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Effects of Er,Cr: YSGG Laser Application in De-Bonding of Different Ceramic Veneer Materials (In Vitro Study)

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Abstract: Background: Ceramic restorations are widely used nowadays as the esthetic demand has increased in the worldwide population, and lithium disilicate and feldspathic porcelain materials are the most widely used veneer materials. The traditional removal procedure for veneers was recently replaced with the use of laser technology to debond the veneers so that the de-bonded veneers can be preserved and re-used. Aim: Up to now, there have been few studies regarding using lasers to remove ceramic laminate; thus, it is clear why this research topic is important for examining the efficiency of lasers in the use of de-bonding for different ceramic laminates with varying compositions and materials. Materials and Methods: This study employed forty-five normal human maxillary first premolars with comparable proportions. The forty-five teeth were initially split into three groups of fifteen teeth, and the teeth were chosen at random. Each group fused pairs of various ceramic materials. A total of fifteen teeth in the first group underwent feldspathic porcelain restorations. The second group contained fifteen restorations made of lithium disilicate glass-ceramic CAD-CAM. In the third group, fifteen teeth were restored using glass-ceramic that had a lithium disilicate glass-ceramic ingot. The RelyX Veneer A1 shade, available from 3M EPSE in the United States, was used to bond all the samples. The specimens were then submerged for approximately 24 h in distilled water at 37 degrees Celsius in order to simulate the conditions in an oral cavity. An Er,Cr: YSGG laser (Waterlase, iPlus, Biolase, from USA) was used with a turbo headpiece and an MX7 sapphire tip for irradiation. Results: The time needed for the ceramic disc to debond was calculated using a digital stopwatch. The average removal times for the feldspathic porcelain, lithium disilicate glass-ceramic ingot, and lithium disilicate glass-ceramic CAD-CAM were 10.067 ± 1.668 s, 5.200 ± 1.146 s, and 5.133 ± 1.125 s, while the removal times ranged from 8–12 s, 4–7 s, and 4–7 s, respectively. Compared to the other ceramic materials, de-bonding the feldspathic porcelain took longer. Conclusions: According to this study, the Er,Cr: YSGG laser application using the same study parameters made it simpler to de-bond lithium disilicate and feldspathic porcelain. Lithium disilicate, as opposed to feldspathic porcelain, transmits laser light more effectively; hence, the results varied depending on the materials, and the debonding occurred primarily at the veneer–cement interface.

Keywords: debonding by laser; ceramic veneer; transmission of laser; Er,Cr: YSGG; different materials

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1. Introduction

Ceramic veneers have modernized cosmetic dentistry and are important tools for smile restorations. In cosmetic dentistry, creating a stunning smile depends on many factors, including technical skill, shade-matching, luting cement, the type of ceramic, and the tooth substrate [1]. The process may fail due to the durability of the adhesive materials or how the procedure is conducted. There could be issues such as cement discoloration, margin infiltration, laminate cracks, or patient dissatisfaction [2]. Small cracks may occur, leading to caries, staining, and gingival reactions [3]. Positioning failure can also occur during the cementation process. However, because restorations are frequently cemented adhesively, the removal process for recreating them is time-consuming and difficult [4]. Diamond or tungsten carbide burs and rotary tools are commonly used for removal [5].

Removing veneers without damaging the natural teeth underneath requires effort and time. Even with magnification, if the dentine is exposed, the iatrogenic damage to the tooth below could reduce the bond strength. Even though it is preferred in unexpected early pulpal inflammatory reactions or misalignment during cementation, a restoration may lose its integrity and cannot be used again. The traditional removal procedure has recently been replaced with a more comfortable laser de-bonding technique to reduce the drawbacks of the earlier technique [6]. In an article published about using laser energy to de-bond orthodontic brackets [7], Tocchio et al. [8] described the de-bonding methods that caused the adhesive resin to degrade. They used the terms photo ablation, thermal ablation, and thermal softening. Using a laser for removing dental veneers will cause photo and thermal ablation of the resinous cement, and it will also have a thermal softening effect. These effects support using lasers for de-bonding but depend on the integrity of the veneers. The restorations can be preserved and used again, decreasing the operation's time and cost. However, the effect of thermal ablation and photo ablation do not cause any injury to dental structure, pulp, and laminate [9]. Water and the organic resin cement components are the first materials to absorb pulsed laser energy, and these materials then expand due to temperature and volume increases. These tiny explosions can be visible as flashes of light, both macroscopically and microscopically. The inorganic materials are part of an explosive force created by the rise in internal pressure, which hydrodynamically ejects a veneer from a tooth's surface [10]. All unwanted or unsuccessful veneers can be successfully removed using erbium family lasers, such as: Er: YAG, which includes erbium: yttrium aluminum garnet, and Er: CrYSGG, which includes erbium and chromium: yttrium scandium–gallium garnet [11]. For de-bonding indirect tooth veneers, erbium lasers can be employed continuously at a wavelength of 2780–2940 nm for two minutes. As a tried-and-true method for removing veneers, it minimizes the danger of fracture by avoiding direct contact with the veneers. Additionally, it has been demonstrated to be a successful conservative choice for minimizing harm to the tooth structure [12]. An important consideration in this process is the restoration's optical characteristics, and the material's crystalline phase significantly impacts the visual aspects of various ceramic types. Ceramic veneers come in different crystalline phases, including feldspathic porcelain and lithium disilicate glass-ceramic [13]. There is a lack of up-to-date clinical data for clinicians on applying lasers to debond various materials with various compositions and fabrication techniques, and using a laser to clinically remove ceramic laminate veneers is mentioned in an insufficient number of books and studies. This study is important because it evaluates the efficiency of applying a laser de-bonding treatment to ceramic restorations made of various materials with various compositions and fabrication techniques, along with the reuse of the de-bonded veneers.

2. Materials and Methods

2.1. Collecting the Samples

Sixty sound maxillary first premolars were extracted from patients between the ages of fifteen and twenty for orthodontic reasons, and all teeth with cracks, caries, enamel defects, abrasions, color changes, or previous restorations were excluded from the study to minimize the impacts of confounding factors. For this in vitro investigation, 45 maxillary first premolars with comparable occluso-cervical and mesiodistal dimensions were selected. Following purification and two days in a 0.1-percent thymol solution as a disinfectant storage solution that inhibited fungi growth, the samples were cleaned with an ultrasonic scaler to remove debris. In order to preserve the teeth while the samples were processed, they were placed in distilled water and kept at room temperature. All teeth were examined with blue-light transillumination to check for enamel cracks and lessen the influences of possible confounding factors.

2.2. Grouping Samples

The forty-five teeth were initially split into three groups of fifteen teeth, and the teeth were chosen at random. Each group fused a pair of various ceramic materials. A total of fifteen teeth in the first group underwent feldspathic porcelain restorations. The second group contained fifteen restorations made of lithium disilicate glass-ceramic CAD-CAM. In the third group, fifteen teeth were restored using glass-ceramic containing a lithium disilicate ingot.

2.3. Sample Insertion into Sample Holder

Every tooth received a unique mold. Cold-cured acrylic resins, color-coded for simple group separation, were poured into plastic cube molds which had measurements of $3 \times 3 \times 1.5$ cm for width, height, and depth, respectively. Vaseline was utilized as a separating agent before adding the cold-cured acrylic resins to the molds. The molds were then filled with the cold-cured acrylic resins, and the teeth were anchored such that only the outer layers of the crowns at level sunder the CEJ were visible. The teeth were then finished after being positioned in the acrylic molds by a dental surveyor such that the buccal surfaces were parallel to the bottoms.

2.4. Preparing the Sample Design

The teeth were prepared with the aid of a high-speed handpiece and a diamond bur, enabling uniform preparation. The high-speed handpiece's adaptation to the surveyor's horizontal arm allowed it to keep the bur's long axis parallel to the tooth's long axis. The acrylic resin block, which supported each sample while being cut, was fitted to the surveyor's movable table through modification. First, a self-limiting, depth-cutting bur and continuous irrigation were used to prepare 0.5-mm-deep depth-orientation grooves on the labial surfaces of the teeth. The prep surfaces were painted using a pen that was not water-soluble. To provide a smooth enamel surface area without going past the depth-orientation groove, the remaining buccal tooth structure between the depth cuts was reduced using a round-end, diamond-tapered fissure bur. In accordance with Ztürk et al. (2013), these preparations were kept up until the color disappeared from the middle third of the painted facial surface [14]. The following measurements describe the ultimate preparation margin: 5 mm length $\times$ 4 mm width. Then, the labial surfaces were polished using a 600-grid silicon carbide paper disc to create consistent, smooth surfaces for the bonding processes.

2.5. Manufacturing the Ceramic Discs

The researchers took great care to keep the dimensions and thicknesses of all the ceramic materials for all samples uniform while fabricating all the restorations in a dental lab. The ceramic materials that were used for this study included feldspathic porcelain (VITABLOCS Mark II from VITA Zahnfabrik, Baden-wuerttemberg, Germany), milling blocks of lithium disilicate IPS e.max CAD—HT (Ivoclar Vivadent, Schaan, Liechtenstein), and a pressing ingot of lithium disilicate IPS e.max Press—HT (Ivoclar Vivadent, Liechtenstein). The A1 color was used for all the ceramics. The manufacturer's instructions were followed to produce fifteen ceramic discs for each material, each measuring 5 mm in diameter and 0.5 mm in thickness.

2.6. Ceramic Disc Bonding

2.6.1. Surface Treatments of the Teeth

All teeth were cleaned and polished using a low-speed handpiece, pumice, and plastic cup. A dental surveyor was then employed during the cementation process for standardization. Every sample was etched with scotch bond etchant of 32-percent phosphoric acid (3M ESPE, Minnesota, USA) for 15 s, and then they were rinsed, washed, and dried. With the aid of a micro-brush, the Single bond Universal Adhesive (3M ESPE, Minnesota, USA) was applied for 20 s to allow for the reactions. Finally, the samples were dried via air spray for 5 s.

2.6.2. Treatment of Ceramic Surface

The porcelain etches (9% buffered hydrofluoric acid, Ultradent, Otah, USA) were used to erode each disc's surface for 20 s on the lithium disilicate glass-ceramic and 60 s on the feldspathic porcelain before washing and drying. RelyX ceramic primer (3M ESPE, Minnesota, USA), a silane binding agent, was applied to the etched discs' surfaces and allowed to react and dry for 1 min.

2.6.3. Ceramic Disc Seating

The porcelain discs were coated with 3M EPSE's RelyX veneer cement in the shade A1. To ensure that all samples had the proper film thicknesses during cementation, the discs were placed with the help of a surveyor using a static force of 200 g spread using a straight surveyor rod placed at the surveyor's arm. The outer surfaces of the ceramic discs were tack-cured for 2 s using a small-diameter light cure tip (Elipar light cure, 3M ESPE), taking care to avoid curing any additional cement. Extra cement from the sides was scraped off using a pointed probe. Then, a 30 s light cure was applied to the discs' borders and each segment. The samples were stored in distilled water at 37 °C for 24 h following the cementation procedure to mimic an intraoral environment.

2.6.4. De-Bonding with a Laser

The laser application was carried out with an Er,Cr: YSGG (Waterlase iPlus; Biolase, California, USA) using a handpiece (Turbo; Biolase) and a sapphire tip (MX7), with the following parameters for each group: the working settings were a free-running pulse, a 20 Hz repetition rate, 4.5 W of power, a 60 µs pulse length, use of the H mode, an air level of 60 percent, a water level of 80 percent, and a non-contact method with a 2 mm distance. A dental surveyor with a turbo handpiece connected was set up for scanning the ceramic discs in such a manner that the tip was set perpendicular to the surfaces at a 2 mm distance. The timer was used to measure the time taken for removing the discs. The means, standard deviations, and ranges were determined. After the samples were removed, the surfaces of the teeth and discs were visually analyzed by a blind examiner under SEM at the University of Basrah-College of Science, Physics Department, to visualize the bonding failure modes. The failure modes were categorized into cohesive failures with the resin cement and adhesive failures between the teeth surfaces and discs within the bonding interfaces.

SPSS version twenty-five was used to perform the statistical analyses. To analyze the data distribution, a Shapiro–Wilk test was applied. A one-way ANOVA test was used to compare the groups numerically and analyze the statistical data. A change was considered statistically significant at a p-value of 0.05 ($p < 0.05$).

3. Results

Laser De-Bonding

An analysis was conducted on the effects of laser application on different ceramic materials. As shown in Table 1, in all groups, the ceramic veneers on the teeth were swiftly and completely removed using the Er,Cr: YSGG laser. While the removal times varied from 8 to 12 s, 4 to 7 s, and 4 to 7 s, respectively, the average removal times for the feldspathic porcelain, lithium disilicate glass-ceramic ingot, and lithium disilicate glass-ceramic CAD-CAM were 10.067 ± 1.668 s, 5.200 ± 1.146 s, and 5.133 ± 1.125 s, respectively. Compared to the other ceramic materials, the feldspathic porcelain required more time to de-bond. The clear results are shown in Figure 1.

Table 1. Descriptive statistics of all groups.

Material Type	N	Mean ± SD	Minimum	Maximum
Feldspathic porcelain de-bonding time (s)	15	10.067 ± 1.668	8.00	12.00
Lithium disilicate glass-ceramic ingot de-bonding time (s)	15	5.200 ± 1.146	4.00	7.00
Lithium disilicate glass-ceramic CAD-CAM de-bonding time (s)	15	5.133 ± 1.125	4.00	7.00

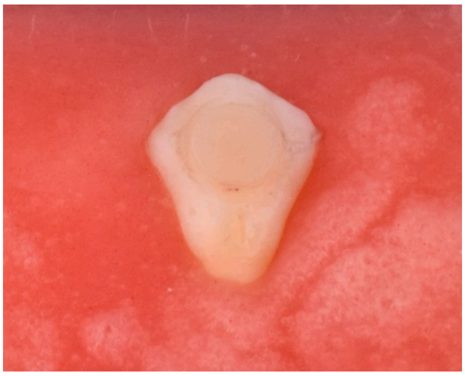


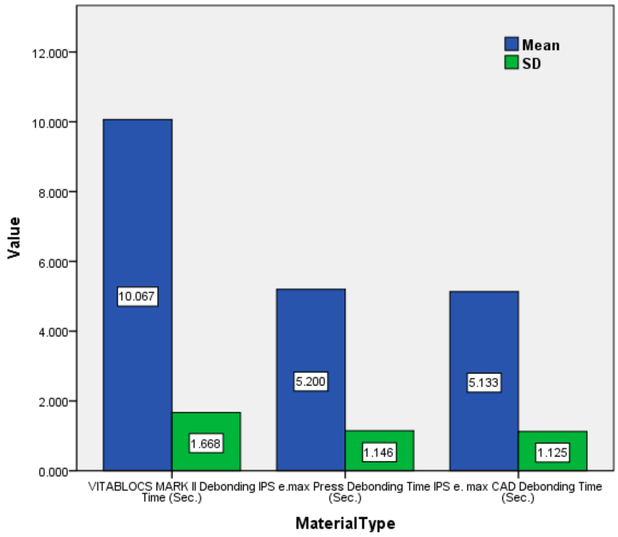
Figure 1. The sample that was cemented.

A one-way ANOVA test was designed with the presumption that the datasets for all three items were normally distributed and adhered to the homogeneity assumptions. According to the outcome shown in Table 2, Figure 2 demonstrates that the feldspathic porcelain boxplot was superior to the others. There were very substantial disparities between the groups, indicating that the laser's effects varied depending on the groups' responses to time. The feldspathic porcelain was statistically significant compared to the lithium disilicate glass-ceramic CAD-CAM and lithium disilicate glass-ceramic ingot, with mean differences of 4.933 s and 4.867 s, respectively, according to Table 2, where the conducted paired comparison test is shown. The difference between the lithium disilicate glass-ceramic CAD-CAM and the lithium disilicate glass-ceramic ingot was only 0.064 s, as shown in Figure 3, but no statistically significant differences were detected.

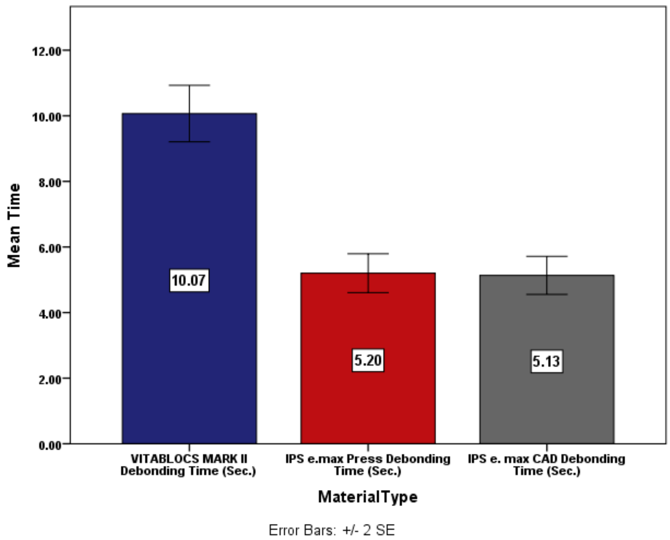
Table 2. One-way ANOVA test result.

Material Type	Levene Statistic (p-Value)	F-Value (p-Value)
Feldspathic porcelain de-bonding time (s)	2.517 (0.093)	67.178 (0.000)
Lithium disilicate glass-ceramic ingot de-bonding time (s)		
Lithium disilicate glass-ceramic CAD-CAM de-bonding time (s)		

Figure 2. The laser irradiation of a ceramic disc bonded to a tooth.



(**a**)



(**b**)

Figure 3. (**a**) Bar chart demonstration of the groups' mean values and SDs. (**b**) Error Bar.

4. Discussion

Lithium disilicate and feldspathic porcelain are two of the most indirectly used materials. Ceramics made using feldspathic materials have become a sensible option because they are more aesthetically pleasing, highly translucent, color-stable, and biocompatible with the tissue around them [6]. However, compared to feldspathic ceramics, lithium disilicate glass-ceramics provide advantages in terms of aesthetics and usability, such as increased fracture resistance, which favors their clinical lifetime [15]. Both exhibit a wide range of hues, mimic translucency, and dental fluorescence, and they are color-stable and maintain brightness regarding aesthetic aspects [16]. Finely structured feldspar ceramic blocks known as VITABLOCS Mark II (VITA Zahnfabrik) are offered for various computer-aided design/computer-assisted manufacturing (CAD/CAM) systems, enabling a variety of single-tooth repairs. A manufactured block has the benefit of having a finished core devoid of residual porosity which could act as a weak spot and result in catastrophic failure. With a bending resistance of between 350 MPa and 450 MPa—much better than feldspathic ceramics—lithium disilicate (Li_2SiO_5) ceramics offer an attractive alternative with superior mechanical properties [17]. Advancements in flexural strength were made possible by increasing the crystal content to approximately seventy percent and fine-tuning the crystal size. These improvements are now accessible for press and CAD/CAM applications. In this study, the tooth preparations were carried out by making the center of the buccal surface a flat surface to ensure even tooth structure removal and an even amount of enamel removal so that discs of standardized diameters and thicknesses were obtained, and many past studies agree with this because in the case of entire buccal surface preparation, an even amount of enamel removal cannot be guaranteed as the thickness of the enamel is more standard at the center of the buccal surface than at the cervical and proximal parts.

Due to its short lifespan, a ceramic veneer may eventually require replacement at irregular intervals [18]. Maintaining the enamel structure while avoiding iatrogenic damage and, as far as is feasible, enabling enamel surface healing are requirements for a successful de-bonding process [19]. Additionally, replacing damaged restorations could take time and put additional tooth structures at risk [20]. Most conventional removal techniques include abrading the veneer with a diamond bur. Discomfort in the patient, a long de-bonding duration, and tooth injury are some drawbacks of the conventional ceramic veneer removal technique. Due to the rising usage of pulsed lasers in dentistry, lasers as alternatives to conventional procedures for removing veneers have recently drawn increased attention [21]. The adhesive resin can be degraded in three different ways using laser energy: thermal softening, thermal ablation, and photo ablation. The laser warms the bonding agent until thermal softening takes place. Thermal ablation happens when the heating is fast enough to reach the resin's vaporization range before the thermal softening that decomposes the resin cement causes the bond to break between the veneer and the tooth, mostly destroying the veneer–cement interface and making a majority of the veneer's surface clean. When very-high-energy laser light interacts with the adhesive substance, photo ablation results. In this instance, the bonds between the atoms of the adhesive resin quickly surpass their dissociation energy levels, leading to the material's breakdown [8]. According to earlier investigations, erbium lasers can separate laminate veneers from one another. Erbium lasers have wavelengths of 2780 nanometers and 2940 nanometers. They may be erbium, chromium-doped yttrium, scandium, gallium, and garnet lasers (Er,Cr: YSGG) or erbium-doped yttrium, aluminum, and garnet lasers (Er: YAG). In our study, lithium disilicate (IPS e.max CAD and press) and feldspathic porcelain (VITABLOCS Mark II) were de-bonded using an Er,Cr: YSGG laser because they have different chemical compositions and crystalline phases that could affect the amount of laser transmission through a ceramic veneer [22]. The laser parameter settings utilized in past studies on laser de-bonding have displayed a range of values which aligned with this study's aims. The most important consideration was to find the de-bonding setting that would perform best while causing the least amount of damage to the tooth structure, especially the pulp.

The parameters used in this study were a repetition rate of 20 Hz, a power of 4.5 W, a pulse duration of 60 µs, the use of the H mode, a water level of 80 percent, and an air level of 60 percent. The water (80 percent) irradiation dose used in this investigation was selected to cool the tooth structure and reduce the pulpal temperature. Kang et al. [23] found that dry laser ablation caused charring and fractures. This study demonstrated variations in the de-bonding times of the feldspathic porcelain and the lithium disilicate glass-ceramic for the two types of CAD and the press. According to the current investigation, the removal of feldspathic porcelain using a laser requires more time compared to the lithium disilicate glass-ceramic for two types of CAD and the press, and there was no difference in the removal time of the lithium disilicate glass-ceramic fabricated by CAD/CAM and the hot-pressed technique. Similar results were found by Sar et al. [7], who reported an 88-percent transmittance for 0.5-mm-thick lithium disilicate-reinforced ceramics and a 68-percent transmittance for 0.5-mm-thick feldspathic ceramics. The transmission ratio of the lithium disilicate-reinforced ceramic was higher than that of the feldspathic porcelain, and the same finding was reported by Zanini et al. [24], who revealed significant differences among the materials tested, with the lithium disilicate glass ceramics showing the greatest laser transmission rates. The compositions of both ceramics may explain why this result occurred with the feldspathic porcelain veneer materials, where the cementing resin layer selectively absorbed the laser energy due to vaporizable components such as the leftover monomer. It has been demonstrated that porcelain can absorb a small amount of water intraorally [25,26]. Erbium laser energy does not freely travel through porcelain veneers. Instead, the water within the porcelain absorbs the light energy, which results in the material's fracture. In contrast, the disilicate lithium ceramic had a lower water absorption rate over the short trial period, according to Morford et al. [4]. This was, they claimed, because the material had a less-porous structure and greater flexural strength than the feldspathic porcelain. Flexural strength appears to be the essential quality for maintaining a veneer's integrity after laser removal.

The mode of failure was examined by an external examiner under a scanning electron microscope (University of Basrah, College of Science, Physics Department) after discussing the methods used in the current studies but without disclosing any information about the sample groups to avoid bias. The mode of failure in the de-bonding process was an indicative factor of enamel damage. In the study by Nalbantgil et al. [27], enamel fractures were not seen, and cement failure made up a majority of the failures.

When the samples were examined under SEM, over 70% of the teeth structures were covered, although certain spots lacked resin cement. This demonstrated that the resin cement's exterior surface was softened by a comparable laser finding, as seen in Figure 4, which was similar to the results of the study by Karagoz et al. [28].When the resin cement layer failed cohesively, resin cement remained on the inner surface of the laminate veneers as shown in Figures 5–7 and the tooth structure as shown in Figure 8, according to the SEM analysis of the teeth and laminate veneers. However, the teeth surfaces had more cement fragments visible. The manner of failure in de-bonding studies is a crucial indicator of where a breakdown has occurred, and it assesses the likelihood of enamel or dentin damage. The risk of a tooth being damaged increases as the de-bonding spot grows nearer to the tooth/resin contact. This study's SEM disclosed that the bond between the veneer and the tooth enamel had discomposed mainly at the veneer–cement interface, keeping a majority of the veneer clean. All samples were de-bonded without severe destruction or removal of the underlying healthy tooth structure, as shown in Figure 8A–C, and no damage or traces of ablation on the teeth surfaces were seen. Similar results were found in the 2011 study by Morford et al., which found that the underlying enamel surfaces showed no damage following laser irradiation for de-bonding. These findings may have been due to the thicknesses of all the specimens being kept at 0.5 mm, which allowed for direct laser absorption by the resin rather than absorption of the laser energy by the ceramics.

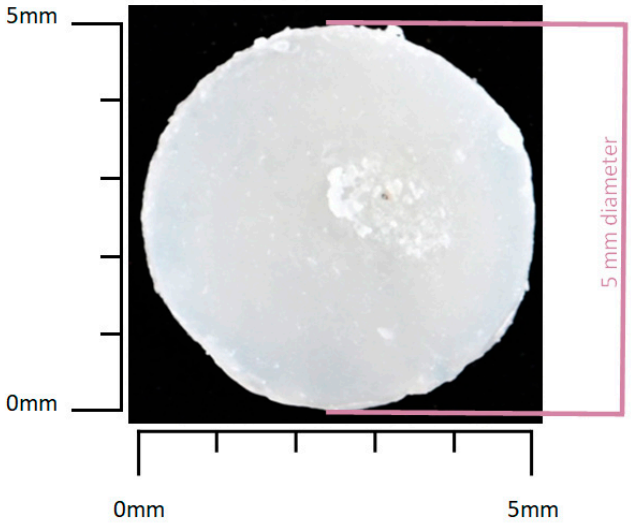


Figure 4. Remaining resin cement on the laminate veneers.

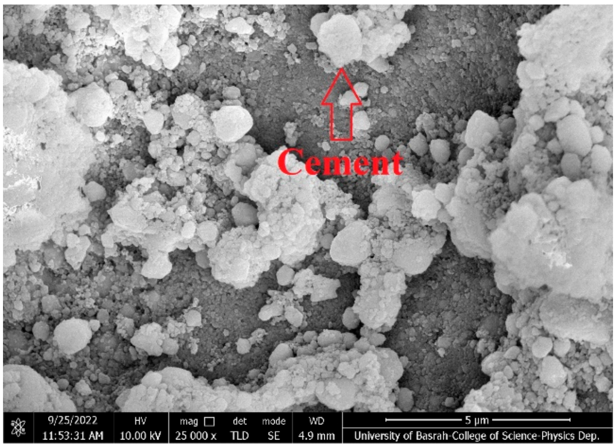


Figure 5. SEM of the feldspathic porcelain intaglio surface (25,000×).

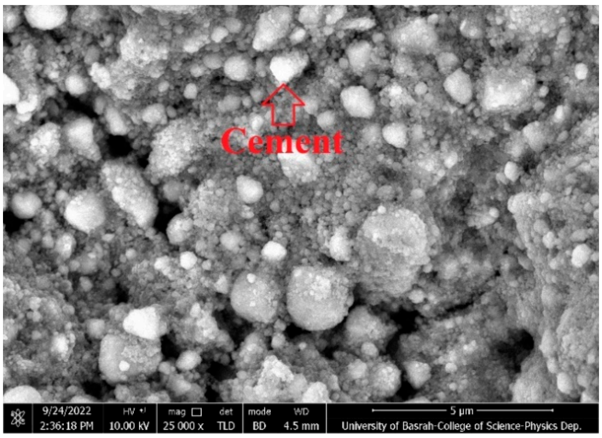


Figure 6. SEM image of the lithium disilicate glass-ceramic ingot intaglio surface (25,000×).

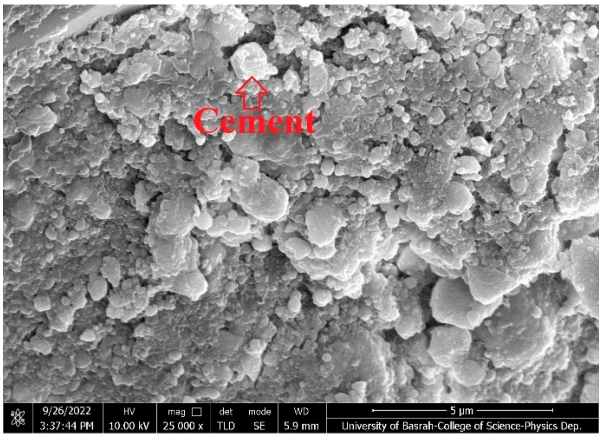
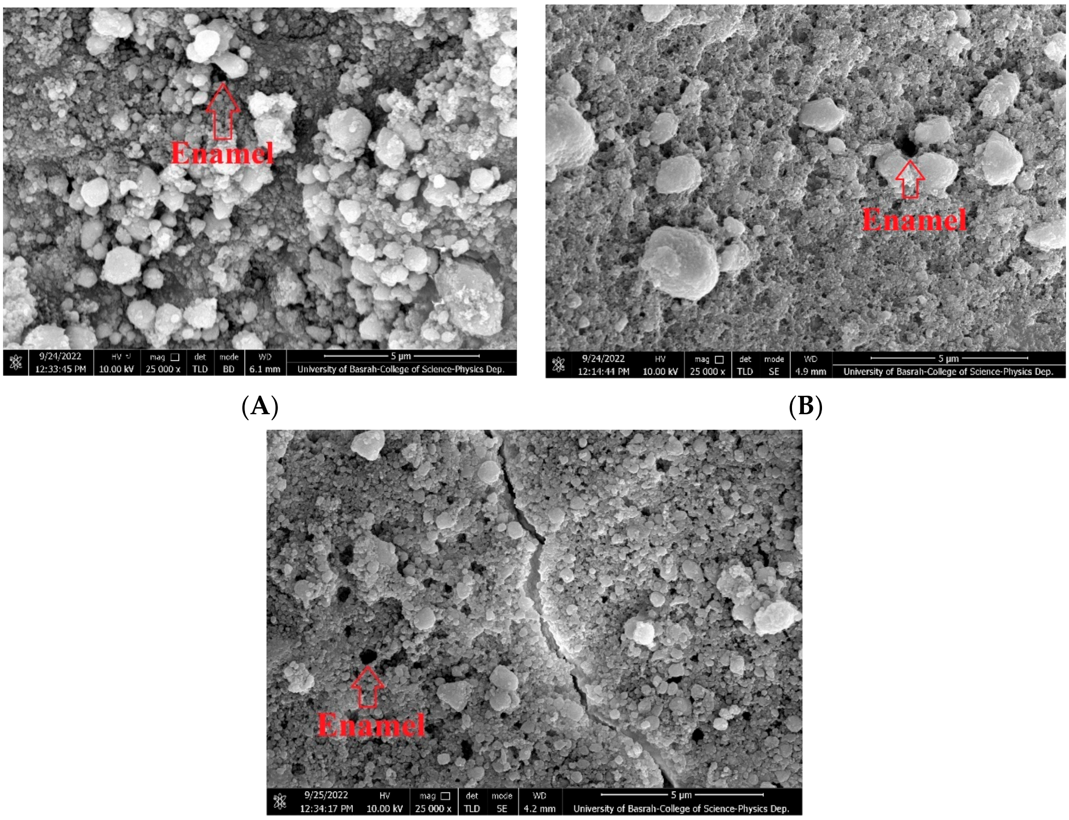


Figure 7. Lithium disilicate glass-ceramic CAD-CAM intaglio surface using SEM at 25,000× (residual cement seen on the SEM of the intaglio surface glass ceramic after Er,Cr:YSGG laser irradiation).



(**A**) (**B**)

(**C**)

Figure 8. (**A**–**C**): SEM of the resin cement and enamel surface for the laser de-bonded feldspathic porcelain, lithium disilicate glass-ceramic ingot, and CAD-CAM specimens, respectively, at 25,000×. The images show no evidence of damage to the underlying enamel surfaces.

This research had certain limitations. Firstly, the wider bonded surfaces could have impacted the bond strength results because the specimens were 5 mm thick. Secondly, energy transfer via only three different veneer materials was examined, and testing a larger range of ceramic materials is generally recommended to ensure that all veneers may be de-bonded using laser irradiation.

5. Conclusions

The Er,Cr: YSGG laser can safely and effectively remove ceramic veneers. The Er,Cr: YSGG laser may be useful for de-bonding feldspathic porcelain and lithium disilicate ceramic veneers when used in the present investigation's settings. However, the effect is material-dependent because the lithium disilicate had better laser transmission than the feldspathic porcelain. The mode of failure of the samples when examined under a scanning electron microscope showed that a majority of the failures were adhesive failures of the cements, and this finding was a good indicator for using an Er,Cr: YSGG laser for veneer debonding without affecting a tooth's enamel. The debonding failures mostly occurred at the veneer–cement interfaces, leaving the enamel unaffected and keeping the de-bonded veneers clean so that they could be reused clinically.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and analyzed during this study are available from the corresponding author on reasonable request.

Conflicts of Interest: The author declares no conflict of interest.

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