**Comparison of 980nm 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 980nm 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. 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 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 at1000x 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.

**Keywords:**

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](#_ENREF_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](#_ENREF_2), [3](#_ENREF_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](#_ENREF_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](#_ENREF_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](#_ENREF_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 root canal and irrigant is injected, thereby removing the debris. It has been shown that conventional syringe irrigation transmitted solutions go no more than 0-1.1mm beyond the needle tip. ([7](#_ENREF_7)) It has been shown that large amount of debris remains in the root canal irregularities after the use of conventional syringe irrigation. ([8](#_ENREF_8), [9](#_ENREF_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](#_ENREF_10)) Irrigation agitation techniques have been proposed recently to remove smear layer from root canal walls. Diode laser irradiation produces agitation of irrigants 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](#_ENREF_11), [12](#_ENREF_12))

The present study will be conducted to validate the previous findings regarding the efficacy of diode laser 940-980nm wavelengths in removing the smear layer from the root canal walls especially the apical one-third. Diode laser has broad range of wavelengths however 940-980nm wavelengths is found to be most suitable for intraoral application. This wavelength has 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 ctivating the solution’. ([13](#_ENREF_13), [14](#_ENREF_14)) Both the 940 and 980nm produce the agitational effects as observed in previous literature. ([15](#_ENREF_15))

Previous studies have shown better smear layer removal by laser activation of EDTAC solution especially from the apical thirds of root canals ([16](#_ENREF_16)). EDTAC dissolves the calcium from the dentinal surface and results in 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](#_ENREF_17)) 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, but no single solution has shown the ability to remove both organic and inorganic components of smear layer. Q-mix 2in1 (DENTSPLY, Tulsa dental sp.) is a newer solution developed to overcome this problem. Diode laser has shown to produce agitation of irrigants and remove the smear layer especially from the apical 1/3rd of root canals. ([18](#_ENREF_18))

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

**MATERIALS AND METHODS:**

**Study Design: Comparative study**

Sample size of 40 teeth was calculated using GPower 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 GPower 3.1sample size calculator at
* Level of significance: 10%
* Power of test: 80%
* Anticipated Population Proportion:
  + Average percentage reduction of smear layer after irradiation with diode laser: 97.99%
  + Average percentage reduction of smear layer after Q-mix irrigation: 81.9%

**INCLUSION CRITERIA**

* 1. 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
   1. Calcifications and other intra canal obstructions
   2. Internal Resorption
   3. 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:**

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

Group (I): control group

Group (II): Q-mix 2in1group

Group (III): Diode laser group

Group (IV): Diode laser in combination with Q-mix group

1. **Experimental procedure:**
2. After instrumentation,

* **Group (I):** irrigated with normal saline
* G**roup (II)**: irrigated with 1ml Q-mix 2in1 for 20 secs for 2 cycles
* **Group (III):** irradiated with 980nm diode laser using 3Watts power in pulsed mode with 200µsecs Ton and 400µsecs T off for 20 secs for 2 cycles as described in Table 1. The fiber optic tip was inserted 1mm short of working length and moved outwards in slow helicoidal movements.
* **Group (IV):** irrigated with 1ml of Q-mix solution and irradiated with diode laser at same settings with solution still within the canal

1. Teeth of all 4 groups were then flushed with 1ml of distilled water to remove any residual debris within the canal
2. **Preparation for SEM:**

* The specimens of all groups were kept in individual vials containing 50% alcohol until they were prepared for scanning electron microscopy
* 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
* The teeth were separated by gentle strokes using mallet and chisel
* Dehydration was performed using a series of ethanol concentrations in increasing order from 60% to 100%, and the specimens was left in each concentration for three hours
* The specimens were then air dried in a drying machine for 24 hours
* Specimens were mounted on SEM holder by double sided carbon tape
* Then the specimens were spattered using a gold-palladium mixture using SPI-MODULETM  sputter coater

**SEM Analysis:**

* SEM assessment was made by using Scanning Electron Microscope (JSM5910, JEOL, Japan). Photomicrographs were taken at 1000x magnification.
* The surface topography of the four groups were examined and the results were recorded photographically.
* Smear layer scores for each tooth was recorded at coronal, middle and apical 3rd of roots according to Guttman scoring system([18](#_ENREF_18), [19](#_ENREF_19)) in a single blind manner.
  + **Score 1** indicates little or no smear layer, and all dentinal tubules are visible
  + **Score 2** indicates little to moderate or patchy mounds of smear layer and many dentinal tubules are visible
  + **Score 3** indicates moderate amounts of scattered or aggregates of smear layer and only few dentinal tubules are visible
  + **Score 4** indicates heavy smear layer covering maximum area of the specimen surface and dentinal tubules are not visible

**STATISTICAL ANALYSIS:**

Remaining smear layer scores for all teeth were analyzed and compared using Kruskal Wallis test. Statistical analysis was performed using IBM SPSS 20 software (IBM SPSS Inc, Chicago, IL).

**ANTICIPATED ETHICAL ISSUES:**

Safe disposal of specimen.

**RESULTS**: Remaining smear layer scores were calculated at the coronal, middle and apical thirds of root canals as shown in the Table 2.

**At the coronal third level:** Group III had the least smear layer scores followed by Group IV with 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.

**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. 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 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.

**DISCUSSION:**

**Smear layer has been a matter of debate a that 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](#_ENREF_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. ([21](#_ENREF_21))

Different methods have been proposed to remove the smear layer from canal walls. Use of Ethylenediamine tetra acetic acid (EDTA) to dissolve the smear layer and achieve clean canal walls was proposed by Ostby. ([22](#_ENREF_22), [23](#_ENREF_23)) Some other decalcifying agents have also shown to remove smear layer including maleic acid, phosphoric acid and citric acid. QMix 2 in 1 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. ([24](#_ENREF_24)) QMix 2in1 solution has been reported to remove smear layer as effectively as 17% EDTA after using 5.25% NaOCl. ([25](#_ENREF_25))

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 980nm 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 compare with NaOCl and Biopure MTAD solutions. ([26](#_ENREF_26), [27](#_ENREF_27)) Despite the continuing innovations in conventional needle irrigation techniques, inefficient removal of smear layer from apical third of root canal maybe attributed to limited penetration of irrigants into apical areas due to limited access. ([28](#_ENREF_28), [29](#_ENREF_29)) 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 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 2940nm and 2760nm and it has shown to effectively remove smear layer by irrigants activation. ([30](#_ENREF_30)) In this present study a 980nm diode laser was used in pulsed mode with a 200micrometer optic fiber. The fiber tip was inserted 1mm 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 root canal. This movement was carried out for 10 secs in each canal and repeated three times with a gap of 10secs. The diode laser used in combination with QMix 2in1 solution provided maximum smear layer removal which is in accordance with previous study. ([31](#_ENREF_31)) Apical 1/3rd of root canals were effectively irradiated by inserting the fiber tip 1mm short of working length and moving outwards slowly at a rate of 1mm/sec as recommended in previous studies. ([12](#_ENREF_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 cavitation process is more dependent on the output power of laser as evidenced by Hmud Raghad et al. 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](#_ENREF_12))

**CONCLUSION:** Within the limitations of this study, it is concluded that 980nm 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 diode laser with different root canal irrigation solutions

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