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EFFECTS OF Nd: YAG LASER IRRADIATION ON THE ROOT CANAL WALL DENTIN OF HUMAN TEETH: A SEM STUDY

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ABSTRACT

The purpose of this study was to observe the morphological and histological changes on the root canal walls after Nd:YAG laser application.

Twenty vital, recently extracted single-rooted human teeth were used for this study. Root canals were cleaned and shaped by a conventional step-back technique – by means of k files up to a 20 k-file type at working length – and subsequently shaped by Ni-Ti root-canal rotary instrumentation up to 30/06 and irrigated with 2.5% hypochlorite solution. Ten teeth (control group) were left unlased, while the other ten teeth were irradiated with Nd:YAG laser by means of a 320 μm fibre inserted in the root canal at 1 mm from the apex with a power of 1.5 Watt and a frequency of 15pps for five seconds in retraction with rotating movements. The control specimen showed debris and smear layer on the root canal surface obscuring the dentin tubules. The root canal walls irradiated with Nd:YAG laser showed a clear glazed surface, some open dentinal tubules and some surface craters with cracks. Such results confirm that smear layer and debris are removable with Nd:YAG laser, however clearing all root canal walls is still difficult and, if the energy level and duration of application are inadequate, a certain degree of thermal damage and morphological changes in dentin structure are observable.

RESUME

Cette étude a pour objectif d'observer les changements morphologiques et histologiques affectant les parois du canal radiculaire après l'application du laser Nd:YAG.

Vingt dents humaines à une racine, vitales et récemment extraites, ont été utilisées pour cette étude. Les canaux radiculaires ont été nettoyés et modelés au moyen d'une technique conventionnelle de type step-back (en utilisant des limes k, jusqu'à une lime de type 20 k, à distance utile). Ensuite les canaux ont été modelés par une instrumentation rotative en Nickel Titane jusqu'à la grandeur de 30/06 et irrigués par une solution d'hypochlorite à 2,5%. Dix dents (groupe de contrôle) ont été laissées non irradiées, tandis que les autres dix dents ont été irradiées par un laser Nd:YAG en utilisant une fibre de 320 μm insérée dans le canal radiculaire à 1 mm de l'apex avec une puissance de 1,5 Watt et une fréquence de 15 pps pour cinq secondes en rétraction et en appliquant un mouvement de rotation. Le groupe de contrôle présentait des débris et du l'enduit parietal sur la surface du canal radiculaire, qui obscurcissaient les tubules dentinaires. Les parois canalaires irradiées par laser Nd:YAG présentaient une surface claire et lustrée, quelques tubules dentinaires ouverts et quelques cratères superficiels avec des fissures. Ces résultats confirment que l'enduit parietal et les débris peuvent être éliminés par le laser Nd:YAG, toutefois le nettoyage de tous les canaux radiculaires est toujours difficile et, si le niveau de l'énergie et la durée de l'application sont insuffisants, un certain degré de dommage thermique et de changements morphologiques peuvent être observés dans la structure de la dentine.

INTRODUCTION

Since the early studies in the 60's, different lasers have been studied in many dental applications (Maiman 1960; Stern et al. 1964; Midda et al. 1991), of which, the use of Nd:YAG (Neodymium-Yttrium-Aluminium-Garnet) laser has shown promising results in endodontics and has been investigated by a number of researchers (Koba et al. 1999). Suggested endodontic applications of Nd:YAG laser include cleaning and shaping root canals to achieve disinfection, removal of smear layer and debris, treatment of periapical tissues and apical sealing after apicectomy. All clinical applications of laser in endodontics have recently been evaluated by Kimura et al. (2000).

Manual and mechanical instrumentation during endodontic treatment creates smear layer, composed of inorganic particles of calcified tissue and organic elements, such as pulp tissue debris and microorganisms.

Several studies demonstrated that cleaning, disinfecting, shaping and obturating root canals all contribute to successful endodontic treatment. Debris and smear layer may be considered deleterious and should be removed since they prevent irrigant solutions, intracanal medicaments and filling materials from penetrating the dentinal tubules and lateral canals.

Some authors agree that removal of the smear layer can be achieved by the alternative use of EDTA and sodium hypochlorite (Goldman et al. 1991). Others conclude that conventional cleansing procedures using common endodontic irrigation solutions and devices fail to adequately clean the root canal system (Sen et al. 1995). Many authors maintain that full root canal sterility cannot be obtained since dentinal tubules and lateral canals diameters are too small to be removed by instruments or irrigation with disinfecting solutions.

The use of laser has been introduced in root canal therapy as an aid to disinfection and removal of debris and smear layer from prepared root canal walls.

Various aspects of the antibacterial effects of irradiation from Nd:YAG laser have been investigated. A strong bactericidal effect from root canal walls lasing was obtained in both in vitro and in vivo studies of human teeth (Rooney et al. 1994; Moritz et al. 1997) .

Levy (8) reported that cleanliness of Nd:YAG laser-treated root canals and the apparent sealing of dentinal tubules could be achieved by the fusion of dentin and deposits of silica on canal wall surfaces. Dederich et al. (1984) used an Nd:YAG laser to irradiate the root canal wall dentin and observed melted, glazed and recristallised surface, which were equally reported by Kimura et al. (2000). According to Goodis et al. (1993), Nd:YAG laser in combination with hand filing cleans root canals surface with a general absence of smear layer and no remaining tissue on canal walls.

The aim of this SEM study was to examine the morphological and histological changes on the surface of endodontically instrumented root canal walls after Nd:YAG laser application.

MATERIAL AND METHODS

Twenty recently extracted, single-rooted human teeth were stored in 10% formalin solution and used for this study. Crowns were removed at the cement-enamel junction and root canals were penetrated to a working length of 1mm less than the actual tooth length, with a 10 k file. The 10 k file was followed by a 15 k file to enlarge the canal. Teeth were prepared with a conventional step-back technique by means of k files. Canals were manually instrumented with a circumferential filing and shaped up to a 20 k-file type at working length and finally shaped with Ni-Ti root-canal rotary instrumentation up to 30/06. Root canals were irrigated with a 2.5% sodium hypochlorite solution between each file and finally dried with sterile paper points. Ten teeth were irradiated with Nd:YAG laser by means of a 320 mm fibre, which represented the diameter of a 35 k file and was inserted in the root canal at 1 mm from the apex with a power of 1.5 Watt and a frequency of 15 pps for five seconds in retraction with rotating movements. This procedure was repeated three times. Ten teeth (control group) were left untreated. Temperature on the root canal surfaces during irradiation was unmonitored in our study.

The two groups of teeth were split into two parts and each part was prepared for electronic scanning microscope evaluation. Specimens were first dehydrated with increasing alcoholic solutions (50%, 75%, 95%, undiluted), than coated with metal with an Edwards S150B sputter coater for 3 minutes. A Philips 505 SEM was used for the observation.

RESULTS

The unlased root canal walls of the control group showed strong evidence of smear layer, which persisted and partially occluded the dentinal tubules (Fig.1). Irrigation with a sodium hypochlorite solution produced a moderate removal of smear layer and organic debris. At higher magnification of the same samples (Fig.2), smear plugs were equally observed.

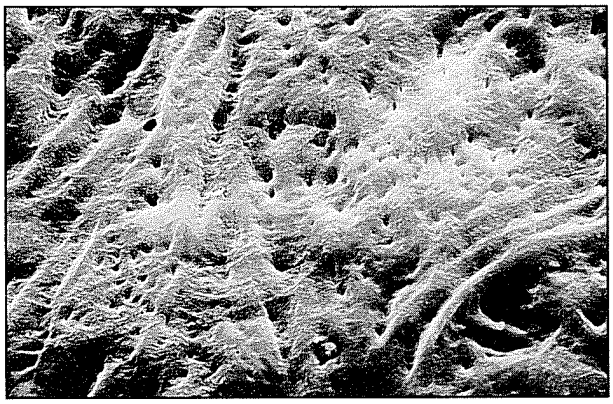

Fig. 1: *Unlased dentin surface (control group). Electron micrograph showing evidence of moderate removal of smear layer and organic debris partially occluding the dentinal tubules of instrumented root canal wall. (1.010 X)*

Fig. 2: *Unlased dentin surface (control group). Electron micrograph showing at higher magnification smear plugs inside dentinal tubules of instrumented root canal wall. (X)*

The directly irradiated dentin walls showed evident morphological changes in dentin structure (Fig.3).

The observed root canal surface appeared melted and glazed, with a complete removal of organic debris and smear layer and the apparent sealing of dentinal tubules by fusion of dentin. In the same area, cracks were also visible. However, at peripheral areas, where the optical fibre was not in direct contact with the dentin wall, laser irradiation produced a very slight removal of debris and smear layer, but no fusion of dentin was visible.

In another region of the irradiated root canal dentin surface (Fig.4), the thermal effect of irradiation did not completely remove the odontoblast processes and organic debris.

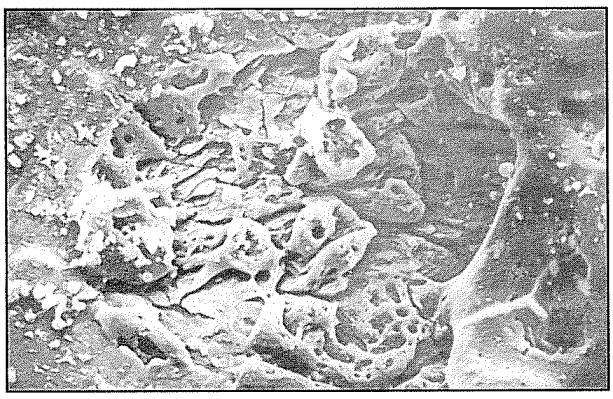

Fig. 3: *Nd:YAG laser irradiated dentin surface. Electron micrograph showing complete removal of organic debris and smear layer and apparent sealing of dentinal tubules by fusion of dentin, which appears melted and glazed. In the same area, cracks are also visible. However, in the surrounding area, where optical fibre did not touch the dentin wall, laser irradiation produced a very slight removal of debris and smear layer. (287 X)*

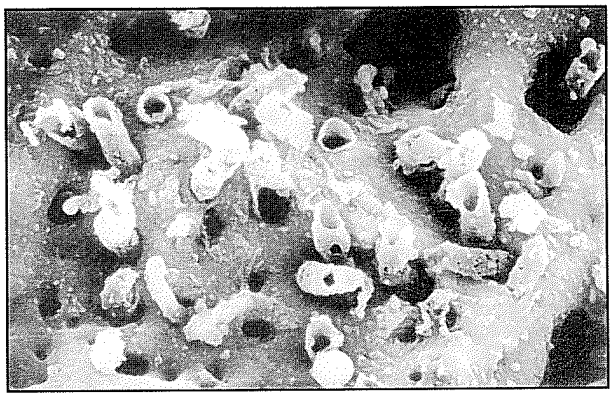

Fig. 4: *Nd:YAG laser irradiated dentin surface. Electron micrograph showing odontoblast processes and organic debris persisting after irradiation. (2.840 X)*

Figures 5 and 6 show a partially melted and glazed dentin surface free of debris and smear layer. The dentin modifications induced by Nd:YAG laser irradiation included dentin tubules partially occluded by fusion of dentin, but some cracks were also visible. It is also worth noting that some tubules remained open.

At very high magnification (Fig.7), the desirable effect of Nd:YAG laser irradiation is evident. Fusion of dentin and consequent occlusion of the dentinal tubules in this area were both particularly visible, whereas only few tubules still remained open. In this microscopic image there is no trace of organic and inorganic debris.

Fig. 5: *Nd:YAG laser irradiated dentin surface. Electron micrograph showing an evident crack between melted and glazed root canal wall. Some dentin tubules remained open. (1.310 X)*

Fig. 6: *Nd:YAG laser irradiated dentin surface. Electron micrograph showing melted dentin surface and open dentin tubules. (1.850 X)*

Fig. 7: *Nd:YAG laser irradiated dentin surface. Electron micrograph showing an evident fusion of dentin resulting in a particularly visible occlusion of dentinal tubules in this area. Only few tubules remained open and no cracks were identifiable in this area. (2.100 X)*

DISCUSSION

Cleaning, shaping and disinfecting root canals are important procedures for successful endodontic treatment. However, instrumentation and irrigation with respect to the polymorphous microflora and the complex root canal anatomy cannot achieve full disinfection and the complete removal of debris and smear layer. Recently, laser irradiation has been introduced in endodontics as an aid to disinfection and removal of the debris and smear layer from instrumented root canal walls.

Many experiments on the effects of disinfection by Nd:YAG laser irradiation were conducted and encouraging results were obtained in several studies. Moritz et al. (1997) noted, in a microbiological examination of the in vivo effects of root canal laser treatment in humans, a marked bacterial reduction in all cases after the first irradiation. Hardee et al. (1994) treated root canals of extracted teeth with the Nd:YAG laser at an output power of 3 Watts for one to two minutes and achieved a 99 percent reduction in test organism. Results from other studies (Ramskold et al. 1997) indicate that lasing with particular settings can effectively sterilise root canals.

In several papers, the mechanism of disinfection was mainly attributed to the thermal effects of the high density energy of the Nd:YAG laser irradiation. As known, the Nd:YAG laser beam does not need to contact a bacterium directly because the heat it generates has a diffusing effect. However, in our SEM study we observed the complete absence of microorganisms only in the directly lased root canal dentine surface. In the

area very close to the lased surface, we observed some intact cocci.

With regard to other effects of Nd:YAG laser irradiation in root canals, a scanning electron microscopic evaluation conducted by Azam Kahn et al. (1997) showed that the Nd:YAG laser energy vaporised the debris and produced a clear glazed surface. Dederich et al. (1984) reported that Nd:YAG laser irradiation sealed dentinal tubules and smoothed root canal walls. Moshonow et al. (1995) observed that Nd:YAG laser in combination with sodium hypochlorite could supplement antibacterial procedures in endodontic treatment and help keep root canals free of debris and smear layer.

In line with the observations of Kymura et al. (2000), the present scanning-electron microscopic evaluation shows that the removal of smear layer and debris by Nd:YAG laser irradiation is possible, although the complete cleansing of all root canal walls and melting of the dentin surface obstructing dentin tubules and lateral canals can hardly be achieved. Morphological modifications of the dentin surface generated by the irradiation were only observable where the optic fibre was in close contact with the dentin walls. Surrounding areas did not seem to be significantly affected by thermal propagation to the extent that debris and smear layer were still visible. Temperature on the root canal surfaces was unmonitored in our study; nevertheless, the observation of cracks suggests that thermal damage and morphological changes in dentin structure can be easily produced whenever the energy level and duration of application is inadequate.

CONCLUSIONS

Based on the results of this scanning-electron microscopic evaluation, Nd:YAG laser irradiation can effectively produce a bactericidal effect, remove the smear layer and evaporate debris. Some images show a large degree of clean and sterile dentin surface and sealed dentinal tubules. However, obtaining full root canal sterility and clearing all root canal walls is still difficult. Laser irradiates straight ahead and makes it almost impossible to irradiate lateral canal walls. It is therefore advisable to improve the fibre tip and the method for full irradiation of all areas of root canal walls.

Results further suggest that a certain degree of thermal damage and morphological changes in dentin structure can be produced, if the energy level and duration of application are inadequate. The clinical application of Nd:YAG laser might be advantageous for endodontic treatment, but future research will need to investigate both the safety and the efficacy of this new and interesting device in the endodontic practice.

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