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Original Research Article

Effect of Laser Irradiation on the Apical Root Canal Sealing

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Abstract: Cleaning and shaping of the root canal system are essential for the successful outcome of endodontic treatment. In addition to the routinely used irrigating solutions, other technologies have been investigated for the treatment of root canal dentine, such as different types of laser systems. ***Purpose*:** The aim of our ***in vitro*** study was to evaluate the effect of different types of laser irradiation (Er:YAG , Nd:YAG, diode laser and photodynamic therapy) on the intracanal dentin and their interference in the apical seal of filled root canals. ***Methodology:*** 72 human single rooted teeth were randomly assigned into 6 groups. Root canal preparation was done using ProTaper Universal rotary system up to F3. The laser irradiation was performed at the end of the traditional endodontic preparation as a final means of decontaminating the endodontic system. Teeth were filled with a core-carrier system ***Guttacore*** (Dentsply, Sirona) and sealer ***AH- plus***. ***Results:*** Statistical analysis showed that all groups had significantly less leakage in apical third than the control group. The laser-treated groups presented better results than *Group II* (Classical disinfection protocol), without statistically significant difference**.** The morphological changes on the apical intraradicular dentin surface caused by Nd:YAG and Er:YAG laser irradiation resulted at least linear dye apical leakage. ***Conclusions:*** Laser irradiation may improve the apical seal of the root canal. Different type of laser systems with appropriate parameters are recommended to be used as an adjunct to the current chemical root canal disinfection protocols.

Keywords: Nd:YAG laser, Er:YAG laser, diode laser, photoactivated disinfection, apical microleakage.

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INTRODUCTION

Cleaning and shaping of the root canal system are essential for the successful outcome of endodontic treatment. The aim is to eliminate microorganisms, tissue remnants and inflammatory irritants from the root canal space using instrumentation and irrigation. The smear layer has a negative impact on root canal sealing, because this combination of organic and inorganic material adheres easily to the root canal wall, reducing the adhesion of sealers. It's total removal improves the adaptation of filling materials to the root canal, increases the bond strength of resin-based endodontic sealers to root dentine and reduces apical and coronal microleakage with most sealers currently used for canal filling by increasing dentin permeability. The permeability of dentin is based on the number and dimension of tubules, according to Pashley (Pashley DH, 1990). During endodontic therapy, dentin permeability can change depending on the treatment technique used (Saleh IM *et al.*, 2002). Permeability can be increased by opening the tubule orifices for better penetration of the sealer or decreased by closing them. Permeability can also be affected by structural alterations that occur after exposure to different irrigating solutions, such as sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), chlorhexidine gluconate, citric acid etc. (Calt, S. & Serper A., 2002; Torabinejad M. *et al.* , 2003; Zehnder M., 2006).

In addition to the routinely used irrigating solutions, other technologies have been investigated for the treatment of root canal dentine, such as endosonics and laser irradiation (Barbosa, P. *et al*., 2014; Blanken, J.W. & Verdaasdonk R.M., 2007; Brugnera-Junior, A. *et al.* 2003). It was determined that various types of lasers suitable for endodontic applications are able to

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remove effectively the smear layer, increase antibacterial activity and promote sealer adhesion. Ultrastructural changes caused by laser irradiation support the increase of endodontic success (Carvalho, C.A. *et al*., 2002).

MATERIALS AND METHODS

The aim of our ***in vitro*** study was to evaluate the effect of different types of laser irradiation (Er: YAG, Nd:YAG, diode laser and photodynamic therapy) on the intracanal dentin and their interference in the apical seal of filled root canals.

72 human single rooted teeth were used for preparation of 72 specimens with equal working length. They were randomly assigned into 6 groups, depending on the desinfection protocol:

Group I*(n=12)*- distilled water (Control group)
Group II*(n=12)*- 2 % NaOCl; distilled water; 17 % EDTA; distilled water
Group III*(n=12)*- 2 % NaOCl; distilled water; 17 % EDTA; distilled water;

Photodynamic therapy (laser λ=660 nm+ FotoSan Agent Low); distilled water

Group IV*(n=12)*- 2 % NaOCl; distilled water; 17 % EDTA; distilled water; laser λ=970 nm
Group V*(n=12)*- 2 % NaOCl; distilled water; 17 % EDTA; distilled water; laser λ=1064 nm
Group VI*(n=12)*- 2 % NaOCl; distilled water; 17 % EDTA; distilled water; laser λ=2940 nm

Root canal preparation was done using *ProTaper Universal rotary system* (Dentsply, Maillefer, Ballaigues, Switzerland) following the recommended sequence (S1, S2, F1, F2 and F3). 2 % Sodium hypochlorite was used as an irrigant to flush the canal clean of dentinal chips and remove the organic debris. 17 % EDTA was used as a lubricant and to help in removal of smear layer and inorganic debris. The canals were also finally thoroughly flushed with distilled water.

The laser irradiation was performed at the end of the traditional endodontic preparation as a final means of decontaminating the endodontic system before root canal filling (Fig.1; Fig.2.). Two separate laser devices were used for the purpose of our study- a diode laser *SiroLaser Blue (Sirona, Germany)* and *AT Fidelis (Fotona, Slovenia).* The protocol for laser application was followed according to the manufacturer's instructions by a well-trained clinician.

Laser irradiation parameters:
Group III- λ=660 nm, 25 mW, 60 sec. (**Diode laser**, SiroLaser Blue, Sirona)
Group IV- λ=970 nm, 1.5 W, 15 Hz (**Diode laser**, SiroLaser Blue, Sirona)
Group V- λ=1064 nm, 1.5 W, 15 Hz, MSP, 300 μ (**Nd: YAG laser**, AT Fidelis, Fotona)
Group VI- λ=2940 nm, 2.4 W, 120 mJ, 20 Hz, VLP, Water-0, Air-2, R14 (**Er: YAG laser**, AT Fidelis, Fotona)

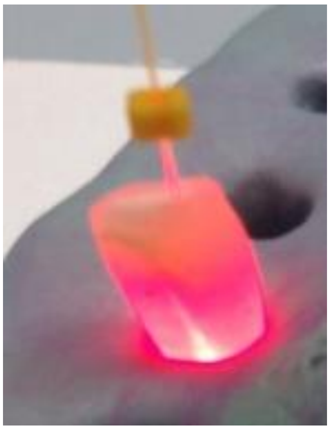

Fig-1: **Diode laser λ=970 nm**

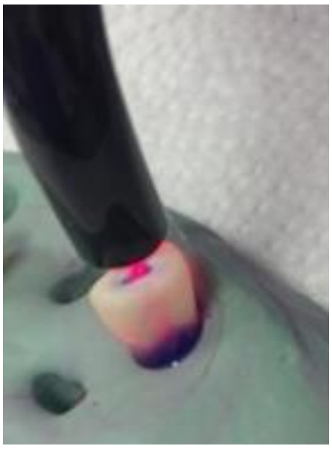

Fig-2: Diode laser λ=660 nm

After irrigation and laser therapy all root canals were dried with paper points and were filled with a core-carrier system *Guttacore (Dentsply, Sirona),* that consists of a cross-linked gutta-percha core, *and sealer AH- plus*. The specimens were stored at 37°C and 100% humidity for one week to allow the sealer to set.

One week after the sealing each root was blotted dry and then covered with two coats of nail polish, except for the apical 2 mm. Nail polish was allowed to air-dry for 24h. The specimens were immersed in 2% methylene blue dye for 72 h.

At this point, the sample was rinsed under the water for 15 minutes. Two opposing longitudinal grooves were made into the dentin on the root surfaces, in order to facilitate the split of the root in half. Each section was then viewed under a stereomicroscope at 20× magnification. Evaluation of the staining of each part was done for three times. The linear dye leakage at the apical third was measured in mm (Fig.3).

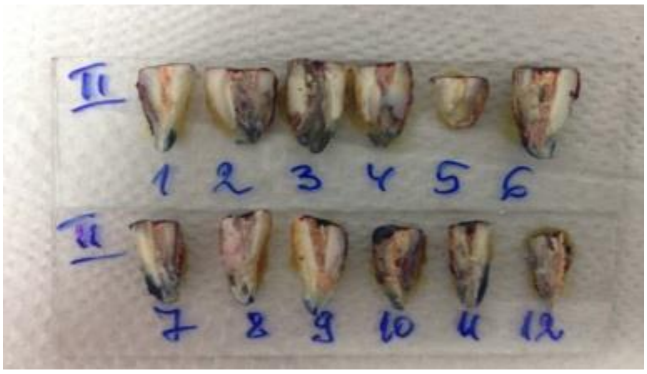

Fig-3: **Experimental specimens**

Statistical analysis was done with SPSS 19.0 statistical software package, using Mann-Whitney and Kruskal-Wallis Tests and p value <0.05 was considered as significant value.

RESULTS

Results of microleakage of dye in each group are presented in Table 1 (Tab.1).

Table-1: Microleakage after root canal filling.

	N	Min	Max	Mean	SD	SE Mean	p-value
I	12	0.0	4.0	1.667	1.073	0.310	
II	12	0.0	5.0	0.958	1.544	0.446	0.037*
III	12	0.0	2.0	0.625	0.678	0,196	0.010*
IV	12	0.0	3.0	0.500	1.000	0,289	0.006*
V	12	0.0	2.0	0.417	0.669	0.193	0.003*
VI	12	0.0	3.0	0.500	0.879	0.254	0.003*

Statistical analysis showed that all groups had significantly less leakage in apical third than the control group *(Group I)*.

The laser-treated groups presented better results than *Group II* (Classical disinfection protocol). The morphological changes on the apical intraradicular dentin surface caused by Nd: YAG and Er: YAG laser irradiation resulted at least linear dye apical leakage. No statistically significant difference was found between group II, III, IV, V and VI (p>0,05).

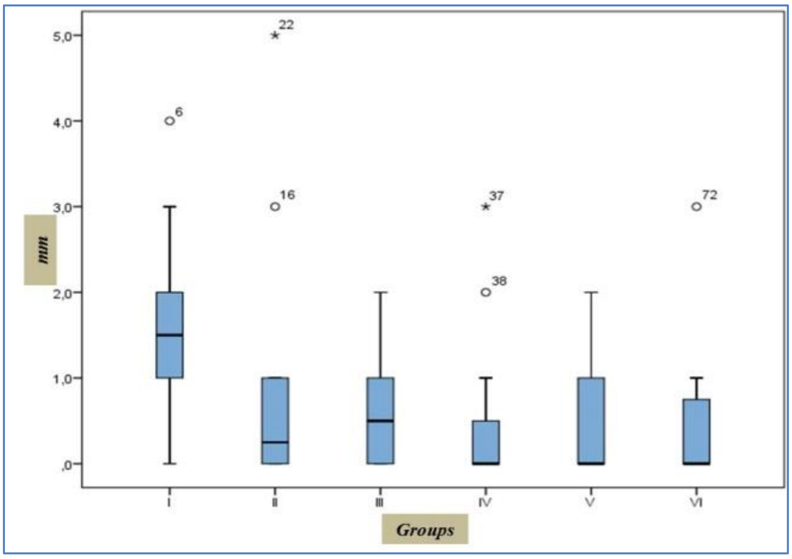

Fig-4: Apical microleakage

The morphological changes on the apical intraradicular dentin surface caused by photodynamic therapy with FotoSan *(Group III*) resulted the most linear dye apical leakage of the laser treated groups (Fig.4).

DISCUSSION

Debris and the presence of a smear layer are detrimental to successful root canal therapy, and microleakage may cause root filling to fail

(Economides, N. *et al*., 2004; Economides, N. *et al*., 1999; Kennedy W. *et al*., 1986; Khayat A & Jahanbin A., 2005). The smear layer is a combination of organic and inorganic debris present on the root canal wall after instrumentation (Sen BH *et al*., 1995). This layer has been described as being superficial on the dentinal surface and packed into the dentinal tubules. Biologically, the presence of the smear layer has been postulated to be an avenue for leakage and a source of substrate for bacterial growth and ingress. When canals were obturated with thermoplasticized gutta-percha and sealer, the frequency of bacterial penetration in the presence of the smear layer has been shown to be significantly higher than with smear layer removal. When the smear layer is not removed, it may slowly disintegrate and dissolve around leaking canal filling materials, or it may be removed by bacterial by-products such as acids and enzymes. Technically the smear layer may interfere with the penetration of gutta-percha into the tubules and the adhesion and penetration of root canal sealers into dentinal tubules (Karagoz-Kucukay I & Bayirli G., 1994; White RR *et al*., 1984).

At present, the main clinical approach is to use the rinse solution for disinfection and removal of smear layer. EDTA combined with sodium hypochlorite wash is most commonly used. Sodium hypochlorite removes the organic debris, and EDTA helps in removal of smear layer and inorganic debris (Guerisoli, D.M., *et al*., 2002; Marending M. *et al*., 2007). Laser treatment of the radicular dentinal walls has been shown to facilitate cleaning of surfaces compared with a combination of NaOCl and EDTA, thus promoting better adaptation of the filling material to the root canal walls (Depraet, F. *et al*., 2005; Miserendino LJ *et al*., 1995; Pécora JD *et al*., 2000). Laser irradiation effectively improved cleanliness, despite the great amount of debris and thick smear layer observed in the apical thirds of teeth (Karlovic Z. *et al*., 2005; Su, D. *et al*., 2017). The laser beam produces different effects on the same tissue at different parameters and the same laser can produce varying effects in different tissues (Özer S., & E. Basaran, 2013). These effects are dependent on the power and the mode of the energy delivery system, type and condition of target tissue, size and form of the optical fibre through which the laser beam is transmitted (Dave D. *et al.*, 2012; Konopka K. & T. Goslinski, 2007**.** Malik R. *et al*., 2010). The main goal of investigators is to find the optimal wavelength and irradiation parameters for smear layer ablation without altering the dentin layer. The areas of thermal injury, carbonisation, cracks and craters in the root canal wall because of laser treatment are undesirable because they reduce the integrity of the tooth structure and decrease the success rate of the endodontic treatment.

The present study was designed to evaluate the effect of laser irradiation with different wavelengths on the apical microleakage of root canals. The apical sealing after root canal filling was compared between six groups, namely the control group, conventional irrigation group and four laser treated groups. Overall the treated groups significantly improved the sealing performance compared with the control group ($p<0.05$). The laser irradiation combined with conventional root canal preparation is superior in improving the performance of root canal sealing ($p<0.01$). Application of laser light in root canal therapy effectively removes the smear layer within the root canal and allows the root canal filling material and the root canal tightly integrated. The morphological changes on the apical intraradicular dentin surface caused by Nd:YAG and Er:YAG laser irradiation demonstrated at least linear dye apical leakage.

However, discrepancies are also noticed among different studies because of the inconsistent laser parameters and experimental conditions used in each study. Therefore, more standardized experiments are needed to optimize the application of laser in clinic. Nevertheless, results from our study now reveal the great the promise of clinical application of laser during root canal teratment. Our investigation demonstrated that the application of four different laser-assisted reports prior to root canal obturation increases the apical sealing of the roots treated.

CONCLUSIONS

Laser irradiation may improve the apical seal of the root canal. Different type of laser systems with appropriate parameters are recommended to be used as an adjunct to the current chemical root canal disinfection protocols.

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