The Effect of Using 1.7 W of 940 nm Diode Laser on Radicular Dentin Permeability and Smear Layer Removal

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Abstract-- Background: Near-infrared diode lasers can be used for several applications, which range from disinfection to smear layer removal in endodontics. This study aimed to evaluate the effect of using 1.7 W of 940 nm diode laser on root canal dentin permeability and removal of the smear layer. Method: twenty-eight extracted human mandibular premolars teeth were instrumented up to X4 file of ProTaper next rotary system (Dentsply Maillefer, Ballagues, Switzerland) irrigated with 1 ml 5.25% NaOcl between files and then randomly divided into 2 groups (n = 14 for each group) control group and diode laser group. Afterward, the roots were coated with nail varnish to made them impermeable and then filled with 2%methylene blue dye, divided horizontally into three segments representing the apical, middle, and coronal thirds then examined under stereo-microscope. Using analytical software, the root section area and dye penetration area were measured, and then, the percentage of clear dye penetration area was calculated. Moreover, scanning electron microscope investigations were accomplished. The non-parametric Mann-Whitney U test was accomplished. Although the statistical analysis showed no significant difference between the two experimental groups over the three root thirds but the dye penetration in diode laser group was significantly higher over the whole root length compared to control group. Scanning electron micrographs of diode laser group showed a distinctive removal of smear layer with preservation of the annular structure of dentinal tubules, while control group produced uneven removal of smear layer, in efficient cleanliness especially in the apical third.

Index Term-- Diode laser, Smear layer, Permeability, Root canal.

1. INTRODUCTION

Although lasers in near infrared region are poorly absorbed neither by minerals nor by water allowing it to penetrate deeply (about 500 μm) and transmit through the dentine to give the disinfection action [1]. It seems necessary to mention that the degree of transitivity of 810-nm diode laser through 1 mm dentin block is approximately 17%. Many investigations proved that both 940 nm and 980 nm diode laser can induce a cavitation bubbles if they are combined with an aqueous irrigant [2, 3].

Cavitation is the formation of vapor-containing bubbles inside a fluid. This process results in the formation of pressure waves/shockwaves characterized by rapid changes in pressure at high amplitude [4]. A forced collapse of bubbles causes implosions that impact on surfaces, causing shear forces, surface deformation, and removal of surface material [5].

The effective removal of organic and inorganic tissue remnants along the complex root canal system raises the success rate of endodontic therapy [6]. Mechanical preparation of root canals will be formed dentin chips and debris that were called smear layer which was if left caused blocking of the dentinal tubules[7, 8].

Presence of smear layer reduce the inter-locking mechanism between filling material and dentin walls [9, 10]. Mechanical preparation of root canal with saline irrigation could not be eliminate microorganisms from infected root canal system, so that, the use of satisfactory irrigation is mandatory to reduce bacteria and complete cleaning effect [11, 12].

The main goal of irrigant solutions is disinfection, dissolving pulp tissue, and enhance mechanical debridement of the canal by flushing out the debris, but there is no single irrigant that achieve all those goals[13]. So the way that is widely used is the successively using of sodium hypochlorite and ethylene di-amine tetra-acetic acid (EDTA) solutions[14]. In spite of this widely used of conventional irrigation method but it has not been sufficiently effective in removing debris and smear layer from the irregularities of the canal[15].
For these reasons in current study, diode laser was used to evaluate its effect on root canal dentin permeability and removal of smear layer.

MATERIALS AND METHOD

Samples collection and preparation:
In current study twenty-eight single-rooted mandibular premolars freshly extracted for orthodontic demands were collected and selected from the age group (18 to 30 years-old) patients. The teeth have been cleaned by washing under distilled water and then soft tissue remnants were removed using ultrasonic scalar carefully, then stored in distilled water containing 0.1% thymol, then the crowns of whole samples were sectioned to obtain roots of same standardized length of 14 mm using double face diamond discs fitted on conventional speed handpiece with water coolant. Canal orifices flared with small round bur of conventional speed handpiece, the working length was determined with size #10 ISO K file 1 mm from the apex which was 13 mm and, then canals were prepared mechanically by rotary system protaper Next (Dentsaply, Germany) till size X4. Chemical irrigation was achieved by irrigation needle 29-gauge, (NaviTip; Ultradent,UT, USA), .27 mm length with 1 mL NaOcl 5.25% between files and finally 1 mL distilled water and dried with paper point protaper Next X4 (dentsaply, Switzerland).

Final irrigation protocol:
After biomechanical preparation of canals the specimens were divided into two groups each group of fourteen teeth as follows:
G1 (n=14): control group, the canal filled with 1mL EDTA 17% (PD, Switzerland) for 1 min., then rinsed with 5 mL NaOcl 5.25% left inside the canal for 5 min.
G2 (n=14): Diode laser 940 nm, 1mL EDTA 17% for 1 min., then rinsed with 5mL NaOcl 5.25%, and the 940 nm diode laser was delivered by fiber-optic endodontic tip, E2 with the tip diameter of 200 μm. Specimens were irradiated with 1.7 W panel setting which is in the power-meter display equal to 1.08 W, CW mode; the fiber tip inserted 2 mm from the apex, in contact mode, and helical movement in a speed of 1mm/s from apical to cervical direction, and repeated two more times according to manufacturer instructions.
After that, specimens of both groups were irrigated with 5 mL distilled water and dried with size X4 paper point (protaper Next, Dentsaply, Switzerland).

Scanning electron microscopic examination (SEM):
Four samples from each group used to investigate ultra-morphological changes, smear layer, and debris removal by SEM. A diamond disc at low speed was used to groove the roots through the buccal and lingual surfaces. Then roots were split longitudinally with a chisel and mallet into two halves, one half was examined and the other was discarded. The samples fixation and dehydration were done according to the protocol used by Marchesan et al. (3) Later on the specimens were fixed on aluminum stubs and metallized with a layer of gold, using vacuum evaporation. The samples were analyzed by SEM (Inspect S50, Czech Republic) and were observed under 1000 magnification.

Permeability test:
This test was done to evaluate the area of dye penetration in apical, middle, and coronal thirds of root canal. Root apex was sealed with wax. Roots surfaces were coated with two layers of nail varnish and left to dry. After that the specimens were filled with 2 % methylene blue dye injected by hypodermal syringe and left for 20 min. at room temperature. When this time had been finished, they were rinsed under running water and the root canals were dried with absorbent paper cones until the cone appeared white. The samples were sectioned horizontally into three parts representing the apical, middle, and coronal thirds. The first 2 mm staining from the cemento-enamel junction was cut and excluded from microscopic evaluation. The prepared root sections were observed under Stereomicroscope (Hamilton, Altay Scientific, Rome, Italy) under the magnification of x40. Then the area of dye penetration and the total root section area were calculated and analyzed by using the measure pictures V 1.0 software (CAD-KAS Kassler Computer software GbR, Germany), then the dye-penetrated area was then multiplied by 100% and divided by the root third area, resulting in the percentage of dye penetration in each root third.

Results: Data that represent permeability of root canal dentin expressed as percentage of dye penetrating area at three level of root canal are displayed as follows:
The summary of descriptive and statistical test for the percentage of dye penetrating area between groups is shown in Table (1):

<table>
<thead>
<tr>
<th>Groups</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>100</td>
<td>46.535</td>
<td>33.048</td>
</tr>
<tr>
<td>Diod Laser</td>
<td>23.080</td>
<td>100</td>
<td>71.605</td>
<td>22.513</td>
</tr>
</tbody>
</table>

From the table above the high mean percentage of net dye penetration was obvious in Diode laser group in comparison with control group and statistically there was highly significant difference between the two groups regardless the site.

In (Table 2): Descriptive statistics between two groups within each site (apical, middle, and coronal).
Table II
Descriptive and statistical test of permeability between groups within sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Groups</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apical</td>
<td>Control</td>
<td>.000</td>
<td>100.00</td>
<td>33.21</td>
<td>35.34</td>
</tr>
<tr>
<td></td>
<td>Diod Laser</td>
<td>23.08</td>
<td>100.00</td>
<td>58.25</td>
<td>26.63</td>
</tr>
<tr>
<td>Middle</td>
<td>Control</td>
<td>4.22</td>
<td>100.00</td>
<td>45.07</td>
<td>32.49</td>
</tr>
<tr>
<td></td>
<td>Diod Laser</td>
<td>47.31</td>
<td>100.00</td>
<td>70.73</td>
<td>14.77</td>
</tr>
<tr>
<td>Coronal</td>
<td>Control</td>
<td>23.64</td>
<td>100.00</td>
<td>61.32</td>
<td>27.78</td>
</tr>
<tr>
<td></td>
<td>Diod Laser</td>
<td>58.25</td>
<td>100.00</td>
<td>85.83</td>
<td>16.79</td>
</tr>
</tbody>
</table>

The data were collected and statistically analyzed using the Statistical Package for the Social Sciences (SPSS, version 21). Shapiro–Wilk test: test the normality distribution of quantitative variables. Mann–Whitney U test (non-parametric test) was done to test whether there is a statistical difference between the two groups.

For permeability test stereomicroscopic images were taken after a transversal cut into three parts corresponds to root thirds as see in (Fig 1).

For the Diode laser group SEM micrographs showed irregular dentinal surfaces in which the smear layer was removed, with evidently open dentinal tubules, and no signs of melting or carbonization. Protrusion of dentinal tubules toward the laser irradiated surface was observed, (Fig. 3).

**DISCUSSION**

Syringe irrigation is a typical method for root canal irrigation; however, Peeters et al. [16] in 2011 stated that this method is not effective in the apical third of the root canal. It is difficult to entirely eliminate the remaining smear layer, especially in the apical third due to the smaller size of the apical third compared with the other regions hinders the circulation and action of the irrigating solutions [17]. Therefore, current study aimed to evaluate the effect of the 940 nm Diode laser against conventional syringe irrigation on root canal dentin permeability and smear layer removal. Previous studies have investigated the efficacy of different concentrations of EDTA in combination with NaOCl for smear layer removal, and currently, this is generally accepted as the most effective method [18] justifying its use in the present study. The control group treated with EDTA exhibited smear layer removal in some areas of the canal mainly in the middle third. While in the experimental group and by using diode laser of 940 nm to irradiate a whole root canal results in smear layer removal in approximately whole area especially apical and middle third.

Moreover, many researches stated an increase in the permeability of dentin after exposure to diode laser. These
findings were mainly resulted from combining a chemical irrigant like EDTA or NaOCl with diode laser, taking into account when water was set as an irrigant solution with diode laser dye penetration that was much lower [19, 20, 21].

Because of its practical application and potential applicability, the 980-nm diode laser has been evaluated in Endodontic field [22-23].

The mechanism for the laser activation of irrigating solutions originates from the absorption of laser energy, the formation of vapor bubbles, the collapse of the bubbles, acoustic streaming, and finally cavitation [24].

CONCLUSION

Based on the result of this in vitro study it can conclude that, root canal dentin irradiated with 940 nm diode laser CW mode power of 1.7 W in speed of 1mm/s of three cycles with resting time of 5 s while NaOCl inside the canal is effective in raising the percentage of root canal dentin permeability with superior statistical results in comparison with control group. A smear layer was removed effectively from root canal dentin walls without any signs of melting or carbonization with preservation of annular shape and protrusions of dentin surface.

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Author Disclosure Statement

No conflicting financial interests exist.

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