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A comparison between er:yag and er,cr:ysgg lasers in debonding of ceramic brackets
An in vitro study

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Abstract

Aim : The aim of the study is to compare the effectiveness of using Er: YAG and Er,Cr:YSGG lasers in debonding of two different types of ceramic brackets and its effect on enamel surface.

Materials and Methods : 72 polycrystalline and 72 monocrystalline ceramic brackets were bonded to 144 freshly extracted human premolars. The teeth were randomly divided into three groups of 48 and each group was further subdivided into 2 subgroups of 24. Group 1 was the control group where mechanical debonding of the two types of ceramic brackets was performed. Group 2 and 3 , Er:YAG and Er,Cr:YSGG lasers were used in the debonding process of the two types of the ceramic brackets , during the laser debonding process , a K-type thermocouple device was used to assess intrapulpal temperature change during laser irradiation. The adhesive remnant index was recorded for all 3 groups. Time needed for debonding was also recorded. Data were analyzed using SPSS version 20, Graph Pad Prism and Microsoft Excel.

Results: Laser debonding ceramic brackets is effective and more convenient than conventional methods. Monocrystalline brackets debond faster with Er:YAG laser than Er,Cr:YSGG laser, but polycrystalline brackets have a highly significant difference in ARI, with Er,Cr:YSGG laser having lower ARI values than the other two methods. The two laser groups' temperature rise was below the biological limit, making ceramic bracket debonding safe. No group had enamel damage.

Conclusions: Er:YAG laser debond monocrystalline brackets faster than polycrystalline brackets. Lasers are more effective in debonding ceramic brackets.

Introduction

Newman began direct orthodontic bracket bonding in 1963 after Buonocore introduced acid etching and bonding materials. Since then, direct bracket bonding has been the preferred orthodontic treatment. The bonding material for orthodontic brackets must meet certain standards. The material must have enough bond strength to withstand mouth forces and orthodontic treatment without failing. To avoid enamel damage during bracket debonding, bond strength should not be excessive. [1]

The adhesive-enamel or adhesive-

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bracket contact and cohesive failure within the adhesive can cause bond failure during bracket removal. Adhesive failure between resin and enamel increases tooth enamel damage risk. This is common with ceramic brackets. Preventing debonded teeth from losing enamel is crucial before orthodontic treatment.[2]

Scholarly literature describes several methods for removing metal and ceramic brackets. These methods use lasers, ultrasonics, and debonding pliers. Laser radiation in orthodontics is a recent development. In orthodontic treatment, lasers are used for mucogingival surgery, enamel surface etching, bracket bonding, and debonding. Many laser systems are used to treat intraoral soft tissue, including Er:YAG, Er,Cr:YSGG, CO2, Nd:YAG, and the diode laser.[3]

The most common dental lasers are Er:YAG (2940 nm) and Er,Cr:YSGG (2790 nm), which have a slight but significant wavelength difference.

Laser systems have numerous advantages, including increased patient cooperation, shorter treatment times, and assisting orthodontists in improving the design of a patient's smile to improve treatment efficacy. The success of orthodontic treatments can also be improved by reducing orthodontic pain and discomfort in the patients. [4,5,6,7]

Lasers used to debond orthodontic brackets may have unintended consequences. An elevated intrapulpal temperature may cause pulp tissue necrosis or pain.[8]

In recent years, ceramic brackets have become more popular due to orthodontic aesthetics. Adults seeking orthodontic treatment are especially affected by this trend. Ceramic brackets are more attractive than metal ones. However, ceramic brackets may cause pain, bracket breakage, and enamel damage during debonding. Ceramic brackets have higher bonding resistance and elastic modulus than metal brackets, causing these issues. Ceramic brackets are less flexible and more fragile, compounding the issues.[9]

Monocrystalline and polycrystalline ceramic brackets are available. Ceramic brackets are mostly alumina. The production method greatly affects ceramic bracket clinical performance. Monocrystalline structure is much stronger than polycrystalline. However, if a scratch occurs, the crack propagates, reducing fracture resistance to levels below polycrystalline brackets. The main difference between monocrystalline and polycrystalline brackets is optical transparency. Monocrystalline brackets are much clearer than polycrystalline ones.[9]

Laser beam transmissibility through ceramic brackets depends on structure, morphology, and composition. Experimental results show that polycrystalline ceramic brackets block more light than monocrystalline brackets.[9]

Ceramic bracket removal clinical considerations: Clinicians using ceramic brackets must consider enamel injury during debonding. These risks have been documented in many clinical trials. Why get orthodontic treatment for cosmetic reasons if removing ceramic brackets could damage enamel? This damage can reduce tooth appearance and require costly treatment, jeopardizing the tooth's long-term health. [9]

Tocchio et al. explain that laser debonding degrades adhesive resin through thermal softening, thermal ablation, or photoablation. Thermal softening occurs when the laser raises the bonding agent's temperature, causing the brackets to fall off the tooth due to gravity. Thermal ablation occurs when the resin is heated rapidly enough to vaporise before thermal softening debonds it. Photoablation only occurs when the adhesive substance is exposed to intense laser light energy, which disrupts molecular bonds. The adhesive resin decomposes. High energy and short pulses are essential for laser photoablation.[10]

The tooth and bracket gradually warm up during thermal softening, which may cause significant elevation. Thermal ablation and photoablation protect pulp tissue with rapid progression and low heat diffusion. [10]

The study compares Er: YAG and Er,Cr:YSGG lasers for debonding two ceramic bracket types and their effect on enamel surface.

Materials and Methods

Research Ethics Approval

The research was granted exemption from the ethics committee as it was performed on extracted teeth for orthodontic treatment purposes in the Department of Orthodontics of Ain Shams University.

Declaration of Interests

This study was part of a master's degree in Orthodontics, Faculty of Dentistry, Ain Shams University. No financial conflicts of interest were declared. The study was self-funded by the principal investigator.

Type of study

An in vitro study

Sample Size Calculation

Sample size calculated depending on a study conducted by Sabuncuoğlu et al. [11] as reference.

We selected 144 freshly extracted maxillary and mandibular premolars extracted for orthodontic purposes at the Orthodontic Department of Ain Shams University.

Inclusion Criteria

a) **Normal anatomical form**
b) **Absence of caries or restorations**
c) **Absence of cracks, fractures, or enamel chipping in the buccal surface.**
d) **No history of previous surface conditioning by chemical agents such as hydrogen peroxide and acid etchant.**

Exclusion Criteria

Teeth with general disturbances in the enamel structure such enamel hypoplasia, enamel hypocalcification, and enamel fluorosis.

Sample Distribution

The teeth were randomly divided into 3 groups (n=144), each group had equal number of teeth (n=48) and each group was further subdivided into two subgroups (n=24).

Randomization method

All teeth were distributed blindly to their groups.

Treatment of the extracted teeth

The extracted teeth were immersed in distilled water at room temperature. The water was changed weekly to prevent bacterial growth. Prior to bracket bonding on the tooth surface, the buccal surface was inspected with magnifying loops of 10X magnification for presence of enamel cracks.

Steps:

- **Prior to bonding, the teeth in the three groups were polished with low-speed handpiece (10,000 to 30,000 rpm), rubber-cup, and non-fluoridated pumice paste for 20 secs.**
- **The teeth in all 3 groups were etched with 37% phosphoric acid gel for 30 secs and were then rinsed for 20 secs, the surface was dried thoroughly until a chalky white appearance of enamel. Two layers of Orthosolo [1] universal bond (Orthosolo, ORMCO) were applied separately using micro brush to etched enamel and dried with air dryer for 10 secs, then cured for 10 secs according to manufacturer instructions.**
- **Adhesive Grengloo [2] (ORMCO) was applied on the back of the monocrystalline brackets [3] (Perfect Clear, Hubit) and on the back of polycrystalline brackets [4] (Matt Orthodontics, USA).**
- **The brackets were placed at 4 mm distance from the buccal cusp tip using a bracket positioning gauge star 670[5] (Nadir & Co., Pakistan)**
- **The brackets were fully adjusted and seated to the tooth surface by applying pressure with an explorer.**
- **Excess adhesive was removed using an explorer.**
- **Curing was performed using an LED curing unit[6] (3M Unitek) with 450 nm wavelength for 10 secs from the mesial and 10 secs from the distal (a total of 20s) at 3mm distance. After the bracket bonding, the teeth were immersed in distilled water at 37 ˚C for 24 hrs to complete polymerization.[12]**

Laser Source:

In the presented study, two laser sources were used, the first was Er:YAG laser[7] (Lightwalker, Fotona) emitting a wavelength of 2.94 µm was used for bracket debonding.

The second laser source was an Er,Cr:YSGG laser [8] (Waterlase iPlus, Biolase, USA) with 2780-nm wavelength.

Laser parameters:

- **Er:YAG laser: 400 mJ, 10 Hz, 800 µs pulse duration , 1.3 mm fiber tip diameter, with air and water spray adjusted at rate 4.**
- **Er,Cr:YSGG: average power 8 W, H-mode was used in non-contact mode with the repetition rate 20 Hz, water 80%, and air 40%, using gold handpiece and MG6 (600 µm) tip.**

[1] Orthosolo, ORMCO, Brea, California, USA
[2] Grengloo, ORMCO, Brea, California, USA
[3] Perfect clear, Hubit, South Korea
[4] Matt Orthodontic, USA
[5] Nadir & Co., Pakistan
[6] Light cure unit 3M Unitek, USA
[7] Lightwalker, Fotona, Slovenia
[8] Waterlase iPlus, Biolase, USA

Brackets Debonding

The specimens were allocated randomly to their groups and subgroups.

- **First Group (control group): mechanical debonding**

Subgroups: 24 polycrystalline and 24 monocrystalline

- **Second Group (Er:YAG)**

Subgroups: 24 polycrystalline and 24 monocrystalline

- **Third group (Er,Cr:YSGG)**

Subgroups: 24 polycrystalline and 24 monocrystalline

Steps of debonding:

Each group and subgroup of teeth were distributed in different jars which were labelled.

The first group (control group):

Mechanical debonding

- **The teeth were held using a clamp where the teeth were well secured between its peaks.**
- **A straight debonding plier was used to debond the ceramic brackets where the peaks of the plier held occlusal-gingival sides of the bracket.**
- **Occluso-gingival movement with slight squeezing force were applied to debond the brackets.**

The second group (Er:YAG) and third group (Er,Cr:YSGG):

- **The teeth were held using a clamp where the teeth were well secured between its peaks.**
- **The probe of the thermocouple was inserted to the access cavity previously prepared.**
- **The probe was held and secured into place using the hands of the operator.**
- **The operator wore protective eyeglasses to protect the eyes from the laser source.**
- **The parameters of the laser were adjusted as previously mentioned.**
- **LASER energy was applied at a distance of 1 mm from the bracket, parallel to the bracket , guided by the tooth surface, directed between the bracket base and the tooth surface, by circular motion around the bracket, to avoid any iatrogenic enamel damage.**

This was applied to both subgroups of polycrystalline and mono crystalline brackets.

Adhesive remnant index (ARI)

After debonding of the brackets, the ARI was evaluated by two different clinicians to test inter observer reliability under 20X magnification under stereomicroscope. Fig (1)

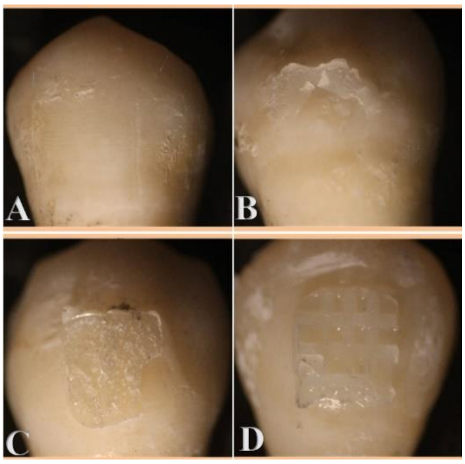

Fig (1) showing the ARI scores of enamel surface after debonding. (A) ARI score 0 no adhesive remnants on the enamel surface.. (B) ARI score 1 less than half of the adhesive remnants on the tooth surface. (C) ARI score 2 more than half of the adhesive remnants on the tooth surface. (D) ARI score 3 all the adhesive remains on the tooth surface and the base bracket imprints are visible on the resin

The tooth surface was blasted with cool air spray to cool off the remaining resin and change color back to green for ease of evaluation.

The Adhesive Remnant Index (ARI) was assessed for all 144 specimens. The ARI scores are classified as follows:

- **Score 0: indicated no adhesive remnants on the enamel surface.**
- **Score 1: indicated less than half of the adhesive remnants on the tooth surface.**
- **Score 2: indicated more than half of the adhesive remnants on the tooth surface.**
- **Score 3: indicated all the adhesive remains on the tooth surface and the base bracket imprints are visible on the resin [13].**

Temperature Measurement:

A k-type thermocouple device was used to measure the fluctuation in temperature during the laser beam application.

A thermocouple, also known as a "thermoelectrical thermometer", is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the Seebeck effect, and this voltage can be interpreted to measure temperature. Thermocouples are widely used as temperature sensors.

The temperature was measured in a continuous manner with a k-type thermocouple device the probe was inserted into the pulp chamber through an access cavity that was performed before bonding of the brackets onto the teeth surfaces, and before application of the laser beam. The initial reading was recorded till it was stable after inserting the probe into the pulp cavity and before application of the laser, then the fluctuation in the temperature was recorded during the application of the laser beam till the bracket was debonded. The temperature was recorded in Celsius.

Time needed for debonding:

A second investigator used a stopwatch to determine the time needed for debonding in each specimen in all groups, in the control group the peak of the debonding plier was secured around the bracket and the second investigator started the stopwatch at the same time as the first investigator started the debonding force.

In the laser groups the time was measured in seconds started corresponding to the laser application till the bracket debond or until minimum force was needed for debonding and the time recorded was tabulated to compare required to debond brackets using the three techniques.

Statistical analysis

Statistical analysis was performed with SPSS 20[9], Graph Pad Prism[10] and Microsoft Excel 2016[11]

All quantitative data were explored for normality by using Shapiro Wilk Normality test and Kolmogorov test presented as minimum, maximum, means and standard deviation (SD) values. All data were presented in (8) tables & (7) graphs.

Tests used:

Exploring data for normality using the Shapiro-Wilk Normality test and Kolmogorov test which is presented in quantitative data. All data were non-parametric. Comparison between two groups was conducted using the Wilcoxon signed-rank test, while comparison between three groups was conducted using the Kruskal-Wallis test. All comparisons in the qualitative data were conducted using the Chi-square test.

Results

Regarding the ARI scores recorded it showed a highly significant difference between polycrystalline and monocrystalline brackets in all groups which is summarized in tables (1)(2).

[9] Statistical Package for Social Science, IBM, USA.
[10] Graph Pad Technologies, USA
[11] Microsoft Co-operation, USA.

Table (1): Frequency and percentages of different scores regarding The Adhesive Remnant Index (ARI) of polycrystalline of group all groups, comparison between all groups by using Chi square test:

Polycrystalline		**Group I**		**Group II**		**Group III**		**P value**
The Adhesive Remnant Index (ARI)		N	%	N	%	N	%	
Score (0)	No adhesive remnants on the enamel surface	3	12.5%	0	0.0%	0	0.0%	0.008*
Score (1)	Less than half of the adhesive remnants on the tooth surface.	5	20.8%	13	54.2%	14	58.3%	
Score (2)	More than half of the adhesive remnants on the tooth surface	6	25.0%	2	8.3%	7	29.2%	
Score (3)	All the adhesive remains on the tooth surface and the base bracket imprint are visible on the resin	10	41.7%	9	37.5%	3	12.5%	

N: frequency %:percentage

*Highly significant difference as P<0.05.

Table (2): Frequency and percentages of different scores regarding The Adhesive Remnant Index (ARI) of monocrystalline of group all groups, comparison between all groups by using Chi square test:

Monocrystalline		**Group I**		**Group II**		**Group III**		**P value**
The Adhesive Remnant Index (ARI)		N	%	N	%	N	%	
Score (0)	No adhesive remnants on the enamel surface	7	29.2%	2	8.3%	2	8.3%	0.01 *
Score (1)	Less than half of the adhesive remnants on the tooth surface.	12	50.0%	10	41.7%	14	58.3%	
Score (2)	More than half of the adhesive remnants on the tooth surface	2	8.3%	2	8.3%	6	25.0%	
Score (3)	All the adhesive remains on the tooth surface and the base bracket imprint are visible on the resin	3	12.5%	10	41.7%	2	8.3%	

N: frequency %:percentage

*Highly significant difference as P<0.05.

Temperature Measurement:

In this study comparing the polycrystalline and monocrystalline ceramic brackets temperature rise in the Er:YAG group was highly significant in which the polycrystalline group had higher temperature rise although it didn't increase the biological limit.

The Er,Cr:YSGG group also was highly significant in which the monocrystalline group had a higher rise in temperature.

Comparing the Er:YAG and Er,Cr:YSGG groups had a highly significant difference in the monocrystalline subgroups in which the Er:YAG had lower rises in temperature, while in the polycrystalline subgroups no significant difference was found.

Time Needed for Debonding

In comparing polycrystalline and monocrystalline brackets in each group only showed a high significant difference in the Er:YAG laser group.

While in intergroup comparison the polycrystalline brackets were insignificantly the lowest in group I , then group III , while group II was significantly the highest. And in Monocrystalline brackets group II was insignificantly the lowest, then group I , while group III was significantly the highest.

Enamel Damage

After evaluation of the teeth after debonding under a stereomicroscope with 20X magnification no noticeable enamel damage such as cracks or tear-outs was observed.

Discussion

Tocchio et al.[10] have proposed that the process of laser debonding involves mechanisms such as thermal softening, thermal ablation, or photo-ablation. Thermal softening is observed when a laser beam with a relatively low power density is applied to the brackets, leading to the softening of the resin material. The brackets will dislodge from the tooth surface due to the force of gravity. Thermal ablation and photo-ablation are techniques that involve the vaporization of resin by the rapid increase in temperature induced by high power density lasers. Consequently, the bracket has the potential to be dislodged from the surface of the tooth.

Several previous research (Nalbantgil et al., [14]; Dostalova et al.[8] Sabuncuoglu et al., [11]; Hibst et al., [15] have demonstrated the efficacy of the Er: YAG laser in diminishing the shear bond strength of polycrystalline ceramic brackets.

Polycrystalline ceramic brackets lack a consistent crystal structure, resulting in reduced transmissibility and increased energy loss as it traverses the bracket and interacts with the resin. Hence, it is imperative to carefully select a laser that can effectively impact the resin while minimizing the generation of excessive heat.

The present investigation employed Er:YAG and Er,Cr:YSGG lasers with varying wavelengths to facilitate the debonding process of both polycrystalline and monocrystalline ceramic brackets. The study aimed to assess and compare the impact of these lasers on the adhesive remnant index (ARI) and Enamel damage in relation to the traditional debonding technique.

The chosen parameters of the lasers were used according to the study performed by Hachem et al. [16] he used the Er:YAG laser in setting of 6W and 9W but when 6W was used,in this study it was found to be very aggressive, so the power was decreased to 4 W which was sufficient in debonding of the brackets, while in Er,Cr:YSGG he used 6W and 9W power in which both powers was effective in debonding of the ceramic brackets showing higher scores of ARI in the 6W group was lower ARI scores in the 9W group hence an average wattage was chosen in this study of 8W to debond the ceramic brackets.

Oztoprak et al.[17] studied Er:YAG laser for bracket debonding by using scanning method. The mechanism of debonding was found to be due to thermal softening of the resin.

In the current study, the mechanism of laser debonding was also thermal softening with the polycrystalline brackets group contradicting those results found by Hachem et al. [16] and matching the results of Oztoprak et al. [17] while it was thermal ablation with the monocrystalline brackets group matching the results of Mundethu et al.[18], Hachem et al.[16,] and Downarowicz et al. [19]

The results align with the idea that the laser transmissibility is better through the monocrystalline rather than polycrystalline ceramic brackets allowing more of the laser energy to pass to the adhesive layer in the monocrystalline brackets leading to debonding by thermal ablation.

In the Er,Cr:YSGG laser groups the brackets failed to debond by thermal ablation and without the need of external force (debonding plier) to debond and this is contradicting the results found by Hachem et al.[16] and Mundethu et al.[18]

Laser energy was applied at a distance of 1 mm from the bracket, parallel to the bracket, guided by the tooth surface, directed between the bracket base and the tooth surface, by circular motion around the bracket, to avoid any iatrogenic enamel damage and focus the laser beam energy on the adhesive until debonding occurred, following the technique in previous studies by Nalbantgil et al. [14], Les'niak et al. [20], and Sedky et al. [21]

The difference in the effect of laser on both monocrystalline and polycrystalline brackets may be due to the decreased transmissibility of laser beam through the non-uniform crystal structure increasing the laser energy loss passing through the bracket to reach the resin, so, for debonding ceramic brackets a laser should be chosen that will directly affect the resin without conducting too much heat.

In the control group, mechanical debonding was performed by a debonding plier, the force was applied occluso-gingivally with minimal squeezing force to avoid fracture of the bracket itself, the debonding process was convenient with no hardships along the way, there was no difference between the debonding of polycrystalline and monocrystalline brackets regarding the technique used.

The force used by the investigator to debond the brackets that failed to debond by just laser application was much less than the force needed to debond the brackets in the control group as described by the investigator, this indicates the effect of the laser applied in decreasing the shear bond strength of the adhesive as described by Oztoprak et al.[17]

The ARI scored difference among groups may be due to the difference in the bracket base morphology which can differ in the bonding strength of the bracket.[22,23,24] or difference in the bonding strength of the adhesive to the type of ceramic microstructure.[25]

Unfortunately, higher ARI scores also mean more post-debond cleanup is required thus extending chairside time. Removing all adhesive during laser debonding eliminates the need for post-debond cleanup and thus decreases the chairside time.

Temperature Measurement

Moving in a circular motion around the bracket not applying the laser on just 1 point and applying the laser with water cooling reduced the probability of increasing the intrapulpal temperature during the debonding. According to Zach and Cohen[26], a 5.5°C temperature increase could cause pulp necrosis in 15% of teeth, thus the laser was applied with water-cooling in the present study to reduce the probability of intra-pulpal temperature increase while debonding the ceramic brackets.

The temperature rise in the Er:YAG group used with polycrystalline brackets was probably due to the longer exposure time to the laser needed to debond the bracket while in the monocrystalline bracket it only took a few seconds which didn't allow for the temperature to rise.

The coolant used with both lasers ensured that the temperature wouldn't surpass the biological limit of the pulp and would prevent pulp necrosis.

Time Needed for Debonding

The study revealed that the debonding process took longer when using lasers on polycrystalline brackets compared to the conventional method. This can be attributed to the time required for the laser energy to be absorbed by the adhesive layer and subsequently transformed into thermal softening. However, the use of lasers for debonding resulted in decreased Adhesive Remnant Index (ARI) scores. This suggests that the need for extensive enamel finishing after bracket debonding can be eliminated.[21]

The use of Er:YAG laser in monocrystalline brackets resulted in a shorter debonding time compared to the standard approach. This suggests that the transmissibility of the laser energy through the monocrystalline brackets was much higher leading to decreased debonding time. However, the application of Er,Cr:YSGG laser, despite the strong transmissibility of the bracket to the laser energy, led to a much slower debonding process which may be due decreased transmissibility of Er,Cr:YSGG laser through the monocrystalline brackets.

Enamel Surface

Zachrisson et. al. asserted that the occurrence of irreversible harm to the enamel surface following fixed orthodontic treatment is unavoidable.

Several factors, apart from the debonding method, can influence enamel damage:

- **The type of bracket used, specifically ceramic brackets, exhibit a greater shear bond strength to enamel compared to metal brackets. Consequently, when these ceramic brackets are removed, they tend to cause more damage to the enamel.**
- **The condition of the enamel surface prior to bonding: the existence of caries, cracks, and fillings diminishes the strength of the enamel surface and raises the likelihood of enamel damage.**
- **Tooth vitality: Non-vital teeth are less resilient than vital teeth and more susceptible to enamel damage.**
- **The most prevalent teeth to develop cracks are the incisors, canines, and first molars.**
- **Post-debond cleaning technique: Utilize tools such as Tungsten carbide bur (TCB), Sof-Lex (SL) discs, ultrasonic tools, pliers (PL), rubbers, or composite burs.**

Upon examination of the teeth following debonding using a stereomicroscope with 20X magnification, no discernible enamel damage, such as cracks or tear-outs, was detected.

Conclusions

1. **Er:YAG laser is faster in debonding of monocrystalline brackets than polycrystalline brackets**
2. **The use of laser in debonding of ceramic brackets generally reduces the ARI score which leads to decreased post debonding enamel finishing.**
3. **The use of lasers in debonding of ceramic brackets is more effective than conventional method.**
4. **Lasers don’t cause a biologically significant rise in temperature making it safe to use.**

Recommendations

1. **Further studies using a universal testing machine in comparing the effect of the two lasers on the two brackets are needed.**
2. **Perform a pilot study to determine the laser power most optimum for debonding for both types of brackets.**

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