A Morphological Study on Root Canal Preparation Using Erbium, Chromium:YSGG Laser

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Purpose: To observe morphological changes of root canal walls, and to evaluate the performance of Er,Cr:YSGG laser irradiation in root canal preparation in vitro.

Materials and Methods: Fifteen extracted single-rooted human mandibular incisors were used for this study. The root canals were prepared by laser irradiation at two different parameters (20 Hz/2 W and 20Hz/3W) using fine fiber tips of two different diameters (320 µm and 200 µm). After laser irradiation, the teeth were bisected longitudinally, and the specimens were observed with a stereoscope and a scanning electron microscope (SEM).

Results: It was possible to prepare root canals using this type of laser irradiation. The irradiated areas of root canal walls showed scaly surfaces and open dentinal tubules.

Conclusion: The Er,Cr:YSGG laser system may be an effective alternative method of preparing straight root canals.

Key words: Er,Cr: YSGG laser, root canal preparation, debris, smear layer, extracted human teeth, SEM.

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Since S. Maiman developed the ruby laser in 1960,[1] many investigations related to applications in dentistry have been carried out using a wide range of lasers. Lasers have been shown to be efficacious in many areas, such as soft-tissue surgery, hard tissue ablation, anesthetic treatment, and disinfection. In terms of removing hard dental tissue, the most promising laser systems are the erbium-doped solid state lasers, which emit mid-infrared radiation in the 2.7 to 3.0 µm range.[2] Several studies have examined the ablility of erbium:yttrium-aluminum-garnet (Er:YAG)[2-8] and erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG)[9-18] laser systems to cut dental hard tissues. In endodontics, many studies have been carried out to examine the removal of debris and smear layer with various instruments[19] and irrigant solutions.[20-23] Recently, a number of authors have shown laser irradiation to produce clean root canals.[24,30] The effectiveness of the Er:YAG laser in removing intracanal debris and tissue remnants was also demonstrated.[24,31] Upon application of the Er:YAG laser in endodontic treatment, the temperature rose by a maximum of 2.0°C, whereas use of the Er,Cr:YSGG laser to remove smear layer and debris from root canals caused a maximum temperature rise of 8.0°C.[32] Thermographic studies using this laser have also supported the notion that this laser does not produce harmful thermal effects on the surrounding tissues.

The use of Er:YAG laser irradiation for root canal preparation has also been examined.[33,34] However, there have been no reports on root canal preparation using Er,Cr:YSGG laser irradiation. The objectives of this study were to observe morphological changes of root canal walls, and to evaluate the ability of Er,Cr:YSGG laser irradiation to prepared root canals in vitro using fine fiber tips.

MATERIALS AND METHODS

Fifteen extracted single-rooted human mandibular incisors having only straight roots were used in this study. The teeth were buccolingually x-rayed to confirm the patent root canals. After crowns of the teeth were cut off at the cementoenamel junction, the root length and original apical size of each tooth were measured. Teeth were randomly divided into five groups, each having three teeth.

The teeth were irradiated using an Er,Cr:YSGG laser (Millenium, Biolase Technology, San Clemente, CA, USA) according to the following parameters: groups 1 and 3, 20 Hz/2 W; groups 2 and 4, 20 Hz/3 W; control group: manual preparation with files. Laser irradiation was performed using two different diameters of fiber tips at each power setting. In groups 1 and 2, tip diameter was 320 µm; in groups 3 and 4, tip diameter was 200 µm. Fiber tip length was 18 mm in all groups. The fiber tip was introduced into each root canal from the orifice and moved nearly vertically with a 2-mm stroke, parallel to the root canal wall. After reaching the working distance, the fiber tip was held in the same spot for 5 s, then pulled out parallel to the root canal wall back to the orifice. The working lengths were established at 3 mm short of the apical foramina. Before laser irradiation, the root canal space was filled with water, and during laser irradiation, root canals were constantly moistened with a water spray device on the handpiece tip. The teeth of the control group were conventionally cleaned and instrumented with K-files; irrigation was performed with 5% sodium hypochlorite (NaOCl) and 3% hydrogen peroxide (H_2O_2). After laser irradiation or instrumentation with K files, the teeth were grooved with diamond burs and longitudinally split into halves.

All specimens were first observed with a stereoscope (SME-10, Nikon, Tokyo, Japan), then dehydrated in a graded series of ethanol (70%, 80%, 90%, and 100%) for 24 h, mounted on stubs, sputtercoated with platinum, and observed again with a scanning electron microscope (PC-SEM) (JSM-5500, JEOL, Tokyo, Japan) at 20 kV.

RESULTS

Groups 1 and 2 (320-µm-diameter laser fiber tip)

This size of fiber tips was easy to manipulate in the root canal.

SEM observation showed that both groups 1 and 2 exhibited similar appearances, regardless of different laser parameters (20 Hz/2 W vs 20 Hz/3 W). On laser irradiated root canal surfaces, debris was vaporized and open dentinal tubules were observed (Figs 1 and 2). However, carbonization and cracks appeared only in some areas of the specimens, and remaining debris of pulp tissue was found in apical areas of the specimens. Carbonization was observed on root canal walls of some specimens, where the root canal showed a slight curvature. Such findings were apparent in some cases regardless of the laser parameters and the size of fiber tips employed. Furthermore, Fig 3 shows a borderline between irradiated areas and non-irradiated areas. Calcospherites were seen on nonirradiated root canal walls, whereas scaly surfaces were found on irradiated areas.

Group 3 and 4 (200-µm-diameter laser fiber tip)

This smaller size of fiber tips could also be easily manipulated in the root canal. However, special care had to be taken to avoid the fiber tip being extruded through the apical foramen, especially in cases where the latter was large.

SEM findings in groups 3 and 4 indicated no differences between the two groups, irrespective of the different laser parameters (20 Hz/2 W vs 20 Hz/3 W). Scaly surfaces of root canal walls and open dentinal tubules were recognized on some parts of the specimens. Remaining pulp tissue debris was observed in many areas (Fig 4), and carbonization appeared in only a few areas of the specimens. Upon laser irradiation, air and water were either removed from the apical foramen or remained there, depending on the original sizes of apical foramina. This situation was observed in every group.

Control group

Debris and smear layer partially remained on the root canal wall, especially near the apical stop.

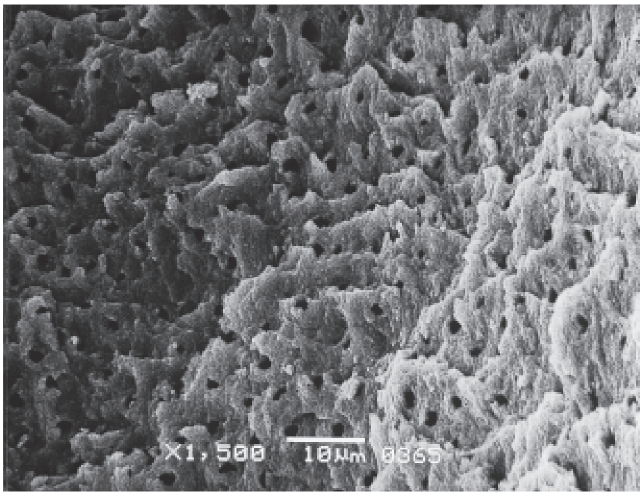

Fig 1 On laser irradiated root canal surfaces of group 1, scaly surfaces and open dentinal tubules were observed. Original magnification 1500X.

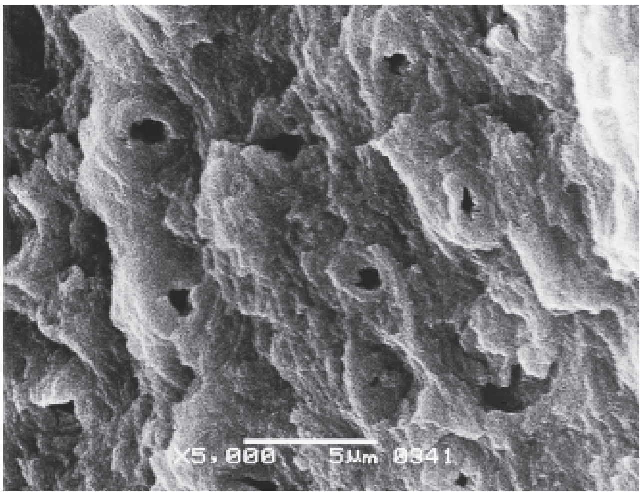

Fig 2 Openings of dentinal tubules were clearly visible and debris was almost vaporized (group 2). Original magnification 5000X.

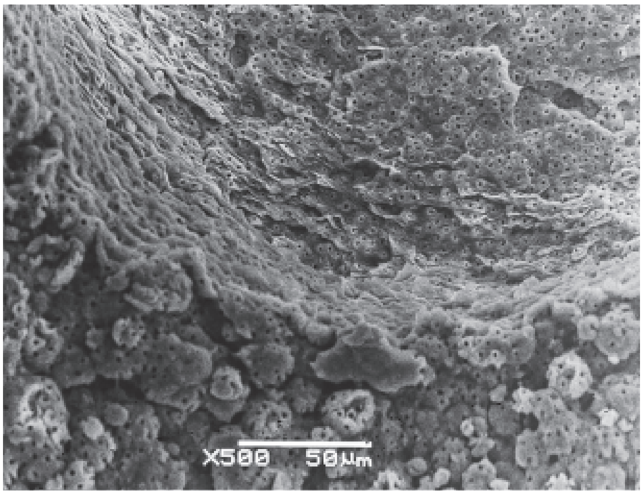

Fig 3 A borderline between irradiated and nonirradiated areas was observed. Calcospherites were seen on nonirradiated root canal walls, whereas scaly surfaces were found on irradiated areas (group 2). Original magnification 500X.

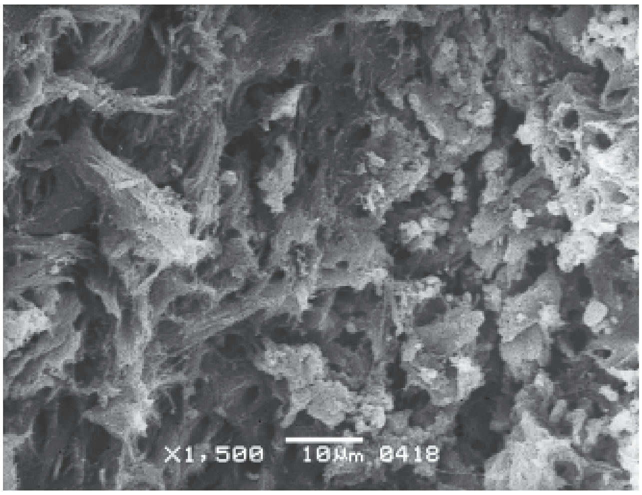

Fig 4 At 1500X magnification of group 3, debris and some remaining pulp tissue were seen.

DISCUSSION

In the recent past, several types of lasers have been investigated for use in endodontic treatment. Argon[24,27,30] and Nd:YAG[24,26] lasers have been shown to be effective in removing debris and the smear layer. Moreover, Er:YAG laser has been proven to be effective for removal of debris and smear layer from the root canal[24,31] without causing thermal side effects,[3,35] because of its characteristic mechanism of hard tissue ablation.[8]

Having a wavelength of 2.78 µm, which lies in the IR region of the electromagnetic spectrum, Er,Cr:YSGG laser is efficiently absorbed in water, and therefore removes dental hard tissue through a characteristic mechanism called “water mediated thermo-mechanical ablation”.[36] This means of hard tissue ablation occurs at temperatures well below the melting point of the mineral phase,[37] so that Er,Cr:YSGG laser does not cause thermal damage to the surrounding tissues during cavity preparations[12,13,17,38] or soft tissue surgery.[39] Eversole et al[13] reported that the Er,Cr:YSGG laser hydrokinetic system (HKS) was effective for dental hard tissue removal and did not provoke any adverse pulpal or periodontal reactions. This laser system was also found to cut dentin and enamel cleanly without exhibiting signs of thermal damage to surrounding tissues.[9] In addition, its use in laser etching[40] and increasing acid resistance[41] of the dental hard tissues has also been established. Thermal injury to periodontal tissues has always been a concern when lasers are applied for intracanal treatment procedures. Eriksson and Albrektsson demonstrated that bone tissue is sensitive to heating at the level of 47 °C.[42] Yamazaki et al reported that with power outputs ranging from 1 to 6 W, the maximum temperature rise resulting from Er,Cr:YSGG laser irradiation of root canal walls without cooling was above 37 °C, whereas with cooling, it was 8 °C.[32] However, with the parameters employed in this study, the temperature rise was between 5.2 to 5.4 °C, which was found in a preliminary study carried out by our group. Furthermore, based on that study's findings on the relationship between the power intensity and carbonization or cracks, 2 W and 3 W were selected for the current study.

In the present study, we examined morphological changes of root canal walls and evaluated the performance of Er,Cr:YSGG laser with an air-water cooling system in root canal preparation. In the majority of cases, SEM findings of laser-irradiated areas clearly demonstrated the scaly and irregular surfaces and open orifices of dentinal tubules. However, carbonization was observed in some cases where slight curvature of root canals could be detected. For the present study, we selected mandibular incisors having only straight canals as proven by radiographs taken preoperatively in the bucco-lingual direction. The fact that we still observed canals with slight curvatures where carbonization was seen could be attributed to undetected curvatures which may have been present in the bucco-lingual direction. In any case, carbonization means that the temperature rose in the root canal beyond clinically acceptable safety levels. Therefore, we suggest other methods for safe laser irradiation below.

The present study used two different sizes of fiber tips having diameters of 320 µm and 200 µm, and according to the manufacturer's information, these had power factors of 0.6 and 0.3, respectively. These tips also had a range of safety zones; the larger the diameter of the fiber tip, the longer the safety zone was. Therefore, we decided to test different diameters of fiber tips in order to investigate the effectiveness of each in root canal preparation. While fiber tips having a diameter of 320 µm were more effective in removal of debris from the root canal, some resistance was encountered during their insertion into root canals, when compared with 200-µm-diameter fiber tips. As a result, they led to more carbonization and step formation than did thinner tips. In contrast, although fiber tips having a 200-µm diameter could be inserted and manipulated in the root canal easily, the effectiveness in cleaning and root canal preparation were reduced and less satisfactory than that obtained with the larger fiber tip. These findings suggest the difficulty in obtaining a clinically desirable result using only a single size of fiber tip. In an attempt to improve this situation, and based on the supporting evidence from a previous study carried out by our group using Er:YAG laser,[33] we suggest the use of a combination of fiber tips having serial diameters in a manner similar to the step-back technique. If carbonization is observed again, we suggest the use of files for initial canal preparation.

In a pilot study carried out by our group to clarify the enlargement by laser irradiation, K-file fit at the level of 1 mm from the apex was checked after laser irradiation. The results showed the size of K-files is almost #20 when a 200-µm-diameter laser fiber tip was used, and #25 or #30 for 320-µm-diameter laser fiber tips. After laser irradiation, the sizes of K-files which fit had increased. Based on the results of a pilot study, the working length used in this study was pre-established at 3 mm from the apical foramina. No scanning electron micrograph showed any destruction of the apical foramen, indicating the formation of the apical stop if the appropriate safety zone is established. However, during laser application in canals having comparatively larger apical foramina, air and water tended to escape through such foramina. Therefore, care should be taken in selecting the root canal for laser treatment, which in turn will obviate air and water escaping through the apical foramina into the periapical tissues. It is also important to select fiber tips whose diameter is larger than the apical foramen, thus preventing the fiber tip entering the periapical tissues after passing through large apical foramina. Furthermore, Cohen et al,[43] while carrying out a study on root canal preparation with Ho:YAG laser, employed fiber tips that emitted the laser beam in a lateral direction. In contrast, the fiber tips used in the present study emitted radiation along the long axis. Seemingly, a laser tip that emits irradiation in a lateral direction may facilitate root canal preparation safely, with clear apical stops. Nevertheless, further research on the effects of this laser should be carried out before it can be clinically applied for root canal preparation.

CONCLUSIONS

Based on the results of this study, it can be concluded that this Er,Cr:YSGG laser system is useful for root canal cleaning and has the potential to be one of the techniques for root canal preparation in straight canals.

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