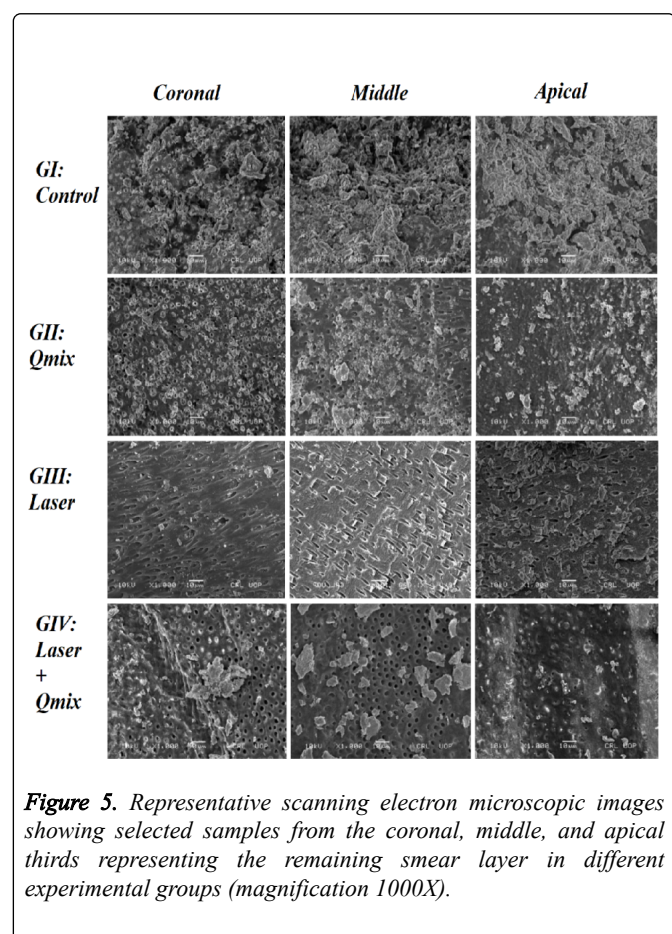


Figure 5. Representative scanning electron microscopic images showing selected samples from the coronal, middle, and apical thirds representing the remaining smear layer in different experimental groups (magnification 1000X).

At the coronal third level: Group III had the least smear layer scores followed by Group IV with a significant difference between them ($p < 0.001$). This was followed by Group II and Group I with a significant difference between Group II and groups III and IV, respectively.

At the middle third level: At the middle third level: Group III and IV had the least smear layer scores with no significant difference between them ($p > 0.001$). This was followed by Group II and Group I with a significant difference between Group II and groups III and IV, respectively.

At the apical third level: Group IV followed by Group III had the least smear layer scores with a significant difference between them. This was followed by Group II and Group I with a significant difference between Group II and Groups III and IV, respectively ($p < 0.001$).

Photomicrographs of the root canals were evaluated for scoring independently by researchers. The remaining smear layer scores of the 2 researchers were compared and if any conflict occurred, the lower score was chosen.

Discussion

Smear layer has been a matter of debate whether it affects the prognosis of root canal treatment or not. However, evidence suggests that this layer is more likely to harbor bacteria and debris that may lead to failure of root canal treatment. McComb and Smith were the initial investigators to find an

irregular, amorphous and granular layer along instrumented root canal walls [20].

The smear layer has been shown to impede the penetration of both intracanal disinfectants and sealer into the dentinal tubules and can potentially compromise the seal of the root canal filling. The smear layer can be packed into the dentinal tubules to a depth of up to 40 μm [1].

Different methods have been proposed to remove the smear layer from canal walls. Use of Ethylenediaminetetraacetic acid (EDTA) to dissolve the smear layer and achieve clean canal walls was proposed by Ostby [21,22]. Some other decalcifying agents have also shown to remove smear layer including maleic acid, phosphoric acid, and citric acid. QMix 2in1 is a newly developed solution that is composed of a polyaminocarboxylic acid chelating agent, a bisguanide antimicrobial agent, a surfactant and deionized water. The surfactant decreases the surface tension of solution thus giving better wettability of root canal walls and providing more efficient removal of smear layer [23]. QMix 2in1 solution has been reported to remove the smear layer as effectively as 17% EDTA after using 5.25% NaOCl [24].

The present study aims to evaluate the efficacy of smear layer removal following irrigation with QMix solution and laser irradiation. Results obtained indicate towards the potential of 980 nm diode laser for canal debridement. Remaining smear layer scores in the laser group and combination group are much lower compared with the control group and QMix group.

QMix 2in1 solution has shown superior smear layer removal as compared with NaOCl and Biopure MTAD solutions [25,26]. Despite the continuing innovations in conventional needle irrigation techniques, inefficient removal of smear layer from apical third of root canal may be attributed to limited penetration of irrigants into apical areas due to limited access [27,28]. This present study aims to overcome this dilemma by using lasers for irrigants activation and smear layer removal.

Lasers have shown promising results in removing the smear layer from root canals. Smear layer removal is achieved by irrigants activation and simultaneous decontamination of the canals. Erbium laser is used at the wavelengths of 2940 nm and 2760 nm and it has shown to effectively remove smear layer by irrigants activation [29]. In this present study, a 980 nm diode laser was used in pulsed mode with 200-micrometer optic fiber. The fiber tip was inserted 1 mm short of the working length and moved outwards in helicoidal movements. This maneuver ensures better safety and minimizes thermal damage in the apical 1/3rd of the root canal. This movement was carried out for 10 sec in each canal and repeated three times with a gap of 10 sec. The diode laser used in combination with QMix 2in1 solution provided maximum smear layer removal which is in accordance with a previous study [30]. Apical 1/3rd of root canals were effectively irradiated by inserting the fiber tip 1 mm short of working length and moving outwards slowly at a rate of 1 mm/sec as recommended in previous studies [12].

During laser activation, the formation of vapor bubbles, the collapse of the bubbles, acoustic streaming, and, finally,

cavitation processes occurred. This cavitation process leads to irrigants activation and subsequent smear layer removal. The threshold for initiation of the cavitation process is more dependent on the output power of laser as evidenced by Hmud Raghad et al. [31]. When comparing the two laser wavelengths, 980 nm generated cavitations more readily in distilled water than 940 nm. This is consistent with the known near-infrared absorption characteristics of water because 980 nm is the more strongly absorbed wavelength of the two [12].

Conclusion

Within the limitations of this study, it is concluded that 980 nm diode laser is an effective tool for irrigant activation and improving the smear layer removal especially from the apical thirds of root canals. This irrigant activation provides better access and penetration into inaccessible areas of root canals. It is recommended that further studies should be conducted to evaluate the interaction with a diode laser with different root canal irrigation solutions.

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Conflicts of Interests

There are no conflicts of interest associated with this research.

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