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e. max Veneers Debonding with Er: YAG 2940nm using two different Laser parameters (In-vitro/In-vivo Study)

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Abstract

The removal of e. max veneers, which are currently the most used type, can be an uncomfortable and time-consuming procedure for both dentist and patient. This challenge arises from the high bond strength between the tooth enamel and laminate veneers, as well as the difficulty in distinguishing between the veneer and the natural tooth, especially when the veneer closely matches the natural tooth in color. The aim of the study was to find the safest and optimal Er: YAG parameter to de-bond e.max veneers using the scanning method, as well as determine the time required for debonding. For the in-vitro phase of the study, 16 extracted upper centrals were prepared to each receive a full anatomical IPS e. max CAD LT (Low Translucency) (Ivoclar Vivadent, Schaan, Liechtenstein) veneer of 1mm in thickness. The e. max veneers were cemented on the labial surface of the teeth using Choice 2 (Bisco Inc., Schaumburg, IL, USA) veneer cement, which was light-cured for 40 seconds. Samples were divided equally (n=8) for each group: Group A was treated with an Er: YAG laser at 3 watts (300 mj and 10 hz); Group B was treated with an Er:YAG laser at 5.4 watts (360 mJ, 15 Hz frequency). Both groups underwent a debonding process using the scanning method. During this process, the time required for the veneers to detach was recorded. After debonding, the samples were examined using a TECHNIVAL 2 stereo microscope (Carl Zeiss, Germany). In the in-vivo phase of the study, three patients with a total of 20 e.max veneers were selected for the removal of the veneers using only Group A parameters, following the same steps as in the in-vitro phase, and the time required for debonding was recorded. Results of the in-vitro phase indicated that there was no statistically significant difference in debonding time: Group A (108.23±8.43) and Group B (110.67±9.00). By inspection under the stereomicroscope, Group B showed signs of excessive heat generation indicated by the presence of blackened veneer cement attached to the prepared surface of the tooth. This is why only Group A parameters were used in the second phase of the study. Results of the in-vivo phase demonstrated a significantly longer debonding time when compared to the in-vitro samples using the same (Group A) parameters, with an average time of 117.69 ± 10.88 seconds. The study's findings suggest that when it comes to debonding e. max veneers with a thickness of 1 mm, using an Er: YAG laser set at 3 watts is a safer choice than using it at 5.4 watts.

Keywords: Er: YAG laser. Laminate veneers. E. max veneer. Scanning method. Lithium disilicate.

Full length article **Corresponding Author*, e-mail: kareem.elenany@gmail.com

1. Introduction

E. max veneers are a popular and in-demand choice for patients who want to improve the appearance of their teeth, whether due to spacing problems, discoloration, or suboptimal shape. However, veneers can become chipped or discolored over time, and may need to be removed and changed. Traditionally, veneers are removed by grinding them away with rotary instruments. This conventional method is time-consuming, requires skill, and can damage the underlying tooth structure. In recent years, lasers have been claimed to be a better option for removing veneers with greater efficiency. The Er: YAG laser is a type of laser that is well-suited for debonding ceramic veneers [1-3]. The Erbium laser emits light at a wavelength of 2940 nm, which is transmitted through the ceramic veneer and then absorbed by water and other organic materials specific to the resin cement. When the laser light is absorbed, it causes these materials to vaporize, which effectively removes them from the surface of the tooth. This process is relatively safe for the tooth structure.

The purpose of this study is to assess the safety and duration required for the Er: YAG 2940 nm laser to de-bond full anatomical e. max veneers that cover the entire labial surface and incisal edge of the tooth, rather than relying on blocks or discs as representations. This approach differs significantly from most previous studies, which relied primarily on discs to represent ceramic veneers. Such representations do not accurately simulate real-world clinical situations in patients' mouths, due to differences in surface area coverage and the potential for crack development and propagation, as well as variations in the time required for removal. This study was conducted initially in-vitro, using extracted teeth, to evaluate the safety of the parameters. Subsequently, the safest parameters were applied in-vivo, involving clinical cases.

2. Materials and methods

2.1. In-vitro

2.1.1. Sample collection and grouping

Sixteen extracted permanent maxillary central incisors of relatively similar dimensions, non-carious, with no visible cracks, were collected and stored in 0.5% chloramine T. solution [4]. These teeth were selected to receive full anatomical e. max CAD ceramic veneer and were divided into 2 groups of 8 central maxillary incisors according to the laser parameters: Group A with laser parameters 3W (300 mj,10 Hz frequency) and Group B with laser parameters 5.4W (360 mJ, 15 Hz frequency).

2.1.2. Specimen preparation

The teeth were placed in a transparent acrylic resin mold 2mm below the cementoenamel junction. Subsequently, they were prepared with incisal butt joint design to receive an e. max ceramic veneer of 1mm thickness, made by the same specialist. Impressions were taken by Elite HD+, which is an addition silicone impression material. Using the one-step impression technique, a light impression material is injected on the prepared tooth, and then the putty impression material is immediately placed over it. Impressions were completed separately and checked for inaccuracies, and in the case of any inaccuracy the impressions were repeated. Impressions were sent to the lab for veneer designing and milling using lithium disilicate IPS e. max CAD blocks shade A2 (Ivoclar, Vivadent; Schann, Lichtenstein), low translucency (LT) [6]. The veneers were 1mm in thickness (Figure 1), which is more than the minimum 0.7 mm thickness recommended by the manufacturer's instructions [5]. These specifications were used to eliminate variations in thickness, shade, opacity, and cement shade.

2.1.3. Specimen bonding

The entire labial surface of the teeth underwent a 30-second acid etching process using 37% phosphoric acid. Subsequently, All Bond Universal (Bisco, USA) was meticulously applied and then cured for 20 seconds. For the fitting surface of the veneer, a 20-second etching with 9.5% hydrofluoric acid (Bisco Ceramic Etch, USA) was carried out, followed by a thorough rinsing using an air-water syringe. After rinsing, silane was applied and left to set for 60 seconds before being air-thinned. Veneer resin cement Choice 2 was injected into the fitting surface of the veneer. The veneer was then placed onto the prepared labial surface of the tooth using gentle finger pressure. It underwent a preliminary light polymerization for 5 seconds. After removing any excess cement using a sharp explorer, we proceeded to achieve complete light polymerization with an energy density of 480 mW/cm², which was maintained for 40 seconds. All samples were stored in saline solution at 37º C for 48 hours before laser debonding [6-8].

2.1.4. Specimen debonding

Laser irradiation was performed using Er:YAG laser with a wavelength of 2940 nm in non-contact mode (focused mode) with handpiece (R02), (Fotona-Lightwalker ST; Slovenia), one sample at a time. The time was recorded using a stopwatch handled by a second person for all the samples as a single specialist laser operator de-bonded each one. Both Groups A and B were de-bonded in a noncontact method using the scanning method [9-12]. The application started near the mesio-cervical margin in a horizontal direction till the disto-incisal margin. Afterwards, the scanning application method was repeated vertically until debonding occurred. No force was applied on the veneer. The irradiation process lasted until the veneer popped off or the last piece of the veneer came out. Stereomicroscope TECHNIVAL 2 (Carl Zeiss, Germany) at 20X magnification was used to evaluate the internal surface of the de-bonded veneer and the de-bonded surface of the tooth for both groups [4,13-14].

2.2. In-vivo

Group A (3W) parameters were applied to the in-vivo part. Three different patients were sent by their treating dentists to remove their veneers, and after explaining everything to both the treating dentists and the patients they agreed to participate in the study maintaining their anonymity. The patients received e.max veneers and wanted to change them. Two of them were not satisfied with the color of their veneers, and had good oral hygiene and no sensitivity. The third patient had gum inflammation due to improper veneer placement and improper excess cement removal, which led to continuous gum bleeding. This patient needed proper oral hygiene measures before proceeding with the veneer laser treatment. This is the only patient who required administration of anesthesia. 3W laser Er: YAG was used to de-bond the e. max ceramic veneer using the scanning method and the duration it took until the veneer popped off (Figure 2), or the last piece fell off, was recorded by a second operator using a stopwatch. The temporaries were placed, smoothed and checked for occlusion, and the patients were given the post operative instructions and sent back to their treating dentist. Data was recorded, tabulated, and statistically analyzed.

3. Results

3.1. Time

3.1.1. Effect of laser power within each material

Intergroup comparisons, mean and standard deviation (SD) values of debonding time (seconds) for different laser powers on e. max.

3.1.1.1. In-vitro e. max

Group B: 5.4W laser (110.67±9.00) had a higher value than Group A 3W laser (108.23±8.43), yet the difference was not statistically significant (p=0.612) (Table 1).

3.1.1.2. In-vivo e. max

In-vivo debonding time (117.69±10.88) was significantly higher than in-vitro measurement (108.23±8.43) (p=0.021) (Table 2 and Figure 3).

3.2. Failure

The failure patterns of laminate debonding were categorized according to the modified criteria by Mak et al., (2002) into three different types [15]:

3.2.1. Type 1

Adhesive failure occurred between the fitting surface (internal surface) of the veneer and the luting resin cement when most of the resin remained on the prepared tooth surface.

3.2.2. Type 2

Adhesive failure took place between the luting veneer resin cement and the prepared tooth surface when most of the resin remained on the fitting (internal) surface of the veneer.

3.2.3. Type 3

Cohesive failure occurred within the luting resin veneer cement when a somewhat equal percentage of the remaining resin veneer cement was found on both the prepared tooth surface and the veneer's fitting surfaces. All of the samples in the laser-irradiated groups had Type 1 failure modes, indicating that the laser had softened the outer surface of the resin cement, resulting in debonding at the resin/ceramic interface, where most of the cement remained on the surface of the tooth and only very small remnants of cement were detected on veneer surfaces [9,16]. Stereomicroscope observation confirms that residual tooth structure is not altered in Group A. In addition, the removal occurred without ablating or damaging any tooth structure. In Group B, black resin cement discoloration left (Figure 4) on all teeth after veneer removal represented potential thermal damage in the area.

3.3. Fracture in-vitro

Group A samples were intact, while in Group B all samples fractured, and the difference was statistically significant (p<0.001) (Table 3).

3.3.1. In Group A

The remaining composite resin was left in a weakened, “powdery” state, which could be easily removed with a hand instrument and gauze.

3.3.2. In Group B

All of the veneer samples fractured into at least three pieces and dislodged during laser irradiation. Stereomicroscopy confirmed that the debonding occurred at the cement to veneer interface. This is an important fact since ablation along the tooth surface would be undesirable and could lead to potential thermal effects. Additionally, the composite that remained on the prepared surface was often darkly discolored.

3.4. Fracture in-vivo with Group A laser parameter

6 (30.0%) of e. max samples were fractured during removal using the Group A parameters (Table 4).

4. Discussion

Ceramic veneers were introduced in the early 1980s as reliable and conservative restorations with excellent, predictable outcomes and performance. They are less invasive and more conservative than full crowns, providing a natural appearance and a promising long-term prognosis. Among the various ceramic materials, glass-based lithium disilicate stands out for its exceptional optical properties, effectively mimicking the characteristics of natural enamel and dentin. Moreover, it boasts reliable mechanical properties, with a bending resistance ranging from 350 MPa to 450 MPa [17-18]. This enhanced flexural strength results from an increased crystal content of nearly 70% and the refinement of crystal size. Ceramic veneers have variable life spans and may eventually need to be changed [19]. Successful debonding depends on preserving the tooth structure (enamel, dentin as well as vitality) in order to be able to replace the veneers with new ones successfully, as well as maintaining good bonding to the new restorations [20]. However, removing it after bonding is a very challenging procedure due to the very strong bond strength, which is granted by using resin luting cements [21]. This scenario is becoming increasingly more common, as more people seek veneers in pursuit of the perfect smile. Whether they aren’t happy with the veneer shade or design, recurrent caries, discoloration or improper seating, the bonded veneer needs to be removed without damaging the tooth [22]. The main purpose of this study was to compare the debonding time between in-vitro and in-vivo cases using the safest and most effective of two different laser parameters in removing a full anatomy lithium disilicate veneer. As stated in former studies using Erbium lasers are suitable and more favorable than the conventional method of using a handpiece to grind the veneer down, which is very technical and time consuming [2,10,22-24]. There is an expectancy that a part of the tooth may be erroneously removed if the operator isn’t paying enough attention or is not using magnification in the case of very close shades between the tooth and the veneer to properly differentiate between them. The safest and most effective laser parameters should be chosen according to veneer type, the tooth bonded surface (whether enamel or dentin), the type of ceramic restoration, and the thickness of ceramic restoration. In most of the studies which used laser-assisted ceramic veneer debonding, the removal procedure was done by similar wave lengths, using either Er: YAG or Er: CR; using different modes of application using similar or different energies; using different ceramic materials of various thicknesses; and with using a variety of resin veneer cements [4,15,24,27-32]. Within the limitations of this study the time taken for removal of 1mm e. max veneer between Group A and B was non-significant in the in-vitro part of the study. On the other hand, the time needed for veneer removal was statistically significant when the in-vitro results were compared to the in-vivo results using only Group A parameters.

Based on the results of this study, a little more time is needed to de-bond lithium disilicate veneers clinically than in-vitro, which could be due to the presence of a neighboring tooth, variation in veneer thickness, or the vitality of the tooth in-vivo (as opposed to extracted ones). Zanini et al., investigated the time of removal of e. max samples, which was documented as a maximum of 30 seconds with 3W and 3.5W [33]. In addition, all samples were intact upon removal. Those results could be due to the fact that the dimensions of the e.max samples were not a true representation of ones in clinical situations, as these veneers covered only a small part of the tooth (3 x3 x 0.7 mm). Albalki et al., studied the efficiency of laser ceramic debonding parameters by Er: YAG laser 2940 nm with various parameters in contact mode 5.4W (360 mj and 15 Hz) and non-contact mode 3W (300 mj and 10 Hz), 4 W (270 mj and and 15 Hz), 4W (400 mj and 10 Hz), and 5.4W (360 mj and 15 Hz), with 1mm X 1 mm prominence at 45 degrees angle to apply a force of 15 N to remove the veneer (5mm x 7mm x 0.7mm thickness) [4]. The mean debonding time was 12.63 seconds in non-contact mode, which was very short time compared to this study. This could be attributed to various factors, like applying a 1 kg weight (15 N) to remove the veneer from the tooth surface; the small size of the veneer, which doesn't cover the entire labial surface of the tooth mimicking clinical situations; and the 0.7 mm thickness of the veneer, which is 30% less in thickness than their counterparts used in this study. Zhang et al., investigated the debonding time of porcelain laminate veneers using Er: YAG at low fluence 5.91 J/cm^2 with 100 mj energy and 30 Hz [34]. The average removal time was 328 seconds, which could be due to storage of the samples after cementing in humid conditions for one week, or using (Duceram kiss,USA), which is a high fusing veneering powder. Gurney et al., concluded that 30 and 60 seconds of laser application were effective in ceramic veneer debonding for a full coverage lithium disilicate restoration of 1.5mm thickness using 3.5W and 4W [35]. Oztoprak et al., used 5W power laser parameter to investigate the shear bond strength values after various application durations. The laser used in the in-vitro study was an Er:YAG 2940 nm wavelength 300 mj and 10 hz, 3W power and 360 mj with 15 hz frequency and 5.4W power to determine the safest and the fastest parameter for e.max veneer removal [10]. Sari et al., found that transmission of laser energy depends on the composition of dental ceramic material used as much as the thickness, with a 0.5 lithium dislicate thickness restoration showing a higher transmission ratio than 1mm thickness of feldespathic ceramics [24]. Morford et al., tested different Er:YAG parameters in-vitro ranging from 133, 217, 316, 400, and 503 mj energies with a repetition rate (frequency) of 10 Hz for veneer debonding. The time recorded for debonding e.max veneers was 100 ±42 seconds for all laser parameters, which is within range with this study [36]. Meanwhile Oztoprak et al., found that 9 seconds was effective to decrease the bond strength of lithium disilicate discs of 0.7mm thickness and 5mm diameter cemented to bovine teeth. Since this study is different in that the anatomical veneers covered the entire prepared labial surface and the incisal edge, and not just the 5mm diameter disc, we used 3W and 5.4W to investigate the safety of their usage on clinical cases. Under the 5.4W parameter, debonding happened after fracturing the veneer into 3 or more pieces, leaving behind black resin cement covering the tooth, indicating a type 1 adhesive failure [10].

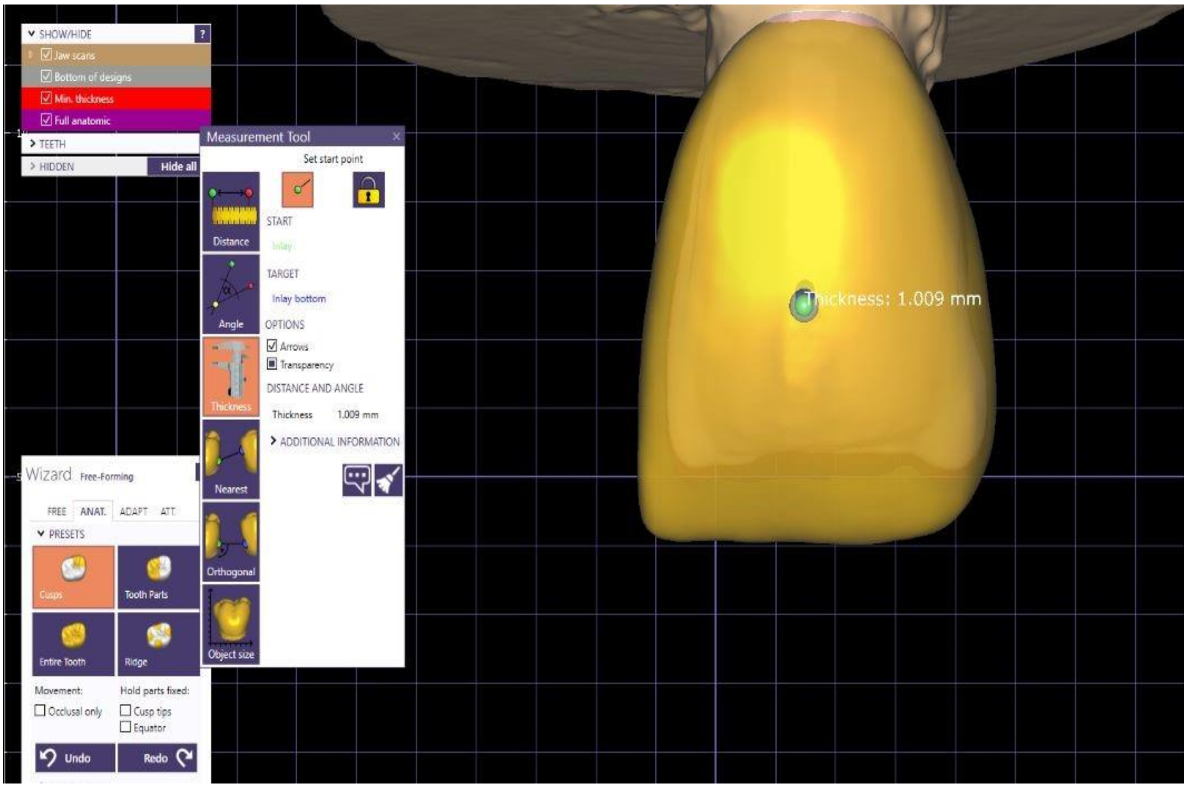

Figure 1: Showing the designing of e.max veneer of 1mm thickness.

Figure 2: Teeth after e.max veneer removal by laser.

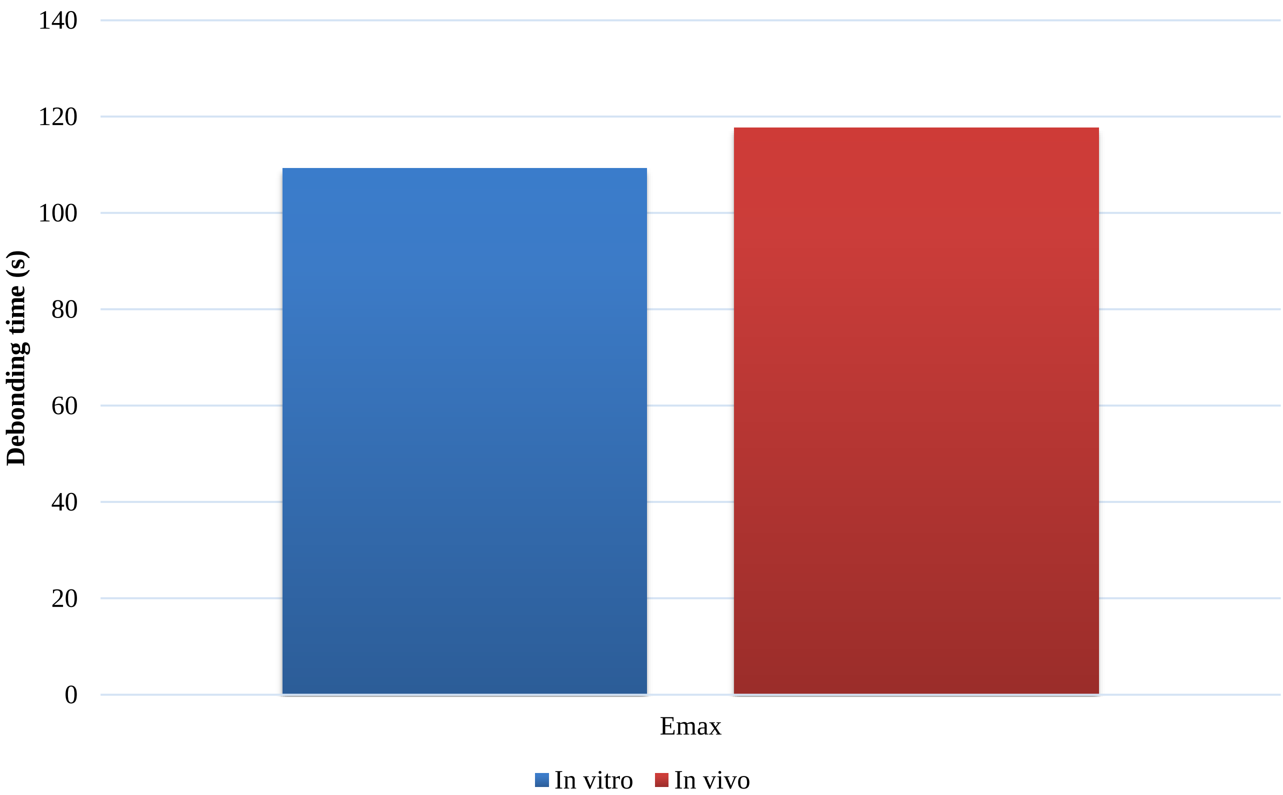

Figure 3: Bar chart showing average debonding time (seconds) for Emax.

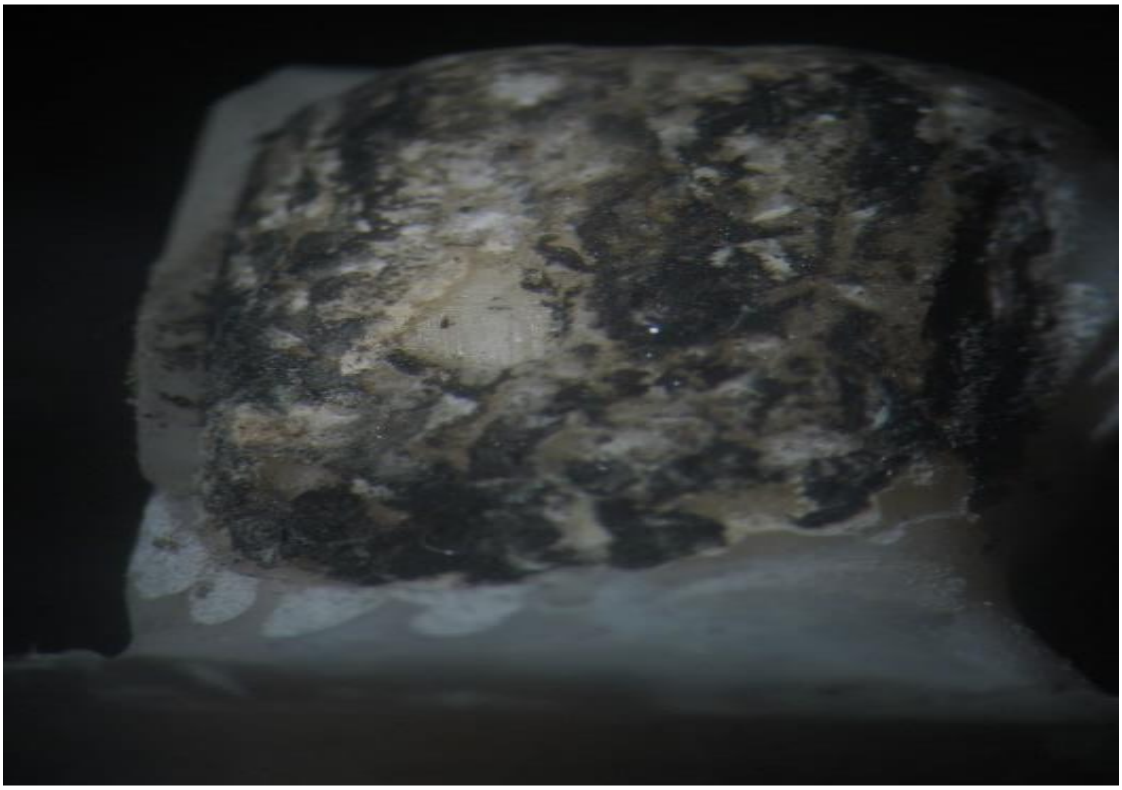

Figure 4: Black veneer cement after using group (B) parameters.

Table 1: Showing difference in removal time of e.max veneers between the 2 groups in-vitro.

Power / Material	Debonding time (seconds) (mean±SD)		p-value
	Group B	Group A	
Emax	110.67±9.00	108.23±8.43	**0.612ns**

Table 2: difference between the removal time of e.max veneers between in-vitro and in-vivo.

Materials	Debonding time (seconds) (mean±SD)		p-value
	In-vitro	In-vivo	
Emax	108.23±8.43	117.69±10.88	**0.021***

Table 3: Showing fracture percentage of e.max veneers between the 2 groups in-vitro.

Laser Parameters	Fracture	n (%)
		e.max
Group (B)	No	0 (0%)
	Yes	8 (100%)
Group (A)	No	8 (100%)
	Yes	0 (0%)

Table 4: Showing percentage of e.max veneer fracture in-vivo.

Fracture	n (%)
	Emax
No	14 (70%)
Yes	6 (30%)

The black resin also indicated potential thermal damage in the area, which is why only the 3W parameter was used in the in-vivo part of the study, since it didn't leave behind burned resin veneer cement. Albalkhi et al., reported that contact mode is less effective than non-contact mode in reducing bonding time, so in this study the Er:YAG laser 2940 nm was used with a non-contact R02 handpiece, which had focal distance of 7-8mm [4]. According to Rechmann et al., such a distance allows for heat diffusion, decreasing the possibility of thermal damage. Water cooling is also necessary during the Er:YAG application. Thus a 4/4 air/water ratio was used for cooling in this study [37]. The failure mode recorded after debonding is an important parameter, which assesses the probable risks of ceramic or tooth damage [38-39]. If the required force to debond the ceramic restoration is more than the cohesive strength of the ceramic material or the tooth itself, then fracture at the tooth surface or the ceramic restoration might happen [40]. Hence, laser debonding parameters and techniques used in previous studies were used here to prevent the risk of tooth and ceramic damage. Samples in this study that were laser irradiated exhibited type 1 failure, where most of the resin cement veneer was left on the tooth surface after laser debonding (adhesive failure). Laser debonding within safe parameters weakens the resin veneer cement, leaving most of the adhesive veneer resin cement on the tooth surface to allow debonding without damaging the teeth. It is clear within the results of this study which parameter is the most adequate and the safest to use when dealing with lithium disilicate veneer. Even though the previous studies mentioned earlier obtained different and varying results, this is perhaps due to the differences in the methodologies used in each study, as well as the large number of variables at play. Most clinical studies used a small sample size-smaller than the ideal- increasing the probability of getting a true false premise for the proposed laser treatment protocol. This is why it is important to develop new studies and test new materials and techniques as they enter the market regardless of the high investment required to develop these studies and other considerable challenges. Despite the differences above, we have within reach a technology that has real potential to be an effective method for debonding veneers while causing less damage to patients' teeth when compared to using rotary diamond instruments. It has advantages for both the dentist and the patient, but it must be used with caution with the appropriate parameters for each clinical situation.

5. Conclusions

As a consequence of this study, we can conclude that using Er: YAG laser 2940 nm is safe for debonding e.max veneers using the proper parameters clinically so as not to damage the tooth. Within the limitations of this study, the following conclusions were drawn:

- Lithium disilicate veneer removal using Er:YAG laser is an effective and safe method when performed with the laser parameter 3W (300 mj and 10 Hz) for a veneer thickness of 1mm.
- Given that there is no statistical significance in terms of the debonding time it took between the 3W and the 5.4W parameters, safety is really the only primary consideration. This study shows that it is safer not to increase the laser power over 3W for lithium disilicate veneers 1mm in thickness in order to prevent tooth damage.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors contribution

The authors confirm their contribution to the paper as follows: Study Design, data collection, analysis, photos and interpretation of results, and draft manuscript preparation by Dr. Kareem Elenany, Prof. Moustafa Gheith, Prof. Magda Ramzy, and Ass. Prof. Karim Aboubakr. All authors reviewed the results and approved the final version of the manuscript.

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