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The Use of a Pulsed Nd: YAG Laser Radiation for the Removal of Intracanal Debris and Smear Layer in Extracted Human Teeth

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Abstract: The efficiency of Nd:YAG laser radiation in removing debris and smear layer from prepared root canal walls was studied. Fifty-seven human extracted single rooted anterior teeth were divided into three groups. A group that was not lased is considered as a control group. The remaining teeth were exposed to different laser parameters regarding laser energy, repetition rate and exposure time. For the case of the set of parameters of 7 mJ laser energy, the cleaning was maximum at 3 p.p.s. repetition rate for 3 seconds exposure time for, the coronal, middle and apical thirds. Above and below this energy level, there was an overdose (melting) or under dose (no effect). Nevertheless for 10mJ laser energy case, the cleaning efficiency was obvious but less than the 7 mJ case.

Introduction

Endodontic therapy in dentistry consists primarily of removing organic material from the root canals, shaping the root canal to accept an endodontic filling material, and then filling the root canal with the appropriate material to seal it from the surrounding oral tissues. The success of endodontic treatment depends on the root canal system being thoroughly cleaned and disinfected followed by the three dimensional obturation of this space (McComb et al.1975, Lan 1999). The attainment of complete procedure is difficult due to the complex morphology of the root canal.

Many studies have demonstrated that the canal preparation techniques produce a considerable amount of smear layer composed of remaining pulp tissue and inorganic dentin debris (McComb and Smith 1975, Takeda 1999). Mukai et al. (1991) suggested that the smear layer have an important effect on bacterial penetration through dentinal tubes. Different irrigants solutions have been used to remove the smear layer, sodium hypochlorite (NaOCl), and ethyldiamine tetra-acetic acid (EDTA). However, NaOCl is shown to be unable to remove the smear layer (Mehi et al. 1999) so does EDTA (Takeda 1999). An ideal root canal irrigants are a bactericidal, which are capable of dissolving organic and inorganic materials (Ingle 1995).

The use of laser irradiation in endodontic have been investigated by several authors. Dedrich et al. (1984) studied the effect of pulsed Nd:YAG laser beam on the root canal wall and its potential to cause melting, recrystallization and glazing of the surface of the wall. Kaba et al. (1991) studied the post-operative symptoms and healing after endodontic treatment of infected teeth using pulsed Nd:YAG laser. Goods et al. (1992) reported that the Nd:YAG laser is able to produce clean root canal wall when combined with hand filing. Harashima et al. (1997) showed that the argon laser radiation had efficient cleaning activity on instrumented root canal surface. Aok et al. (1991), Takede et al. (1999) and Albert et al. (1999) showed that the effect of Er:YAG laser is efficient in removing the smear layer and cleaning the wall of the root canal. The study of a scanning electron microscope (SEM) study of dentin lased with argon, CO_2, and Nd:YAG lasers. It was concluded that the angle between the laser beam and the target surface and the distance between them are the most important parameter

(Ivica et al. 1998). Harashima et al. (1997) studied the efficiency of Nd:YAG laser to remove intracanal debris and smear layer in extracted human teeth. They showed that laser effects depend on the power and mode of the energy delivery system, type and condition of target tissue, size and form of the optical fiber through which the laser beam is transmitted.

A part from the fact that most of the previous works were not systematic regarding the involved laser parameters, the achieved results were not conclusive enough to yield efficient clinical application. Much work is needed to cover that deficiency. Accordingly we believe that the present work is a trial to fulfill this objective.

Materials and Methods

A total of 57 extracted human single rooted incisor and canine teeth were used. The teeth were stored in 10% formalin solution till the starting the experiment. The teeth were mechanically cleaned and sectioned transversely at the cementoenamel junction using a low speed hand diamond disk and water coolant. A flat surface perpendicular to the vertical axis of the tooth was produced and thus eliminating all possible obstructions in the access preparation. The working length of each root canal was established at 1mm shorter than that of apical foramen with size K type file size 15 (dental instrument for spiral dipping of the root canal).The root canal was cleaned and shaped up to size 50K type file at the working length and flared using step back technique. The patency of the canal was ensured by passing no.10 K type file until the file protrudes 3 mm beyond the apical foramen. The pulpal contents and other debris were removed using barbedbroaches (dental instrument) during canal instrumentation. The canals were irrigated with 2 ml of 2.25% sodium-hypochloride (NaOCl) and hydrogen-peroxide (H_2O_2) 3% before using the next larger size. Finally the canal was rinsed with distilled water to avoid the development of sodium chloride (NaCl) crystals. The root canals were then dried with absorbent paper points.

The teeth were divided into three groups. Three teeth were taken in one of these groups and twenty seven in each of the other groups. The control group was unlased, twenty-seven teeth in each of the remaining two groups were further divided into nine subgroups, three teeth in each subgroup. The laser device used in this experiment was a home made Nd:YAG laser coded (DL02). This laser emits pulsed infrared radiation at a wavelength of 1.064 μm with pulse duration of 200 μs .The delivery system is silica, multimode, graded index optical fiber.

In each experiment one of the laser parameters was kept fixed. These parameters are exposure time and repetition rate. The energy of the laser was fixed at 7 mJ for all the nine subgroups one of the two twenty seven group. The other twenty-seven teeth were also divided to nine subgroups. The laser energy was fixed at 10 mJ for the second 27 groups throughout.

The teeth length were measured by a vernior to divide the root to apical third, middle third & coronal third. The optical fiber was twisted in the root canal and was placed parallel to the canal wall at the beginning of each third starting with the apical first then the middle third and lastly the coronal third. After the teeth had been prepared and lased, two teeth from each subgroup were bisected longitudinally into two halves .Two parallel longitudinal grooves were made, with diamond burs without penetrating the root canal on both external surfaces to facilitate their fracture. The specimens were dehydrated by series of graded ethanol alcohol and observed with a scanning electron microscope (SEM). The specimens were viewed at coronal, middle and apical third for the evaluation of the cleaning technique. The third tooth in each subgroup was prepared in a ground section from the middle third of the root and examined under the light microscope.

Results and Discussion

Plate 1 is a SEM photograph of the unlased conventionally treated samples. It is clear that areas with thick smear layer and debris are blocking the dentinal tubules. Out of 27 sets of experiments corresponding to 7 mJ laser energy with various combination of repetition rate and exposure time, only three exhibited positive outcome. Plates 2- a and b are photographs of the lased group with 7 mJ at 3 p.p.s repetition rate for 3 s exposure time and 3 p.p.s. repetition rate for 1s exposure time respectively. The cleaning effect was found to be sharp in the incisal third and middle third. While at the apical third, the cleaning efficiency of the Nd:YAG laser was obvious at 3 p.p.s repetition rate for 3sec exposure time. Plate 2-c shows clean root canal walls with evaporated (ablated) debris and smear layers. The result of the 10 mJ

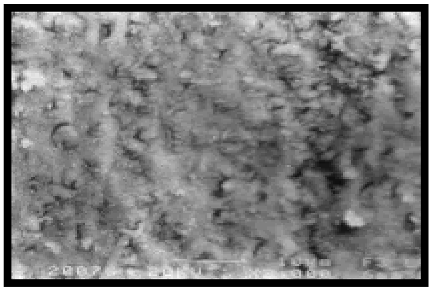

Plate 1: Middle third of root canal of tooth from unlased group showing debris remains on the canal wall. Magnification 2000 X.

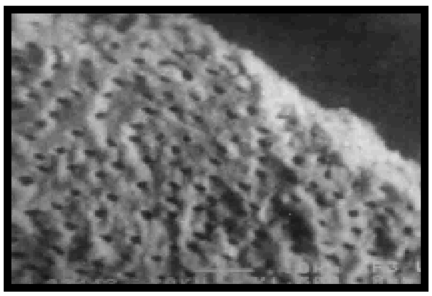

Plate 2-a: Incisal third of root canal of tooth from lased group. E/P=7 mJ, 3Hz rep. rat, 3 s exposure time. Magnification 1500 X

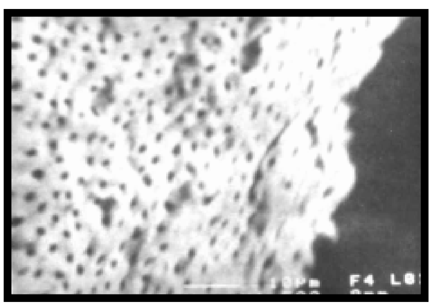

Plate 2-b: Middle third of root canal of tooth from lased group. E/P=7 mJ, 3Hz rep. rat, 3s exp. time. Magnification 1500 X

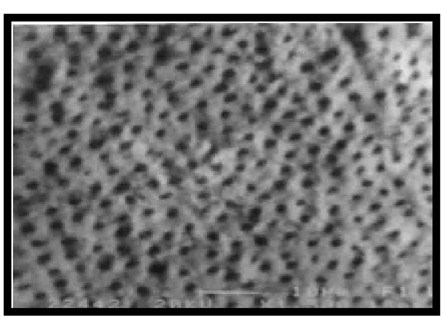

Plate 2-c: Apical third of root canal of tooth from lased group. E/P=7 mJ, 3Hz rep. rat, 3 s exp. time. Magnification 1500 X

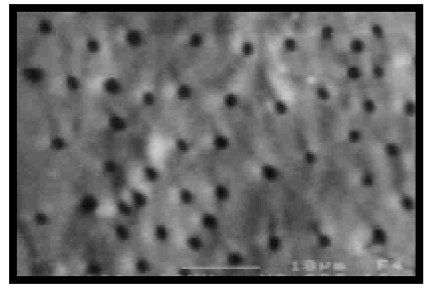

Plate 3-a: Incisal third of root canal of tooth from lased group. E/P=10 mJ, 9Hz rep. rat, 1s exp. time. Magnification 2000 X

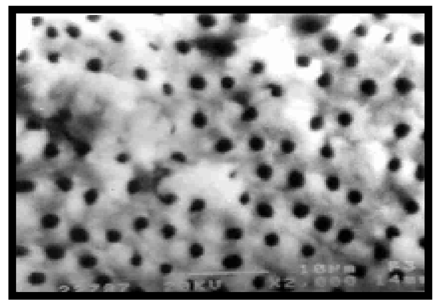

Plate 3-b: Middle third of root canal of tooth from lased group. E/P=10 mJ, 3 Hz rep. rat, 1s exp. time. Magnification 2000 X

set of experiments showed similar effects but at different combination of laser parameters namely repetition rate and exposure time. Out of 27 experiments corresponding to 10 mJ with varies combination of repetition rate and exposure time, only four of them showed positive effects. Plate 3-a is a photograph of a lased group with 10 mJ at 9 p.p.s. repetition rate for 1sec exposure time in the coronal third.

Plate 3-b is a photograph of the middle third at 3 p.p.s. repetition rate for 3sec exposure time. Similar results were observed for the apical third at 1 p.p.s. repetition rate for 3sec exposure time .In all these cases a clear root canal wall was observed.

Optical microscope investigations of 19 purposely prepared slides for most of the irradiated samples were made. The results showed smooth outlines surrounding the root canal in the specimens where the ablation was perfectly done by laser radiation. Melting of the dentin on the wall of the canal was also obvious. A rough outline surrounding the pulp is clear in the samples where the smear layer is present (Plates 4-a, b and c).

Plate 4-a: Rough outline surrounding the root canal. E/P=7mJ 1Hz rep.rate.1s exp.time.

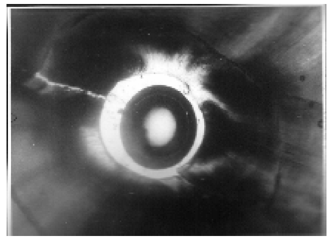

Plate 4-b: Smooth outline surrounding the root canal. E/P=7mJ,3 Hz rep.rate,3s exp.time . Ablation is perfect.

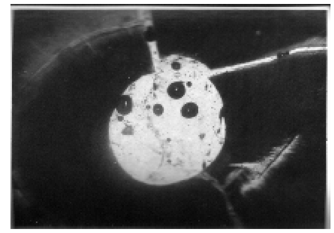

Plate 4-c: Smooth outline surrounding the root canal. E/P=7mJ,9Hz rep.rate,3 s exp.time. Melting is observed.

Table 1: Dentine changes according to various pulsed Nd:YAG laser parameters. (Energy per second =7mJ, Fluence =1.4 J/cm^2 , Peak power =35 W, X= Present)

Repetition Rate (Hz)	Exposure Time(s)	Location 1/3	Dose J/cm^2	Dentinal Tubule	Smear Layer	Melting
	9	incisal	113.4		X	X
	9	middle		X	X	X
	9	apical			X	X
	3	incisal	37.8		X	X
9	3	middle			X	X
	3	apical			X	X
	1	Incisal	12.6		X	X
	1	middle			X	X
	1	Apical		X		
	9	Incisal	37.8	X	X	
	9	middle		X		
	9	Apical		X		
	3	Incisal	12.6	X		
3	3	middle		X		
	3	Apical		X		
	1	Incisal	4.2	X		
	1	middle		X		
	1	Apical		X		
	9	Incisal	12.6		X	
	9	middle			X	
	9	Apical			X	
	3	Incisal	4.2	X	X	
1	3	middle		X	X	
	3	Apical		X	X	
	1	Incisal	1.4	X	X	
	1	middle		X	X	X
	1	Apical		X	X	X

Conclusions

Ablation may simply be defined as the removal of small amount of matter from material bulk. This removal (i.e. ablation) may occur via various mechanisms. In general two mechanisms are well defined namely the photothermal and the photochemical ablation. The removed materials from the bulk may be in different form such as debris, gasses, vapor or plasma. Dentine changes according to various pulsed Nd:YAG laser parameters are shown in Tables 1 and 2. We expect that at 1 p.p.s. repetition rate, the deposited energy is not enough to cause either photothermal or photochemical ablation, but when the repetition rate goes up to 3 p.p.s., combination of thermal stress and volume stress leads to ejection of material not in vapor form but in the form of debris and small fragment. At 9 p.p.s. repetition rate the deposited energy is high enough to melt these fragments and debris before their ejection.

Moreover we expect that increasing the repetition rate to a higher value should again eject that molten material as vapor or plasma. In conclusion the latter case is not favorable although ablation is achieved because of high likely thermal damage. So we believe that 3 p.p.s. repetition rate and 3s exposure time dose may achieve the objective with safe or minor thermal damage.

Table 2: Dentine changes according to various pulsed Nd:YAG laser parameters. (Energy per second =10 mJ, Fluence= 2 J/cm^2, Peak power =50 W, X = Present).

Repetition Rate (Hz)	Exposure Time(s)	Location 1/3	Dose J/cm^2	Dentinal Tubule	Smear Layer	Melting
	9	incisal	162			X
	9	middle				X
	9	Apical				X
	3	incisal	54		X	
9	3	middle			X	
	3	apical		X	X	X
	1	incisal	18	X		
	1	middle		X	X	
	1	apical		X		
	9	incisal	54	X	X	X
	9	middle		X		
	9	apical			X	X
	3	incisal	18	X		
3	3	middle		X		
	3	apical		X		X
	1	incisal	6		X	
	1	middle			X	
	1	apical		X	X	
	9	incisal	18		X	
	9	middle			X	
	9	apical			X	
	3	incisal	6	X	X	
1	3	middle			X	
	3	apical			X	
	1	incisal	2	X	X	
	1	middle		X	X	
	1	apical		X	X	

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استخدام ليزرالنيديميوم ياك لإزالة المسحات و المخلفات في داخل قنوات الجذور للأسنان المقلوعة

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الخلاصة

ان الغرض من البحث هو دراسة كفاءة ليزر النديميوم يـاك (06ر1 مـايكرومتر)، بعـرض نبـضة 200 مايكروثانية لقشط وإزالة المسحة لقناة عصب الجذر بعد رفع السن . استخدم فـي هـذه الدراسـة سـبعة وخمسين سن بشري علوي أحادى الجذر . وزعت الجذور عشوائيا إلى ثلاث مجا ميع ، مجموعة قياسـية ومجموعتين تجريبية ، حسب تعرضها لمتغيرات مختلفة لمعلمات الليزر من قدرة، تكرارية نبضة ومدة تعريض. تم فحـص الأسنان بعد التشعيع من كل مجموعة بالمجهر الإلكتروني الماسح والمجهر الضوئي بعد تقطيع الأسنان وتحضيرها كل حسب دواعي الفحص لذلك الجهاز. أظهرت النتائج حدوث إزالة تامة لطبقة المسحة الناتجة من عملية جرف قنوات الجـذور لكـلا المجموعتين عند تكرارية نبضة 3 هيرتز وظهور مناطق انصهار و إعادة تصلب لكلا المجموعتين عند تكراريـة نبـضة 9 هيرتز.