ORIGINAL ARTICLE

Effects of erbium-and chromium-doped yttrium scandium gallium garnet and diode lasers on the surfaces of restorative dental materials: A scanning electron microscope study

M Hatipoğlu, Ç Barutcigil[1]

Departments of Periodontology, and [1]Restorative Dentistry, Faculty of Dentistry, Akdeniz University, Antalya, Turkey

Abstract

Aim: The aim of this study is to evaluate the potential effects of laser irradiation, which is commonly performed in periodontal surgery, on the surfaces of restorative materials.

Materials and Methods: Five different restorative dental materials were used in this study, as follows: (1) Resin composite, (2) polyacid-modified resin composite (compomer), (3) conventional glass ionomer cement (GIC), (4) resin-modified glass ionomer cement (RMGIC), and (5) amalgam. Four cylindrical samples (8 mm diameter, 2 mm height) were prepared for each restorative material. In addition, four freshly extracted, sound human incisors teeth were selected. Two different laser systems commonly used in periodontal surgery were examined in this study: A 810 nm diode laser at a setting of 1 W with continuous-phase laser irradiation for 10 s, and an erbium-and chromium-doped yttrium scandium gallium garnet (Er, Cr: YSGG) laser at settings of 2.5 W, 3.25 W, and 4 W with 25 Hz laser irradiation for 10 s. Scanning electron microscopy (SEM) analysis was performed to evaluate the morphology and surface deformation of the restorative materials and tooth surfaces.

Results: According to the SEM images, the Er, Cr: YSGG laser causes irradiation markings that appear as demineralized surfaces on tooth samples. The Er, Cr: YSGG laser also caused deep defects on composite, compomer, and RMGIC surfaces because of its high power, and the ablation was deeper for these samples. High-magnification SEM images of GIC samples showed the melting and combustion effects of the Er, Cr: YSGG laser, which increased as the laser power was increased. In amalgam samples, neither laser left significant harmful effects at the lowest power setting. The diode laser did cause irradiation markings, but they were insignificant compared with those left by the Er, Cr: YSGG laser on the surfaces of the different materials and teeth.

Conclusion: Within the limitations of this study, it can be concluded that Er, Cr: YSGG laser irradiation could cause distortions of the surfaces of restorative materials. Diode lasers can be preferred for periodontal surgery.

Key words: Erbium chromium-doped yttrium scandium gallium garnet, diode laser, restorative dental materials, scanning electron microscope

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Introduction

With their technological advancement, dental lasers are more frequently used as an alternative to traditional surgery for various esthetic and functional periodontal surgical procedures such as gingivectomy, gingivoplasty, surgical

Address for correspondence:
Dr. Mükerrem Hatipoğlu,
Department of Periodontology, Faculty of Dentistry, Akdeniz University, 07058-Antalya, Turkey.
E-mail: mukerremhatipoglu@hotmail.com

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crown lengthening, vestibuloplasty, frenectomy, removal of soft tissue pathologies, subgingival curettage, periodontal pocket disinfection, and reduction of gingival hypertrophy, as well as scaling and root planning.[1] With the use of lasers, postoperative pain is substantially reduced, minimal damage occurs in and around the target organ, minimal bleeding occurs during surgery, the surgical area is cleaner, and the risk of bacterial contamination is reduced.[2-4] Despite such advantages, soft tissue lasers do affect the surrounding tissues and might cause crater-like defects on dental hard tissues during periodontal surgery.[5,6]

Many patients in need of periodontal surgery may have direct or indirect restorations close to the area that would undergo surgical intervention, and the effects of the lasers used in periodontal surgery on these restorations have not been sufficiently investigated. Unintentional laser contact may cause various degrees of deterioration on the surfaces of these restorations, potentially leading to bacterial adhesion or esthetic impairment.[7-9] Furthermore, the magnitude of damage in the adjacent restorations might be severe enough to require the replacement of the restoration. The limited studies available in the literature on this subject have mostly investigated the effects of soft tissue lasers such as neodymium-doped yttrium aluminum garnet (Nd: YAG) and carbon dioxide (CO_2) lasers on indirect restorative materials,[4,9] and the effects of erbium-and chromium-doped yttrium scandium gallium garnet (Er, Cr: YSGG) lasers, which can also be used in soft tissue surgery, have not been investigated. Er, Cr: YSGG has a wavelength of 2780 nm and is well-absorbed by water and to a lesser extent, hydroxyapatite.[10,11] The water content of dental soft and hard tissues thus absorbs the energy produced by the Er, Cr: YSGG laser, which leads to the ablation of the target tissue.[12] Since the water content of soft tissues is higher than that of dental hard tissues, Er, Cr: YSGG lasers are used at lower levels of power for soft tissue procedures.

It is known that resin composites, compomers, glass ionomers, and sometimes amalgam are most frequently preferred for the restoration of the regions that are mostly exposed to periodontal laser surgery, such as root surfaces. Therefore, investigation of the effects of lasers on these restorative materials is important for clinicians to evaluate the risks of laser exposure during surgical procedures.[9] This issue might substantially affect the decisions of dentists that frequently use lasers in various soft tissue procedures, which are gradually becoming widespread. Given the historically strong interest in damage to dental hard tissues, surprisingly little attention has been directed toward the consequences of accidental laser irradiation of dental restorations.

The aim of this *in-vitro* study is to assess the potential effects of Er, Cr: YSGG and diode lasers, which are frequently used in periodontal surgery at various levels of power, on the surfaces of direct restorative materials by means of a scanning electron microscope (SEM).

Materials and Methods

Sample preparation

Five different restorative dental materials were used in this study, as follows: (1) resin composite, (2) polyacid-modified resin composite (compomer), (3) conventional glass ionomer cement (GIC), (4) resin-modified glass ionomer cement (RMGIC), and (5) amalgam. The materials and their compositions are listed in Table 1. Four cylindrical samples (8 mm diameter, 2 mm height) were prepared for each restorative material using a Teflon mold on glass slabs, as per the manufacturers' directions. Photopolymerizable materials were set using a light-curing unit (3M ESPE Elipar S10, St. Paul, MN, USA), and the surfaces of the samples were polished with aluminum-oxide-coated disks (Sof-Lex; 3M ESPE, St. Paul, MN, USA). Amalgam samples were allowed to set for a minimum of 24 h before polishing.

Table 1: Restorative materials used in this study

Material	Brand	Manufacturer	Composition	Lot
Composite	3M Z250	3M ESPE, St. Paul, MN, USA	Organic matrix: Bis-GMA, UDMA, bis-EMA Filler: Zirconia/silica	N332268
Polyacid-modified resin composite (compomer)	Dyract extra	Dentsply DeTrey, Konstanz, Germany	Organic matrix: Bis-EMA, urethane resin, TEGDMA, trimethylolpropane trimethacrylate, carboxylic acid–modified dimethacrylate resin Filler: Strontium alumina sodium flour phosphors silicate glass, strontium flour, silicon dioxide	1204001130
RMGIC	3M PhotacFil Quick Applicap	3M ESPE, St. Paul, MN, USA	Na-Ca-Al-La-fluorosilicate-glass, 2-hydroxyethylmethacrylate, diurethane dimethacrylate, mono-and di-hema phosphate, difunctional monomers, activator (amine), copolymer of acrylic acid and maleic acids, camphorquinone stabilizers (radical captors, chelating agents)	511189
GIC	Voco Ionofil	VOCO, Cuxhaven, Germany	Powder: Calcium aluminum fluorosilicate glass Liquid: Polyacrylic acid, tartaric acid, water	1210268
Amalgam	Cavex Avalloy	Cavex Holland, Haarlem, The Netherlands	Lathe-cut Gamma-2 free, 45% Ag, 30.5% Sn, 24% Cu, 0.5% Zn	120320

RMGIC=Resin-modified glass ionomer cement, GIC=Conventional glass ionomer, Bis-GMA=Bisphenol-A glycidyl dimethacrylate, Bis-EMA=Ethoxylated bisphenol-A dimethacrylate, UDMA=Urethane dimethacrylate, TEGDMA=Triethylene glycoldimethacrylate

The samples were polished with a polishing kit (Kerr Identoflex Amalgam Polishers, Bioggio, Switzerland) after setting. In addition, four freshly extracted, sound human incisor teeth were selected. All calculus deposits and soft tissue were removed with a hand scaler. The teeth were sectioned vertically and stored in distilled water at 37°C. The lasers were irradiated to approximately 1 mm below the cement-enamel junction.

Laser irradiation

Two different laser systems commonly preferred in periodontal surgery were used in this study: An 810 nm diode laser (Epic, Biolase, Irvine, CA, USA) with a tip of 300 μm in diameter (e3 tip) and an Er, Cr: YSGG laser (Waterlase iPlus, Biolase, Irvine, CA, USA). The Er, Cr: YSGG laser system emits photons at a wavelength of 2.78 μm. The delivery system consisted of a fiber-optic tube terminating in a hand piece with a sapphire crystal tip bathed in an adjustable air-water spray. A G6 series tapered tip that was 600 μm in diameter and 6.0 mm in length was used.

Four different laser irradiation procedures were applied for each restorative material and tooth sample, as follows:

- 2.5 W, 25 Hz Er, Cr: YSGG irradiation for 10 s, 40% water/20% air
- 3.25 W, 25 Hz Er, Cr: YSGG irradiation for 10 s, 40% water/20% air
- 4 W, 25 Hz Er, Cr: YSGG irradiation for 10 s, 40% water/20% air
- 1 W, continuous phase, 810 nm diode laser irradiation for 10 s.

Scanning electron microscope investigation

Scanning electron microscopy analysis was performed to evaluate the changes in morphology and the surface deformation of the restorative materials and root surface. In the literature, SEM images are used extremely often for surface analysis. For this SEM evaluation, the samples were dried and sputter-coated with gold and palladium using a sputter-coating device (Polaron SC7620 Sputter Coater, VG Microtech, West Sussex, England). The SEM images were obtained using an electron microscope (Zeiss-Leo 1430 SEM, Angstrom Scientific Inc., NJ, USA) with magnifications of 100×, 500×, and 3000×.

Results and Discussion

Numerous studies have been conducted to investigate the effects of different types of lasers on dental surfaces.[13,14] It has been quite clearly demonstrated that CO_2 and Nd: YAG lasers have harmful effects on dental surfaces, and SEM images have revealed carbonized, cracked, and melted surfaces.[13-15] In addition, it has been showed that erbium-doped yttrium aluminum garnet (Er: YAG) lasers do not have such effects, but instead produce a surface similar to an acid-etched surface by removing the smear layer over the surface.[16] Hossain *et al.*[17] investigated the effects of Er, Cr: YSGG laser irradiation on dental hard tissues by SEM and reported that the laser leads to demineralization without causing crack formation and exposes dentin tubules. In the present study, the Er, Cr: YSGG laser did not cause cracks or fractures on dental surface, and the demineralization became deeper as the level of power was increased. The dentin surface became rough because of recrystallization, and there was also a lack of smear layer. On the dentin surface, the orifices of dentinal tubules were almost exposed, and intertubular dentin seemed to ablate more than peritubular dentin, leading to the protrusion of the dentinal tubules. The number and size of the dentin tubules increased with the power of the laser [Figure 1]. Mehl *et al.*[18] reported that such changes observed on dentin are associated with intensified laser effects. Although previous studies have demonstrated that diode lasers are safe,[15,19] in agreement with this study, it has been noted that they might have devastating effects on dental surfaces at high levels of power.[20] Kilinc *et al.*[15] showed that diode lasers only affected certain regions in one sample, and the surfaces of all other samples remained intact.

In the image of the resin composite after Er, Cr: YSGG laser irradiation [Figure 2], it is observed that the deformation, in general, bears combined traces of ablation, combustion, and melting. The deformation is deepened as the power of the laser is increased. The depth of the defect created by the laser pulse increased with the laser power. It has been shown that this relationship was logarithmic, with a very high correlation between laser power and ablation depth. Mazouri and Walsh[9] investigated the effect of CO_2 laser irradiation on esthetic restorative materials and stated, in line with this study that laser irradiation left burning and melting marks on composite surfaces. A previous study reported that the effects of lasers on composites change depending on the type of laser. The effect of CO_2 laser on a composite is irrecoverably devastating. The surfaces of the samples were carbonized, and the diameter of the damage was substantial. The effect of a Nd: YAG laser was also remarkable, but the magnitude of damage was not as high as that caused by the CO_2 laser. Although the effect of the diode laser was invisible, small defects and deformations have been detected at high magnification during SEM evaluation.[15] In the present study, the effect of diode laser irradiation on the surface of resin composites was very slight, as well.

The SEM images of the compomer samples are very similar to those of the composite samples [Figure 3]. In particular, the Er, Cr: YSGG laser caused deep defects on the compomer surfaces because of its high power, and the ablation was even deeper than that of the resin composite samples. The diode laser also caused deeper irradiation markings than those in the resin composite, but they were

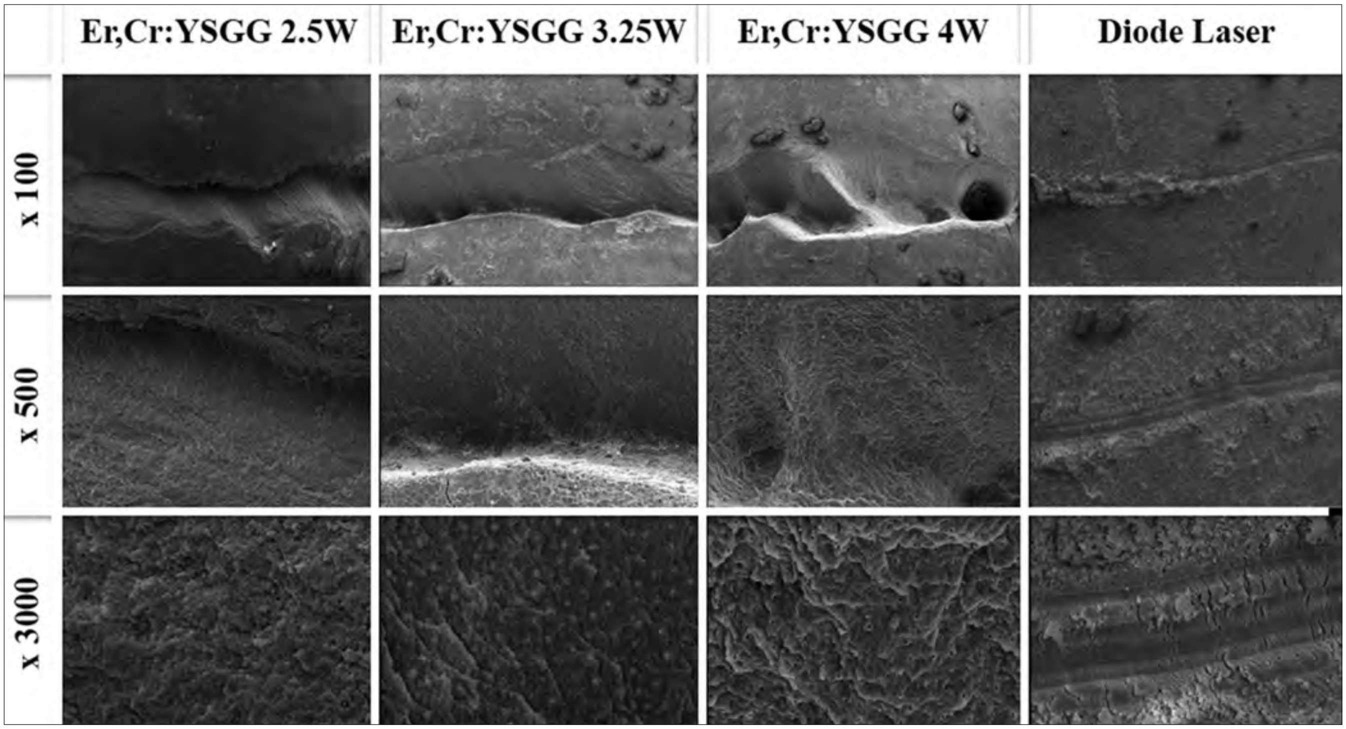

Figure 1: Scanning electron microscopy images of tooth samples

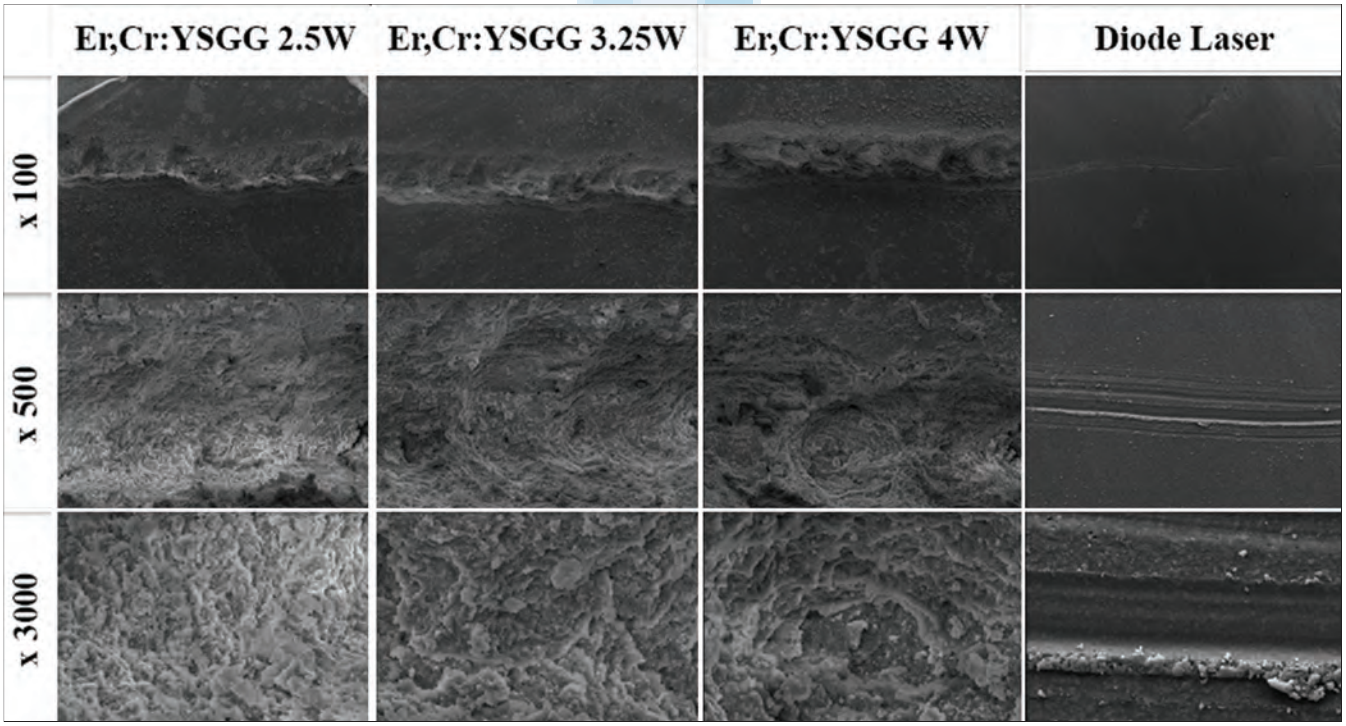

Figure 2: Scanning electron microscopy images of resin composite samples

still insignificant compared with those caused by the Er, Cr: YSGG laser.

The Er, Cr: YSGG laser left shallow irradiation markings on conventional GIC. However, the high-magnification images show melting and combustion effects, which increased as the power was increased. This effect was especially apparent in the samples exposed to the 4 W laser irradiation. Superficial damage caused by the diode laser left an indistinct irradiation marking that could hardly be seen by the naked eye [Figure 4]. In the literature, there may be a deficiency in the studies investigating the effects

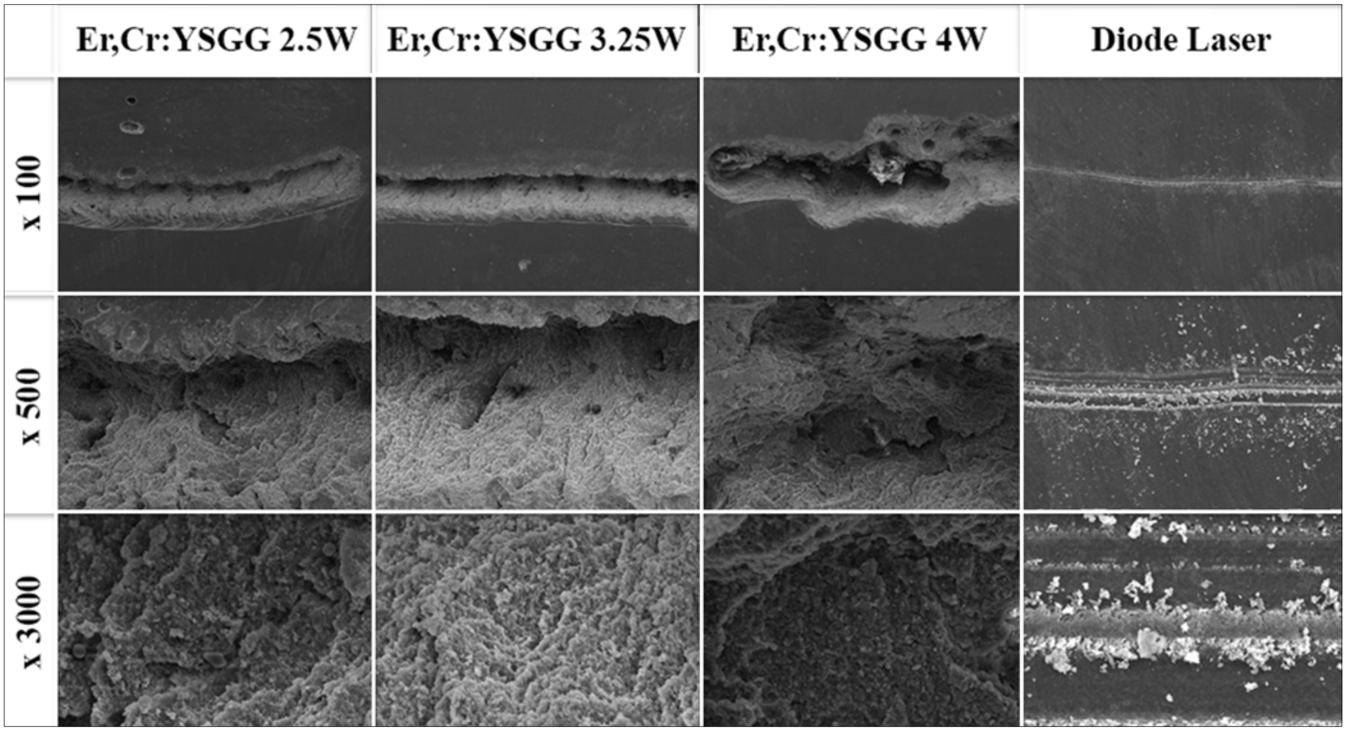

Figure 3: Scanning electron microscopy images of compomer samples

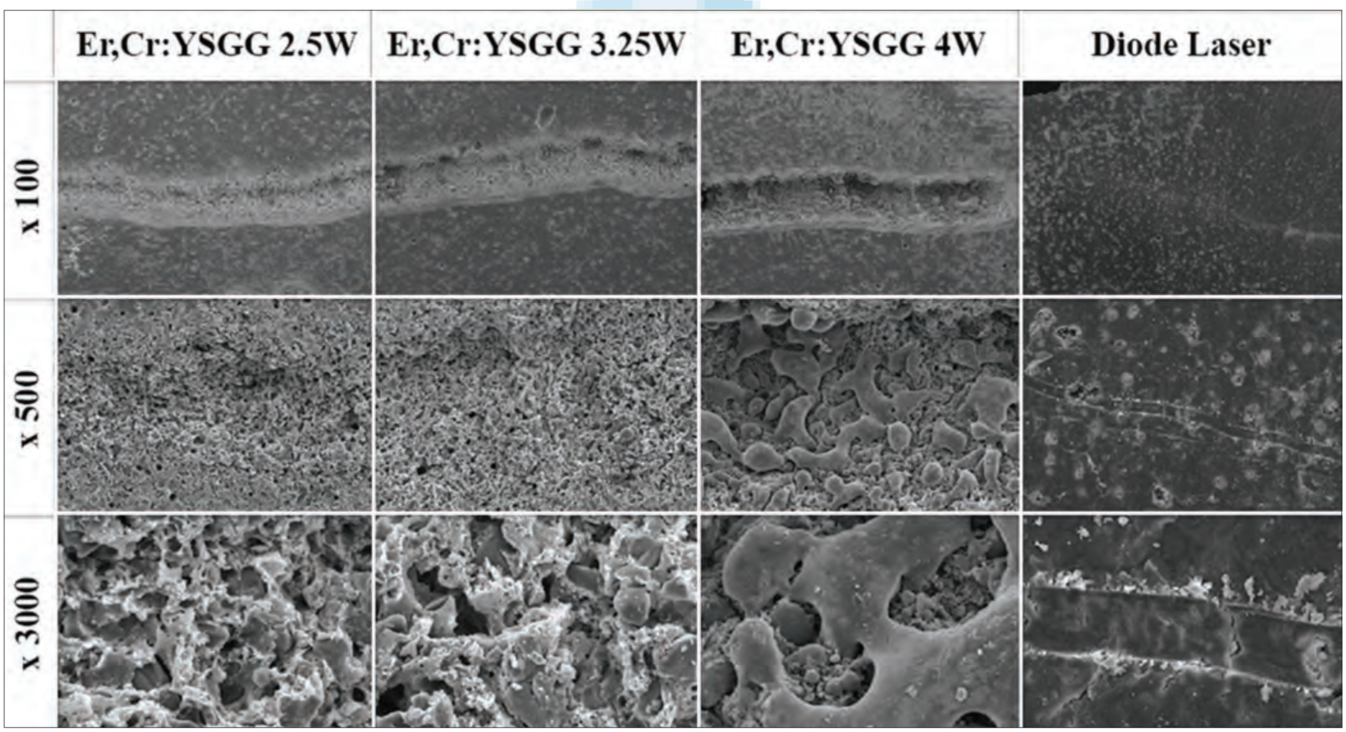

Figure 4: Scanning electron microscopy images of glass ionomer cement samples

of lasers on GIC. For this reason, the present study serves as a pilot study.

The SEM images of the surfaces of RMGIC showed deformations that look much more like those in the compomer and composite than those of the conventional GIC. This might have resulted from the resin matrix content of RMGIC. The Er, Cr: YSGG laser caused ablation defects on RMGIC similar to those in the materials with higher resin contents. This effect was more remarkable than that seen with other materials. The diode laser has a much smaller effect than the Er, Cr: YSGG laser. However, RMGIC was found to be less durable than the composite, compomer, and conventional glass ionomer against the diode laser [Figure 5]. Mazouri and Walsh[9] examined the irradiation markings left by a CO_2 laser on the surfaces of composite and compomer samples using a dissecting microscope. They reported that the effect of the CO_2 laser on composite samples was more remarkable than that on compomer materials. Nevertheless, they reported that materials containing resin with less or even no filler are more likely to experience ablation effects under laser irradiation.[9] Similarly, the present study found RMGIC, which does not include filler, to be the most affected material.

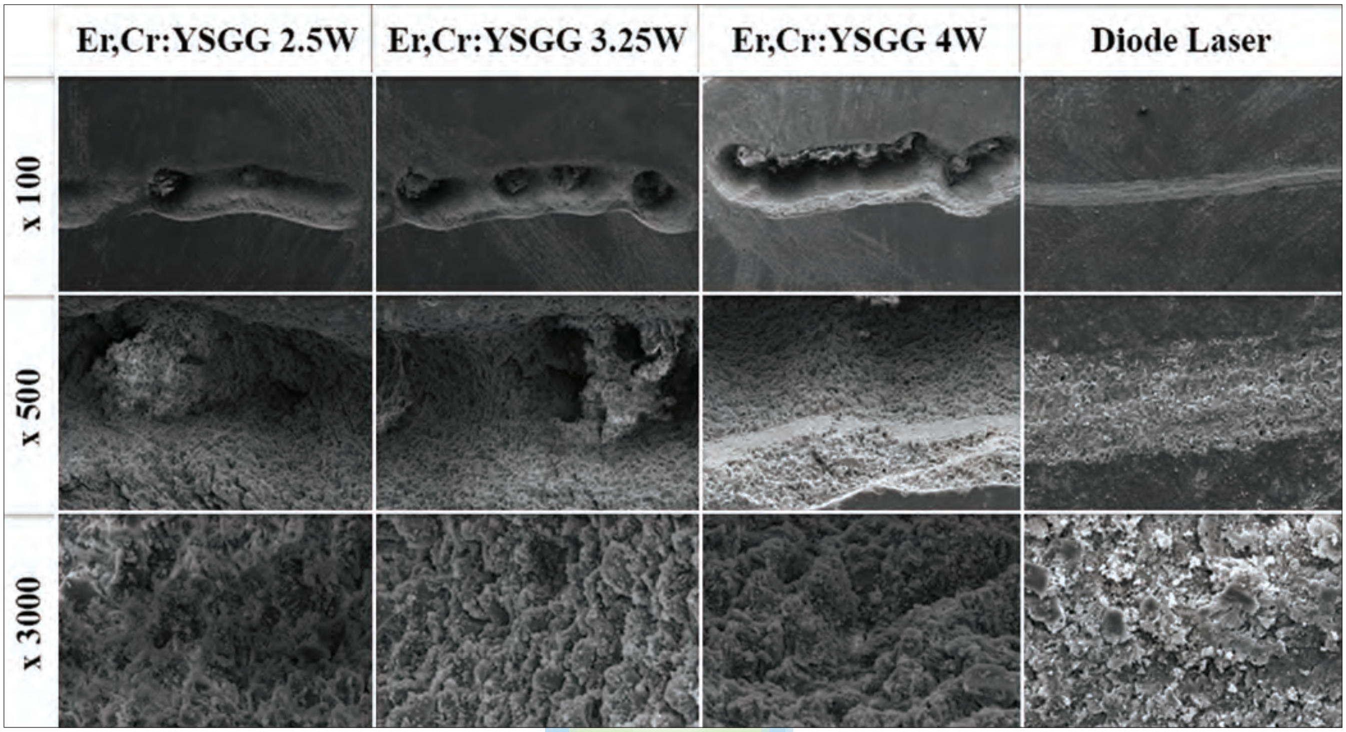

Figure 5: Scanning electron microscopy images of resin-modified glass ionomer cement samples

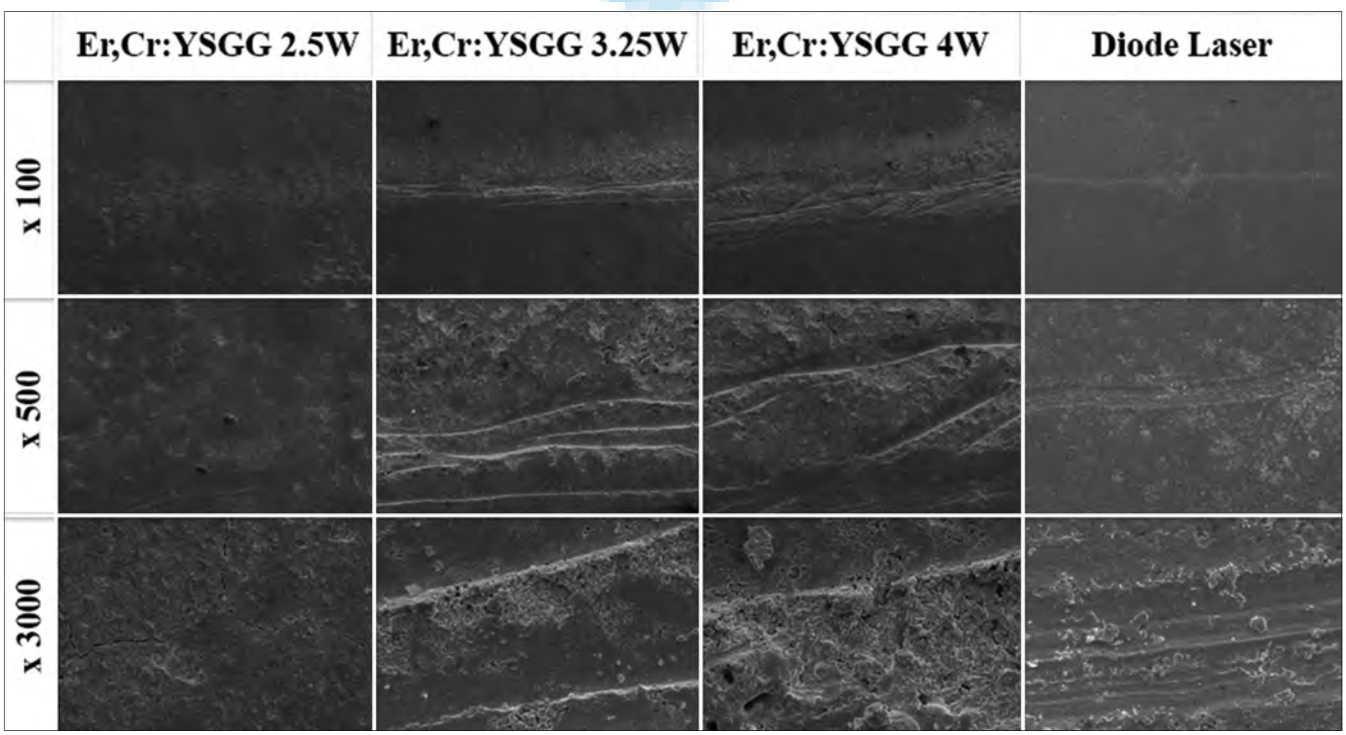

Figure 6: Scanning electron microscopy images of amalgam samples

For amalgam samples [Figure 6], the Er, Cr: YSGG laser had almost no harmful effects on the surface at the lowest power setting. The irradiation damage (markings) was deepened and widened as the laser power was increased. Previous studies have investigated the effects of different types of lasers on amalgam surfaces.[15,21] It was reported that an Nd: YAG laser caused harmful crater-like damage on amalgam surfaces that seemed to make replacement of the restoration necessary. However, CO_2 laser irradiation left a marking in the form of a fine line on the surface.[15] Similarly, the 810 nm diode laser left an indistinct irradiation marking that was hardly visible without magnification.[15] In the present study as well, the diode laser left an invisible irradiation marking on amalgam surface that could be detected at × 3000 × magnification. However, it has been reported that pits and defects, no matter how small, increase the risk of plaque retention and consequently corrosion of amalgam.[21] Mercury vapor, which would appear as a consequence of laser contact on the amalgam surface, should be kept in mind under such conditions, and appropriate suctioning should certainly be performed.[21]

Along with esthetic problems on existing restorations, fractures, cracks, bacterial adhesion, and plaque retention may also be caused by the lasers frequently used in surgical procedures for soft tissue, which may lead to secondary decay and periodontal problems.[7,22]

Since shorter chair-side time is preferred in current dentistry practice, unplanned clinical complications that might lead to replacement of intact restorations are unacceptable and troublesome. The present study evaluated the effects of two different types of lasers widely used for soft tissue surgeries in clinical practice on traditional direct restorative materials and dental tissue. The aim was to facilitate the choice of the laser and mode specifically for the type of current restoration in the gingival surgery area.

Clinical conditions were mimicked as much as possible in the design of the experimental method of this present study. For example, the application of the laser to samples for 15 s by an expert operator was preferred rather than using a device that holds the end of a laser. The operator tried to apply the laser to the samples at a 45° angle along a straight line for 15 s. This was intended to imitate the contact that is likely to occur during a gingival surgical procedure on restorations.

Although the results of this study do not completely reflect the clinical *in vivo* conditions, the data and images have provided substantially important and detailed information. Nevertheless, information obtained in this study should be verified with long-term clinical studies.

Within the limitations of this *in vitro* study of the effects of lasers on restorative materials, it can be concluded that Er, Cr: YSGG lasers should not be used because of their irreversible effects on the surfaces, particularly at high power settings, unless absolutely necessary.

Since the 810 nm diode laser showed recoverable effects, it can be considered safe, even though it does affect most restorative materials. A routine polishing procedure is recommended for all restorative materials after procedures performed using diode lasers.

Further long-term clinical studies are necessary to validate the findings of this study.

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