Comparative Evaluation of the Effectiveness of Er:YAG Laser and Other In-house Refurbishing Methods for Reconditioning Stainless Steel Brackets

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ABSTRACT: Since its inception, bonding of orthodontic brackets has made tremendous advances and continuous efforts are being made to find better bonding materials. The retentive strength of these brackets on the tooth surfaces has increased considerably with time, but bracket dislodgement is still a problem for orthodontists. Rather than choosing to replace the dislodged bracket with a new one, the clinician has the option of re-using the old bracket after subjecting it to a suitable method of refurbishing. To overcome the delays associated with commercial recycling, in-house methods have been developed. The in-house refurbishing methods employed in this study were the sandblasting method, thermal method, and adhesive removal by tungsten carbide bur and by Er:YAG laser. The Er:YAG laser technique has the highest refurbished shear bond strength, followed by the sandblasting method, thermal method, and the tungsten carbide method, which had the least shear bond strength value and is not fit for clinical usage. After refurbishing, the brackets were investigated by ESEM (Environmental Scanning Electron Microscope) to find out the effectiveness of the refurbishing methods. ESEM indicates that the adhesive removal was found to be almost complete with this group when compared to other groups.

Keywords: brackets, refurbishing, lasers.

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Bonding in orthodontics has undergone several facelifts since its inception in orthodontics. The bonding of orthodontic attachments to etched enamel surfaces with dental resins was introduced by Buonocore in 1951.[1] By the late 1970s, the bonding of orthodontic brackets had become an accepted clinical technique. One of the commonly faced problems during treatment is bracket dislodgement,[2] which can be due to improper operator technique, patient behavior that includes accidental breakage due to occlusal trauma, variation in the enamel surface, and bracket properties. Thus, a significant number of teeth are rebonded in orthodontic practice. Generally, practitioners would discard a dislodged bracket and replace it with a new bracket in subsequent visits, hence escalating the cost and duration of treatment.[3]

Research has been focused on the process of bracket refurbishing. The brackets can be recycled by sending them to commercial recycling companies, but it is time consuming, and dislodged brackets cannot be rebonded in the same appointment. In-house methods such as the thermal method (direct flaming only[4] or

Buchman's method[5]) or mechanical methods (sandblasting,[6] green stone,[7] tungsten carbide bur[8]) offer a more realistic, simple and cost effective alternative. Lasers have also been used for this purpose.

The efficacy of orthodontic treatment depends upon several parameters. One such parameter, of utmost importance to the orthodontist, is the bracket's shear bond strength, which indicates the retentive strength of the bracket on the tooth. The very purpose of the study of reusing a debonded bracket is lost if it doesn't provide adequate bond strength. Hence, this study was undertaken to evaluate the effectiveness of Er:YAG laser along with other methods of in-house refurbishing for reconditioning stainless steel brackets.

MATERIALS AND METHODS

This study was carried out on 100 premolars, extracted as a part of orthodontic treatment. The extracted teeth were then cleansed, and after careful debridement, the teeth were stored in saline at room temperature. The teeth used were between one to six months after extraction. Teeth which had an abnormal morphology, were carious or hypoplastic, or otherwise damaged were not included in the study. These 100 teeth were mounted using clear acrylic, with their root tips embedded in acrylic. They were then bonded with mandibular premolar metal brackets (Gemini series, 3M Unitek; St Paul, MN, USA) using Transbond XT light cure composite (3M Unitek).

The bonding procedure was performed. The buccal surfaces of the teeth were polished with pumice slurry using a rubber cup mounted on a slow-speed handpiece. They were then washed with distilled water and dried using compressed, oil-free air. The teeth were then etched with Transbond etching gel (3M Unitek) for 15 s and subsequently rinsed with water and dried. This was followed by applying Transbond XT (3M Unitek) primer using an applicator brush. As per the manufacturer's instructions, adhesive was placed on the mesh of the bracket and, with the help of a bracket-holding tweezer, the brackets were positioned on the teeth at the center of the crown. The flash was removed with the help of a probe from all four sides of the bracket. The brackets were then light cured using a light-curing unit (3M ESPE; St Paul, MN, USA) for 20 s. Each of the 100 teeth was then mounted on an acrylic block with only its crown exposed. The acrylic blocks were color coded and divided into 5 groups with 20 teeth in each group.

The acrylic block which held the tooth along with the bonded bracket was then packed in a plastic pouch. The same procedure was followed for 100 brackets. The teeth were then immersed in artificial saliva for 24 h so that the pH of the oral environment could be simulated. The groups were designated as

Group I – control group
Group II – refurbished by the sandblasting method.
Group III – refurbished by the thermal method.
Group IV – refurbished by the adhesive grinding method.
Group V – refurbished by Er:YAG laser.

Control Group (Group I)

Group I was tested in a Lloyd's universal testing machine (Lloyd Instruments; Fareham, UK) for their shear bond strength. The crosshead speed was set at 1 mm per minute.[9] The load required for debonding each bracket was recorded and the shear bond strength value was obtained.

Eighty brackets belonging to the groups II, III, IV and V were then debonded using debonding pliers,[9] and after debonding, each bracket and the corresponding acrylic block were placed back in a separate pouch and numbered. The brackets which were distorted during debonding were discarded and new samples were prepared. These 80 teeth were then refurbished using the four methods according to experimental group.

Sandblasting Group (Group II)

The sandblasting method consisted of subjecting the bracket bases to aluminum oxide particles of size 50 µm after they were debonded using debonding pliers. The distance between the sandblasting handpiece and the bracket base was approximately 5 mm. Each bracket was sandblasted for 20 to 40 s under a pressure of five bars until bonding resin was no longer visible to the naked eye and the bracket base appeared frosted. After sandblasting, they were cleaned with acetone and dried in compressed air. The brackets were then placed back into the same pouch to which they belonged.

Thermal Group (Group III)

The process consisted of three steps:

1. Burning off the old bonding material.
2. Removing the remaining inorganic filler: pre liminary polishing.
3. Electropolishing the attachment: final polishing.

Burning off the old Bonding Material

The brackets were held with a bracket holding tweezer and the base of the bracket was heated using the nonluminous zone of the flame until the debonded bracket became cherry red, in order to burn off the residual composite resin on the base. After this stage, a properly heated bracket appeared discolored.

Removal of remaining inorganic filler – preliminary polishing

The brackets were placed on an ultrasonic vibrator for 20 or 30 minutes until the filler was gone from the mesh and other areas of the attachment.

Final treatment – electropolishing

The final polishing was done separately for each bracket. The bracket was locked on to the steel forceps and was dipped into the polishing tank for 5 s to produce a brilliant finish. They were then washed in distilled water and placed back in the pouch whence they came.

Adhesive Grinding Using a Tungsten Carbide Bur (Group IV)

Grinding of the bracket base was done using a tungsten carbide bur operated on a straight slow-speed hand piece at a speed of 25,000 rpm for approximately 25 s until the composite was removed.[10] Care was taken during grinding not to expose and damage the metal mesh.[11] Brackets were then replaced back in their respective pouches.

Adhesive Removal Using Er:YAG Laser (Group V)

Er:YAG laser (Fotona Fidelis Plus II Er:YAG and Nd:YAG Combo Machine; Ljublana, Slovenia) of 250 mJ of energy at 12 Hz with an average power of 3 W was applied to the bracket using a noncontact handpiece. The lasing time was 5 s. The Er:YAG laser has a wavelength of 2.94 µm. Adhesive was removed by holding the bracket with a bracket holding tweezer away from the body and lasing the base of the bracket from top to bottom. Protective eyewear provided by the manufacturer was used for the whole procedure. After furbishing, the brackets were replaced back in their respective pouches.

Rebonding of Teeth

The 80 brackets belonging to groups II, III IV and V were then rebonded on to the same re-prepared tooth to which they were bonded earlier in a similar fashion. The teeth were prepared by removing the residual composite resin using a tungsten carbide bur operated on a straight slow-speed handpiece.The removal of the composite was considered complete when the tooth surface seemed smooth and free of composite to the naked eye under the light of an operatory lamp. They were then immersed again for 24 hours in artificial saliva prior to testing.

A Lloyd's universal testing machine (Model L R 100) (Lloyd Instruments) was used for shear bond testing at a cross-head speed of 1 mm per minute. Each tooth's facial surface was parallel to the direction of force during the shear strength testing. Force was applied to the bracket/tooth interface by a flattened steel rod. The load at bracket failure was recorded by a computer connected to Lloyd machine. The shear bond strength values were calculated in MPa by dividing the debonding force in Newtons by the area (mm^2) of the bracket base.[12]

The bracket base area was 10.611 mm^2 as provided by the manufacturer.

Environmental Scanning Electron Microscopy (ESEM)

After refurbishing, the brackets were investigated by ESEM (Environmental Scanning Electron Microscope; Phillips X L 30 series; Eindhoven, the Netherlands) at the Technical University of Vienna, Austria to find out the effectiveness of the refurbishing methods.

Table 1 Mean shear bond strengths (MPa)

Groups	Mean shear bond strength (MPa)
I	10.14 ± 5.55*
II	5.422 ± 1.67
III	5.254 ±1.63
IV	3.082 ± 1.07
V	8.133 ± 2.65*

* These groups differed significantly from the others ($p < 0.05$).

Statistical Analysis

The differences between the shear bond strength data were evaluated by one-way ANOVA and the post-hoc Duncan test using Tukey's HSD method. The significance was determined at a probability value of $p < 0.05$ for both tests.

RESULTS

The mean shear bond strength values are given in Table 1. Significant differences were found between the Er:YAG laser technique, with the highest refurbished shear bond strength, and the other methods. The sandblasting method had the second highest refurbished shear bond strength, with the mean refurbished values of the thermal and electropolishing method falling below those of the sandblasting method. The tungsten carbide bur group showed the lowest bond strengths. The control group and the laser group exhibited statistically similar bond strengths.

On examination of the refurbished brackets by ESEM the following was observed (compare with Fig 1, control group):

Sandblasting Group (Group II) (Fig 2)

Complete removal of adhesive from the bracket base was not seen. The mesh and the intermesh cavities were filled with adhesive, even though no visible adhesive was remaining on the bracket, with the remnant adhesive found in curvatures. Only the overhanging adhesive was found to have been removed.

Thermal and Electropolishing Group (Group III) (Fig 3)

Complete removal of adhesive from the bracket base was not seen. Adhesive remnants were found remaining within the meshwork. The meshwork was also seen to be roughened.

Tungsten Carbide Bur Group (Group IV) (Fig 4)

Incomplete removal of adhesive was seen in this group. The mesh network and the adhesive were found scraped to the same level and the adhesive was removed to that level only. Flattening and loss of meshwork was seen.

Er:YAG Laser Group (Group V) (Fig 5)

Adhesive removal was found to be almost complete with this group. The bracket base was seen to closely resemble that of the control group. The adhesive remnant on the bracket base was negligible. The meshwork was clearly visible but a slight pickling of the metal was seen. Pickling refers to removal of the composite without altering the surface characteristics of the retentive part in the orthodontic bracket.

DISCUSSION

Refurbishing the orthodontic brackets has a major advantage in terms of ecological conservation and reduction in cost, apart from the other advantages.[12] The question of cross contamination does not arise in this case as it is done on an individual basis. Matasa[13] has claimed that a bracket can be reused upto five times, whereas Wheeler and Ackerman's[14] observations were that single recycling was of negligible clinical importance.

The brackets can be recycled by sending them to commercial recycling companies but these procedures require time, and usage of a new bracket would seem more feasible rather than sending them to such recycling companies.[15] Thus, to overcome the delays associated with commercial recycling, in-house methods have been developed.

In this study, in order to ensure standardization, all the teeth were bonded according to manufacturer's instructions, and for each specimen tested for its refurbished shear bond strength, excess adhesive was removed with a tungsten carbide bur before rebonding. Throughout the first debonding, the brackets of the experimental groups were debonded by pliers to

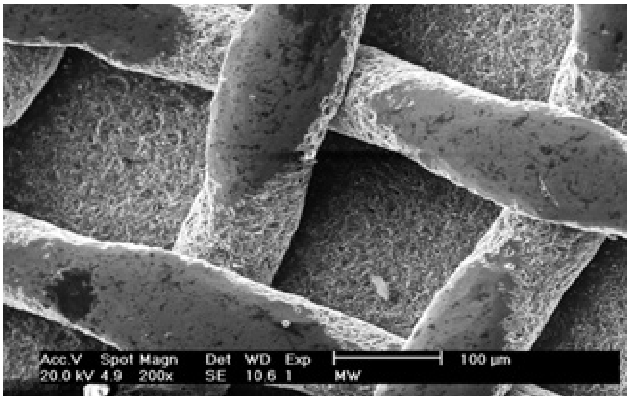

Fig 1 ESEM image of control group at 200X magnification.

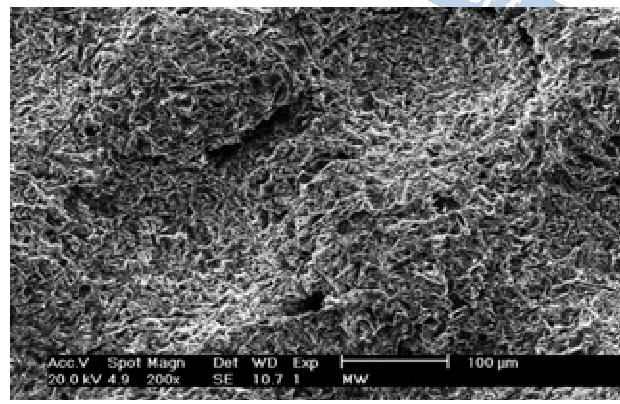

Fig 2 ESEM image of sandblasting group at 200X magnification.

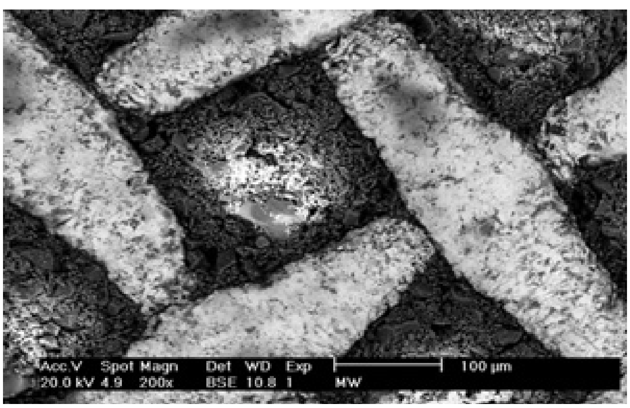

Fig 3 ESEM image of thermal group at 200X magnification.

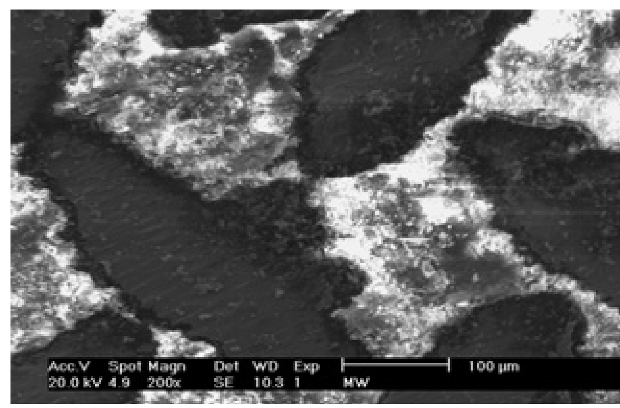

Fig 4 ESEM image of tungsten carbide bur group at 200X magnification.

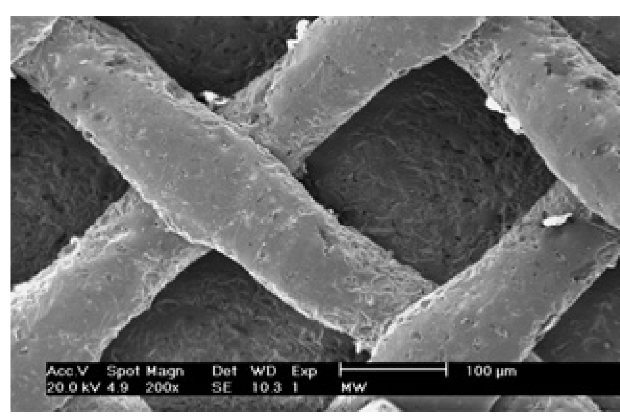

Fig 5 ESEM image of Er:YAG group at 200X magnification.

mimic in vivo debonding conditions and to ensure that their surfaces would represent clinically debonded surfaces.

The main goal of refurbishing brackets is to remove the bonding material from the bracket base without damaging or distorting the bracket base and other areas of the attachment.[16] The in-house refurbishing methods employed in this study were the sandblasting method, thermal and electropolishing method, adhesive removal by tungsten carbide bur, and Er:YAG laser.

The Er:YAG laser operates at a wavelength of 2.94 μm and in a pulsed waveform.[17] Er:YAG laser was used for the study because of the advantage of water spray, and because the depth of energy penetration is negligible, it eliminates the risk of unwanted collateral damage, as well as the associated postoperative morbidity.

It is evident from the results that the Er:YAG laser technique had the highest refurbished shear bond strength, which was significantly greater that that achieved with the other methods. The increased shear bond values could be due to the lower penetration energy of Er:YAG laser and the selective absorption of the laser in composites. An increase in penetration would have caused surface alteration of metal, thereby reducing the bond strength. The selective absorption property of Er:YAG laser favoring composites led to the complete removal of resins from the brackets (see Fig 5 and Almeida et al[18]), which was directly proportional to the bond strength achieved.

The sandblasting method had the second highest refurbished shear bond strength. The increase in shear bond strength values can be attributed to microroughness created by the alumina particles, therefore creating an increased bonding surface area which is essential for retention.

The mean refurbished values of the thermal and electropolishing method were below the sandblasting method. The use of heat is a critical factor. In this method, removal of the acrylic bonding agent is the most critical part of the refurbishing process and requires long exposure to heat. Complete pyrolysis of the resin occurs only at temperatures around 770°C, and during this phase of pyrolysis of resins, it forms acids which are a possible source of intergranular attack. Exposure to heat may lead to stress, relieving or softening cold-worked metal along with decreasing corrosion resistance. Exposure of a bracket to increased temperature also directly affects the hardness and theoretical tensile strength of the metal, which may render it more vulnerable to masticatory damage.[12] Brackets refurbished by the thermal method render them more susceptible to tarnish and corrosion, and this in turn can be responsible for its failure in the mouth.[19] Therefore, the use of the thermal method is questionable with all the above observations coming into play.

The adhesive grinding method using tungsten carbide bur recorded the least shear bond strength well below the accepted limit and not fit for clinical usage. The grinding of the base using a tungsten carbide bur appears quick, simple and easy to perform, but the grinding leaves behind a smooth surface with much of the mesh being scraped off.[9] This in turn leads to low bond strength values.

The Environmental Scanning Electron Microscope (ESEM) is a relatively new innovation in scanning electron microscopes specifically designed to study wet, oil bearing, or insulating materials. Polymers, biological cells, plants, soil, bacteria, concrete, wood, asphalt and liquid suspensions have been observed in ESEM without prior specimen preparation or gold coating. Advantages of using ESEM are that it is not necessary to make nonconductive samples conductive. Material samples do not need to be desiccated and coated with gold palladium, and thus their original characteristics may be preserved for further testing or manipulation. In addition, the water vapor acts as the electron ground path away from the sample and the electron signal produces more than one ion per electron, so the signal is amplified without extra electronics, which can add noise to the image.

The ESEM image (Fig 5) clearly shows that the adhesive removal was complete in group V (laser), which was similar to control group.

CONCLUSION

The highest values for shear bond strength of the samples tested were obtained from the control group, which proved to be adequate for clinical usage.

Rebonded brackets have a lower bond strength when compared to the initial shear bond strength.

Er:YAG laser was the most efficient method for refurbishing, followed by sandblasting. The thermal method, however, demands justification due to the disadvantages it carries, and the adhesive grinding method is not a suitable method of refurbishing

The study shows that Er:YAG Laser can be used as an alternative method of refurbishing when the cost considerations are not taken into account.

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