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Laboratory investigation of the efficacy of Holmium:YAG laser irradiation in removing intracanal debris

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ABSTRACT

Current endodontic therapy involves debridement and desinfection of the root canal by means of mechanical instrumentation and chemical irrigation. However, several studies have shown that these techniques fail to achieve complete cleansing. Recently, lasers have been suggested for use within root canals. This study was conducted to determine the efficacy of Holmium:YAG laser irradiation in removing intracanal debris and smear layer. Root canal surfaces of freshly-extracted human teeth were exposed to pulsed Ho:YAG laser radiation. Subsequently, laser induced structural changes were investigated using scanning electron microscopy. Temperature measurements during irradiation were performed by means of thermocouples. The results of this survey give a preliminary indication of the ability of the Ho:YAG laser to improve current endodontic treatment modalities. However, limitations exist with regard to circumscribed and well-quantified irradiation of root canal surfaces, due to the lack of perpendicular delivery of the laser beam. Additional studies will be required to develope suitable optical transmission systems, in order to achieve complete cleansing and to avoid damage to the periradicular tissues, respectively.

Keywords: endodontics, Holmium:YAG laser, optical fibre, root canal, temperature

1. INTRODUCTION

Current endodontic therapy involves debridement and desinfection of the root canal by means of mechanical instrumentation and chemical irrigation. However, several studies[1] have shown that these techniques fail to achieve complete cleansing. Recently, lasers have been suggested for use within root canals[2,3,4,5]. This study was conducted to determine the efficacy of Holmium:YAG laser irradiation in removing intracanal debris and smear layer.

2. MATERIALS AND METHODS

The experimental unit consisted of 98 freshly-extracted single-rooted teeth. The selected human teeth were extracted because of advanced periodontal disease or for prosthetic considerations. All teeth were free of caries and/or restorations. Immediately upon extraction, adherent soft tissue, dental calculus and plaque were carefully removed. Subsequently, the crowns of all teeth were removed at or just below the cementoenamel junction to create roots of equal length. In addition, chemomechanical preparation by means of K-type instruments and irrigation with 2.6 % sodium hypochlorite solution was performed. The working length of each root canal was established 1 mm short of the apical foramen. The apical seat was prepared to a size 60 file. Finally, the canals were gently dried with paper points. The prepared teeth were randomly diveded into three groups:
I. 18 teeth were positioned in hydroxyethylcellulose, kept at a temperature of 36 °C. The hydroxyethylcellulose was used as a heat sink to simulate thermal properties of periodontal tissues surrounding the root surface. A 320 µm core quartz fibre attached to a Ho:YAG laser unit (Quantronix, Darmstadt, Germany) was inserted inside the root canal. The fibre tip was placed 1 mm short of the working length. The laser was activated for a 20-s period. During the irradiation procedure the fibre tip was retrieved coronally. Two lasing cycles were con-

ducted. Temperature measurements during irradiation were performed by means of two thermocouples. One was fixed on the external root surface and the other was used to check the hydroxyethylcellulose at 36 °C (figure 1). The Ho:YAG laser, operating at a wavelength of 2.10 µm, was used at a repetition rate of 5 and 10 Hz, respectively, with a pulse duration of 200 µs. The output was adjusted from 1 to 2 W.

II. 40 teeth were split longitudinally into two halves. The canal concavities of 30 teeth were immediately irradiated for 3 s in order to create a line of single craters (power level: 1-2 W, repetition rate: 5 Hz). Prior to lasing, 30 concavities were blotted dry („dry" ablation), whereas the other 30 were moistened with 0.9 % sodium chloride solution („wet" ablation). The Ho:YAG laser beam was delivered to the target surface by placing the (320 µm core) quartz fibre tip 1 mm from the canal concavity by means of a hydraulic micrometer. 10 teeth served as a control group and were not lased. Upon completion of the irradiation procedure the samples were fixed in glutaraldehyde, rinsed in buffer, dehydrated in a series of graded ethanol solutions (30 to 100 %), critical-point dried, sputter coated with gold-palladium to a thickness of 200 Ångstroms, and examined by scanning electron microscopy.

III. 40 teeth were positioned in hydroxyethylcellulose, kept at a temperature of 36 °C. 30 teeth underwent Ho:YAG laser treatment using a 320 µm core quartz fibre, placed 1 mm short of the working length and activated as it was withdrawn coronally. The laser application was done in two sequences of 20 seconds each. The power settings were 1.0, 1.25, 1.5, 1.75 and 2.0 W with a 5 or 10 Hz repetition rate and a 200 µs pulse duration. After laser treatment, the teeth were split longitudinally into two halves. A control group consisted of 10 teeth in which the fibre was passed up into the canal and subsequentially retrieved without activating the laser. The canal concavities were fixed in glutaraldehyde, rinsed in buffer, dehydrated in a series of graded ethanol solutions (30 to 100 %), critical-point dried, sputter coated with gold-palladium to a thickness of 200 Ångstroms, and examined by scanning electron microscopy.

3. RESULTS

3.1. Temperature measurements (Group I)

The temperature distribution on the external root surface was recorded from 30 s before laser treatment to 60 s after cessation of irradiation. The following data illustrate the maximun temperature increase at power levels of 1.0, 1.5 and 2.0 W with repetition rates of 5 and 10 Hz, respectively, used for group I.

5 Hz/1.0 W	⇒	6.5 °C	10 Hz/1.0 W	⇒	9.0 °C
5 Hz/1.5 W	⇒	9.8 °C	10 Hz/1.5 W	⇒	14.1 °C
5 Hz/2.0 W	⇒	15.0 °C	10 Hz/2.0 W	⇒	22.3 °C

3.2 SEM examination (Group II and III)

The lased portions were scored according to the following criteria:

0 No effect
1 Slight surface changes (photo 1)
2 Open tubules, remnants of debris (photo 2)
3 Open tubules, free of debris (photo 3)
4 Patches of fusion and recrystallization (photo 4)
5 Consistent surface glazing with cracking (photo 5)

All root surfaces in the unlased control groups exhibited mild cracking due to the preparations required for scanning electron microscopy. Figure 2 depicts the appearance of canal concavities after Ho:YAG laser irradiation in order to create lines of single craters as described for group 2, whereas figure 3 illustrates the maximum surface changes induced by a Ho:YAG laser beam within the root canal as explained for group 3. Thorough investigation of the root surfaces revealed more than one SEM score within the same canal. Here and there, circumscribed areas with no noticeable lasing effects were detected.

4. CONCLUSION

The results of this survey give a preliminary indication of the ability of the Ho:YAG laser to improve current endodontic treatment modalities. However, limitations exist with regard to circumscribed and well-quantified irradiation of root canal surfaces, due to the lack of perpendicular delivery of the laser beam. Additional studies will be required to develope suitable optical transmission systems, in order to achieve complete cleansing and to avoid damage to the periradicular tissues, respectively.

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