# Effect of multiple debonding sequences on shear bond strength of new stainless steel brackets

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## ABSTRACT

**Objectives:** This in-vitro study aimed at evaluating the effect of three debonding sequences on the shear bond strength (SBS) of new stainless steel (SS) brackets.
**Materials and Methods:** Stainless steel twin brackets (0.022-inch, American Orthodontics, Sheboygan, WI, USA) were bonded with light cure adhesive (Transbond XT, 3M Unitek, St. Paul, MN, USA) to 80 newly extracted human premolars after acid etching with 37% phosphoric acid (30 s). Brackets were debonded with a universal testing machine, and new brackets were bonded to teeth using the same adhesive and same manner. This process was repeated twice, and brackets were debonded within 24 h after bonding. The longitudinal changes of average SBS were assessed with the repeated measures ANOVA. *Post-hoc* tests using the Bonferroni correction were also used to compare the average SBS at three debonding sequences.
**Result:** The mean SBS decreased significantly after each debonding sequence ($P < 0.01$). The corresponding mean values (standard deviation, 95% CI) after the first, second, and third debonding sequences were 22.88 MPa (4.08, 21.97–22.79), 19.36 MPa (4.54, 18.62–20.64), and 16.67 MPa (4.27, 15.72–17.62), respectively. There was no significant difference among the adhesive remnant index (ARI) scores of three debonding sequences ($\chi^2 = 5.067$, df = 6, $P = 0.53$).
**Conclusion:** Average SBS after three debonding sequences was significantly decreased, but was above the recommended 5.9–7.8 MPa. *In-vivo* studies are required to validate the finding of this study.


**Key words:** Adhesive remnant index, enamel, multiple debonding, orthodontic brackets, shear bond strength

## INTRODUCTION

Orthodontic brackets are the main means of tooth movement for orthodontist. The elimination of the remaining adhesive material following failure of brackets or debonding procedures removes about 50 μm of enamel[1,2] and the processes of rebonding may led to a significantly different shear bond strength (SBS) between the bracket and tooth surface. Clinicians may use new brackets or recycled stainless steel (SS) brackets, a process that is associated with the structural changes of brackets. The common methods for bracket recycling are; heat application to burn the bonding agent that follows by electrolytic polishing for oxide removal; as well as the combined use of high-frequency vibrations, electrochemical polishing, and chemicals to dissolve the bonding agent.[3-5] These methods can be associated with reduction in bond strength, particularly after thermal recycling;[6,7] although it has been claimed that recycled brackets offer a similar bond failure profile to new brackets.[8] Some clinicians may also reuse debonded brackets with in-office reconditioning of the debonded bracket using sandblasting[9-13] or laser reconditioning,[14] as a method of rebonding of the same bracket, perhaps to address the drawbacks associated with commercial recycling.

In order to address the issues associated with recycling brackets, clinicians can use new brackets. Previous studies on the effect of multiple bondings on the SBS, using new brackets, are limited;[15-21] these studies often used small sample

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sizes[15-17,20,21] or used bovine teeth.[16] The aim of the present *in-vitro* study was to examine the effect of three debonding sequences on the SBS of new SS brackets bonded to human teeth.

### Null Hypothesis

The null hypothesis for this study was "There is no difference among the SBSs of new SS brackets bonded to human teeth after three sequences of debonding."

## MATERIALS AND METHODS

This study was performed using 80 noncarious freshly extracted premolars after ethical approval granted by the ethics committee of the Shahid Beheshti University of Medical Sciences. The age of the patients whose extracted teeth we used varied between 11 and 16 years. All teeth were caries-free and did not have any cracks, fractures, hypercalcification on the buccal surface, which could influence the bonding process. The teeth were cleaned, lightly pumiced, and stored in distilled water at room temperature before use.

### Assessment of Shear Bond Strength

Teeth were polished with fluoride-free pumice paste (Dentatus, Tehran, Iran), using rubber cap for 15 s, then washed with tap water for 15 s and air-dried. One operator performed the bonding process, after etching the specimens with 37% phosphoric acid (3M Unitek, St. Paul, MN, USA) for 30 s. Each bracket (0.022-inch twin brackets, American Orthodontics, Sheboygan, WI, USA) was bonded with a Transbond XT adhesive (3M Unitek, St. Paul, MN, USA) and light-cured (Bonart-Art-L2 Light Curing Unit, Bonart Co. Ltd., Taipei, Taiwan) according to the instruction provided by the adhesive's manufacturer. The bracket base size was approximately 11.85 $mm^2$. No bond enhancer was used for bonding procedures. Overall, 240 SS brackets were used and bonded with 4 mm distance from the occlusal surface. The excess adhesives were removed using a dental explorer.

In order to ensure all brackets were bonded in the same plane a mounting jig appliance consisting of a stand containing a 0.021 × 0.025 inch SS wire was used; this was placed in the bracket's slot when teeth were put in molds containing self-cure acrylic resin [Figure 1]. The specimens were not exposed to thermocycling and brackets were debonded after 24 h. During force application, each tooth with its own acrylic base was put in one jaw of the universal testing machine (Zwick/Roell Zo20, Ulm, Germany) and a specimen holder was used to ensure constant load parallel to the tooth surface [Figure 2]. The other part of the machine exerted an occlusal-gingival load to the upper surface of the bracket between the upper wings and bracket base using a blade, producing a shear force at the bracket tooth interface. The blade, which was perpendicular to the bracket's slot, exerted a force at a crosshead speed of 1 mm/min until rupture of the bracket-tooth union.[22] The required forces for debonding (failure load) were recorded as Newtons, and subsequently, the SBSs (MPa) calculated and used as control for future comparisons. The day after debonding, residual adhesives on tooth surfaces were removed using a low-speed TC tungsten carbide bur (Mani, Tokyo, Japan) until the enamel surface reached its glaze. In order to make sure the entire adhesive remnant has been removed, a new bur was used for every 2 specimens and the etched surface was also evaluated by the operator under magnification to ensure all of the adhesive remnants had been removed. Teeth were subsequently cleaned and etched as mentioned earlier. After each debonding sequence, new SS brackets were bonded to the teeth with the same orthodontic adhesive. This process was repeated twice, and the SBS values were calculated.

### Adhesive Remnant Index

The buccal surfaces and bracket bases were evaluated using Stereomicroscope (Siemens, Munich, Germany) and one operator (PT) used the adhesive remnant index (ARI), as described by Årtun and Bergland,[23] and scored the adhesive remaining on the teeth:

- 0, no adhesive left on the tooth
- 1, less than half of the adhesive left on the tooth
- 2, more than half of the adhesive left on the tooth
- 3, all the adhesive left on the tooth with the mesh pattern visible.

### Statistical Analysis

The statistical analysis was performed using SPSS software, Ver. 17 (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). Descriptive statistics such as means, standard derivations (SD), range, and 95% confidence intervals (CI) were calculated for average SBS at three debonding sequences. For assessing the longitudinal changes of average SBS in three debonding sequences, the repeated measures ANOVA were used. *Post-hoc* tests using the Bonferroni correction were also used to compare the average SBS at three debonding sequences. The Chi-square test was

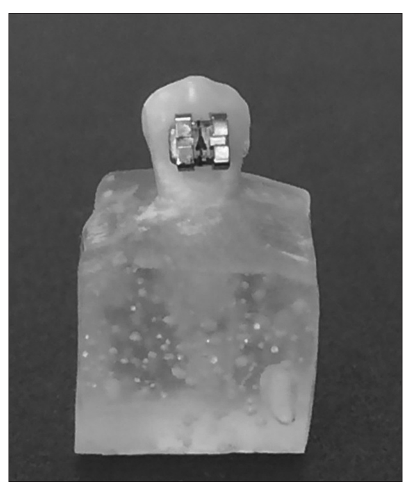

**Figure 1:** The view of a specimen (premolar tooth with bonded brackets) embedded in acryl

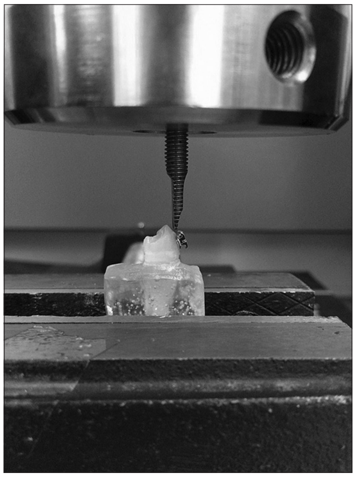

**Figure 2:** Profile view of a specimen before shear bond strength testing

also used to evaluate differences in the ARI scores among the three sequences of debonding. The level of significance was set at $P < 0.05$.

## RESULTS

The descriptive statistics for three debonding sequences is shown in Table 1. The analysis of variance indicated significant differences among the SBS values for all three debonding sequences ($P < 0.01$). The mean SBS decreased after each debonding sequence, which was statistically significant ($P < 0.01$) [Table 2]. The mean SBS (SD, 95% CI) after the first, second, and third debonding sequences were 22.88 MPa (4.08, 21.97–22.79), 19.36 MPa (4.54, 18.62–20.64), and 16.67 MPa (4.27, 15.72–17.62), respectively.

The amount of residual adhesive on the buccal tooth surface as evaluated by the ARI scores is shown in Table 3. The Chi-square test did not reveal significant differences among the ARI scores of three sequences of debonding ($\chi^2 = 5.067$, df = 6, $P = 0.53$). Therefore, the null hypothesis of the present study was fully rejected.

## DISCUSSION

Bracket failure can be common in practice and its effect on the subsequent bond strengths is important. In a busy orthodontic practice, a significant number of teeth may need to be rebonded[17] and clinicians may choose to rebond a new or a recycled bracket. Reports on the effect of multiple debonding and bonding procedures on SBS, using new/recycled brackets, are sometimes contradictory. The present study had a sample size of 80 and was adequately powered to detect the differences in SBS following multiple debonding of new brackets.

A significant decline in the SBS after each debonding sequence was observed in the present study; the first stage had the highest SBS (mean SBS = 22.88 MPa) followed by the second and third stages (Mean SBS of 19.63 and 16.67 MPa, respectively). Comparison of the present findings and the previous studies would be challenging. This is due to the different retaining devices that were used (human/bovine teeth or plastic cylinders), or different study sample sizes, bracket types (different brands, new, recycled), bracket base sizes, recycling methods (thermal, chemical, or sandblasting), or methods of bond strength assessment (shear or tensile) that were used. The observed reduction in the SBS is probably due to the partial destruction of the etching pattern[18,19] and the weaker retentive enamel morphology.[17,24] Nonetheless, our findings contrast with the reports of no significant change in the SBS[15-17,20] or increase in the SBS following debonding with the new brackets.[18,19,21] The different findings in those studies could be due to the small sample sizes[15-17,20,21] that were not able to detect the differences between groups, dissimilar specimen types (molars[16,17] vs. premolars[21]). Alternatively, different etching times (30 s,[16-18] or 60 s[15]) or curing times, differences in the time gap between bonding and debonding (½-h after bonding[16,17] vs. 24 h[21]), and dissimilar used bonding materials could explain the contradictory findings.

After bond failure, clinicians may use new or recycled brackets. One of the earliest studies that evaluated the effect of recycling on bond strength concluded that it was dependent on the bracket type and the recycling method.[4] The present study

**Table 1: Mean, SD and 95% CI of SBS in MPa for 3 debonding sequences**

| Debonding sequence | *N* | Mean SBS (SD) | 95% CI of mean | Range |
|---|---|---|---|---|
| First | 80 | 22.88 (4.08) | 21.97-22.79 | 10.92-31.76 |
| Second | 80 | 19.36 (4.54) | 18.62-20.64 | 10.70-28.62 |
| Third | 80 | 16.67 (4.27) | 15.72-17.62 | 10.06-18.37 |

SD – Standard deviation; SBS – Shear bond strength; CI – Confidence interval

**Table 2: The *post-hoc* tests using the Bonferroni correction show the longitudinal changes in the average SBS at each debonding sequence which was highly significant (*P*<0.01)**

| Debonding sequence | Debonding sequence | Mean difference in SBS (MPa) | Significance |
|---|---|---|---|
| First | Second | 3.52 | 0.00 |
| First | Third | 6.21 | 0.00 |
| Second | Third | 2.69 | 0.00 |

SBS – Shear bond strength

**Table 3: The ARI scores on buccal surfaces of the teeth after 3 debonding sequences**

| ARI scores* | Debonding sequences | | |
|---|---|---|---|
| | First | Second | Third |
| 0 | 0 | 2 | 0 |
| 1 | 40 | 38 | 35 |
| 2 | 36 | 37 | 40 |
| 3 | 4 | 3 | 5 |

*ARI scores – 0: No adhesive left on the tooth; 1: Less than half of the adhesive left on the tooth; 2: More than half of the adhesive left on the tooth; 3: All of the adhesive left on the tooth with the mesh pattern visible. $\chi^2$=5.067; df=6; *P*=0.53. ARI – Adhesive remnant index assessed the SBS but looking into other studies that assessed the bond strength, including the tensile bond strength, we found similar patterns, similar to investigations that used recycled brackets[6,7,13,25-28] such as the study by Wright and Powers.[25] They assessed the tensile bond strength using small sample sizes of 5 brackets in each recycled bracket group and used plastic cylinders as retaining devices.[25] Another study with a small sample size also reported a decline in tensile bond strength, which was dependent on the method of recycling.[29] Reddy *et al*.[27] investigated the effect of thermal recycling and similarly reported a reduction in bond strength (shear and tensile) as a result of recycling. The reduction in SBS following recycling is not a common finding,[28] and depending on the bracket type and the method of recycling, conflicting results have been reported. For instance, when self-ligation brackets were bonded to bovine enamel, the reconditioning process lowered the SBS of Smart-Clip and Damon3 MX brackets, but significantly increased the bond strength values for Quick brackets.[28]

A limitation of the study was the lack of information on the mechanism for the reduced adhesion as no scanning electron microscopy (SEM) of the enamel or bracket surfaces was performed. The present study used a common method (ARI)[20-24,30] to assess the amount of adhesive left on the enamel surface. An analysis of the failure sites demonstrated that ARI scores were found to be similar after all three debonding sequences. However, the similar pattern of ARI did not explain the changes in SBS, which needs further investigation using the SEM technique. Although we did not use recycled bracket it was interesting that the present findings were in agreement with some studies that evaluated the ARI scores of rebonded new or reconditioned/recycled brackets.[20,28,29] The average SBS after two debonding processes was still above the recommended 5.9–7.8 MPa by Reynolds.[31] The minimum effective etching time with 37% phosphoric acid was reported to be 30 s,[32] which was employed in the present investigation. It seems that resurfacing the enamel using a tungsten carbide bur, acid-etching the enamel for 30 s,[32] and use of a new bracket offer reasonable bond strength.

The limitations of the *in-vitro* studies should be considered in interpreting the present findings. Most reported *in vivo* bond strengths might not be as high as those measured using the *in-vitro* models. The average reported *in vivo* bond strengths were approximately 40% less than the *in-vitro* studies.[33] The gradual decrease in bond strength of composites due to aging and storage of material in saliva is another factor that should be considered before making clinical recommendations.[34]

The storage medium for the present study was distilled water. According to a recent systemic review,[35] many studies used distilled water; however, it has been suggested that teeth must be ideally stored in thymol solutions and not water as this may reduce bond strength significantly. The purpose of this study was to compare the SBS after bonding procedures using new brackets and as the storage medium was the same for all specimens, the effect on the findings of comparisons should be minimal. Bearing in mind the discussed limitations, the present findings suggest the average SBS of new SS brackets is decreased after two debonding procedures, but is still above the recommended required bond strength.

## CONCLUSION

The SBS of new SS brackets after two debonding procedures significantly decreased, but was still above the recommended required bond strength (5.9–7.8 MPa). *In-vivo* studies are further required to validate the finding of the presen study.

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