SEM study of the effect of heat on dentin structure of root canal system treated by Endox and ND: YAP Laser

Faiza Al-Shaheri*, BDS and Saad Al-Nazhan‡, BDS, MSD

A new endodontic machine (Endox Endodontic System) used to vaporize the inflamed pulp tissue was recently introduced in the markets. The high frequency current generated by this machine was tested on extracted human teeth to see whether or not it could cause damage to the dentin structure. It was compared to the Nd: YAP laser machine. Twenty freshly extracted human teeth were mounted in batty silicon and plaster of Paris, respectively, before starting the experiment. The crowns were cut off at the cemento-enamel junction and the working length was determined. They were divided into two groups (10 each for every machine). In addition, four teeth with no treatment were used as control. The teeth were sectioned sagitally at the end of the experiment and the root canals were examined with the scanning electron microscope. The results revealed that the smear layer was totally removed by the two machines. The Endox machine did not cause any damage to the dentin structure, whereas the laser caused severe damage. It was concluded from this study that the use of Endox System causes no detectable harm to the dentin structure of the root canal system compared to the laser therapy.

Introduction

When irreversible pulpitis is diagnosed, a rapid and effective management should be performed. Such procedure requires total removal of the bulk of the inflamed pulp tissue especially when there is pain on percussion. Hedstrom files or barbed broaches are usually used to remove the inflamed tissue.[1] The use of such instruments is very practical in cases of large-sized root canals. Laceration of the pulp tissue, forcing the pulp tissue apically and breakage of the instrument could occur while dealing with small-sized canals.[2] According to Walton and Torabinejad,[3] flare-up is likely to occur due to inflamed pulp tissue, which in turn becomes a major irritant.

Recently, the laser and Endox Endodontic System have been suggested to vaporize the inflamed pulp tissue when it is needed to be removed.[4,5] The laser machine uses light while the Endox System uses high current. A scanning electron microscopic evaluation was reported by Dederich *et al*.[6] They showed that the laser irradiation effect varied from no effect, to disruption of the smear layer, to actual melting and recrystalization of dentin depending upon the magnitude of the irradiation energy. The effect of the heat generated by the Endox System on the pulp tissue of the root canal system has only been reported in few instances.[5] In addition, little attention has been paid to the effect of the heat generated by the Endox System on the ultrastructure of the dentinal root canal system. Therefore, the purpose of the present investigation was to examine and compare the structural changes in root dentin of the root canal system after application of heat by the Endox System to those changes induced by Nd/YAP laser treatment, using the scanning electron microscope (SEM).

Materials and Methods

Twenty-four caries free, freshly extracted human anterior and premolar teeth were collected from the orthodontic clinic. They were stored in 10% formaldehyde until use. Radiographs were taken before and after extraction to examine the root canal space. Teeth with resorption, pulp stones or cracks were excluded. The crown of each tooth was cut off at the cemento-enamel junction in order to simplify access to the root canal using high speed and water coolant. The teeth were randomly divided into the following groups:

The first group of 4 teeth served as control. The pulp tissue of those teeth was not removed. The second group comprised 10 teeth. They were used

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*Consultant, Ministry of Health, Al-Khobar, KSA
Riyadh, KSA
‡Associate Professor, Department of Restorative Dental Sciences, College of Dentistry, King Saud University
Riyadh, KSA

Address request for reprints to:
Dr. Saad Al-Nazhan
RDS Department
College of Dentistry
King Saud University
P. O. Box 60169
Riyadh 11545, KSA

for testing the Endox Endodontic System† according to the manufacturer directions. The teeth were mounted in batty silicon before starting the experiment. The pulp tissue was left intact. The teeth were treated by inserting the flexible metal probe in the predetermined working length of the root canal. A very short electronic fulguration, one impulse, of very high intensity and high frequency current for a time of less than one-tenth of a second, was carried out. This fulguration instantly vaporized the pulp tissue that surrounded the probe.

The third group consisted of 10 teeth. These were used to test the effect of laser beam on the dentin structure. The Nd: YAP laser machine* was used according to the manufacturer's directions. The laser wavelength was set at 1.34 μm, in the middle infrared range with an emission pulse at a repetition rate of 10 Hz with 260mJ of energy for a duration of 150 μs. The roots were mounted in plaster of Paris boxes and the working length was determined before starting the experiment. The laser treatment was done using a 200 μm fiberoptic probe mounted on a micromanipulator, introduced inside the root canal and advanced apically to a level 3mm coronal to the apical end of the canal. Single pulses of laser energy were emitted at levels 1 mm apart, as the fiberoptic probe was withdrawn coronally stepwise, with a minute rest period between pulses to prevent temperature builds up in the root canal system.

All the teeth were stored in 10% formaldehyde solution immediately after finishing the experiment. To facilitate their fracture, two parallel, longitudinal grooves, which did not penetrate the root canal, were made on both external surfaces of the teeth. The teeth were then carefully split with a hammer and chisel, mounted on copper stubs, air-dried for 24h, and sputter coated with gold for examination in a JEOL scanning electron microscope operated at an accelerating voltage of 25kv.

Results

On SEM examination of group 1, specimens appeared normal with regular appearance of dentinal tubules and dentin structure which was covered by a smear layer. Collagen fibers could be seen in a network form (Fig. 1).

In group 2, the heat generated by Endox Endodontic System caused total evaporation of the smear layer without causing any damage to the dentin structure (Fig. 2).

Regular pattern of open dentinal tubules could be seen. Debris were less prevalent and the pulp tissue was severely destroyed (Fig. 3).

In group 3, the specimens irradiated with the Nd: YAP laser showed total removal of the smear layer. The dentin structure of the experimental canal wall was severely distorted and melted (Fig. 4). The regular pattern and arrangement of the dentinal tubules was lost. In some areas, the dentinal tubules were occluded by laser-melted dentin particles resulting in disconnected spheres of fused dentin (Fig. 5).

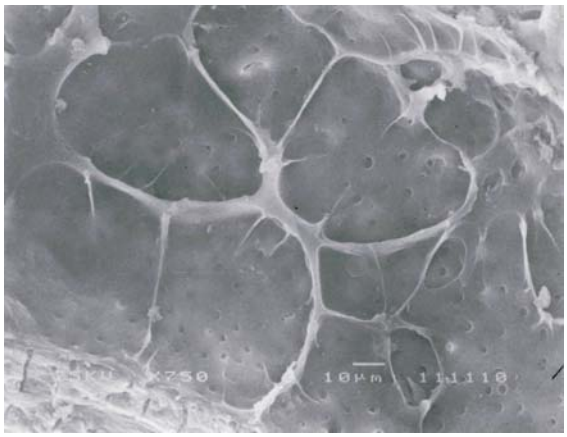

Fig. 1. SEM micrograph of normal controlled dentin structure at apical one-third. Note the intact collagen fibers. The dentinal tubules are covered with a smear layer (x 750).

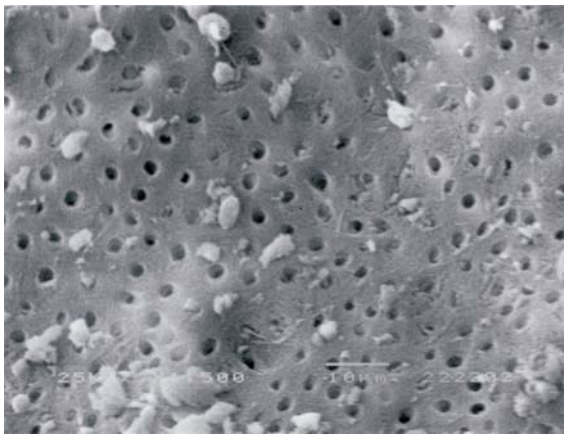

Fig. 2. Dentin specimen irradiated with Endox System. The structure of the dentinal tubules in the middle one-third was opened with less debris and no smear layer (x 1500).

Discussion

Devitalization of inflamed pulp tissue to relieve dental pain is a very old technique that was used in the past.[7] Pulps were cauterized with red-hot

+ Lysis International, Italy
* LOKKI, France

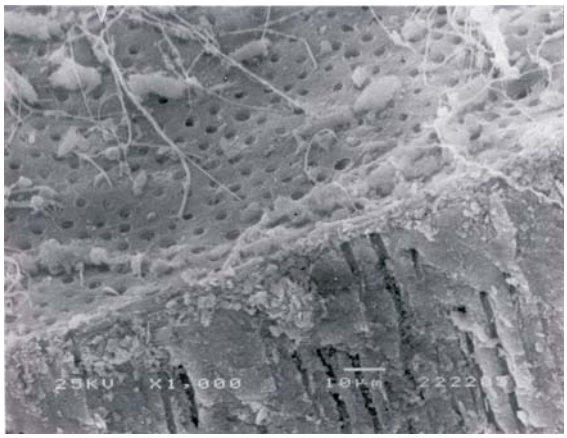

Fig. 3. Dentin specimen irradiated with Endox System showing destructive pulp tissue remnants (x 1500).

Fig. 4. Dentin specimen irradiated with the Nd: YAP laser. The smear layer was totally removed and the dentinal tubules were partially or totally occluded by melted dentin particles (x 2000).

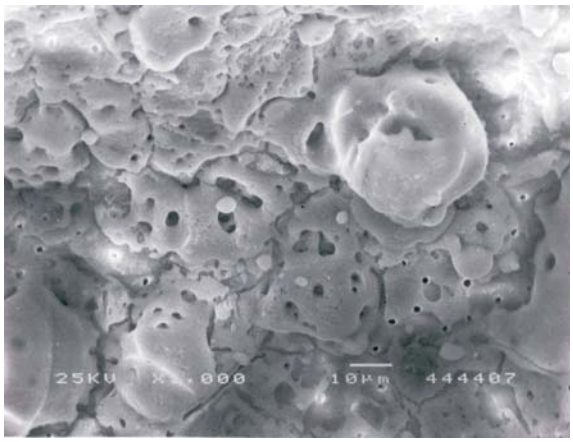

Fig. 5. Dentin specimen irradiated with the Nd: YAP laser. The structure of the dentin is totally destroyed (x 1000).

cautery inserted inside the root canal of the painful tooth. This usually resulted in total vaporization of the pulp tissue.

Roots were mounted into rubber mold for the Endox experiment and plaster of Paris boxes for the laser experiment to avoid hand injury and to give better support for the roots of the extracted teeth during the insertion of the needle of the Endox and the optical fiber of the laser accordingly.

Endox Endodontic System is an electrical machine that vaporizes the soft tissue at high electrical frequency impulses through a very fine smooth flexible needle. It is a modification of the cauterization method used to remove the pulp tissue as well as disinfection of the root canal system.[8] According to the manufacturer, the system released a very short electronic fulguration of very high intensity and high frequency, 600 MHz, for a time of less than one-tenth of a second. The fine smooth needle is also used to measure the apical distance as an electronic apex locater.

SEM observations of the tested freshly extracted teeth revealed no damage of the dentin structure. The dentinal tubules were clearly seen indicating absence of the smear layer but the remnants debris of pulp tissue were still present in a more destructive phase. This was attributed to the high frequency generated by the system. The presence of normal dentin structure after using the Endox System was attributed to the short duration time. This observation is similar to the findings of Haffner *et al.*[5,9] using the same machine and technique who reported that the pulp tissue in the radicular apex could be vaporized only if the apical measurement allows the needle to reach precisely the apical opening. Removal of the smear layer was reported to improve the obturation of the root canal system, resulting in a better therapeutic prognosis.[10,11]

Haffner *et al.*[9] studied the Endox Endodontic System clinically on root canals of twenty teeth of patients manifesting symptoms of irreversible pulpitis. The high frequency current was released, canals were instrumented and the endodontic treatment was completed after seven days using gutta-percha. They reported that the use of the Endox system was not considered uncomfortable by the patients. In addition, they recommended that patients should be given local anesthesia before the application of fulguration. Effective root canal instrumentation should be carried out after using the Endox System to remove all debris prior to the obturation.

Laser has shown great promise in endodontic treatment, including vaporizing soft tissue, removing the smear layer, and melting the dentin

surface.[4] Successful clinical use of laser depends largely on the wavelength, power, pulse duration, exposure time and type of tissue. The nature of the interaction between laser irradiation and tissue depends on the absorption of light and its conversion into heat. Thermal properties of the irradiated materials also play an important role in determining the extent of the effect. The Nd: YAP pulsed laser used in this study is commonly used for pulpectomy, root canal retreatment and root canal fillings.[11-13] It has a short-pulse duration time and, consequently, high power output (10w). The high-energy laser beam could ionize the air above the surface of the tissue and create microplasma. Microplasma creation has a high temperature, about 10,000 C,[14] and follows the acoustic shock. Although the pulse duration time applied was very short (150 µs), the caustic shock could break the tissue into fragments. Hot gases from the microplasma vaporize these tissue fragments. The holes in the fused dentin area are considered as residuals of gas bubbles that are generated during the melting and recrystalization process of the hydroxyapatite.[13]

During laser ablation, temperature increases in the residual tissue. Due to this temperature increase, the laser beam causes ultrastructural and compositional changes in the tissue surrounding the impact point.[13] The evaporation of water and/or organic content of the smear layer cause changing of the surface topography of the smear layer. This gives a melting appearance to its surface. In addition, the close distance between the canal wall and the laser tip caused complete loss of the smear layer. According to Tewfik et al.,[15] all of the laser energy transmitted directly to the dentin will lead to the destruction of the peri- and intertubular dentin, causing an increase of the tubular diameter. The 1 mm spacing between laser pulses was used in an attempt to obtain some overlap in laser changes of the root canal dentin surface to prevent creation of nonlased segments. Results of the present SEM were similar to those reported by Dederich *et al.*,[6] Farge *et al.*,[13] Tewfik *et al.*[15] and Goodis *et al.*[16] The destructive dentin should be well instrumented during root canal therapy before obturation.

It is concluded from this study that the use of Endox System causes no harm to the dentin structure of the root canal system compared to the laser therapy. Further investigations should be carried out to see whether the heat generated by the machine would harm the surrounding vital tissues including the periodontal ligament and alveolar bone.

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