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EVALUATION OF THE EFFECTS OF ER-YAG LASER WITH A DIGITAL SCANNING TIP ON DEBONDING OF CERAMIC BRACKETS VS. THE CONVENTIONAL METHOD

ER-YAG LAZERİN DİJİTAL TARAMA UCU İLE SERAMİK BRAKETLERİN DEBONDİNGİ ÜZERİNE ETKİSİ VE KONVANSİYONEL DEBONDİNG METOT İLE KARŞILAŞTIRILMASI

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ABSTRACT

Objective: The aim of this study was to evaluate the effect of the Erbium-doped Yttrium Aluminum Garnet (Er-YAG) laser with a digital and homogeneous scanning (X-Runner) tip on the debonding process of ceramic brackets, comparing with conventional methods.

Method: 80 extracted teeth were divided equally into four groups regarding the bracket material and the debonding procedure: Polycrystalline+ Laser (PL), Monocrystalline+ Laser (ML), Polycrystalline+ Conventional (PC) and Monocrystalline+ Conventional (MC). Enamel cracks were examined both before and after debonding and the remaining adhesive on the enamel surface was evaluated by using the adhesive reminant index (ARI) with the aid of a stereomicroscope. Additionally, the effect of the Er-YAG laser on pulpal temperature rise and the extent of penetration of Er-YAG laser beams into the adhesive were measured. The nonparametric Kruskal-Wallis statistical test was employed to evaluate remaining adhesive on the tooth surface and enamel cracks, while the Mann-Whitney statistical test was utilized to assess temperature rise.

Results: No significant differences in enamel cracks or fractures were observed between the experimental groups concerning both bracket material and debonding procedure ($p>0.05$). Significant differences were found in ARI scores and pulpal temperature changes between the ML and PL groups. ($p<0.05$) Additionally, SEM images revealed that the Er: YAG laser beam did not significantly penetrate the adhesive and had no impact on the enamel surface.

Conclusion: The Er:YAG laser, especially when used with the X-Runner head, provides precise control and minimal thermal impact, ensuring no damage to the enamel or pulp. Therefore, it can be safely utilized for the removal of ceramic brackets in clinical settings.

Key Words: Debonding, Er:YAG Laser, Monocrystalline, Polycrystalline

ÖZ

Amaç: Bu çalışmanın amacı, Erbiyum doped Yttrium Alüminyum Garnet (Er-YAG) lazerin, dijital ve homojen tarama (X-Runner) başlığı kullanılarak, seramik braketlerin debonding işlemi üzerindeki etkisini geleneksel yöntemlerle karşılaştırarak değerlendirmekti.

Yöntem: Seksen adet çekilmiş diş, kullanılan braket ve debonding prosedürü açısından dört gruba ayrıldı: Polikristalin+ Lazer (PL), Monokristalin+ Lazer (ML), Polikristalin+ Konvansiyonel (PC) ve Monokristalin+ Konvansiyonel (MC). Mine çatlakları hem debonding öncesinde hem de sonrasında incelendi ve mine yüzeyinde kalan yapıştırıcı stereomikroskop yardımıyla artık adesiv indeksi (ARI) kullanılarak değerlendirildi. Ayrıca, Er-YAG lazerin pulpal sıcaklık artışı üzerindeki etkisi ve Er-YAG lazer ışınlarının adeziv içine nüfuz etme derecesi ölçüldü. Diş yüzeyinde kalan yapıştırıcıyı ve mine çatlaklarını değerlendirmek için parametrik olmayan Kruskal-Wallis istatistiksel testi kullanılırken, sıcaklık artışını değerlendirmek için Mann-Whitney istatistiksel testi kullanıldı.

Bulgular: Deney ve kontrol grupları arasında braket materyali ve debonding prosedürü açısından mine çatlakları veya kırıkları açısından önemli bir fark gözlenmedi ($p>0,05$). ML ve PL grupları arasında ARI skorları ve pulpal sıcaklık değişimlerinde önemli farklar bulundu. ($p<0,05$). Ek olarak, SEM görüntüleri Er: YAG lazer ışınının yapıştırıcıya önemli ölçüde nüfuz etmediğini ve mine yüzeyinde hiçbir etkisi olmadığını ortaya koydu.

Sonuç: Er:YAG lazer, özellikle X-Runner başlığıyla kullanıldığında, hassas kontrol ve minimum termal etki sağlayarak mine veya pulpaya zarar vermemektedir. Bu nedenle, klinik ortamlarda seramik braketlerin çıkarılması için güvenle kullanılabilir.

Anahtar Kelimeler: Debonding, Er: YAG Lazer, Monokristalin, Polikristalin

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INTRODUCTION

Orthodontic brackets come in three main types: plastic, ceramic, and metal. Metal brackets are commonly used, but there's growing demand for more aesthetically pleasing options. Initially, plastic brackets were used for their appearance but faced issues such as slot deformations, wing fractures, and discoloration [1]. Ceramic brackets, introduced in the 1980s, addressed many of these issues with improved resistance to deformation and discoloration. However, ceramic brackets can still cause problems like bracket fractures, increased friction, wear on teeth, and enamel fractures during removal [2,3].

Various debonding techniques have been developed to address these challenges, including conventional, ultrasonic, electrothermal, and laser methods [4]. Conventional debonding can lead to enamel damage, bracket fractures, and discomfort [5]. Laser systems stand out due to their ability to shorten the debonding time, reduce the required force, and thus enhance patient comfort [6,7]. To avoid potential unwanted side effects, the type of laser device, laser radiation technique, parameters used, as well as the type and technical specifications of the brackets, should be carefully assessed prior to the debonding procedure [8]. To date, Nd:YAG, CO_2, and Er:YAG lasers, has been explored to reduce these issues. Among these, Er:YAG lasers produce less heat, which may minimize potential damage [9-11]. This study introduces the use of the X-Runner (LightWalker, Fotona, Slovenia) homogenous scanning system in combination with the Er:YAG laser for debonding, to the best of our knowledge, the first use of this digital scanning device in such procedures. The X-Runner head offers advanced capabilities, including digital control over the shape and size of the treatment area, as well as the ability to adjust the number of scans and the interval between them [12,13].

The purpose of this study is to evaluate the effectiveness of Er:YAG laser with a digital and homogeneous scanning (X-Runner) tip in the debonding process of ceramic brackets (both polycrystalline and monocrystalline) by evaluating enamel cracks, the residual adhesive remaining on the enamel surface, the effect of laser on intrapulpal heat and the extent to which the laser penetrates into the adhesive.

METHOD

Study Sample

Statistical power analysis was performed at α=0.05, 80% power, to determine the sample size, and as in similar studies, it was determined that at least 20 teeth were needed in each group [14]. For this experimental study, eighty extracted human mandibular incisors which were free of cracks, visible damage or fillings were collected in 4 months at the department of Oral and Maxillofacial Surgery at Bezmialem University. The roots were separated from the crowns 2 mm from the cementoenamel junction using an aerator to measure temperature changes. A hole was drilled in the lingual surface of the crowns for the thermocouple's J-type cable (Fig 1). Tooth enamel surfaces were examined under 60X magnification for cracks and breaks before and after the procedure using a scoring method by Kitahara et al. (Fig 2) [15].

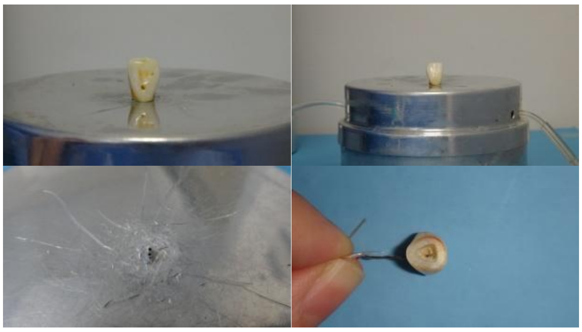

Figure 1. Placement of a Thermocouple on the Sample and Its Connection to the Fixture

Figure 2. Stereomicroscopic Images of Enamel Surfaces with and without Visible Cracks

Two types of brackets were used: polycrystalline brackets (Fascination ice, Dentaurum, Germany) with chemical retention and monocrystalline brackets (Inspire Ice, Ormco, USA) with mechanical retention. Teeth were polished, washed, dried, and etched with 37% orthophosphoric acid before applying Transbond XT primer and adhesive.

The samples were divided into four groups according to the bracket material and the debonding procedure: Polycrystalline+ Laser (PL), Monocrystalline+ Laser (ML), Polycrystalline+ Conventional (PC) and Monocrystalline+ Conventional (MC). Brackets were bonded to the crowns and light-cured. Afterwards, samples underwent thermal cycling (5,000 cycles between 5°C and 55°C with 30-second immersion and 15-second transition times).

Outcome Measures

A stereomicroscope (SMZ 1000, Nikon, Japan) was used to assess adhesive residues. The samples were examined at 1X (10 times) magnification and the ARI scoring was used to evaluate the adhesive residues remaining on the teeth (Table 1) [16]. Enamel surfaces were evaluated before and after adhesive removal, with further analysis using scanning electron microscopy (SEM) to assess laser penetration and proximity to enamel.

Table 1. Adhesive Remnant Index (ARI) Scoring

Definition	Score
No adhesive remains on the tooth surface	**0**
Less than 50% of the adhesive remains on the tooth surface	**1**
More than 50% of the adhesive remains on the tooth surface	**2**
All adhesive remains on the tooth surface	**3**

Data Collection

For debonding, polycrystalline brackets were removed using Weingart pliers by holding the mesial and distal wings of the bracket and rotating them from right to left; while monocrystalline brackets were removed using manufacturer-specific disposable plastic pliers. The pliers were positioned on the bracket wings in an occlusal and gingival orientation, and debonding was carried out with a single, straight motion from gingival to occlusal.

Er: YAG laser debonding was performed with the following parameters: 2970 nm wavelength, 1 W power, 600 mJ pulse energy, 2 Hz pulse frequency, non-contact mode, Medium Short Pulse (MSP) mode, without water, and 90% air. Using the digitally controlled X-Runner head, the scan shape was adjusted to be rectangular and slightly larger than the bracket base area (4mmx4mm). Each sample was scanned horizontally and homogeonously three times in succession, with no time intervals between scans. Out of 40 samples scanned, 32 were successfully debonded in three scans, and 6 were debonded in two scans. For 2 samples, 2 additional scans were performed to ensure complete debonding. Thermal changes occurring during Er: YAG laser application were measured using a setup that included a 0.36-mm-diameter J-type thermocouple (Omega Engineering, Stamford, Conn) and a data receiver with four sensors at the other end of the cable (Emko, EPLC9600-PID QUADRO).

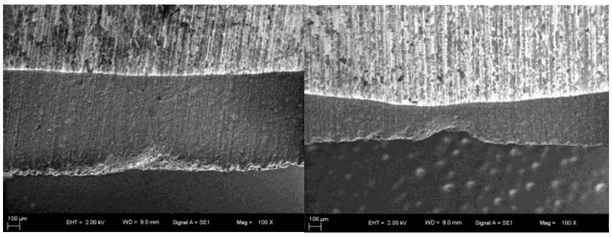

Figure 3. Cross-Sectional Images After Debonding of Monocrystalline Brackets (A), Pollycristalline Brackets (B)

Ethical Approval

All participants agreed to take part in the study and signed written informed consent. The study received ethical approval from Bezmialem Vakıf University Faculty of Dentistry Clinical Research Ethics Committee (date: 03.06.2015, approval number: 11/9).

Statistical Analysis

The statistical analysis was performed using the SPSS (SPSS/PC Version 16.0; SPSS Inc., Chicago, IL, USA) Significance level was set as p<0.05. Arithmetic mean (Mean) ± standard deviation (SD) and median values were used to define quantitative data. The Mann-Whitney test was used for the temperature increase evaluation. Kruskall-Wallis analysis, a nonparametric test, was used to evaluate whether there was a statistical difference between the groups in the enamel surface examination and ARI scoring evaluation.

RESULTS

The enamel surface evaluation findings before bonding and after debonding are shown in Table 2. No statistically significant difference was found between conventional- Er-YAG laser debonding groups before and after debonding in terms of enamel cracks and breaks (p>0.05). Similarly, when monocrystalline and polycrystalline brackets were evaluated in terms of enamel cracks, there was no statistically significant difference (p>0.05).

Table 2. Enamel surface evaluation findings before bonding and after debonding

Groups	N	Mean				Median		Min		Max		Std. Dev	
		T1	*P* value	T2	*P* value	T1	T2	T1	T2	T1	T2	T1	T2
ML	20	1,00	0,647	1,05	0,707	0,562	0,510	1,00	1,00	0	0	3	3
PL	20	0,80		0,90		0,523	0,447	1,00	1,00	0	0	2	2
MC	20	0,85		0,90		0,671	0,641	1,00	1,00	0	0	3	3
PC	20	0,90		0,90		0,447	0,447	1,00	1,00	0	0	2	2

ML: Monocrystalline Laser; PL: Polycrystalline Laser; MC: Monocrystalline Conventional; PC: Polycrystalline Conventiona;, Std. Dev: Standard deviation.

Table 3 shows the evaluation of residue adhesives remaining on the enamel surface using two different removal techniques. When ARI scores were evaluated in terms of both debonding procedure and bracket types, the difference between the groups was found to be statistically significant (p<0.05). Within the laser debonding groups (PL- ML), a significant difference in ARI scores was observed (p<0.05), with ML groups showing higher scores than PL. Comparing polycrystalline brackets, those debonded conventionally (PC) had higher ARI scores than those debonded with lasers (PL).

Table 3. ARI Score findings after debonding

Groups	N	Mean	Std. Dev	Median	Min	Max	*P* value
ML[a]	20	2,85	0,366	3,00	2	3	0,044
PL[a]	20	2,45	0,510	2,00	2	3	
MC	20	2,85	0,489	3,00	1	3	
PC	20	2,85	0,366	3,00	2	3	

ML: Monocrystalline Laser; PL: Polycrystalline Laser; MC: Monocrystalline Conventional; PC: Polycrystalline Conventional; Std. Dev: Standard deviation. The superscripts indicate a statistically significant difference between the groups.

Monocrystalline samples showed temperature changes between 2.6°C and 5.8°C, with an average increase of 3.71°C ± 1.15°C. Polycrystalline samples had changes ranging from 0.1°C to 5°C, with an average increase of 2.03°C ± 1.64°C. The monocrystalline group (ML) had significantly higher temperature increases compared to the polycrystalline group (PL) (p<0.05).

In the debonding process with Er:YAG laser X-Runner tip, SEM analysis was performed at 100 X magnification to see how much the laser penetrated into the adhesive resin. SEM images revealed that the Er: YAG laser penetrated 168 μm into a 670 μm adhesive layer for monocrystalline brackets and 126 μm into a 370 μm adhesive layer for polycrystalline brackets (Fig 3).

DISCUSSION

The findings of the present study revealed that, while the Er YAG laser does not cause a temperature increase that will damage the tooth, when the ARI values are examined, the effect of the laser using the X runner digital tip did not reach the enamel that remained in the adhesive. In laser debonding, no enamel cracks occurred and it was concluded that it can be used safely.

In recent years, alternative debonding procedures have been investigated to prevent microcracks in enamel and bracket damage during traditional debonding of ceramic brackets with pliers. Several studies have demonstrated that laser debonding of ceramic brackets is feasible and protects the enamel by leaving the adhesive on the bracket surface [17-19]. This suggests that laser debonding could be an effective method for removing ceramic brackets while preserving the enamel.

To date, CO2, Nd: YAG and Er: YAG lasers have been investigated for their ability to thermally soften adhesive resin during debonding. In this study, we selected the Er: YAG laser for its lower ceramic absorption and reduced thermal effects compared to other lasers [20,21]. Additionally, we explored the Er: YAG laser's X-Runner head, a previously unstudied feature. The X-Runner head, while similar to traditional non-contact Er: YAG handpieces, demonstrates superior control by allowing precise adjustments of parameters such as energy, frequency, mode, and air/water ratios through its digital display. It also allows for customization of the shape (circular, rectangular, or hexagonal) and size (width and height for rectangles, and diameter for circles and hexagons), as well as adjustment of the number of scans and waiting time between them, ensuring uniform application [12,22].

In this study, no enamel fractures or cracks were observed in either monocrystalline or polycrystalline brackets during debonding with the Er: YAG laser or conventional methods, indicating the safety of both techniques for ceramic bracket removal. This finding aligns with the literature, which notes that enamel cracks can occur regardless of the debonding method used [23-25]. It also suggests that adhering to the manufacturer's guidelines can help prevent bracket fractures during conventional debonding.

Studies have indicated that the duration and energy of laser application can have iatrogenic effects on pulpal damage [26-28]. Research on lasers has found that a temperature increases of up to 5.5°C is considered safe, as 85% of the teeth used in these studies remained vital, while a temperature rise of 1.8°C was associated with no pulpal damage [28]. In the current study, the average increase in pulpal temperature during debonding was 3.71°C ± 1.15°C. The maximum temperature rise observed was 5.8°C, with most samples recording temperatures below 5.5°C. These results indicate that the Er: YAG laser with the X-Runner tip does not adversely affect pulpal temperature. Another finding of our study is that polycrystalline brackets are more effective than monocrystalline brackets in minimizing increases in pulp temperature.

In this study, ARI did not show any statistically significant difference between the Er: YAG laser and the conventional method. This finding aligns with the results reported by Dostalova et al. [29] and Sedky et al. [30] and Sarı et al. [31]. However, some studies have reported contrary findings [4,32]. These discrepancies may be attributed to variations in laser parameters and types utilized across different research studies. In the current study, the lowest ARI score (2) was found in the polycrystalline (PL) group. Alakus-Sabuncuoglu et al. [33] and Tozlu et al. [34] studied the effects of debonding ceramic brackets with Er:YAG laser by evaluating the residual adhesive index after the debonding procedure. The authors concluded that the use of Er:YAG laser for debonding polycrystalline ceramic brackets was associated with increased residual adhesive index scores, which is in contrast to our findings. Our findings suggest that mechanically bonded monocrystalline brackets may be more effective than chemically bonded polycrystalline brackets during the laser debonding process. However, these results are in consistent with other findings in the literatüre [12,35].

SEM analysis showed that, as supported by the literature, Er: YAG laser beams did not reach the enamel surface and remained confined to the bonding resin during the debonding process for both polycrystalline and monocrystalline brackets, confirming the procedure's safety [26,35,36].

Limitations

This study has some limitations that need to be addressed. We conducted our study on incisors. The number of laser scans or the method of laser application may vary in premolars or molars. Pulpal temperature can also be evaluated in these teeth. However, premolars and molars may differ in terms of enamel crack formation after bracket removal. Therefore, further studies are needed to address these limitations.

CONCLUSION

This study demonstrates that both Er: YAG laser and conventional methods are safe for debonding ceramic brackets, as no enamel fractures or cracks were observed. The Er: YAG laser effectively minimizes increases in pulpal temperature, with results suggesting a temperature rise well within safe limits. Furthermore, the advanced features of the X-Runner enhance its significance by providing superior precision and efficiency, making the Er: YAG laser with the X-Runner head a highly effective and reliable alternative for ceramic bracket removal.

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