



The Efficacy of Er:YAG Laser on Intrapulpal Temperature Rise of Class V Cavity Preparation

Tamara S. Al-Qaradaghi⁽¹⁾, Ali S. Mahmood⁽¹⁾ and Raad N. Dayem⁽²⁾

(1) *Institution Of Laser For Postgraduate Studies, University of Baghdad, Baghdad, Iraq*

(2) *Conservative Department, College of Dentistry, University of Sulaimani, Sulaimani, Iraq.*

(Received 10 May 2010; accepted 2 May 2011)

Abstract: The objective of this study is to determine the efficacy of class V Er:YAG laser (2940 nm) cavity preparation and conventional bur cavity preparation regarding Intrapulpal temperature rise during cavity preparation in extracted human premolar teeth. Twenty non carious premolar teeth extracted for orthodontic purposes were used and class V cavity preparation was applied both buccal and lingual sides for each tooth. Samples were equally grouped into two major groups according to cavity depth (1mm and 2mm). Each major group was further subdivided into two subgroups of ten teeth for each (twenty cavities for each subgroup). Twinlight Er:YAG laser (2940 nm) with 500mJ pulse energy, P.R.R of 10 Hz and 63.69 J/cm² energy density was used. The analysis of the data collected revealed that there was highly significant difference between subgroups of each group, i.e., (Er:YAG laser and conventional bur cavity preparation). Also there was a highly significant difference between both group 1 and group 2 subgroups (with 1mm and 2mm cavity depth). Best results were obtained from subgroup A which represents class V cavities prepared using Er:YAG laser with energy density of 63.69 J/cm². Er:YAG laser cavity preparation with energy density of 63.69 J/cm² was less temperature rise than conventional bur cavity preparation taking into account the invitro temperature rise of class V cavity preparation.

Introduction

Cavity preparation, polymerization of lining and restorative materials, with or without the use of light-polymerization systems, are all potential sources of temperature rise at the cavity walls and, as such, must be regarded as having the ability to produce an increase in intrapulpal temperature (Smail, et al., 1988).

Heat production during tooth preparation and mechanical damage are major sources of trauma. Zach and Cohen showed that a rise of 5.58 °C in the pulp caused considerable damage, resulting in complete loss of vitality in 15% of teeth (Zach and Cohen, 1965).

Effective ablation of dental hard tissues by means of Er:YAG (Erbium: Yttrium- Aluminum Garnet) laser system has been reported and its application in the removal of carious tissues or cavity preparations for restorations has been

expected in the dental clinic (Hibst and Keller, 1989)

The Er:YAG laser ablates dental hard tissues effectively, due to its highly efficient absorption in both water and hydroxyapatite crystals (Hossain, et al., 1999) and produces minimal thermal damage to the surrounding tissues (Hibst and Keller, 1989), especially when irradiated with continuous water spray (Munro GA, et al., 1996).

A great sort of investigations have reported the ability of Er:YAG laser to cut or ablate tooth structure, removal of carious lesion, cavity preparation (Paghdiwala, 1991).

Fortunately, because of its mechanical ablation process by microexplosions, Er:YAG laser ($\lambda = 2.94 \mu\text{m}$) offers new prospects for effective enamel and dentin removal without significant thermal effect (Hibst and Keller, 1989). The quality of the cut is high compared

with other infrared lasers, and the surface is left intact. Histological studies have indicated that pulpal response to Er:YAG laser irradiation is minimal, reversible, and similar to that of a high-speed handpiece (Sonntag, et al., 1996 and Eversole, et al., 1997).

The first temperature measurements performed showed that damage to the pulp can be avoided by a suitable choice of laser parameters and adequate use of water spray, which provides a safely margin for clinical application (Visuri, et al., 1996).

The purpose of this in vitro study is to compare intrapulpal temperature elevation between different instruments used in cavity preparation; Er:YAG laser and conventional handpiece during 1 mm and 2 mm cavity depths.

Materials and Methods

Twenty non carious upper and lower premolar teeth, which were extracted for orthodontic purposes, were used in the present study consist of five lower first premolars and fifteen upper first premolars. They were collected and stored in distilled water bath at 37°C. Then, they were hand scaled with GC American curate for removal of any calculus deposits, and polished with pumice and rubber cups for removal of any stain when present. The teeth were grouped into two major groups. Each group was subdivided into two subgroups, each subgroup consists of ten teeth (twenty cavities), as following:

Group 1: Represents temperature variance during 1 mm cavity depth.

A) Er:YAG laser cavity preparation (pulse energy=500 mJ, P.R.R.= 10 Hz).

B) Conventional bur cavity preparation.

Group 2: Represent temperature variance during 2 mm cavity depth.

A) Er:YAG laser cavity preparation (pulse energy=500 mJ, P.R.R.= 10 Hz).

B) Conventional bur cavity preparation.

Laser Device

The laser device used in this study was Twinlight, FOTONA, ("Twinlight" CODE G-60.328, FOTONA, Italy), the therapeutic laser, which is a solid state pulsed Er:YAG laser emitting radiation at wavelength of 2940 nm. The pulse energy of the therapeutic Er:YAG laser is from 60-500 mJ. It is adjustable in the

range of 60-200 mJ in 20 mJ steps and 200-500 mJ in 50 mJ steps. The pulse width ranges 200-250 μ s. The P.R.R. is also adjustable from 2-25 Hz, exposure time 40 second with a spot size of 1 mm at 10 mm distance from the target. The laser handpiece used in this study was the R02F handpiece with exit window (sapphire window). The cavity preparation was done with distilled water cooling irrigation spray merging from the jet nozzle in the head of the R02F laser handpiece, with flow rate 3 mL/min.

Cavity Preparation

Standardized class V cavities were prepared on both buccal and lingual surfaces (3 mm height incisocervically, 3 mm width mesiodistally and both 1 mm and 2 mm depth respectively) about 1 mm occlusal to the cemento-enamel junction. As a result, 20 cavities were prepared with conventional dental bur (as shown in Figure 1) and 20 cavities were prepared with Er:YAG laser.

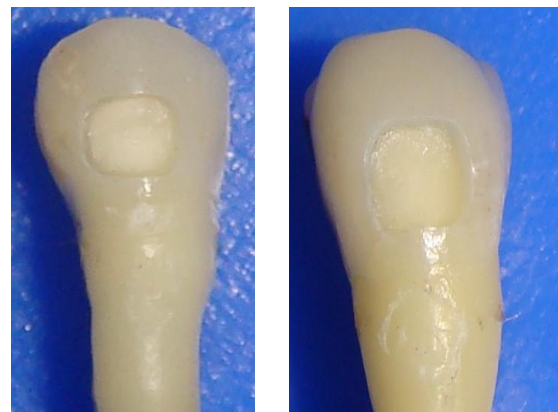


Fig. (1): Cavity preparation with conventional handpiece

A 3-4 mm of the apical portion of teeth roots for all samples of the three groups were cut so that the tip of thermocouple probe can be placed easily inside the pulp chamber. Then the content of the pulp were extirpated by barbed broach and the root canal was enlarged using a K-file to size 80, so the probe of thermocouple can be introduced easily inside the pulp chamber. Then, the root canal was irrigated with normal saline and dried with air spray. After apical preparation the thermocouple probe was placed inside the pulp chamber and X-ray was taken for each tooth to check that the thermocouple probe was introduced properly inside the pulp chamber.

Er:YAG laser cavity preparation:

In the second subgroup, cavities were prepared utilizing Er:YAG laser system (Twilight, FOTONA) that emits photons at a wavelength of 2940 nm. The laser irradiation was performed in a non-contact mode to remove dental hard tissue with a focused beam of 500 mJ energy, a repetition rate of 10 Hz under a continuous water mist (3 mL/min), a spot size of 1mm at 10 mm (by using the survey) distance at right angle to the tooth surface as possible. The ablation procedure was done as overlapped circles of ablation on the tooth surface (as shown in Figure 2).

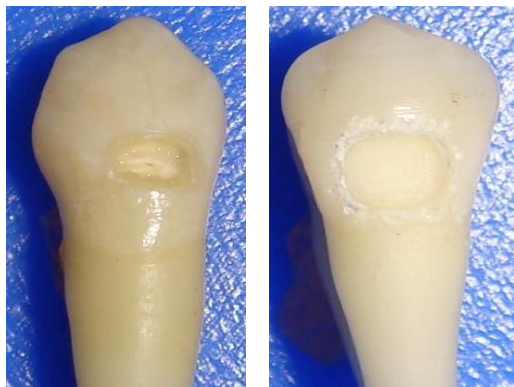


Fig. (2): Cavity preparation with Er:YAG laser

The space between tooth and laser handpiece was obtained by placing the manikin on the table of surveyor and fixing the Er:YAG

handpiece with the arm of the surveyor at a distance of 10 mm from the tooth structure.

Temperature Reading during Cavity Preparation

Before cavity preparation was done, the digital Multimeter (K-type thermocouple TP-01) was turned on and temperature reading was recorded as original reading. After that the cavity preparation was started and again maximum temperature elevation was recorded during 1 mm cavity depth. Finally as the depth of cavity was near 2 mm, final peak temperature was attained. Then the difference between original reading and both 1 mm, 2 mm readings was recorded as temperature variance during 1 mm and 2 mm.

Results

Group 1

Table 1 lists the highest values of temperature change for Er:YAG laser and conventional handpiece that were 2 and 3 °C. While the lowest values of temperature change for Er:YAG laser and Conventional handpiece that were 0 and 1 °C respectively while the mean of temperature variance for Er:YAG subgroup and conventional subgroup were 0.7 and 1.7 °C (as shown in Figure 3).

Table (1) Descriptive statistics of group1

	Means	SD	SE	Min	Max	Range	C.V%
Er:YAG	0.700	±0.571	0.128	0.00	2.00	2.00	81.57
Conventional	1.700	±0.733	0.164	1.00	3.00	2.00	43.12

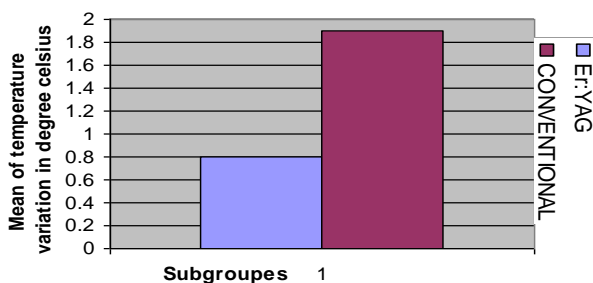


Fig. (3): Mean of temperature variation in group1

ANOVA test between and within the tested subgroups showed a highly significant difference (p < 0.001). The data are listed in

Table 2. T-test between Er:YAG laser subgroup and conventional subgroup showed a highly significant difference (p < 0.001), data are listed in Table 3.

Table (2) ANOVA table of group1

	F-test	P-value	Sig.
Er:YAG	410.98	0.000	HS
Conventional			

*P<0.001 High significant

Table (3) T-test between group1

	Means	SD	t-test	p-value	Sig.
Er:YAG	0.700	±0.571	4.81	0.000	HS
Conventional	1.700	±0.733			

*P<0.001 High significant

Group 2

Table 4 shows the highest values of temperature change for Er:YAG laser and Conventional handpiece that were 2 and 4 °C. While the lowest values of temperature change for Er:YAG laser and Conventional handpiece that were 1 and 2 °C, mean of temperature variance for Er:YAG subgroup and conventional subgroup were 1.55 and 3.35 °C(as shown in Figure 4).

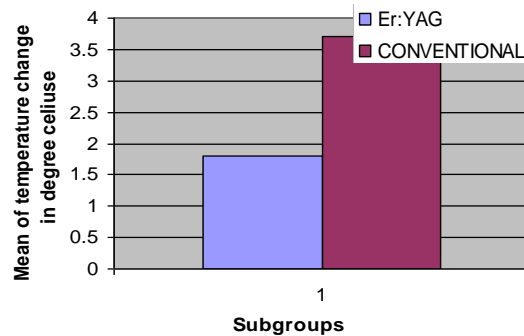


Fig.(4): Mean of temperature variation in group2.

Table (4) Descriptive of group2

	Means	SD	SE	Min	Max	Range	C.V%
Er:YAG	1.55	±0.510	0.114	1.00	2.00	1.00	32.90
Nd:YAG	10.05	±0.945	0.211	8.00	11.0	3.00	9.403
Conventional	3.35	±0.743	0.167	2.00	4.00	2.00	22.18

*N=20

ANOVA test between and within the tested subgroups showed a highly significant difference (p<0.001). Data are shown in Table 5. T-test between Er:YAG laser subgroup and conventional subgroup showed a highly significant difference (p<0.001), data are shown in Table 6.

Table (5) ANOVA table of group2

	F-test	P-value	Sig.
Er:YAG	704.84	0.000	HS
Conventional			

*P<0.001 High significant

Table (6) T-test between group 2

	Means	SD	t-test	p-value	Sig.
Er:YAG	1.55	±0.510	8.91	0.000	HS
Conventional	3.35	±0.743			

*P<0.001 High significant

Group 1 and Group 2

A statistical analysis (t-test) was calculated to compare between the tested subgroups of group 1 and group 2, as listed in Table 7. There was a highly significant difference between all tested subgroups of both group1 and group2. Also the mean temperature variation between group1 and group2 is shown in Figure 5.

Table (7) T-test between group 1 and group 2

	t-test	p-value	Sig.
Er:YAG	4.96	0.000	HS
Conventional	7.06	0.000	HS

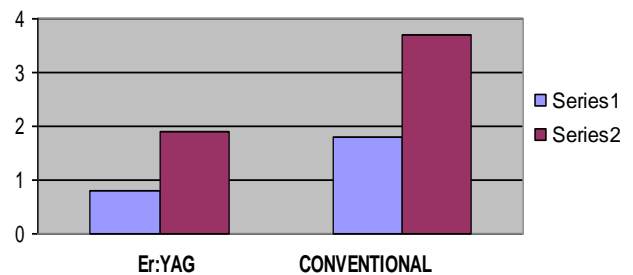


Fig. (5): Mean of temperature variation between group1 and group2

Discussion

Heat generation and temperature elevation is one of the inherent problems experienced during cavity preparation. Er:YAG laser at 2940 nm has a high absorption in water and good coupling to mineralized structure that is hydroxyapatite crystals, the local extensive heating of water in mineralized tissue leads to microexplosions in the liquid phase, the resulting microfragment are removed by high pressure caused by the steam (Clarckson, 1992), this may explain the variance in temperature between the Er:YAG laser subgroup and conventional bur subgroup, this result come into agreement with Cavalcanti et al. in (2002) (Cavalcanti, et al., 2002), and Armengol et al. in (2000) (Armengol, et al., 2000). Actually the mechanism of action between conventional handpiece and Er:YAG laser handpiece completely different, that's to say conventional handpiece remove the hard tissue substance by friction of the rotating bur while Er:YAG laser ablate hard tissue by mean of Photothermal (Photoablation) (Kazuaki, et al., 2006), the maximum temperature variation for Er:YAG laser and conventional bur were 2 °C and 3 °C respectively in 1mm depth, and 2 °C and 4 °C respectively in 2mm, temperature elevation less than 5 degree C considered non threaten to pulp tissue. (Zach and Cohen,1965) nevertheless Er:YAG laser showed a better results than conventional bur, this come into agreement with Vinicius et al in (2005) (Vinicius, et al., 2005), moreover the photothermal interaction mechanism causes the intertubular dentin to be ablated more than the peritubular dentin, because of more water content in the former this results in the usual cuff-like appearance of the peritubular dentin and irregular dentin surface in Er:YAG laser treated dentin (Armengol, et al., 2003).

Regarding the dentin thickness, it is known that this thickness has a decisive role in the generation of the intrapulpal temperature; lower premolar teeth characterized with high pulp level so lower dentin thickness than upper premolars in other words, with thinner dentin temperature inside the pulp chamber will be higher (Nair, et al., 2003), because of the age restriction of samples the main type of dentin is primary dentin this may be responsible for temperature variance between samples. Consistent with previous observations (White et al., 1999 and Burkes, et al., 1992), the present

study revealed an increase in pulpal temperature with decreasing remaining dentin thickness (RDT). The fact that water might inhibit the ablation depths because of high absorption of the Er:YAG laser radiation in water is of concern (Hossain, et al., 1999).

Burkes E.J., et al., in (1992) showed that when dental hard tissues were irradiated by an Er:YAG laser accompanied with fine water mist, not only could the temperature be suppressed, but the cutting efficiency could also be increased also Visuri et al., (1996), evaluated the effects of water spray during Er:YAG laser irradiation on dental hard tissues and found that increasing the water minimally reduce the ablation efficiency. When teeth are irradiated with fine water mist, neither carbonization nor melting in the cavities or its surrounding tissues was found (Hossain, et al., 1999). Teeth exhibited some differences in tooth morphology, dentin structure, size, and location of the pulp cavity. This may explain the temperature differences between the teeth tested (Ottl and Lauer, 1998).

Conclusions

The Er:YAG laser cavity preparation with energy density 63.69J/cm² has proved to be an efficient technique in cavity preparation in comparison to the conventional bur cavity preparation regarding the temperature variance of class V cavity preparations of premolar teeth.

Increasing the cavity depth; decreasing remaining dentin thickness resulted in higher intrapulpal temperature.

References

- Armengol V, Laboux O., Weiss P, Jean A., Hamel H. (2003) Effects of Er:YAG and Nd:YAP laser irradiation on surface roughness and free surface energy of enamel and dentin : An in vitro study. *J. oper dent.*, **28**: 67-74.
- Armengol V., Jean A., Marion D. (2000) temperature rise during Er:YAG and Nd:YAP laser ablation of dentin. *J Endod.* **26**: 138.
- Burkes E.J., Hoke J., Gones E., Wolbarsht M. (1992): Wet versus dry enamel ablation by Er:YAG. *J. Prosthet Dent.* **67**: 847.
- Cavalcanti BN, Otani C, Rode SM. (2002) High-speed cavity preparation techniques with different water flows. *Journal of Prosthetic Dentistry.* **87**:158-161.

- Clarkson D. (1992): Lasers in dentistry. Dental update.115-118.
- Eversole LR, RizoIU I, Kimmel Al. (1997): Pulpal response to cavity preparation by an erbium, chromium:YSGG laser-powered hydrokinetic system. J Am Dent Assoc. **128**, 106.
- Hibst R, Keller U. (1989): Experimental studies of the application of the Er:YAG laser on dental hard substances: 1. Measurement of the ablation rate. Lasers Surg Med. **9**: 338-344.
- Hossain M, Nakamura Y, Yamada Y, Kimura Y, Nakamura G, Matsumoto K. (1999): Ablation depths and morphological changes in human enamel and dentin after Er:YAG laser irradiation with or without water mist. J Clin Laser Med Surg. **17**:105-109.
- Kazuaki Yonemoto, Toru Eguro, Toru Maeda. (2006) Application of DIGNOdent as a guide for removing carious dentine with Er:YAG laser. Journal of Dentistry.**34**: 269-276.
- Munro GA, Hilton TJ and Hermes A. (1996) in vitro microleakage of eached and rebounded class V composite resin restorations. Oper. Dent. **21** :203-208.
- Nair PN, Baltensperger MM, Luder HU, Eyrich GK. (2003) Pulpal response to Er:YAG laser drilling of dentine in healthy human third molars. Laser Surg Med. **32**: 203
- Ottl P., Lauer HC. (1998)Temperature response in the pulpal chamber during ultrahigh-speed tooth preparation with diamond burs of different grit. J Prosthet Dent. **80**.
- Paghdwala AF. (1991) Er:YAG laser hard tissue effects. In: Lasers in Dentistry. Westford, Massachusetts: Penn Well Publishing. 63-75.
- Smail SR, Patterson CJ, Mclundie AC, Strang R. (1988) In vitro temperature rises during visible-light curing of a lining material and a posterior composite, J Oral Rehabil. **15**: 361-6.
- Sonntag KD, Kutzman B, Burkes J, Hoke J, Moshonov J. (1996) Pulpal response to cavity preparation with the Er:YAG and Mark 111 free electron lasers, Oral Surg Oral Med Oral Pathol Oral Radio1 Endod. **81**:695-702.
- Vinicius R., Geraldo M., Edgar Y.,Niklaus U., Ruchele D., Carlos P.(2005) Intrapulpal temperature during preparation with ErYAGlaser:an in vitro study. Photomedicine and Laser Surgery.**23**: 182.
- Visuri SR, Walsh JT, 14 HA. (1996) Erbium laser ablation of dental hard tissue: effect of water cooling. Lasers Surg Med. **18**:294-300.
- White, J.M., Mark, C.F., and Goodis, H.E.(1999) Intrapulpal temperature during pulsed Nd:YAG laser treatment on dentin. in vitro. J. Periodontol. **65**:255-259.
- Zach L, Cohen G. (1965) Pulp response to externally applied heat, Oral Surg Oral Med Oral Pathol. **19**:515-30.

فعالية تحضير الحفرة السنية بواسطة ليزر الايريبيوم- ياك و تأثيرها على ظاهرة ارتفاع درجة

الحرارة داخل اللب السني: دراسة مختبرية

تمارة سردار القرداغي⁽¹⁾ علي شكر محمود⁽¹⁾ رعد نعمة دايم⁽²⁾

(1) معهد الليزر للدراسات العليا، جامعة بغداد، بغداد، العراق

(2) كلية طب الاسنان، جامعة السليمانية، السليمانية،العراق

الخلاصة الهدف من هذه الدراسة هو قياس فعالية التحضير السني للحفرة السنية من النوع الخامس بواسطة ليزر الايريبيوم- ياك بالمقارنة مع الطريقة التقليدية و تأثيرها على ارتفاع درجة الحرارة داخل اللب السني. أختبرت عينة لهذه الدراسة مكونة من عشرين سن مقلوع من الضواحك لاغراض تقويمية. تم تقسيم العينات الى مجموعتين رئيسيتين: المجموعة الاولى تمثل التغير في درجة الحرارة داخل اللب السني عند عمق 1 ملليمتر والمجموعة الثانية عند عمق 2 ملليمتر من الحفرة السنية قسمت كل مجموعة الى مجموعتين فرعية متساوية مكونة من عشرة عينات, تم استخدام ليزر الايريبيوم- ياك ذي الطول الموجي (2940nm) والمجهز من شركة "Twinlight" حيث اختبرت للدراسة المعلمة الاتية: طاقة النبضة 500 mJ, تكرارية النبضة 10 Hz وبكثافة طاقة مقدارها 63.69 J/cm² عند التحليل الاحصائي للمعلومات المتعلقة بالمقارنة بين المجموع الفرعية, اظهرت نتائج الدراسة فروقات احصائية عالية جدا بين المجموعتين 1,2 وكانت افضل النتائج الاحصائية للمجموعة الفرعية A ولكلا المجموعتين والتي تمثل عينات تم تحضيرها بواسطة ليزر الايريبيوم-ياك. يستنتج من الدراسة ان استخدام ليزر الايريبيوم-ياك في تحضير الحفرة السنية من النوع الخامس وبكثافة طاقة مقدارها 63.69 J/cm² كان افضل من الطريقة التقليدية في تأثيره على ارتفاع درجة الحرارة داخل اللب السني.