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Effect of Er:YAG laser on debonding zirconia and lithium disilicate crowns bonded with 2- and 1-bottle adhesive resin cements

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Abstract:

Statement of problem: Erbium-doped yttrium-aluminum-garnet (Er:YAG) laser debonding of zirconia and lithium disilicate restorations are increasingly used for a range of clinical applications. Using rotary instruments to remove such restorations for any purpose has proven to be challenging. Erbium laser has been reported to be a conservative method for removing ceramic restorations. There is little data in the literature about the effect of adhesive resin cement type on the debonding time of the ceramic restoration using Er:YAG laser.

Objectives: To evaluate and compare the time required for Er:YAG laser to debond zirconia and lithium disilicate crowns bonded with a 2- and 1-bottle adhesive resin cement systems.

Material and methods: Forty extracted premolars teeth were prepared and scanned for milled 40 CAD/CAM crowns. Teeth were randomly assigned into groups (n=10 per group): 3 mol% yttria-partially stabilized zirconia crowns 3Y-PSZ (G1a) bonded with Panavia™ V5 (2-bottle adhesive resin cement), Zirconia 3Y-PSZ crowns (G1b) bonded with RelyX™ Ultimate (1-bottle adhesive resin cement), and for the lithium disilicate crowns bonded with the two types of cements (G2a, G2b) . Each specimen was irradiated with an Er:YAG laser at 300 mJ, 15 Hz, 5.0 W, and 50-microsecond pulse duration (super short pulse mode). The irradiation time required for crowns to be successfully debonded was recorded for each specimen. Data were statistically analyzed using ANOVA and Tukey HSD post-hoc test ($p<0.05$), at the 95 percent level of confidence. The intaglio surface of the debonded crown was analyzed using scanning electron microscopy (SEM).

Results: The mean ±standard deviation times needed for crown debonding were 5.75 ±2.00 minutes for the G1a group, 4.79 ±1.20 minutes for group G1b, 1.69 ±0.49 minutes for group G2a, and 1.12 ±0.17 for group G2b. There was no statistically significant difference in debonding time between the 2- and 1- bottle adhesive resin cement within the groups G1a and b (p=0.2914), or between groups G2a b (p=0.7116). Statistically significant difference (*P*<.05). was found between groups G1a and G2a and b and between G1b and G2a and b were SEM analysis showed no changes in the microstructure of the ceramic surface after Er:YAG laser irradiation.

Conclusion: Zirconia and lithium disilicate restorations can be debonded using Er:YAG lasers in a safe and efficient manner. There is no significant difference in the debonding time between the 2- and 1- bottle adhesive resin cement systems used in this study.

Introduction:

In recent decades, many different types of dental ceramic materials have been developed to satisfy the esthetic expectations of patients and professionals.[1] Enhancements in the mechanical, physical, and manufacturing properties of ceramic materials aim to closely mimic the structure of natural teeth.[2] Additionally, enhancements in the bonding technique of these ceramic restorations to natural teeth have also increased the use of ceramic restorations in dentistry.[3-5]

Nowadays, lithium disilicate and zirconia are the most commonly used ceramic materials for restoring anterior and posterior teeth with different types of restorations (veneers, inlays, onlays, crowns, and other fixed dental prosthesis), ensuring excellent function and esthetics.[5-8]

Modern dental technology, such as intraoral scanning and computer-aided design and manufacturing (CAD/CAM), has enabled rapid fabrication of dental prostheses.[9-12] Despite these advancements, replacement of these ceramic restorations is inevitable due to factors such as fracture of the restoration, microleakage of the luting cement, discoloration, or any other failure.

One of the drawbacks of these adhesively luted ceramic prostheses is the difficult removal procedure in one-piece with conventional removal techniques. The conventional removal technique by using a handpiece with cutting burs could be a long procedure and lead to damage to the underlying natural tooth structure due to difficulty in differentiating between the color of the cement and the tooth structure.[2,13-17]

Erbium lasers have been studied as an alternative method for the removal ceramic restorations from tooth abutment. The light emitted by erbium lasers, for example, (Er:YAG) laser, can penetrate through translucent ceramic materials, be selectively absorbed by water molecules and remaining monomers in luting cements, causing the molecules to evaporate and the cement to debond. Although there are numerous benefits to this approach, a number of clinical operating factors may have an impact on its effectiveness, such as the different types and thicknesses of ceramics, different laser parameters, and different types of cements and their chemical compositions.[2,14,15,18]

Cement type plays a role in the laser debonding of ceramic restorations.[19,20] There is little information in the literature about the transmission of Er:YAG lasers through ceramics bonded with different adhesive resin cement systems. Therefore, the purpose of this study was to evaluate the effect of the transmitted Er:YAG laser energy through lithium disilicate and zirconia crowns cemented with 2- and 1-bottle adhesive resin cements *in vitro*. The null hypothesis is that there are no significant differences in the effect of Er:YAG laser on debonding of ceramic crowns luted with 2- or 1-bottle adhesive resin cements..

Materials and Methods:

This study was conducted under the Code of Medical Ethics of XXXXX. Forty freshly extracted human premolars, sound and free of caries, cracks, or restorations were used for this study (n=10 per group). The evaluated teeth were cleaned from any attached soft tissue using a hand scaler and stored in a saline solution at 37 ºC until the time of preparation. Each tooth was embedded in an acrylic resin mold, leaving the crown part of the tooth exposed for preparation. Then, all teeth were prepared by the first author (S.S.) with a high-speed electric motor handpiece and diamond rotary instruments with generous air and water coolant to receive zirconia or lithium disilicate crowns according to the manufacturer’s instructions. Two groups of ceramic crowns were fabricated (n=20 per group): 3Y-PSZ (G1) (Katana HT; Kuraray Noritake Dental Inc, Japan) and lithium disilicate (G2) (IPS E.max; Ivoclar Vivadent, Liechtenstein) as a control. For the crown preparation design, the margin width for the axial reduction was 1 mm for both materials, and the occlusal reduction was 1.2 mm for the zirconia crowns and 1.5 mm for the lithium disilicate crowns. The margin configuration was a rounded shoulder and was prepared by using a modified shoulder diamond rotary instrument (847KR; Komet, USA). All the preparations were tapered between 6 and 10 degrees for passive crown fitting.

After preparations, all the teeth were numbered and scanned using an intraoral scanner (3Shape Trios 4, Copenhagen, Denmark). The scanned file was then exported to MeshMixer© (Autodesk, Inc.) software, where the prepared tooth surface area [mm^2] and cement volume [mm3] were calculated. Then, crowns were virtually designed by CAD software (3Shape Dental System 2020, Copenhagen, Denmark) and then milled by PrograMill PM7 milling machine (Ivoclar Vivadent: Schaan, Liechtenstein) from unsintered zirconia discs of (3Y-PSZ) and lithium disilicate IPS E.max blocks. The milled crowns were then sintered or crystallized, stained, and glazed according to the manufacturer's recommendation. Subsequently, all fabricated crowns were tried on the prepared teeth to determine fit. 3Y-PSZ crown intaglio surface is treated with air-particle abrasion with 50-micron particles at 30 PSI pressure for 15 seconds and at a 10 mm distance. The crowns were bonded first with Panavia V5, a 2-bottle adhesive resin cement (Kuraray Noritake Dental Inc. Tokyo, Japan). After air-particle abrasion, the 'ceramic primer' is applied according to the manufacturer's instructions; this group is referred to as G1a. The second group is bonded with RelyX Ultimate, a 1-bottle adhesive resin cement (3M ESPE, Oral Care, St Paul, MN, USA), in which the crown surface is treated with a self-adhesive bonding agent (Scotchbond Universal, 3M ESPE, Oral Care, St Paul, MN, USA); this group is referred to as G1b. The same procedure was repeated for the lithium disilicate crowns, referred to as G2a and G2b, but instead of air-particle abrasion, the crown surface is treated with 5% hydrofluoric acid for 20 seconds before bonding and according to the manufacturer's instructions.

Crowns were seated on the specimens by manual pressure, and excess cement was removed after tack-polymerization for 2 seconds with a Valo curing light with an irradiance value of 1180 mW/cm^2 (Ultradent, Utah, USA), on both the facial and lingual surfaces. Then, the light curing was continued for an additional 20 seconds on the buccal, lingual, and occlusal surfaces, mimicking the clinical application. After cementation, the specimens were kept in a humidor prior to the crown debonding procedure.

Then, all specimens were irradiated with the Er:YAG laser (LightWalker; Fotona, Ljubljana, Slovenia) at 2940 nm with the following manufacturer recommended parameters: 335mJ; 15Hz; 5.0W, 4 water/4 air, operation mode: SSP mode with a tipless handpiece (HO_2, Fotona) at a distance of 5-8 mm and irradiation directed perpendicular to the crown.[21-24] Throughout the irradiation procedure, air and water sprays was utilized. The irradiation was carried out with continuous axial motion on buccal and lingual surfaces, simulating clinical scenarios in which interproximal locations are inaccessible, and was performed by the same operator. Darkening of the cement was observed under the crowns, indicating ablation of the cement and disruption of the adhesive seal. The dislodgement of the crown was assessed after irradiation of all surfaces and periodically during additional irradiation until the crown could be removed using light tapping, elevating forces, and digital manipulation either by a gentle finger-pulling action or by passively lifting off the crown with an instrument applied along the buccal and lingual margins opening due to loss of adhesive strength of cement between tooth and restoration. If the crown could not be successfully removed, additional intervals of irradiation and crown manipulation followed until the crown was successfully debonded. The irradiation time (minutes) required for the crowns to debond was recorded for each specimen. The debonding times for each group were analyzed for statistical significance using ANOVA and Tukey HSD post-hoc tests ($p<0.05$), at the 95% level of confidence.

After debonding, the surface integrity and the mode of adhesive failure of the debonded crowns following laser irradiation were examined using a scanning electron microscope (SEM) (Hitachi S-4700 Field Emission Microscope, Tokyo, Japan).

Results:

In all groups, crowns were successfully debonded without damage to the crown or tooth structure. The mean ±standard deviation times needed for crown debonding were 5.75 ±2.00 minutes for the group G1a, 4.79 ±1.20 minutes for the group G1b, 1.69 ±0.49 minutes for the group G2a, and 1.12 ±0.17 minutes for the group G2b (Table 1). There was no statistically significant difference between the 2- and 1- bottle adhesive cements that were used within the between zirconia G1a and G1b ($p=0.2914$), and lithium disilicate groups G2a and G2b ($p=0.7116$). However, statistically significant difference ($P<.05$) was recorded between groups G1a and G2a and b, and between G1b and G2a and b, . The mean ±standard deviation surface areas of the prepared teeth were 109.9 ±10.0 mm^2 for the 3Y-PSZ groups and 83.4 ±8.9 mm2 for the lithium disilicate control group.

Visual and SEM examination did not reveal any damage or major structural changes suggestive of photoablation or thermal ablation (Figure 1). The adhesive failure was demonstrated on both interfaces with residual cement seen mostly attached to the intaglio surfaces of the crowns. No carbonization, cracks or fractures in the macro- or microstructure were observed on the tooth and/or the ceramic crown surfaces. However, occasionally signs of partial ablation of both cements layer produced by the Er:YAG laser irradiation were noticed. In the SEM images of the crown/cement interface for the both cements showed cement explosion, ablation and hydrodynamic ejection (Figure 2).

Discussion:

Consistent with previous research, the use of Er:YAG laser to debond all ceramic restorations is regarded as a risk-free, time-efficient alternative to conventional methods that does not result in harm to the crown or tooth structure.[2,20,24,25] In terms of the time required for laser-assisted crown debonding, the null hypothesis that there would be no difference between 2-bottle and 1-bottle adhesive resin cement systems was accepted irrespective of the ceramic types utilized in this study.

Similar to previous reports, light microscopy analysis of the dental hard tissues and ceramic crowns subsequent to the debonding procedure unveiled that they remained undamaged. (Figure 1).[21,24,26,27] The laser debonding method appears to leave a smear layer and residual cement layer covering the dentin surface in contrast to when a rotary instrument is used for crown retrieval (Figure 2).[26]

The results of this study demonstrated that the average debonding time for the 3Y-PSZ zirconia crowns bonded with 2- and 1- bottle adhesive resin cements were three to four times longer than time needed to debond lithium disilicate crowns. Thus, practitioner should be reserve longer appointment time to debond zirconia crowns than lithium disilicate crowns. These findings agree with previous studies.[1,2,20,24,25]

The bonding method between the two evaluated resin cements differ in that the 2- bottle adhesive resin cement (Panavia V5) relies on a use of primer that is applied to the crown and a self-etching tooth primer that is applied to the tooth structure. The 1-bottle adhesive resin cement (RelyX Ultimate) relies on using a Scotchbond Universal adhesive that is a tooth-self-etching primer and a crown primer in one bottle. The findings of the present study demonstrated no difference in the debonding time of the ceramic crowns when using Er:YAG laser regardless of the resin cement type. However, the type of ceramic plays a significant role in the laser transmission and debonding time which was consistent with previous studies. [1,20,24,28]

The shorter laser debonding time for lithium disilicate ceramic material is due to the inherent higher translucency values of less crystalline-based ceramics in comparison with zirconia materials, which are denser crystalline-based ceramics. Furthermore, laser energy absorption and penetration through lithium disilicate material are greater than through zirconia material.[2,24,25,29] The debonding procedure by Er:YAG laser is based on thermal ablation or explosion and hydrodynamic ejection, as demonstrated in the SEM images of the crown-to-cement interface for both tested cements (Figure 2). After resin cement absorbs the finally transmitted laser energy which is called cement ablation, the ceramic crowns can be successfully debonded without damage to the crown or tooth structure.

The Er:YAG laser power settings used in this study (335 mJ; 15 Hz; 5 W) were previously established as effective parameters to achieve crown debonding without harming the pulpal tissue which are consistent with previous studies.[2,20,27,30.31]

This study contains few limitations that must be highlighted for future research. This study was conducted on extracted teeth, which may not reflect the exact clinical condition. Therefore, clinical trials demonstrating the *in vivo* debonding time of ceramic crowns are necessary. In addition, only two cement types and one crown thickness (1 mm) were used. Different cement types and ceramic thicknesses may affect the debonding time findings. Furthermore, there was no standardization in the tapping force used by the clinician to remove the crowns from the teeth (difficult to calibrate), which could alter the debonding time.

Conclusion:

Within the limitations of this study, the following conclusions can be drawn:

1- Zirconia and lithium disilicate restorations can be debonded by Er: YAG lasers in a safe and efficient method.

2- The debonding time of zirconia is longer than lithium disilicate restorations.

3- There is no significant difference in the debonding time between the 2- and 1- bottle adhesive resin cement systems used in this study.

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Table 1. Mean values and standard deviations for crown debonding in minutes using Panavia V5 (2-bottle) and RelyX Ultimate (1-bottle) adhesive resin cements.

Group (n=10)	Mean time (mins)	St.dev	P
3Y-PSZ/ Panavia™ V5 (G1a)	**5.75[a]**	**2.00**	**0.2914**
3Y-PSZ/ RelyX™ Ultimate (G1b)	**4.79[a]**	**1.20**	
Lithium Disilicate/ Panavia™ V5 (G2a)	**1.69[b]**	**0.49**	**0.7116**
Lithium Disilicate/ RelyX ™Ultimate (G2b)	**1.12 [b]**	**0.17**	

Same superscript letter indicates no statistical significance (*P*>.05)

Figure 1: Scanning electron microscope images of intaglio surfaces of ceramic restorations following irradiation with Er:YAG laser. Black arrows indicate ceramic surfaces without any noticeable damage while white arrows indicate residual cement. A, 3Y-PSZ zirconia bonded with Panavia V5. B, 3Y-PSZ zirconia bonded with RelyX ultimate, C. Lithium disilicate bonded with Panavia V5 and D, Lithium disilicate bonded with RelyX ultimate.

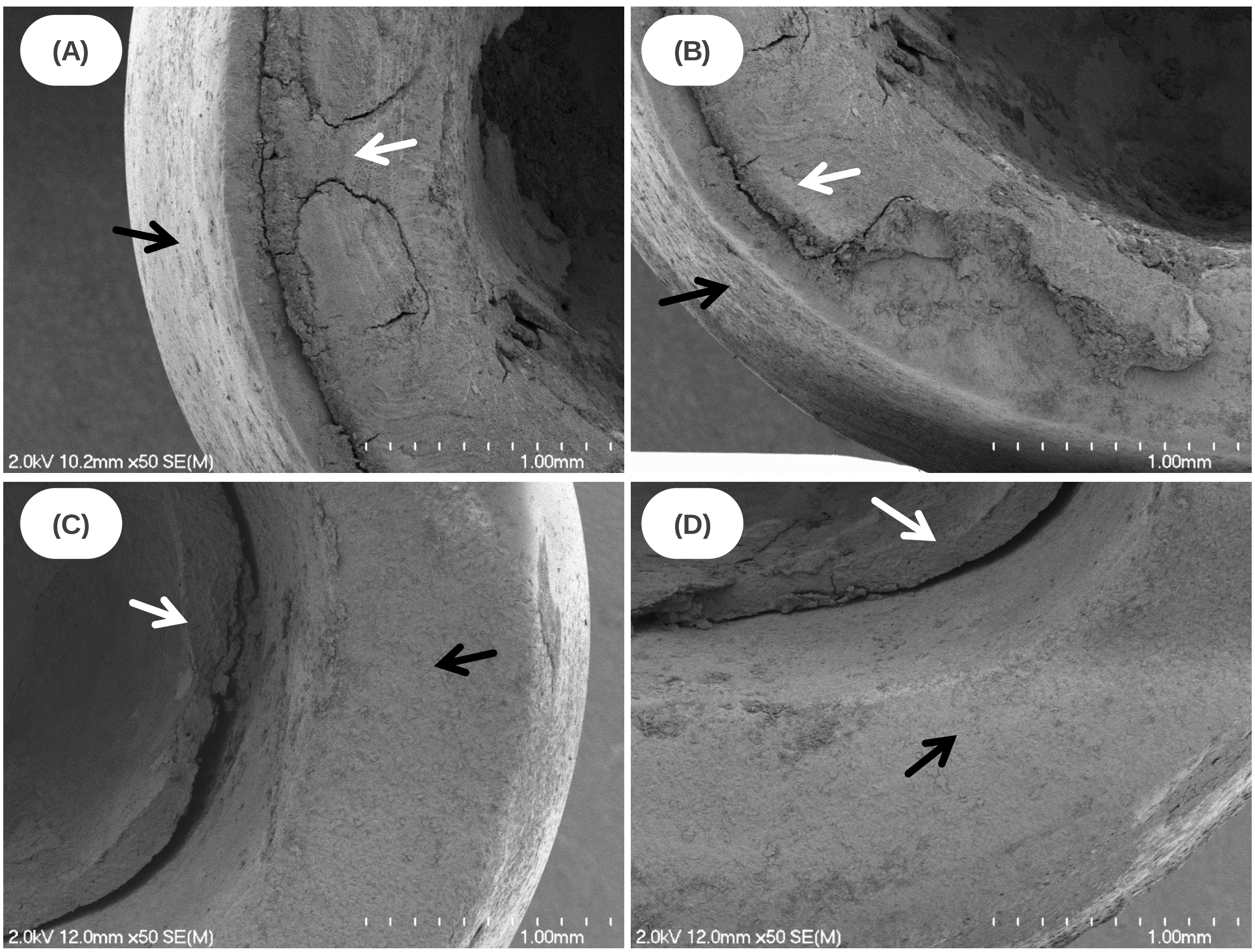

Figure 2: Scanning electron microscope images of the crown/cement interface. White arrows indicate cement explosion, ablation, and hydrodynamic ejection.