

Effect of Er:YAG laser on debonding strength of laminate veneers

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ABSTRACT

Objective: The purpose of this study was to evaluate the debonding strength of laminate veneers after using erbium-doped: yttrium aluminium garnet (Er:YAG) laser. **Materials and Methods:** A total of 60 bovine mandibular incisor teeth were divided into two groups ($n = 30$). Cylindrical specimens ($0.7 \text{ mm} \times 5 \text{ mm}$) were fabricated from Empress II ceramic. Then, they were cemented to incisors using dual-cured resin cement (Variolink II). In the first group, no laser application was performed. The Er:YAG laser was applied on each laminate veneer at the test group for 9 s by using the scanning method. Shear force to remove the laminate veneers were applied with universal testing machine at a crosshead speed of 1 mm/min. **Results:** Results of this study exhibited significant differences between the control ($27.28 \pm 2.24 \text{ MPa}$) and test group ($3.44 \pm 0.69 \text{ MPa}$) ($P < 0.05$). **Conclusion:** This study shows that application of Er:YAG laser decreased the bond strength of laminate veneers.

Key words: Debonding, erbium-doped:yttrium aluminium garnet laser, laminate veneers, scanning method, shear bond strength

INTRODUCTION

In recent years, lasers have become popular in the dental field. There are several types of lasers that are used specifically for different applications.^[1] The neodymium-doped yttrium aluminium garnet (Nd:YAG) laser is used to reduce tooth sensitivity,^[2] remove caries,^[3] bleach teeth,^[4] roughen the ceramic surfaces^[5] and improve the adhesion of composite resins.^[6] The erbium-doped: yttrium aluminium garnet (Er:YAG) laser has been used in different fields, such as caries removal, tooth cavity preparation and surface treatment for restorative materials.^[7-11] Another laser is the CO₂ laser. This laser is suitable for etching zirconia implants,^[12] adhering resin cements to the enamel^[13] and porcelain surfaces^[14] and creating roughness on the ceramic surfaces.^[15]

Lasers have been used for debonding ceramic brackets for more than 20 years.^[16] Tocchio *et al.*^[17] stated that

Nd:YAG laser debonding occurs by thermal softening, thermal ablation or thermally induced photoablation. In thermal softening, the bonding agent is heated until it softens. Thermal ablation occurs when the laser energy is high enough to raise the temperature of the resin, whereas photoablation occurs when the high laser energy interacts with the resin material.^[17]

Porcelain laminate veneers (PLVs) are frequently used in restorative dentistry because of their esthetic properties.^[18] These restorations are a safe and an effective treatment modality for teeth with poor esthetics. However, they have limited longevity because luting resin cements are sensitive to discoloration, wear, microleakage and marginal fractures, which adversely affect the esthetic results. Microleakage has been more frequently encountered with an exposed dentine during the preparation for PLVs.^[19] In addition, microleakage was associated with the presence of caries, discoloration or a gingival

How to cite this article: Iseri U, Oztoprak MO, Ozkurt Z, Kazazoglu E, Arun T. Effect of Er:YAG laser on debonding strength of laminate veneers. Eur J Dent 2014;8:58-62.

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DOI: 10.4103/1305-7456.126243

reaction in clinical situations.^[19-24] In such cases, removing the laminate veneers may be required, leading to a retreatment of the restorations. In addition, removing the porcelain veneers may be time-consuming and the tooth structure adjacent to the veneer may be removed.^[25]

Stacey^[26] investigated the adhesion of porcelain-resin/cement-tooth complex. He reported that a very strong complex was obtained by luting the PLV. The bond strength of the porcelain-resin/cement-tooth complex (63 MPa) was significantly higher than the resin cement-tooth (31 MPa) and resin cement-porcelain (33 MPa) bond strengths. However, polymerization shrinkage in the amount of 2.6-5.7% occurred, which may create a marginal opening or loss of the seal.^[27]

In the literature, it has been clearly stated that laser debonding is an effective method that works by controlling the amount of thermal energy delivered.^[17,28-34] Several studies evaluated the efficacy of lasers on debonding using many variables and techniques, such as types of lasers,^[17,28] energy levels,^[29,30,33] brackets,^[17,28,33] resins,^[28,29,33] application durations^[34] and magnitude of applied stresses.^[17,32]

The Er:YAG, Nd:YAG and CO₂ lasers have thermal effects on water-containing tissues.^[35] Although the Er:YAG laser has a lesser thermal effect than the Nd:YAG laser, there are similar effects on the adhesive resin.^[36,37] The resin materials that contain water or residual monomers absorb the Er:YAG laser light.^[38] Strobl *et al.*^[28] evaluated the effect of CO₂ and Nd:YAG lasers on the removal of aluminum brackets and revealed that laser-aided debonding significantly reduced the debonding strength through a thermal softening of the resin. Tocchio *et al.*^[17] used an Nd:YAG laser light to debond aluminum brackets and they stated that laser energy could degrade the adhesive resin by thermal softening, thermal ablation or photoablation. Obata *et al.*^[30] investigated the debonding of ceramic brackets with a CO₂ laser and reported that CO₂ laser debonding was clinically useful for orthodontic treatment. Oztoprak *et al.*^[39] developed a new method to debond ceramic brackets using a scanning Er:YAG laser thoroughly along the surface of the brackets. The authors revealed that the laser application efficiently debonded the ceramic brackets.

All these studies^[17,28,30,39] confirm the efficiency of the laser debonding of ceramic brackets, but there is no

study that confirms the efficacy of the laser debonding of laminate veneers. Therefore, the purpose of this study was to evaluate the effect of an Er:YAG laser on the debonding strength of all-ceramic laminate veneers.

MATERIALS AND METHODS

A total of 60 extracted, non-carious, permanent bovine mandibular incisors were used because of their availability and physical properties.^[40,41] The roots were cut-off and the crowns were stored in a 0.1% thymol solution until use. The labial surface of the enamel was positioned parallel to the metal cylinder. After curing the embedded autopolymerizing resin (Fortex Cold Curing Dental Polymer 2000, Germany), the teeth were ground to expose the enamel underwater. The bonding surfaces of the enamel were polished with 180-, 320-, 600- and 1200-grit silicon carbide papers (English Abrasives, London, England) under water-cooling on a polishing machine (Phoenix Beta Grinder/Polisher, Buehler, Germany). Then, the surfaces were polished, rinsed and dried with air. Subsequently, the enamel surfaces were etched with 37% phosphoric acid for 30 s, washed and dried. The PLV specimens (IPS Empress II, Ivoclar Vivadent, Schaan, Liechtenstein) were fabricated according to the manufacturer's instructions (i.e. 0.7 mm in height, 5 mm in diameter). Then, the specimens were cemented to the labial surfaces of the incisors with dual-cured resin cement (Variolink II, Ivoclar Vivadent, Schaan, Liechtenstein) and light cured for 20 s.

Before the shear bond strength testing, the samples were stored in distilled water at 37°C for 48 h. Afterward, the samples were randomly divided into two groups ($n = 30$). The first group was the control group and the second group was the test group. The laser was applied to the test group specimens. The laser used for this study was an Er:YAG laser (VersaWave, HoyaConbio, Fremont California, USA) that was applied without water at a power of 5 W (50 Hz × 100 Mj) with a wavelength of 2940 nm. The application tip (1 mm in diameter) was positioned perpendicularly at a distance of 2 mm from the PLVs. The laser energy was applied to the test groups by scanning through the surface of the PLVs for 9 s. Scanning was performed with horizontal movements parallel to the surface, as described by Oztoprak *et al.*^[39] [Figure 1].

A shear bond strength-testing machine (Instron 3345, Instron Corp., Norwood, MA, USA) was used for the experiment. The samples were mounted onto the

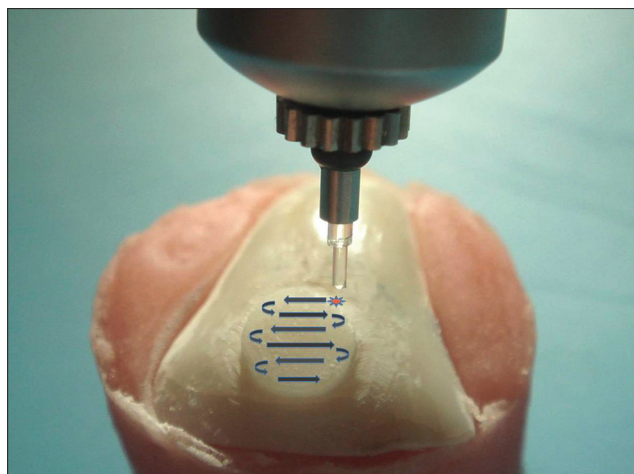


Figure 1: The scanning method used in the study

machine 1 s after the laser pulse had been applied. They were stabilized to ensure that the 1-mm-thick edge of the shearing blade was positioned as close as possible to the tooth-laminate interface. The shear force was applied to the laminate veneers inciso-gingivally at a crosshead speed of 1 mm/min. The shear bond strength values were recorded in MPa.

Statistical analyses were performed with GraphPad Prisma, version 3.0 (San Diego, USA). The Kolmogorov-Smirnov test was used to determine the distribution of data. A *t*-test was used for a statistical analysis of the data and quantitative comparisons between the groups. A statistically significant difference was considered to be $P < 0.05$.

RESULTS

Table 1 shows the mean shear bond strengths of the laminate veneers to the enamel surfaces. The results revealed that there were statistically significant differences between the control and test groups ($P < 0.05$). The control group had a significantly higher shear bond strength values (27.28 ± 2.24 MPa) than the laser-irradiated group (3.44 ± 0.69 MPa).

DISCUSSION

When the laminate veneers must be removed, retreatment may be needed if the veneers are damaged. The retreatment is time-consuming and expensive. Previous studies verified that lasers that soften the adhesive resin are effective for the removal of ceramic brackets.^[17,28,29,31-34,39] However, there are currently no studies that confirm the efficacy of laser debonding for laminate veneers. Therefore, a laser-initiated debonding mechanism that works by degrading the

Table 1: Mean shear bond strength values and SD in MPa ($n=30$)

Groups	N	Mean	SD	P
Control	30	27.28	2.24	0.000*
Test	30	3.44	0.69	

* $P < 0.05$, MPa: Megapascals, SD: Standard deviation

adhesive resin was utilized in this study to remove the laminate veneers without damage.

In the present study, an Er:YAG laser light at a wavelength of 2940 nm and power of 5 W was applied for 9 s in the test group. According to the shear test, the bond strength values were significantly lower (3.44 ± 0.69 MPa) in the laser-irradiated group compared with the control group (27.28 ± 2.24 MPa). A possible explanation for this result is that laser energy may degrade the adhesive resin. This result agrees with the previous studies that investigated the bracket-resin bonding.^[17,28-34,39]

Strobl *et al.*^[28] used a laser beam shutter that had a thermally insulated fork to prevent a quick heating of the bracket in their investigation. The authors removed the polycrystalline and monocrystalline aluminum brackets using CO₂ and Nd:YAG lasers. The authors reported that the laser application significantly reduced the debonding strength of the brackets. In addition, the monocrystalline brackets required a lower energy laser for debonding than the polycrystalline brackets.

Obata *et al.*^[30] used a super pulse and normal pulse CO₂ laser to investigate the debonding of ceramic brackets both *in-vivo* and *in-vitro*. One operator performed an *in-vivo* study to remove the brackets. In this study, a rotational force was applied with tweezers to remove the bracket after applying the laser to each tooth. The shear force was then measured *in-vitro* using a 2- and 3-W power generated by the super pulse laser. It was concluded that laser debonding was clinically useful when the super pulse CO₂ laser was applied to an orthodontic treatment. Oztoprak *et al.*^[39] stated that debonding the ceramic brackets using a scanning Er:YAG laser for 9 s was an efficient method. The authors found that the shear bond strength values decreased from 20.75 MPa (group without the laser) to 9.52 MPa (laser group). Nalbantgil *et al.*^[34] investigated the effect of different application durations of the Er:YAG laser on debonding strength and the intrapulpal temperature change during debonding. The mean shear bond strength was 8.81 MPa when the Er:YAG laser was applied for 9 s, which was

significantly lower than the control group (22.76 MPa). Although the temperature rise was 4.59°C during the 9-s laser application, this value is still lower than the safety threshold (5.5°C) designated to not cause damage to the pulpal tissues.^[42] Therefore, this laser procedure may be used on thin veneer structures.

Tocchio *et al.*^[17] used an Nd:YAG laser at wavelengths of 248, 308 and 1060 nm with power densities between 3 and 33 W/cm² to debond two types of ceramic brackets with an externally applied stress of either zero or 0.8 MPa. No enamel or bracket damage was reported as a result of the Nd:YAG laser debonding. According to these investigators, thermal softening, thermal ablation or photoablation can explain the debonding mechanisms that enable the adhesive resin to degrade with laser energy. During thermal softening, the adhesive resin decomposes due to the transmission of heat thorough the ceramic bracket. The brackets still feel cool after debonding because thermal ablation and photoablation proceed rapidly and with little heat diffusion; therefore, the tooth and bracket stay near physiologic temperatures. In most of the previous studies, different lasers with a more easily absorbed wavelength (106, 308 and 1000 nm) was preferred to debond the ceramic brackets.^[28-32]

Thermal ablation and photoablation occurs when a very high-energy laser light interacts with the adhesive material, causing it to decompose.^[17] Laser light transmission without a loss of energy through the bracket to the resin is believed to be very important to achieve this phenomenon. Depressions of decomposition of the bracket bases, black deposits, localized carbonization -like changes to the remnant resin and eruptions of dissolved ceramic on the bracket bases were reported. These burned-out spots verified that the Nd:YAG laser has a higher degree of enamel transmissibility than the CO₂ laser. Due to the short application period, the rise in the intrapulpal temperature was only 5.1°C. Therefore, when using Nd:YAG lasers, care should be taken based on the amount of heat conducted and its application duration.

The effects of thermal cycling and long-term storage on bond strength were not evaluated in this study. Although long-term storage is important for clinical conditions, the bond strength results of short-term *in vitro* tests may provide helpful leverage for evaluating clinical conditions. Only one type of all-ceramic material, resin cement and laser were used. In addition, surface analyses of the fractured specimens were not performed, which was a limitation

of this study. Therefore, further studies are necessary to investigate the different ceramic materials, resin cements and laser types with various parameters. The morphological changes in the surfaces of teeth after laser irradiation should also be evaluated.

CONCLUSIONS

Examining the effects of Er:YAG laser irradiation on laminate veneers using a scanning method produced the following findings:

- A laser-aided debonding using a scanning method was efficient for debonding laminate veneers
- An Er:YAG laser application effectively reduces the shear bond strength of laminate veneers, making tooth removal easy.

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