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http://dx.doi.org/10.17096/jiufd.39114 ORIGINAL RESEARCH

DEBONDING OF CERAMIC BRACKETS BY ER:YAG LASER

Seramik Braketlerin Er:YAG Lazer ile Sökümü

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ABSTRACT

Purpose: *The objective of the present study is to evaluate the effects of Er:YAG laser debonding of ceramic brackets on the bond strength and the amount of adhesive resin remnant.* ***Materials and Methods:*** *Twenty human mandibular incisors were randomly divided into two groups of 10 and polycrystalline ceramic brackets (Transcend series 6000, 3M Unitek, Monrovia, CA, USA) were bonded on enamel surfaces. Group 1 was the control group in which no laser application was performed prior to the shear bond strength (SBS) testing. In Group 2, Er:YAG was applied in 3W power for 6 seconds using the scanning method. The brackets were tested for SBS with an Instron universal testing machine and results were expressed in megapascals (MPa). The amount of adhesive remnant was evaluated with Adhesive Remnant Index (ARI). One-way analysis of variance and Tukey's post-hoc tests were used for statistical analysis.* ***Results:*** *Mean ± standard deviation of SBS values in the control group was 13.42 ±1.23 MPa and 8.47 ±0.71 MPa in the Er:YAG group and this difference was statistically significant ($p<0.05$). The evaluation of ARI scores demonstrated more adhesive was left on the enamel surface with Er:YAG group.* ***Conclusion:*** *3W power Er:YAG laser application with the scanning method to polycrystalline ceramic brackets demonstrated lower bond strengths and higher ARI scores during the debonding procedure.*

Keywords: *Orthodontic bracket; Laser; Shear strength; Bracket debonding*

ÖZ

Amaç: *Bu çalışmanın amacı seramik braketlerin Er:YAG lazer ile sökümünün bağlanma dayanımı ve artık adezif rezin miktarı üzerindeki etkilerini değerlendirmektir.* ***Gereç ve Yöntem:*** *Yirmi adet insan alt kesici dişi rastgele olarak eşit sayıda numune içeren iki gruba ayrıldı. Polikristalin seramik braketler (Transcend series 6000, 3M Unitek, Monrovia, CA, USA) dişlerin mine yüzeylerine yapıştırıldı. 1. grup kontrol grubu olup, makaslama bağlanma dayanımı (MBD) testinden önce lazer uygulaması yapılmadı. 2. Gruptaki numunelere 3W gücündeki Er:YAG lazer tarama metoduyla 6 saniye uygulandı. Bütün braketlerin MBD değerleri Instron cihazında ölçüldü ve ölçü birimi megapascal (MPa) olarak ifade edildi. Ayrıca, Artık Adezif İndeksi (AAİ) skorları hesaplandı. İstatistiksel analiz için tek yönlü varyans analizi ve post hoc Tukey testleri kullanıldı.* ***Bulgular:*** *Her bir grup için ortalama SBS değerleri; kontrol grubunda 13.42 ±1.23 MPa, Er:YAG lazer uygulanan grupta 8.47 ±0.71 MPa olarak ölçüldü. Bu farkın istatistiksel olarak anlamlı olduğu belirlendi ($p<0.05$). AAİ skorlarının değerlendirilmesi Er:YAG lazer uygulanan grupta mine yüzeyinde daha fazla adezifin kaldığını gösterdi.* ***Sonuç:*** *Polikristalin seramik braketler tarama metoduyla 3 W gücünde Er:YAG lazer uygulandığında braket sökümü esnasında daha düşük bağlanma dayanımları ve daha yüksek ARI skorları göstermiştir.*

Anahtar kelimeler: *Ortodontik braket; Lazer; Makaslama dayanımı; Braket sökümü*

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Introduction

The use of ceramic brackets has increased in recent years in line with the increase in the number of adults who are treated with fixed orthodontic treatment. Ceramic brackets have considerable aesthetic advantages in comparison to metal brackets. However, they may lead to problems such as pain, bracket breakage and enamel damage (cracks, breakage) during debonding due to high bonding resistance and their high elastic modulus in comparison to metal brackets as well as their low flexibility and higher fragility (1-5).

Using specialized hand tools and utilization of various techniques such as ultrasonic or electrothermal debonding have been suggested in order to overcome such problems encountered during debonding (2, 5). In addition, lasers are used experimentally for ceramic bracket debonding. Lasers are effective in softening the adhesion at the bracket/resin interface by producing heat energy. Therefore, problems such as enamel break, bracket detachment and pain experienced during debonding can be solved (2, 5). In addition, lasers have advantages over other debonding methods such as decreasing debonding force and shortening debonding time.

Widespread use of laser systems today has been evaluated in various studies by considering variables such as effectiveness of lasers in debonding process, energy levels, bracket type, resin type and the force magnitude (6-9). On the other hand, the type of laser used in most of the previous studies is CO_2 laser, which can be easily absorbed by ceramic brackets (6, 8). Remaining few studies have suggested the use of Nd:YAG laser. However, it was reported that 69% - 75% of the laser beam would reach to the enamel surface. In addition, this type of laser could cause damage on the tooth surface and pain experienced during debonding may increase (10). There are only two studies illustrating the usage of Er:YAG laser for debonding purpose. In the first of these, Mundethu *et al*. (11) reported that 95% of the ceramic brackets on the 3rd molar teeth were debonded by using Er:YAG laser (600 mJ). In the other, Öztoprak *et al*. (12) successfully debonded ceramic brackets on bovine lower incisor teeth with Er:YAG laser (4.2 W, 9 sec.) scanning.

The purpose of the present study was to evaluate the effectiveness of Er: YAG (3 W, 6 sec.) that was used in debonding procedure of polycrystalline ceramic brackets in human lower incisor teeth.

Materials and Methods

Twenty extracted, intact, lower incisor teeth (central and lateral) were used. Possible plaque and soft tissue remaining on the teeth surface was removed by the aid of water and brush and the teeth were kept in 0.1% thymol solution. Subsequently the teeth were evaluated in stereomicroscope (Olympus SZ61; Olympus Optical Co., Tokyo, Japan) at X10 magnification in terms of cavity or enamel crack presence.

The teeth with cavity, restoration and surface anomalies were not included in the study. The cleaned and dried enamel surfaces were etched with 37% phosphoric acid for 30 sec. and then washed with water and dried. Twenty polycrystalline alumina brackets (Transcend series 6000, 3M Unitek, Monrovia, CA, USA) were used. The brackets with Transbond XT adhesive (3M Unitek, Monrovia, CA, ABD) placed in their bases were brought to a proper position on the labial surfaces of the lower incisor teeth, pushed lightly and the excess adhesive was cleaned with a sharp curette. The adhesive was light polymerized for 10 seconds from four sides of the bracket reaching a total of 40 seconds for each specimen (Demetron LC, SDS Kerr; light output: 400 mW/cm^2). Teeth were embedded in acrylic blocks (Orthocryl, Dentaurum, Ispringen, Germany) so that the enamel surfaces were exposed. Before the test stage, the samples were kept in 37^{0}C distilled water for 48 hours.

The samples were divided into 2 groups randomly. In Group 1 which is the control group, no process was performed prior to the breaking test (SBS – Shear Bond Strength test) (n=10). In group 2, prior to SBS test, scanning was made on the enamel surface (n=10) by Er:YAG laser (Fotona, At Fidelis, Ljubljana, Slovenia) with the following parameters: 2940-nm wavelength, MSP (maxi short pulse) mode, pulsation width:100 microseconds (µs), pulsation frequency:10 Hertz (Hz), power:3W. The equipment was used at the mode of contact with air and water, with 120 mJ (millijoule) pulsation energy, 1 mm away from the bracket surface by a single researcher for 6 sec. The scanning was made starting at the upper distal wing of the bracket by moving horizontally and parallel to the bracket slot, and subsequently, at the upper mesial wing, bracket slot, low distal wing and finally to end at the low mesial wing (reverse letter S) (Figure 1).

The bonding resistance of the samples was evaluated by universal test equipment (Shimadzu Autograph AG-IS, Kyoto, Japan). The knife edge shaped metal tip of the Instron device was placed parallel to the tooth-bracket mid surface to apply a 0.5mm/min to perform the SBS test. The value at the moment of separation of bracket from the teeth surface was calculated in Newton (N) unit and it was converted to megapascal (MPa) (MPa=N/mm^2 x 0,980665). All measurements were performed by the same operator (S.E.) under standard clinical conditions. After the brackets are separated, in order to determine the breakage region and type, breakage surfaces were examined in stereomicroscope (Olympus SZ61; Olympus Optical Co, Tokyo, Japan) with X10 magnification and they were scored between 0 and 3 according to ARI (adhesive remnant index) system (score 0: there is no adhesive remaining at the tooth surface, <%10; score 1: there is less than 50% adhesive remaining at the tooth surface; score 2: there is more than 50% adhesive remaining at the tooth surface; score 3: all adhesive is left at the tooth surface, (>90%).

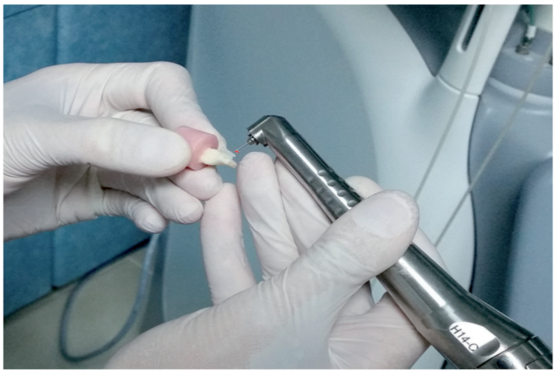

Figure 1. *Laser application.*

Statistical Analysis

MS Excel 2003 (MS Excel 2003 © 1985-2003 Microsoft Corporation) and SPSS for Win. Ver. 2000 (SPSS INC, Chicago, IL, USA) software were used for used for statistical analysis. Normality of the distribution was evaluated with Kolmogorov-Smirnov test. One-way analysis of variance (ANOVA) and Tukey's test were used for multiple and post-hoc pairwise comparisons, respectively. p values less than 0.05 were considered significant.

Results

Mean SBS values are summarized in Table 1. Significant differences were observed among mean SBS values of the two groups. ANOVA test showed Group 1 to have significantly higher SBS values than Group 2 (P<0.001).

The distribution of failure modes as expressed by ARI scores is given in Table 2. While Group 2 exhibited mainly failures at the enamel-resin interface, with more than 50% of the adhesive remaining (ARI: 2 and ARI:3), Group I showed mainly failures at the enamel-resin interface, with less than 50% of the adhesive remaining (ARI: 1). No enamel fractures were observed in any of the tested specimens.

Table 1. *Mean Shear Bond Strength test (SBS) values (MPa: Megapascal).*

SBS (MPa)	n	Mean	SD	Max (MPa)	Min (MPa)
Group I	10	13.42	1.23	15.01	11.54
Group II	10	8.47	0.71	9.46	7.06

Table 2. *Adhesive Remnant Index scores for each group.*

Groups	0	1	2	3
Group I	2	4	4	0
Group II	0	1	4	5

0, no residual adhesive remaining on the enamel; 1, less than 50% of the adhesive remaining; 2, more than 50% of the adhesive remaining; 3, all of the adhesive remaining, with a distinct impression of the bracket base.

Discussion

It was reported that the debonding force in orthodontics should be between 6MPa to 8 MPa to prevent possible damages from occurring to teeth and periodontal tissues (13). On the other hand, it was reported that when ceramic brackets are used, this force could reach 20 MPa and cracked-breakages could develop in the enamel and breakage could occur in the brackets (14, 15). Recently, lasers which minimizes enamel damage during the debonding of ceramic brackets and facilitates the debonding process, are used as an alternative to mechanical methods. When lasers are used for debonding, they destroy the structure of the adhesive at the bracket/resin interface by thermal softening, thermal ablation or photo ablation (16). Briefly, thermal softening takes place at low laser power levels (the transmitted heat is absorbed in the bracket first and it affects the adhesive indirectly) whereas at high laser power levels, when laser is applied to the resin directly, thermal ablation or photo ablation occurs (16). It was reported that monocrystalline and polycrystalline ceramic brackets have shown different reactions to laser light at different wavelengths due to different optic characteristics (17). Successful results were reported with CO_2 (10600 nm), Nd:YAG (1060 nm), KrF (248 nm), XeCl (308 nm) lasers and debonding force, as well as enamel damage risk, were found to decrease significantly (4, 9, 16, 18). Our findings are consistent with those of previous studies which showed that the lasers are effective in debonding of ceramic brackets by smoothing adhesive resin (4, 6, 7, 9, 12, 16, 18). Er:YAG laser (3W) disrupted the resin structure and diminished SBS force. However, higher ARI scores were observed in the study group in comparison to the control group. This illustrates that there is a negative correlation between the bonding resistance and ARI scores which is consistent with previous studies (7, 9, 12).

CO_2 lasers were used in most of the previous studies owing to their high wavelengths and well absorption rate by ceramic brackets (4-9, 18). Tocchio *et al*.(16) applied CO_2 laser at 3-33 W/cm^2 force and at the wavelengths of 248nm, 308nm and 1060nm for 3, 5 and 24 seconds for ceramic bracket debonding, and no enamel or bracket damage were observed in any of the samples. Ma *et al*.(6) and Rickabaugh *et al*.(18) used modified debonding clips along with CO_2 laser, and they found significant differences between the tensile debonding forces of the samples in the study and control group samples. They reported that the brackets can be extracted from the tooth surface by the debonding clip until reaching the adhesive softening temperature of the brackets. They showed that immediate extraction of the brackets at the softening temperature has prevented the heat energy stored in the bracket to be transmitted to the teeth thereby preventing the temperature rise (6, 18). Obata *et al*. (8) investigated the bonding and debonding of ceramic brackets by super-pulsating and normal-pulsating CO_2 laser both *in vivo* and *in vitro*. In the *in vivo* study, following the laser application to each tooth, rotation forces were applied by the aid of clips and the brackets were removed. In the *in vitro* study, shearing forces of CO_2 lasers with 2 W and 3 W forces were measured. It was concluded that using super pulsating CO_2 laser (2 W and 3 W) for debonding was more beneficial than using it for bonding (8). Feldon *et al*. (19) examined shearing bonding resistance by using diode laser of 2 and 5 W/cm^2 force for 3 second for debonding monocrystalline and polycrystalline ceramic brackets and they reported that laser application did not reduce the required forces for the removal of polycrystalline ceramic brackets, and it diminished the force magnitude required for debonding of monocrystalline ceramic brackets.

Thermal softening by CO_2 lasers increases the temperature in the inner pulp chamber and may lead to pulp damage. Hayakawa *et al*. (10) used Nd:YAG laser that could affect resin structure directly by the thermal ablation and photo ablation effects. They showed that Nd:YAG laser is more effective in ceramic bracket extraction at 2 Joules and that it decreased the polycrystalline ceramic brackets' bonding resistance more than it does for monocrystalline brackets (6, 8). They showed that high pulsating Nd:YAG laser had lower ceramic absorption levels in comparison to CO_2 laser and, after laser application, the ceramic brackets were removed by thermal ablation or photo ablation (10). Thermal ablation or photo ablation occurs when higher power laser beam interacts with adhesive material. This process causes the disruption of adhesive structure (16). It is believed that laser beam transmittance is significant without resin energy loss by means of the bracket for thermal ablation or photo ablation to take place (12). For this purpose, Hayakawa *et al*. (10) applied laser energy under the wing of each bracket for the ceramic bracket to the labiolingual direction for gingiva which are the thinnest part and for the coronal surface to correspond to the midpoint mesiodistally. It was shown that Nd:YAG laser caused disruption and collapse at the base of the bracket and the remaining adhesive caused localized changes similar to carbonization and black remains and these burned parts verified that Nd:YAG laser had enamel permeability more than that of CO_2 laser (10). In addition, it was reported that since Nd:YAG laser gives this high energy during the short application period, inner pulp temperature increase was only 5.1 ^{0}C (10). In addition, Strobl *et al*. (9) extracted alumina ceramic brackets with monocrystalline and polycrystalline structure by using Nd:YAG (1060nm) and CO_2 (10600 nm) laser in their study, and reported that both types of laser application for debonding purpose warmed the labial surface of the bracket and this heat dispersed through the resin from inside of the bracket and softened adhesive resin thermally and facilitated debonding. Moreover, they illustrated that monocrystalline brackets needed less laser energy in comparison to polycrystalline brackets (9). In the usage of Nd:YAG laser for debonding purpose, length of the application period and heat transmittance amount should be cared for. Further, it would have been better to evaluate intrapulpal temperature change in conjunction with the SBS values. There are only two studies in orthodontic literature evaluating debonding effectiveness by using Er:YAG laser. In the first study conducted by Öztoprak *et al*.(12), ceramic brackets pasted to cattle low incisors were removed by using Er:YAG laser (4.2 W, 9 sec.) and it was reported that there was lower SBS values in the group which was applied laser (9.52 MPa) in comparison to the control group (20.75 MPa). Although the results of this study were in line with our results (laser applied group was 8.47 MPa, control group was 13.42 MPa), usage of cattle teeth instead of human teeth (different enamel contents) and different power and application period of the used laser makes the comparison of this study and our study difficult (12). Although a decrease in SBS values in laser application similarly and the closeness of the average SBS values in the group where laser is applied, our SBS values of the control group teeth were lower. The other study was conducted by Mundethu *et al*. (11) and it was shown that the brackets pasted to 3rd molar teeth were extracted effectively by Er:YAG laser. In this study, usage of 3rd molar teeth with curved surface caused differences in composite thickness and therefore differences in SBS values and this makes the comparison difficult (11). In addition, although the results of our study are in line with the results of the previous studies as the laser application of the previous studies by using CO_2, Nd:YAG and Er:YAG laser was an effective method in bracket debonding, other than the different laser types and application techniques, we think that differences can be seen depending on the bracket type, adhesive type and pasting technique and the comparison of the previous studies would not be appropriate (2, 3, 7, 11).

In the present study, ARI scores were found to be higher in the study group samples where Er:YAG laser scanning was made. In the laser applied study group samples, owing to the low SBS values, brackets were removed easily and on the other hand ARI scores were found to be high. This meant that there was more adhesive left at the enamel surface and this increased the cleaning period of teeth surface and made their cleaning more difficult. Moreover, inner pulp heat increases could occur during the cleaning of remaining adhesive. Therefore, it is necessary that studies are needed evaluating thermal effects on the pulp during remaining adhesive cleaning at debonding and afterwards with the debonding SBS value prior to the application of Er:YAG laser *in vivo* conditions.

Different studies reported that inner pulp heat increase could occur during debonding of the brackets by laser at between 5.5 ^{0}C and 28.7 ^{0}C (1, 6, 18). It was reported that as long as the heat increase at the pulp room does not go over the acceptable limits determined by Zach and Cohen (5.5 ^{0}C) (20), it would not cause a permanent damage in the pulp. CO_2 laser usage in the extraction of ceramic brackets could lead to excessive heating (150 ^{0}C) of pulp tissue (6, 8). Therefore, different laser types started to be preferred. In the studies examining Nd:YAG laser effect on pulp, conflicting results were observed. (21, 22) Shoji and Horiuchi (22) determined in their study conducted with Nd:YAG that 4 weeks after the laser application, they determined low level calcified tissues in the pulp and reported that as the energy level increased, dentin repair tissue amount of the pulp increased as well. In the previous studies comparing the effects of Er:YAG and Nd:YAG laser systems, which are used for debonding, on the pulp, it was reported that although both laser systems had similar effects on adhesive resin, Er:YAG laser caused less intrapulpal heat increase in comparison to Nd:YAG laser (23, 24). In a study investigating intrapulpal heat increase in Er:YAG laser usage during debonding, it was reported that heat increase did not go over 5.5 ^{0}C and ceramic brackets can be removed without damaging the enamel and pulp tissue and that 6 sec scanning method as the application time was ideal (25). Furthermore, it was also reported that another crucial point to prevent pulp heat change during the debonding of ceramic brackets was performance of the 2nd laser application after giving minimum 5 minute interval if the bracket was not able to be extracted during the first 5-6 -second application (25). Therefore, instead of application of Er:YAG for 6 sec. and applying laser application at a single point, we preferred to do it as a scanning starting from the upper distal corner in order to prevent excessive heat increase in the pulp although it takes a longer time and in order to allow tissue cooling.

Another factor affecting SBS values is the thickness of the composite material. However, no special method was able to be found to standardize the composite material thickness in the previous studies (1, 12, 26). We did not use any standardization method for composite material thickness in our study, however, since we used lower central and lateral incisor teeth with smoother buccal surface in comparison to other teeth, we think that the composite layer is relatively thin and its thickness is relatively equal along the entire surface.

There are studies investigating the effect of laser debonding process on SBS value at the same time with bracket extraction and laser application, right after laser application and a few hours before the application (12, 16, 25). The common result of these studies is that by shortening the time between the laser application and extraction phase as much as possible, more successful results are achieved. In Abdul-Kader and Ibrahim's study (27) where laser application period is ignored, ceramic brackets were extracted right after laser application and 1 minute after laser application, and SBS values were compared. It was reported that lower enamel resistance was required when brackets were extracted right after laser application. They explained these results based on the fact that bonding softened up right after laser application and therefore the brackets were extracted by less force (27). In our study, we preferred to debond the brackets by SBS test right after the laser application.

Conclusion

Application of Er:YAG laser thermally softened adhesive resin structure, lowered the bonding resistance of ceramic brackets, and enabled their debonding. However, ARI score increased by Er:YAG laser application, extended the remaining adhesive cleaning time and can lead to temperature increases within the pulp. Therefore, thermal effects of Er:YAG laser application on pulp tissue should be further investigated.

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Conflict of interest
None declared

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