



The effect of Er, Cr: YSGG laser parameters on dentin: a scanning electron microscope (SEM) study

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Abstract:

Aim: The parameters of the laser-used cavity preparation and roughening procedures are important for their effects on hard tissue. We aimed to analyze the in vitro ablative and etching effect of the Erbium Chromium, Yttrium Scandium Gallium Garnet (Er, Cr: YSGG) laser on the human dentin using scanning electron microscopy (SEM), comparing six different laser parameters in this study.

Materials and Methods: Seven non-carious, sound-extracted human third molar teeth were used. To abrade the teeth and expose the dentine, a diamond bur was used. The laser was applied to the dentin surface of the teeth with 1–6-Watt (W) power, and a tooth was left for control. All examples were evaluated with a SEM.

Results: SEM observation of the irradiated dentin showed that different energy parameters did not give the same results because of the presence of induced alterations (microcracks, melting, flakes) resulting from the thermal effect. It was observed that the effect created by using 1-2 W created indentations similar to chemical etching. Hard tissue ablation was also observed at 4-5 W parameters, and tissue melting and crack formation was observed at 6 W parameters. Since the study focused on morphological changes, statistical analysis was not performed.

Conclusion: Lower energy levels (1-2 W) are advised for etching, while higher levels (4-5 W) are suggested for cavity preparation in dentin. Avoidance of energy levels exceeding 6 W is recommended. Further studies with increased variables and sample sizes are needed on this topic.

Keywords: Er, Cr: YSGG Laser, etching, ablation, power, scanning electron microscopy.

1. Introduction:

With the approval of the FDA for erbium lasers in 1997, lasers have become more widely used in hard tissue procedures and have become an important part of dentistry. Erbium lasers (Er: YAG, Er: YSGG and Er, Cr: YSGG) are well absorbed due to their wavelength by collagen, hydroxyapatite, and water components and can therefore function effectively in both soft tissue and hard tissue. The water absorption coefficients of Er, Cr: YSGG, and Er: YAG are 1200 mm^{-1} and 400 mm^{-1} .^[1-5] These are also being used in restorative dentistry for cavity sterilization, treatment of dentin hypersensitivity, cavity preparation, and etching of enamel and dentin. Several past studies have evaluated the laser tooth cutting and etching effect^[6-15]

Although different lasers can be used for hard tissue preparation, Moritz has recently explained the advantages of the water-induced ablation method.^[2] The advantage of the Erbium wavelength is that it is better absorbed by water than by the dental tissue. Since the enamel and the dentin consist of a relatively high percentage of water, the laser has a very low penetration depth. The strong absorption property is used to hold down the development

of heat during ablation since water absorbs the laser radiation better than the dental hard tissue, and the rising of the temperature of the tissue is relatively low during ablation. As a result, the water reaches its boiling point and causes a micro explosion in the tooth. Finally, this divides the surrounding tissue into very small pieces and, at the same time, blows them apart.^[2]

Previously, SEM studies investigating the effect of the laser on dental tissues have attracted the attention of many researchers. These studies were occasionally performed with different dental lasers at different energy levels and application procedures.^[16-21] Up to date, SEM examinations for Er, Cr: YSGG laser have generally focused on 1 W recommended for roughening and 4-5 W recommended for dentin preparation. For example, Shinkai et al. investigated the effect of ablation on enamel and dentin by applying 4 Ws of power with different air and water parameters. The authors demonstrated through their studies that varying the air-to-water ratio has an impact on the extent of ablation in dentin.^[22] On the other hand, Cvikl et al. examined the effects of different energy settings of Er: YAG laser on dentin morphology in their study on extracted human teeth. Based on the SEM evaluations, Cvikl and colleagues stated that the best energy

level for adhesion is 4-W energy level ^[23]. Moreover, Kato et al. ^[24] performed an in-vitro study using Er, Cr: YSGG laser and air-turbine and examined the effects of preparation methods on enamel and dentine with the SEM study. In this study, while the smear layer is not observed on the surfaces prepared by laser, the authors showed the presence of the smear layer in preparations prepared using an air turbine. ^[24] Eliminating the formation of a smear layer during cavity preparation removes the need for acid application and washing procedures. This omission can result in time savings during the process. To the best of our knowledge, despite previous studies on this topic, there has been limited exploration of the powers of 2, 3, and 6 W. Nonetheless, varying power levels may offer expanded treatment options and produce different effects. For instance, one of these treatment options includes utilizing the power level that induces a vitrification effect, which could be applied in treating dentin sensitivity, provided it does not result in the ablation of dentin. With the motivation that there is no study yet showing the effects of different parameters when preparing a cavity with the Er, Cr: YSGG laser, we aimed to analyze the in vitro ablative and etching effect of the Er, Cr: YSGG laser on the human dentin using scanning electron microscopy, comparing six different laser parameters in this study.

2. Material and Methods:

2.1 Ethics, consent, and permissions

The research protocol for the present study was prepared according to the regulations for the anonymous collection of biological samples approved by the ethical committee of the Canton of Geneva, Switzerland (Human Research Act, article 2, line 2), which stipulates that such anonymous tooth collection does not need to be submitted to approval by an ethical committee. ^[10]

2.2 Study Population

In this study, seven human third molar teeth without caries or cracks were used. The samples were kept in 10% formalin at +4 degrees Celsius to prevent the growth of bacteria until the enamel removal. Then, under running water, the tissue was removed from the scraps. Diamond fissure burs (*Diatech 836-0186-ML, Swiss Dental Instruments, SWISS*) were used to remove enamel and reach dentin and replaced with a new one in each tooth preparation. Er,

Cr: YSGG laser was used in our study (Waterlase MD, Biolase, San Clemente, California). It has a solid system containing Chromium: Yttrium-Scandium-Gallium-Garnet. Its wavelength is 2780 nm. Air and water parameters can be adjusted digitally via the display. Six teeth were irradiated with Er, Cr: YSGG laser according to the manufacturer's recommendations, using G Tip. During the laser application, the head of the device was held perpendicular to the tooth surface and at a distance of 2 mm from the tooth surface. In this study, laser application was omitted for the first tooth, while the subsequent teeth were subjected to the following laser parameters: the second tooth received 1W, 20 Hz, with 65% air and 55% water parameters; the third tooth received 2W, 20 Hz, with 65% air and 55% water parameters; the fourth tooth received 3W, 20 Hz, with 65% air and 55% water parameters; the fifth tooth received 4W, 20 Hz, with 65% air and 55% water parameters; the sixth tooth received 5W, 20 Hz, with 65% air and 55% water parameters; and the seventh tooth received 6W, 20 Hz, with 65% air and 55% water parameters. In the study, a 600 µm sapphire non-contact tip was used in the non-contact phase; the working distance in the focus mode is 1-2 mm. During laser procedures, physicians used glasses provided by the company to protect against the harmful effects of laser lights on the eye. Samples were coated with 100 Angstroms thick gold-palladium to evaluate the surface properties in SEM (fig). Later, these samples were examined with SEM (JSM 6400, Tokyo, JAPAN) 100 and 2000 magnifications in the Metallurgical Department of Middle East Technical University (METU).

Statistical analysis:

Statistical analysis was not conducted in this study, aligning with the approach taken in certain comparable studies where various researchers investigated morphological changes in dental hard tissues using SEM. ^[24, 26]

3. Results:

In this study, seven human third molar teeth were utilized. The initial sample (not subjected to laser treatment for comparison) was examined, revealing that the dentin surface was entirely coated with a smear layer, accompanied by the presence of significant cracks. The length of the cracks varied between 10 and 20 microns (Fig 1a).

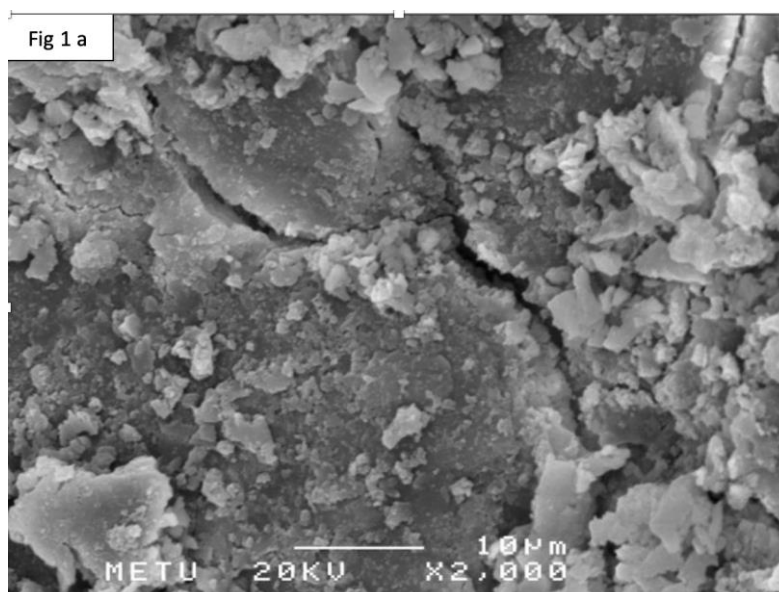


Fig 1.a.

The second sample of 1-W laser was examined; the opening was observed in several tubule mouths, and no cracks or melting were observed. The number of open dentin tubules was noted as 12 (Fig. 1b).

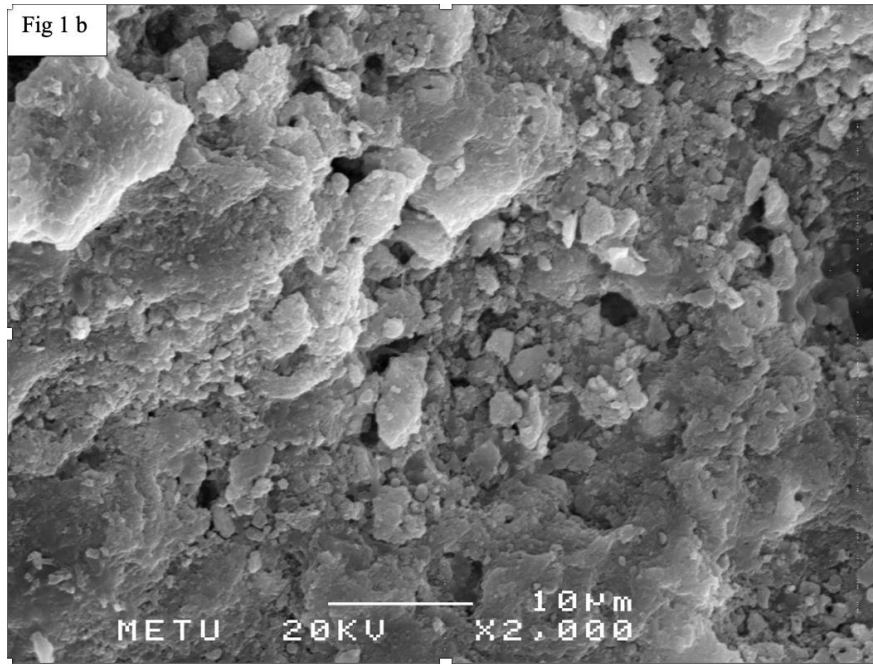


Fig 1 b

In the third sample, where a power of 2W was applied, it was observed that both the tubule mouths opened and a layered structure formed. No cracks or melting were present, and the count of open dentin tubules was 15.(Fig. 1c).

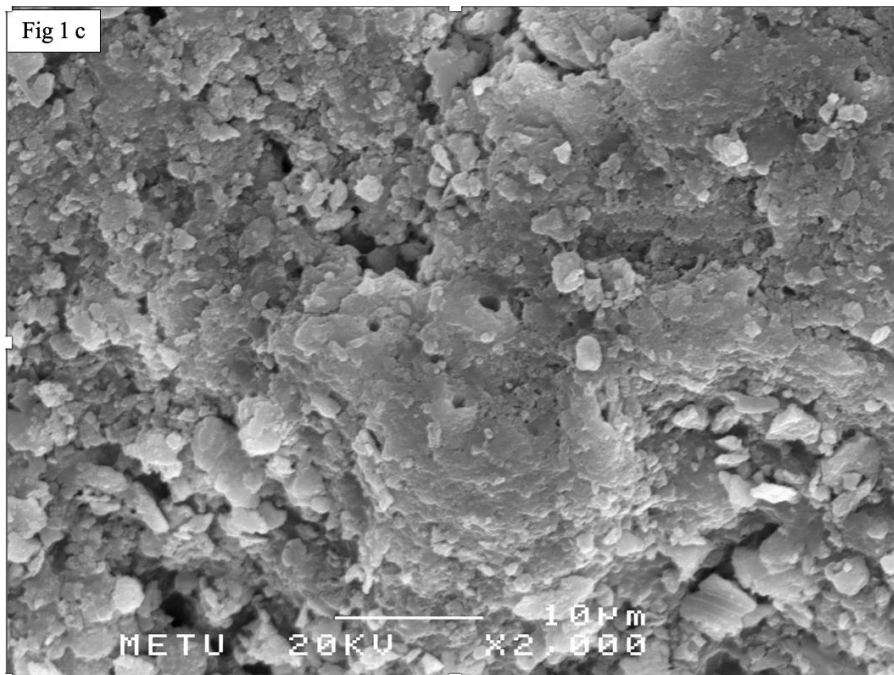


Fig 1 c

Furthermore, in the SEM examination of the fourth sample treated with 3W, it was observed that a more protruding surface was formed, and the number of open dentin tubules increased. No cracks and melts were found in this example. We found the number of open dentin tubules was 28 (Fig. 1d).

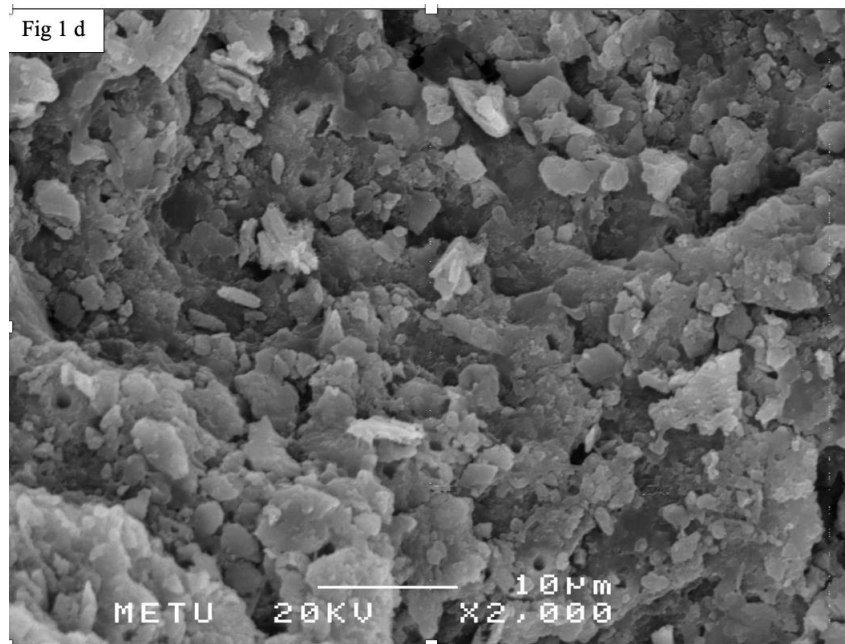


Fig 1 d

Additionally, in the SEM examination of the fifth sample, subjected to 4W, it was observed that the overhanging protrusions were notably prominent, with a count of 50 open dentin tubules, and no cracks or melting were present. (Fig.1e).

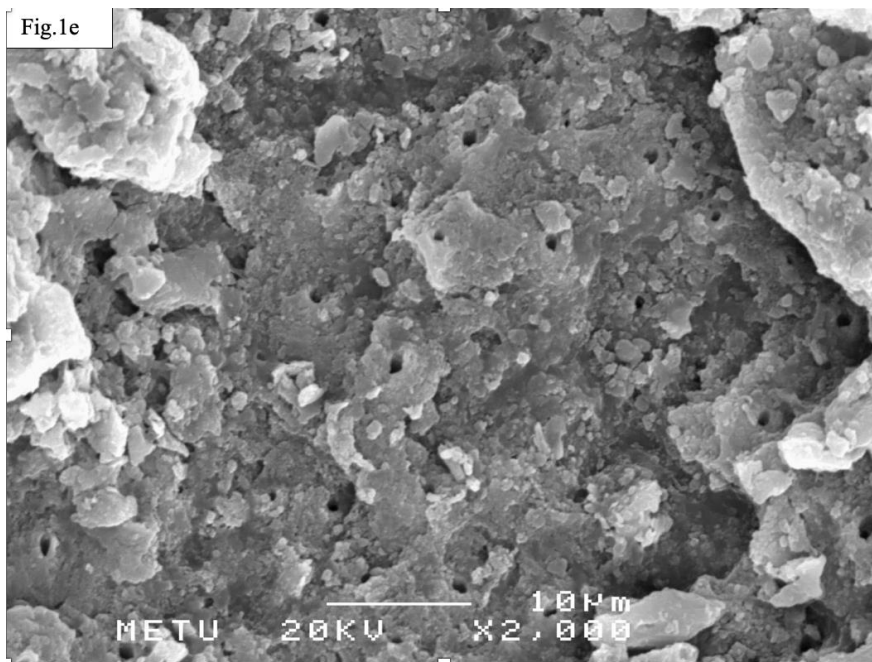


Fig.1e

Lastly, in the examination of the sixth sample with 5-W laser applied, approximately 40 open tubule mouths were observed. Some melting foci were observed in the dentin. No crack areas were observed. (Fig.1f).

Fig.1f

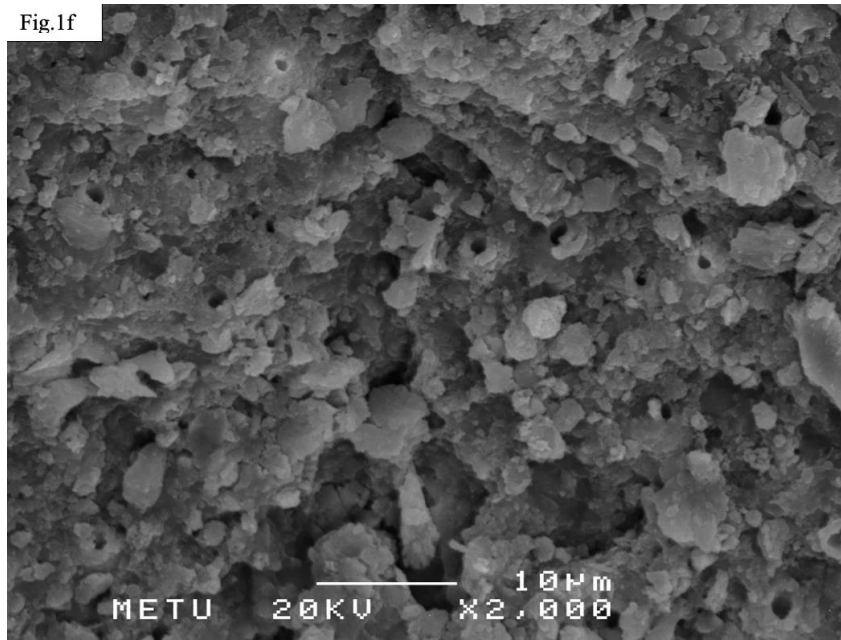


Fig.1f

When we examined the last example (No: 7), it was noticeable that the SEM images were very different from the structure of normal dentine. Due to the high level of power applied to this sample, the melting foci have been widespread, flowing in the form of lava and shedding tubule mouths. The open tubule mouth is not visible in the dentin applied at 6 W, and no crack formation was found (Fig.1g).

Fig.1g

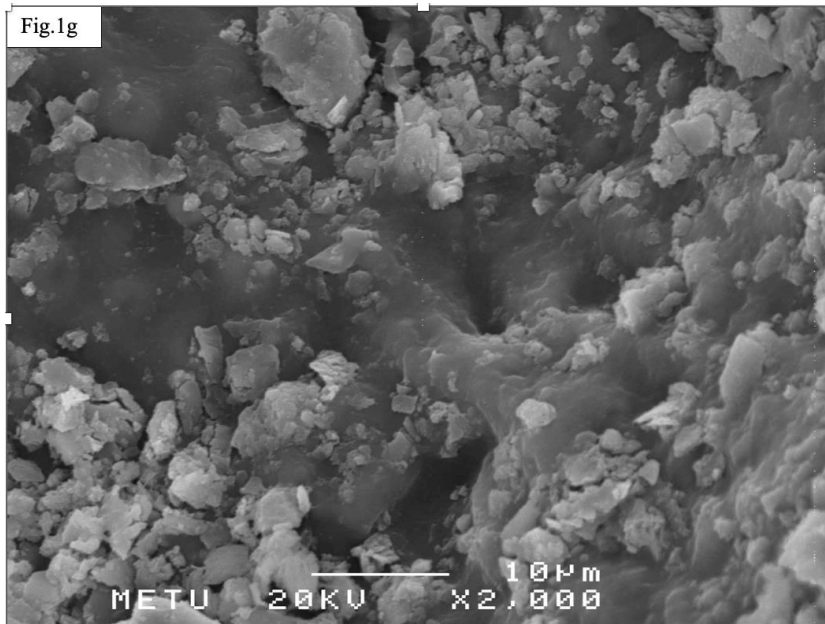


Fig.1g

Additionally, in the SEM evaluation of the dentin, it was observed that no smear layer was present in the laser-applied samples at various energy levels. Instead, the opening of dentinal tubule mouths and the formation of a step-like indented surface were noted. Conversely, a smear layer was observed in the dentin subjected to drill preparation. It was observed that at a 6 W energy level, the dissolution foci in the dentin and the tubular mouths of the dentin were completely blocked in some areas II, III, and IV. It was observed that peritubular dentin was more prominent at higher energy levels, and the calcified matrix was not damaged. It was observed that, with laser application at a 5-6 W energy level, there was no smear layer. However, there were some melting areas at these energy levels. At 1-4 W energy levels, there was no smear layer on the surfaces, the tubule mouths were opened, and the peritubular dentin and calcified matrix were protected. Figure 2 shows the relative depth increase from 1 W to 6 W in the 100-magnification SEM images, where the samples are analyzed as pulse shapes. (Fig 2. a-f)

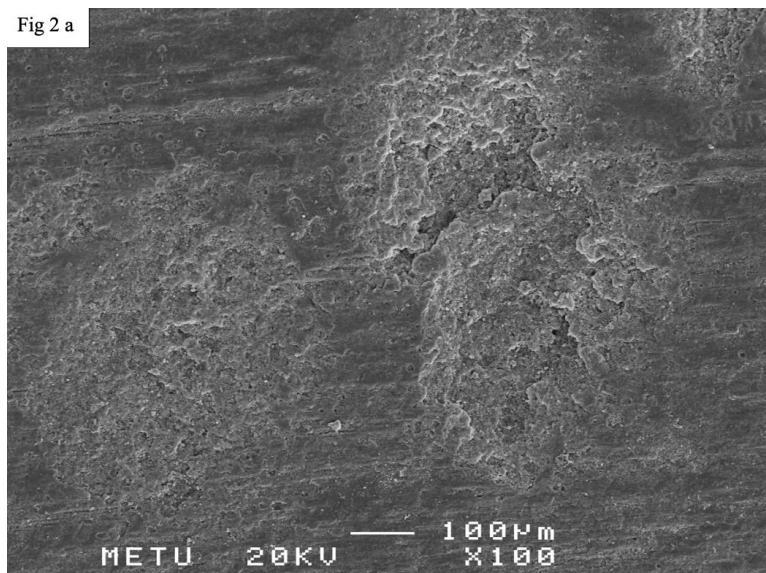


Fig 2 a

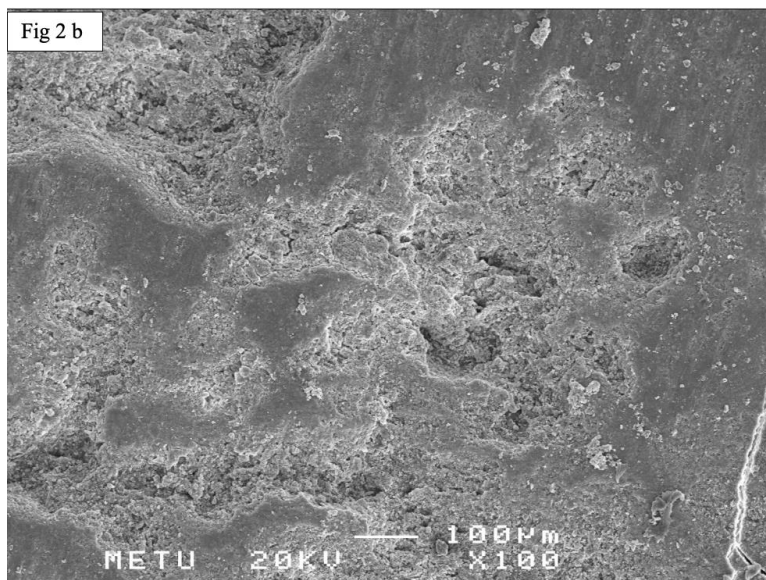


Fig 2 b

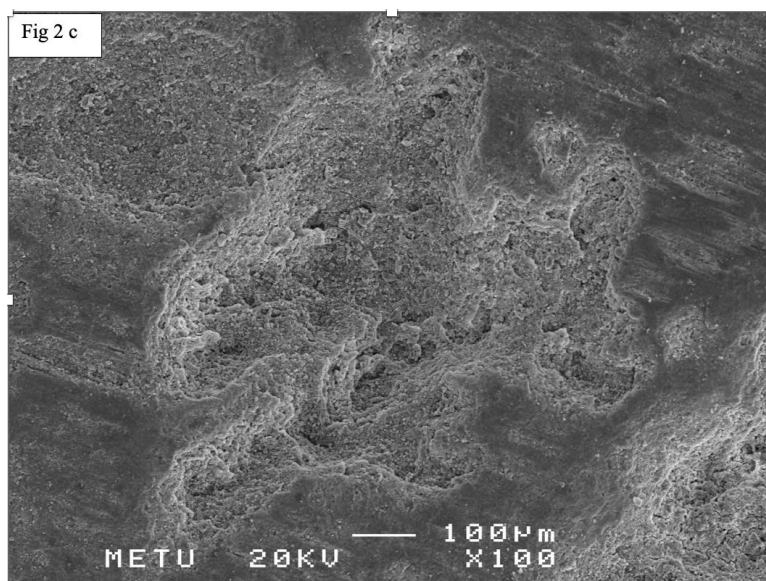


Fig 2 c

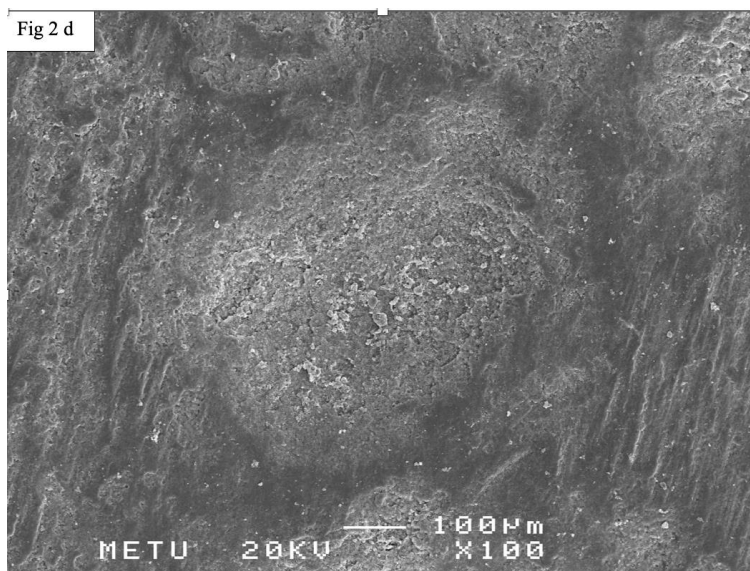


Fig 2 d

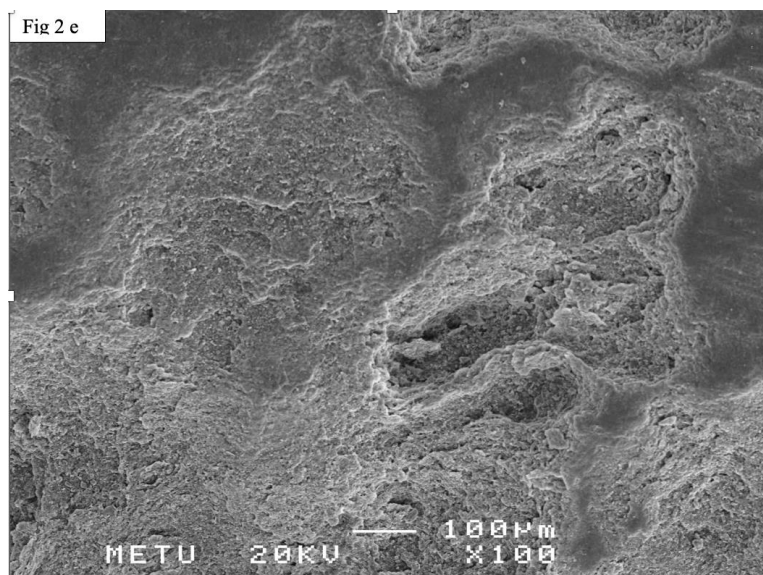


Fig 2 e

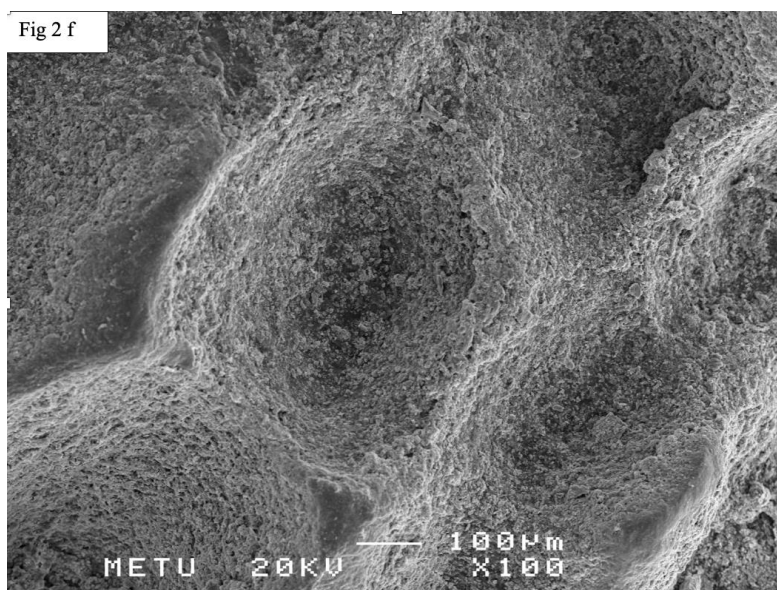


Fig 2 f

4. DISCUSSION:

In our study, it was observed that applying power levels of 1, 2, 3, 4, 5, and 6W resulted in different surface features. We observed signs of roughening, the opening of the tubule mouths, ablation, and melting in proportion to the increase in the applied power. The effects of laser on hard tissue vary depending on factors such as the type of laser, the tissue to which it is applied, and its power. Therefore, many researchers have tended to investigate the effects of lasers on enamel and dentin in the roughening and cavity preparation stages with SEM.^[25-31] In an in-vitro SEM study performed by Akhoundi et al., the morphological changes of enamel were examined using Er: YAG laser roughening or acid etchant. The authors reported that there is no permanent damage to the enamel in the roughening method using a laser.^[32] Although we examined similar subjects, the examination of enamel is not similar because the authors used a single parameter in their study, unlike our study. The reason for this is whether manufacturers recommend applying different parameters to different processes. The practitioner needs to know the effects of the parameter to be used on the tissue in procedures such as cavity preparation and roughening or removing dentin sensitivity, which are frequently used in restorative treatment. For this reason, in our study, we planned to observe the effect of 1-6 W energy levels, which can be used in the treatment, preparation, and roughening of dentin sensitivity, on dentin morphology.

In present study, melting was observed in the sample treated with 6W. However, Sun et al. applied the Er, Cr: YSGG laser with various parameters to caries-free sclerotic dentin and investigated its surface properties using SEM in their study.^[33] Even though they utilized extracted bovine teeth with air/water ratios very similar to ours, the outcomes they obtained, particularly at 6W, differed from our findings. This difference may be attributed to the presence of sclerotic dentin in the bovine tooth used, which could have influenced the outcome of the study. In our study, an ablation pit caused by a laser pulse was noticed in the X100 SEM image from the sample where 4 W was applied. Open dentinal tubules and layered structures were observed in the X2000 SEM magnification of these crater-like pits, which play a role in cavity preparation. In addition, the SEM evaluation findings were the same as the findings we obtained using the 4 W energy level and the Er, Cr: YSGG laser study of Trelles et al.^[34] in which different energy levels were used (4 W for preparation, 1.5 W for roughening). Furthermore, in our study, no acid was applied to the laser-treated surfaces. Only the impact of laser energy levels on the dentin surface was examined. The images acquired from dentin after laser preparation align with those obtained in our study at a 4W energy level. In their study, Bertrand et al.^[35] used Er: YAG (Opus 20, UK) laser (500 mJ, 10 Hz, accompanied by air and water) in preparations of human molars and found that on the laser-treated and acid-etched dentin surface, only the dentinal tubule mouths were removed from the laser-prepared cavity. They reported that it was wider, but the calcified matrix was dissolved, and the dentinal tubule mouths were not opened in some areas, which formed a ladder-like layered surface structure. In our study, there was a ladder-like appearance in the X2000 SEM images of dentin where 4 W was applied. Additionally, in their vitro study using Er: YAG (Key II, Germany) and Er, Cr: YSGG (Biolase, USA) lasers, Stock et al.^[36] showed with SEM that dentin has a crater-like, layered surface appearance and that this appearance is not heat-related. In our study, it was observed in the X100 SEM images that crater-like shapes formed on the dentin surface where 4-5-6 W was applied.

The dentin surface applied to the 6 W energy level, where we observe the melting focus, also seemed insufficient in terms of retention in our study. On the contrary, Marracini et al.^[37] in their in vitro studies investigating different pulse duration applications of two different lasers (CO2 and ER, YAG) using bovine teeth, found that the CO2 laser caused the melting foci in the dentin to be weaker in terms of forming a retentive surface. Similar to our study, Chiniforush et al.^[38] in their in vitro study with the Er: YAG laser, applied energy levels of 0.5, 1, 1.5, 2, 2.5 W and reported that they did not observe melting foci and tooth cracks at any level, and also reported that under 3W. They stated that they found the applications suitable for dentin ablation. Finally, in our study, despite working with air and water support at all power levels, we observed a melting focus in the X2000 SEM image on the surface where 6W power was applied, which we attributed to heat. Table 1 shows the morphological changes in the samples.

Case No	Tooth type	Laser Watt	Micro crack	Melting	Open dentin Tubules	Prot. Surface	Layered structure
1	Third Molar Bucal dentin	0	Yes	No	No (0)	No	No
2	Third Molar Bucal dentin	1	No	No	Yes (12)	Yes	Yes
3	Third Molar Bucal dentin	2	No	No	Yes (15)	Yes	Yes
4	Third Molar Bucal dentin	3	No	No	28	Yes	Yes
5	Third Molar Bucal dentin	4	No	No	50	Yes	Yes
6	Third Molar Bucal dentin	5	No	No	60	Yes	Yes
7	Third Molar Bucal dentin	6	No	Yes	5	No	No

Table 1: Morphological changes in samples

5. CONCLUSION

This study confirms the possibility of performing ablation within defined limits, and forming microcavities with a finely etched and rough surface that is well prepared for treatment with adhesive restorative materials. For best results, lower levels of energy (1-2 W) for etching and higher levels of energy (3-4 W) for cavity preparation procedures in the dentin are recommended. By examining the effects of power levels on the dentin surface in detail in studies with more samples, the practitioner will be able to decide which power level to use for which procedure more accurately. Moreover, considering that lasers are used for purposes such as tooth whitening, dentin desensitization, laser anesthesia, destruction of gum groove bacteria, dentin roughening, and ablation. We believe that larger-scale studies will enable dentists to be sure of their effects on hard tissue.

Abbreviations: Er Cr: Erbium Chromium, YSGG; Yttrium Scandium Gallium Garnet, W; Watt

Declarations

Acknowledgments:

Not applicable.

Authorship contribution statement

All authors contributed significantly and equally, and all authors approved the final form of the manuscript.

Availability of data and materials

The data supporting this study's findings is available from the corresponding author, Zeynep Yenen, upon a reasonable special request.

Ethical Approval:

NA

Funding:

None

Conflict of Interest:

The authors declare no competing interests

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