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Debonding of Leucite-reinforced Glass-ceramic Veneers Using Er, Cr:YSGG Laser Device: Optimizing Speed with Thermal Safety

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Clinical Relevance

Removing laminate veneers on anterior teeth by using an Er,Cr:YSGG dental laser can be completed faster than previously reported while maintaining thermal safety.

SUMMARY

Objective: When laminate veneer restorations require removal, the process is tedious, time-consuming, and potentially damaging to the underlying tooth structure. The purpose of this study was to evaluate the removal of Empress CAD milled laminate veneers on extracted human central incisors by using an Er,Cr:YSGG dental laser while optimizing speed and maintaining thermal safety.

Methods and Materials: A total of 22 extracted human incisors were mounted in acrylic blocks. Conservative veneer preparations were made on all samples with a high-speed dental handpiece with a diamond bur and air/water spray. The 22 blocks of IPS Empress CAD were designed and milled into laminate veneers with a CAD/CAM System and luted to the prepared teeth. An Er,Cr:YSGG dental laser was fitted with a handpiece and laser fiber (600-μm diameter cylindrical fiber, 6 mm in length). Laser parameters were 333 mJ/pulse, 30 Hz, 80% air, 50% water, 600-μm diameter fiber tip, at a fluence of 885.96 J/cm2. The laser fiber tip was held directly on the surface of each veneer in contact, perpendicular to the surface, and moved slowly, covering the labial surface while firing.

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Results: At the laser parameters tested (333 mJ/pulse, 30 Hz, 80% air, 50% water, 600-μm diameter fiber tip), the average duration of exposure to completely remove each laminate veneer was 14.16 ± 0.60 seconds, with a range of 10.75 to 21.25 seconds. The average thickness of each veneer measured at the midfacial was 0.75 +/- 0.03 mm. The mean intrapulpal temperature increase for this period was 0.71°C ± 0.15°C.

Conclusions: A regression model between time and thickness (*p*<0.0001) proved to be significant. However, the same cannot be said when the same modeling was tested between temperature and thickness. It can therefore be concluded that as the thickness of a veneer increases, more time is necessary to remove a veneer using Er,Cr:YSGG laser energy; however, increasing thickness does not necessarily result in an increase in pulpal temperature. Within the limitations of this study (single restorative material and single luting agent), it can be concluded that removing CAD Empress laminate veneer restorations using an Er,Cr:YSGG laser is reliable and thermally safe, even at an average of 10 W of power at 30 Hz. Additionally, thermal safety is maximized with adequate aerosolized water spray.

INTRODUCTION

Porcelain and ceramic veneer restorations have evolved into a reliable aesthetic solution for many dental situations, including darkening, fractures, failing restorations, or misalignment. For over 30 years, these restorations have proven to be especially appropriate to improve the appearance of malpositioned teeth, and they can be a significantly more minimally invasive option (in lieu of full coverage) where there are extensive existing restorations or decay.[1,2] When a laminate veneer fails, it is most likely a result of decay or microleakage.[3,4,5,6,7,8]

Due to the ever-increasing bond strengths of current luting agents, the task of removing porcelain or ceramic indirect veneer and crown restorations can be a frustrating and time-consuming process.[9] The most common method of removing failed laminate veneer restorations is by using a high-speed handpiece fitted with a coarse diamond bur.[10] Albeit common, this method can be lengthy, uncomfortable, and lead to tooth or pulpal damage because of friction, heat, and vibration.

An additional challenge includes the issue that the highly aesthetic qualities of contemporary restorative materials can make it difficult to distinguish the margin between veneer and tooth during removal.[9] As a result, attempts have been made to cement laminate veneers using luting agents modified with a fluorescing dye. Should the need for veneer removal arise, the fluorescing agent results in less damage to the underlying tooth structure because of improved contrast.[11] Laminate veneer removal using an erbium laser eliminates the need for these specialized materials and procedures because the ablative process does not rely on visual inspection or visual acuity.

Existing research and clinical reports have demonstrated success when using an erbium laser for the purpose of removing failed porcelain or ceramic restorations.[12] It has been suggested that the primary effect of the laser energy occurs not on the veneer or the tooth surface, but instead, in the resin luting agent, which is caused at least partially by thermal softening of the material.[13] However, if the luting cement is ablated rapidly, thermal softening and heat conduction is avoidable.[14,15,16]

There are also reports of using other laser wavelengths to etch porcelain surfaces in order to improve bond strength.[17,18,19,20,21] Likewise, there have been studies demonstrating the effectiveness of using an erbium laser to reduce the shear bond strength of porcelain to tooth by laser irradiation.[22] However, scientific papers on the true effects of laser energy on these restorations and to the underlying teeth are limited.

The actual method of ablation of the resin luting cement by laser energy is multifaceted. Erbium lasers demonstrate the highest absorption in water. The pulsing laser energy is first absorbed by the water and organic components within the resin cement, causing expansion as a result of an increase in temperature and a subsequent increase in volume. These microexplosions can be seen as flashes of light and are visible both macro- and microscopically. The increase in internal pressure results in an explosive force that includes the inorganic substances, which separates the veneer from the tooth surface by hydrodynamic ejection.[23,24,25]

The aim of the present study was to test multiple laser parameters while using an Er,Cr:YSGG laser to remove milled leucite-reinforced glass-ceramic veneer restorations from extracted human central incisors. The IPS Empress CAD ingots used exhibit a homogeneous distribution of leucite crystals. The leucite crystals are evenly and densely distributed. The diameter of the crystals is 1–5 μm, and the crystal phase volume is 35%–45% by volume.[26]

While previous recommendations regarding the parameters to remove laminate veneers were generally much lower than those used in this study, the authors intended to determine the most efficient laser parameters to successfully remove veneer restorations as quickly as possible without overheating the tooth and dental pulp. To this end, preliminary trials of various combinations of laser pulse, power, and water spray were completed prior to the initiation of this study. What is reported in this paper are the observations of the laser parameters at maximum power output on the device being tested. Saving time is of little help if the pulpal temperature increase becomes significant. Rechmann and others have demonstrated both conservative and "worst case" removal of crowns using an erbium laser.[27] In those trials, the goal was to remove the veneers intact in the rare case they were misaligned during cementation.

METHODS AND MATERIALS

A total of 22 recently extracted human maxillary central incisors were obtained from a tooth bank and mounted in acrylic blocks, leaving the clinical crown and 2 mm of root surface exposed. Conservative veneer preparations (restricted to enamel, nonincisal wrap) were made on all samples by a single operator (DC), with a high-speed dental handpiece with a medium grit, round-ended diamond bur and air/water spray. Preparations were made by first using a depth cutting bur to 0.6 mm (MADC-006; Axis Dental, Coppell, Texas, USA) and finished with diamond burs to a feather-edge gingival margin (Peter Brasseler Holdings, LLC, Savannah, Georgia, USA). The root apices were opened with a Gates-Glidden bur to allow access for a 1.5-mm diameter Type-J sheathed and grounded thermocouple (IC-SS-116-G-6; Omega Engineering Inc, Stamford, Connecticut, USA). Prepared samples were stored in 0.1% thymol solution until use.

The 22 blocks of IPS Empress CAD (Ivoclar Vivadent, Inc, Amherst, New York, USA) were designed and milled by another operator (DR), with a Cerec Omnicam and Cerec MC XL CAD/CAM System (Dentsply Sirona, Inc, York, Pennsylvania, USA). The thickness of the completed veneers was recorded in the midfacial area by operator JG, using a 500-302 caliper (Kerr Corporation, Orange, California, USA). Before cementation, each veneer was placed on its respective tooth preparation and the fit was confirmed visually and with a sharp dental explorer, using 6.0x magnification loupes (EF Loupes; Designs for Vision, Bohemia, New York, USA). Veneer preparations were etched with 35% phosphoric acid solution (Ultra-Etch; Ultradent Products, Inc, South Jordan, Utah, USA) for 20 seconds, rinsed with water spray for 10 seconds, and air dried. Bonding agent was applied (Peak Universal Bond; Ultradent Products, Inc) for 10 seconds, air dried with 50% pressure for 10 seconds, and light cured for 10 seconds (DemiUltra; Kerr Co, Orange, California, USA). The veneers were then luted to the prepared teeth using Variolink Esthetic LC (Ivoclar Vivadent, Inc, Amherst, New York, USA), according to the manufacturer's specifications. Specimens were stored in distilled water for at least 48 hours before laser irradiation.

Each sample (tooth embedded in acrylic block) was secured to a ring stand using a 3-prong vinyl coated support clamp. The thermocouple probe was positioned vertically, directly below the tooth sample using a similar support clamp, with the tip of the probe extending into the amputated root to the top of the pulp chamber. A dental latex dam was used to protect the probe housing and another was placed to protect the root of each tooth from inadvertent water contact. In order to confirm accuracy and sensitivity of the thermocouple setup, a curing light with an irradiance of 1135 mW/cm^2 (8-mm diameter tip with a 60° angle) was used after first stabilizing the temperature for 30 seconds before each treatment, and again for 30 seconds following the complete removal of each veneer (DemiUltra). In all cases, intrapulpal temperature normalized after laser irradiation stopped, demonstrating that there was no lag in thermal transfer, which could potentially cause a latent rise in temperature following treatment. The curing light control was confirmed, as the pulpal temperature increased 2°C after 30 seconds of light activation. (See Figure 1)

An Er,Cr:YSGG dental laser (Waterlase iPlus; Biolase, Inc, Irvine, California, USA) was fitted with a handpiece and laser fiber tip (600-µm diameter cylindrical fiber, 6 mm in length). The laser parameters were 333 mJ/pulse, 30 Hz (10.0 Watts), 80% air, 50% water, 600-µm diameter fiber, at a fluence of 885.96 J/cm^2. Quantitatively, laser energy is described in terms of the actual optical energy delivered per unit area (J/cm^2), which is called the laser fluence. The pulp chamber was filled with a conductive silicone paste (Omegatherm 201; Omega Engineering, Inc, Stamford, Connecticut, USA). A single experienced operator (CW) performed all trials, while another operator (JG) set up and monitored the thermocouple and recorded time measurements. The laser fiber tip was held directly on the surface of each veneer in contact, perpendicular to the surface, and activated when instructed by the timekeeper. The fiber tip was slowly moved across the surface approximately 2 mm/second, in contact, until each veneer was either dislodged whole or in fragments. Veneer fragments were retained for future evaluation.

RESULTS

All of the veneer samples fractured into at least three pieces and dislodged during laser irradiation. Light microscopy confirmed that the debonding occurred at the cement to veneer interface. This is an important fact since ablation along the tooth surface would be undesirable and could lead to potential thermal effects. Additionally, the composite that remained on the prepared surface was often darkly discolored. In all cases, the remaining composite resin was left in a weakened, "powdery" state, which could be easily removed with a hand instrument and gauze.

At the laser parameters tested (333 mJ/pulse, 30 Hz, 80% air, 50% water, 600-μm diameter fiber), the average duration of laser exposure to completely remove each laminate veneer was 14.71 ± 3.05 seconds, with a range of 11.5–21.25 seconds. The mean intrapulpal temperature increase for the irradiation period was 0.85 ± 0.88°C increase (Figure 1).

A Pearson correlation analysis was used to measure the strength of the linear relationship between the time, thickness, and temperature variables. The correlation coefficient between time and thickness was 0.67 and between time and temperature was 0.30 (Figures 2 and 3). Therefore, time and thickness were correlated moderately and positively; however, there was a weak positive correlation between time and temperature.

A simple linear regression analysis of the data between time in seconds, and thickness in mm was run. The regression line can be interpreted as follows: for every one-unit increase in the thickness of the veneer (1 mm), the value of time increased on average by 17.5 seconds ($p \leq 0.00058$). Although the average midfacial thickness for all samples was greater than the manufacturer's recommended 0.7 mm, 10 of 22 veneers were slightly less than 0.7 mm. It should be noted that this measurement was made at the true midfacial point of each veneer, which is positioned in a more gingival direction compared with the images on the manufacturer's product brochure, which is closer to the incisal edge. Since the preparations gradually increased from 0.6 mm at the gingival margin to 0.7 mm or more at the incisal edge, it would make sense that the facial reduction as measured at the midfacial of each preparation would vary and often be between 0.6 mm and 0.7 mm. In general, the time it took to remove each veneer increased in direct proportion to the thickness.

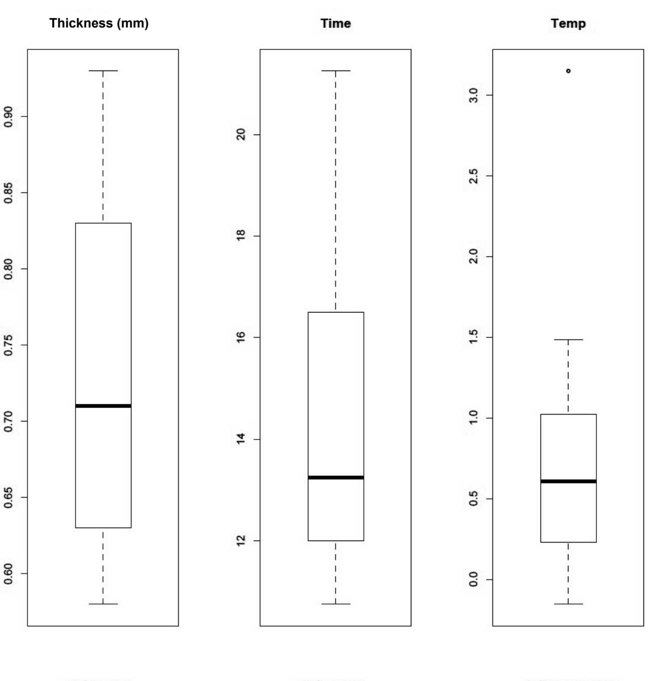

Figure 1. *Plots representing thickness of veneer (mm), time for removal (sec), and pulpal temperature change (ºC).*

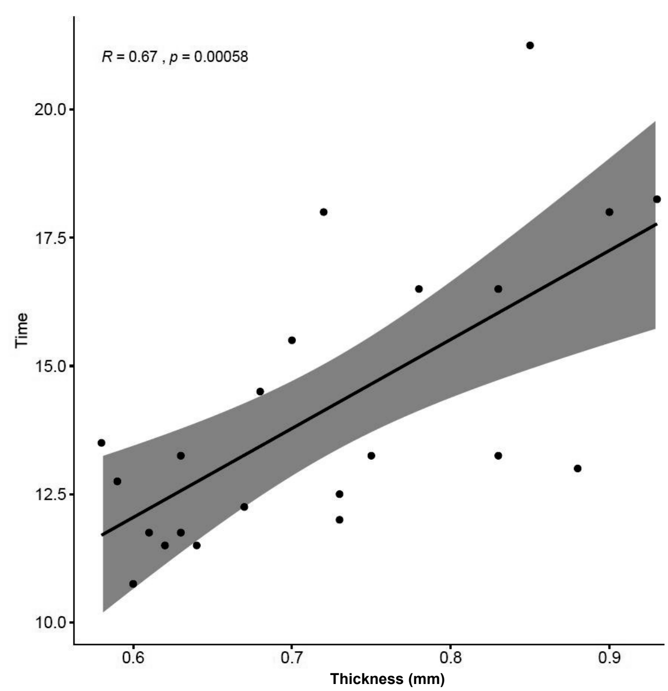

Figure 2. *The Pearson correlation coefficient between time and thickness is 0.67 (p=0.00058).*

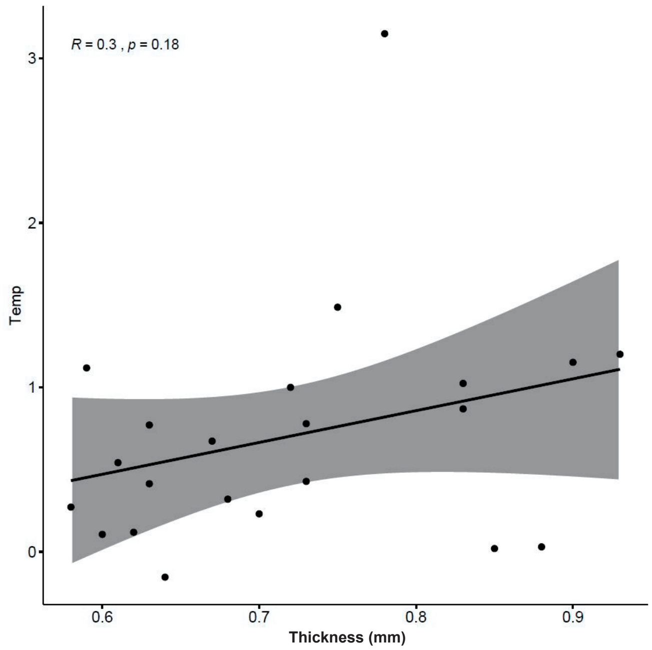

Figure 3. *The Pearson correlation coefficient between temperature and thickness is 0.30 (p=0.18).*

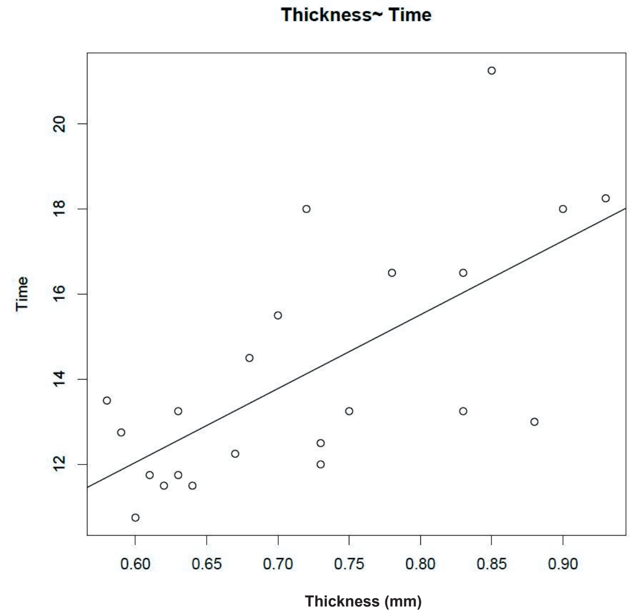

Figure 4. *The regression line is Time = 1.637 + 17.348 x Thickness. This regression line can be interpreted as follows: For every one-unit increase (1.0 mm) in Thickness of the veneer, the value of Time will increase on average by 17.348 seconds. The* p-value *of the model is reported as 0.00058 ≤ 0.05, which is significant.*

DISCUSSION

Van As and others have previously suggested lower laser fluences to debond laminate veneers.[27] In the Van As cases, the total laser treatment time was estimated to be as much as 60 seconds at 5–6 W average power; however, fiber size and fluence were not disclosed. Morford and others reported delivering varying average laser power values between 1.33 and 5.03 W delivered by way of a 1.1-mm diameter sapphire optical tip, in contact with the veneer surface.[28] The average treatment time was 113 ± 76 seconds, with a range of 31–290 seconds. Because of a concern for potentially unsafe intrapulpal temperatures, during preliminary trials, the authors used similar laser parameters, which resulted in outcomes similar to those reported previously. In another study, Rechmann and others tested all-ceramic IPS E.max CAD crowns using an erbium laser at 560 mJ/pulse and 10 Hz (5.6 W). Fluence was 45 J/cm^2 at the ceramic surface, which was approximately 5 mm from the tip.[29]

When comparing pulpal temperature rise in extracted human molars, Penn and others demonstrated that none of the tested devices (erbium laser, CO_2 laser, and the traditional high speed handpiece) caused an increase of more than 3.56°C, which was well under the generally accepted threshold of 5.5°C.[30,31,32,33,34,35] A study presented by Rizoiu and others, and a more recent presentation by this author has shown a decrease in intrapulpal temperature during dental cavity preparation using an Er,Cr:YSGG laser device.[36] More recently, Zach and Cohen's work[37] has come under question, as others have suggested that the "probably tolerable" thermal limit may actually be significantly higher than 5.5°C.

The results presented in this report, including the thermal data, suggest that laser debonding of laminate veneers can be successful at higher power densities, as the increase in pulpal temperature is minimal with sufficient water spray. In fact, it was shown that, despite what might otherwise be expected, higher laser energy did not cause a significant rise in pulpal temperature because of the short duration of laser exposure. Of course, thickness of laminate veneer, material type or even luting agent may result in different irradiation times. The importance of copious amounts of water spray during laser ablation cannot be overstated. As far back as 2007, Kang and others demonstrated that charring and cracks were the result of dry laser ablation.[38] Craters created in human enamel with the addition of water spray were relatively clean and without thermal damage. For this reason, the maximum amount of aerosolized water spray was deemed necessary (100% = 36 ml/minute).[39]

The inert nature of the ceramic material used in this study suggests that fracturing is likely due to the lower flexural strength as compared with zirconia, for instance (200-220 MPa vs 1,000 MPa).[28,29,30] In the case of porcelain, it has been shown that there can be a minute amount of water absorption, intraorally. If veneers are made of porcelain, erbium laser energy does not pass through freely. Instead, the light energy is absorbed by the water contained within the porcelain, causing fracture of the material.[27,31,32]

CONCLUSION

A regression model between time and thickness ($p<0.0001$) proved to be significant. However, the same cannot be said when the same modeling was tested between temperature and thickness. It can therefore be concluded that as the thickness of a veneer increases, more time is necessary to remove a veneer using Er,Cr:YSGG laser energy; however, increasing thickness does not necessarily result in an increase in pulpal temperature.

Within the limitations of this study, it can be concluded that removing CAD Empress laminate veneer restorations using an Er,Cr:YSGG laser is reliable and thermally safe, even at an average of 10 W at 30 Hz. Thermal safety is maximized so long as there is adequate aerosolized water spray.[38] Limitations of this study at the present time are that only one veneer material and one resin luting cement were tested. Further studies are necessary to compare results for different materials and various luting agents.

Conflict of Interest

The corresponding author is a consultant for Biolase, Inc, the manufacturer of the laser device used in this study. No monetary or support of any kind was received for this study.

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