



## The Effect of using 940 nm Diode Laser in Comparison with Endoactivator on Radicular Dentin Permeability and Smear Layer Removal (An in Vitro Study)

Ruaa M. Al-Mafrachi Lutfi G. Awazli and Mohammed A. Al-Maliky

*dentistrymohamed@yahoo.com.*

*Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq.*

(Received 18 September 2017; accepted 14 November 2017)

**Abstract:** The aim of this study is to assess the effectiveness of 940 nm diode laser in comparison to Endoactivator in elimination of smear layer in terms of radicular dentin permeability and ultra-structural changes of root canal walls by SEM evaluation. Twenty-eight single-rooted extracted lower premolars were instrumented up to size X4 (protaper Next, Dentsaply) and divided into two experimental groups according to the irrigation system, G1; activated by EndoActivator and G2; activated by Diode laser 940 nm, CW mode, 1.7 W. Afterward, the roots were made externally impermeable, 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 net dye penetration area was calculated. Additionally, scanning electron microscope investigations were accomplished. The non-parametric Mann-Whitney U test was done and showed significant difference between the two experimental groups over the three root thirds and the dye penetration in diode laser group was significantly higher over the whole root length compared to the Endoactivator 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 EndoActivator group produced uneven removal of smear layer, in efficient cleanliness especially in the apical third.

**Keywords:** Diode Laser. Endoactivator. Smear Layer. Permeability. Ultrastructure.

### Introduction

The effective removal of organic and inorganic tissue remnants along the complex root canal system is a major condition in the success of root canal treatment. These tissue remnants or smear layer reduce dentin permeability, stand as a hurdle that inhibit the penetration of intracanal medicaments into dentin, and hide the microorganisms present in deep dentin. Chemical agents like NaOCl and EDTA that are widely conjugated with mechanical instrumentation have been suggested to approve root canal disinfection (Carrotte 2005). To enhance cleanliness, irrigants should be in contact with root canal (Zehnder 2006). The conventional syringe irrigation method delivers

solutions no further than 0–1.1 mm beyond the needle tip (Munoz and Camacho-Cuadra 2012). This way is inadequate for the sufficient cleaning of the complex anatomy of root canal system including isthmus, fins, lateral and accessory canals (Mancini, Cerroni et al. 2013). Therefore, introduced different irrigation systems have been introduced to enhance the mechanical action and flow and distribution of irrigating solutions within the root canal system (Mancini, Cerroni et al. 2013) and (Gu, Kim et al. 2009), particularly at the apical third level. One of these systems is the EndoActivator System (Dentsply Tulsa Dental Specialities, Tulsa, OK, USA) which is a sonically driven canal irrigation system that includes a portable

hand-piece and 3 types of disposable flexible polymer tips of different sizes that do not cut root dentin (Uroz-Torres, González-Rodríguez et al. 2010).

According to the composition of chemical agents, each acts on radicular dentin in a specific way and presents certain morphological changes on dentin surface. The same standard can be applied in laser-assisted root canal treatment. Each laser has a specific property, because they emit different wavelengths, stimulating a different tissue interaction (Uroz-Torres, González-Rodríguez et al. 2010). Diode lasers of 810, 940, and 980 nm wavelengths offer a better penetration to formally inaccessible areas of the tubular network (Moritz, Gutknecht et al. 1997), (Gutknecht, Franzen et al. 2004) and (Schoop, Kluger et al. 2004), allowing the decontamination action to deeper layers of dentin. However, the use of these lasers is usually combined with chemical irrigants due to their limited ability to remove smear layer. Recently, Faria et al. (Faria, Sousa-Neto et al. 2013) carried an in vitro study to evaluate the effect of 980 nm diode laser on the ultrastructure and fracture resistance of radicular dentin. They hypothesized that after 980 nm diode laser irradiation of root canal, a modified smear layer was observed in specimens that were irrigated with water and then laser irradiated with 1.5 and 3 W/100 Hz. Also, studies proved that using diode lasers that emit at wavelengths of 940 and 980 nm, have been shown to induce cavitation in water-based fluids, with the formation and implosion of bubbles of water vapor (Hmud R. et al., 2010).

In the current research, the efficiency of 940nm diode laser in root canal treatment compared to EndoActivator sonic device is thoroughly investigated, concerning dentin permeability and smear layer removal of radicular dentin.

#### **Materials and Methods:**

##### **Samples Collection and Preparation:**

In this study, twenty-eight single-rooted mandibular premolars freshly extracted for orthodontic demands were collected. The teeth have been cleaned with distilled water and then soft tissue remnants were removed using ultrasonic scaler and then polished and stored in distilled water containing 0.1% thymol, (Alkahtani et al., 2014). After that, 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 hand-piece. Canal orifices were flared with small round bur of conventional speed hand-piece. 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 (Dentsply, Germany) till size X4 (Al-Karadaghi et al., 2015). 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 (Dentsply, Switzerland).

##### **Final Irrigation Protocol:**

After the biomechanical preparation of canals, the specimens were divided into two groups each group of fourteen teeth as follows:

G1 (n=14): EndoActivator (Dentsply Tulsa), the canal was filled with 1mL EDTA 17% for 1 min., then rinsed with 5mL NaOCl 5.25% and agitated with the EndoActivator red tip (25/0.04) at 10,000 cpm for 60s according to manufacturer's instructions (Elnaghy et al., 2016). G2 (n=14): Diode laser 940 nm, 1mL EDTA 17% for 1 min., then rinsed with 5mL NaOCl 5.25%, agitated with 940 nm diode laser, the delivery was by fiber-optic endodontic tip, E2 with the tip diameter of 200 µm, Specimens were irradiated with 1.08 W, CW mode; the fiber tip was inserted 2 mm from the apex, in contact mode, and helicoidal movement in a speed of 1mm/s (by hand training) from apical to cervical direction. This was accomplished in 18 s and repeated two times resulting in a total irradiation time of 36 s according to manufacturer instructions (Alfredo et al., 2009). After agitation procedure, all specimens were irrigated with 5 mL distilled water and dried with size X4 paper point (protaper Next, Dentsply, Switzerland).

##### **Scanning Electron Microscopic Examination (SEM):**

Four samples from each group were used to investigate the 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. (Marchesan, 2008). Then 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 500 x magnifications.

**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 sticky wax. The roots' surface was coated by two coats of nail varnish and dried. After that the specimens were filled with 2 % methylene blue dye injected by hypodermal syringe and left for 20 min. at room temperature. When time was over, they were rinsed thoroughly under running water. The root canals were dried with absorbent paper cones. The samples were sectioned horizontally into three parts representing the apical, middle, and coronal

thirds. The first 2 mm starting from the cemento-enamel junction was cut and excluded from microscopic evaluation (Al-Karadaghi et al., 2015). The prepared root sections were observed under Stereomicroscope (Hamilton, Altay Scientific, Rome, Italy) under the magnification of ×40. 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).

**Results:** Data that represent permeability of root canal dentin expressed as percentage of dye penetrating area at three levels of root canal are displayed as follows:

The summary of descriptive and statistical test for the percentage of dye penetrating area among the experimental groups is shown in Table (1):

**(Table 1)** Descriptive and statistical test of Permeability among groups

Groups	Min.	Max.	Mean	±SD	Median	Mean Rank	Mann-Whitney U test	
							Z	Sig.
Endo Activator	0	100	48.354	31.905	47.230	23.90	2.937	0.003 HS
Diod Laser	23.080	100	71.605	22.513	76.155	37.10		

HS=Highly significant at P<0.01.

From the Table above, the high mean percentage of net dye penetration was obvious in diode laser group in comparison to EndoActivator group and there was statistically

highly significant difference between the two groups.

In **(Table 2)**; a descriptive and statistical test of permeability between groups within each site was described.

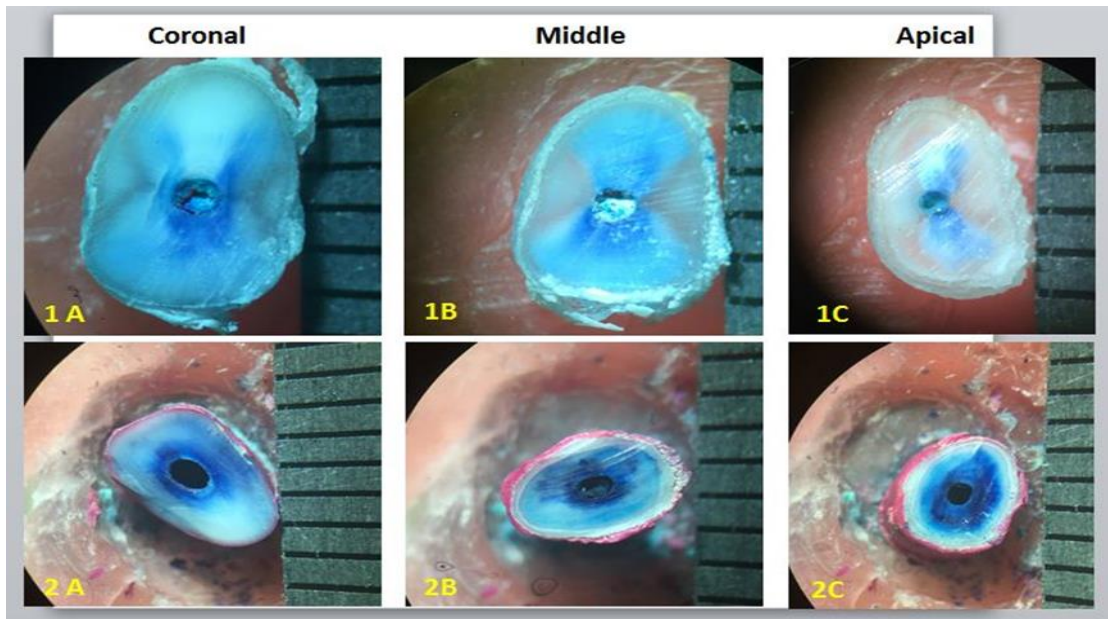
**(Table 2)** Descriptive and statistical test of permeability between groups within sites.

Site	Groups	Min.	Max.	Mean	±SD	Median	MR	Mann-Whitney U test	
								Z	Sig.
Apical	EndoActivator	.000	100.000	27.519	32.779	25.570	7.85	2.012	0.043 Sig.
	Diod Laser	23.080	100.000	58.258	26.633	52.055	13.15		
Middle	EndoActivator	15.520	100.000	58.339	27.750	56.985	8.95	1.172	0.247 NS
	Diod Laser	47.310	100.000	70.727	14.774	73.820	12.05		
Coronal	EndoActivator	19.930	100.000	59.203	26.676	55.620	7.40	2.394	0.019 Sig.
	Diod Laser	58.250	100.000	85.829	16.791	91.990	13.60		

NS=not significant at P>0.05, Sig. =Significant at P<0.05

As noticed from the Table above, there was a significant difference between the experimental groups at the apical and coronal level. On the other hand, it is non-significant at the middle third of the root but, the highest median and mean rank percentage can be observed for the diode laser group. The data were collected and statistically analyzed using the Statistical Package for the Social Sciences (SPSS,

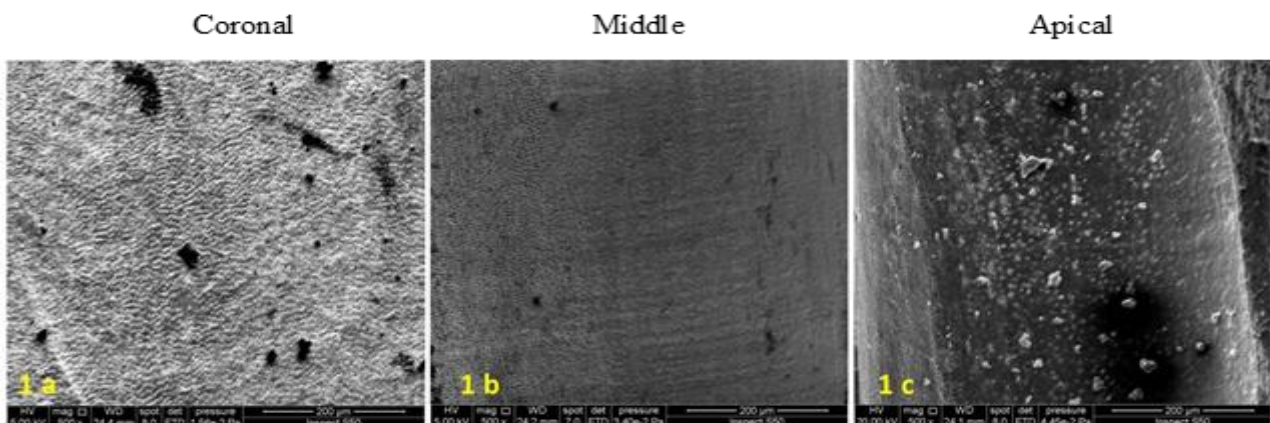
version21). Shapiro-wilk test to test the normality distribution of quantitative variables. Mann-Whitney U test the nonparametric test was done to determine whether there is a significant difference among the groups regardless of the level and among the groups and within the group at different levels. For permeability test stereomicroscopic images were taken after transversal cuts into three parts corresponding to root thirds as seen in (Fig. 1)



(Fig. 1) Stereomicroscope image after transversal cuts and dye solution penetration for experimental groups correspond to root third, (A), (B) and (C) represent coronal, middle, and apical thirds respectively, and the number in the figure represent the group which mean: (1) represent G1, Endoactivator group, (2) represent G2, Diode laser group.

Scanning electron microscope micrographs was taken for each third (apical, middle, and coronal) of specimens at 500 x for two groups. In EndoActivator group smear layer and debris have been mostly removed in some areas; also

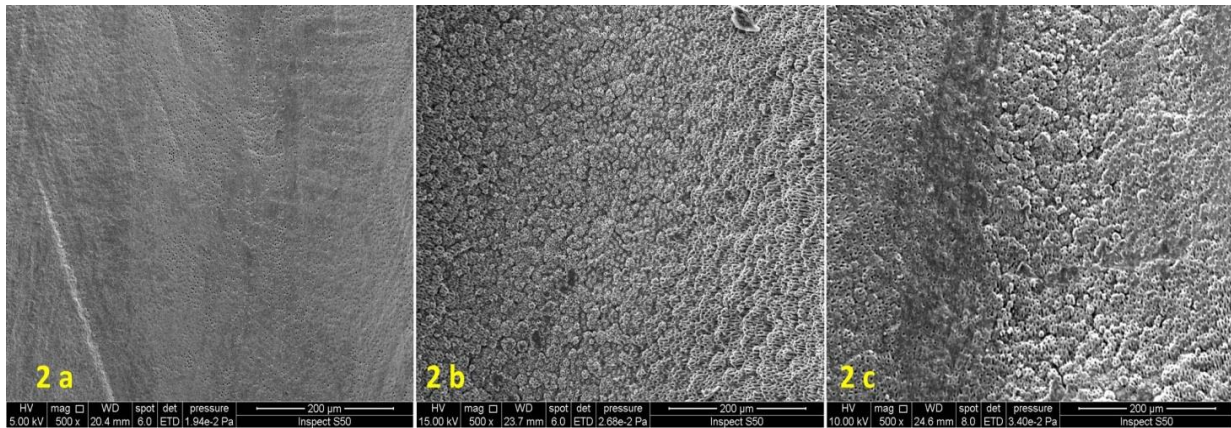
some areas showed dentinal tubules occlusion totally or partially by smear layer and debris, inefficient cleanliness mainly in the apical third of the root. ( Fig. 2).



(Fig. 2) Scanning electron microscope of root canal dentin for G1, Endoactivator group (500×) (a), (b), and (c) corresponds to root thirds coronal, middle, and apical.

The micrographs of Diode laser group revealed encrusted irregular dentinal surfaces in which the smear layer was removed, with evidently open dentinal tubules, and no signs of melting or

carbonization were given. Protrusion of dentinal tubules toward the laser irradiated surface was observed, (Fig. 3).



(Fig. 3) Scanning electron microscope of root canal dentin for G2, Diode laser group (500×) (a), (b), and (c) corresponds to root thirds coronal, middle, and apical.

### Discussion

Effective chemomechanical preparation of the apical region is especially important for successful root canal treatment. Syringe irrigation is a standard procedure for root canal irrigation, but this technique is not efficient in the apical third of the root canal. It is difficult to completely remove the residual smear layer, particularly in the apical third of the root, because the smaller size of the apical third compared with the other thirds impedes the circulation and action of the irrigating solutions (Torabinejad, Cho et al. 2003) and (Mancini, Armellini et al. 2009). Acoustic and hydrodynamic properties of irrigants have been studied to improve the effectiveness of irrigating solutions in the apical region (Weller, Brady et al. 1980); agitation with a laser has been used in endodontic therapy to reduce the number of bacteria and to modify the surface of the root canal (George, Meyers et al. 2008). Therefore, the present study investigates whether agitation with EndoActivator and a diode laser 940 nm improves removal of smear layer in all root thirds in terms of radicular dentin permeability and ultrastructural changes of root canal walls by SEM evaluation. The absorption of a root canal irrigant depends on the type of irrigating solution and the wavelength of the laser. In a

recent study by Moon et al (Moon, Kim et al. 2012), activation with a 1320-nm Nd:YAG laser with NaOCl or EDTA was found to be much better than NaOCl for sealer penetration into dentinal tubules. It has been shown that the absorption of EDTA at 1320 nm is higher than at the 810-nm wavelength (Meire, Poelman et al. 2014). 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. In the present study, an 940 nm diode laser was used with 5.25% NaOCl.

Remarkably, in the middle and apical thirds of root canals, the highest number of open dentinal tubules was noticed in diode laser group.

Clinically, the root is enclosed by the bone socket, and the canal behaves as a closed-end channel. This situation results in gas entrainment at the end of this region, producing a vapor lock effect during the irrigation procedure. The mechanism for the laser activation of irrigating solutions generates from the absorption of laser energy by irrigant solution, the creation of vapor bubbles, and the collapse of the bubbles, acoustic streaming and cavitation. So, that explains the removal of smear layer by using laser.

The reduced cleaning efficiency of the EndoActivator compared with the laser activation in this study is supported by the results obtained by (Jiang, Verhaagen et al. 2010). When EndoActivator tip is placed in the apical level, there is a certain amount of dampening happens when there is contact with the canal walls. This inhibits the free oscillation of the sonic tip, reducing the efficient streaming of the irrigant. This result is obtained more via statistical results of percentage of net dye penetration area.

### Conclusions

Based on the results of this in vitro study, it can be concluded that radicular dentin irradiation with 940 nm diode laser is effective in increasing dentin permeability with superior statistical results when compared with EndoActivator group. A smear layer and debris are removed effectively from root canal walls and appear to have an interesting application in laser-assisted root canal treatment.

### References

- Alfredo, E., Souza-Gabriel, A. E., Silva, S. R. C., Sousa-Neto, M. D., Brugnera-Junior, A., & Silva-Sousa, Y. T. (2009). Morphological alterations of radicular dentine pretreated with different irrigating solutions and irradiated with 980-nm diode laser. *Microscopy research and technique*, 72(1), 22-27.
- Alkahtani, A., Al Khudhairi, T. D., and Anil, S. (2014). A comparative study of the debridement efficacy and apical extrusion of dynamic and passive root canal irrigation systems. *BMC oral health*, 14(1), 12.
- Al-Karadaghi, T. S., Franzen, R., Jawad, H. A., and Gutknecht, N. (2015). Investigations of radicular dentin permeability and ultrastructural changes after irradiation with Er, Cr: YSGG laser and dual wavelength (2780 and 940 nm) laser. *Lasers in medical science*, 30(8), 2115-2121.
- Carrotte, P. (2005). "21st century endodontics: part 4." *International dental journal* 55(5): 334-340.
- Elnaghy, A. M., Mandorah, A., & Elsaka, S. E. (2017). Effectiveness of XP-endo Finisher, EndoActivator, and File agitation on debris and smear layer removal in curved root canals: a comparative study. *Odontology*, 105(2), 178-183.
- Faria, M. I. A., et al. (2013). "Effects of 980-nm diode laser on the ultrastructure and fracture resistance of dentine." *Lasers in medical science* 28(1): 275-280.
- George, R., Meyers, I. A., and Walsh, L. J. (2008). Laser activation of endodontic irrigants with improved conical laser fiber tips for removing smear layer in the apical third of the root canal. *Journal of Endodontics*, 34(12), 1524-1527.
- Gu, L. S., Kim, J. R., Ling, J., Choi, K. K., Pashley, D. H., and Tay, F. R. (2009). Review of contemporary irrigant agitation techniques and devices. *Journal of Endodontics*, 35(6), 791-804.
- Gutknecht, N., Franzen, R., Schippers, M., and Lampert, F. (2004). Bactericidal effect of a 980-nm diode laser in the root canal wall dentin of bovine teeth. *Journal of clinical laser medicine & surgery*, 22(1), 9-13.
- Hmud, R., Kahler, W. A., George, R., and Walsh, L. J. (2010). Cavitation effects in aqueous endodontic irrigants generated by near-infrared lasers. *Journal of Endodontics*, 36(2), 275-278.
- Jiang, L. M., Verhaagen, B., Versluis, M., and van der Sluis, L. W. (2010). Evaluation of a sonic device designed to activate irrigant in the root canal. *Journal of endodontics*, 36(1), 143-146.
- Mancini, M., Armellin, E., Casaglia, A., Cerroni, L., and Cianconi, L. (2009). A comparative study of smear layer removal and erosion in apical intraradicular dentine with three irrigating solutions: a scanning electron microscopy evaluation. *Journal of Endodontics*, 35(6), 900-903.
- Mancini, M., Cerroni, L., Iorio, L., Armellin, E., Conte, G., and Cianconi, L. (2013). Smear layer removal and canal cleanliness using different irrigation systems (EndoActivator, EndoVac, and passive ultrasonic irrigation): field emission scanning electron microscopic evaluation in an in vitro study. *Journal of endodontics*, 39(11), 1456-1460.
- Marchesan, M. A., Brugnera-Junior, A., Souza-Gabriel, A. E., Correa-Silva, S. R., and Sousa-Neto, M. D. (2008). Ultrastructural analysis of root canal dentine irradiated with 980-nm diode laser energy at different parameters. *Photomedicine and laser surgery*, 26(3), 235-240.

- Meire, M. A., Poelman, D., and De Moor, R. J. (2014). Optical properties of root canal irrigants in the 300–3,000-nm wavelength region. *Lasers in medical science*, 29(5), 1557-1562.
- Moon, Y. M., Kim, H. C., Bae, K. S., Baek, S. H., Shon, W. J., and Lee, W. (2012). Effect of laser-activated irrigation of 1320-nanometer Nd: YAG laser on sealer penetration in curved root canals. *Journal of endodontics*, 38(4), 531-535.
- Moritz, A., Gutknecht, N., Goharkhay, K., Schoop, U., Wernisch, J., and Sperr, W. (1997). In vitro irradiation of infected root canals with a diode laser: results of microbiologic, infrared spectrometric, and stain penetration examinations. *Quintessence International*, 28(3).
- Munoz, H. R. and K. Camacho-Cuadra (2012). "In vivo efficacy of three different endodontic irrigation systems for irrigant delivery to working length of mesial canals of mandibular molars." *Journal of Endodontics* 38(4): 445-448.
- Schoop, U., Kluger, W., Moritz, A., Nedjelik, N., Georgopoulos, A., and Sperr, W. (2004). Bactericidal effect of different laser systems in the deep layers of dentin. *Lasers in surgery and medicine*, 35(2), 111-116.
- Torabinejad, M., Cho, Y., Khademi, A. A., Bakland, L. K., and Shabahang, S. (2003). The effect of various concentrations of sodium hypochlorite on the ability of MTAD to remove the smear layer. *Journal of Endodontics*, 29(4), 233-239.
- Uroz-Torres, D., González-Rodríguez, M. P., and Ferrer-Luque, C. M. (2010). Effectiveness of the EndoActivator System in removing the smear layer after root canal instrumentation. *Journal of Endodontics*, 36(2), 308-311.
- Weller, R. N., Brady, J. M., and Bernier, W. E. (1980). Efficacy of ultrasonic cleaning. *Journal of Endodontics*, 6(9), 740-743.
- Zehnder, M. (2006). "Root canal irrigants." *Journal of Endodontics* 32(5): 389-398

## تأثير استخدام ليزر دايود 940 نانومتر ومقارنته مع جهاز الاهتزاز الصوتي اندواكتيفيتير على نفاذية العاج الجذري وازالة طبقة السميير (دراسة مختبرية)

محمد عبود قنبر

لطفی غلام عوازلی

روى المفرجي

معهد الليزر للدراسات العليا، جامعة بغداد، بغداد، العراق

**الخلاصة:** الهدف من هذه الدراسة هو لفحص تأثير ليزر دايود 940 نانومتر ومقارنته مع جهاز الاندواكتيفيتير في ازالة طبقة السميير عن طريق فحص نفاذية العاج الجذري وفحص المجهر الالكتروني الدقيق. الطريقة: استخدم لهذه الدراسة ثمان وعشرون سن احادي الجذر وتم تحضير القناة ميكانيكيا بنظام بروتبيير نيكست لغاية الحجم الرابع ثم تم تقسيم العينات الى مجموعتين: مجموعة جهاز الاندواكتيفيتير، و مجموعة ليزر الدايدود 940 نانومتر نمط شعاع مستمر بقوة 1.7 واط. لنتائج: ظهر اختلاف واضح احصائيا بين مجموعتي التجربه. الاستنتاجات: ادى استخدام ليزر دايود 940نانومتر في داخل القناة الجذريه كمحفز لمحلول الصوديوم هايبيوكلورايت الى فتح قنوات العاج بشكل واضح وعليه سيكون استخدامه فاعلا في فتح قنوات العاج الجذريه وكذلك يساعد في الاتصال الميكانيكي بين الحشوه وقنوات السن فبدلك يحد من الالتهاب المستقبلي المتوقع بسبب عدم التنظيف الجيد للقناة.