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Er,Cr:YSGG Laser Irradiation of Glass Ceramic Veneers: Shear Bond Strength and Intra-pulpal Temperature

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Abstract

Introduction: Glass ceramic veneers are intensely bonded to the underlying tooth structure, so the conventional method (grinding) for their removal is destructive and time-consuming for both veneers and the underlying tooth structure. This study evaluated the shear bond strength (SBS) that is required for the removal of leucite reinforced (LR) glass ceramic of different thicknesses after Er,Cr:YSGG laser irradiation and the effect of this type of laser on intra-pulpal temperature.

Methods: The enamel surfaces of 40 bovine mandibular incisors were arbitrarily divided into four main groups (n = 10) after preparation, based on the thicknesses of veneer discs, which were fabricated from LR glass ceramic: C1: Control group, L1: Laser-treated group in which LR discs were 0.5mm in thickness and 5mm in diameter, C2: Control group, and L2: Laser-treated group in which LR discs were 1mm in thickness and 5mm in diameter. Temperature measurement was taken for laser-irradiated groups before and at the end of laser treatment, which was applied using a scanning technique for 60 seconds with an Er,Cr:YSGG laser at 2.5 W and 25 HZ. SBS was evaluated using the universal testing machine for all samples. After de-bonding, a stereomicroscope was used to estimate the failure mode based on the adhesive remnant index (ARI). The independent samples t-test was performed to analyze the recorded data.

Results: The Er,Cr:YSGG laser significantly decreased SBS for Laser-treated groups ($P \leq 0.05$). The SBS decreased with decreasing disc thickness, with no statistically significant differences ($P > 0.05$). ARI had higher scores for the laser-treated groups than for the control groups. Laser irradiation increased intra-pulpal temperature slightly but within the safety range (5.5 ºC).

Conclusion: Using the Er,Cr:YSGG laser with the scanning technique could be a safe and effective tool for de-bonding LR glass ceramic veneers.

Keywords: Shear bond strength, Er,Cr:YSGG laser, Glass ceramic veneers, Intra-pulpal temperature.

Introduction

For years, full crowns were the treatment of choice to solve esthetic problems for patients with esthetic issues in their teeth.[1] Recently, the advancements in ceramic materials have created the opportunity for glass ceramic veneers to serve as a conservative and esthetic alternative to full crowns. These veneers, typically 0.5-1.0 mm in thickness, are adhesively bonded to tooth structure with resin luting cement after minimal invasive tooth preparation, which is usually restricted to enamel.[2] Dental practitioners preferred these indirect restorations for their good esthetic appearance, biocompatibility, conservative technique, high fracture resistance, low rate of de-bonding, and patient satisfaction.[3] However, failure in glass ceramic veneers, such as micro-leakage and recurrent caries, chipping fracture, and patient-related factors like restoration shade indicate the removal of these veneers.[4] The intense bond between tooth structure and these resin-bonded ceramic restorations makes their removal difficult, so grinding them using a high-speed handpiece is the typical method for their removal.[5] In contrast, it is a time-consuming, uncomfortable, and destructive procedure for both restorations and underlying tooth structure.[6] Thus, using a laser as a tool assisting in veneer de-bonding has been proposed to reduce the disadvantages of their removal by the conventional method.[7] Different laser sources, such as Nd:YAG,[8] Er:YAG,[9] CO_2,[10] and Er,Cr:YSGG lasers,[11] have been utilized for ceramic veneers de-bonding. While several studies demonstrated that the Er,Cr:YSGG laser was an efficient tool to achieve this purpose,[7,12,13] some researchers indicated comparable de-bonding performance with other laser systems, particularly the Er:YAG laser.[8-10] Thus, the selection of the laser system may rely on specific clinical parameters and desired results. Al-Araji and Sulaiman[7] tested the Er,Cr:YSGG laser with specific settings for the de-bonding of laminate veneers, and they reported promising results, considering the Er,Cr:YSGG laser an efficient de-bonding option. Also, Alikhasi et al[13] evaluated the efficiency of Er,Cr:YSGG laser in the de-bonding of glass ceramic veneers luted to bovine teeth using resin cement; they proved that this type of laser was effective and yielded successful de-bonding

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results. Hence, the Er,Cr:YSGG laser has been chosen as the irradiation source in this study.

The purposes of the current investigation were to estimate the influence of Er,Cr:YSGG laser irradiation on the shearing force of veneer discs fabricated from leucite reinforced (LR) glass ceramic with different thicknesses along with the mode of failure estimation. Also, it aimed at assessing the intra-pulpal temperature following laser treatment.

LR glass ceramic material is commonly used in aesthetic dentistry. However, it has been less investigated than feldspathic and lithium disilicate ceramics, particularly its de-bonding properties. Walinski et al[6] previously tested intra-pulpal temperature changes during Er,Cr:YSGG laser-assisted de-bonding of LR ceramic veneers. Their study, conversely, was limited to a single veneer thickness and applied a contact lasing mode. However, the current study evaluated two different veneer thicknesses utilizing a scanning lasing technique with different laser parameters. Furthermore, intra-pulpal temperature was assessed after one minute of irradiation rather than following de-bonding as in Walinski and colleagues' study. These methodological variations reveal novel insights into the thermal impact of the Er,Cr:YSGG laser and its efficacy in de-bonding LR ceramic veneers under different clinical situations, demonstrating the novel approach chosen in this research.

The first null hypothesis stated that the SBS of LR ceramic discs luted to bovine teeth would not be affected by Er,Cr:YSGG laser treatment, whereas the second null hypothesis to be tested was that the thickness of ceramic veneer discs did not significantly influence the SBS during laser treatment. The third null hypothesis stated that the intra-pulpal temperature of bovine teeth would not exceed the critical safety range (5.5 °C) following laser irradiation.

Materials and Methods

Sample Collection and Preparation

Approval for this study was received from the Research Ethics Committee (REC) at the University of Mosul/ Dentistry College in Mosul, Iraq, with the registration code of UoM.Dent. 25/1018. This investigation used forty freshly extracted, non-carious bovine mandibular incisors. The cows from whom the teeth were taken were between two and three years old. Teeth were cleaned using a hand scaler to remove soft tissue remnants that were still attached, then polished with fluoride-free pumice. Tooth samples were restored at first in thymol solution (0.1%) for 24 hours at room temperature (25 ± 5 °C), then kept in distilled water.[9] Afterwards, under heavy water irrigation, the roots were cut off at the CEJ level using a diamond disc, and with a barbed broach, the pulp tissues were removed from the crown section; sodium hypochlorite was used at first for rinsing the pulp chamber space, followed by distilled water.[12]

A veneer vernier was used to standardize the thickness of the enamel and dentin for pulpal temperature measurement. The vernier was placed with one end inserted through the orifice, which resulted from the root cutting to the inside pulp chamber touching the dentin, while the other end touched the labial enamel. Only teeth with a thickness range of 3-4 mm were selected for the study. A wire was inserted into the orifice of the tooth before embedding it in epoxy resin to prevent tooth blockage during resin pouring. The mixing of cold cure Epoxy Resin (Veracril, Colombia) was performed as stated by the manufacturer's instructions and poured into molds. The molds were 30 mm in diameter and 30 mm in height, with a side hole to pass the thermocouple wire through it (except for control groups). Embedding teeth in the molds that were filled with acrylic resin was done so that the enamel surface was parallel to the floor (parallel to the basal area of the mold) and the wire inside the tooth could pass through the side hole. After complete polymerization, the wire inside the pulp chamber was removed, and the labial surface of the teeth was flattened to get the treatment area within the enamel of about 6 mm in diameter. This treatment was performed under running water using silicon carbide disks (#400, #600 grit up to #800 grit). This procedure was accomplished by applying each grit for 30 seconds to reduce enamel thickness by 0.1-0.2 mm.[13] Molds were then kept in deionized water at room temperature (25 ± 5 °C) before starting the cementation process.

Fabrication of Veneer Discs

LR glass ceramic (IPS Empress; shade ETC2; Ivoclar Vivadent®, Schaan, Liechtenstein) was used to fabricate forty veneer discs in the lab according to the manufacturer's directions.

Sample Categorization

Forty LR glass ceramic discs were arbitrarily divided into four main groups (n = 10) based on disc thickness as follows:

- C1: Control (non-lased) group and L1: Laser-treated group in which LR discs were 0.5mm in thickness and 5mm in diameter
- C2: Control (non-lased) group and L2: Laser-treated group in which LR discs were 1mm in thickness and 5mm in diameter.

For laser groups, pulp temperature measurement was taken before and immediately after 60 seconds of disc irradiation.

Cementation of Veneer Discs

Tooth Surface Treatment

The prepared area of the enamel surface was subjected to etching for 30 seconds using 34% phosphoric acid

(Scotchbond Universal Etchant, 3M ESPE), followed by water rinsing and dryness. Adhesive Universal® (Pen, Lightcure, Ivoclar, Vivadent®, Schaan, Liechtenstein) was then painted over the prepared enamel area and cured for 20 seconds using LED curing light of 1200 mW/cm² intensity.[9,14]

Veneer Disc Treatment and Cementation

The treatment of ceramic veneer discs and their cementation to the treated tooth surface was done as per the manufacturer's instructions. The inner side of the ceramic discs (intaglio surface) was etched using 49% hydrofluoric acid (IPS Ceramic Etching Gel®) (Ivoclar, Vivadent®, Schaan, Liechtenstein) for 20 seconds, followed by thorough water rinsing and air dryness for 10 seconds. Afterwards, silane Monobond Plus® (Ivoclar, Vivadent®, Schaan, Liechtenstein) was painted on the inner discs' side and left to air dry for 60 seconds.[15] Cementation of discs was performed using resin-based cement (Variolink Esthetic® LC (shade light +)) (Ivoclar, Vivadent®, Schaan, Liechtenstein), which was applied to the treated surface of veneer discs. Each disc was then carefully positioned on the prepared enamel area and subjected to a load of 100 g, which was applied through a glass plate. The glass plate was placed on top of the ceramic discs, and the load was placed on it for one minute. Initial curing was applied for one second to remove excess cement, followed by final curing for 20 seconds. The sample assemblies were then preserved in deionized water at 37 °C for 24 hours before de-bonding procedure.[2,6]

Laser Parameters

Laser treatment was performed using the Er,Cr:YSGG laser (Waterlase MD®, Biolase; Irvine, USA) according to the settings tabulated in Table 1. These laser settings were based on those documented by Al-Araji and Sulaiman,[7] who determined them as the safest and most clinically effective settings, producing consistent veneer de-bonding outcomes with minimum thermal damage risk to the pulp.

The samples were positioned on a surveyor with a modified arm to which the laser handpiece was attached; this allowed the laser tip to be placed perpendicularly, with a space 2 mm away from the veneer disc. Laser treatment was carried out for 60 seconds using a scanning technique, which consisted of horizontal movements applied perpendicularly to the surface of the discs. Irradiation of every veneer disc was done from the incisal to the cervical region, then in a reversed direction for 10 seconds, which represented 1 cycle. As the laser treatment time was established at 60 seconds, each disc underwent 6 lasing cycles.[7]

Experimental Procedures

Temperature Measurement

A K-type thermocouple was utilized to estimate the intra-pulpal temperature changes for teeth after Er;Cr;YSGG laser treatment.[11] The thermocouple was inserted into the canal space through the side hole and allowed to touch the inside dentin of the pulp chamber; then, it was secured using sticky wax and adhesive tape. The temperature was recorded for the laser-treated groups before laser irradiation and immediately at the end of the irradiation period. The difference in temperature between the two intervals was recorded and analyzed.[13]

Table 1. Er,Cr:YSGG Laser Settings

Type of Laser	Solid Status
Wavelength	2780 nm
Air	70%
Water	30%
Type of handpiece	MD (non-contact)
Application technique	Scanning
Pulse-duration	60 μs
Pulse-energy	100 mJ
Frequency	2.5 W
Power	25 Hz
Operating mode	Hyper-Pulse
Spot diameter	0.6mm
Spot diameter at the specimen	0.6mm
Treatment time	60 seconds

Assessment of Shear Bond Strength

A universal testing machine (Gester International Company; China) was utilized to assess the shearing force required for veneer de-bonding. Each tested sample was positioned in a mounting jig designed to permit loading parallel to the adhesion interface. The shear test was conducted by applying the force in an inciso-gingival direction using a 0.5 mm chisel at a testing speed of 1 mm/min parallel to the specimen surface.[6] The SBS values required for veneer de-bonding were calculated in Newton (N) and subsequently transformed to Megapascals (MPa) according to the following formula:

$(\text{MPa}) = (\text{N})/(\text{Area})$, $\text{Area} = \pi r^2$ ($\pi = 3.14$ and $r = 2.5$)
$\text{MPa} = \text{N}/19.63$.[16,17]

Assessment of Failure Mode

The de-bonded surfaces of all specimens were investigated under a stereomicroscope (Optika Microscopes®; Italy) with a magnifying power of 20X to assess the failure mode based on the adhesive remnant index (ARI). Artun and Bergland[18] established the following categorization for ARI scores: 0: zero adhesive residue left on the tooth, 1: below 50% of the adhesive residue left on the tooth, 2: above 50% of the adhesive residue left on the tooth, and 3: 100% of the adhesive residue left on the tooth. In the current study, ARI scores were determined by utilizing

Image J Software Program, Java, USA. At first, the software program labeled and calculated the total diameter (5 mm) of the veneer disc adhesive surface area and considered it baseline data for all specimens. Then, after de-bonding, the residual adhesive remnants on the enamel surfaces of the teeth were labeled on the photograph, and their surface area was estimated and matched to the baseline total adhesive surface area to calculate the precise scores.

Analysis of Data

Statistical procedures were performed via SPSS software (version 26 for Windows). The normality of data distribution was checked by the Kolmogorov-Smirnov test. Since the data were normally distributed, the independent samples t-test was performed to make comparisons between control and study groups and between study groups of different thicknesses at $P \leq 0.05$.

Results

The Shear Force With the Mode of Failure Evaluation

Descriptive statistical results for the SBS of the control and laser-treated groups are shown in Table 2. The highest SBS mean was 10.6202MPa for the C2 group, whereas the lowest was for the L1 group (4.6571MPa). The results revealed a statistically significant reduction ($P = 0.000$) in the SBS following laser treatment for both disc thickness groups. The SBS for L1 was less than that of L2. However, no statistically significant difference was seen ($P = 0.351$).

The ARI scored 0 for all groups. The majority of control groups had scores of 1 and 2, while Laser-treated groups mostly recorded scores of 2 and 3, which are considered higher in comparison to the control group (ARI) scores illustrated in Table 3. Figure 1 demonstrates (ARI) scores 1, 2, and 3, respectively.

Temperature measurement

The findings of the temperature measurement are presented in Table 4. There was a slight elevation in temperature from the initial measurement. However, this elevation was within the safety range (less than 5.5 °C). The highest elevation in the temperature difference range was for the L1 group (0.9-2.6 °C), while the L2 group illustrated a lower temperature difference range (0.8-2.2 °C).

Discussion

Clinically, removing glass ceramic veneers (either by grinding or mechanical force) as one piece without harming the underlying tooth structure is difficult due to the intense bond between teeth and these indirect restorations.[19,20] Therefore, lasers with selected parameters have been suggested to initiate a de-bonding mechanism and facilitate the intact removal of veneers. The Er,Cr:YSSG laser was chosen for this study as it is widely utilized in dental clinics for its broad range of applications in both soft and hard tissue treatments and it has less heat production than other laser systems like Nd:YAG and CO2 lasers. Furthermore, it emits a wavelength of 2780 nm, which allows water and residual monomers in adhesive resins to absorb it efficiently.[21,22]

Bovine incisors were used in this investigation rather than human teeth as they have broad and flat labial surfaces, which enable the best adaptation of LR glass veneer discs to the tooth surface. Moreover, Yassen et al[20] proved in their article that human and bovine teeth are comparable in histology and dental anatomy and produce a similar adhesion behavior.

Our research findings stated that after laser treatment, the shear force for both thicknesses of LR veneer discs decreased significantly compared to control groups, and this might be related to the effect of laser on resin cement, so this result disproved the first null hypothesis. During lasing, laser energy will be transmitted through ceramic veneers to resin cement, which will absorb the residual energy and yield their degradation by one of the three proposed mechanisms as stated by Tocchio et al[22]: thermal softening, photo-ablation, and thermal ablation. In thermal softening, the application of laser energy was carried out until the luting resin cement warms up and flows over the tooth surface, which reduces its mechanical integrity and yields simplified veneer removal. This mechanism is specifically advisable in clinical situations when the de-bonding of veneers luted with light-cured or dual-cured resin cements is required as these resin cements soften by heat, and also when less mechanical stress on enamel is crucial as it allows less traumatic veneer removal. However, in photo-ablation, bonding resins decompose due to an increase in the energy of their atoms

Table 2. Descriptive Statistical Results and Independent Samples T-Test for the SBS of Control and Laser Groups

Groups	Min.	Max.	Mean	SD	t Value	*P* Value
C1	8.26	11.68	9.9395	1.20040		
L1	3.3	6.09	4.6571	0.77122		
C1/L1					-11.706	0.000[a]
C2	9.60	12.28	10.6202	0.90545		
L2	4.01	5.89	4.9736	0.70484		
C2/L2					-15.561	0.000[a]
L1/L2					-0.956	0.351[b]

[a] Significance at $P \leq 0.05$. [b] non-significance at $P > 0.05$.

Table 3. Frequency and Percentage Distribution of ARI Scores

(ARI) Scores	(C1)	(L1)	(C2)	(L2)
0	0 (0%)	0 (0%)	0 (0%)	0 (0%)
1	3 (30%)	0 (0%)	3 (30%)	0 (0%)
2	5 (50%)	2 (20%)	6 (60%)	4 (40%)
3	2 (20%)	8 (80%)	1 (10%)	6 (60%)

beyond the dissociation energy limits. Therefore, photo-ablation starts at high power densities, but low-power densities indicate thermal softening in comparison to thermal ablation. Photo-ablation is commonly associated with an Er,YAG laser; its mechanism involves direct breakdown of the resin matrix by the high absorption rates of laser energy, so it is advantageous in clinical cases where selective bonding agent removal is needed without harming the veneer or enamel tooth surface, precisely in scenarios where accuracy is critical, like preserving delicate veneers. In thermal ablation, there is a rapid increase in adhesive resin temperature to the level of evaporation, which leads to ceramic veneers to 'blow off' the tooth surface.[22,23] This mechanism is considered aggressive as it promotes heat transmission to the dental pulp, so it should be used cautiously. Clinically, thermal ablation may be required when rapid de-bonding is mandatory. However, efficient cooling and careful thermal control are obligatory to ensure pulp health.

In the current study, a scanning laser technique was employed, wherein the laser beam was moved across the surface of the LR veneer discs rather than being fixed at a single point. Scanning alone did not induce disc blow-off; rather, this effect was enhanced by thermal ablation.[9] Also, the low-power laser used (2.5 W and 25 Hz) did not stimulate thermal ablation or photo-ablation, which is initiated by high laser energy.[9,16] Accordingly, thermal softening was the suggested mechanism of de-bonding. Al-Araji and Sulaiman[7] and Al-Karadaghi et al[16] illustrated that the resin cement was physically interrupted, possibly due to the presence of resin cement methacrylate, which is considered a target chromophore for laser light. Hence, both thermal softening and physical interruption were the expected de-bonding mechanisms.

Many studies were in line with our findings, which indicated that the SBS decreased following laser treatment even though using different laser sources, ceramic veneer materials, luting agents, and variable experimental situations. The results of this investigation showed that thicker LR ceramic veneer discs needed a higher SBS to be de-bonded; this was in accordance with the studies of Yilmaz et al[2] and Giraldo-Cifuentes et al.[12] A good explanation for these findings is that veneer thickness may have an effect on the amount of laser light transmitted through them and reach the resin cement causing it to deteriorate. In other words, the increase in ceramic disc thickness reduces the laser energy transmitted through

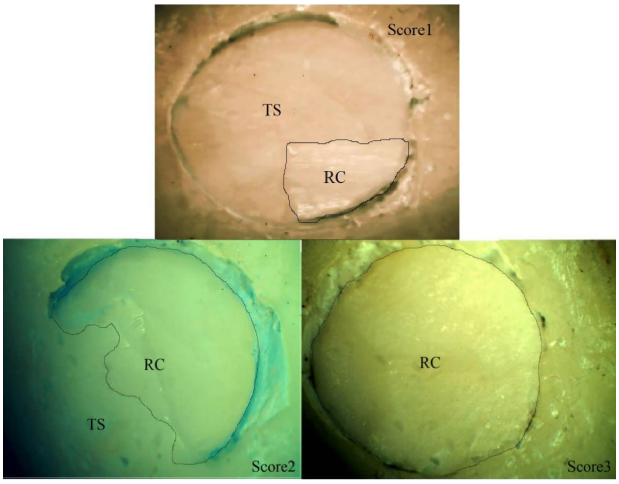

Figure 1. Adhesive Remnant Scores for the Failure Mode Assessment

them, and this agrees with Al Araji and Sulaiman[7] and Sari et al.[24]

In the present investigation, LR veneer disc thickness and SBS correlated positively. However, this correlation was not significant, which supported the second null hypothesis as the decrease in LR veneer disc thickness did not significantly diminish the SBS needed for de-bonding.

The ARI scores are considered a marker for determining the de-bonding site of ceramic adhesive and assessing the likelihood of enamel fracture following the de-bonding procedure.[25] The nearer the de-bonding site is to the enamel surface, the higher the liability for enamel harm. In other words, when the failure occurs at the enamel-cement interface, the possibility of enamel harm increases. In contrast, when the failure occurs at the veneer cement interface, the possibility of enamel harm decreases as most of the resin cement stays on the tooth surface.[16,26] In the current study, a stereomicroscope at a 20X magnification was used to estimate the failure mode, which showed that the majority of samples for laser groups (L1 and L2) were of 2 and 3 ARI scores. This indicates that most adhesive resins persisted on the tooth surface, and the probability of enamel harm like tear or fracture was reduced, which is considered a significant clinical finding as it implies an improvement in enamel preservation due to reduced stress applied to enamel during the de-bonding procedure. A possible explanation for this finding is that during laser irradiation, the high temperature produced by the laser softened the superficial layer of the resin cement, resulting in its decomposition. Also, Er,Cr:YSSG emits a wavelength of 2780 nm, which allows the readily vaporizable constituents like water and residual monomers in adhesive resins to absorb it efficiently and then evaporate, causing the adhesive resin to decompose. As a sequel to this decomposition, the adhesive resin is not as strong as before lasing.[7,9] Most of the samples for control groups (C1 and C2) had 1 and 2 ARI scores, which also indicated a low risk of enamel damage. However,

Table 4. Temperature Change in Laser-Irradiated Groups Pre- and Post-Irradiation

N	(L1)			(L2)		
	Initial Temp. °C	**Final Temp. °C**	**Differences °C**	**Initial Temp. °C**	**Final Temp. °C**	**Differences °C**
1	19	21.2	2.2	16.8	18.6	1.8
2	19.4	20.5	1.1	17.1	17.9	0.8
3	19.4	22.0	2.6	17.4	19.5	2.1
4	20.4	21.6	1.2	17.2	19.4	2.2
5	21.2	22.2	1.0	17.3	19.4	2.1
6	19.1	20.1	1.0	17.2	18.4	1.2
7	19.2	20.5	1.3	17.4	18.5	1.1
8	20.3	21.5	1.2	16.5	18.6	2.1
9	20.9	22.0	1.1	17.9	19.5	1.6
10	21.5	22.4	0.9	17.5	19.6	2.1
	Mean		1.36	Mean		1.71

according to the ARI index, the damage percentage is considered higher than that in laser groups, highlighting the conservative aspect of the laser in veneer de-bonding. Ultimately, laser-assisted veneer de-bonding could limit the use of mechanical force, potentially reducing the patient's discomfort throughout the de-bonding process. Therefore, it could be highly effective in improving patient comfort. Although patient comfort was not assessed in this investigation, our findings gave a hint to the less traumatic de-bonding procedure, so we anticipate it to be more comfortable for the patients.

These results demonstrated that SBS and ARI scores were inversely correlated, which refers to reducing the risk of enamel tears or fracture after lasing, and this came in agreement with the findings of previous studies by Oztoprak et al[9] and Naseri et al.[11]

Increasing pulpal temperature is a significant concern associated with laser-aided ceramic veneer debonding.[16] Zach and Cohen[27] stated that increasing pulpal temperature above 5.5 °C will be considered harmful and irritating to the dental pulp. Our findings showed no elevation in temperature above 5.5 °C, which supported the third null hypothesis. The maximum elevation in temperature was 2.6 °C for L1 and 2.2 °C for L2, which was within the physiological range to maintain pulpal health; this may be owing to water and air cooling used during laser irradiation, which prevented pulpal temperature from exceeding the critical threshold. This came in agreement with Rechmann et al[28] and Downarowicz et al.[29] Also, the scanning method that was first introduced and suggested by Oztoprak et al[9] and the low-power laser tested in this study greatly contributed to keeping the pulpal temperature within safety limits.[7]

There are a few limitations in this in vitro study; that is, only one exposure time (60 seconds), one pulse duration, and one cement type were investigated. Therefore, future in vivo studies are suggested to estimate the findings by applying other light-cure resin cements such as RelyX Veneer, Choice™2 LC, and G-Cem™ light cure. Furthermore, testing dual-cure resin cements, such as RelyX Ultimate and Panavia V5, with different irradiation treatment procedures would be advisable. Also, difficulties in clinical work and patient satisfaction should be inspected.

Conclusion

Er,Cr:YSGG laser settings applied in the current investigation using the scanning method effectively assisted in safely de-bonding LR glass ceramic veneers with minimum intra-pulp temperature elevation.

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Authors' Contribution

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Writing–review & editing: Zahraa Sabah Abdulwahhab, Ibtehal Mohammad Hussein.

Competing Interests
The authors confirm that there is no conflict of interest.

Ethical Approval
This study was conducted following all standards and policies of the local human subjects oversight committee. It received approval from the Research Ethics Committee (REC) at the University of Mosul/Dentistry College in Mosul, Iraq, with the registration code UoM.Dent. 25/1018 on 28 November, 2024.

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References
1. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent. 2000;28(3):163-77. doi: 10.1016/s0300-5712(99)00066-4.
2. Dundar Yilmaz B, Seyfioglu Polat Z, İzgi AD, Toprak Gündüz D, Seseogullari-Dirihan R. 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;8(2):131-9. doi: 10.17126/joralres.2019.021.
3. 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;9(4):570-3. doi: 10.4103/ccd.ccd_632_18.
4. Bajunaid SO. Review of techniques for the intact removal of a permanently cemented restoration. Gen Dent. 2017;65(5):48-53.
5. Azzat A. A novel approach to veneer removal: a clinical case report using Er,Cr:YSGG Laser. Oral Health. 2018;18(9):42-5.
6. Walinski CJ, Gibson JE, Colvert DS, Redmond DC, Jafarian JH, Gregory PN, et al. Debonding of leucite-reinforced glass-ceramic veneers using Er,Cr:YSGG laser device: optimizing speed with thermal safety. Oper Dent. 2021;46(1):100-6. doi: 10.2341/18-005-l.
7. Al-Araji SI, Sulaiman AR. The efficiency of Er,Cr:YSGG laser on the debonding of different thicknesses of ceramic veneers. Braz J Oral Sci. 2022;21:e226952. doi: 10.20396/bjos.v21i00.8666952.
8. Hayakawa K. Nd:YAG laser for debonding ceramic orthodontic brackets. Am J Orthod Dentofacial Orthop. 2005;128(5):638-47. doi: 10.1016/j.ajodo.2005.03.018.
9. Oztoprak MO, Nalbantgil D, Erdem AS, Tozlu M, Arun T. Debonding of ceramic brackets by a new scanning laser method. Am J Orthod Dentofacial Orthop. 2010;138(2):195-200. doi: 10.1016/j.ajodo.2009.06.024.
10. Tehranchi A, Fekrazad R, Zafar M, Eslami B, Kalhori K, Gutknecht N. Evaluation of the effects of CO2 laser on debonding of orthodontics porcelain brackets vs. the conventional method. Lasers Med Sci. 2011;26(5):563-7. doi: 10.1007/s10103-010-0820-y.
11. 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. Lasers Dent Sci. 2020;4(3):157-63. doi: 10.1007/s41547-020-00101-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. Photobiomodul Photomed Laser Surg. 2020;38(10):640-5. doi: 10.1089/photob.2019.4752.
13. 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 feldespathic and lithium disilicate veneers. J Lasers Med Sci. 2019;10(3):211-4. doi: 10.15171/jlms.2019.34.
14. Loffredo MC, Hanashiro FS, Steagall 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;61(358):244-50. doi: 10.1590/0366-69132015613581882.
15. Pineda-Vásquez L, Fons-Font A, Bustos-Salvador JL, Alonso-Pérez-Barquero J, Román-Rodríguez JL. Shear bond strength of debonded ceramic restorations re-cemented by means of a cleaning and retreatment protocol. J Clin Exp Dent. 2019;11(6):e506-11. doi: 10.4317/jced.55706.
16. Al-Karadaghi SS, Jawad H, Al-Karadaghi T. The influence of pulse duration and exposure time of Er,Cr:YSGG laser on lithium disilicate laminate debonding, an in vitro study. Heliyon. 2023;9(3):e14600. doi: 10.1016/j.heliyon.2023.e14600.
17. Al-Askary RA, Ismail SA, Al-Sabawi NA. Bond strength of endodontic sealers to gutta percha and dentin. Rafidain Dent J. 2013;13(2):282-9. doi: 10.33899/rden.2020.165182.
18. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod. 1984;85(4):333-40. doi: 10.1016/0002-9416(84)90190-8.
19. Iseri U, Oztoprak MO, Ozkurt Z, Kazazoglu E, Arun T. Effect of Er:YAG laser on debonding strength of laminate veneers. Eur J Dent. 2014;8(1):58-62. doi: 10.4103/1305-7456.126243.
20. 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.
21. Abed Al Moneim S, Gasgoos S. Influence of Er,Cr:YSGG and diode lasers on the surface roughness of enamel at fissure area: an in vitro study. Rafidain Dent J. 2023;23(2):312-20. doi: 10.33899/rdenj.2023.131336.1133.
22. Tocchio RM, Williams PT, Mayer FJ, Standing KG. Laser debonding of ceramic orthodontic brackets. Am J Orthod Dentofacial Orthop. 1993;103(2):155-62. doi: 10.1016/s0889-5406(05)81765-2.
23. El-Damanhoury HM, Salman B, Kheder W, Benzina D. Er:YAG laser debonding of lithium disilicate laminate veneers: effect of laser power settings and veneer thickness on the debonding time and pulpal temperature. J Lasers Med Sci. 2022;13:e57. doi: 10.34172/jlms.2022.57.
24. Sari T, Tuncel I, Usumez A, Gutknecht N. Transmission of Er:YAG laser through different dental ceramics. Photomed Laser Surg. 2014;32(1):37-41. doi: 10.1089/pho.2013.3611.
25. Gasgoos S, Saed R. The effect of thermocycling on shear bond strength of two types of self-etch primers. Rafidain Dent J. 2009;9(2):246-53. doi: 10.33899/rden.2009.9113.
26. 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;27(6):1151-5. doi: 10.1007/s10103-011-1018-7.
27. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol. 1965;19:515-30. doi: 10.1016/0030-4220(65)90015-0.
28. Rechmann P, Buu NC, Rechmann BM, Finzen FC. Laser all-ceramic crown removal and pulpal temperature--a laboratory proof-of-principle study. Lasers Med Sci. 2015;30(8):2087-93. doi: 10.1007/s10103-015-1738-1.
29. Downarowicz P, Noszczyk P, Mikulewicz M, Nowak R. Thermal effect of Er:YAG and Er,Cr:YSGG used for debonding ceramic and metal orthodontic brackets: an experimental analysis. Adv Clin Exp Med. 2020;29(5):557-63. doi: 10.17219/acem/118844.