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Article

The contribution of ceramic thickness and adhesive type on the de-bonding strength of dental ceramic veneers using Er,Cr:YSGG laser.

La contribución del espesor de la cerámica y el tipo de adhesivo a la resistencia de desunión de las carillas dentales de cerámica con láser Er, Cr: YSGG.

Berivan Dundar Yilmaz.[1]
Zelal Seyfioglu Polat.[1]
Ayca Deniz Izgi.[1]
Derya Toprak Gunduz.[2]
Roda Seseogullari Dirihan.[3]

Affiliations: [1]Dicle University Dentistry Faculty, Prosthodontics Dept, Diyarbakır, Turkey. [2]Adiyaman University Dentistry Faculty, Prosthodontics Dept, Adiyaman, Turkey. [3]Turku University, Dental Materials Dept, Turku, Finland.

Corresponding author: Berivan Dündar Yilmaz. Dicle University Dentistry Faculty Prosthodontics Dept. 21280 Diyarbakır, Turkey. Phone: (90-506) 5595181. E-mail: berivandndr@yahoo.com

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Abstract: Purpose: De-bonding strength of ceramic veneers by laser use needs to be evaluated in detail. The aim of this study, is to determine the contribution of ceramic thickness and cementing agents to the de-bonding strength of ceramic veneers using Er,Cr:YSGG laser. Methods: A total of 120 maxillary central incisors specimens were randomly divided into twelve groups on the basis of disc thickness, cementing agent, and Er,Cr:YSGG laser use. Under laboratory conditions, 120 IPS Empress II system discs 0.5mm, 1mm, and 2mm in thickness were applied to the tooth surfaces, for laser use. An Er,Cr:YSGG laser system was applied to the central surface of the IPS Empress II discs on specimens in all laser groups (Groups 1,3,5,7,9,11). Then the shear bond strength (SBS) for all specimens were tested with a testing machine at a speed of 0.5mm/min. The SBS values were considered as the de-bonding strength. Results: The mean de-bonding strength values for Groups 9 and 11 (0,5 mm disc thickness + laser application) have the lowest median load (0.000 N), while Group 4 (2mm disc thickness + no laser) has the highest median load (573.885 N). The de-bonding strengths of all the groups without laser application were higher than those of all groups with laser use. When laser is applied, the mean de-bonding strength decreases with decreasing disc thickness, and it reaches zero at 0.5mm thickness of discs cemented by self- or total-etch adhesives. Conclusions: The de-bonding strength decreases with laser use, and decreasing disc thickness. In the absence of laser, the mean de-bonding values of discs cemented by a total etch adhesive system are always higher than those of discs cemented with a self-etch adhesive system. Without any extra load, all 0.5mm thick discs were dislodged from teeth while applying or testing the laser.

Keywords: *Lasers, erbium-doped yttrium aluminum garnet; dental veneers; ceramics; tooth preparation; dental debonding.*

Resumen: Propósito: La resistencia de desunión de las carillas de cerámica mediante el uso del láser debe evaluarse en detalle. El objetivo de este estudio es determinar la contribución del espesor de la cerámica y los agentes de cementación a la resistencia de desunión de las carillas de cerámica utilizando el láser Er, Cr: YSGG. Métodos: Un total de 120 incisivos centrales maxilares se dividieron al azar en doce grupos según el grosor del disco, el agente de cementación y el uso del láser Er, Cr: YSGG. En condiciones de laboratorio, se aplicaron en las superficies de los dientes 120 discos del sistema IPS Empress II de 0,5mm, 1mm y 2mm de grosor, para uso con láser. Se aplicó un sistema láser Er, Cr: YSGG a la superficie central de los discos IPS Empress II en muestras de todos los grupos de láser (Grupos 1,3,5,7,9,11). Luego, la resistencia de la unión al cizallamiento (SBS) para todas las muestras se probó con una máquina de prueba a una velocidad de 0.5mm/min. Los valores de SBS se consideraron como la fuerza de desunión. Resultados: Los valores medios de resistencia de desunión para los Grupos 9 y 11 (espesor de disco de 0,5mm + aplicación de láser) demostró la carga media más baja (0,000 N), mientras que el Grupo 4 (espesor de disco de 2 mm + sin láser) tuvo la carga media más alta (573.885 N). Las fuerzas de desunión de todos los grupos sin aplicación de láser fueron superiores a las de todos los grupos con uso de láser. Cuando se aplica el láser, la fuerza media de desunión disminuye al disminuir el grosor del disco, y llega a cero con el grosor de 0,5mm de los discos cementados, para ambos adhesivos de grabado. Conclusiones: la fuerza de desunión disminuye con el uso del láser y disminuye con el grosor del disco. En ausencia de láser, los valores medios de desunión de los discos cementados con un sistema de adhesivo de grabado total son siempre más altos que los de los discos cementados con un sistema de adhesivo de autograbado. Sin ninguna carga adicional, todos los discos de 0,5mm de grosor se desprendieron de los dientes al aplicar el láser.

Palabras Clave: *Lasers de erbio; itrio aluminio y garnet; coronas con frente estético; cerámica; preparación del diente; desconsolidación dental.*

INTRODUCTION.

Ceramic veneers have been widely used as dental treatment materials since 1980's. [1-7] They are adhesively cemented with a light-curing or self-curing resin after the tooth has undergone minimal invasive preparation, which is typically limited to enamel, the outer layer of a tooth.[8,9] Dental veneers are thinly tooth-colored materials designed to cover the front surface of teeth to improve appearance. Some imperfections such as cracks, gaps and flaws on the surface of the teeth can also be aided by dental veneers. These imperfections can be fixed without advanced and painful surgical procedures. Aesthetic issues (cracks, fractures, abrasion, color changes), biological problems (bruises, loss of support, periodontal problems) and technical complications (loss of retention, fracture of support teeth, materials complications) may occur in these restorations over time, and they may need to be dismantled.[10]

Removing the porcelain veneers from the teeth is achieved by applying a mechanical force. Such force may lead to fracture of the ceramics or division of the tooth with the restauration.[11] Conventional removal methods mostly include grinding down the veneer with a diamond bur. Patient discomfort, long duration of de-bonding, and damage to the tooth are some disadvantages of the conventional laminate veneer removal procedure. With the growing role of pulsed lasers in dentistry, lasers have recently been increasingly investigated as an alternative method for removing veneers.[8,9,12-23] The effects of laser methods on de-bonding strength of porcelain veneers have been assessed in many studies.[8,9,12,15,17,20-23] Cement type has also been examined for re-cementing restorations.[24,25] The effects of ceramic thickness on early bond strength, color masking, fracture resistance and flexural strength have also already been evaluated.[26,30]

To the best of our knowledge, the variation of the de-bonding strength of ceramic veneers on ceramic thickness and luting agent under laser application has not been yet evaluated.

The objective of this study is to determine how the de-bonding strength of ceramic veneers depends upon ceramic thickness and adhesive types, under laser use. The de-bonding strength was also determined without the use of laser. Teeth extracted for periodontal reasons, ceramic discs with different thickness (0.5mm, 1mm and 2mm) and two different luting agents (Panavia F and RelyX ARC) were used as material. Groups were composed on the basis of ceramic thickness, adhesive type and Er,Cr:YSGG laser use. Groups were compared statistically.

MATERIALS AND METHODS.

Tooth specimens and assignment of groups

One hundred twenty maxillary central incisors (60 for control groups) extracted for periodontal reasons were selected for this study. They were free of cracks, caries and fractures. One hundred twenty IPS Empress II ceramic discs were also prepared as described below. They were equally divided into three groups (40 discs in each group) on the basis of disc thickness. Then twelve experimental groups were formed in according to disc thickness, luting agents and Erbium-Doped Yttrium Aluminum Garnet Laser use (Er,Cr:YSGG laser) application. Prepared tooth specimens were assigned randomly to these twelve groups (total n=120, n=10 per group). Materials used in this study are described in Table 1. For convenience, the groups and relevant parameters are also shown in Table 2 and Table 3.

Tooth space preparation and conditioning of tooth surface

All teeth were stored in 0.9% NaCl solutions. To inhibit microbial growth the water was changed weekly. All external debris was removed using an ultrasonic scaler (Mini Piezon, EMS Piezon Systems, Nyon, Switzerland). After removing debris, the extracted teeth were kept in

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an isotonic solution during the study. Guide grooves were opened using a high-speed hand piece (NSK, Nakanishi Inc, Germany) and a porcelain laminate preparation bur kit (M Diatek, Switzerland) was used for surface preparation. Particular care was taken to cut the enamel surface less than 0.5mm deep and to stop cutting at the enamel border. Care was also taken to obtain perfect parallel surfaces suitable for adhering the IPS Empress II ceramic discs.

A 35% phosphoric acid gel (Adper Scotchbond, 3M ESPE; Seefeld, Germany) was applied to the surface of the teeth in groups 3,4,7,8,11 and 12, using a microbrush for 15s. Care was taken to completely rinse the etching gel for 15s and then the tooth was air dried. Teeth were conditioned and primed with a total-etching adhesive (Rely X ARC, 3M, ESPE, Seefeld, Germany) and polymerized for 10 s with a polymerizing unit (Polofil Lux, Halogen light; Voco, Cuxhaven, Germany). Teeth in groups 1, 2, 5, 6, 9 and 10 were conditioned and primed with a self-etching system (Clearfil SE Bond, Primer; Kuraray Co. Ltd, Kurashaki, Japan) and polymerized for 10s with a polymerizing unit (Polofil Lux, Halogen light; Voco, Cuxhaven, Germany) while those in groups 3, 4, 7, 8, 11 and 12 were conditioned and primed with a total-etching system.

IPS Empress II systems discs fabrication and cementing to the tooth surface

Under laboratory conditions, 120 IPS Empress II system discs (IPS Empress II, Ivoclar, Schaan, Liechtenstein; 0.5 mm (n=40), 1mm (n=40), and 2mm (n=40) in thickness and 5mm in diameter were prepared for application to the tooth surfaces. Hydrofluoric acid (4 %) was applied for 60s to the surfaces of the 120 IPS Empress II system discs. All surfaces were then washed with water under pressure using an air/water spray for 20s. Each surface was then dried for 20s using air spray only. Silane coupling agent (Espe-Sil, 3M Espe AG) was applied onto the surface of the discs using a clean brush and left for 3mm allowing the silane to react. Finally, the surfaces were made ready for cementing.

Dual-cure resin cements were used to cement the IPS Empress II discs to the surfaces: In groups 3, 4, 7, 8, 11 and 12, the IPS Empress II discs were cemented with Rely-X ARC resin cement. In groups 1, 2, 5, 6, 9 and 10, Panavia-F cement was used, according to the manufacturer's instructions. The cementing procedure for all teeth was performed under a 750g load. For all teeth, the roots surfaces were embedded in autopolimerizing acrylic resin (Takilon, Rodent SRL, Milano, Italy) using a 2.5×2.5×2 cm standard acrylic matrix with the crown facing upward. Following completion of polymerization, each sample in the matrix was prepared for the experiment by cutting its edges without damaging the acrylic blocks.

Applying Er,Cr:YSSG laser and testing of shear bond strength

In all laser groups specimens (Group 1,3,5,7,9,11), an Er,Cr:YSGG laser system (Waterlase MD, Biolase, USA) was applied to the central surface of the IPS Empress II discs. The distance between the tip of the device and the surface was kept at 1 mm, and the laser beam was applied to the entire surface for 180s. The laser was applied at a wavelength of 2,780nm with a pulse duration of 140µs and a repetition rate of 20Hz. The laser output power was 5.5 W (275mJ pulse energy). Laser energy was delivered through a fiber-optic system via a sapphire tip terminal 600 µm in diameter and the surface was bathed with an adjustable air/water spray using a water level of 80% and an air level of 90%.

After applying the Er,Cr:YSGG laser system on the corresponding groups, the shear bond strength (SBS) for all specimens was tested with the composite block and the edge of the enamel surface on the crosshead of the testing machine (LRX, Lloyd Instruments Ltd., Fareham, UK) at a speed of 0.5mm/min. The force recorded in Newton was considered as the de-bonding strength of ceramic veneers from teeth.

Failure Analysis and scanning electron microscopy

Classification of the enamel failures was made according to the adhesive remnant index (ARI). All samples were then scanned at the KOSGEP research laboratory of Erciyes University, Turkey. The applied laser surfaces of the discs bases were examined from representative failure types under scanning electron microscopy (Leo 440 computer-controlled digital scanning electron microscope) at 3.80 Å resolution. (Figure 1A, 1B, 1C)

Statistical Analysis

Mean, standard deviation and median values of de-bonding strength were calculated for continuous and discrete variables respectively. The means of groups were analyzed by one-way ANOVA followed by the Post-Hoc Bonferroni test. The medians of groups were analyzed by the Kruskall-Wallis test followed by the Mann-Whitney U-test with Bonferroni correction. Logarithmic transformation was used to stabilize the variance of data before the ANOVA. Two-sided *p*-values were considered statistically significant at p=0.05 or below. Statistical analyses were carried out using the statistical packages for SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA).

Figure 1. Scanning electron microscopy of surfaces of the discs bases.

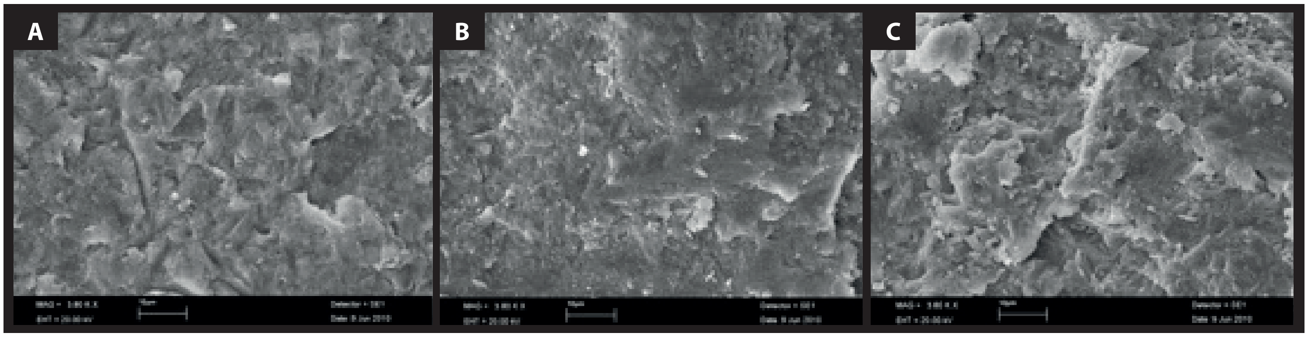

Figure 2. Dependence of debonding SBS on groups.

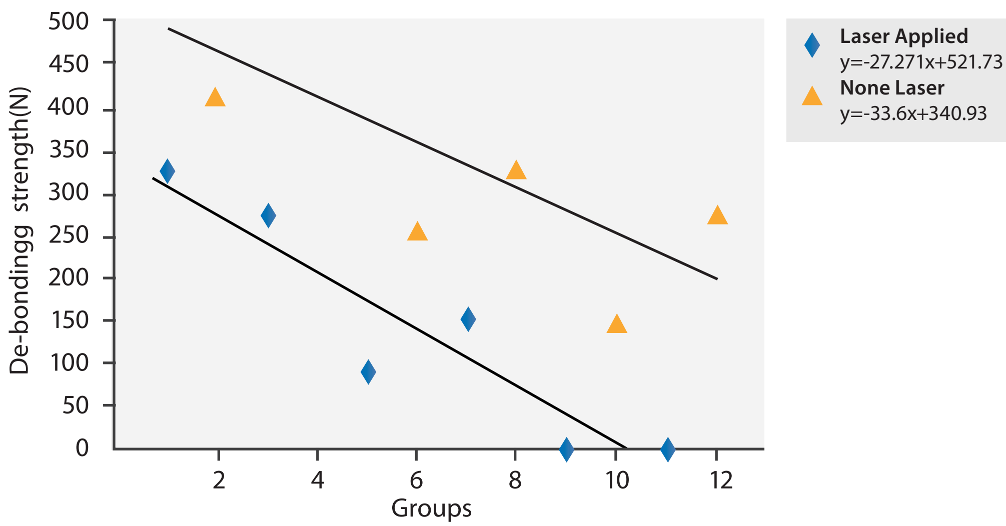

Figure 2. Dependence of debonding SBS on disc thickness.

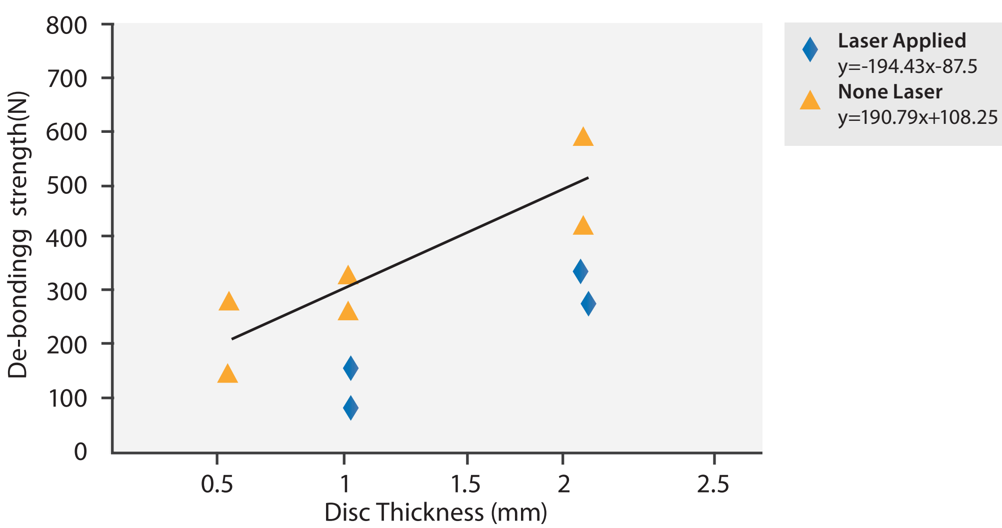

Table 1. Materials used in this study.

Product	Manufacturer	Compoition According to manufacturer
Panavia F	Kuraray Dental, Osaka, Japan	Bis-GMA with 10-methacryloyloxydecyl dihydrogen phosphate (MDP)
Rely-X ARC	3 M Dental Products, St Paul, MN	Bis-GMA, TEGDMA, zirconia, silica filler dimethacrylate polymer, amine
Clearfil SE Bond (SE; SE-PB)	Kuraray Co., Osaka, Japan	Primer: MDP, HEMA, hydrophilic dimethacrylates, N, N-diethanol p-toluidine, CQ, water Bond: MDP, HEMA, Bis-GMA, hydrophobic dimethacry-lates, silanated colloidal silica, N,N-diethanolp-toluidine, CQ
Adper Scotchbond Multi-Purpose Adhesive (MP)	3M ESPE Dental Products, St.Paul, MN USA	HEMA, Bis-GMA, Catalysts

Bis-GMA: bisphenol A diglycidyl ether dimethacrylate. **HEMA:** 2-hydroxyethyl methacrylate. **MDP:** 10-methacryloyloxydecyl-dihydrogen phosphate.

Table 2. The means and standard deviations of decementation strengths of groups.

Group name	Thickness mm	Etching System Self Etching *or* Total Etching	LASER Aplication	x±SD Mean Median Load (Newton)	Std. Deviations	ANOVA F	*p*
Group 1[a]	2	Self Etching	Laser	317.4	183.3	24.815	≤0.001
Group 2[b]	2	Self Etching	No	411.1	133.3		
Group 3[c]	2	Total Etching	Laser	275.6	165.1		
Group 4[d]	2	Total Etching	No	573.8	130.1		
Group 5[e]	1	Self Etching	Laser	91.41	89.66		
Group 6[f]	1	Self Etching	No	256.5	54.78		
Group 7[g]	1	Total Etching	Laser	151.9	105.7		
Group 8[h]	1	Total Etching	No	325.1	76.89		
Group 9[i]	0.5	Self Etching	Laser	.000	0000		
Group 10[j]	0.5	Self Etching	No	144.9	75.71		
Group 11	0.5	Total Etching	Laser	.000	0000		
Group 12	0.5	Total Etching	No	272.7	75.47		

[a]: The mean value of Group 1 was found significant difference with; Group 4,5,9,11 (*p*≤0.001),Group 6 (p≤0.049), Group 10 (*p*≤0.030).
[B]: The mean value of Group 2 was found significant difference with; Group 4,9,11 (*p*≤0.001), Group 5 (*p*≤0.013).
[C]: The mean value of Group 3 was found significant difference with; Group 5,7,9,10,11 (p≤0.001).
[d]: The mean value of Group 4 was found significant difference with; Group 5,6,7,8,9,10,11,12 (p≤0.001).
[e]: The mean value of Group 5 was found significant difference with; Group 8 (p≤0.001), Group 12 (p≤0.016).
[f]: the mean value of Group 6 was found significant difference with; Group 8 (p≤0.029).
[g]: the mean value of Group 7 was found significant difference with; Group 9 (p≤0.001), Group 10 (p≤0.001).
[h]: the mean value of Group 8 was found significant difference with; Group 9,11 (p≤0.001), Group 10 (p≤0.017).
[i]: the mean value of Group 9 was found significant difference with; Group 12 (p≤0.001).
[j]: The mean value of Group 10 was found significant difference with; Group 12 (p≤0.001).

Table 3. Failure modes obtained for the enamel and the disc bases after disc removal.

	Thickness (mm)	Etching System	Application	Dislodged*	0	1	2	3	Enamel Fracture
Group1/Group 2	2	Sef	Laser	0/0	3/3	0/1	1/3	3/1	3/1
		Self	NO						
Group 3/Group4	2	Total	Laser	0/0	0/0	0/0	2/7	3/1	5/2
		Total	No						
Group 5/Group 6	1	Self	Laser	0/0	0/0	0/4	0/4	10/2	0/0
		Self	NO						
Group 7/Group 8	1	Total	Laser	0/0	2/0	0/4	3/4	3/0	2/0
		Total	No						
Group 9/Group 10	0.5	Self	Laser	10/0	0/2	0/1	0/6	10/1	0/0
		Self	NO						
Group 11/Group 12	0.5	Total	Laser	10/0	0/6	0/0	0/4	10/0	0/0
		Total	No						

Self ething System: Panavia F. **Total Ething System:** Rely X ARC. ***:** During applying laser or testing. **Score 0:** No adhesive luting agent left on the enamel surface. **Score 1:** Less than half of the adhesive luting agent left. **Score 2:** More than half of the adhesive luting agent left. **Score 3:** All adhesive luting agent left on the enamel surface, with a distinct impression of the discs.

RESULTS.

De-bonding strength of ceramic veneers

The mean de-bonding strength values for each group are listed in Table 2. Group 9 (0.5mm disc thickness+self-etch adhesive system + laser application) and Group 11 (0.5mm disc thickness + total etch adhesive system + laser application) have the lowest median load (0.000 N), while Group 4 (2mm disc thickness + total etch adhesive system + no laser) has the highest median load (573.885 N). The de-bonding strengths of all groups are shown in Figure 2. It can be observed that laser application causes a clear decrease in de-bonding strength in all groups. The dependence of the de-bonding strength on disc thickness is shown in Figure 3. It can be observed that the de-bonding strength is linearly proportional to disc thickness. The de-bonding strength obtained by laser use is almost zero for discs 0.5mm thick, and it increases with increasing disc thickness.

The de-bonding strengths obtained without laser at each thickness are higher than the corresponding ones with laser use. The results shown in Figure 2 and Figure 3 can be confirmed by statistical analysis. Grouping variables were laser application, absence of laser, disc thickness and luting agents.

Significant differences, given as footnote under Table 2, were observed among the groups. Whenever a significant difference was determined between any two groups, some variables of these groups were different. Accordingly, the observed difference is directly caused by one of such variable in agreement with Figure 2 and Figure 3. The mean de-bonding values of ceramic veneers on resin type are shown in Table 2. The effect of self-etch and total-etch systems can be analyzed on the basis of laser application: In the absence of laser, the mean de-bonding values of total-etch specimens are always higher than those using self-etch. When laser is applied, the mean de-bonding strength decreases with decreasing disc thickness, and it reaches zero at 0.5mm thickness for both self- and total- etch adhesive systems.

Failure sites

Table 3 shows failure modes obtained for the enamel and the disc bases after disc removal. It can be observed that dislodging is complete for all 0.5 mm thick discs when laser is applied. The ARI scores of groups 9 and 11 (0.5mm disc thickness + laser application) are clearly different from those of groups 10 and 12 (0.5mm thickness + no laser use). The ARI scores of groups 9 and 11 are also different from those of other groups with 1mm and 2mm disc thickness.

Statistical analysis confirmed these results: There were significant differences among the ARI scores of Groups 5,9,11 and other groups (*p*=0.04 for Kruskall-Wallis). For almost all specimens in groups 5,9,11, the adhesive resin was left on the enamel surface (ARI score 3 and no enamel fractures were recorded). For all specimens in groups 5,9,11, the disc base coating was completely intact. When de-bonded by using laser, the site of failure was exclusively at the disc-adhesive interface without disc base damage. No fracture in the body of the discs was observed in the laser groups. Representative SEM photographs from the disc base surfaces are presented in Figure 1. There were no differences between groups with and without laser application.

DISCUSSION.

In this study, the effect of Er,Cr:YSSG laser on de-bonding of ceramic restorations luted by different adhesive resins were examined. Regarding previous works related to IPS Empress II system discs, leucite-reinforced glass ceramic with increased translucency, smaller grain size, and leucite crystals distributed in a more homogeneous mode has been reported.[8,9,14] Maxillary central incisors were used due to their suitable flat labial faces in order to ensure optimal adaptation to the tooth surface and their potential usage for esthetic restorations. The luting systems suitable for indirect ceramic restorative techniques can be divided into two subgroups according to the bonding agent used before cementation: One group utilizes etch-and-rinse adhesive systems (total etch adhesive systems), and in the other self-etching primers are applied.[24] Self-adhesive cements were introduced as a new subgroup of resin cements.

These materials were designed with the purpose of overcoming some limits of both conventional and resin cements. Self-adhesive cements do not require any pretreatment of the tooth substrate: once the cement is mixed, application is accomplished through a single clinical step. Clinicians' demands for simplification of luting procedures are addressed, as the application procedure leaves little or no room for mistakes induced by technique variations.[24] Any mismatch will affect the stress distribution between the adhesive cement-tooth complex. Water uptake during thermo-cycling could also be affected depending on the thickness of the adhesive between the porcelain discs base and the tooth surface. In order to keep the film thickness standard, adhesion of the porcelain discs was performed under a load of 750g in this study.

Laser has been used intensively in dental medicine to remove dental veneers.[8,9,13-22] Laser energy can degrade the adhesive resin by three methods:Thermal softening, thermal ablation, and photo ablation. Thermal softening occurs when the laser heats the bonding agent until it softens. Thermal ablation occurs when heating is fast enough to raise the temperature of the resin into its vaporization range before de-bonding by thermal softening occurs. Photo ablation occurs when very high-energy laser light interacts with the adhesive material. In this case the energy level of the bonds between the adhesive resin atoms rapidly rises above their dissociation energy levels, resulting in decomposition of the material.[31]

It can be observed in Figure 2 that that mean median load for groups in which laser was applied is always lower those without laser. This indicates that laser decreases SBS between teeth and ceramic disk, it weakens bonding, and makes the removal of porcelain from tooth easier. Also as seen in Table 3 and Table 4, Er,Cr:YSSG laser application to discs 0.5mm thick (groups 9 and 11) is very effective for reducing the shear bond strengths of porcelain restorations. In this case, no additional force was needed to remove the ceramic discs. Such complete dislodging is a notable finding of our study. All of these findings are consistent with previous studies indicating effective removal of porcelain veneers from teeth by laser application.[8,9,12-23]

To the best of our knowledge, there is no previously published study directly about the effect of thickness or adhesives on de-bonding strength of ceramics exposed to laser. However, SBS between ceramic and tooth is known to be dependent on adhesive types.[32,33] The color masking ability and flexural strength of ceramics are noted to be also influenced by their thickness.[27,29,30] In addition, failures located between the dentin surfaces and bonding agent are due to the adhesive.[26] In the present case, the site of failure was at the disc-adhesive interface. So the present findings are in consistent with such previous studies.

CONCLUSION.

Laser application caused a significant decrease in de-bonding strength of all groups. The de-bonding strength obtained without laser application was always higher than by laser-use. The de-bonding strength of ceramic discs increases with increasing thickness of discs. The strength obtained by laser application is almost zero for 0.5mm thick discs luted by self *-or* total- etch adhesives.

In the absence of laser use, the mean de-bonding values of discs with total etch adhesive system are always higher than those of discs with self-etch adhesive. Dislodging of ceramics from teeth was completed for all 0.5mm thick discs when laser was applied. The ARI scores of groups 9 and 11 (0.5mm disc thickness + laser application,) were clearly different from than those of groups 10 and 12 (0.5mm thickness + no laser use), and of other groups with 1mm and 2mm thick discs.

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