

Comparative study of diode lasers used for two time intervals for the treatment of teeth with vertical root fractures

Maram E. Khallaf, Doaa M. Saadony

Department of Restorative and Dental Materials, National Research Centre, Cairo, Egypt

Correspondence to Maram E. Khallaf, BSc, MSc, PhD, Department of Restorative and Dental Materials, National Research Centre, Dokki, Cairo, 12622, Egypt.
e-mail: maram_3@yahoo.com

Received: 30 April 2019

Revised: 20 October 2019

Accepted: 21 October 2019

Published: xx xx 2019

Journal of The Arab Society for Medical Research 2019, 14:57–61

Background/aim

Vertical root fracture treatment is considered a challenge in endodontics. And no single approach up till now gives satisfactory results. The present study aimed to compare the effect of a 970 nm diode laser in a continuous wave at different time intervals with a resin-based sealer or a resin-based sealer only on sealing of vertical root fractures of extracted teeth.

Materials and methods

Thirty upper single-rooted teeth were sectioned below the cement enamel junction. A groove of 5 mm length and 1 mm width was done at the root surface. Specimens were divided into three groups (10 each). Group 1 using sealer only, group 2 using a 970 nm diode laser irradiation at a power of 1.5 W at continuous mode for 60 s, and group 3 using a 970 nm diode laser irradiation at a power of 1.5 W and at continuous mode for 90 s. In groups group 2 and group 3, the root fracture line was filled with a sealer followed by diode laser irradiation and the gap size was examined by scanning electron microscopy. Temperature rise at the root surface was also measured using a temperature meter. Statistical analysis was carried out using one-way analysis of variance and the Tukey test ($P < 0.05$).

Results

The statistical analysis showed that using laser with a 1.5 W/90 s group 3 showed the statistically least fracture gap ($1.22 \mu\text{m}$) while group 1 showed a gap of $8.57 \mu\text{m}$ and group 2 a gap of $2.44 \mu\text{m}$.

Conclusion

The present study concluded that the application of a 970 nm diode laser at 90 s decreased the gap between the sealer and the root surface at the fracture line in extracted teeth.

Keywords:

diode laser, root fracture, scanning electron microscope, sealer

J Arab Soc Med Res 14:57–61

© 2019 Journal of The Arab Society for Medical Research
1687-4293

Introduction

Vertical root fracture (VRF) can be considered as one of the hardest conditions to diagnose and to treat effectively. It has several causes including pin and post placement, seating of intracoronar restorations that could exert forces on the remaining coronal and root structures and excessive loads on the spreader during lateral condensation of the gutta-percha [1].

Up till now, treatment of VRF has focused on filling of the crack line with materials to block communication between the root canal and the periodontium. Several materials have been suggested including glass-ionomers, adhesive resin, bone cement, and mineral trioxide aggregate. However, the problem facing most of these materials is lack of a strong bond to dentin or the low biocompatibility of some of these materials. Unfortunately, the long-term prognosis of VRF is poor and eventually extraction of the involved tooth is the only solution [2].

Since laser has been introduced in dentistry 40 years ago, its applications and uses are continuously growing. Diode laser is considered to be one of the most commonly used lasers in the dental field. Energy is transmitted through thin flexible fibers that can fit the size and curved shapes of the root canals. Diode laser wave lengths have good penetration potential together with low interaction with water and hydroxyapatite [3,4]. It was also documented that there is reduction in the microbial count in inaccessible areas such as dentinal tubules after diode laser irradiation [5,6]. A study reported that diode lasers (of 810–980 nm wavelength range) can penetrate to a depth ten thousand times greater than that of an erbium-doped yttrium aluminum garnet (Er:YAG) laser,

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

and its effect can be seen deeper within the dentinal tubules [7].

The thermal effect induced by diode laser application in dental hard tissues is considered to be very limited. Nevertheless, a glaze layer is produced, which allows for a strong bond against mastication. Also, a hermetic seal is found for fractures with small gaps [8].

Nowadays diode laser is highly recommended in the dental field due to various benefits including its economic advantage; it also aids in sealing; bactericidal effect and the rise of temperature while using a diode laser was shown to be in the acceptable range for permanent teeth [9]. It is important to consider the heat that the laser produces when used in endodontics as it may damage the periodontal structures around the tooth [10].

In laser-assisted root canal treatment, the type of laser and radiation protocol can cause temperature increase at the external root surface that may have an effect on the alveolar bone. Eriksson and Albrektsson described the increase in temperature of more than 47°C to be unsafe for periapical structures [11]. Accordingly, Gutknecht *et al.* [12] and Machida *et al.* [13] stated that to avoid damage to bone regeneration or periodontal ligament around the tooth, the temperature of the laser in root canal treatment should not exceed 10°C above the body temperature. The effect of laser on the tooth is influenced by the wavelength, duration of exposure, irradiation mode, power density, and tissue type [14]. The conduction of heat to the tissue surrounding the tooth is also affected by the presence of air or water during irradiation. The apical constriction and the narrow dentin thickness in the apical region are the most vulnerable areas to temperature elevation [11].

Resin-based sealers can also be used to bond to the root canal dentinal wall thus allowing for a good seal which could be used in VRF treatments. However, its use with a laser was not thoroughly studied before. Thus, the aim of this study was to evaluate the effect of a diode laser at an output of 1.5 W with a resin sealer to seal VRFs at different times of laser exposure.

Materials and methods

Materials used

- (1) Dental scaler used was from SONICflex 2000, KaVo Co. (Kavo Bismarckring, Germany).

- (2) Resin sealer used was AdSeal sealer from Meta Biomed Inc. (Chungbuk, Korea).
- (3) Diode laser source used was SiroLaser Advance class III, Sirona Dental (Sirona Bensheim, Germany).
- (4) Temperature meter used was from Jenway 3510 bench pH meter (Jenway, Staffordshire, UK).

Study design

Thirty human maxillary incisors were selected after being examined macroscopically and radiographically to have straight root with complete apices. Soft tissue debris was removed from the surface using a dental scaler and the teeth were stored in 0.1% thymol. Later, the teeth were washed under running water for 24 h to remove thymol residues. Decoronation was done 1 mm below the cemento-enamel junction with a high-speed fissure bur with a copious coolant. Specimens were divided randomly into three equal groups (10 each) as follows:

- (1) Group 1: groove filled with a sealer only.
- (2) Group 2: groove filled with a sealer and irradiated with laser for 60 s.
- (3) Group 3: groove filled with a sealer and irradiated with laser for 90 s.

Ethical consideration

All procedures were done in accordance with the Ethics Committee of the National Research Centre in accordance with Helsinki Declaration 1964. Teeth collected were indicated for extraction for treatment purposes from autonomous patients of the outpatient clinic in the National Research Centre. All patients were informed about the practical steps of this study and approval was signed.

Methods

Preparation of the groove

A longitudinal groove with dimensions of 1 mm width, 5 mm length, and a depth of 1.5 mm had been done using a high-speed fissure bur on either the labial or lingual surface. 17% EDTA was used to remove the smear layer followed by ultrasonic vibration for 2 min. The specimens were rinsed with copious distilled water and air.

Adseal sealer was mixed according to the manufacturer's instructions and packed in groups 1, 2, and 3. In groups 2 and 3 the groove filled by the sealer was irradiated using diode laser for 60 s in group 2 and 90 s in group 3. The laser source was a gallium-aluminum-arsenide (Ga AlAs) diode laser at a wavelength of 970 nm and at a power of 1.5 W with a frequency of 100 Hz. It was

provided through a flexible optic fiber of diameter 320- μm with a straight handpiece in a noncontact technique; continuous forward-backward movement was performed.

Temperature rise measurement

The temperature rise was measured using a PH/mV/temperature meter a thermocouple held along the root surface either at the apical third, middle third, or the cervical third on the proximal surface. The proximal surface of the tooth was chosen because the thickness of the root was least on the proximal surface and so more sensitive to temperature changes. The thermocouple was connected via a converter to a multimeter that displayed temperature readings with precision. The room temperature was kept constant at 20°C [11]. During tests, the tooth was held between the thumb and the index finger so that they were in contact with most of the root surface, leaving free the area where the thermocouple was attached. When held with the fingers, the temperature of the tooth increased slightly above the room temperature, which was taken as the starting temperature. The fiber of the laser was inserted into the wet root canal and activated at designated power settings. The laser tip was inserted till the working length and was gradually withdrawn 2 mm every second in a circular motion, according to Acchen University protocol, which gave the maximum temperature recorded by a PH/mV/temperature meter. Readings were recorded at 1.5 W continuous modes. It is important to note that there was a loss of power at the distal end of the fiber tip, mainly due to the joints and loss of transmission through the fiber used, but this loss was standardized for all the samples.

Preparation for the scanning electron microscopic examination

The specimens were serially dehydrated in graded ethanol solutions (50, 60, 70, 80, 90, 95, 100% ethanol) at 45 min intervals, and then mounted on aluminum stubs and examined under a Hitachi scanning electron microscope (SEM) (Model S-800, Tokyo, Japan). The gap width at the groove interface was measured.

Statistical analysis

The mean and standard deviation values were calculated. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests and showed parametric (normal) distribution. One-way analysis of variance followed by Tukey post-hoc test was used to compare between more than two groups in nonrelated samples. The significance level was set at P less than or equal to 0.05. Statistical analysis was

performed with IBM SPSS Statistics version 20 for Windows (SPSS statistics version 20, IBM, Armonk, New York, USA).

Results

Results of the mean and SD of the gap width for the experimental groups are shown in Table 1. There was a statistically significant difference between the three groups where $P < 0.001$. Group 1 showed the largest gap (8.57 ± 0.80) followed by group 2 (2.40 ± 0.11) and the smallest gap was found in group 3 (1.22 ± 0.13).

SEM images of groups 1, 2, and 3 are shown in Fig. 1. SEM shows the gap found between the sealer and the tooth surface which indicates the efficacy of the sealing of different groups. Images show that the gap was found to be largest in group 1 (sealer only) where the gap was found in all images along the interface between the sealer and the tooth surface followed by group 2 (sealer with laser for 60 s) where areas of complete sealing were found in some samples; however, most of the samples showed a small gap between the sealer and the tooth surface and least in group 3 (sealer with laser for 90 s) where almost no gap was found in some samples and minimal gap was found in most of the samples indicating complete sealing of the gap in this group.

The mean results of the temperature rise at the root surface measured by the temperature meter was found to be less for group 2 (sealer and diode laser for 60 s; 43 °?) than group 3 (sealer and diode laser for 90 s; 53 °?) while group 1 (sealer only) had no temperature rise than the starting temperature as no laser was applied during treatment of the VRF (Fig. 2).

Discussion

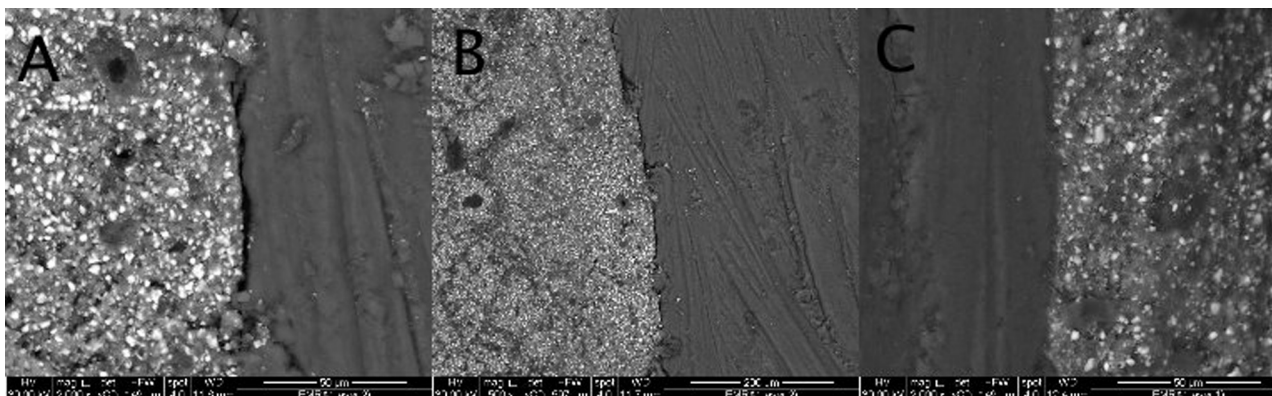
Endodontically treated teeth are susceptible to fracture because of their weakened structure. It was previously attempted to use diode laser alone for the treatment of root fractures, but it was found to be unsuccessful as it required heating of the fracture line to the high melting

Table 1 Mean and SD values of the gap distance in the three groups

Groups	Gap distance	
	Mean (μm)	SD
Group 1: sealer only	8.57 ^a	0.80
Group 2: sealer and diode laser 60 s	2.40 ^b	0.11
Group 3: sealer and diode laser 90 s	1.22 ^c	0.13
<i>P</i> value	<0.001*	

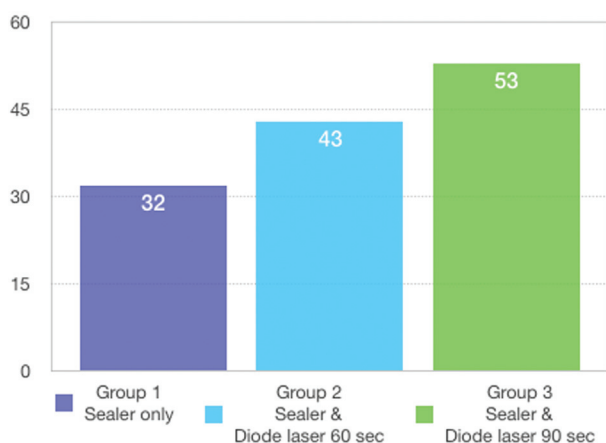
Means with different small letters (a, b, c) in the same column indicate statistically significance difference at $P < 0.05$.

Figure 1



Scanning electron microscope images showing wide gap distance in group 1 (sealer only) (A), a smaller gap in group 2 (sealer and diode laser 60 s) (B), while there is almost no gap in group 3 (sealer and diode laser 90 s) (C).

Figure 2



Bar chart representing the temperature rise of the three groups in degree Celsius.

point of dentin. However, the use of a sealer could allow for heating the fracture line to the low melting point of the sealer thus ensuring sealing of the fracture line without causing any damage to the surrounding tissues [15]. It is to be mentioned that the temperature elevation induced by laser irradiation is not a concern for the tooth itself as the tooth with root fracture is usually nonvital.

Lasers emitting wavelengths in the infrared region are proposed for various dental hard tissue applications because enamel, dentin, and cementum contain hydroxyapatite. Hydroxyapatite absorbs wavelengths in the infrared region (9.0–11.0 μm), this is due to the presence of phosphate, carbonate, and hydroxyl groups within the crystal structure. The wavelength of the diode laser is within the infrared range; it also has a thin, flexible light-conductor fiber and so it is recommended for endodontic treatments [16,17].

SEM evaluation was done for multiple planes until indication of fusion of the sealer with the fracture line was seen. SEM evaluation also showed some heat induced cracks. Some areas revealed cementum melting and re-solidification or even separation from underlying dentin.

In a comparison of the results obtained from SEM, it was found that SEM micrographs of group 3 (sealer and diode for 90 s) showed less gap, followed by group 2 (sealer and diode for 60 s), while SEM showed that there is a large gap between the sealer and the fracture line of root canal wall in group 1 (sealer only). This could be explained by the fact that the use of a sealer together with the diode laser allows for heating of the fracture line until the melting of the sealer, thus ensuring sealing of the fracture line with minimal gap formation [15] (needs explanation and reference).

Laser parameters used in this study were the manufacturer's parameters set at continuous mode and 100 Hz; these parameters were also used in a previous study by Alfredo [8], who found that the 980 nm diode laser irradiation of root canal dentine with power 0.5 and 3.0 W using frequency continuous wave at 100 Hz frequency, increased the bond strength of AH Plus sealer, but did not affect adhesion of Epiphany sealer. A study by Macedo *et al.* [18] have shown that agitation of EDTA using the 980 nm diode laser improved the bond strength of the epoxy-based sealer to the root canal walls.

An important issue with the use of lasers is heat production; different technical and dental procedure strategies were suggested to control it [15]. It was found that the temperature rise depends on the type

of laser used and also the procedure to be done. The rise is said to be between 10.3 and 14.4°C [17]. In-vitro studies found this temperature to be 47.3–51.4°C at the tooth surface. The maximum acceptable temperature without causing any harm would correspond to 54°C, any increase in temperature above this could result in bone necrosis [10]. Ramsköld *et al.* [19] explained that an increase of 10°C above body temperature for 1 min is considered to be the threshold for the safety of the periodontal tissue. The bone is considered more prone to injuries caused by temperature elevation because of its lower degrees of vascularization when compared with periodontal membrane [17]. Thus, it is mandatory to know the limit of temperature rise at the root surface before treatment is attempted in clinical situations. The previous studies have shown that the alveolar bone is irreversibly damaged if temperature increased 10°C above the body temperature for 1 min [10,11]. Our results showed that when laser power is 1.5 W in a continuous mode, using a radiation duration of 60 or 90 s the maximum safe temperature was not exceeded. If we added to that the body effect of cooling by circulation and heat dissociation, the used powers would be very safe.

In all thermal experiments of this work, the canal was totally free of any blood and filled with irrigants during laser application. Because this laser is highly absorbed by hemoglobin and if blood remnants were present it would cause thermal damage, also presence of irrigation in the root canal helps in laser energy distribution to gain the best results and avoid point damage in dentin walls [20]. The irrigants can also work as cooling agents after laser application as they help the root to return to its baseline temperature faster than allowing heat to dissipate passively [19].

Conclusion

Within the limitations of this study, it is possible to conclude that the 970 nm diode laser at 90 s with a sealer could seal the fracture line of the VRF in extracted teeth.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- Chai H, Tamse A. Vertical root fracture in buccal roots of bifurcated maxillary premolars from condensation of Gutta-percha. *J Endod* 2018; 44:1159–1163.
- Wang Y, Lee B, Tseng C, Lin F, Lin C. In vitro study of root fracture treated by CO₂ laser and DP-bioactive glass paste. *J Formos Med Assoc* 2008; 107:46–53.
- Wang X, Sun Y, Kimura Y, Kinoshita J, Ishizaki N, Matsumoto K. Effects of diode laser irradiation on smear layer removal from root canal walls and apical leakage after obturation. *Photomed Laser Surg* 2005; 23:575–581.
- Schoop U, Kluger W, Dervisebegovic S. Innovative wavelengths in endodontic treatment. *Laser Surg Med* 2006; 38:624–628.
- Gutknecht N, Franzen M, Schippers M, Lampert F. Bactericidal effect of a 980 nm diode laser in the root canal wall dentin of bovine teeth. *J Clin Laser Med Surg* 2004; 22:9–13.
- Lee B, Lin Y, Chia J. Bactericidal effects of diode laser on *Streptococcus mutans* after irradiation through different thickness of dentin. *Laser Surg Med* 2006; 38:62–69.
- Bornstein E. Near-infrared dental diode lasers. Scientific and photobiologic principles and applications *Dent Today* 2004; 23:102–108.
- Alfredo E. Temperature variation at the external root surface during 980-nm diode laser irradiation in the root canal. *J Dent* 2008; 7:529–534.
- Schoop U, Kluger W, Moritz A, Nedjelik N, Georgopoulos A, Sperr W. Bactericidal effect of different laser systems in the deep layers of dentin. *Lasers Surg Med* 2004; 35:111–116.
- Gutknecht N, Franzen R, Meister J, Vanweersch L, Mir M. Temperature evolution on human teeth root surface after diode laser assisted endodontic treatment. *Lasers Med Sci* 2005; 20:99–103.
- Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. *J Prosthet Dent* 1983; 50:101–107.
- Gutknecht N, Kaiser F, Hassan A, Lampert F. Long-term clinical evaluation of endodontically treated teeth by Nd: YAG lasers. *J Clin Laser Med Surg* 1996; 14:7–11.
- Machida T, Wilder-Smith P, Arrastia AM, Liaw LH, Berns MW. Root canal preparation using the second harmonic KTP: YAG laser: a thermographic and scanning electron microscopic study. *J Endod* 1995; 21:88–91.
- Anic I, Matsumoto K. Dentinal heat transmission induced by a laser-softened gutta-percha obturation technique. *J Endod* 1995; 21:470–474.
- Karatas E, Arslan H, Topcuoglu H, Yilmaz C, Yeter C, Ayranç L. The effect of diode laser with different parameters on root fracture during irrigation procedure. *Artificial Organs* 2016; 40:604–609.
- Depraet F, Bruyne M, Moor R. The sealing ability of an epoxy resin root canal sealer after Nd:YAG laser irradiation of the root canal. *Int Endodon J* 2005; 38:302–309.
- Umana M, Heysselaer D, Tielemans M, Compere P, Zeinoun T, Nammour S. Dentinal tubules sealing by means of diode lasers (810 and 980 nm): a preliminary in vitro study. *Photomed Laser Surg* 2013; 31:1–8.
- Macedo H, Messias D, Rached-Júnior F, De Oliveira L, Silva-Sousa Y, Raucci-Neto W. 1064-nm Nd:YAG and 980-nm diode laser EDTA agitation on the retention of an epoxy-based sealer to root dentin. *Braz Dent J* 2016; 27:424–429.
- Ramsköld LO, Fong CD, Strömberg T. Thermal effects and antibacterial properties of energy levels required to sterilize stained root canals with an Nd:YAG laser. *J Endod* 1997; 23:96–100.
- Anic I, Tachibana H, Matsumoto K, Qi P. Permeability, morphologic and temperature changes of canal dentine walls induced by Nd:YAG, CO₂ and argon laser. *Int Endod J* 1996; 29:13–22.