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Thermal Effects of 940 nm Diode Laser on Dental Socket Blood after Teeth Extraction for Diabetic Patients

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Abstract: Background: High percentage of diabetes patients complain from post extraction hemorrhage. Many types of hemostatic materials are used to stop bleeding after teeth extraction: diode lasers are good hemostatic agents owing to their highly absorption by hemoglobin therefore they are used in soft tissue procedures with relatively no effects on dental hard tissues due to their poorly absorption by water and hydroxyapatite. **Objectives:** The aim of this study is to evaluate the efficiency of diode laser to assist the clot formation after tooth extraction for type II diabetes patients with minimum temperature elevation to prevent periodontal destruction. **Materials and methods:** From 12 type II diabetes patients (7 males and 5 females with age mean of 49.5) blood samples are obtained for the pilot study of clot formation and for studying the thermal effects of laser on blood, then the selected dose is applied on the extracted dental sockets of diabetes patients. **Results:** A significant difference is observed in the temperature of blood before and after laser application; the mean temperature elevation is less thanthe critical temperature of periodontal destruction. Moreover, firm blood clot is formed over the extraction site; the follow up of patients shows good healing with relatively no complications. **Conclusions:** Diode laser assists in the coagulation of the dental socket after tooth extraction without thermal damage to the periodontium.

Key words: Diode Laser, Critical Temperature, Pilot Study, laser Assisted Coagulation.

Introduction

Diabetes Miletus or DM is a systemic disease characterized by chronic elevation in blood glucose level. The patient is considered to be diabetic when the fasting glucose level in blood is 126 mg/ dl or higher, the glycosylated hemoglobin is 6.5% or higher, random glucose level is 200mg/dl or higher (Alamo et al., 2011). This occurs due to a decrease or absence in the level and/ or action of insulin which regulates the normal metabolism of carbohydrates, fats and proteins (Ismail et al., 2015).

Diabetes can be classified into many types which differ from each other in the main characteristic features:

Type 1 DM which is called insulin dependent DM or juvenile diabetes: in this type of DM there is a deficiency or absence in insulin due to a destruction in beta cells of pancreas. Thus, the patient feels hungry, thirsty, tired as well as increasing urination rates (Lucaccioni and Iughetti, 2016).

Type 2 DM or Non-insulin dependent DM or adult-onset: this type is the most common one wherein the resistance to insulin increases leading to a gradual decrease in the secretion of

insulin and then increasing the glucose level in the blood. This type is often seen in obese persons or those with elevated levels of blood lipids (Matthews, 2002).

Type 3 is Gestational diabetes which is glucose intolerance that occurs during pregnancy. Although glucose level returns to its normal rate after delivery; some of the patients are at risk of developing DM in future (McAnulty, 2000).

Tooth extraction for diabetes patients is accompanied by many complications such as dry socket, swelling and abnormal bleeding (Karbassi et al., 2015). Many hemostatic agents are used after tooth extraction to stop bleeding such as sutures, some chemical agents (e.g. Tranexamic acid, Ferric sulphate and silver nitrate), hemostatic resorbable gauze, bone wax and electrocautery (McCormick, 2014).

Lasers are used in dentistry as hemostatic agents, photocoagulation was used first time in 1960 for retina. In 1964, lasers were used by Goldman for oral soft tissue procedures that produced excellent hemostasis (Amid et al., 2012).

Diode lasers are used to coagulate deep portions of oral mucosa due to their absorption by hemoglobin. Laser diode is smaller in size and cheaper than other dental lasers, they reduce the need for sutures, bleeding and postoperative complications (Azma and Safavi, 2013).

Materials and Methods:

In the dental clinic in Institute of Laser for Postgraduate Studies, University of Baghdad, 12 diabetes patients (type II) came for dental extraction.

From those patients blood samples of 10 cc were taken (Figure 1.).

Fig. 1. Blood sample in EDTA tube.

Each sample was stored in EDTA anticoagulant tube in room temperature for 5 minute. Upside down movement of tube was done twice each 2 minutes, then this sample was divided equally on 20 eppendroff tube as 0.5 cc in each one. These tubes were divided to 4 sets; each set consisted of 5 samples and each sample in the set was exposed to a different power but with the same distance between laser tip and blood surface.

These sample were used for pilot study to select the proper laser dose that produces firm and stable blood clot with minimum temperature elevation to avoid peridontium destruction.

Laser device (Epic 10 diode laser 940 nm Biolase, USA) was used with a disposable tip (Biolase E3-7, 7 mm in length and 300µ in diameter) as shown in Figure 2.

Fig.2. diode laser 940 nm with protective eye glasses.

Laser tip was perpendicular to the blood samples surfaces, powers of 1, 2, 3, 4 and 6 W were used for 10 seconds for each set as one power for each sample. For the first set, the distance was 3 mm between laser tip and blood surface, the second set tip surface-distance was 6 mm, 9 mm for the third set and 12 mm for the fourth.

At a power of 3 W (dose= 103.44 J/cm^2) the clot was firm and covered the sample surface area when the distance was 12 mm between laser tip and the blood surface.

For blood temperature measurement: Temperature was measured at 2 points in each sample (4 to be with the level of alveolar bone and 13 mm deep to the surface which is the mean of dental root length) before, during and after laser exposure by a digital thermometer

connected to a computer and the data were recorded and stored by a specific software.

Blood samples of 2 cc were obtained from 12 Type II diabetes patients stored as the same as those in pilot study then each sample was divided in to 4 eppendroff tubes as 0.5 cc of blood in each one.

These tubes were put in water bath in a temperature of 37 ± 0.5ºC (as human temperature), until they gain the same temperature.

For each patient blood, four temperature measurements were done as follows:

1st sample exposed to 3W of radiation for 10s and 12 mm tip-surface distance, thermocouple was 4 mm deep to the sample surface.

2nd sample exposed to 3W of radiation for 10s and 12 mm tip-surface distance, thermocouple was 13 mm deep to the sample surface.

3rd sample exposed to 6W of radiation for 10s and 12 mm tip-surface distance, thermocouple was 4 mm deep to the sample surface.

4th sample exposed to 6W of radiation for 10s and 12 mm tip-surface distance, thermocouple was 13 mm deep to the sample surface.

Temperature was measured at the 2 points for each power before, during and after laser exposure by a digital thermometer connected to a computer and the data were recorded and stored by a specific software, then the statistical analysis was made to investigate the laser effects on blood temperature.

Patients' Methods:

Eleven diabetic patients with age ranged between (44-55 years) had teeth extractions. Before the procedure, many investigations were done to each patient, these investigations included: random blood sugar (RBS), Hemoglobin A1C test, bleeding time, clotting time tests, hemoglobin level (Hb), and Packed Cell Volume (PCV), also blood pressure, medical, dental history and patient's medications. Local anesthesia Mepivacaine 3%, two carpules were used for each patient; laser was applied immediately after tooth removal. Follow up was after 3, 10 and 21 days after operation to examine the extraction sites clinically and radiological investigations were held in day 21, notes were recorded by operator and patient in a questionnaire paper.

Results:

Pilot Study:

The pilot study showed that in this present work the best dose for blood clot formation was 103.44 J/ cm² obtained by 3W for 10 s on a surface area of 0.29 cm².

Temperature Changes:

Temperature was measured before, during and after laser exposure. Changes in temperature were measured second by second by a digital thermometer connected to a computer and recorded by software (AMPROBE).

Table 1 shows the highest values of temperature change for each sample after laser radiation.

Table 1: samples highest temperature changes for different laser powers and thermocouple depth.

Power W	**Thermo couple depth mm**	**samples highest temperature change ºC**											
		#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**
3	**4**	**2.0**	**1.9**	**1.6**	**1.9**	**1.8**	**1.5**	**1.3**	**1.5**	**1.4**	**1.3**	**1.1**	**1.4**
3	**13**	**1.5**	**1.1**	**1.5**	**1.4**	**1.3**	**1.1**	**1.2**	**1.3**	**1.0**	**1.3**	**1.1**	**1.0**
6	**4**	**3.2**	**2.1**	**3.1**	**2.3**	**2.8**	**2.6**	**3.0**	**3.0**	**2.4**	**2.3**	**2.2**	**2.3**
6	**13**	**3.4**	**2.4**	**3.3**	**2.0**	**2.8**	**2.1**	**2.8**	**2.2**	**2.2**	**1.8**	**2.1**	**1.3**

Statistical Analysis:

Shapiro- Wilk test was done to test the normality of data distribution. The analysis shows that the distribution of data at 6W power and 4 mm thermocouple depth is not normal, other data were distributed normally.

For the thermal effect of diode laser on the temperature of blood before and after laser paired, t-test is done for normally distributed data and Mann- Whitney test for abnormal data distribution.

1- Blood temperature difference before and after laser application (3W, 10 s and 0.29 cm² spot area) and thermocouple depth 4 mm to the sample surface are shown in Table 2.

Table 2. Paired t-test for temperature difference before and after laser application.

Groups	Means	SD	Paired t-test value	P	Sig
Before laser application	**36.8583**	**0.17816**	**18.987**	**0.00**	**HS**
After laser application	**38.4167**	**0.34068**			

The difference between blood temperature before and after laser application of this group was highly significant P= 0.00, < 0.05.

2- Blood temperature difference before and after laser application (3W, 10 s and 0.29 cm² spot area) and thermocouple depth 13 mm to the sample surface are shown in Table 3.

Table 3. Paired t-test for temperature difference before and after laser application

Groups	Means	SD	Paired t-test value	P	Sig
Before laser application	**36.7667**	**0.16143**	**24.066**	**0.000**	**HS**
After laser application	**38.0000**	**0.19069**			

The difference between blood temperature before and after laser application of this group was highly significant P= 0.00, < 0.05.

3- Blood temperature difference before and after laser application (6W, 10 s and 0.29 cm² spot area) and thermocouple depth 4 mm to the sample surface are shown in Table .

Table 4. Wilcoxon test for temperature difference before and after laser application

Groups	mean	SD	Test statistic Z	P	Sig
Before laser application	**36.7667**	**0.13707**	**3.065**	**0.02**	**S**
After laser application	**39.3750**	**0.31659**			

The difference between blood temperature before and after laser application of this group was significant P= 0.02, < 0.05.

4- Blood temperature difference before and after laser application (6W, 10 s and 0.29 cm² spot area) and thermocouple depth 13 mm to the sample surface are shown in Table 5.

Table 5. Paired t-test for temperature difference before and after laser application.

Groups	Means	SD	Paired t-test value	P	Sig
Before laser application	**36.8000**	**0.16514**	**12.998**	**0.000**	**HS**
After laser application	**39.2500**	**0.53001**			

The difference between blood temperature before and after laser application of this group was highly significant P= 0.00, < 0.05.

Temperature Elevation by Different Laser Powers:

Table 6 shows the results of statistical analysis of temperature difference between two blood groups.

Table 6. Mann-Whitney test for temperature difference between 3and 6W laser powers on blood samples

Groups	Mean	Z	P	Sig
3W laser power	**39.3750**	**4.150**	**0.000**	**HS**
6W laser power	**38.4167**			

The 1st group was exposed to 3W laser power for 10s on 0.29 cm² surface area and the 2nd was exposed to 6W laser power for 10s on 0.29 cm² surface area. The temperature was measured by a digital thermometer when the thermocouple was 4 mm deep to the sample surface for both groups.

The difference between blood temperature elevation by 3 and 6W laser power was highly significant P= 0.00, < 0.05.

For temperature difference between two blood groups, 1st group was exposed to 3W laser power for 10s on 0.29 cm² surface area and the 2nd was exposed to 6W laser power for 10s on 0.29 cm² surface area. The temperature was measured by a digital thermometer when the thermocouple was 13 mm deep to the sample surface for both groups.

Table 7 shows descriptive analysis between the two groups, Table 8 shows the statistical difference between the groups obtained from independent t-test.

The difference between blood temperature elevation by 3 and 6W laser power was highly significant P= 0.00, < 0.05.

Table 7. Descriptive statistics for temperature elevation by 3 and 6W diode laser

Groups	Std Error Mean	Std Deviation	Mean	N
3W laser power	**0.05505**	**0.19069**	**38.0000**	**12**
6W laser power	**0.15300**	**0.53001**	**39.2500**	**12**

Table 8. Independent t-test for temperature elevation by 3 and 6W diode laser

t-test	df	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P	Sig
				Lower	Upper		
7.687	**13.801**	**1.250**	**0.162**	**-1.599**	**-0.900**	**0.00**	**HS**

Patients' Results:

For laser assisted coagulation extraction site, firm clot was formed and covered the extraction area, no bleeding, swelling, abnormal pain during the 24 hours after extraction. No dry socket or swelling was seen in the extraction site, patients had no pain or discomfort in days 3 and 10 post extraction. On day 21, the wound was relatively closed and no complications occurred. According to patient questionnaire, all of the patients in this work preferred laser assisted coagulation after tooth extraction rather than conventional methods. Figures 3 shows tooth extraction and post-operative follow up clinical results for the laser assisted coagulation for a type II diabetes patient.

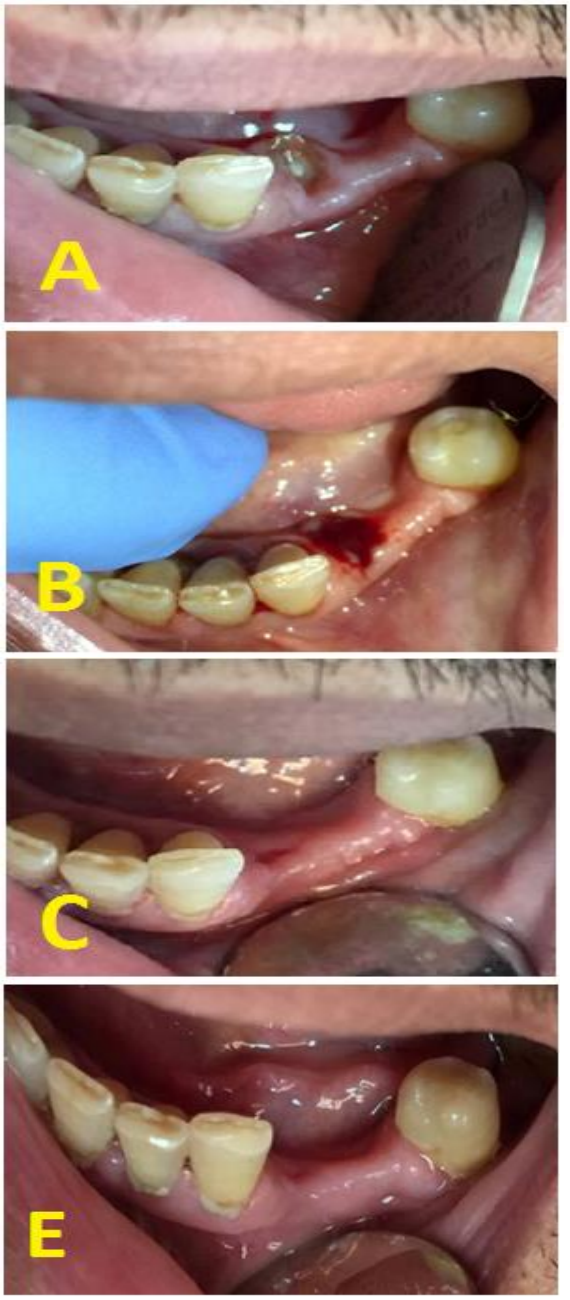

Figure 3. Laser assisted coagulation after mandibular left canine extraction for a male patient. (A) Before extraction, (B) After extraction immediately post laser application, (C) 3rd day after extraction, (D) 10th day after extraction, (E) 21st day after extraction.

Discussion

Diode laser elevates the temperature of blood for less than 10°C, temperature elevation by 10°C for one minute causes irreversible destruction of the periodontium (Ribeiro et al., 2005). This means that the elevation of blood temperature after laser exposure in the present work is acceptable and safe for the periodontal tissue.

Absorption coefficient of 940 nm laser in blood is 0.25-0.28mm^{-1}, scatter coefficient is 0.6-0.64 mm^{-1} and the optical extinction coefficient is 0.82-0.86 mm^{-1} which means that clotting of blood after diode laser exposure occurs due to chromophore absorption, while scattering plays the major rule in healing the surrounding tissue (Mirdan, 2012).

Patients were satisfied by the results of laser assisted coagulation by 10.34 W/cm² laser power density, healing occurred without post extraction complications while in the study done by Karbassi et.al. in 2015 when 23 teeth were extracted and hemostasis took place by conventional method many complications occurred including: abnormal hemorrhage in 30.4%, abnormal pain in 26.1%, fever and infection in 27.1%, swelling in 21.7% and dry socket in 17.4% (Karbassi et. al., 2015).

No previous studies were done about coagulation and temperature elevation by lasers in oral surgery.

Conclusions:

1- The chosen dose for vivo application causes acceptable elevation in socket temperature and it is harmless to the periodontium.

2- Post extraction laser assisted coagulation produces faster healing and relatively no complications in comparison to conventional methods.

3- Patients in this study prefer post-extraction laser assisted coagulation rather than conventional extraction.

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التأثير الحراري لدايود ليزر 940 نانومتر على الدم في مقابس السن بعد قلع الاسنان لمرضى السكري

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الخلاصة : مقدمة: يستخدم الدايود ليزر استخداماً واسعاً في انسجة الفم الرخوة كونه يساعد على تخثر الدم بسبب الامتصاص العالي لاطواله الموجيه المختلفه من قبل الهيموغلوبين والميلانين الموجودة فيها من دون ان يسبب ضرر للانسجة العظمية والسنية القريبة كون هذه الاطوال الموجية ضعيفة الامتصاص من قبل الماء و الهيدروكسيبتايت والتي تعتبر المكون الرئيس لهذه الانسجة. **الهدف:** اثبات امكانية دايود ليزر للمساعدة بتكوين الخثرة الدموية بعد قلع الاسنان لمرضى السكري مع ارتفاع بسيط في درجات الحرارة لمنع تضرر الانسجة الساندة. **المواد والطرق:** من 12 مريض بالسكري 7 ذكور و 5 اناث تم اخذ نماذج دم لغرض عمل دراسة تجريبية على تكوين الخثرة و دراسة تأثير الليزر الحراري على الدم بأستخدام دايود ليزر 940 نانومتر ثم قلع اسنان 11 مريض بالسكري و استخدام الجرعة المختارة على موضع السن المقلوع. **النتائج:** لنماذج الدم المأخوذة من 12 مريض بالسكري و بمعدل عمر 49,5 عام اثبتت الاختبارات الاحصائية وجود فروقات في معدلات درجات الحرارة قبل وبعد الليزر و ان معدل ارتفاع درجة حرارة الدم لا يسبب اي ضرر لانسجة الاسنان وان خثرة الدم المتكونة ثابتة على موضع قلع السن. **الاستنتاج:** تبين ان الدايود ليزر هو عامل مخثر جيد و ان التأثير الحراري للجرعة المختارة للتخثر غير مؤذي لانسجة ما حول الاسنان.