

## Effect of Er:YAG Laser Irradiation on Shear Bond Strength of Two Porcelain Laminate Veneers Bonded to Tooth Surface

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### Abstract

**Background and Aim:** The conventional procedure for removal of porcelain laminate veneers (PLVs) is time-consuming and inconvenient. The purpose of this study was to evaluate the efficacy of Er:YAG laser for debonding of PLVs.

**Materials and Methods:** Forty-eight intact extracted human maxillary anterior teeth received discoid PLVs (24 feldspathic and 24 e-max ceramic). The PLVs had 0.7 mm thickness and 4 mm diameter. After cementation of all PLVs with a light-cure cement, samples were stored at 37°C distilled water for 48 h. Samples of each ceramic were randomly divided into 3 groups of 8 samples. Then, laser was irradiated on the cemented PLVs as follows: (I) feldspathic PLVs without laser irradiation (control group), (II) feldspathic PLVs with laser irradiation (6 s, 10 Hz, 200 mJ, 2 W), (III) feldspathic PLVs with laser irradiation (6 s, 10 Hz, 300 mJ, 3 W), (IV) e-max PLVs without laser irradiation (control group), (V) e-max PLVs with laser radiation (6 s, 10 Hz, 200 mJ, 2 W), (VI) e-max PLVs with laser irradiation (6 s, 10 Hz, 300 mJ, 3 W). The shear bond strength of all samples was measured using a universal testing machine. We used Mann-Whitney and Kruskal-Wallis tests for data analysis ( $P < 0.05$ ).

**Results:** Laser irradiation decreased the shear bond strength of both ceramics. But this decrease was only significant for the e-max group ( $P < 0.05$ ). No significant difference was found between different laser irradiation powers in the two ceramic groups.

**Conclusion:** Er: YAG laser is effective for debonding of e-max PLVs.

**Key Words:** Dental Porcelain, Dental Veneers, Lasers, Solid-State, Resin Cements

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### Introduction

With increasing demand for maximum esthetics, the use of ceramic restorations is an important part of dentistry, and the use of these restorations is increasing due to maximum esthetics and lack of metal in their structure (1-3). Porcelain laminate veneers (PLVs) are

among these restorations that provide optimal esthetics for patients (4). In the construction of PLVs, glass ceramics such as feldspathic and e-max press are more commonly used. One disadvantage of these ceramics, in comparison with alumina and zirconia-based ceramics, is lower mechanical properties due to the high

content of glass (5,6). In the event of breakage of PLVs due to mechanical loads, they need to be removed from the tooth surface, and re-impression is required to create a new ceramic veneer (4,7). In addition to the breakdown of PLVs, some other problems may necessitate their replacement including changes in the color of resin cement, tooth caries, poor esthetics, microleakage, and marginal failure leading to undesirable esthetics (4). Removal of PLV from the tooth surface is a time-consuming process, and there is also the possibility of damaging the adjacent tooth structure (4,8,9). A few studies have been carried out on new techniques for removal of PLVs (10,11).

In the recent years, use of dental lasers has become usual. There are different types of lasers with different applications especially in dentistry. In dentistry, laser was used for debonding of ceramic brackets from the tooth surface several years ago (12-14). The efficacy of lasers for debonding of orthodontic ceramic brackets has been evaluated in several studies with different parameters and techniques (15-19). Debonding of ceramic brackets occurs because of the degradation of adhesive resin. Also, laser energy degrades the resin by three different mechanisms: thermal softening, thermal ablation, and photo ablation (20,21). Thermal softening is a relatively slow method and can significantly increase the temperature of tooth structure. Thermal ablation refers to quick vaporization of adhesive resin. It is due to the laser energy that instantly heats the resin (21). Photo ablation occurs when high-energy laser light interacts with a material, without any form of thermal damage (22). This technology can be used to remove ceramic laminate veneers. Er:YAG laser, similar to Nd:YAG laser, has thermal effects on water-containing tissues. The thermal effect of Er:YAG laser is lower than Nd:YAG, but they have similar effects on adhesive resins (12,14). Increasing the pulse repetition rate during the removal of composite resin causes a linear increase in pulpal temperature, but this increase is not harmful. This characteristic for living tissues reduces the risk of thermal side effects (23,24). It is well known that Er:YAG laser (2940 nm) is able to

ablate and remove cement, composite resin, and glass ionomer selectively while the tooth structure is maintained intact throughout the process, due to the high absorption of laser in the composite resin and the difference between the ablation thresholds of composite resin and intact tooth structure (25). The debonding mechanism of resin cements using Er:YAG laser is mostly based on thermal ablation and photo ablation of the composite resin cement (20,26).

Despite to the great benefits of using laser, there are concerns about it because different parameters play a role in regulating laser irradiation and its effects on the target tissue. Lasers may alter the morphology of solid materials, and change the chemical structure of their surfaces (25). Questions exist regarding the parameters of laser irradiation that bring about optimal results without damaging the tooth surface. Few studies have been published on removal of ceramic restorations such as ceramic laminates and fixed partial denture restorations using laser irradiation (4,8-10). Therefore, the aim of this study was to evaluate the effect of Er:YAG laser on shear bond strength of PLVs.

## Materials and Methods

### *Tooth preparation:*

Forty-eight freshly extracted, non-carious human permanent maxillary anterior teeth were used in this in vitro, experimental study. The study was approved by the ethics committee of Shahed University of Medical Sciences (ethical approval code: Shahed. REC. 1394.58). All teeth that had caries, enamel defects, severe abrasion, or severe color change were excluded from the study to minimize the impact of confounding factors. The remnants of the periodontal ligament were removed from the root surface using a brush. After washing with water, samples were stored in 0.1% thymol solution until use. The teeth were placed in acrylic resin molds and prepared for PLVs in standardized dimensions. The labial surface of the teeth was shaped flat with the diamond wheel bur (818-diamond wheel bur; Jota, Switzerland). The bonding surfaces of the enamel were polished with OptiDisk (Kerr,

Switzerland) according to the sequence provided by the manufacturer.

*Porcelain veneers:*

Twenty-four feldspathic (VITA VMK master, Germany) and 24 e-max (IPS e-max Press, Ivoclar Vivadent, Liechtenstein) PLV discs were prepared with 0.7 mm thickness and 4 mm diameter as described below (4). A 4-mm diameter disc-shaped mold was used to make PLVs according to ISO-TS 11405 standard (4).

PLVs were fabricated in a dental laboratory according to the manufacturer's instructions. The samples were polished consecutively with 600, 800, 1000, and 1200-grit abrasive papers (Matador German warriors, Germany) to obtain standardized surfaces. All PLVs were bonded to the prepared surfaces of the teeth using Choice 2 light-cure resin cement (Bisco, USA) according to the manufacturer's instructions. The specimens were kept in distilled water at 37°C for 48 h in an incubator. Then, the samples of each group were randomly divided into three subgroups:

- 1) Feldspathic PLVs without laser irradiation (control group, n=8)
- 2) Feldspathic PLVs with laser irradiation (6 s, 10 Hz × 200 mJ = 2 W, n=8)
- 3) Feldspathic PLVs/ with laser irradiation (6 s, 10 Hz × 300 mJ = 3 W, n=8)
- 4) E-max laminate without laser irradiation (control group, n=8)
- 5) E-max laminate with laser irradiation (6 s, 10 Hz × 200 mJ = 2 W, n=8)
- 6) E-max laminate with laser irradiation (6 s, 10 Hz × 300 mJ = 3 W, n=8)

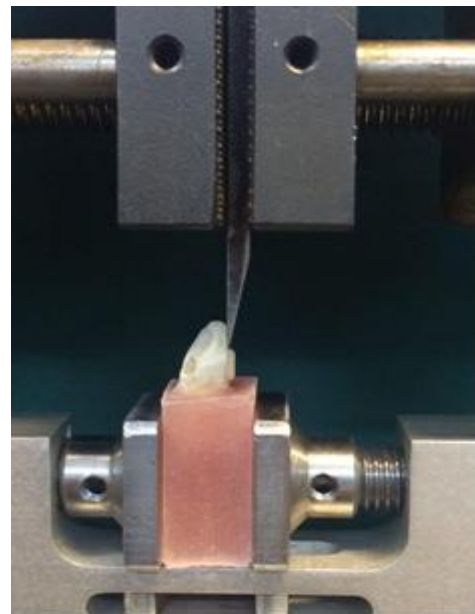
We used Fourier-transform infrared spectroscopy (FTIR) to evaluate whether ceramic materials have specific absorption bands in the infrared wavelength spectrum. For this purpose, one sample of feldspathic and one sample of e-max PLV were used.

To test whether or not Choice 2 adhesive cement absorbs infrared laser energy for ablation, we used FTIR to determine its absorption bands in the infrared spectrum. To achieve a basic understanding about absorption characteristics, a disc-shaped sample of the cement with 1 mm thickness and 4 mm

diameter was prepared and light cured for 40 s on both sides.

The laser utilized in this study was Er:YAG laser (DEKA M.E.L.A., Italy) that was applied with a wavelength of 2940 nm with water spray. The application tip had 1 mm diameter and was positioned perpendicularly at 2 mm distance from the laminate surface (non-contact mode). Irradiation was performed with horizontal movements parallel to the surface as described by Oztoprak et al (13). During laser irradiation, some PLVs were completely separated from the surface of the teeth, while others remained attached after irradiation. These samples were examined for shear bond strength test.

A shear test was performed with a universal testing machine (Model 3345; Instron Corp., Norwood, MA, USA) with 1 mm/min crosshead speed and load rate of 50±2 N/min. The force was applied to the laminate inciso-gingivally, producing a shear force at the laminate-tooth interface (Figure 1). Shear bond strength values were measured in megapascals (MPa) at a crosshead speed of 1 mm/min.



**Figure 1.** Sample being tested in a universal testing machine

After separation of PLVs from the tooth surface during the shear bond strength test, the bonding surface of all specimens (48 samples) was investigated under a stereo-microscope (SMP-200, HP, USA) at 20× magnification to determine the mode of failure as adhesive failure at the interface between the adhesive and the adherent (enamel or ceramic laminate), cohesive failure within the adhesive layer, or substrate failure (27).

#### Statistical analysis

The collected data were entered into SPSS version 24 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to determine the distribution of data. The Mann-Whitney test was used for quantitative comparisons between e-max and feldspathic groups. The Kruskal-Wallis test was applied to compare the shear bond strength of the three groups. We used Bonferroni adjustment by multiplying the Dunn's P value for post-hoc test. The Fisher's exact test was used to compare the mode of failure.  $P < 0.05$  was considered significant.

#### Results

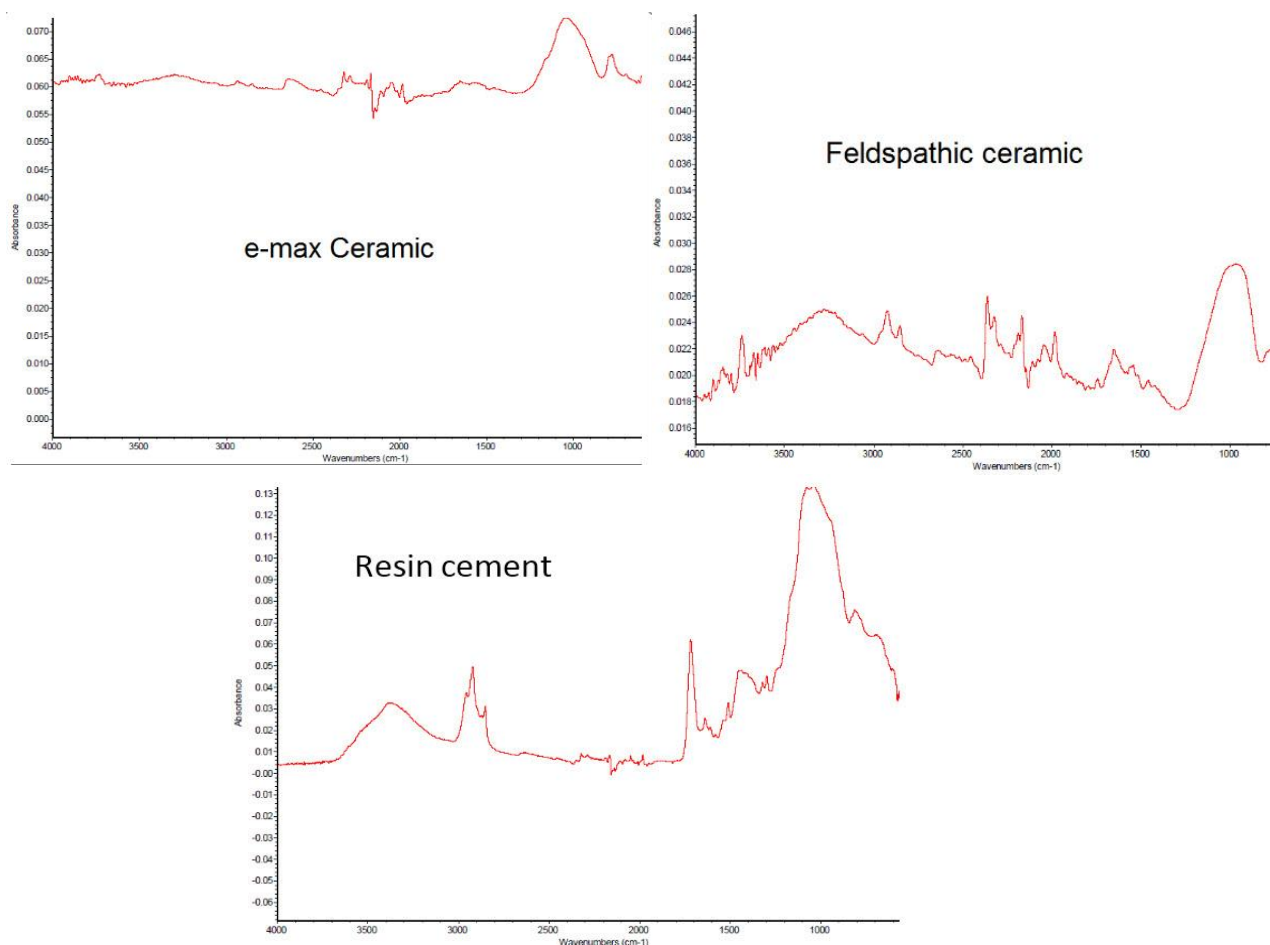
The results of FTIR showed that the oxygen-hydrogen bands (OH) and  $H_2O$  in feldspathic ceramics were higher than in e-max, but the band of silica was higher in e-max (Figure 2). The mean shear bond strength in feldspathic group ( $22.366 \pm 8.122$  MPa) was significantly higher than that in e-max group ( $3.121 \pm 1.674$  MPa) ( $P < 0.001$ ; Table 1). Four samples in the second group, and 5 samples in the sixth group were completely deboned after irrigation. No significant difference was found between the three subgroups of feldspathic ceramics ( $P > 0.05$ ). There was a significant difference between the three subgroups of e-max ceramic ( $P = 0.006$ ). The shear bond strength in the control group was significantly higher than that in the 3 W laser group ( $P = 0.017$ ), but there was no significant difference between 2 W laser group and control and 3 W laser groups ( $P = 0.06$ , and  $P = 0.558$ , respectively). Table 2 shows the distribution of modes of failure. There was no significant

difference in the mode of failure among the groups ( $P > 0.05$ ).

#### Discussion

In this study, the efficacy of Er:YAG laser irradiation for debonding of PLVs was evaluated as a conservative strategy. The mean shear bond strength in feldspathic ceramic group was significantly higher than that in e-max group. After laser irradiation, the shear bond strength decreased in both feldspathic and e-max ceramics. However, the reduction in shear bond strength was statistically significant only in e-max ceramic compared with the control group.

Al-Maajoun et al. (28) reported that there was a statistically significant difference in shear bond strength of the e-max ceramic after laser irradiation between the control group and the two laser groups, which was consistent with the results of our study. They used CO<sub>2</sub> and Er,Cr:YSGG lasers in their study and did not find any difference between the two laser types. In a study by Nalbantgil et al, (18) Er:YAG laser irradiation resulted in a significant decrease in shear bond strength, and debonded the ceramic brackets from the tooth surface, which was consistent with the findings of the present study. Oztoprak et al. (13) irradiated IPS Empress II laminates with 5 W Er:YAG laser for 3, 6 and 9 s and then measured the shear bond strength. The results showed that all three irradiation times significantly decreased the bond strength, but the highest decrease was noted following laser irradiation for 9 s. In another study by Iseri et al, (4) Er:YAG laser was used on laminate veneers made by IPS Empress II. The results of their study showed that the shear bond strength was significantly lower in the laser group. Rechmann et al, (8,9,29) in three studies reported the use of Er:YAG laser for debonding of ceramic restorations and concluded that laser can be successfully used to efficiently debond all-ceramic full-contour crowns. In a study by Gurney et al, (30) Er,Cr:YSGG laser was used to debond all-ceramic restorations. They reported that this laser was useful in comparison with



**Figure 2.** Fourier-transform infrared spectroscopy. Peaks at around 1100 and 3400 nm wavelengths indicate the presence of OH bands and silica in the materials used. The amount of silica in E-max ceramic was higher than that in feldspathic ceramics

**Table 1.** Mean shear bond strength (MPa) in feldspathic and e-max ceramic groups

Group	Feldspathic Mean ( $\pm$ standard deviation)	E-max Mean ( $\pm$ standard deviation)
2 W	22.210 ( $\pm$ 4.269)	1.900 ( $\pm$ 0.534)
3 W	18.572 ( $\pm$ 9.544)	1.385 ( $\pm$ 0.515)
Control	26.317 ( $\pm$ 8.551)	4.383 ( $\pm$ 1.204)
P-value*	0.186	0.006
Total	22.366 ( $\pm$ 8.122)	3.121 ( $\pm$ 1.674)

\*Significance level set at  $P < 0.05$ , Mann-Whitney test

**Table 2.** Distribution of failure mode of the samples

Ceramic group	Failure mode	Control N(%)	2 W N(%)	3 W N(%)	Total N(%)
Feldspathic	Adhesive	4 (16.7)	6 (25)	5 (20.8)	15 (62.5)
	Cohesive	4 (16.7)	2 (8.3)	3 (12.5)	9 (37.5)
	Total	8 (33.3)	8 (33.3)	8 (33.3)	24 (100)
E-max	Adhesive	8 (33.3)	7 (29.2)	8 (33.3)	23 (95.8)
	Cohesive	0 (0.0)	1 (4.2)	0 (0.0)	1 (4.2)
	Total	8 (33.3)	8 (33.3)	8 (33.3)	24 (100)
Total	Adhesive	12 (25)	13 (27.1)	13 (27.1)	38 (79.2)
	Cohesive	4 (8.3)	3 (6.3)	3 (6.3)	10 (20.8)
	Total	16 (33.3)	16 (33.3)	16 (33.3)	48 (100)

high-speed burs and electric handpieces.

The material and the thickness of the veneering layer are among the important factors affecting the amount of laser energy passing through the ceramic veneering. Sari et al. (31) evaluated the laser energy transmission of feldspathic ceramics, leucite-reinforced glass, lithium-disilicate reinforced glass, yttrium stabilized zirconia core, and yttrium-stabilized monolithic zirconia at 0.5 mm and 1 mm thicknesses and found that lithium disilicate-reinforced ceramics with 0.5 mm thickness and feldspathic ceramic with 1 mm thickness allowed the passage of the lowest amount of laser energy. In our study, it was also found that the laser transmission energy in lithium disilicate ceramic (e-max) was higher than that in feldspathic porcelain. Morford et al, (20) also observed that by increasing the ceramic thickness, the amount of laser energy passing through the ceramic decreased. The amount of energy passing through the leucite glass-ceramic was also lower than that of lithium disilicate glass-ceramic. Different ceramics have been used in various studies as laminate veneer or full crowns (4,8,9,13,20,29). Nalbantgil et al. (18) reported that laser irradiation time had a significant effect on shear

bond strength. As the laser irradiation time increased, the amount of force required for debonding decreased. Oztoprak et al. (13) found that with 3-second irradiation, the bond strength decreased by approximately 50% compared with the control group. Increasing the irradiation time results in an increase in the pulpal temperature. Nalbantgil et al. (18) reported that when the irradiation time was 9 s, the pulp temperature increased by 4.59°C. However, it was still far from the critical temperature threshold of 5.5°C (32). They also suggested rotational movement of laser handpiece during laser irradiation to prevent pulpal temperature rise (18).

The use of laser for debonding of laminate veneers and ceramic crowns has been suggested (10,33,34). Laser can be effective for this purpose without damaging the tooth surface or the ceramic surface and even without changing the chemical composition of ceramic surface (34). During laser debonding, laser energy passes through the ceramic. Then, resin cement absorbs the remaining energy (4,20,26).

The main mechanism for debonding of all-ceramic restorations by the use of Er:YAG Laser is based on "thermal ablation" and

"photo-ablation" of resin cements (20). The mechanism of ablation of cured composite resin is explosive vaporization, followed by hydrodynamic ejection (35). Theoretically, in the process of thermo-mechanical ablation induced by light, the water in the media or within the material absorbs the laser energy, and rapidly evaporates and expands, resulting in pressure and force in the surface. During the ablation of composite resins, the organic compounds in the composite resin are rapidly melted, and high force is generated following an increase in melting volume. When sufficient amount of resin has been ablated, debonding begins (20,35,36).

In the present study, Er: YAG laser was used because it has less thermal effect than Nd:YAG or CO<sub>2</sub> lasers (12,14). It is also emitted at a wavelength of 2904 and can therefore be well absorbed by adhesive resins containing water, or monomers remaining in resin cements (23). The Er:YAG laser beam is well absorbed by water and hydroxyapatite due to the presence of OH groups (37). Considering this, and based on the FTIR graphs of different ceramics, it can be concluded that any ceramic containing higher amounts of OH groups and water better absorbs the Er:YAG laser energy and any ceramic that has less OH and water passes the laser beam. According to a study by Morford et al, (20), the wave number for silica is about 1100 nm, for OH is about 3400-3600 nm and for water is 3640-3750 nm. Therefore, it can be concluded that e-max ceramics have lower amounts of OH group and water than feldspathic ceramics. In other words, the laser beam passes well through the e-max ceramics, but some of the laser energy is absorbed by the feldspathic ceramic, and part of it reaches the cement layer. The resin cement used in the current study absorbs the energy of the laser beam by OH groups. Therefore, according to the FTIR graphs of this study, it can be concluded that Er:YAG laser beam results in damping of e-max veneers more effectively than the feldspathic ceramic. This finding was in good agreement with the data obtained from the analysis of shear bond strength data.

As mentioned earlier, laser can degrade the

cement by creating micro-explosions resulting from water absorption. Al-maajoun et al. (28) used CO<sub>2</sub> and Er,Cr:YSGG lasers, and did not use water spray because of the damage to the ceramic surface by the explosion. Iseri et al. (4) did not use water spray for cooling either. On the other hand, one of the problems with the use of laser to remove laminates is the increase in temperature of vital teeth, which can damage the pulp. Al-maajoun et al. (28) observed brown discoloration in dentin and attributed it to increased temperature or carbonization by laser. In our study, no color change was observed in dentin. In the study by Nalbantgil et al, (18) no discoloration was observed after laser irradiation. Oztoprak et al. (38) reported that changes such as localized carbonization-like black deposits were observed in residual resin cement. Rechmann et al. (29) observed no discoloration in the dentin bonding area. It was suggested that water use during laser irradiation may be useful to prevent pulpal temperature rise and consequent pulpal damage. In the present study, irradiation was carried out under water spray in order to reduce the possibility of thermal damage. Moreover, low laser power was used, which reduces the chance of thermal damage to the pulp. Despite this decrease in laser power, the results of the present study still showed a decrease in shear bond strength of laminate ceramic veneers following Er:YAG laser irradiation.

Another factor that can be effective in debonding of laminate veneers is the type of resin cement. Different studies have used different light-cure and dual-cure cements (4,8,9,13,29). Tak et al. (26) investigated the effect of Er:YAG laser irradiation on different cements. The results showed that all resin cements had ablation volume due to laser irradiation.

Volume measurement of resin cements after laser irradiation showed that the mean volume loss of G-Cem LinkAce and MultilinkN Automix cements was similar, but there was no significant difference between them and Panavia F2.0, Variolink II and RelyX Unicem U100. The highest cement loss was also observed in G-Cem

LinkAce and the lowest in RelyX Unicem U100. In the present study, we used Choice 2 light-cure cement. One limitation of this study was the lack of simultaneous control of dental temperature changes during laser irradiation. The thickness of the veneers is also clinically different in different dental sites, which was overlooked in the present study. It appears that a study that can simultaneously consider several factors such as tooth temperature changes during laser irradiation, irradiation time, ceramic thickness and type of resin cement can lead to optimal results.

### Conclusion

1. The use of Er:YAG laser decreased the shear bond strength of PLVs made of e-max ceramic.
2. In e-max ceramic, the shear bond strength decreased by increasing the laser energy. However, this decrease was not statistically significant.
3. In the feldspathic group, despite the decrease in shear bond strength, it was not significant

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