

# Comparison of Dentin Permeability After Tooth Cavity Preparation with Diamond Bur and Er:YAG Laser

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## Abstract

**Objectives:** The aim of this study was to compare the permeability of dentin after using diamond bur and Er:YAG laser.

**Materials and Methods:** Seventy-two recently extracted, intact, and restoration-free human permanent molars were used in this study. The samples were randomly divided into three groups of 24 each and class I cavities were prepared as follows. Group 1: High speed diamond bur with air and water spray. Group 2: Er:YAG laser. Group 3: Er:YAG laser followed by additional sub-ablative laser treatment. Each group consisted of two subgroups with different cavity depths of 2mm and 4mm. The entire cavity floor was in dentin. Two samples from each subgroup were observed under scanning electron microscope (SEM). The external surfaces of other samples were covered with nail varnish (except the prepared cavity) and immersed in 0.5% methylene blue solution for 48 hours. After irrigation of samples with water, they were sectioned in bucco-lingual direction. Then, the samples were evaluated under a stereomicroscope at  $\times 160$  magnification. The data were analyzed using two-way ANOVA and Tukey's HSD test.

**Results:** Two-way ANOVA showed significant difference in permeability between groups 2 and 3 (laser groups with and without further treatment) and group 1 (bur group). The highest permeability was seen in the group 1. There was no significant difference in dentin permeability between groups 2 and 3 and no significant difference was observed between different depths (2mm and 4mm).

**Conclusion:** Cavities prepared by laser have less dentin permeability than cavities prepared by diamond bur.

**Keywords:** Dental Cavity Preparation; Lasers, Solid-State; Dentin Permeability

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## INTRODUCTION

Post-operative tooth hypersensitivity is one of the most common complaints that engages many patients [1].

The following theories have been suggested for this sensitivity [2]:

1- Nerve endings are stimulated directly by stimulants.

2- Odontoblasts are connected to the nerves chemically or electrically and when these odontoblasts are stimulated, the nerves also become stimulated.

3- When dentinal tubules are open, rapid movement of dentinal fluid stimulates the nerves and causes sensitivity [3]. Dentinal tubules may be exposed by enamel removal or loss of periodontium and subsequent cementum removal from the root surface [4]. On the basis of this theory, in order to treat tooth hypersensitivity, it is necessary to use a method that seals dentinal tubules and reduces dentin permeability and further sensitivity.

Laser was introduced as an alternative tool for cavity preparation. In this study, Er:YAG laser was used for removal of tooth structure. Er:YAG laser is mostly absorbed by water in hard tissues and removes enamel and dentin as fast as rotary instruments [5,6].

Interaction between lasers and tissues is affected by some parameters such as laser wavelength and tissue factors [7]. In general, laser is a safe and efficient tool for caries removal and patients find it a comfortable modality that needs fewer anesthetic injections [8-10].

The effects of different kinds of lasers on exposed dentinal tubules of teeth roots have been evaluated and it has been concluded that Er:YAG laser, CO<sub>2</sub> laser, Ga-Al-As laser and Nd:YAG laser reduce dentin permeability [11,12].

In another research, Esteves-Oliveira et al. studied the permeability and configuration of dentinal tubules of root canals after irradiation with Nd:YAG laser, Er:YAG laser and diode laser. They reported that irradiation of Er:YAG laser and diode laser increased dentin permeability while Nd:YAG laser reduced it [13]. Since Er:YAG laser is one of the lasers used for tooth preparation, this research was performed to study the effect of tooth preparation by this laser on dentin permeability in different depths. The null hypothesis of this study was that the Er:YAG

laser and diamond bur would not have different effects on dentin permeability.

## MATERIALS AND METHODS

Extracted human third molars were collected during three months prior to the study and 72 intact teeth without caries or cracks were selected for this experiment. The teeth were kept in normal saline during this period and in the last week prior to the test the teeth were placed in 0.1% thymol solution for disinfection. Samples were randomly divided into three groups (each group included 24 teeth). Each group consisted of two subgroups (A and B) with different depths (2 mm and 4 mm). Cusps were flattened and then the cavities were prepared as follows. Group 1: Class I cavities were prepared with the cross-sectional area of 2×4mm and depth of 2 mm for subgroup A and 4mm for subgroup B (i.e. subgroup A: 2×4×2 mm and subgroup B: 2×4×4 mm). Cavities were prepared with flat end cylindrical diamond bur (Ø=1mm, 835, Teezkavan Co., Tehran, Iran) using high speed handpiece under air and water spray on occlusal surfaces. Group 2: Cavities were prepared by Er:YAG laser (Smart 2940 Plus, Deka Co., Calenzano, Italy) with power of 3W, wavelength of 2940nm, frequency of 10Hz, energy of 300 mJ and non-contact mode. Laser handpiece was kept perpendicular to tooth surface and water and air spray were used along with laser irradiation. Group 3: Cavity preparation was similar to that in group 2 but after cavity preparation, cavities were retreated by Er:YAG laser with different sub-ablative parameters (power of 0.5W, wavelength of 2940nm, frequency of 10Hz and energy of 50mJ). The dimensions of prepared cavities in subgroups A and B of groups 2 and 3 were similar to those of group 1. Dye penetration method was used to compare dentin permeability of different groups. Two samples of each group were not placed in dye solution. These samples were evaluated using SEM and photography.

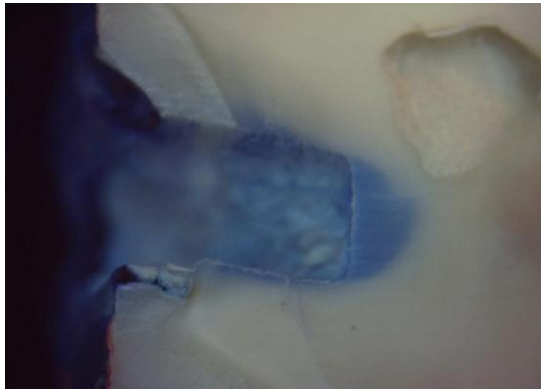


Fig. 1. Dye penetration (Magnification:  $\times 160$ ).

External surfaces of the remaining 10 teeth of each group were covered with nail varnish (except for cavities with 1mm margin around them) and root apices were covered with wax. This procedure was performed to prevent dye penetration from other sites that may alter the results.

Afterward, samples were placed in 0.5% methylene blue (each subgroup in a separate container) at room temperature for 48 hours. Samples were rinsed with water for 15 minutes and kept at room temperature for one hour to dry. Samples were sectioned longitudinally in bucco-lingual direction using low-speed saw (Isomet, Buehler Co., IL, USA).

After sectioning, high resolution photographs were captured using a stereomicroscope (Olympus SZX, Olympus Co., PA, USA) (Fig. 1).

Samples were observed under a stereomicroscope at  $\times 160$  magnification and the average depth of dye penetration was measured in millimeters using Olympus image analysis software (Soft Imaging System Co., Berlin, Germany). The extent of dye penetration in different groups was compared and the significance of the differences was evaluated [14]. It should be noted that stereomicroscope at  $\times 40$  magnification was used in similar studies [15, 16]. However, in this study a more accurate device was utilized to yield accurate results. SPSS software (Version 16, SPSS Inc., Chicago, IL, USA) was used to analyze the results using two-way ANOVA and Tukey's HSD test.

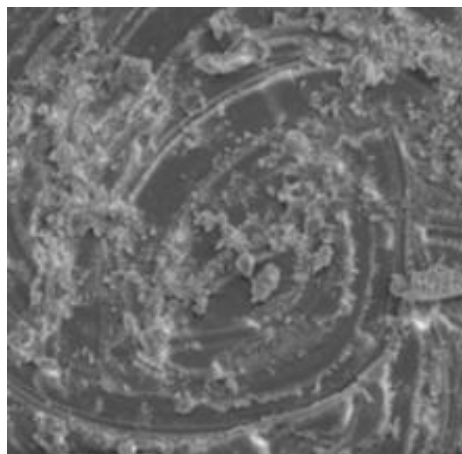
## RESULTS

Based on statistical analysis of the results, there was no significant correlation between the cavity preparation method and cavity depth ( $P=0.993$ ). The mean and standard deviation values of permeability in different groups are shown in Table 1. According to the statistical analysis, preparation depth did not have a significant effect on dentin permeability ( $P=0.902$ ). On the other hand, permeability was significantly different in the three cavity preparation groups so that the permeability in groups 2 and 3 (laser with or without additional treatment) was lower than that of the bur group ( $P=0.004$  and  $P=0.040$ , respectively).

Table 1. Permeability and dispersion indexes (0.01mm)

Preparation	Permeability				
	Num.	Avg.	Std.	Max.	Min.
Bur (2mm)	10	126.48 <sup>a</sup>	36.04	166.71	60.36
Bur (4mm)	10	124.28 <sup>a</sup>	49.18	212.76	59.35
Laser (2mm)	10	77.34 <sup>b</sup>	42.97	171.22	21.63
Laser (4mm)	10	77.75 <sup>b</sup>	59.20	218.72	34.29
Laser with treatment (2mm)	10	91.09 <sup>b</sup>	40.03	152.88	33.17
Laser with treatment (4mm)	10	88.61 <sup>b</sup>	27.27	141.72	49.30

\* Same letters indicate statistical similarity.



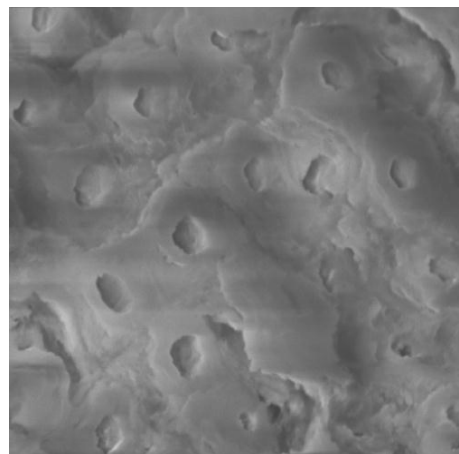
**Fig. 2.** SEM micrograph of the bur group (Magnification:  $\times 1000$ ).

There was no significant difference between dentin permeability of laser groups (with or without additional treatment) ( $P=0.637$ ). Furthermore, the results of SEM indicated that in the bur group, only smear layer was observed and dentinal tubules were not clearly visible (Fig. 2). In the laser groups, smear layer was not seen and some of the dentinal tubule orifices were obstructed (Figs. 3 and 4).

## DISCUSSION

The aim of this study was to compare dentin permeability of cavities with different depths (2mm and 4mm) prepared by diamond bur and Er:YAG laser (with or without surface treatment).

Hydrodynamic theory of tooth hypersensitivity explains that the movement of dentinal fluid in dentinal tubules creates dentin hypersensitivity. On the basis of this theory, it is concluded that if a factor reduces dentinal fluid movement, it can reduce dentin hypersensitivity [17]. There are many physical and chemical mechanisms that may result in reduced dentin permeability and thereby lower tooth sensitivity such as growth of intra tubular crystals caused by saliva or dentinal fluid, absorption of plasma proteins into the inner surface of dentinal tubules, or the formation of smear layer on the surface of exposed dentin [17].



**Fig. 3.** SEM micrograph of the laser group without treatment (Magnification:  $\times 8000$ ).

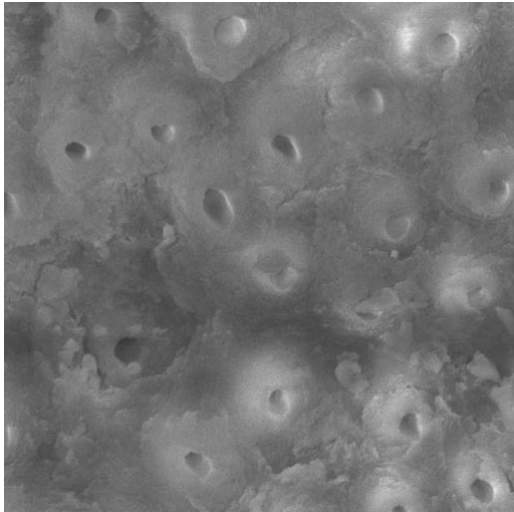
Overall, the study purpose was to further explore the effect of tooth cavity preparation with Er:YAG laser particularly on dentin permeability, which may improve tooth sensitivity. In this study, the Er:YAG laser was selected because it is a practical and efficient tool to remove dental caries [18].

Aranha et al. studied the effects of Er:YAG laser and Nd:YAG laser on dentinal tubules' permeability in root surface and found that these lasers seal dentinal tubules and reduce dentin permeability [12].

These results are in accordance with our findings.

Matsui et al. studied the effect of three different lasers ( $\text{CO}_2$ , Er:YAG and Ga-Al-As) on permeability of exposed dentinal tubules and compared the results with those of the control group, which was not under laser irradiation. In the laser groups, the orifices of dentin tubules were obstructed and no sign of methylene blue dye penetration into pulp chamber was observed; whereas, in the control group there were many open dentinal tubule orifices, and dye penetration into the pulp chamber was detected [11].

Gholami et al. irradiated Nd:YAG,  $\text{CO}_2$ , diode and Er:Cr:YSGG lasers on dentin surface and studied the diameter of dentinal tubules. They observed that dentinal tubule diameters decreased after laser irradiation [19].



**Fig. 4.** SEM micrograph of the laser group with treatment (Magnification:  $\times 6000$ ).

It seems that Er:YAG laser melts hydroxyapatite minerals of the peritubular dentin and shrinks the diameter of tubules and reduces dentin permeability.

Previous studies [6,11,12] reported that irradiation of Er:YAG and diode laser on the dentin of root canal can remove smear layer and open dentinal tubule orifices and increase radicular dentin permeability, while irradiation of Nd:YAG laser reduces dentin permeability [13,20].

These results are in contrast to our results. These differences might be attributed to factors such as the site and the direction and duration of irradiation, which can have significant effects on the results.

As seen in our study, there were no significant differences in dentin permeability in different depths of 2mm and 4mm regardless of the form of cavity preparation by bur or laser. In bur groups, this may be because of presence of debris that occludes dentinal tubule orifices to some extent (Fig. 2) and as a result, the differences in tubular width in different depths had no significant effect on dentin permeability. In the laser groups as seen in SEM observations (Figs. 3 and 4), many of dentinal tubules were obstructed regardless of cavity depth; hence it can be concluded that

the permeability was the same in depths of 2mm and 4mm.

## CONCLUSION

Under the limitations of this study, it is concluded that application of Er:YAG laser for cavity preparations can considerably reduce dentin permeability compared to conventional diamond bur preparation regardless of the cavity depth.

## REFERENCES

- 1- Madhu PS, Setty S, Ravindra S. Dentinal hypersensitivity?--Can this agent be the solution? *Indian J Dent Res.* 2006 Oct-Dec; 17(4):178-84.
- 2- Trowbridge HO. Review of dental pain-histology and physiology. *J Endod.* 1986 Oct; 12(10):445-52.
- 3- Orchardson R, Gillam DG. Managing dentin hypersensitivity. *J Am Dent Assoc.* 2006 Jul; 137(7):990-8.
- 4- Addy M, Hunter ML. Can tooth brushing damage your health? Effects on oral and dental tissues. *Int Dent J.* 2003;53 Suppl3:177-86.
- 5- Hossain M, Nakamura Y, Yamada Y, Murakami Y, Matsumoto K. Microleakage of composite resin restoration in cavities prepared by Er,Cr:YSGG laser irradiation and etched bur cavities in primary teeth. *J Clin Pediatr Dent.* 2002 Spring;26(3):263-8.
- 6- Apel C, Meister J, Götz H, Duschner H, Gutknecht N. Structural changes in human dental enamel after sub-ablative erbium laser irradiation and its potential use for caries prevention. *Caries Res.* 2005 Jan-Feb;39(1): 65-70.
- 7- Cavalcanti TM, Almeida-Barros RQ, Catão MH, Feitosa AP, Lins RD. Knowledge of the physical properties and interaction of laser with biological tissue in dentistry. *An Bras Dermatol.* 2011 Sep-Oct;86(5):955-60.
- 8- Ceballos L, Toledano M, Osorio R, García-Godoy F, Flaitz C, Hicks J. ER-YAG laser pretreatment effect on in vitro secondary

- caries formation around composite restorations. *Am J Dent.* 2001 Feb;14(1):46-9.
- 9- Karaarslan ES, Usumez A, Ozturk B, Cebe MA. Effect of cavity preparation techniques and different preheating procedures on microleakage of class V resin restorations. *Eur J Dent.* 2012 Jan;6(1):87-94.
- 10- Hossain M, Kimura Y, Nakamura Y, Yamada Y, Kinoshita JI, Matsumoto K. A study on acquired acid resistance of enamel and dentin irradiated by Er,Cr:YSGG laser. *J Clin Laser Med Surg.* 2001 Jun;19(3):159-63.
- 11- Matsui S, Kozuka M, Takayama J, Ueda K, Nakamura H, Ito K, et al. Stimulatory Effects of CO<sub>2</sub> Laser, Er:YAG Laser and Ga-Al-As Laser on Exposed Dentinal Tubule Orifices. *J Clin Biochem Nutr.* 2008 Mar;42(2):138-43.
- 12- Aranha AC, Domingues FB, Franco VO, Gutknecht N, Eduardo Cde P. Effects of Er:YAG and Nd:YAG lasers on dentin permeability in root surfaces: a preliminary in vitro study. *Photomed Laser Surg.* 2005 Oct;23(5):504-8.
- 13- Esteves-Oliveira M, de Guglielmi CA, Ramalho KM, Arana-Chavez VE, de Eduardo CP. Comparison of dentin root canal permeability and morphology after irradiation with Nd:YAG, Er:YAG, and diode lasers. *Lasers Med Sci.* 2010 Sep;25(5):755-60.
- 14- Chinelatti MA, Ramos RP, Chimello DT, Borsatto MC, Pécora JD, Palma-Dibb RG. Influence of the use of Er: YAG laser for cavity preparation and surface treatment in microleakage of resin-modified glass ionomer restorations. *Oper Dent.* 2004 Jul-Aug;29(4):430-6.
- 15- Karaarslan ES, Usumez A, Ozturk B, Cebe MA. Effect of cavity preparation techniques and different preheating procedures on microleakage of class V resin restorations. *Eur J Dent.* 2012 Jan;6(1):87-94.
- 16- Karaman E, Ozgunaltay G. Polymerization shrinkage of different types of composite resins and microleakage with and without liner in class II cavities. *Oper Dent.* 2014 May-Jun;39(3):325-31.
- 17- Pashley DH. Dentin permeability, dentin sensitivity, and treatment through tubule occlusion. *J Endod.* 1986 Oct;12(10):465-74.
- 18- Matsumoto K, Kimura Y. Laser therapy of dentin hypersensitivity. *J Oral Laser Appl.* 2007 Jan 1;7:7-25.
- 19- Gholami GA, Fekrazad R, Esmail-Nejad A, Kalhori KA. An Evaluation of the Occluding Effects of Er;Cr:YSGG, Nd:YAG, CO<sub>2</sub> and Diode Lasers on Dentinal Tubules: A Scanning Electron Microscope In Vitro Study. *Photomed Laser Surg.* 2011 Feb;29(2):115-21.
- 20- Takeda FH, Harashima T, Kimura Y, Matsumoto K. Comparative study about the removal of smear layer by three types of laser devices. *J Clin Laser Med Surg.* 1998 Apr;16(2):117-22.