Morphological Changes in Dental Hard Tissues Using Diamond Rotary Instruments and Er,Cr:YSGG Laser: A Comparative Study

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This dissertation was presented by Dr. Natasha Merchant at the 1st International Conference, Society of Oral Laser Applications (SOLA) in India on 27th - 29th Oct 2006.

Purpose: This in vitro study was designed to morphologically analyze, using ESEM, any differences in the microscopic surface of Class V cavities using rotary diamond abrasive instruments and Er,Cr:YSGG laser.

Materials and Methods: Twenty extracted human premolars were used. The teeth were brushed and cleaned under tap water and stored in distilled water at room temperature. The teeth were divided into two groups containing 10 teeth each. Standardized Class V cavities were prepared on the buccal surface of all teeth. Cavities in group 1 teeth were prepared using a high-speed air turbine handpiece. Cavities in group 2 teeth were prepared using an Er,Cr:YSGG laser (Waterlase). The laser emits a wavelength of 2790 nm with a pulse frequency of 20 Hz. The delivery tip was held at a distance of 1.5 mm from the target tissues and used in a back and forth motion.

Results: The margins of the cavities prepared by conventional diamond rotary instruments were sharp and more irregular. Smear layer and debris were seen covering the peripheral walls and the depth of the cavity in the rotary preparations. The walls of the cavity prepared by the laser were smooth and the dentinal tubules were not plugged. Ablation of hard tissues was observed in the laser preparations.

Conclusion: Dental lasers are highly efficient tools in cavity preparation. Not only are they completely safe, but they also provide better surface morphology, which has characteristic features for better retention of the restorative materials.

Keywords: dental lasers, hard tissues, Class V cavities, rotary abrasives, ESEM analysis, Er,Cr:YSGG laser.

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The theory of lasers was first explained by Einstein in 1917.[1] The laser was for the first time demonstrated by Maiman[2] after the pioneering work of Basov, Prokhorov, and Townes.[3] Since then, lasers have been used in several fields, notably including medicine.

The application of lasers on dental hard tissues was first explored in an experiment by Stern and Sognnaes in 1964.[4] They used a ruby laser for hard tissue ablation. However, these trials were not very successful: the ruby laser showed the expected ability to ablate dental hard tissues, but the treatment led to a marked rise in temperature in the surrounding tissues, resulting in their damage.[5] In 1965, similar results were obtained while using Nd:YAG and CO_2 lasers for dental hard tissue ablation.[6] Similar results were also seen with holmium lasers.[7]

Until 1997, however, there was no laser option for treating dental caries. In 1997, the FDA approved the Er:YAG (Erbium:Yttrium-Aluminum-Garnet) as the first laser for use in treating human dental caries. Despite their initial promise, the earlier lasers generated considerable heat during the treatment process; in some cases, it even adversely affected the patients' nerves.

Since then, dentistry has seen great advances in the field of laser dentistry. The hard-tissue dental laser currently available to the dentist has proven to be a safer and more proficient cutting instrument than the one originally approved in 1997. A new laser, Er,Cr:YSGG (Erbium, Chromium: Yttrium-Scandium-Gallium-Garnet) is capable of precisely cutting through dental hard and soft tissues.

Lasers in dentistry have great potential in terms of minimizing the patient's fear of the "drill". In most cases, lasers also eliminate the need for local anesthesia. Traditional rotary instruments tend to have an irritating sound and they transmit uncomfortable vibrations, whereas the new dental lasers produce a "popcorn popping" sound whenever an energy pulse engages water.

This study was undertaken to compare the morphological changes produced in dental hard tissues by conventional rotary instruments vs Er,Cr:YSGG dental laser.

MATERIALS AND METHODS

Twenty extracted human premolars were used. The teeth were brushed and cleaned under tap water and stored in distilled water at room temperature. The teeth were divided into 2 groups containing 10 teeth each. Standardized Class V cavities were prepared on the buccal surfaces of all teeth.

Group 1

Class V cavities were prepared in 10 teeth on the buccal surface using a high-speed air turbine handpiece and diamond bur (HM21-010, Meisinger; Düsseldorf. Germany). The dimensions of all cavities were 3 x 2 x 2 mm. The air turbine used worked at the rate of 200,000 rpm.

Group 2

Class V cavities were prepared in the other 10 teeth on the buccal surfaces using an Er,Cr:YSGG laser. These also had a dimension of 3 x 2 x 2 mm. The laser used for this study was the Waterlase (Biolase Technology; San Clemente, CA, USA). The laser emits a wavelength of 2780 nm with a pulse frequency of 20 Hz. The delivery tip (G6) was held at a distance of 1.5 mm from the target tissues and used in a back and forth motion.

All the teeth in this study were hand held during the cavity preparation process. Both before and after the procedure, all teeth were stored in distilled water at room temperature. All samples thus obtained were subjected to Environmental Scanning Electron Microscope (ESEM). For the purpose of the analysis, the samples were not prepared in any manner, ie, no sputtering or sectioning of the samples was required.

ESEM

The ESEM was used at the metallurgy department of the Automotive Research Association of India (ARAI) in Pune. The ESEM works by bombarding the surface of a material with a beam of electrons and detecting those that are emitted or backscattered, which allows the operator to observe down to a resolution of ca 10 nanometers. This provides intricate details of the material structure. ESEM permits the imaging of wet systems with no prior specimen preparation.

RESULTS

1. The cavity margins with the rotary preparation were sharp and irregular (Fig 1).
2. The cavity margins with the laser preparation were irregular but smooth (Fig 2).
3. There was smear layer and debris scattered all over both the prepared and unprepared enamel surfaces when rotary preparation was performed (Fig 3).
4. A total absence of smear layer and debris on the enamel surface was observed with the laser preparation. The enamel prisms were seen, with their lock and key mechanisms clearly visible (Fig 4).
5. The dentinal tubules of the rotary preparation were completely clogged and plugged with debris (Fig 5).
6. In contrast, the dentinal tubules were patent, open, and appeared clean with the laser preparation. They were devoid of any smear layer or debris (Fig 6).

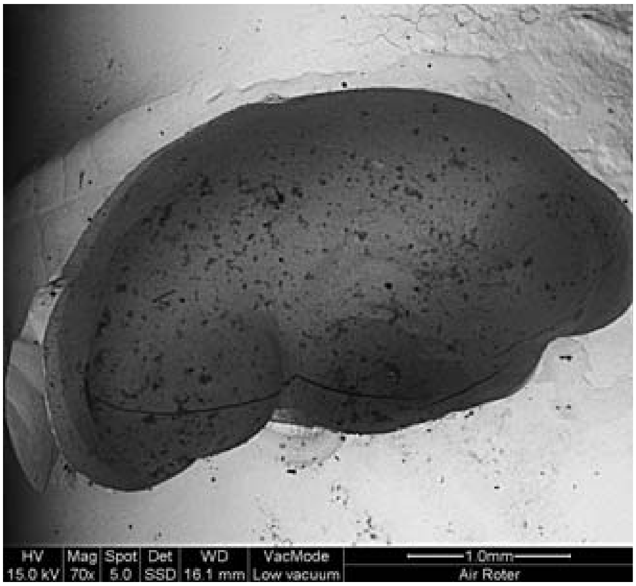

Fig 1 Cavity preparation by a conventional rotary abrasive instrument shows sharp and irregular margins.

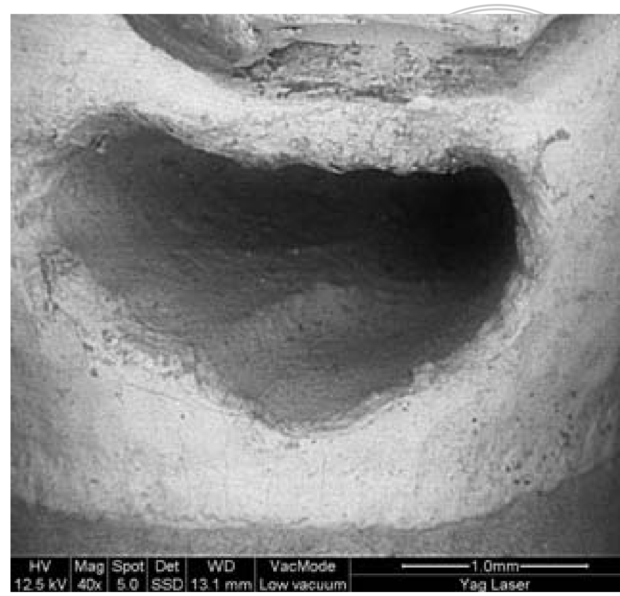

Fig 2 The cavities prepared with the dental laser (Er,Cr:YSGG) have margins which appear smoother, rounded, and more regular.

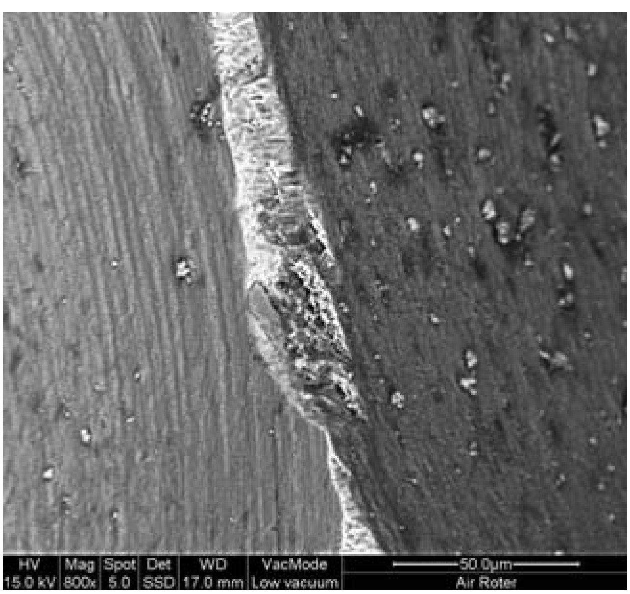

Fig 3 The axial wall of a cavity prepared with a conventional diamond rotary abrasive instrument is shown. On one side of the cavity margin, there is prepared enamel surface, while on the other the unprepared enamel surface is seen. Smear layer and debris are seen spread all over the prepared and unprepared enamel surfaces.

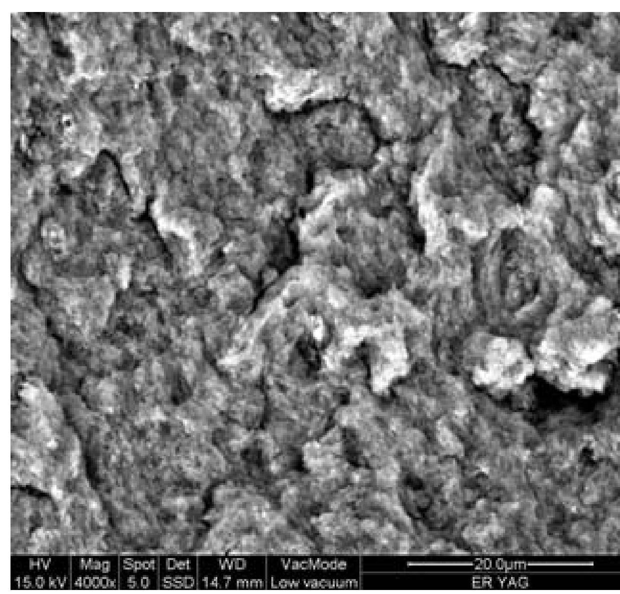

Fig 4 An enamel surface of a Class V cavity prepared with an Er,Cr:YSGG laser is devoid of any smear layer or debris. The surface of the enamel appears rough. Typical uneven ablation edges are seen. The enamel prisms show an irregular course and a microretentive pattern on the surface.

DISCUSSION

The primary reason for removal of dental hard tissues is to rid the tooth of the decayed and carious tooth structure and to prepare a cavity form which will be ideal to receive a restorative material. G.V. Black[8] described the principle of "extension for prevention", which has since changed to a more conservative, less invasive approach.

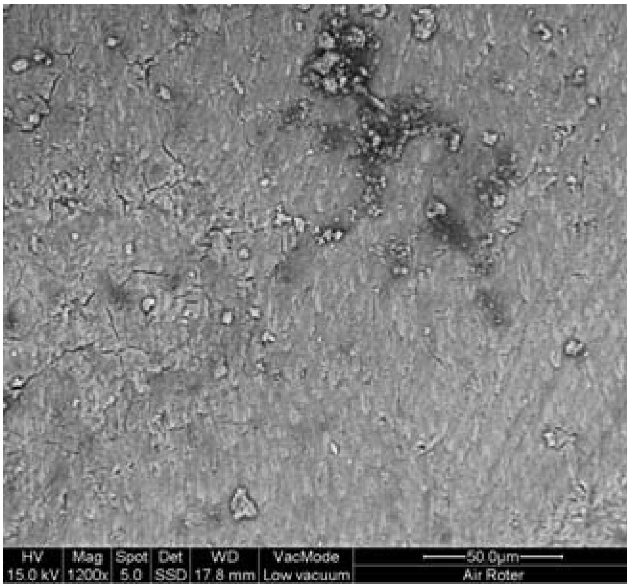

Fig 5 The dentin surface of a cavity prepared with a rotary instrument shows dentinal tubules that are completely blocked and clogged with dentinal debris. The surface lacks adequate roughness.

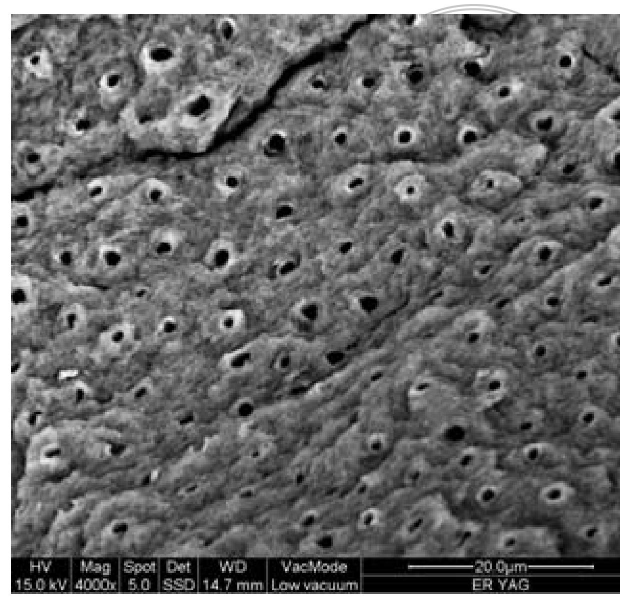

Fig 6 The dentin surface of a laser preparation exhibits open, patent dentinal tubules. They appear devoid of any debris. The characteristic surface roughness is evident, as is the difference in the densities between the peritubular and intertubular dentin. As the peritubular dentin is harder, the intertubular dentin is more easily ablated, making the dentinal tubules appear to protrude.

The development of dental turbines with variable speeds of rotation changed the face of dental practice. Speeds as high as 200,000 rpm have resulted in a rapid removal of the carious tissues without causing much pain to the patients. However, one of the main problems faced in cavity preparation is the rise of temperature at the surface of the target tissues, which is sometimes as high as 700 to 900°C. This rise in temperature is known to destroy the surrounding tissues and also affect the dental pulp. An increase in temperature above 5.5°C can kill a large percentage of the pulp cells.[9]

In laser preparations, intensive electromagnetic energy is used for the ablation of the tissues. The ablation speed of the laser is much less than that achieved with the conventional rotary instruments. The use of erbium lasers has become established in the last few years. The specific wavelengths of the erbium lasers are better absorbed by water than dental tissues. As the dentin and enamel both contain a high percentage of water, the penetration of laser energy is much less.

As explained above, most of the radiation is absorbed by the water, but some conduction of heat cannot be avoided; thus, a water spray is used for cooling. Through an adequate water spray, thermal damage to the pulpal tissues can be avoided.[10,11]

In our samples, we observed that the margins of the cavity preparation were sharper, more edgy, curved, and irregular in the cavities prepared with rotary instruments, but the laser preparations showed margins that were smoother and more regular.

The rotary preparation showed smear layer and debris on both the prepared and the unprepared enamel surfaces. The acid-etching technique is generally used to remove the debris on the prepared cavity surface before restoration with composites. But what is really done to the unprepared enamel surfaces? They are left untreated, as the debris are not visible to naked eye. It then becomes difficult to ensure a 100% restoration of health for this tooth, even if the best restorative procedures or materials are used.

The laser-prepared enamel appeared to be devoid of any debris or smear layer. The enamel prisms could be beautifully appreciated and their lock and key mechanism could also be seen. The characteristic roughness of the cavity surface was observed and uneven ablation patterns were seen, demonstrating the microretentive nature of the laser-prepared cavities.

The rotary-prepared dentin was covered with smear layer and debris. The dentinal debris clogged all the dentinal tubules, and hence they were not characteristically depicted on the scanning images. The acid-etching technique, required to rid the surface of all debris, open up the dentinal tubules, and produce a certain roughness and irregularity on the tooth surface, can be omitted when using dental lasers.[12] The dentin in the laser preparation appeared open, patent, and fresh, devoid of all debris and smear layer. The strong microroughness of the dentin was seen in the laser preparation. The difference in the densities between the peritubular and intertubular dentin could be observed. The peritubular dentin, being harder, was more difficult to ablate as compared to the intertubular dentin, and hence the dentinal tubules appear to protrude from the cavity surface.

It has also been proven in the literature that some micro-organisms from the debris travel a certain depth through the dentinal tubules and cause mono-infections.[13] A strain called *Enterococcus fecalis* is known to travel to a depth of over 1100 nm down dentinal tubules and cause mono-infection. These strains are resistant, and hence very difficult to eliminate once the infection sets in. In contrast, laser preparation kills bacteria. For this reason, laser-prepared cavities are known as sterile cavity preparations.

CONCLUSION

This study was designed to better understand the morphological changes in the dental hard tissues by using conventional rotary instruments and Er,Cr:YSGG dental laser. The observations made with the ESEM helped us draw our conclusions. The morphological differences observed in the two different groups of teeth have clinical implications, as described again below.

The surface of the cavities prepared with the dental laser had no smear layer or dentinal debris. The dentinal tubules were open and patent in the case of the laser preparation, but were clogged in the rotary preparations. This observation makes it possible to state that the acid-etching procedure is not mandatory when using dental lasers for cavity preparations. In addition, the absence of smear layer and debris ensured an extremely low risk of mono-infections, which could be otherwise caused due to the host of microbes present in this smear layer. Moreover, the laser cavity preparation, being sterile, makes the restorations more predictable.

The rough surface texture produced with laser made it better suited for micromechanical bonding of composite restorations. Open dentinal tubules help achieve resin-tag formation, which is essential for bonding when performing composite restorations.

Thus, the dental laser has several obvious advantages over conventional cavity preparation with high-speed turbines and diamond abrasive instruments.

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