European Journal of Research in Dentistry 2019; 3: 8–13
DOI: 10.35333/ERD.2019.7

ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA

Effects of Different Er:YAG Laser Parameters on Debonding Forces of Lithium Disilicate Veneers: A Pilot Study

Farklı Er: YAG Lazer Parametrelerinin Lityum Disilikat Venerlerin Çıkarılma Kuvvetlerine Etkisi: Pilot Çalışma

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Abstract

Objectives: The aim of this study was to investigate the effects of different Er:YAG laser application parameters on shear bond strength values of all-ceramic restorations cemented to different tooth surfaces.

Materials and Methods: Thirty lithium disilicate ceramic disc specimens (thickness of 1 mm and diameter of 3 mm) were fabricated and cemented by using a dual-cure resin cement to 30 non-carious, extracted mandibular incisors, which were divided into 2 as; tooth reduction on enamel and on dentin. Six test groups (n=5) were designed according to the application method; 1st group on enamel and without laser application, 2nd group on dentin and without laser application, 3rd group on enamel and laser applied (600mJ, 2 Hz), 4th group on dentin and laser applied (600mJ, 2 Hz), 5th group on enamel and laser applied (165mJ, 30 Hz), 6th group on dentin and laser applied (165mJ, 30 Hz). The Er:YAG laser was applied on each specimen for 3 seconds. After the laser application, all groups were subjected to shear bond strength test until fracture. The failure modes were also examined. The data were statistically analyzed by using one-way ANOVA and post hoc T-test at a 0.05 level of significance.

Results: According to one-way ANOVA test, there was statistically significant differences between the groups ($p<0.05$). Post hoc T-test revealed no statistically significant difference only between the groups 2 and 5. The mean shear bond strength of the specimens of group 1 was statistically higher than that of all the other groups ($p<0.001$).

Conclusion: Er:YAG laser-irradiation is a successful and effective application in removing ceramic veneers. When the depth of the tooth reduction amount increases, parameters such as; the frequency and energy of the laser application can be reduced for restorations with the same thicknesses.

Keywords*: Er:YAG laser, ceramic veneer, shear bond strength.*

Öz

Amaç: Bu çalışmanın amacı, farklı Er: YAG lazer parametrelerinin, farklı diş yüzeylerine simante edilmiş tam seramik restorasyonlarda makaslama bağlanma dayanımı değerlerine etkisini araştırmaktır.

Gereç ve Yöntemler: Otuz adet lityum disilikat seramik disk (1 mm kalınlık ve 3 mm çapında) üretildi ve labial yüzeylerinde mine ve dentin seviyesinde diş preparasyonu yapılan 30 adet çekilmiş çürüksüz alt kesici dişe simante edildi. Uygulama yöntemine göre 6 test grubu tasarlanmıştır (n=5); 1. grup mine yüzeyinde ve lazer uygulanmamış, 2. grup dentin yüzeyinde ve lazer uygulanmamış, 3. grup mine yüzeyinde ve Er: YAG lazer (600mJ, 2 Hz) uygulanan, 4. grup dentin yüzeyinde ve Er: YAG lazer (600mJ, 2 Hz) uygulanan, 5. Grup mine yüzeyinde ve Er: YAG lazer (165mJ, 30 Hz) uygulanan, 6. grup dentin yüzeyinde ve Er: YAG lazer (165mJ, 30 Hz) uygulanan. Er: YAG lazer her örneğe 3 saniye boyunca uygulandı. Lazer uygulama işleminden sonra, tüm gruplar kopma oluşana kadar makaslama bağlanma dayanımı testine tabi tutuldu. Numunelerin kopma paternleri incelendi. Elde edilen veriler istatistiksel olarak tek yönlü ANOVA ve post-hoc T-test kullanılarak 0.05 anlamlılık düzeyinde analiz edildi.

Bulgular: Tek yönlü ANOVA testi sonuçlarına göre gruplar arasında istatistiksel olarak anlamlı fark elde edilmiştir ($p<0.05$). Post hoc T-testine göre sadece 2. ve 5. gruplar arasında istatistiksel olarak anlamlı fark olmadığını görülmüştür. Grup 1'deki örneklerin ortalama makaslama bağlanma dayanımı değerleri, diğer tüm gruplardan istatistiksel olarak daha yüksek bulunmuştur ($p<0.001$).

Sonuç: Er: YAG lazer seramik venerlerin çıkarılmasında başarılı ve etkili bir uygulamadır. Aynı kalınlıktaki restorasyonlar için, diş preparasyon derinliği arttıkça, lazer uygulama frekansı ve enerjisi gibi parametreler azaltılabilir.

Anahtar Kelimeler: *Er:YAG lazer, seramik vener, makaslama bağlanma dayanımı.*

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Submitted / Gönderilme: 23.01.2019 **Accepted/Kabul:** 14.05.2019

Introduction

Nowadays, all-ceramic materials have been developed to maintain sufficient aesthetics and strength at the same time (1). Especially, the lithium disilicate glass-matrix ceramics, which have improved properties such as relatively high strength, translucency, biocompatibility, and adhesive bonding ability, are widely used in different types of restorations (laminate veneers, inlays, onlays, crowns, and 3-unit anterior fixed partial dentures) (2). By luting with resin cements, this kind of glass-matrix ceramics have sufficient structural durability, fracture resistance and color harmony. Resin cements have many advantages like; presenting low dissolution in saliva, providing high bond strength, increasing the fracture resistance of the all-ceramic restoration, having different color options and providing advanced aesthetics for final restoration. Besides these advantages, one of the major disadvantages of such adhesively luted ceramics is that the challenging removal procedure and it is almost impossible to remove the resin bonded all-ceramic restoration in one piece by the conventional removal techniques (1).

The removal of most kinds of fixed partial dentures or crown restorations are made by using crown remover instruments. But, this kind of instruments do not work for removing resin bonded all-ceramic restorations. The conventional removal method for resin bonded ceramic restorations mostly performed by grinding the restoration with rotary burs because of high bond strength of resin cement both to the tooth structure and ceramic material (3). However, it is relatively; uncomfortable for patient, time-consuming, also having some risk about damaging the underlying tooth structure because of the lack of color contrast among the ceramic–cement–tooth interfaces. In addition, loss of restoration integrity prevents the reuse of the restoration, which could be desirable in case of the misalignment of the restoration during cementation or unexpected early inflammatory pulpal responses (1,4). To eliminate the disadvantages of conventional removal method, the use of laser debonding techniques was recently introduced as an alternative, more comfortable, safe, and conservative restoration removal method (4).

The use of lasers in dentistry for debonding the orthodontic brackets (5,6) and porcelain veneers has been documented in recent years (7). For this purpose, several lasers such as CO_2 (8), Nd:YAG (9), diode (10), ytterbium fiber (11) and Er:YAG (12) lasers were used and evaluated in many studies (4). There are few reports in the literature, which performed using Er:YAG (2940 nm) lasers (1,3,4,6,9,12-16). The Er:YAG laser is highly absorbed in resin materials, so that it is an effective technique for the removal of composite resin fillings (4). Results of all experimental (6,7,13-15) and clinical (16-20) studies showed that erbium lasers are effective in reducing the shear bond strength of all-ceramic restorations, resulting in an easy removal of the restorations with none or minimal damage to teeth or ceramic surfaces (21).

It has already been known that lasers' energy transmission changes according to the dental ceramic type. For instance, a lithium disilicate veneer fabricated in 0.5 mm thickness presents higher transmission ratio than a feldspathic ceramic in 1 mm thickness (3,21). Several studies evaluated the efficiency of this technique in debonding of ceramics by using different parameters as laser energy, frequency, and application time (13-15). The aim of this study was to investigate the effects of different Er:YAG laser application parameters (particularly; energy and frequency) on debonding strength values of lithium disilicate restorations cemented to different tooth surfaces. The null hypothesis of this study was that the higher power parameters would provide lower shear bond strength values for samples both cemented on enamel and dentin surface.

Materials and Methods

Thirty non-carious, mandibular incisors extracted for periodontal reasons were cleaned of soft tissue debris and stored in 0.1% thymol solution until use. After retentive metal rings were placed thorough the prepared hole at the root region to get retention, all incisor samples were embedded in self-cure acrylic resin; labial surface perpendicular to horizontal plane. The tooth reductions were made by using a parallel-sided diamond bur with a high-speed handpiece which was placed on a surveyor (KaVo EWL Typ 990; Kavo Elektrotechnisches Werk GmbH, Leutkirch im Allgau, Germany) that provided parallelism between the bur and the tooth surface to make a standard reduction. Labial surfaces of the teeth were initially prepared by placing depth-orientation grooves (15 tooth surface for enamel 0.3 mm in depth and 15 tooth surfaces for dentin 1mm in depth) with a depth preparation bur. Then, the samples were prepared without exceeding the depth-orientation grooves to provide a flat enamel and dentin surface area. Finally, the prepared labial surfaces were polished using a 600-grid silicon carbide paper disc on a polishing machine to obtain a standardized flat surface for bonding procedures. Thirty lithium disilicate (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) disc specimens (thickness of 1 mm and diameter of 3 mm) were fabricated according to the manufacturers' instructions and were cemented on prepared tooth surface by using dual-cure resin cement (Variolink N; Ivoclar Vivadent, Schaan, Liechtenstein). All specimens were divided into 6 groups (n=5); 1st group on enamel surface and without laser application, 2nd group on dentin surface and without laser application, 3rd group on enamel surface and laser applied (600mJ, 2 Hz), 4th group on dentin surface and laser applied (600mJ, 2 Hz), 5th group on enamel surface and laser applied (165mJ, 30 Hz), 6th group on dentin surface and laser applied (165mJ, 30 Hz) (Table 1).

Table 1. Distribution of study groups.

Groups		Application
Control E	CE	On enamel without laser
Control D	CD	On dentine without laser
Laser 1E	L1E	On enamel with 1.2 W power
Laser 1D	L1D	On dentine with 1.2 W power
Laser 2E	L2E	On enamel with 4.95 W power
Laser 2D	L2D	On dentine with 4.95 W power

After the cemented in first and second group samples were stored in distilled water at 37°C for 24 hours, their shear bond strength were measured by using a Universal testing machine (AG-5 kNG; Shimadzu, Tokyo, Japan) with a crosshead speed of 0.5mm/min. Er:YAG laser was applied on specimens of group L1E and L1D for 3 second pulse durations at 1.2W (600mJ, 2 Hz) of power. Er:YAG laser was applied on specimens of group L2E and L2D for 3 second pulse durations at 4.95W (165mJ, 30 Hz) of power. The application mode of Er:YAG laser was contact type and used at a 2-3 mm distance from ceramic discs with water/air cooling (1:1 of ratio) (Fig 1). After the laser application, shear bond strength was measured by using a universal testing machine (AG-5 kNG; Shimadzu, Tokyo, Japan) with a crosshead speed of 0.5 mm/min (Fig 2).

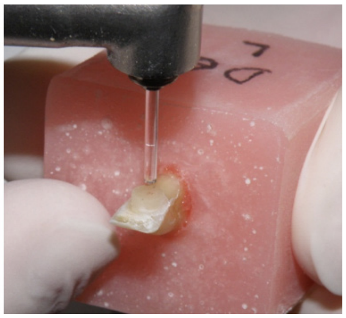


Fig 1. The contact type Er:YAG laser handpiece in situ.

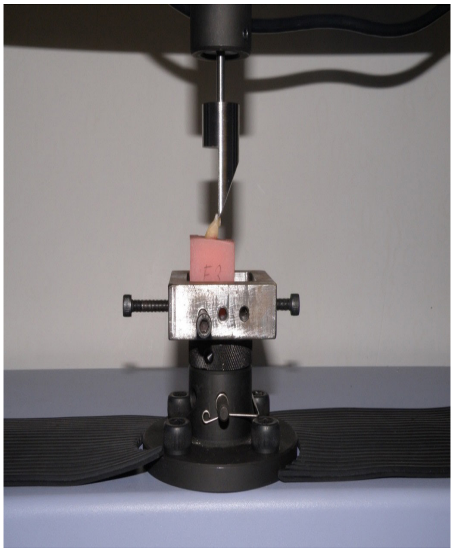


Fig 2. The shear bond strength test made by using a universal testing machine.

The debonded samples were examined under a stereomicroscope (Leica MZ 75; Leica Microsystems, Bensheim, Germany) under ×40 magnification. The bond failure modes were classified according to the modified criteria into 3 types. Type1: Adhesive failure between the internal surface of the veneer and the luting resin cement, when most of resin remained on tooth surface. Type2: Adhesive failure between the luting resin cement and the tooth surface, when most of resin remained on the internal surface of the veneer. Type3: Cohesive failure within resin cement (Fig 3).

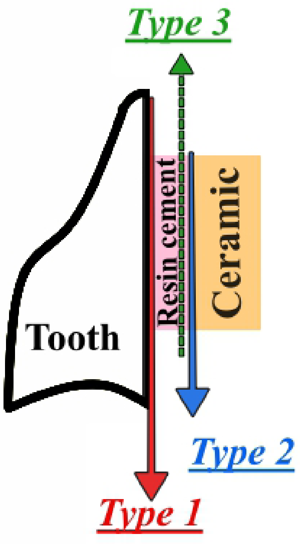


Fig 3. The schematic view of failure modes.

All statistical analysis were performed by using IBM SPSS V23 (Chicago, IL, USA). In addition to calculation of the mean value and the standard deviation, one-way ANOVA test was used to examine the shear bond strength values of the groups. Statistically significant differences between the groups were evaluated with post hoc T-test at a 0.05 level of significance.

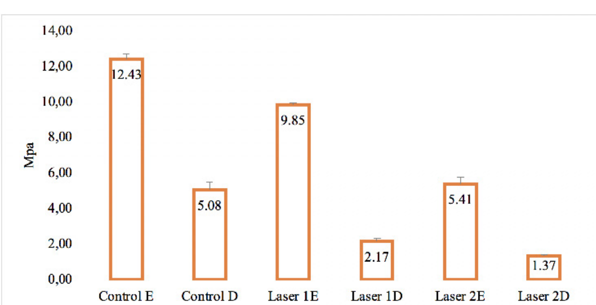
Results

The mean values of shear bond strength (in MPa) and the respective standard deviation values are shown in Table 2. According to one-way ANOVA test, there was statistically significant differences between the groups ($p<0.05$). Post hoc T-test revealed statistically significant differences between most of the groups, while there was no between the groups CD and L2E (Fig 4). The mean shear bond strength of the specimens of group CE was statistically higher than that of all the other groups ($p<0.001$). The mean shear bond strength of laser-irradiated groups were significantly and dramatically reduced when compared with the control groups (CE with L1E and L2E, CD with L1D and L2D). The laser application and increasing laser power parameter processes made a statistically significant influence on the shear bond strength of the tested specimens.

Table 2. Statistical differences between groups

	Mean ± Standard Deviation (Mpa)	p
CE	12.43 ± 0.30 [a]	<0.001
CD	5.08 ± 0.45 [b]	
L1E	9.85 ± 0.13 [c]	
L1D	2.17 ± 0.16 [d]	
L2E	5.41 ± 0.38 [b]	
L2D	1.37 ± 0.03 [e]	

[(a-e)] The groups signed with the same letter have no statistically significant difference



*No statistical differences were found in between ($p<0.05$)

Fig 4. Graphical view of shear bond strength values in each groups (in MPa)

Table 3 shows the frequency distribution of failure modes for each group. While the specimens of control groups showed type 2 and type 3 failure modes, type 1 failure mode was observed in all of the laser-irradiated groups. None of the specimens showed type 2 and type 3 failure modes in laser-irradiated groups.

Table 3. Frequency distribution of the failure modes.

Groups	Type 1	Type 2	Type 3
CE	-	3	2
CD	-	4	1
L1E	5	-	-
L1D	5	-	-
L2E	5	-	-
L2D	5	-	-

Discussion

The results obtained in this pilot study supported the hypothesis that the higher power parameters would provide lower shear bond strength values for samples both cemented on enamel and dentin surface. In recent years, the usage of lasers in prosthetic applications for the removal of all-ceramic restorations with different parameters (such as; wavelengths, energy and frequency) has been increasing, being one of the popular topics. The effect of Er:YAG laser application has already been investigated on debonding of orthodontic brackets, all-ceramic laminate veneers and resin bonded restorations. Most of the studies have presented different power parameters, by changing laser energy, frequency, application duration and mode (3,4,7,13-20). In this study, 2 different application parameters by changing the laser energy and frequency in standard duration and mode, were investigated.

The laser parameter settings of previous studies about laser debonding present different values according to the aim of that study. Searching about the most effective parameter on debonding with least damage to the tooth structure and especially to the pulp at the same time is the most important issue. Mundethu et al. (12) used Er:YAG laser without air or water spray, at 600 mJ of energy, with 2Hz of frequency and 800 µs pulse duration (1,2W) for examining the removal of the bracket without the use of any additional external force. Morford et al. (3) used an Er:YAG wavelength at a low repetition rate of 10 Hz and energy setting of 133, 217, 316, 400, 503 mJ (1.33 W – 5W) with a short pulse duration of 100 µsec. Oztoprak et al. and Iseri et al. (6, 22), selected a laser parameter at a power of 5 W (50 Hz×100 mJ) for comparing the shear bond strength after different application durations. Albalkhi et al. (23) examined the efficiency of ceramic removal by using Er:YAG laser in different laser parameters (such as; application mode, energy, frequency, power); Group of contact application of 360mJ, 15Hz, 5.4W and groups of non-contact application and laser parameters of 360mJ, 15Hz, 5.4W/ 400mJ, 10Hz, 4W/ 270mJ, 15Hz, 4W/ 300mJ, 10Hz, 3W. Rechmann et al. (13-15) applied Er:YAG laser at 10 Hz repetition rate and at the energies of 126-590 mJ (1.26 – 5.9 W) for all ceramic veneers debonding. Buu et al. (24) applicated an Er:YAG laser with 10 Hz, 135 mJ, pulse duration of 150 µs and 1,100 µm straight quartz fiber tip, contact mode, air spray for 2 different porcelains (lithium disilicate and leucite). Different power values were selected for debonding of all-ceramic samples in different thickness. In present study, 2 different power values presenting the lowest and highest wattages as in the previous ones; 1.2 wattages, which has higher laser energy but lower frequency and 4.95 wattages, which has lower laser energy, but higher frequency were selected.

When choosing the optimum laser parameters to be used for debonding; the depth of preparation of the tooth surface, the type of ceramic material and the thickness of the restoration should be considered. Sari et al. (4) published a study about the absorption and transmission amount of the Er:YAG laser through different types of ceramics. This study reported that a lithium disilicate restoration with a 0.5 mm of thickness presented more transmission ratio when compared with feldspathic ceramics in 1 mm thickness. As another result of the study, when the thickness of the ceramic specimen increases, the laser transmission decreases (4). Albalkhi et al. (23) published a study about the efficiency of debonding porcelain laminate veneers by using several laser parameters and 2 different application modes of Er:YAG laser. This study samples were 0.7 mm thickness. Gurney et al. (7) investigated the efficiency of different wattage of Er:YAG laser debonding on lithium disilicate restorations 1.5 mm in thickness. In current study, the lithium disilicate samples were fabricated 1 mm in thickness and 3 mm in diameter.

Some studies (17,18) showed that the removal of veneers lower than 1 mm in thickness may be satisfactory by using short laser duration (between 9 and 15s); whereas, the removal of lithium disilicate and zirconia crowns with an increased thickness needed application duration between 30s and 120s (16,19,20). Oztoprak et al. (6) reported that a lasing time of less than 10s was effective for reducing the shear bond strength of lithium disilicate discs in thickness of 0.7 mm and a diameter of 5 mm. Liu et al. (25) used Nd:YAG laser in different parameters (power-duration) such as; 3 W-3s, 2 W-5s and 5 W-2s, and, reported that the laser energy of 3 W for 3s was effective for removal of a ceramic bracket without a pulp injury. In the current study, application duration was selected as 3 seconds.

In many studies, the effect of laser irradiation on shear bond strength during ceramic bracket debonding and all-ceramic veneer removal were investigated (26). It was shown by the previous studies that lasers were effective in debonding ceramic veneers by decreasing the shear bond strength (5,6,10,12). According to the results of the current study, laser applied groups required significantly less shearing force than the control groups. The application duration were 3 seconds and lasing 3 seconds caused a bond reduction of close to 50 percent with low power lasing and more than 50 percent with high power lasing. Orthodontic bracket or all-ceramic disc debonding studies revealed similar decrease rates with our study. The shear bond strength values of control groups were found lower than other studies. This may be related to the size of samples, which was 3 mm in diameter, was smaller than previous studies.

In debonding studies, the mode of failure is an important index of where the failure occurred and evaluates the probable risks of enamel or dentin damage (5,6,27). As the debonding location gets closer to the tooth/resin interface, the damage risk of the tooth increases (27). In this study, most of samples in the control groups had type 2 failure; indicating that the debonding location was between the tooth and resin cement. All of the samples in laser-irradiated groups had failure modes of type 1; indicating that the outer surface of the resin cement was softened by laser and the debonding location was between resin/ceramic interface.

This study has some limitations. The number of specimens per group was small, and, larger sample size could affect the data. Secondly the size of the specimens was 3 mm in diameter and wider bonded surface could affect the bond strength values.

Conclusion

Within the limitations of this study the following conclusions were drawn:

1. Both of 2 application parameters decreases the bond strength of resin bonded lithium disilicate samples whether on enamel or dentin surfaces.

2. The increase in the wattage of the laser application decreases the bond strength for samples both on enamel and dentin surface.
3. The frequency and laser energy, which constitute laser power level should be changed according to the thickness of the all-ceramic restoration and bonded tooth surface type.
4. The application duration would also be different according to the bonded surface area of the all ceramic restoration.
5. The laser application for debonding an all-ceramic restoration prevents damage both to the tooth structure and the ceramic restoration, when used with proper parameters.

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