



Er:YAG Laser Debonding of Lithium Disilicate Laminate Veneers: Effect of Laser Power Settings and Veneer Thickness on The Debonding Time and Pulpal Temperature

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Abstract

Introduction: Er:YAG laser is a non-destructive tool for debonding of laminate veneers. This study investigated the effect of different laser powers on the pulp temperature and the time required to perform the debonding of lithium disilicate laminate veneers with different thicknesses.

Methods: The labial enamel of 48 maxillary central incisors was flattened and polished. The teeth were restored with flat lithium disilicate ceramic veneers (4.0 mm×6.0 mm) with one of two different thicknesses (0.5 and 1.0 mm). Veneer debonding was performed with an Er:YAG laser with a wavelength of 2940 nm, pulse duration of 100 μm (VSP mode), 10 Hz, and one of the three laser power settings: 1.5 W (150 mj), 3.0 W (300 mj), and 5.4 W (540 mj) (n=8). Veneer detachment time and intra-pulp temperature change (ΔT) were measured. Statistical analysis was performed using the two-way ANOVA and Bonferroni's post hoc test (α=0.05). The correlation between debonding time and temperature change was calculated using Pearson's correlation.

Results: The longest time was recorded to remove the 1.0-mm veneer at 1.5 W (P<0.05) and the shortest time was recorded when deboning the 0.5 mm veneer with 5.4 W (P<0.05). ΔT decreased significantly with increasing laser power. A low correlation was found between time and ΔT (R²=0.113).

Conclusion: Laser power and veneer thickness are important factors for veneer debonding; thinner veneers are removed faster. When debonding thick veneers, 5.4W laser power is more efficient and causes fewer changes to the pulp temperature.

Keywords: Veneer; Debonding; Laser; Er:YAG; Pulp temperature.



Introduction

In recent years, the aesthetic expectation of the patients has increased considerably and led to the use of porcelain laminate veneers in a wide range of dental practices.^{1,2} Dental laminate veneers are thin, aesthetic, tooth-coloured restorations cemented to the facial surface of the anterior teeth using light-cured resin cement after minimal tooth preparation that is mainly limited to the enamel structure.³

The porcelain laminate veneer has many indications, as it is the treatment of choice to manage teeth with poor aesthetics, such as peg-shaped lateral incisors, enamel hypoplasia, fluorosis, tetracycline discolouration, diastemas closure, dark teeth, fractures, failing restorations, or misalignment.^{4,5} All these clinical problems could be easily managed by dental veneers, avoiding the need for advanced and painful surgical

procedures.⁶ The longevity of veneers is limited by such factors as caries, microleakage, marginal discolouration, cracking, chipping or fracture, incorrect placement during cementation, and sometimes aesthetic reasons from a patient's perspective.⁷ Under these circumstances, veneer removal and replacement may be mandatory.

Lithium disilicate (LiSi) is a vitreous ceramic with improved properties among different dental ceramic systems. Compared to other porcelain ceramics, LiSi has relatively higher strength, enamel-like translucency, superior biocompatibility, and high bond strength to resin cement.⁸

The strong bonding between the LiSi veneer and tooth surface is due to the very high bond strength of the resin cement to the main enamel substrate tooth surface, and thus, the veneer removal in case of failure is a challenging, time-consuming procedure⁹ and potentially damaging to

the underlying tooth structure.¹⁰

When veneer removal is dictated, the conventional way is achieved by using traditional instruments with mechanical force, such as crown tractors, chisels, manual or automatic removers,¹¹ or a rotary instrument using a diamond bur to grind the veneer.¹² Although veneer debonding by grinding is complete, it is time-consuming and associated with patient discomfort, and the underlying tooth structure may be affected due to friction, heat, vibration, and the integrity of the veneers being compromised.¹³ Another factor to be considered is the difficulty of differentiating the veneer margin from the tooth structure due to the high aesthetic standard of modern restorative materials, leading to excessive tooth structure loss during veneer removal.^{14,15}

Due to advancements in laser technology with the widespread use of lasers in dentistry, lasers have recently been introduced as an alternative method for veneer debonding.¹⁶ Laser-aided debonding significantly facilitates the debonding of the adhesive resin, which may reduce the pain associated with the debonding procedure and yield less risk of enamel damage.¹⁷⁻¹⁹

The laser parameters (power, pulse duration, frequency and lasing time) are the main factors that affect the debonding process, along with many other variables related to the ceramic materials, such as chemical composition, type, shade, opacity and thickness, as well as the type and shade of the resin cement.^{8,12,20,21} On the other hand, the Er:YAG laser has the advantage of debonding the ceramic veneer without damaging the underlying tooth structure or the restoration and can be rebonded again, which is a time- and cost-saving technique for the dentist and the patient.^{22,23}

Thermal irritation of the pulp with the possibility of temperature increase inside the pulp is one of the issues that arise when using the laser in the debonding procedure.^{11,24,25} Many studies have evaluated the temperature rise, using the 5.5°C increase in intrapulpal temperature as a benchmark threshold to avoid pulpal tissue damage.^{26,27} A study by Alikhasi et al concluded that the application of laser was an effective, quick and harmless method for the removal of laminate veneers and with a temperature rise of less than 5.5°C.²⁵ Another study by Nalbantgil et al found a direct relationship between the temperature rise and the lasing duration, but the temperature remained below 5.5°C.²⁸ However, other articles reported an increase in the pulpal temperature, which can be reduced by sufficient air-water cooling and altering the laser parameters.¹¹

There is no general consensus in the literature on the best laser parameters for veneer debonding.¹⁵ Therefore, this study was designed to investigate the effect of different laser power outputs to debond veneers with varying thicknesses on the pulpal temperature change and the required time of laser application to achieve debonding.

The null hypotheses were that there is no difference in time needed for or temperature rise during debonding ceramic veneers with different laser energy outputs and that the veneer thickness has no significant effect on these tested parameters.

Materials and Methods

Forty-eight non-carious maxillary central incisors were collected from leftover teeth extracted during routine dental treatment. Informed patient consent was obtained with approval by the University of Sharjah Ethics Committee (REC-21-10-09-03-S).

The roots were cut at 2 mm below the cementum-enamel junction. The labial enamel was flattened and polished with a series of SiC papers up to 600 grit, mounted on an automatic grinder/polisher (EcoMet 30, Buehler, IL, USA). Depending on the thickness of the ceramic veneer, the teeth were evenly divided into two groups of 24 teeth each. A lithium disilicate CAD/CAM block (IPS e.max CAD, Ivoclar Vivadent, Shan, Liechtenstein) was cut with a precision saw (Isomet 1000, Buehler Lake Bluff, IL, USA) to form flat glass-ceramic veneers (4.0 mm × 6.0 mm), with two thicknesses (0.5 and 1.0 mm). All prepared veneers were tempered at 850°C in a furnace (Programat P300/P500; Ivoclar Vivadent AG, Schaan, Liechtenstein) using a lithium disilicate crystallization program preset by the manufacturer.

One surface of the ceramic veneer was etched with 5% hydrofluoric acid for 20 seconds (IPS ceramic etching gel, Ivoclar Vivadent), cleaned with an air/water spray for 60 seconds, and dried with oil- and moisture-free compressed air. A silane-containing ceramic primer (Monobond Plus, Ivoclar Vivadent, AG, Schaan, Liechtenstein) was applied to the etched ceramic surface for 60 seconds and air-dried for 10 seconds. The enamel surface was etched with 37% phosphoric acid for 20 seconds, rinsed and dried. A universal adhesive resin (Adhese Universal, Ivoclar, Vivadent) was applied to the enamel surface and massaged onto the tooth surface for 20 seconds. After the adhesive was air-dispersed, it was light-cured for 10 seconds using a light emitting diode (LED) light-curing device (Bluephase, Ivoclar, Vivadent). Laminate veneers were cemented to the enamel surface with a light-curing adhesive composite (Variolink Esthetic LC, Ivoclar, Vivadent). A standardized 20 g load was applied for 20 seconds to allow the veneer to fully conform and the excess cement to extrude. Excess cement was removed from the veneer margin with a microbrush and the cement was lightly cured from the top of the veneer for 20 seconds. All samples were stored in double-distilled water for 1 week to allow bond maturation prior to laser exfoliation.

The Er:YAG laser (Fidelis AT; Fotona, Ljubljana, Slovenia) was used for veneer debonding. The laser parameters used in this study are shown in [Table 1](#). The

laser was applied by scanning the veneer surface in a circular motion from the perimeter to the center. Each group of samples was further divided into three groups ($n=8$) according to the laser power setting: 1.5 W (150 mJ), 3.0 W (300 mJ), or 5.4 W (540 mJ). The time required to remove the veneer was measured in seconds using a digital timer. The test was terminated when 4 minutes passed without debonding the veneer.

The temperature was measured continuously during laser application using a K-type thermocouple and a digital thermometer (GMH 3211, GHM Group – Greisinger, Regenstauf, Germany). The thermocouple tip was placed in the pulp chamber directly opposite the veneered surface. The intrapulpal temperature change (ΔT) was calculated using the following formula:

$$\Delta T = T_i - T_{\max}$$

Where T_i is the initial temperature and T_{\max} is the maximum temperature reached until debonding.

The enamel surfaces were scanned under a stereomicroscope (Leica EZ4, Leica, Wetzlar, Germany) at 30x magnification with embedded digital camera LAS EZ software for PC (Leica Microsystems, Wetzlar, Germany). The failure modes were analyzed by two examiners and categorized into one of the following four types: Type 1) resin cement to enamel adhesive, type 2) adhesive in cement, type 3) cement to ceramic adhesive, and type 4) adhesive in ceramic.

Two-way analysis of variance (ANOVA) was used to test the effects of variables (ceramic thickness and laser settings) on the collected data, followed by pairwise comparisons between experimental groups ($\alpha=0.05$). A post-hoc Bonferroni test was performed. Statistical analysis was performed using SPSS software (version

15.0, SPSS Inc., Chicago, IL, USA). A two-sided Pearson correlation analysis was used to determine the relationship between mean time values and temperature change.

Results

The results of this study are shown in Table 2. The ANOVA showed a highly significant effect ($P<0.001$) of both variables (ceramic restoration thickness and laser parameters) on time and temperature changes required to debond the veneers. ΔT decreased significantly with increasing laser power, with 1.5 W power showing the highest ΔT ($P<0.05$) for 1.0 mm veneer removal, but no statistical difference for 0.5 mm veneer removal was seen ($P>0.05$), regardless of the power used. 1.0 mm veneer debonding at 1.5 W power recorded the longest time ($P<0.05$), reaching up to 4 minutes for some samples. Meanwhile, the shortest debonding times were recorded for the 0.5 veneers using 3.0W and 5.4 W laser applications, which were statistically different from 1.5W ($P<0.05$). A two-sided Pearson correlation analysis of the results is shown graphically in Figure 1. A low correlation between mean time values and temperature changes was found ($R^2=0.113$). All specimens tested exhibited type 2 and type 3 failures (Figure 2).

Failures were primarily cohesive within the cement or adhesive between the cement and the ceramic. No enamel or ceramic failure was observed, regardless of veneer thickness or laser power used.

Discussion

This study investigated the effect of different laser powers on pulp temperature changes and the time required to debond LiSi veneers of different thicknesses. Our results showed a significant effect ($P<0.001$). Therefore, the two null hypotheses in this study were rejected.

The removal of cemented laminate veneers is indicated in many clinical situations, including the removal of aesthetically compromised veneers or veneers with marginal deviations that cause gingival and periodontal problems.²⁹ In addition, a recently fabricated veneer that was malpositioned during cementation necessitated removal and re-cementation if the veneer remained undamaged after debonding from the tooth surface.

Table 2. Mean Values and Standard Deviation of the Temperature Change (ΔT) and Time to Veneer Debonding (s) of the Two Veneer Thicknesses Tested, Using Different Laser Energy Outputs

	ΔT (°C)		Time (s)	
	0.5 mm	1.0 mm	0.5 mm	1.0 mm
1.5 W	0.7±0.20 ^{Aa}	5.7±1.79 ^{Ab}	27.58±7.97 ^{Aa}	199.12±44.45 ^{Ab}
3.0 W	0.4±0.10 ^{Aa}	2.1±0.75 ^{Bb}	4.72±2.43 ^{Ba}	14.05±5.00 ^{Bb}
5.4 W	0.4±0.23 ^{Aa}	0.8±0.48 ^{Ca}	2.10±0.86 ^{Ba}	5.10±2.73 ^{Ca}

*Within a column, the same Lower-case superscript letters show mean values with no statistically significant difference ($P>0.05$).

*Within a row, the same Upper-case superscript letters show mean values with no statistically significant difference ($P>0.05$).

Table 1. Laser Parameters Used in the Study

Type of laser	Er:YAG
Model and manufacturer	Fidelis AT; Fotona, Ljubljana, Slovenia
Wavelength	2940 nm
Emission mode	Very short pulse mode
Pulse duration	100 μ s
Delivery system	7-mirror Articulated arm with non-contact handpiece (R02)
Energy distribution	Inhomogeneous
Average power	1.5 W (150 mJ) \times 10 Hz 3.0 W (300 mJ) \times 10 Hz 5.4 W (360 mJ) \times 10 Hz
Spot diameter at the tissue	0.9 mm
Average power density at the tissue	235.79 W/cm ² 471.57 W/cm ² 848.83 W/cm ²
Water irrigation	40 mL/mm
Air and aspirating airflow	40 mL/mm

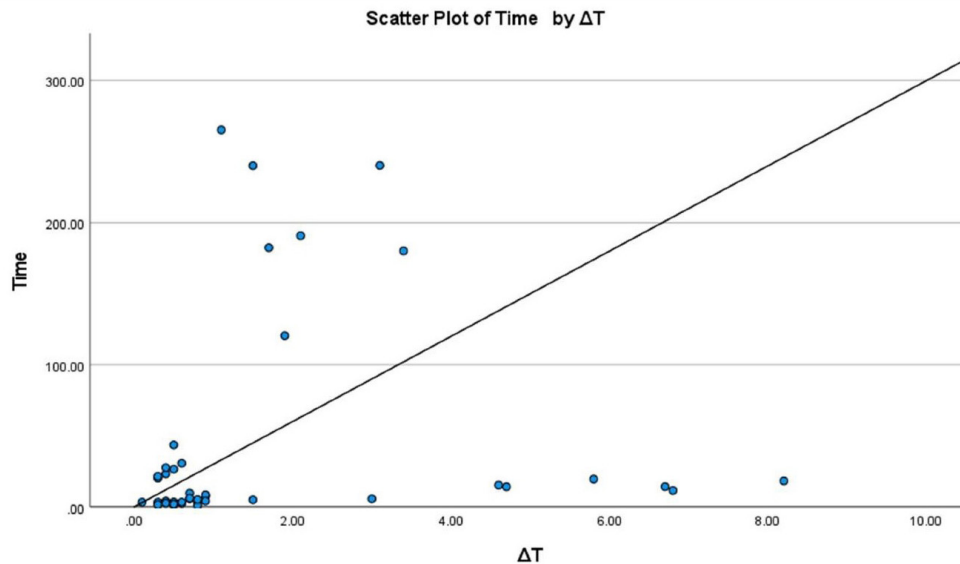


Figure 1. Correlation Between the Time to Veneer Debonding (s) and the Temperature Change (ΔT)

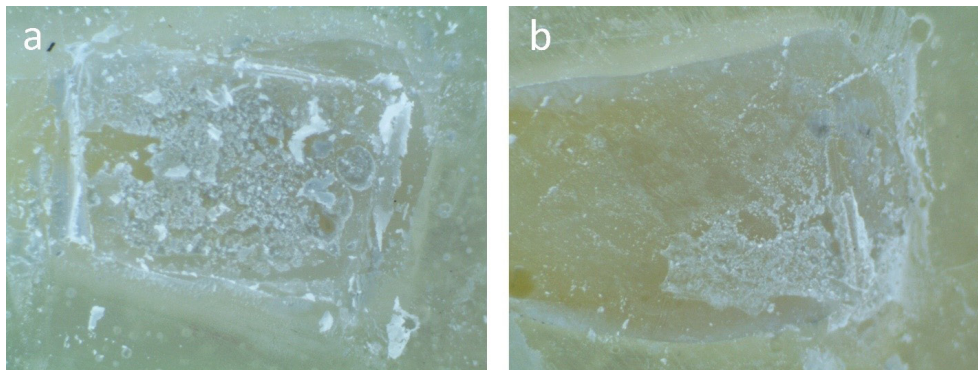


Figure 2. Representative Stereomicroscope Images with 30 \times Magnification, Showing the Enamel Surface After Veneer Debonding With (a) Cohesive Failure in Cement (Type 2) and (b) Adhesive Failure Between Cement and Ceramic (Type 3)

The removal of ceramic veneers in the dental office is a time-consuming process and needs high shear forces to debond the veneer; this would result in heat generation, pain and damage to the tooth structure.³⁰

The use of lasers is a critical technique for removing the ceramic veneer. The process requires the transmission of laser energy through the ceramic veneer, absorption by resin cement and degradation of cement by one of the three assumed mechanisms: thermal ablation, photoablation and resin softening.²⁰ During thermal softening, luting resin cement is heated until it softens, and the veneer glides off the tooth surface. While in photoablation, the decomposition of the bonding resin cement occurs due to the rapid increase in the energy level of bond resin atoms above their dissociation energy levels.³¹ Accordingly, it is concluded that photoablation occurs at high-power densities, but thermal softening occurs at low-power densities in comparison with thermal ablation.²⁰ However, in case of the rapid increase in the temperature to the range of vaporization in an adhesive resin, thermal ablation could happen, which leads to

veneer blowing off the tooth surface, and this may occur before thermal softening.³²

Therefore, the magnitude of the laser energy is the most critical laser parameter that affects debonding time. It was stated that there is an inverse relationship between the pulse energy and the pulse repetition rate (the frequency).³³ When the frequency is kept to the minimum, increasing the average power results in greater pulse energies, which will reach the ablation threshold of the resin cement and consequently cause debonding in a shorter time.¹³

In this study, a low frequency was kept constant at 10 Hz, and three different average powers were used (1.5, 3.0 and 5.4 W) to determine the least power that can result in debonding in the shortest time and the minimal thermal effect on the pulp. The results of this study revealed that high power (5.4 W) resulted in rapid blowing of the veneer, indicating photoablation. On the other hand, using a low-power laser (1.5 W) caused the veneer to slide off the tooth surface, which indicate thermal softening. Laser irradiation on the veneer surface can be localized

or in a scanning pattern. In our study, a scanning method was used when removing veneers. This approach showed promising results, with the removal of all tested veneers achieved at different times and with different forces (Table 1).

In some samples, veneer detachment required the veneer to be lightly touched or moved with a plastic instrument during or after laser application. However, many samples showed veneer blow-off without touching the veneer with a plastic instrument. These observations are in agreement with the findings reported by Oztoprak et al, who reported no explosive blow-off of the veneers when the scanning method was applied, which means that thermal ablation and photo-ablation are not causative mechanisms and that the debonding might be due to other underlying mechanisms of degradation and not thermal softening and physical disruption in resin cement.³⁴

The veneer debonding could happen as a result of failure in the cement-veneer interface that will cause no damage to the tooth structure or in the enamel-cement interface which may cause enamel damage. In our study, the scanning electron microscope analysis found that most failures were in the veneer-cement interface; similarly, Morford et al reported that failure occurred in the veneer-cement interface and veneer surfaces were clean and free of cement.⁹ This study found that laser application did not affect ceramic surfaces; the main bulk of resin cement remained on the tooth surface. Indeed, the thickness of the veneer and the type of cement are directly related to these findings.

The results of the stereomicroscopic analysis showed that deboned veneers with 0.5 mm thickness have less cement attached to the veneer surface compared to those with 1.0 mm thickness, and this could be due to the relation between veneer thickness and the amount of laser energy transmission through the veneer surface toward the adhesive cement. Similar results were reported by Sari et al, who found a higher transmission ratio for 0.5-mm-thick lithium disilicate ceramic compared to 1-mm-thick feldspathic ceramic.²¹ Accordingly, the use of lasers to debond ceramic veneers might be done without enamel damage, though ceramic type and thickness should be taken into consideration to adjust the laser power and application time during the debonding process.²³

The risk of enamel damage increases as the failure site gets closer to the enamel-adhesive interface. In the current study, failure was mainly within the cement or between the cement and the ceramics and no enamel fracture was observed (Figure 2). The duration of the laser irradiation in our study was not determined in advance similar to other studies, and this was important to find the exact time required to debond the ceramic veneer to avoid the shear force on teeth during ceramic veneer removal. Accordingly, it was essential to correlate the time needed

to debond the veneer and the heat generation during the veneer debonding process. This approach is necessary to find the time threshold of laser irradiation and the heat generated.

In this current study, for both 0.5- and 1-mm-thick ceramic veneers, increasing the power from 1.5 W to 3.0 W to 5.4 W helped decrease the time required for veneer debonding. This indicates the importance of energy/power in debonding the ceramic veneer from the tooth structure. Energy is essential for heat generation and necessary for the ablation of adhesive cement. A reverse relationship was found between the transmission of laser light through ceramic materials and the thickness of the ceramic, and significant differences were found among the materials tested, with lithium disilicate ceramics exhibiting the highest laser transmission.²³ Accordingly, we can assume that in the present study, the highest laser transmission occurred with the 0.5-mm ceramic veneers, and this could be the reason for the less time that was required to debond the veneer, compared to that needed to debond veneers of 1 mm thickness (Table 1).

An increase by 5.25°C has been reported as the critical threshold of dental pulp temperature during laser application.²⁶ Therefore, the precise measurement of pulp temperature during laser application is essential for determining safe laser parameters; otherwise, irreversible pulpal damage may occur.²⁷ Zach and Cohen investigated the effect of heat on the dental pulp histologically. The results of their study indicated that no pulpal damage was detected with an increase in temperature up to 5.5°C; meanwhile, dental pulp irritation was detected when exceeding this threshold.²⁸

The Er:YAG laser was used in this study because it has a negligible thermal effect compared to the Nd:YAG lasers.³¹ The laser application method is another factor that affects heat transfer in the pulp. Oztoprak et al reported that debonding with laser scanning of the surface of the ceramic bracket rather than just one spot reduces the thermal effect of laser energy.³⁴

In this study, it was found that the temperature rise during laser ceramic veneer debonding correlated with veneer thickness and laser energy. Therefore, increasing the laser power reduced the temperature and time required to debond the veneer. Moreover, using the same power, the time required to debond a 1-mm-thick veneer was longer than that for a 0.5-mm-thick veneer. In other words, increasing the temperature was directly related to increasing veneer thickness and decreasing the power of the applied laser. The maximum temperature rise (5.7 ± 1.79) was recorded at the lowest power (1.5 W) when debonding a 1-mm-thick veneer, the lowest temperature rises (0.4 ± 0.10 and 0.4 ± 0.23) were recorded at a power of 3.0 W and 5.4W respectively, when debonding 0.5 mm thick veneers.

The use of the scanning method in this study may be a

factor preventing the increase in intrapulpal temperature during veneer detachment with the Er:YAG laser. According to Nalbantgil et al, the thermal effects can be minimized by changing the laser type and parameters, application method, cooling air, and water spray.²⁸ However, debonding a 1-mm-thick ceramic veneer using 1.5 W of power took more than 199 seconds and the temperature rise exceeded the generally accepted threshold of 5.5°C. In contrast, a 0.5-mm-thick ceramic veneer peeled off in less than 6 seconds and had a temperature rise of less than 1°C. This indicates that the application time of the laser is the most important factor in determining the thermal effect of the laser.

In this study, the use of different energies (150, 300 and 540 mJ/pulse) had a significant effect on the debonding. Using 5.4-W reduced the time required to remove 0.5mm and 1mm thick ceramic veneers compared to a 1.5-W or 3.0-W temperature rise combined. From this, it can be concluded that increasing the veneer thickness requires the use of more Er:YAG laser energy for a longer period of time, thereby increasing the pulp temperature.^{11,35}

Conclusion

The Er:YAG laser is an efficient and fast method for debonding lithium disilicate veneers, providing that the proper settings are employed. The time required for debonding is dependent on the veneer thickness, with the thinner veneers being faster to remove. Increasing the laser power output up to 5.4 W is more efficient in veneer debonding, and it causes a limited pulpal temperature rise compared to low power settings, which may induce harmful thermal effects on the pulp tissues, especially when debonding thick veneers.

Conflict of Interests

None to be declared.

Ethical Considerations

This study was approved by the University of Sharjah Research Ethics Committee (Approval # REC-18-10-09-03-S).

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