

A comparative evaluation of the effectiveness of erbium-doped yttrium aluminum garnet laser with other in house refurbishing methods for reconditioning stainless steel and ceramic brackets. An environmental scanning electron microscope and shear bond strength analysis: An *in-vitro* study

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Abstract

Introduction: Brackets can be recycled by sending them to a commercial recycling company but it is time consuming and the bracket cannot be bonded in the same appointment. Hence in-house methods for recycling of brackets would be beneficial to both the orthodontist and the patient. **Aim:** In our study, we compared the shear bond strength of brackets after being recycled with erbium-doped yttrium aluminum garnet (ER:YAG) laser, sandblasting and the thermal method. **Materials and Methods:** The study was carried out on 126 extracted premolars. The bonding procedure was performed with mandibular premolar metal and premolar ceramic brackets. Eighty-four teeth were subdivided into three groups for each method of recycling. These groups were further subdivided into two groups of 14 teeth each for the types of brackets used. Prior to the initial bonding the bracket was also viewed under an environmental scanning electron microscope to examine the meshwork of the brackets and once again after the respective recycling methods had been performed. **Results:** We found that for stainless steel brackets, the sandblasting method was superior to the ER:YAG laser, as the recycled brackets showed a higher shear bond strength. For ceramic brackets the ER:YAG laser recycled group had the highest recycled shear bond strength therefore was the best method of recycling ceramic brackets.

Key words: Erbium-doped yttrium aluminum garnet, recycling brackets, stainless steel and ceramic

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INTRODUCTION

One of commonly faced problems in orthodontic treatment is bracket dislodgement, and we may discard a dislodged bracket and replace it with a new one, but this would only increase the cost and duration of treatment. Brackets can be recycled by sending them to a commercial recycling company but it is time consuming and the bracket cannot be bonded in the same appointment. In our study, we compared the shear bond strength of brackets after being recycled with an erbium-doped yttrium aluminum garnet (ER:YAG) laser, sandblasting and the thermal method.

MATERIALS AND METHODS

The study was carried out on 126 extracted premolars. The bonding procedure was performed with mandibular premolar metal brackets, and premolar ceramic brackets, without the metal slot. The teeth were then bonded with the bracket being placed at the center of the crown. Eighty-four teeth were subdivided into three groups (28 each) for each method of recycling. These groups were further subdivided into two groups of 14 teeth each for the types of brackets used. A universal testing machine was used to find each group shear bond strengths after rebonding of brackets, as well as establishing a control group reading, during the first debonding. Prior to the initial bonding the bracket was also viewed under an environmental scanning electron

Microscope to examine the meshwork of the brackets. After the brackets were debonded and their shear bond strengths recorded they were recycled by the ER:YAG laser at a wavelength of 2.94 μm , sandblasted with a particle size of 50 μm , and thermo recycled. For thermo recycling the brackets were held with a tweezer and the base of the bracket was kept in the nonluminous part of the flame until it became cherry red. Thereafter, it was immediately dipped in room temperature water bath. Their meshwork once again viewed under the environmental scanning electron microscope (ESEM) to examine the condition of the meshwork and amount of adhesive removed from the bracket base.

RESULTS

We found that for stainless steel brackets, the sandblasting method was superior to the ER:YAG laser, as the recycled brackets showed a higher shear bond strength. For ceramic brackets the ER:YAG laser recycled group had the highest recycled shear bond strength, therefore, was the best method of recycling ceramic brackets.

DISCUSSION

Matasa^[1] has stated that a bracket can be reused upto five times, whereas Wheeler and Ackerman^[2] have observed that a bracket which underwent single recycling was of negligible clinical importance. All 84 teeth were bonded with Transbond XT (3M UNITEK, Pune, India) according to the manufacturer's instructions to ensure standardization.

Olsen *et al.*^[3] concluded from their study that the changes in bond strength may also be due to the changes in morphological characteristics of the enamel surface as a result of the remnants adhesive. Thus to eliminate the bias arising from incomplete removal of the composite from the enamel surface by the operator which would in turn cause a reduction in the shear bond strength, 42 teeth (half the sample size) were discarded, while another 42 freshly extracted teeth were prepared and included in the study. Debonding was done by an instron machine to establish the shear bond strength. Both the ceramic brackets, as well as, the stainless steel brackets (42 each) were recycled with sandblasting, thermal method and the ER:YAG laser, respectively (14 in each group).

A good method of recycling a bracket is any method that removes the bonding material effectively from the bracket base without damaging the bracket base and distorting the bracket or any other areas of attachment.^[4]

Stainless steel brackets

As stated by Reynolds^[5] in 1975 the optimal bond strength required clinically was 7.85 MPa, whereas in our study we got an average initial bond strength of 9.36 MPa for ER:YAG, sandblasting, and thermal method which was clinically acceptable. After debonding, the brackets were recycled using the three methods that are, thermal, sandblasting, and laser.

Thermal method

It was found that there was a significant reduction in the shear bond strength of the brackets which were recycled by the thermal method. This reduction was found to be 6.23 ± 4.89 MPa [Table 1]. It was greater than the reduction seen in the brackets recycled by sandblasting and laser. This indicates that the thermal method was least effective in the recycling of the brackets and is in accordance with what Quick *et al.*,^[6] reported in their study. Post recycling of the brackets, a shear bond strength of 3.53 MPa was found which was in accordance with the shear bond strength in a study reported by Bahnasi *et al.*^[7] who found the shear bond strength to be 3.43 MPa.

Sandblasting

A shear bond strength of 7.14 ± 0.78 MPa [Table 2] was found after recycling the brackets with sandblasting. This

was found to be higher than the shear bond strength reported by Arun *et al.*^[8] (5.422 ± 1.67 MPa) who used 50 μm sized alumina particles, but lower than the shear bond strength found by Bahnasi *et al.*^[7] (8.77 MPa).

Erbium-doped yttrium aluminum garnet laser

In our study, recycling shear bond strength of 6.10 ± 1.32 MPa [Table 3] was found. This was decreased as compared to Arun *et al.*^[8] who used an ER:YAG laser as well but found a shear bond strength of 8.133 ± 2.65 . However, a frequency of 20 Hz was used in our study whereas their study they used a 12 Hz laser.

They also compared the ER:YAG laser with sandblasting and found that brackets were recycled by the laser showed a higher shear bond strength as compared to sandblasting. When an overall comparison was done of the three methods of recycling, it was evident that there was a significant difference between the reductions in shear bond strength between groups [Table 4] (One-way ANOVA test).

However, in our study, we found that the brackets recycled by sandblasting showed a better shear bond strength clinically as compared to ER:YAG. But, the difference between the two groups was not statistically significantly (*Post-hoc* Tukey's test).

The group with the highest reduction in shear bond strength post recycling, the thermal method, showed a significant reduction in bond strength when compared to both the ER:YAG laser as well as the sandblasting group. Thus, it can be concluded that sandblasting and laser method can be useful for recycling the brackets.

Ceramic brackets

Martina *et al.*^[9] found the shear bond strength of ceramic brackets to be 15.52 MPa, which is in accordance with the average initial bond strength of 12.09 MPa in our study.

Thermal recycling

Gaffey *et al.*^[10] recycled ceramic brackets by heat and then treated them with silane and in another group with heat, silane, and hydrofluoric acid. In both instances, the shear bond was less than their control. The shear bond strengths were 9.1 MPa and 0.7 MPa, respectively. As compared to our study, which recorded a shear bond strength of 3.20 ± 1.24 MPa [Table 5], the heat treated and silane treated group showed a higher recycling bond strength and could be accounted for by the addition of silane.

Sandblasting recycling

Chung *et al.*^[11] found a shear bond strength of 2.97 ± 2.29 MPa when recycling the ceramic brackets with sandblasting

alone. This value was lower than our study value of 6.93 ± 3.18 MPa [Table 6]. However, in the same study, they treated the sandblasted recycled brackets with a sealant, the

Table 1: Shear bond strength (MPa) of stainless steel brackets after recycling using thermal method

Thermal method (mean \pm SD)		
Before	After	Difference
9.77 \pm 4.81	3.53 \pm 0.40	6.23 \pm 4.89

SD – Standard deviation

Table 2: Shear bond strength (MPa) of stainless steel brackets after recycling using sandblasting

Sandblasting method (mean \pm SD)		
Before	After	Difference
9.25 \pm 2.14	7.14 \pm 0.78	2.11 \pm 1.66

SD – Standard deviation

Table 3: Shear bond strength (MPa) of stainless steel brackets after recycling using Er:YAG

Er:YAG laser (mean \pm SD)		
Before	After	Difference
9.07 \pm 3.63	6.10 \pm 1.32	2.96 \pm 3.63

Er:YAG – Erbium-doped yttrium aluminum garnet; SD – Standard deviation

Table 4: Comparison of mean reduction in shear bond strength of stainless steel brackets with all three methods

Methods of recycling (mean \pm SD)			
Thermal method ^a	Sandblasting method ^b	Er:YAG laser method ^c	P
6.23 \pm 4.89	2.11 \pm 1.66	2.96 \pm 3.63	0.012*

*Between group: ANOVA, $P < 0.05$ (statistically significant) within groups, *Post-hoc* Tukey's: a > b, * $P = 0.013$, b > c, $P = 0.810$, a > c, * $P = 0.05$. Er:YAG – Erbium-doped yttrium aluminum garnet; SD – Standard deviation

Table 5: Shear bond strength (MPa) of ceramic brackets after recycling using thermal method

Thermal method (mean \pm SD)		
Before	After	Difference
12.07 \pm 0.68	3.20 \pm 1.24	8.87 \pm 1.47

SD – Standard deviation

Table 6: Shear bond strength (MPa) of ceramic brackets after recycling using sandblasting

Sandblasting method (mean \pm SD)		
Before	After	Difference
12.04 \pm 3.16	6.93 \pm 3.18	5.10 \pm 4.49

SD – Standard deviation

shear bond strength increased to 7.65 ± 5.62 MPa, which was similar to our value. This increase in bond strength was due to the sealant flowing and filling the micro etched surface and increasing the bond strength.

Erbium-doped yttrium aluminum garnet recycling

The brackets recycled by ER:YAG laser showed a shear bond strength of 7.15 ± 3.24 MPa [Table 7] which is less than the strength found by Ahrari et al.,^[12] who found the shear bond strength of ceramic brackets recycled with ER,CR:YSGG laser at 3.5 W and 4 W to be 14.3 MPa and 12.8 Mpa, respectively. This difference in these findings would be due to the different lasers used in their study.

The group that showed the least reduction in the shear bond strength after recycling was the brackets which were recycled by ER:YAG laser [Table 8]. Thus it can be concluded that for ceramic brackets the best method of recycling would be the ER:YAG laser or sandblasting the brackets, however, recycling of the brackets with the thermal method is not recommended as it had a poor recycled shear bond strength, as well as the aesthetic of brackets, is compromised.

Environmental scanning electron microscope

As a supplement to the shear bond strength analysis, we also viewed the bracket bases under an ESEM to examine the quantity of adhesive removed along with any damage to the bracket bases.

Stainless steel brackets [Figure 1]

Under the magnification of $\times 200$ the maximum adhesive was removed by the ER:YAG [Figure 2] without damaging the meshwork of the brackets. However, sandblasting [Figure 3] showed higher shear bond strength, but this can

be explained on the basis of the alumina particles causing the meshwork to become roughened and increasing the surface area which increased the mechanical retention of the bracket. The same occurred with a study conducted by Basudan^[5] where they found the stainless steel brackets base to have a roughened appearance. A study by Diedrich and Dickmeiss^[13] actually found an increase in shear bond strength of sandblasted brackets by 34% as compared to untreated brackets. The thermal recycled [Figure 4] brackets showed the percentage of adhesive between the meshwork was higher as compared to the ER:YAG laser group. Thus the shear bond strength was higher in the ER:YAG laser group as compared to the thermal group.

Ceramic brackets [Figure 5]

Under ESEM magnification of $\times 200$ before recycling we viewed grooves on the base of the bracket. We found that sandblasting was the most efficient in removing the adhesive but there was damage to the base of the bracket in the form of flattening of the base which decreased the

Table 7: Shear bond strength (MPa) of ceramic brackets after recycling using Er:YAG laser

Er:YAG laser (mean \pm SD)		
Before	After	Difference
12.16 \pm 0.89	7.15 \pm 3.24	5.01 \pm 3.08

Er:YAG – Erbium-doped yttrium aluminum garnet; SD – Standard deviation

Table 8: Comparison of mean reduction in shear bond strength of ceramic brackets with all three methods

Methods of recycling (mean \pm SD)			
Thermal method ^a	Sandblasting method ^b	Er:YAG laser method ^c	P
8.87 \pm 1.47	5.10 \pm 4.49	5.01 \pm 3.08	0.004*

*Between group: ANOVA, $P < 0.05$ (statistically significant) within groups, Post-hoc Tukey's test: a > b, * $P = 0.011$, b > c, $P = 0.997$, a > c, * $P = 0.009$.
Er:YAG – Erbium-doped yttrium aluminum garnet; SD – Standard deviation

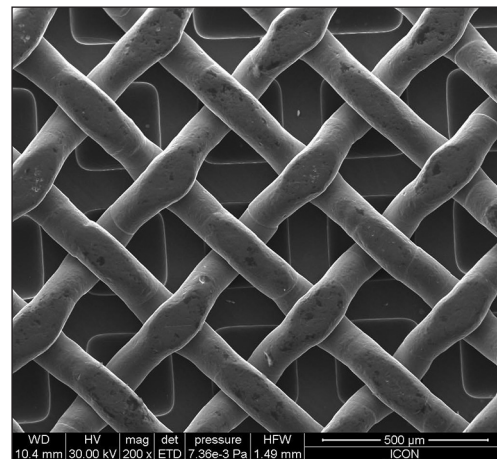


Figure 1: The meshwork of the stainless steel bracket under, $\times 200$

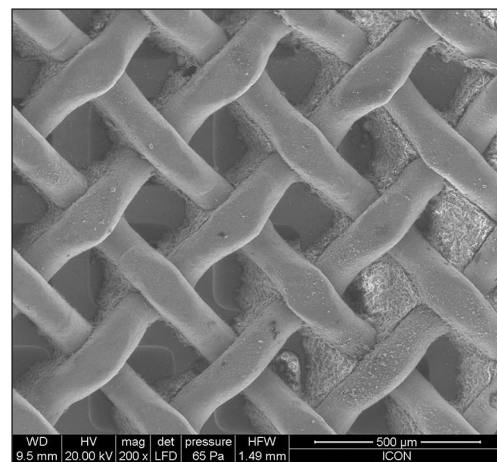


Figure 2: The meshwork of the stainless steel bracket at $\times 200$ after recycling with erbium-doped yttrium aluminum garnet laser showed maximum adhesive removal without damaging meshwork

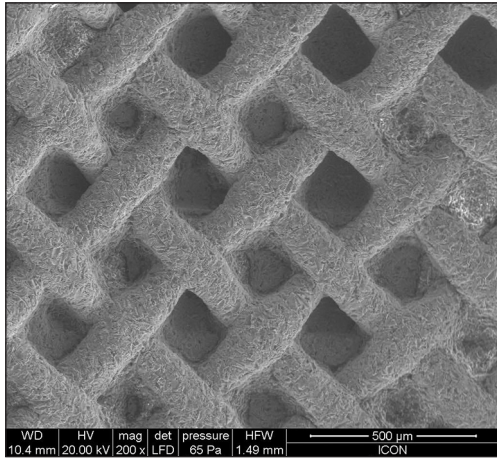


Figure 3: The meshwork of stainless steel brackets, viewed at a magnification of $\times 200$, after being recycled with sandblasting. Note the meshwork has become roughened, increasing the surface area and incomplete removal of composite

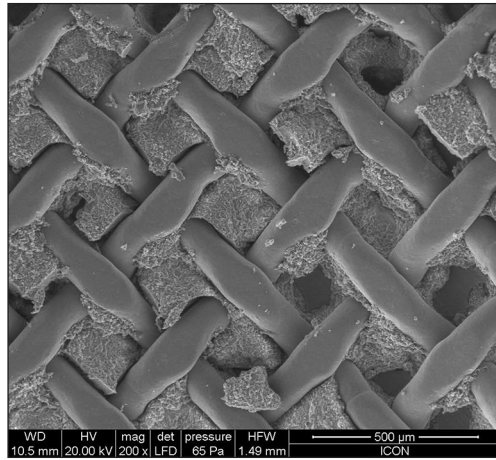


Figure 4: The meshwork of the stainless steel bracket after being recycled by thermal method viewed at $\times 200$ reveals that there is no damage to the base of the bracket, however, the percentage of adhesive removal was low

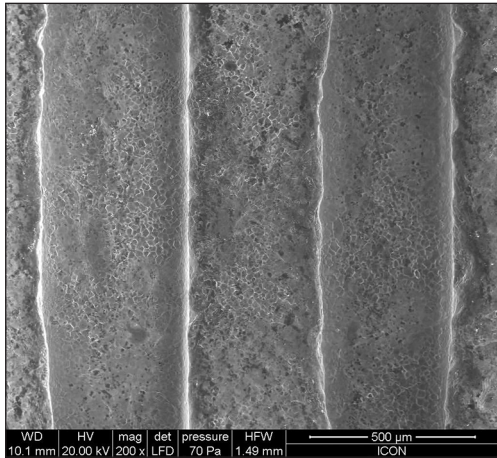


Figure 5: The untreated ceramic brackets at magnification of $\times 200$ showed grooves on the base of bracket

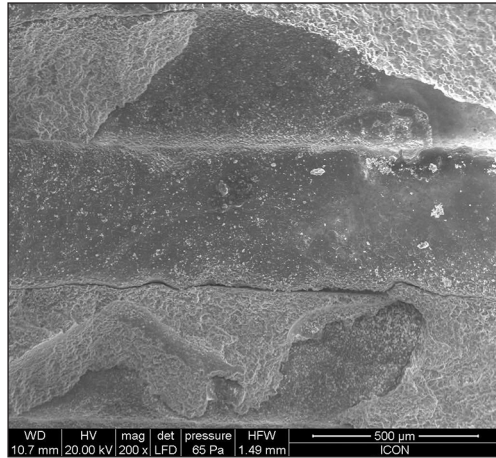


Figure 6: The base of ceramic bracket after erbium-doped yttrium aluminum garnet laser recycling showed removal of the adhesive with less damage to the bracket base

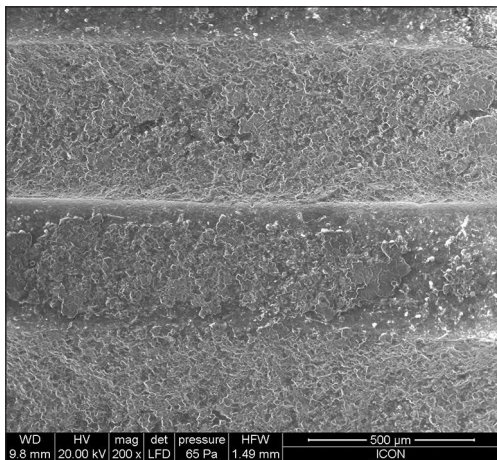


Figure 7: The base of ceramic bracket after sandblasting showed removal of the adhesive but there was damage to the base in the form of flattening of the base

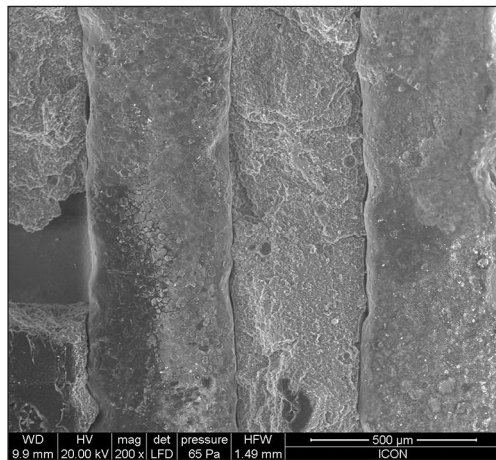


Figure 8: The base of ceramic bracket after thermal recycling showed damage to the base of bracket by formation of cracks and voids and least amount of removal of composite

bond strength. The laser recycling group [Figure 6] showed removal of the adhesive with less damage to the base of the bracket, hence it showed higher shear bond strength compared to the sandblasting group [Figure 7]. On viewing the group that was recycled using the thermal method [Figure 8], it was seen that the base of the bracket had been damaged by the formation of cracks and voids and showed the least amount of adhesive removal. This would explain the lowest shear bond strength between the groups.^[14-20]

CONCLUSION

From our study, we yielded the following:

1. The ER:YAG laser was the most effective in recycling the ceramic brackets, as it removed the highest percentage of adhesive with least damage to the bracket base. However, for stainless steel it was second best to sandblasting.
2. The stainless steel brackets that were recycled by sandblasting showed the highest recycled shear bond strength but for the ceramic brackets the recycled shear bond strength was less than the ER:YAG laser.
3. The brackets recycled by the thermal method showed a significant decrease in recycled shear bond strength for both ceramic and stainless steel brackets.
4. While comparing all three methods we found that the ER:YAG laser was the method of choice for recycling ceramic brackets. But for stainless steel brackets the most effective method is the sandblasting method.
5. On ESEM evaluation, it was seen that the thermal method damaged the ceramic brackets while removing the least amount of composite from both the stainless steel as well as ceramic bracket base.
6. The sandblasted group showed a roughened bracket base for stainless steel brackets with sufficient removal of the adhesive, whereas the ceramic bracket bases were damaged by the alumina particles.
7. The ER:YAG laser group on ESEM evaluation showed the least amount of damage to the both the stainless steel as well as ceramic bracket bases.

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Conflicts of interest

There are no conflicts of interest.

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