Histological Changes in Pulp After Tooth Preparation with High-speed Handpieces and Er:YAG Laser: A Light-microscopic Analysis

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Purpose: This light microscopic histological analysis was undertaken to evaluate the effect of cavity preparation with Er:YAG laser on pulp and was compared to cavity preparation with conventional burs in high-speed handpieces.

Materials and Methods: Cavities were prepared in 20 premolars using a conventional bur in a high-speed handpiece (group I) and with Er:YAG laser in another 20 premolars (group II). Ten premolars were used as control (no cavity preparation, group III). All the teeth from groups I, II and III were extracted. The teeth were then sectioned into 4- to 5-micron-thick sections. After preparing the tissue sections, staining was performed using eosin and hematoxylin stains. All the sections were observed under light microscopy at 4X to 40X magnification to examine the morphology of the normal odontoblasts and variations, if any. Statistical analysis was done on number of samples with different scores. The pulp responses were categorized into two scores: 1: normal responses; 2: moderate inflammatory responses.

Results: The Er:YAG group showed that 18 treated teeth responded normally and 2 teeth showed a moderate response. The bur-treated teeth resulted in normal responses in 8 teeth and moderate responses in 12 teeth. The statistical analysis showed that response between groups I and II was not significantly different, but group II (Er:YAG laser) showed a better response compared to group I (bur-treated).

Conclusion: Light microscopy revealed less histological change in the pulp when Er:YAG laser was used to prepare teeth compared to teeth prepared with conventional burs in a high-speed handpiece. The laser preparation showed histological findings similar to those of non-manipulated or control teeth.

Keywords: tooth preparation, high-speed handpieces, Er:YAG lasers.

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The development of dental turbines and angle pieces has proceeded rapidly in the last few decades. The high-speed, multi-edged tools and fine diamond grinding pieces have led away from the classical drilling procedure, to a more or less grinding form of tissue removal.

Despite the general advantages of the rotating tools, certain limitations in their use exist. For instance, caries-selective and minimally invasive excavation is not possible with such instruments.[2]

In 1989, experimental work by Keller and Hibst using a pulsed erbium YAG (2,940 nm) laser, demonstrated its effectiveness in cutting enamel, dentin and bone.[5] Since 1987, the clinical perspective of laser use on hard dental tissues has grown by introducing the Er:YAG and Er,Cr:YSGG lasers, which have the advan-

Table 1 Number of specimens in each group	
Group	Number of teeth
I – routine handpiece preparation	20
II – laser preparation	20
III – control, no cavity preparation	10
Total number of teeth	50

tage of reducing thermal effects and creating a precise contour of the section zone.[11]

Many studies have been done to evaluate thermal changes occurring during cavity preparations with various lasers, but very few histological studies have been undertaken to observe the effect of temperature changes during cavity preparation on the pulp. This study was undertaken to evaluate histological changes in the pulp following cavity preparation using Er:YAG lasers and is compared to the pulpal changes after preparation with a high-speed handpiece.

MATERIALS AND METHODS

The study was undertaken after approval was obtained from the Ethics Committee. Fifty intact first premolars were included the study (Table 1), which were indicated for orthodontic extraction from patients between the ages of 19 and 32 years. The patients were informed about the purpose of the study, details of the procedure, approximate time taken for procedure and side effects (if any). Written informed consent was obtained from each patient before starting the procedure. The digital pre-operative orthopantomographs were evaluated for the thickness of enamel and dentin to standardize the depth of cavities and remaining dentin thickness, and patients were selected accordingly.

In order to standardize the study, premolars from each side of the mouth were allocated to a particular group. In all the patients, right premolars were prepared with Er:YAG laser and left premolars were prepared using the high-speed handpiece.

Conservative box-shaped preparations were done on occlusal surfaces of 20 premolars (group I). Each tooth was isolated with rubber-dam. A bur (pear-shaped diamond) with a head length of 3 mm and tip diameter of 0.8 mm was used to prepare the Class I cavities. Preparation was started by entering the deepest occlusal pit with a high-speed handpiece (FSK) under water coolant. Standardized depth for the cavity preparation was kept as 1.5 mm for all the teeth. This was done by measuring half the depth of the cutting portion of the bur along the buccal cavosurface, and re-checking the depth using a periodontal probe. The length and width of the cavity preparation was kept 3mm x 3mm as standard for all the teeth. This was confirmed with the digital vernier caliper.

For laser preparation, Er:YAG laser (Fotona; Ljubljana, Slovenia) (group II), which has a wavelength of 2,940 nm, was used with water coolant according to the following parameters: 0.47 mm diameter tip in contact with the surface, 200 mJ and 20 Hz (panel setting), 0.54 transmission factor, 0.9J/cm^2 of energy density and 100 ms pulse duration. Overall, 20 premolars – maxillary and mandibular – were used for laser cavity preparation. Patients were provided with safety goggles and apron before starting the procedures, and all teeth were isolated with rubber-dam. For both the groups, cavity preparation was done without anesthesia. The control group (group III) included 10 intact premolars. No cavity preparation was done in control group.

All the teeth from group I, II, and III were extracted immediately following cavity preparation using following procedure: Local anesthesia was given to the patients. After achieving anesthesia, teeth were extracted with the help of premolar forceps. Post-operative instructions were given to all the patients.

After extraction, 2 mm of the root end was cut with the high-speed handpiece. Teeth were immersed in 10% formalin solution for 24 h and then subjected to decalcification. Decalcification, processing of the teeth, and staining were performed according to Ross.[20] All the sections were observed under light microscopy (4X, 10X, 40X) for studying the morphology of the normal odontoblasts and any variations.

The pulpal responses were scored accordingly: score 1 – normal (histological features showed dentinal tubules surrounding the pulp with no inflammatory cells); score 2 – moderate (histological features showed pulp with moderate number of inflammatory cells).

Proportions were compared between different study groups by using either Pearson's chi-square test with Yate's Continuity correction or Fisher's exact test (two-tailed) as appropriate. In the present study, $p < 0.05$ was set as the level of significance. See Fig 1 for study design.

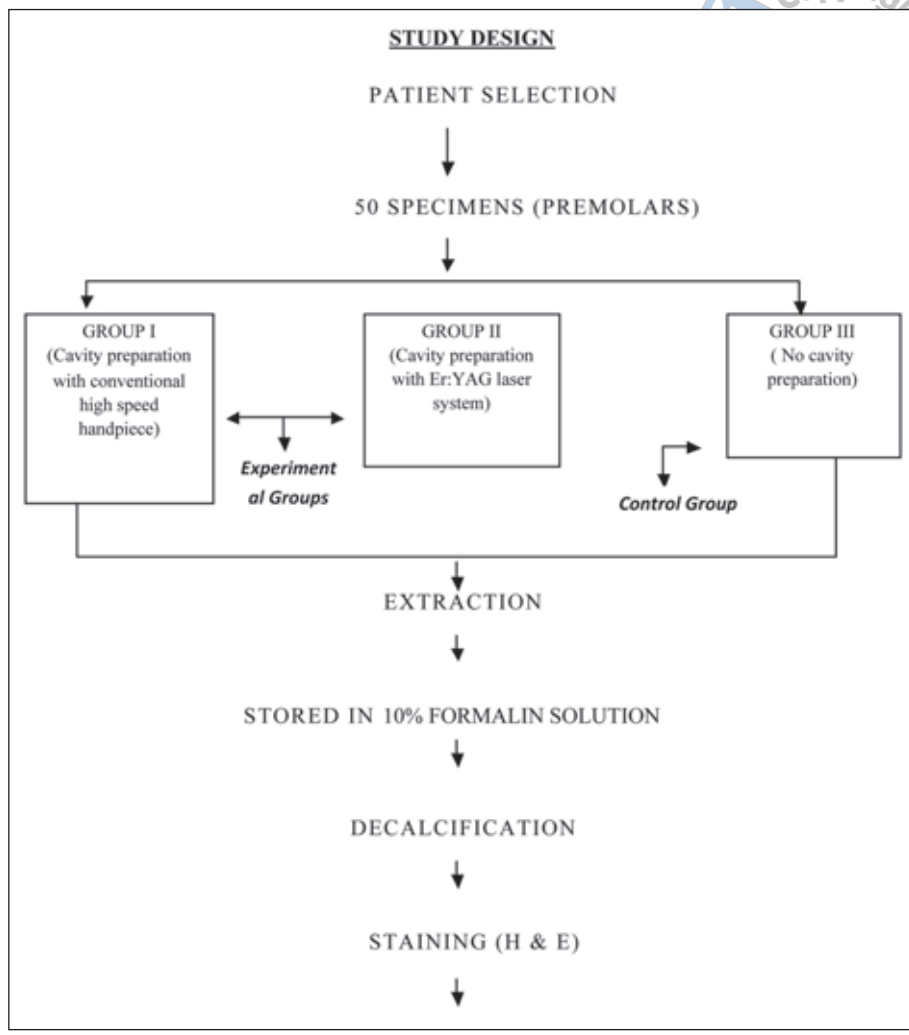

Fig 1 Study design.

RESULTS

Scores of Pulpal Responses in Different Groups

- Group III: The control specimens showed normal pulp architecture with a continuous odontoblastic layer and normal pulpal stroma (Figs 2-4).
- Group II (Er:YAG laser): Out of the 20 teeth evaluated, 18 had a score of 1 and only 2 teeth showed a score of 2 (Figs 5-8).
- Group I (conventional high-speed handpiece): Of 20 teeth evaluated, 12 had a score of 1and 8 showed a score of 2 (Figs 9-12).

Table 2 and Fig 13 show the distribution of scores by group. In this study, there was no statistically significant difference between the responses of the laser group (Group II) and high-speed handpiece group (Group I). Out of 20 samples treated with laser systems, only 2 samples showed moderate responses. The other 18 samples showed normal histological features. While group I showed 12 samples with moderate responses, 8 samples were shown to have a normal response. The incidence of focal and generalized inflammation was lower for the laser group.

DISCUSSION

Dentin and pulp tissues are specialized connective tissue of mesodermal origin. These two tissues are considered as a single tissue, thus forming the pulp-dentin complex; with mineralized dentin comprising the ma-

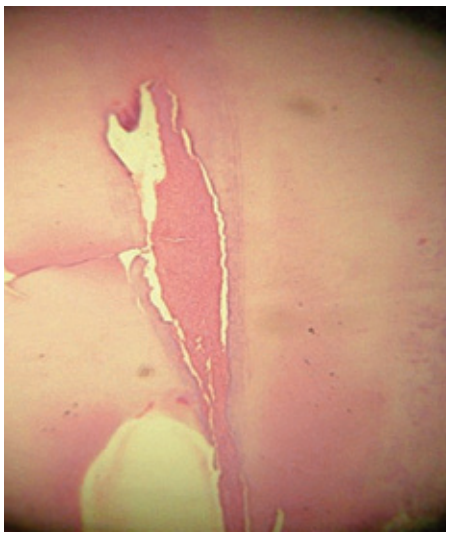

Fig 2 Group III: The decalcified H & E stained section (4X magnification) shows dentinal tubules surrounding a central core of pulp tissue.

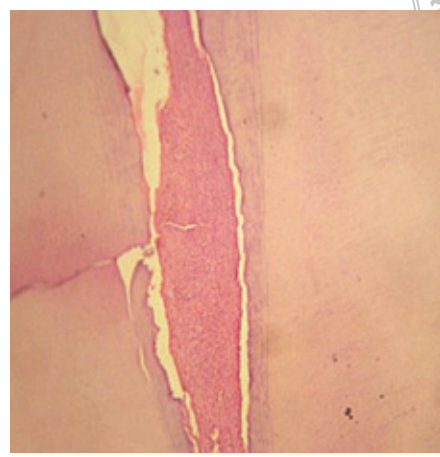

Fig 3 Group III: The decalcified H & E stained section (10X magnification) shows pulp core surrounded by dentinal tubules. The odontoblastic layer is intact.

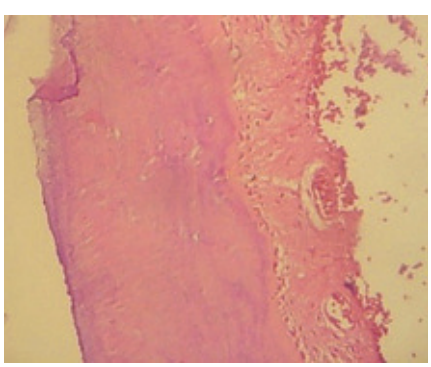

Fig 4 Group III: The decalcified H & E stained section (40X magnification) shows dentin with odontoblastic lining (white arrow) and normal pulp tissue.

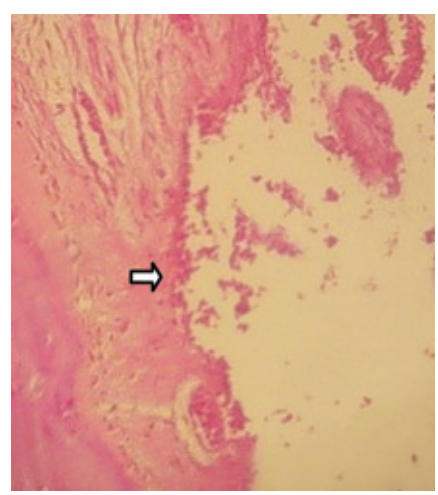

Fig 5 Group II: The H & E stained decalcifies section (10X) shows pulp tissue with blood vessels, few lymphocytes and extravasated red blood cells (white arrow).

ture end product of cell differentiation and maturation. It is because of odontoblastic cell processes that dentin is considered a living tissue, with the capability to react to physiological and pathological stimuli.[14,17]

For this study, patients scheduled for orthodontic correction and in need of extraction of the maxillary and mandibular first premolars were selected. These young permanent teeth are subject to less age-related change, with minimal secondary dentin formation.

A variety of stimuli have been demonstrated to have an effect on the pulp. Pulpal irritants have been classified as mechanical, thermal, chemical, and infective. When normal intact teeth are stimulated thermally, dentinal fluid expands or contracts faster than does the volume of the tubules that contain the fluid, which causes hydrodynamic activation of intradental nerves.

The procedure of cavity preparation induces destructive changes in pulp at the affected site as well

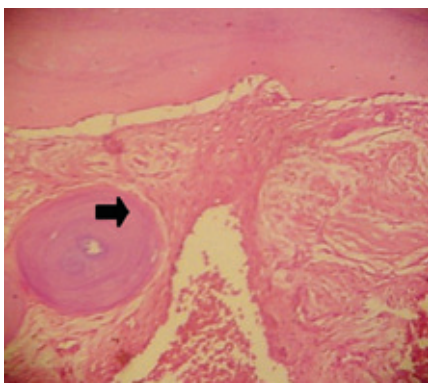

Fig 6 Group II: The H & E stained decalcified section (4X) shows pulp tissue with a mild chronic inflammatory cell infiltrate. Few extravasated red blood cells and hematoxyphilic globular area suggestive of pulp stones were also seen (black arrow).

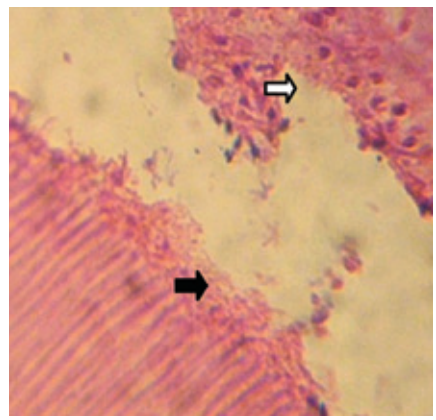

Fig 7 Group II: The decalcified H & E stained section (40X) shows dentinal tubules. The inner surface of dentin is lined by columnar odontoblasts (black arrow). The higher magnification showing diffuse chronic inflammatory cells predominantly lymphocytes (white arrow).

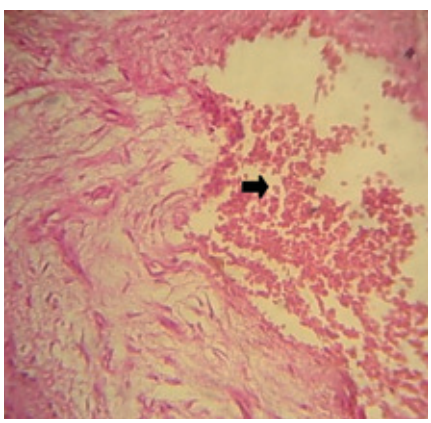

Fig 8 Group II: The H & E stained decalcified section (40X) shows pulp with lymphocytes and extravasated red blood cells (black arrow).

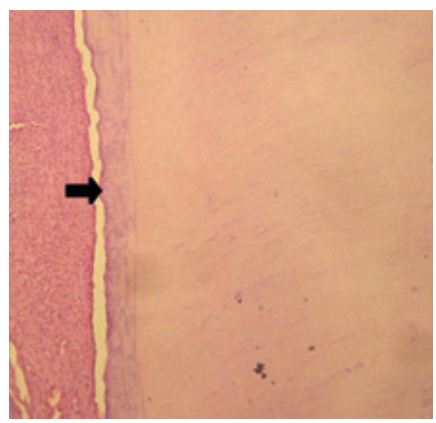

Fig 9 Group I: The decalcified H & E stained section (4X) magnification) shows pulp core surrounded by dentinal tubules and diffuse chronic inflammatory cells (black arrow).

as acute inflammatory reaction. The first cells usually involved in the inflammatory process in the pulp are odontoblasts. The pulp irritants cause an acute exudative response (acute inflammation). This may resolve when the irritant is mild, or the response may become proliferative if the irritation continues for a long time (chronic inflammation). If the odontoblasts survive, they are capable of depositing further reactionary dentin. If not, pulpal mesenchymal cells take the place of degenerated odontoblasts to differentiate into odontoblast-like cells, resulting in the formation of reparative dentin.[20]

A superficial cavity preparation that cuts the odontoblastic processes close to the dentino-enamel junction usually produces only mild irritation. As the cavity depth is increased and with the cutting of the odontoblastic processes, there is an increase in irritation with a consequent increase in the rate of production of

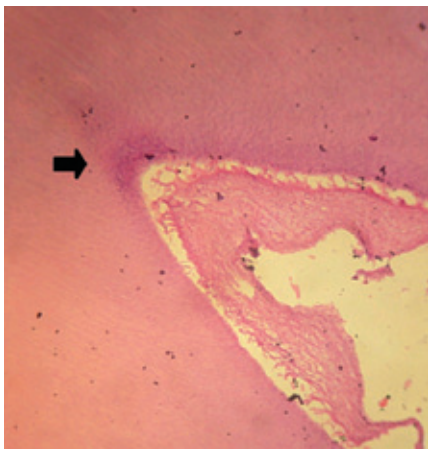

Fig 10 Group I: The decalcified H & E stained section (10X) shows dentinal tubules surrounding the pulp. The pulp consists of diffuse chronic inflammatory cells (black arrow).

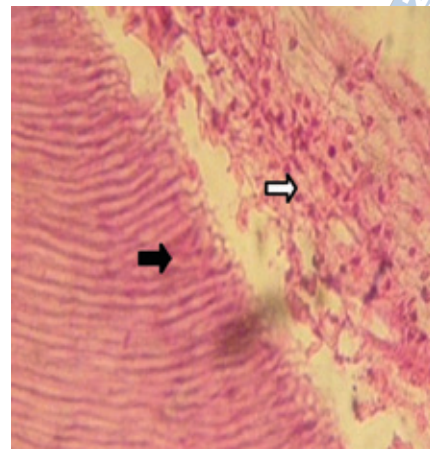

Fig 11 Group I: The decalcified H & E stained section (40X) shows dentinal tubules surrounding the pulp (black arrow). Diffuse chronic inflammatory cells predominantly lymphocytes are seen (white arrow).

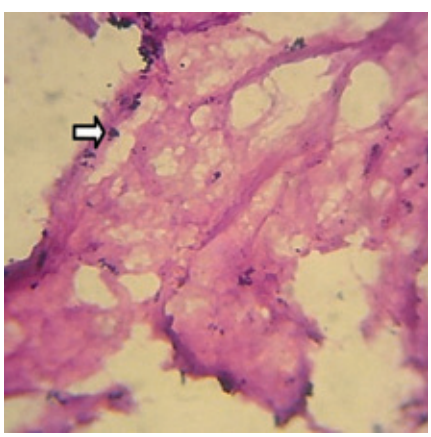

Fig 12 Group I: The decalcified H & E stained section (40X) shows dentinal tubules surrounding the pulp. The pulp consists of diffuse chronic inflammatory cells predominantly lymphocytes (white arrow).

reparative dentin. The degree of inflammatory reaction of the pulp is also increased proportionately, in direct relation to depth of the cavity preparation.[20]

As cavity preparation presents mechanical irritation to the pulp, this study was undertaken to compare and evaluate the changes in histology of pulp after preparing cavities with Er:YAG laser vs conventional high-speed handpieces.[14]

Since the first application of a laser device in dentistry, the commercial availability of a suitable dental laser for safe and efficient cavity preparations has been a cherished goal in dental medicine. The primary prerequisite for such an instrument is its ability to preserve the integrity of the tooth pulp.[13,15]

The Er:YAG laser, which was used in this study, operates at a wavelength of 2,940 nm and in a pulsed waveform. It has a variety of hard-tissue applications, including the following:[3] caries removal, cavity preparation in both enamel and dentin, preparation of root canals.

In this study, the samples treated with a bur in a conventional high-speed handpiece showed 8 samples with moderate inflammatory reactions out of 20 samples while 12 specimens showed a normal response. This moderate inflammation can be due to various factors. The normal tissue pressure of the pulp is between 5 and 20 mm Hg; however, subsequent to the cutting of dentin, it can exceed 60 mm Hg in localized areas. High tissue pressure beneath newly exposed dentinal tubules promotes an outward fluid flow that may carry the odontoblast cell body into the tubules, causing some inflammatory reactions.[12] Another factor which can be responsible for a moderate inflammatory response can be vibration produced by the handpiece and the inability of water spray to sufficiently cool the cutting site, as water becomes displaced by the high-speed rotation of burs.[1,4,6,17] High-speed cutting is disadvantageous when burs are countersunk into the dentin, since water is excluded in a confined region. Burns of the dentin following the use of high-speed instruments have been demonstrated histologically in various investigations.[14]

The present results are similar to the findings of some previous studies.[7,8,9,12] It was concluded that the

Table 2 Comparison of scores between all groups

Score	Group I	Group II	Group III
I	12	18	10
II	8	2	0
Total specimens	20	20	10

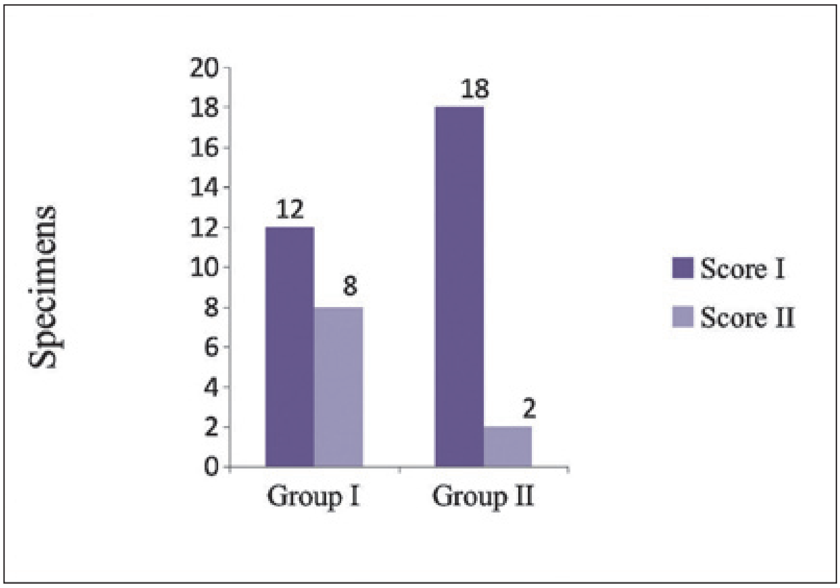

Fig 13 Scores of group I (bur preparation) and group II (laser preparation).

Er:YAG laser is effective in ablation of enamel and dentin while changes in pulp temperature were observed to be within acceptable limits. The enamel and dentin surfaces produced by the laser appeared flaky and scaly. In the current investigation, no obvious fractures or charring of the enamel or dentin surfaces were observed in the histological sections. There was no significant difference in the pulp response to Er:YAG laser cavity preparation when compared with cavities prepared with the high-speed handpiece. In another study on the response of the dental pulp to Er:YAG laser cavity preparation, blood flow in the pulp was measured with laser Doppler flowmetry. Those authors concluded that the use of the Er:YAG laser for cavity preparation could avoid detrimental pulp reactions.[19]

The mechanism of interaction between water, laser light, and hard tissues is not clearly understood and is somewhat controversial. However, the role of water-cooling for the effective Er:YAG laser ablation of dental hard tissues is well accepted. Earlier mechanistic studies focused on tissue dehydration. However, tissue dehydration due to laser-induced water diffusion was proved unlikely, because only approximately half of the water is actually diffusible. In addition, the diffusion rate is slow (several hours to a day). Thermal analysis studies have shown that tissue heating to over 200°C or 300°C would be necessary to remove diffusible water. Temperatures as high as 800°C are required to remove more tightly bound water molecules.[3,11,12,18]

The prime chromophore of the Er:YAG wavelength is water. The free running micro-pulsed emission mode results in rapid and extensive vaporization. When tissue is exposed to this wavelength, small amounts of water contained in enamel and dentin are vaporized, causing explosive dislocation of the gross structure. Compared to drilling methods, the explosive outward effect of erbium laser energy results in minimal thermal diffusion through the tooth structure. Coaxial with this laser is a water spray, to aid in dispersing ablation products and to provide cooling of the target tissue.[12,16] Thus, in this study water coolant was used with Er:YAG laser.

Other factors responsible for a better effect of the laser system can be the wavelength of Er:YAG laser

(2094 nm), which falls close to the absorption peak of water and shielding effect of debris on the ablated surface.[3,15,16]

This study provides histological evidence that the Er:YAG laser under investigation did not thermally damage the pulp and induced only very subtle defense responses of the pulp-dentin complex when used with the specific energy settings, pulse duration within thermal relaxation time, wavelength close to absorption peak of water, and water cooling. Further studies need to be conducted to examine the ultrastructural morphology of the pulp.

CONCLUSION

Within the limitations of this study, light microscopy revealed less histological change in the pulp when Er:YAG laser was used to prepare teeth compared to teeth prepared with conventional burs in a high-speed handpiece. The laser preparation showed histological findings similar to those of non-manipulated or control teeth.

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