



# The efficiency of ErCr:YSGG laser on the debonding of different thicknesses of ceramic veneers

Sarah Ihsan Al-Araji<sup>1,\*</sup> , Abduladheem Raouf Sulaiman<sup>1</sup> 

<sup>1</sup> Department of Conservative Dentistry, College of Dentistry, University of Mosul, Mosul, Ninevah, Iraq.

**Corresponding author:**

Sarah Ihsan Al-Araji  
Email: sarah.dep40@student.uomosul.edu.iq  
Phone Number: 009647730663756

**Editor:** Altair A. Del Bel Cury

**Received:** September 12, 2021

**Accepted:** February 25, 2022



**Aims:** To verify the efficacy of Er,Cr:YSGG laser for debonding of lithium disilicate (LD) reinforced glass ceramic veneers of different thicknesses. **Methods:** Forty bovine teeth were prepared and randomly divided into four groups (n=10/group) according to the ceramic disc thickness: C0.5 (Control group) and L0.5 (Laser irradiated group) in which LD discs had a thickness of 0.5mm and 5mm diameter; C1 and L1 in which LD discs had a thickness of 1mm and 5mm diameter. The lithium disilicate discs (IPS E.max<sup>®</sup>, shade HTA2) were fabricated following the manufacturer's recommendations and cemented to the prepared tooth surface. The Er,Cr:YSGG laser was applied to the laser groups at 2.5W and 25Hz for 60seconds. Universal testing machine was used to evaluate the shear bond strength for all samples at a cross head speed of 1mm/min in an incisio-gingival direction parallel to the sample surface. After debonding, the samples were examined under stereoscope to evaluate the mode of failure according to the adhesive remnant index (ARI). **Results:** Laser irradiation significantly diminishes the shear bond strength from 10.868 MPa to 3.778 MPa for C0.5 and L0.5 groups respectively (p=0.00) and from 14.711 MPa to 4.992 MPa for C1 and L1 groups respectively (p=0.00). The shear bond strength required for debonding increased with increasing thickness of discs, but without significant difference (p=0.110). Higher ARI scores were seen in the laser groups (more cement remaining adhered to the tooth) when compared to the control groups. **Conclusions:** The Er,Cr:YSGG laser could be an effective and useful tool in debonding of lithium disilicate ceramic veneers as it decreases the shear bond strength required for veneer debonding.

**Keywords:** Dental veneers. Ceramics. Lasers. Shear strength.

## Introduction

Laminate veneers are considered conservative esthetic restorations that are very thin ceramic facings which consist of 0.5 to 1.0 mm thick ceramic adhesively bonded by a light-curing or self-curing resin cement, after the tooth has received minimally invasive preparation, which is usually restricted to enamel<sup>1</sup>. The great interest of these indirect restorations is due to their conservative preparation, resistance to fracture, high aesthetic quality, reduced discoloration, good tissue acceptance, lower debonding rate, and patient satisfaction<sup>2</sup>.

The retention of these ceramic restorations is dependent almost completely on chemical and micromechanical adhesion among the luting resin cement and porcelain surface from one side and the tooth surface from the other side<sup>3</sup>. This creates an intense bonding connection between the tooth and the ceramic surfaces, hence making it difficult to debond the ceramic restoration in a single piece<sup>4</sup>.

Several factors like recurrent caries, ceramic fracture or chipping and patient-described problems with a restoration's shade, shape or position have caused the need to remove these restorations. Such clinical cases need intact removing of the restoration, without harming the underlying tooth structure and to allow rebonding after laboratory repair<sup>5</sup>.

The typical method for removal of resin bonded ceramic restorations is mostly performed by grinding the ceramic restoration with rotary burs<sup>6</sup>. However, it is considered a time-consuming procedure, destructive, expensive, uncomfortable<sup>7</sup>, in addition of having some risk of harming the underlying dental structure.

Therefore, in order to eliminate the drawbacks of conventional removal method and to decrease the irreversible enamel surface harm, laser assisted veneer debonding have been suggested<sup>1</sup>. This new technique of veneer debonding was inspired by its practice on orthodontic ceramic brackets that began in early 1990s<sup>4</sup> and which its success was evidenced by several studies<sup>8,9</sup>. There are various laser sources that have been used for this purpose such as the Nd:YAG<sup>10</sup>, Er:YAG<sup>9</sup>, Er,Cr:YSGG<sup>8</sup> and CO<sub>2</sub><sup>11</sup> lasers, but most researchers agree that for debonding aims, the Er:YAG and Er,Cr:YSGG lasers yield better results than other laser system<sup>12,13</sup>.

Calabro et al.<sup>14</sup> (2019) in their case report stated that the Er:YAG laser assisted debonding of 11 ceramic laminates compared to the conventional removal method, was more efficient and comfortable both to the patient and the dentist, less time consuming and with preservation of the remaining tooth structure. Alikhasi et al.<sup>7</sup> (2019) as well proved the efficiency Er, Cr: YSGG in successful debonding of feldspathic and lithium disilicate (LD) glass ceramic veneers luted with resin cement on bovine teeth.

Therefore, the aim of the current research was to investigate the effect of Er,Cr:YSGG laser on the shear bond strength (SBS) of ceramic discs made from lithium disilicate and the effect of the ceramic thickness on this laser debonding, together with evaluating the mode of failure. The first null hypothesis to be investigated was that the Er,Cr:YSGG laser irradiation would not affect the shear bond strength of LD ceramic discs bonded to the teeth. While the second null hypothesis was that the ceramic thickness has no effect on shear bond strength during the laser debonding of these ceramic discs.

## Materials and Methods

### 1. Specimens collection and preparation

The study was approved by "Research Ethics Committee of Mosul University/College of Dentistry" under Record reference number (UoM.Dent/DM.A.L.70/21). Forty extracted, noncarious, bovine mandibular incisor teeth were utilized in the present study. The teeth were extracted from cows of age between 2-3 years. The Teeth were cleansed with a hand scaler to remove any attached soft tissue followed by polishing with fluoride-free pumice and were preserved in 0.1% thymol solution at room temperature ( $25\pm 5^{\circ}\text{C}$ ) for 24 hours (h.) and then stored in distilled water<sup>6</sup>. The roots were cut off using a diamond disk at the level of the CEJ under copious water irrigation. The pulp tissues in the crown portion were removed using barbed broach, then the pulp chamber space was rinsed with sodium hypochlorite followed by distilled water.

Cold cure Epoxy Resin (Veracril, Colombia) was mixed according to the manufacturer's instruction. Then it was poured into moulds with a diameter of 35 mm and 35 mm height. When embedding the specimens in acrylic resin, the labial surface of the tooth was located in such a way that it was parallel to the bottom of the mould (parallel to the floor)<sup>6</sup>.

After the setting of the cold cure resin, the middle third of the labial surface of the teeth was treated with silicon carbide disks of #400, #600 grit up to #800 grit under running water in order to make a flat treatment area of  $5\pm 1$  mm diameter within enamel by applying each grit for 30 seconds(s.)<sup>7,15</sup>. Then the moulds were stored in distilled water at room temperature ( $25\pm 5^{\circ}\text{C}$ ) till the time of cementation.

### 2. Discs preparation

Forty lithium disilicate glass ceramic discs (IPS E.max<sup>®</sup> Press; shade HTA2; Ivoclar Vivadent<sup>®</sup>, Schaan, Liechtenstein) were fabricated in the laboratory following the manufacturer's instruction.

### 3. Study design and specimens grouping

Ceramic discs ( $n=40$ ) made of lithium disilicate (IPS E.max<sup>®</sup>) were randomly divided into four groups ( $n=10$ ) as follow:

**C0.5:** Control (non lased) group with a thickness of 0.5 mm and 5 mm diameter.

**L0.5:** Laser irradiated group with a thickness of 0.5 mm and 5mm diameter.

**C1:** Control (non lased) group with a thickness of 1 mm and 5 mm diameter.

**L1:** Laser irradiated group with a thickness of 1 mm and 5 mm diameter

### 4. Discs cementation

The prepared enamel surface of the tooth was dried, and etched with phosphoric acid (Scotchbond Universal Etchant 3M ESPE) for 30 s., then was rinsed thoroughly with water and air dried using air syringe. Adhese Universal<sup>®</sup> (Pen, Light

cure) (Ivoclar, Vivadent®, Schaan, Liechtenstein) adhesive was then applied to the prepared enamel surface, allowed to rest for 20 s. then air-dispersed, and light-cured for 20 s. with a LED curing light (WoodPecker®, China) at 1200 mW/cm<sup>2</sup> light intensity<sup>16</sup>.

The ceramic discs were cemented to the prepared enamel surface of the bovine teeth according to the manufacturers' specifications. IPS Ceramic Etching Gel® (4.9% hydrofluoric acid) (Ivoclar, Vivadent®, Schaan, Liechtenstein) was applied to the internal surfaces of the discs (intaglio surface) for 20s. Then, disc specimens were rinsed and dried thoroughly with water spray and air respectively, then silane Monobond Plus® (Ivoclar, Vivadent®, Schaan, Liechtenstein) was applied to the internal surfaces of the discs for 60 s. and allowed to air dry<sup>16,17</sup>. Variolink Esthetic® LC (shade light+) (Ivoclar, Vivadent®, Schaan, Liechtenstein) resin-based cement was then applied to the internal surface of the disc which was seated into place on the prepared flat tooth surface under load by using a glass slide applied on the ceramic disc over which a load of 75 mg was applied for 1 minute. An initial cure of 1 s. from each side of the disc with the LED curing light was applied to remove excess cement. The final cure of the cement was accomplished afterwards with a 20 s. light-cure with the curing light in contact with the glass slide and figure (1) shows the completed cemented disc. Finally, the samples were stored in distilled water and stored at 37°C for 24 h. prior to the debonding procedure<sup>16</sup>.



**Figure 1.** Completed cemented sample.

## 5. Laser settings

Er,Cr:YSGG laser (Waterlase MD®, Biolase; Irvine, USA) was used in this study following the parameters<sup>16</sup> expressed in (Table 1):

**Table 1.** Er,Cr:YSGG laser parameters

Er,Cr:YSGG laser parameters	
Laser category	Solid-state
Wavelength	2780 nm
Water	30%
Air	70%
Handpiece type	MD (noncontact)
Tip type	ZipTip MZ6
Application technique	Scanning technique
Pulse energy	100 mJ
Pulse duration	60 $\mu$ s
Frequency	25 Hz
Average power	2.5 W
Operation Mode	H
Length of treatment	60 s.

The specimens were placed on a surveyor, and the laser handpiece was fixed on a modified arm so that the laser tip is positioned perpendicular at a distance of 2 mm to the ceramic disc<sup>7</sup> and scanning movements were performed which are horizontal movements perpendicular to the disc surface<sup>9</sup> (Figure 2). Each disc was irradiated from incisal to cervical area and vice versa in 10 s. which is considered as one cycle. Since the period of irradiation was 60 s., this means that each disc was irradiated for 6 cycles.

**Figure 2.** Laser irradiation of the ceramic disc cemented to the bovine tooth

## 6. Experimental procedure

### 6.1. Shear bond strength measurement:

Universal Testing Machine (Gester®, Gester International Co.; China) was used to evaluate the shear force needed for disc debonding, for both the control and laser irradiated groups. The specimen was placed in a specially designed mounting jig that allowed the specimen to be loaded parallel to the adhesive interface (Figure 3). The test was performed by applying force incisio-gingivally, with a crosshead speed of 1 mm/min parallel to the sample surface, creating a shear debonding force at the laminate-tooth interface<sup>6</sup>.

Shear bond strength values were recorded in Newton (N) and converted into megapascals (MPa) as follow:  $MPa = N/area$ ,  $Area = \pi r^2$  ( $\pi = 3.14$ ,  $r = 2.5$ ),  $MPa = N/ 19.63$ .



**Figure 3.** Universal machine loaded with specimen, the blade is parallel to the adhesive interface

### 6.2. Mode of failure evaluation

A stereomicroscope (Optika Microscopes®; Italy) was used to examine the debonded surfaces of all samples at a 20X magnification to evaluate the mode of failure. In the present study the “adhesive remnant index (ARI)” according to Artun and Bergland<sup>18</sup> (1984) was used for the mode of failure evaluation with the following classifications: 0: No adhesive remaining on the enamel surface, 1: Less than half of the adhesive remaining on the tooth surface, 2: More than half of the adhesive remaining on the tooth surface, 3: All the adhesive remaining on the tooth surface.

The ARI scores were evaluated by using ImageJ software program. In the software program, the total bonding area of the ceramic disc (5mm diameter) was marked first and measured to be considered as standard for all the samples. Then, the residual adhesive remained on labial surfaces of teeth after debonding was also marked on the photograph and its surface area measured and compared to the standard total bonding area in order to determine the exact score.

## Statistical analysis

The statistical analyses were accomplished utilizing the statistical packages for SPSS 25.0 for Windows (SPSS Inc., Chicago, IL, USA). The normality of the distribution of data was estimated with Kolmogorov-Smirnov and Shapiro test. Independent samples *t*-test was applied to compare between control and laser irradiation and between groups. Statistical significance was established at  $P < 0.05$ .

## Results

Descriptive statistics for control and study groups is presented in table (2). It was found that the highest SBS was for C1 (14.71 MPa), while the lowest for L0.5 (3.77 MPa).

There was a significant reduction in the shear bond strength after laser irradiation for both 0.5mm and 1mm disc thickness groups as shown in table (2). The SBS of L0.5 was lower than L1, but without significant difference between them ( $p=0.110$ ).

The ARI scores for the laser groups (L0.5, L1) was higher compared to the control groups (C0.5,C1) as shown in table (3). In L0.5 and L1, the majority of the samples were of score 2 and 3. While in C0.5 and C1, the majority were of score 0 and 1.

**Table 2.** Descriptive statistics and Independent samples *t*-test for the shear bond strength(MPa) of the control and study groups

Groups	Minimum	Maximum	Mean	Std. Deviation	T	P value
C0.5	8.22	14.27	10.8680	2.0283		
L0.5	1.17	5.92	3.7784	1.3783		
C0.5/L0.5					9.141	0.00*
C1	10.49	19.34	14.7113	2.9326		
L1	2.32	7.63	4.9923	1.8238		
C1/L1					8.901	0.00*
L0.5/L1					-1.680	0.110 <sup>x</sup>

**C0.5:** control,0.5 mm thickness; **L0.5:** laser irradiated,0.5 mm thickness; **C1:** control,1 mm thickness; **L1:** laser irradiated, 1 mm thickness; \*: Indicates a significant difference at  $P \leq 0.05$ . <sup>x</sup>: Indicates non-significant difference at  $P > 0.05$ .

**Table 3.** Frequency distribution of ARI scores

ARI score	C0.5	C1	L0.5	L1
0	2 (20%)	3 (30%)	0 (0%)	0 (0%)
1	6 (60%)	5 (50%)	1 (10%)	0 (0%)
2	2 (20%)	2 (20%)	6 (60%)	6 (60%)
3	0 (0%)	0 (0%)	3 (30%)	4 (40%)

## Discussion

Limited removal methods of laminate veneers are available. The traditional method is by grinding the restoration which is time consuming, destructive for both the restoration and tooth structure<sup>7</sup>. Other method by using mechanical force may demand high valued shearing force to debond which would lead to pain and even enamel fracture<sup>6</sup>. Therefore, the use of lasers have been developed to be employed as a valuable choice specially when intact removal of ceramic restorations is required.

The aim of the present study was to assess the Er,Cr:YSSG laser applied with selected laser parameters, as a conservative and alternative technique for veneer debonding of different thicknesses luted by total etch adhesive resin. The idea behind this method of veneer debonding came from its ancestors 'the Laser assisted debonding of ceramic brackets' that has gained a great popularity and success in clinical practice<sup>8-10</sup>.

In this study, bovine permanent mandibular incisors instead of human permanent incisors were utilized because they possess a suitable large flat labial surfaces that ensure optimal adaptation of the ceramic discs to the tooth surface and also its easy availability. This may be considered a limitation that must be taken into account, but Yassen et al.<sup>19</sup> (2011) in their literature review had shown similarities between bovine and human dental anatomy and histology, and especially similar behaviors in relation to the adhesion technique. Er,Cr:YSSG laser was used in the current study since it causes fewer thermal effect compared to other lasers like Nd:YAG or CO<sub>2</sub> lasers<sup>20</sup> and its large presence in the dental clinics because of their wide application area in hard and soft tissue procedures. It also emits a wavelength of 2780 nm and can therefore be effectively absorbed by water and residual monomer present in adhesive resins<sup>21</sup>. The laser parameters were the same as in Phillips study<sup>16</sup> (2012) who considered this parameters to be the safest for pulpal health. During the use of Er,Cr:YSSG laser in other applications like surgical procedures, cavity preparation etc., the laser light should be kept away from the adhesively cemented fixed restoration as it lowers its bond to the underlying tooth structure.

In general, several precautions should be followed for safety use of laser in dentistry. The dental operating area should have warning signs and limited access during the laser treatment. The operator should be well trained to use the laser device. The operator, patient and the surgical team should wear protective eyewear so that any direct or reflected laser light or energy doesn't cause ocular damage<sup>22</sup>. Reflective instruments and those with mirrored surfaces should be avoided since they can



cause damage to non-target tissues. Infection protocol should be followed. The smoke or vapor produced during the laser treatment should be evacuated using high volume suction<sup>23</sup>.

According to the results of our study, there was a significant decrease in the shear bond strength after the application of laser for the two ceramic thicknesses compared to the control groups. Therefore, the first null hypotheses was rejected. This may be due the action of laser on the resin cement. During laser irradiation, laser energy is transmitted throughout the ceramic veneer. Then, the remaining transmitted energy is absorbed by the resin cement. Tocchio et al.<sup>24</sup> (1993) revealed that debonding of ceramic brackets takes place due to the degradation of the resin cement. They explained this phenomena by three different mechanisms: thermal softening, thermal ablation, and photoablation. In thermal softening, the laser is applied until the bonding agent becomes warm and flows on the tooth surface. Thermal ablation occurs when the temperature increases in the adhesive resin until evaporation and "blow off" of the veneer occurs. In photoablation, the energy between the bonding resin atoms increases fast and results in decomposition of the material<sup>8</sup>. The Er,Cr:YSSG laser debonding technique using the scanning technique utilized in the current study didn't cause "blow off" that may suggest photoablation or thermal ablation. However, when the target chromophore is methacrylate of the resin cement, it would be logical to suggest that there is a physical interruption of the resin cement rather than only thermal softening. This is in agreement with Oztoprak et al.<sup>9</sup> (2010). Also "thermal ablation" and "photo-ablation" of luting cements have been suggested to be the major mechanism for debonding of all-ceramic restorations<sup>21</sup>. Photoablation and thermal ablation happen when a very high-energy laser light reacts with the luting resin, inducing it to deteriorate<sup>25</sup>. Whereas in our study, low laser energy was used and no blow off occurs, so thermal softening with physical interruption was the possible debonding mechanism.

Many studies have also got comparable results of decreasing in shear bond strength after the laser application despite of using different types of lasers, ceramic materials, luting agent and other experimental conditions<sup>13,21,26</sup>.

There are few studies available investigating the effect of thickness of lithium disilicate veneer material on shear bond strength when exposed to Er,Cr:YSSG laser. According to our results, ceramic discs with greater thickness required higher shear bond strength for debonding. This came in agreement with other studies. Yilmaz et al.<sup>1</sup> (2019) used 120 IPS Empress II discs of three different thicknesses (0.5 mm , 1 mm, 2 mm) and found that during laser debonding, the 2 mm discs needed more debonding force than the 1 mm and 0.5 mm and that all the 0.5 mm discs were debonded without any external load during the laser exposure. Giraldo Cifuentes et al.<sup>27</sup> (2020) tested four different thicknesses (0.4 mm, 0.8 mm, 1.2 mm and 1.6 mm) and concluded that the thicker veneers demonstrated greater resistance to debonding than the thinner ones. This can be explained that the thickness may affect the amount of the laser transmission that reach the resin cement and ablate it. Sari et al.<sup>28</sup> (2014) stated that the Er:YAG laser energy transferred throughout the ceramic material reduced with increasing thickness of the ceramic sample. While Azzat<sup>4</sup> (2018) in his case report concluded that the ceramic composition and thickness has an effect on the amount of

erbium laser energy transmission, which in turn affected on the debonding strength. In the present study, there was a positive correlation between the ceramic thickness and shear bond strength but without significant difference, therefore the second null hypothesis was accepted as the ceramic thickness didn't have a significant effect on decreasing the shear bond strength required for debonding.

The ARI index is an important indicator for the position of ceramic-adhesive debonding site and for estimation of the probability of enamel damage after debonding<sup>29</sup>. The closer the debonding interface is to the enamel, the greater is the risk for enamel damage<sup>8</sup>. In the current study, higher ARI scores were seen in the laser groups (L0.5, L1) in comparison to the control groups (C0.5,C1). As most of the specimens in the laser groups had a ARI score of 2 and 3, this means that the majority of the adhesive remained on the tooth and the risk of enamel damage decreased. During laser irradiation, the laser softens the superficial layer of the resin cement while it is hot, in addition as it cools decomposition of the resin cement might occur, therefore the adhesive cement is not as strong as previously and the majority of the cement remained adhered to the tooth surface<sup>9</sup>. However, in the control groups (C0.5,C1) most of the specimens were of 0 and 1 ARI score which indicates that the site of debonding was closer to the enamel and the risk of enamel damage increased.

The present results illustrated that laser-assisted debonding of ceramic veneers can reduce the frequency of occurrence of the debonding site at the enamel-adhesive interface and therefore reduce enamel harm. These results was in agreement with previous studies<sup>8,9</sup>.

In conclusion, Er,Cr:YSGG laser can be evaluated as a valid and conservative method in ceramic veneer debonding. The application of the Er,Cr:YSGG laser using the parameters of the current study may be useful in removing lithium disilicate ceramic veneers, avoiding their damage, and protecting the enamel.

## Conflict of Interests

None

## Funding

None

## Data availability

Datasets related to this article will be available upon request to the corresponding author.

## Author contribution

Al-Araji SI: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing—original draft preparation, Writing—review and editing, Project administration. Sulaiman AR: Methodology , Investigation, Resources, Writing—review and editing, Visualization, Supervision, Project administration. All authors have read and agreed to the published version of the manuscript.

---

## References

1. Yilmaz BD, Polat ZS, Izgi AD, Gunduz DT, Dirihan RS. The contribution of ceramic thickness and adhesive type on the de-bonding strength of dental ceramic veneers using Er,Cr:YSGG laser. *J Oral Res.* 2019 April;8(2):131-9. doi: 10.17126/joralres.2019.021.
2. Zhang Y, Rocca JP, Fornaini C, Zhen Y, Zhao Z, Merigo E. Erbium-Doped, Yttrium-Aluminum-Garnet Laser Debonding of Porcelain Laminate Veneers: An Ex vivo Study. *Contemp Clin Dent.* 2018 Oct-Dec;9(4):570-3. doi: 10.4103/ccd.ccd\_632\_18.
3. Loffredo MC, Hanashiro FS, Steagall Júnior W, Youssef MN, de Souza-Zaroni WC. Influence of irradiation with Er:YAG laser on the shear bond strength of a resin cement to feldspathic ceramic - in vitro study. *Cerâmica.* 2015 Apr-Jun;61(358):244-50. doi: 10.1590/0366-69132015613581882.
4. Azzat A. A novel approach to veneer removal:a clinical case report using Er,Cr:YSGG Laser. *Oral Health.* 2018 Sep;42-5.
5. Bajunaid SO. Review of techniques for the intact removal of a permanently cemented restoration. *Gen Dent.* 2017 Sep-Oct;65(5):48-53.
6. Oztoprak MO, Tozlu M, Iseri U, Ulkur F, Arun T. Effects of different application durations of scanning laser method on debonding strength of laminate veneers. *Lasers Med Sci.* 2012 Jul;27(4):713-6. doi: 10.1007/s10103-011-0959-1.
7. Alikhasi M, Monzavi A, Ebrahimi H, Pirmoradian M, Shamshiri A, Ghazanfari R. Debonding Time and Dental Pulp Temperature With the Er, Cr: YSGG Laser for Debonding Feldspathic and Lithium Disilicate Veneers. *J Lasers Med Sci.* 2019 Summer;10(3):211-4. doi: 10.15171/jlms.2019.34.
8. Naseri N, Ghasemi N, Baherimoghadam T, Azmi A. Efficacy of Er,Cr:YSGG laser for debonding of ceramic brackets and prevention of enamel damage and intrapulpal temperature change. *Laser Dent Sci.* 2020 Aug;4(3):157-63. doi: 10.1007/s41547-020-00101-y.
9. Oztoprak MO, Nalbantgil D, Erdem S, Tozlu M, Arun T. Debonding of ceramic brackets by a new scanning laser method. *Am J Orthod Dentofacial Orthop.* 2010 Aug;138(2):195-200. doi: 10.1016/j.ajodo.2009.06.024.
10. Hayakawa K. Nd:YAG laser for debonding ceramic orthodontic brackets. *Am J Orthod Dentofacial Orthop.* 2005 Nov;128(5):638-47. doi: 10.1016/j.ajodo.2005.03.018.
11. Tehranchi A, Fekrazad R, Zafar M, Eslami B, Kalhori KAM, Gutknecht N. Evaluation of the effects of CO<sub>2</sub> laser on debonding of orthodontics porcelain brackets vs. the conventional method. *Lasers Med Sci.* 2011 Sep;26(5):563-67. doi:10.1007/s10103-010-0820-y
12. Giraldo-Cifuentes H, España-Tost A, Arnabat-Dominguez J. Er,Cr:YSGG laser in the debonding of feldspathic porcelain veneers: an in vitro study of two different fluences. *Photobiomod Photomed Laser Surg.* 2020 Oct;38(10):640-45. doi: 10.1089/photob.2019.4752
13. Al-maajoun MK, Henar TE, Tost AE, Terren CA. CO<sub>2</sub> and Er,Cr:YSGG Laser applications in debonding ceramic materials: an in vitro study. *Open J Dent Oral Med.* 2017 Jul;5(3):25-30. doi: 10.13189/ojdom.2017.050301.
14. Calabro DE, Puglisi R, Mesquita AMM. Removal of 11 Laminate Veneers with Er-Yag Laser. *J Dent Sci.* 2019;7(1):63-9.
15. Karagoz-Yildirak M, Gozneli R. Evaluation of rebonding strengths of leucite and lithium disilicate veneers debonded with an Er:YAG laser. *Lasers Med Sci.* 2020 Jun;35(4):853-60. doi: 10.1007/s10103-019-02872-8.
16. Phillips WB. Thermal changes in the dental pulp during Er,Cr:YSGG laser removal of IPS e.max Press Lithium Disilicate Veneers [dissertation]. Ohio State University; 2012 [cited 2021 nov 4]. Available form: [http://rave.ohiolink.edu/etdc/view?acc\\_num=osu1337742959](http://rave.ohiolink.edu/etdc/view?acc_num=osu1337742959).

17. Pineda-Vásquez L, Fons-Font A, Bustos-Salvador J, Alonso-Pérez-Barquero J, Román-Rodríguez J. Shear bond strength of debonded ceramic restorations re-cemented by means of a cleaning and retreatment protocol. *J Clin Exp Dent*. 2019 Jun;11(6):e506-11. doi: 10.4317/jced.55706.
18. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod*. 1984 Apr;85(4):333-40. doi: 10.1016/0002-9416(84)90190-8.
19. Yassen GH, Platt JA, Hara AT. Bovine teeth as substitute for human teeth in dental research: a review of literature. *J Oral Sci*. 2011;53(3):273-82. doi: 10.2334/josnusd.53.273.
20. Mehl A, Kremers L, Salzmann K, Hickel R. 3D volume-ablation rate and thermal side effects with the Er:YAG and Nd:YAG laser. *Dent Mater*. 1997 Jul;13(4):246-51. doi: 10.1016/S0109-5641(97)80036-X.
21. Morshedi E, Zavaree MA, Hakimaneh SMR, Shayegh SS, Pirmoradian M, Torabi S, et al. Effect of Er:YAG laser irradiation on shear bond strength of two porcelain laminate veneers bonded to tooth surface. *J Islam Dent Assoc Iran*. 2020 Jan;32(1-2):21-9. doi: 10.30699/jidai.32.1.2.21.
22. Boddun M, Sharva V. Laser hazards and safety in dental practice: a review. *Oral Health Care*. 2020 Jan;5:1-4. doi: 10.15761/OHC.1000189.
23. Pradeep S, Anitha SR, Ravi S, Shivalinga BM, Jyothikiran H. Dental lasers: A review of safety essentials. *Int J Orthod Rehabil*. 2016;7(3):112-4. doi: 10.4103/2349-5243.192535.
24. Tocchio RM, Williams PT, Mayer FJ, Standing KG. Laser debonding of ceramic orthodontic brackets. *Am. J. Orthod Dentofacial Orthop*. 1993 Feb;103(2):155-62. doi: 10.1016/s0889-5406(05)81765-2.
25. 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 Jan-Mar;8(1):58-62. doi: 10.4103/1305-7456.126243.
26. Hussein GAE, Youssef AE, Gutknecht N, Samhan TM. Debonding Of Lithium Disilicate and Feldspathic Veneers with Er, Cr: YSGG Laser Bonded with two different curing mode Resin Cement. *AJDS*. 2021 Jan;24(1):19-26. doi: 10.21608/ajdsm.2020.48964.1134.
27. Giraldo-Cifuentes H, Gómez JC, Guerrero ANL Muñoz J. Effect of an Er,Cr:YSGG laser on the debonding of lithium disilicate veneers with four different thicknesses. *J Lasers Med Sci*. 2020 Fall;11(4):464-8. doi: 10.34172/jlms.2020.72.
28. Sari T, Tuncel I, Usumez A, Gutknecht N. Transmission of Er:YAG laser through different dental ceramics. *Photomed. Laser Surg*. 2014 Jan;32(1):37-41. doi: 10.1089/pho.2013.3611.
29. Tozlu M, Oztoprak MO, Arun T. Comparison of shear bond strengths of ceramic brackets after different time lags between lasing and debonding. *Lasers Med Sci*. 2012 Nov;27(6):1151-5. doi: 10.1007/s10103-011-1018-7.