The Effect of Diode Laser Irradiation on Root Canal Dentin

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Abstract

This research is to investigate the effect of 810 nm diode laser irradiation root dentine mineral contents and smear layer removal when used along with 2.5% (NaOCl) and 17% (EDTA) irrigation.

Eighteen (18) freshly extracted permanent premolar teeth were collected; the sample was chemo- mechanically prepared using ProTaper rotary nickel-titanium ((Ni-Ti) instruments and 2.5% (NaOCl). The Sample was divided into, Group A: (8) teeth treated with 5 ml of 17% EDTA only for 1 minute, Group B: (8) teeth were treated with 5 ml of 17% EDTA A for 1 minute then irradiation with 2 W power continuous wave of 810 nm diode laser. A control group of (2) teeth were irrigated only with 5 ml saline. Teeth were then sectioned, (1000x and 2000x) photomicrographs of the root canal walls were taken at 2 mm, 7 mm, and 12 mm depth from the apex the examined under SEM.

Regarding smear layer removal no statistically significant difference was detected between the two groups (P>0.05) in term of cracks and conjugation less changes were observed in teeth treated with EDTA a lone compared with Diode +EDTA group (12.5% & 21% respectively).

810 nm diode laser irradiation of root canal dentin irrigation has no significant effect on removal of smear layer. It can cause more dentine erosion with slightly more additional loss of mineral content when used along with NaOCl and EDTA.

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Introduction

Root canal instrumentation produces a layer of organic and inorganic material called the smear layer that may also contain bacteria and their by-products. It can prevent the penetration of intracanal medicaments into dentinal tubules and influence the adaptation of filling materials to canal walls.[1]

The use of ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl) solution is widely accepted as an effective irrigation regimen to remove organic and inorganic remnants of smear layer.[2] However, studies have shown that, conventional needle irrigation with NaOCl and EDTA is less effective in cleaning apical areas compared to coronal areas of root canal systems[3,4] and more 35% of the root canal system remains untouched after chemomechanical instrumentation.[5]

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It has been also reported that, use of EDTA alone or in combination with NaOCl have a detrimental effect on the major inorganic components of dental hard tissue [Calcium (Ca) and phosphorus (P)] and is capable of decreasing the Ca/P ratio of the root canal dentin significantly.[6,7] Any change in the Ca/P ratio may change the original proportion of organic and inorganic components, which in turn changes the permeability, microhardness and solubility of root canal dentin and may also adversely affect the sealing ability and adhesion of resin based cements and root canal sealers.[8,9]

Lasers have wide spectrum of applications in dentistry. High power lasers are mainly used in oral surgery for soft tissues cutting or excision procedures. While low power lasers have other therapeutic application for example, to repair damaged nerves, reduce dentine hypersensitivity or as an adjunct to surgical or non-surgical periodontal or endodontics treatments.[10-12]

Diode laser is known to be an effective and predictable method when performing

surgeries in oral soft tissues, with number of advantages over other types of lasers.[13] The device is a small size, ease of use and relatively low price which make it affordable tool in clinical practice.

Recently it has been also shown that the use of dental laser devices can be of extra advantageous for root canal procedures as lasers can provide better access to formerly unreachable parts of the root canal system.[14,15] Studies have demonstrated that diode laser is able to disinfect the root canal system in both in vitro[16,17]and in vivo.[18] Other studies showed that it can have a synergistic effect with root canal irrigants.[19,20]

Using the SEM and the EDX the aim of the present study is to investigate the effect of 810 nm diode laser irradiation root dentine mineral contents and smear layer removal when used along with 2.5% sodium hypochlorite (NaOCl) and 17% ethylenediaminetetraacetic acid (EDTA) irrigation.

Materials and methods

Specimen preparation. Ethical approval for the study obtained from the institutional review board of College of Dentistry, Ajman University of Science & Technology (RD-03 19/1/2014).

Eighteen (18) freshly extracted human mature permanent premolar teeth were collected; all the teeth were evaluated radiogrphically & under a stereomicroscope to verify the presence of single canal, mature apex and absence of any resorption or endodontic obturation. The teeth with caries, cracks and dilacerations were excluded from the study.

Teeth were then decoronated using a high-speed diamond bur to obtain a uniform root length of 14 mm. The pulp tissue was extirpated using barbed broach (Dentsply-Maillefer, Switzerland), and the working length was established by inserting a No. 10 K file into each root canal. The samples was then chemo-mechanically prepared using ProTaper rotary nickel-titanium ((Ni-Ti) instruments (Dentsply Maillefer) with Tri Auto ZX device up to size 40/.06 (F4). Between each instrument, 2 mL of 2.5% NaOCl was used.

Later the Sample was divided into:

- Group A: Eight (8) teeth were treated with 5 ml of 17% EDTA only for 1 minute.
- Group B: Eight (8) teeth were treated with 5 ml of 17% EDTA A for 1 minute then irradiation with 2 W continuous wave of 810 nm diode laser (VERONA, Italy).

A control group of two (2) teeth were irrigated only with 5 ml of sterile saline for 5 minutes and show the presence of the smear layer.

Irrigation procedure. Irrigation was performed using a 27 gauge side vented needle (Appli Vac, Vi Vista Dental Products, and USA). The needle was placed within 1-2 mm of the working length in each canal. Canals were then irrigated with 2 ml of 2.5% NaOCl for 1 min between each instrument change. After instrumentation, canals received a final flush of 5 ml of 17% EDTA (Merc, Darmstad, Germany) for 1 min. This was followed by a flush of 5 ml of distilled water for 1 min to remove any remnants of irrigating solutions and the canals were then dried with sterile paper points (Dentsply-Maillefer, Ballaigues, Switzerland).

Laser irradiation. The 810-nm diode (gallium aluminum arsenide) (VERONA, Italy) laser was used for irradiation in group B with an output power of 2 W. A 200 μ fiber optic tip was activated and moved from coronal to apical direction (2 mm/s) for a total of 7 s. The fiber optic tip was held in an oblique direction to the root canal dentin to mimic the clinical situation.

SEM and EDX analysis. All the prepared teeth were then longitudinally grooved using a diamond disk (Diatec Swiss Dental, Switzerland) to obtain a total of 36 halves.

Samples from both groups were irrigated with 5 ml of distilled water for 1 min and subsequently dehydrated at 120°C in a hot air oven for 30 min. Specimens were then mounted on aluminum stubs, sputter-coated with gold and introduced into the vacuum chamber of a SEM LEO 440i, Tokyo, Japan). Photomicrographs of the root canal walls were then taken at 2 mm, 7 mm, and 12 mm depth from the apex. Apical, middle, and coronal thirds were specified accordingly.

The photomicrographs were taken for each third at 1000x and 2000x. The photomicrographs were evaluated by two independent evaluators who were unaware of the experimental groups to which the samples belonged. To guide examiners during morphological

and ultra-structural analyses, scores were established based on images obtained under the SEM.

The amount of smear layer was graded between 1 and 4 according to the method described by Rome et.al.[21] EDX analysis of the same samples was done under EDX analyzer (Oxford Inc, Concord, MA,USA) to assess the Ca, P and Mg content and to determine the Ca/P ratio.

Statistical analysis. For the whole sample, Wilcoxon signed rank test was used to evaluate the smear layer score, then paired t-test was used to evaluate the smear layer and the mineral contents at the coronal, middle and apical third of tested sample. *P*<0.05 was considered statistically significant. The statistical analysis was done by using SSPS 21 (Chicago, IL, USA).

Results

SEM evaluation of smear layer. According to Rome et al. [21] scoring criteria, more than 70% of the examined samples in both groups showed significant removal of the smear layer in coronal, middle and apical third (score1) of the examined teeth (Figure1A and B).

All samples in the EDTA+ Diode laser treated group (Group B) recorded scores 1&2 and none recorded scores 3&4 However, no statistically significant difference was detected between the two groups (Table 1. *P*>0.05).

Dentinal changes. When evaluating the degree of erosion, more than one third of the specimens (30%) had erosion in the inner dentin layer for samples treated with EDTA alone. Diode laser +EDTA treated group demonstrated dentinal erosion in about 42% of the tested sample.

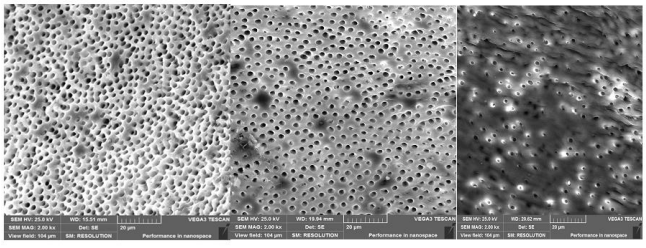

Figure 1A. SEM of Coronal, Middle & Apical Thirds of EDTA Treated Group (Original Magnification at 2000X).

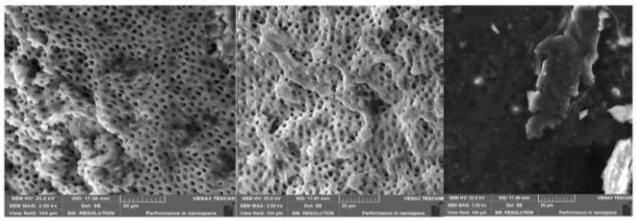

Figure 1B. SEM of Coronal, Middle & Apical Thirds of Diode+EDTA Treated Group (Original Magnification at 2000X).

Group	Coronal (%)	Middle (%)	Apical (%)	Total (%)	Z value	*P* value
Group A						
S1	6 (75)	5 (62.5)	6 (75)	70.8		
S2	0 (0)	3(37.5)	2 (25)	20.8		
S3	1 (12.5)	0(0)	0 (0)	4.2		
S4	1 (12.5)	0(0)	0 (0)	4.2		
Group B						
S1	6(75)	7 (87.5)	4(50)	70.8	-0.509	0.61
S2	2(25)	1(12.5)	4(50)	29.2		
S3	0 (0)	0 (0)	0 (0)	0 (0)		
S4	0 (0)	0 (0)	0 (0)	0 (0)		

Table 1. SEM Results of the Tested Groups.

For the inter tubular dentin changes in term of cracks and conjugation the less changes were observed in teeth treated with EDTA treated group when compared with Diode +EDTA treated group (12.5% & 21% respectively).

EDX findings. Regarding mineral analysis, EDX analyzer aimed toward the center of the SEM image of all tested sample (Figure 2).

Table 2 highlights the Ca, P and Mg levels in the coronal, middle and apical thirds of the root canal. Calcium & phosphorus content was the lowest in Diode +EDTA group than EDTA alone treated group, Mg levels remain nearly the same in both groups. Regarding the middle third of the canal, both calcium and phosphorus levels showed marked reduction in their contents in Diode+EDTA group when compared with EDTA treated group (*P*0.05). Mg levels was the lowest in the diode+EDTA when compared with EDTA group (*P*<0.05). In apical third of the canal, it has been shown that both Calcium and Phosphorus were greatly reduced when the root canal is treated with Diode+EDTA. Mg levels were the lowest in apical third of Diode+EDTA treated group. Regarding Ca/P ratio there was no significant changes in both groups in coronal, middle and apical third (Table 2 *P*>0.05).

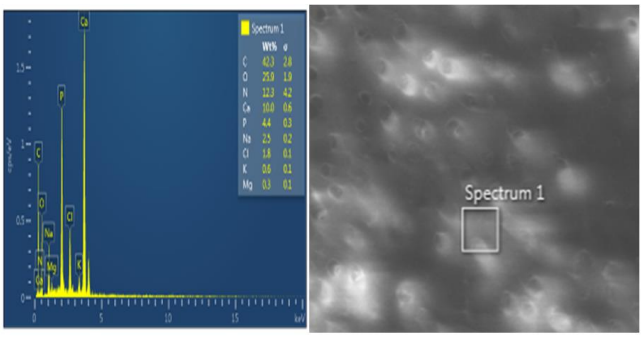

Figure 2. Mineral Content Analysis by EDX Analyzer.

Group	Ca	P	Mg	Ca/P
Group A Coronal Portion	Mean ±SD 16.9±16.6	Mean±SD 6.0± 4.61	Mean±SD 0.4± 0.14	Mean±SD 2.6± 2.04
Group **B** Coronal Portion	2.88 ± 8.1	1.84 ±4	0.33±0.3	1.81±0.51
P value	0.02*	0.02*	0.4	0.13
Group A Middle Portion	16.38±12.45	7.41± 4.78	0.50± 0.18	2.17± 0. 4
Group **B** Middle Portion	5.15 ± 4.3	2.24± 1.75	0.25±0.08	3.76±5.27
P value	0.06	0.05*	0.04*	0.39
Group A Apical Portion	8.88 ±6.46	4.4±3.23	0.36±0.11	2.02±0.32
Group **B** Apical Portion	6.24±5.66	2.43±2.1	0.22±0.1	3.89±5.32
P value	0.39	0.2	0.29	0.35

Table 2. Mineral Content Values & Ca/P Ratio of the Test Group.

Discussion

The present study was carried out to investigate the effect of 810 nm diode laser along with 2.5% NaOCl and 17% EDTA irrigation on removal of the smear layer from root canal walls, as well as to examine their effects on dentin structure using SEM and measuring the mineral contents (Ca, P, Mg) using EDX.

With regards to smear layer, in the present study both tested groups showed marked smear layer removal on root surfaces in all coronal, middle and apical third compared to the positive control. However, the use of 810 nm diode laser to irradiate of root canal dentine along with 2.5% NaOCl and 17% EDTA irrigants has a minimal synergistic effect in smear layer removal. There was no significant difference between with 2.5% NaOCl and 17% EDTA treated group and the with 2.5% NaOCl,17% EDTA and diode laser treated group (*P*> 0.05).

Recent studies have suggested diode laser as an adjusted to root canal disinfectant due to it is antibacterial efficiency.[16-18] Other studies have been claimed that diode laser works efficiently at lower power with less heat production with power output ranging from 0.5 W to 7 W[22] with better penetration of into the dentinal tubules compared to other laser types.[23]

According to the literature, the use of 810-980 nm diode laser irradiation of root canal dentin showed ultra-morphological changes that ranged from complete smear layer removal to dentin fusion.[24,25] The result of our study was in contrary to previous studies[19,20,25,26] which demonstrate a significantly better removal of smear layer with the use of 810-980 nm diode laser irradiation together with 2.5% NaOCl and 17% EDTA. An explanation to this contradiction is the differences in the power of setting used. (i.e low power of setting “2W pulsed mode” used in the current study). Variables such as shape and size of the irradiation tips and modes & frequencies of irradiation are also considerable importance. In their studies Saraswathi et al.[20] showed significantly better smear layer removal with diode irradiated group, however teeth were irradiated after sectioning, this model dose not accurately simulate clinical situation. The inconsistency of study models and differences is sample sizes can also contribute to the results outcome.

The use of 17% EDTA with 2.5% NaOCl usually lead to erosion effect in inner wall of dentin. This erosion was usually due to the fact that EDTA takes 2 Ca^{++} from inner dentin wall which is considered as one of the main disadvantages of using 17% EDTA as root canal irrigant.[24] While erosion was seen in EDTA-treated teeth, an increase of erosion degree was noted on root canal walls after additional irradiations with diode laser, similar findings were seen in other studies.[20,27,28]

Regarding the mineral content, previous studies have shown that 17% EDTA can demineralize the inorganic parts of dentin.[29] This finding was consistent with that of a present study especially at apical part with the Ca and P content where markedly reduced when compared with that in middle and coronal thirds.

Although the calcium & phosphorus contents was even lower in Diode group, the present study have demonstrated the use of 810 nm diode laser along with 2.5% NaOcl and 17% EDTA did not have any effect on the Ca/P ratio of root dentin.

Conclusions

Hence, in conclusion, the result of this study showed that an 810 nm diode laser irradiation of root canal dentin along with NaOCl and EDTA irrigation, has no significant effect on removal of smear layer. It can cause more dentine erosion with slightly more additional loss of mineral content compared to the use of NaOCl and EDTA alone.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

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