# The Effects of In-office Reconditioning on the Morphology of Slots and Bases of Stainless Steel Brackets and on the Shear/Peel Bond Strength

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**Abstract**

***Objectives***: *To compare the effect of five in-office bracket reconditioning methods on: (i) bracket slot width and inter-wing gap measurements; (ii) the appearance of the bracket bases under scanning electron microscope (SEM), and; (iii) shear/peel bond strength (SPBS).*

***Setting***: Ex vivo *study.*

***Method***: *One hundred and twenty-five brackets were initially bonded and were divided into five experimental groups and reconditioning by the following methods: (i) adhesive grinding using green stone (Gp II); (ii) sandblasting (Gp III); (iii) direct flaming (Gp IV); (iv) using the BigJane machine (Gp V), and; (v) application of Buchman method (Gp VI).*

***Outcomes***: *Distortion of the brackets. Scanning electron miscropy of three representative specimens from each group. The remaining brackets were rebonded, then shear/peel forces to failure were measured (SPBS).*

***Results***: *The ANOVA and multiple comparison test exhibited a statistical, but not clinical, significant increase in the bracket measurements of Group VI. There was a significant reduction (28%) in the SPBS of Group II. Under the SEM, the wire mesh structure was maintained; however, the amount of adhesive remnants greatly varied among the groups.*

***Conclusions***: *Although none of the in-office reconditioning methods employed adversely affected the bracket base and/or the bracket measurements, reconditioning with a green stone was not effective. Sandblasting method and direct flaming are recommended because of simplicity and time-saving advantages.*

*Index Words:* Bracket Base, Bracket Recycling, Bracket Slot, In-office Reconditioning, Stainless Steel Brackets.

## Introduction

Orthodontists are commonly faced with the decision of what to do with 'loose' brackets, and/or with inaccurately located brackets that need respositioning during treatment (Wright and Powers, 1985; Regan *et al*., 1993). One solution is to recycle the brackets. However, the efficiency of the orthodontic treatment will be affected by any distortion of the bracket base, change in the slot size, and/or reduction in bracket bond strength produced during the reconditioning process. As a result, when brackets are recycled, the method used should completely remove the bonding material from the bracket without distorting the bracket. Importantly, the slot tolerance of the recycled bracket should not only be changed, but also the potential for good bonding should not be reduced. While there are several commercial recycling methods available, these are impractical to perform at the chairside. As a result, several in-office bracket reconditioning methods have been introduced. These include a variety of mechanical methods (e.g. handpieces with rotary burs or chairside sandblasting), a variety of thermal methods (e.g. direct flaming or heating in a furnace), and a combination of both mechanical and thermal methods (e.g. the Buchman method which consists of direct flaming to burn off the composite, followed by sandblasting and electropolishing). The effectiveness of these methods has been evaluated in several investigations. For example, a reduction in the bracket bond strength was reported after grinding the adhesive with a green stone to the surface of the mesh base (Wright and Powers, 1985). Alternatively, when the resin surface of the bracket was roughened with a green stone, the rebond bond strength was not changed (Egan *et al*., 1996). In addition, a study by Regan *et al*., (1993) revealed that the difference between the bond strength results obtained following bracket base preparation with a green stone and a more complicated process, i.e. Buchman method, was not significant. When sandblasting techniques using a high-speed stream of aluminum oxide particles propelled by compressed air were evaluated by Sonis, (1996). Millet *et al*. (1993) and MacColl *et al*. (1998), it was found that sandblasting increased the bond strength and the survival time of the new brackets. In addition, when the shear bond strengths of previously failed bonded metal brackets subjected to air abrasion was compared with new brackets, no significant differences between the two groups were found (Sonis, 1996). Another method was introduced by the Esmadent recycling company, which has advertised a BigJane machine, that can be purchased for bracket

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recycling in the office (Buchman, 1980). It was found that, one recycling using this machine is of negligible clinical importance without compromising retention or mechanical precision of the edgewise mechanism (Wheeler and Ackerman, 1983).

The aim of this study was to evaluate and compare the effects of five in-office reconditioning methods of metallic brackets on: (i) the bracket slot width and inter-wing gap dimensions; (ii) the bracket base appearance under the SEM; and (iii) the shear/peel bond strength (SPBS) of the bracket.

## Materials and Methods

### *Preparation of brackets for recycling*

One-hundred-fifty new metallic lower incisor brackets (full size diamond standard edgewise twin bracket, 0·022-inch slot, Cat. #3420500, ORMCO Corporation, Glendora, California, USA), with 9·68-$mm^2$ bracket base surface area, were divided into six groups, one control (Group I ) and five experimental groups (Groups II–VI), each was composed of 25 brackets. Experimental brackets were initially bonded to a flat translucent polytetrafluoroethylene sheet (PTFE) using a light-cured highly filled orthodontic adhesive (Transbond XT, 3M Unitek Corporation/3M, Monrovia, California, USA), in strict accordance with the manufacturer's instructions. This step was carried out without the benefit of etching, so that predictable plastic sheet/adhesive separation would occur on debonding.

Both the plastic sheet and the bracket bases were coated with a thin layer of primer, which was thinned with a gentle stream of oil- and moisture-free air, then light-cured for 10 seconds (Elipar Highlight light curing unit ESPE Dental-Medizin GmbH and Co. KG, D-82229 Seefeld, Germany). The adhesive was applied to the bracket base. The bracket was then positioned on the PTFE sheet and seated under a standard force (500 g weight) (Basudan, 1998). The excess resin flash around the base was removed with a dental explorer. Light was then applied for 10 seconds on each of the proximal sides of the bracket to cure the adhesive. The brackets were easily debonded using a tweezers (Hommacher, Solinqen, Germany stainless HSC 014-05) to either the mesial or distal tie wings, then examined visually and microscopically (Swift Institute, International model 7819551, Tokyo, Japan) at ×20 magnification to ensure that failures were at the resin/plastic sheet interface. Following bracket debonding, five different reconditioning methods were applied on the experimental groups to remove the resin layer attached to the bracket base prior to rebonding (Table 1). The control group was neither bonded initially nor reconditioned.

### *Measurement of Possible Change in Bracket Dimensions*

All brackets were then examined for bracket measurements using the measuring microscope of a microhardness tester (Micromet II Microhardness tester, Buehler Ltd. Illinois, USA) at ×100 magnification. We recorded two slot measurements (a and $a^1$); then the average was calculated for each bracket. To measure the mesiodistal inter-wing gap b and $b^1$ measurements were taken, then the average was calculated (Figure 1). One examiner carried out all measurements. The measurements of the control group were taken at two different times in order to assess the intra-examiner method error. Any differences were evaluated with the student *t*-test for paired samples, double determination method error, and coefficient of reliability (Houston, 1983).

### *Scanning Electron Microscope Examination of the Bases*

We then selected three representative brackets from each experimental group after being examined under a stereo-

TABLE 1 *In-office bracket reconditioning methods employed*

| | In-office reconditioning methods |
|---|---|
| Group II | **Grinding:** a green stone operated on straight slow-speed handpiece* at a speed of 25,000 revolutions per minute for approximately 25 seconds. |
| Group III | **Sandblasting:** a Danville portable-sandblasting unit† with 50 μm aluminium oxide abrasive powder was used. The distance between the bracket base and the handpiece head was fixed at 10-mm distance. Each bracket base was sandblasted for 20–40 seconds under 5 bars (72·5 psi) line pressure. |
| Group IV | **Direct flaming:** the flame tip of a gas torch flame‡ was pointed at the bracket base for *c.* 3 seconds, during which the bonding agent started to ignite and burn out. Then, the bracket was immediately quenched in water at room temperature and dried in an air stream. |
| Group V | **BigJane machine§ method:** the brackets were placed for 60 minutes in the furnace, which was preheated to 850°F (454·4°C), then quenched immediately in room temperature cement solvent¶. This was followed by ultrasonic cleaning** for 10–15 minutes, rinsing in hot running water, and drying in an air stream. The 25 brackets were loaded into the wire basket supplied , then electropolished using the supplied cement solvent for 50 seconds. |
| Group VI | **Buchman method:** a Bunsen burner flame was directed at the bracket base for a few seconds (5–10 seconds) until the bonding agent started to ignite and burn, then quenched in water at room temperature . Then, a laboratory sandblaster†† with 50 ∞m aluminium oxide particles was used to sandblast the bracket for 5 seconds. The line pressure and the distance between the nozzle tip of the sandblaster and the bracket base were fixed as described in Group III. The third step was to electropolish the brackets. |

*Kavo Elektrotechnisches, Type 4415, Werk GmbH D-7970 Leulkirch im Allgau, West Germany.
†Microetcher II™ precision sandblaster, Danville Engineering Inc. San Ramon, CA, USA.
‡Dental Microtorch/Pat.pend., 3000 SGT Prince, butane lighter gas, Tokyo, Japan.
§Big Jane Model E3762, ESMA Inc. South Holland, Illinois, USA.
¶ESMA-ORTHO liquid, ESMA Inc. South Holland, Illinois, USA.
**Sonicer, Yoshida, Osaka, Japan.
††Clean, Sandy, Yoshida Dental Mftg. Co., Ltd., Osaka, Japan.

microscope (Swift Institute) at ×20 magnification. The bracket bases of the representative specimens were viewed, examined, and photographed at ×35 magnification using a scanning electron microscope (JEOL, JSM–T 330 A, JEOL, Ltd. Tokyo, Japan) at an operating voltage of 25 kV.

### *Shear/Peel Bond Strength Testing*

The remaining 22 brackets of each of the experimental groups were rebonded, while the Control brackets were bonded for the first time, to modified acrylic cylinders with holes filled with a light-cure composite material (Restorative Z100, 3M Scotchbond, St. Paul, MN 55144-1000, USA; Basudan,1998). Bond strength testing was carried out on a universal testing machine (Instron, Model 8500 PLUS Dynamic Testing System, USA, 100 Royall Street, Canton, MA 02021-1089) using a customized mounting jig (Basudan, 1998). An occlusogingival load at 0·5 mm/min cross-head speed was applied to the bracket by moving the lower jaw upwards producing shear force at the bracket adhesive interface and parallel to the bracket base (Figure 2). The load required for debonding was recorded and converted to the maximum shear/peel stress in megapascals.

### *Statistical Analysis of the Data*

Kruskal–Wallis one-way ANOVA by ranks was used to evaluate any differences in the effect of reconditioning methods on slot width and inter-wing gap measurements of the brackets. When a significant difference was present, a non-parametric Tukey type multiple comparison test was used to identify which of the group(s) was different (Zar, 1996). A one-way analysis of variance (ANOVA) was used to evaluate the effect of reconditioning methods on debonding shear stress Any significant differences revealed by ANOVA were further investigated using a Tukey B test. Significance for all statistical tests was set at 5 per cent ($P \leqslant 0{\cdot}05$).

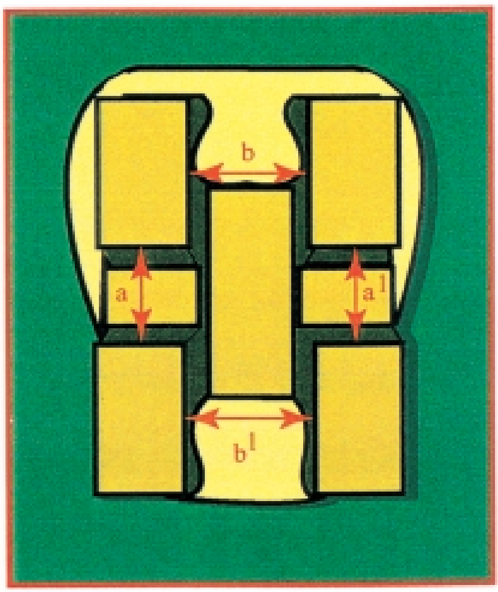



FIG. 1 Front view of the bracket used showing the four measurements taken; a and $a^1$ for slot width measurement, b and $b^1$ for inter-wing gap measurement.

## Results

### *Change in Bracket Dimensions*

The error analysis revealed that the method of measurement was reliable. Table 2 shows slot width and inter-wing gap values for each group. Data analysis revealed that there was a difference in both measurements between groups (ANOVA, $P < 0{\cdot}00001$). Tukey tests showed that both the slot width and the inter-wing gap means of Group VI (Buchman method) were significantly different from those of other groups at the 0·05 level of significance.

### *Scanning Electron Microscopic Examination of the Bases*

Examination of the bases with an SEM revealed that the control bracket had a smooth base with a multi-stranded wire structure and clean retentive areas in between the wire strands (Figure 3a). Viewing the brackets in the SEM after reconditioning showed variation of surface differences between the groups. Figure 3b shows one of the

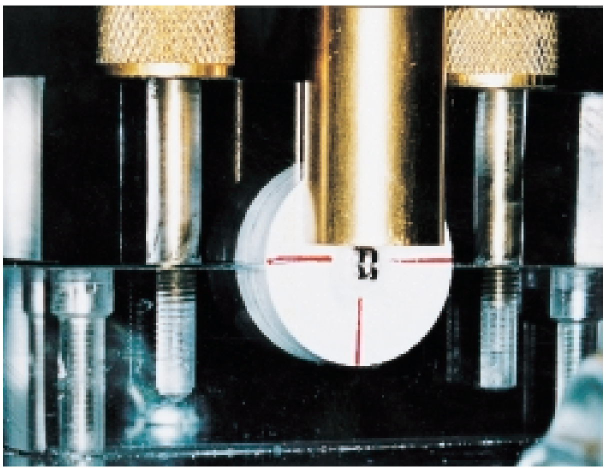
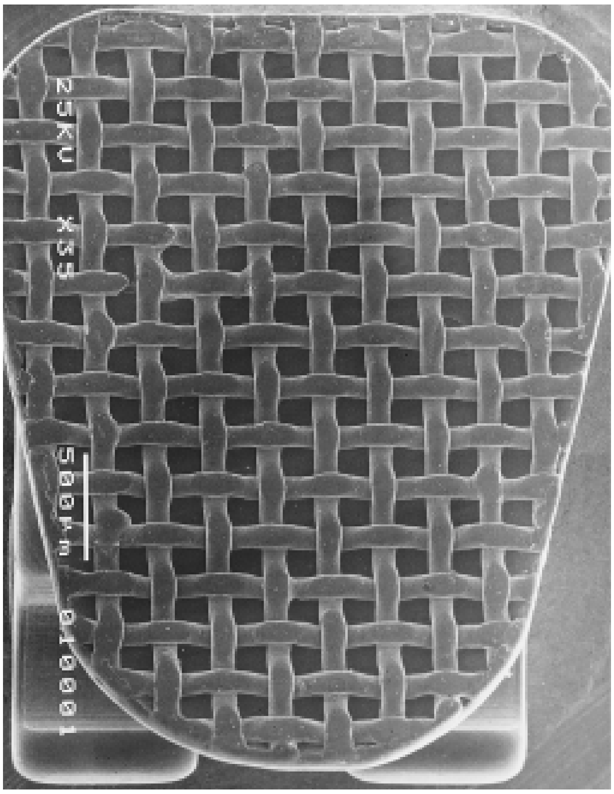


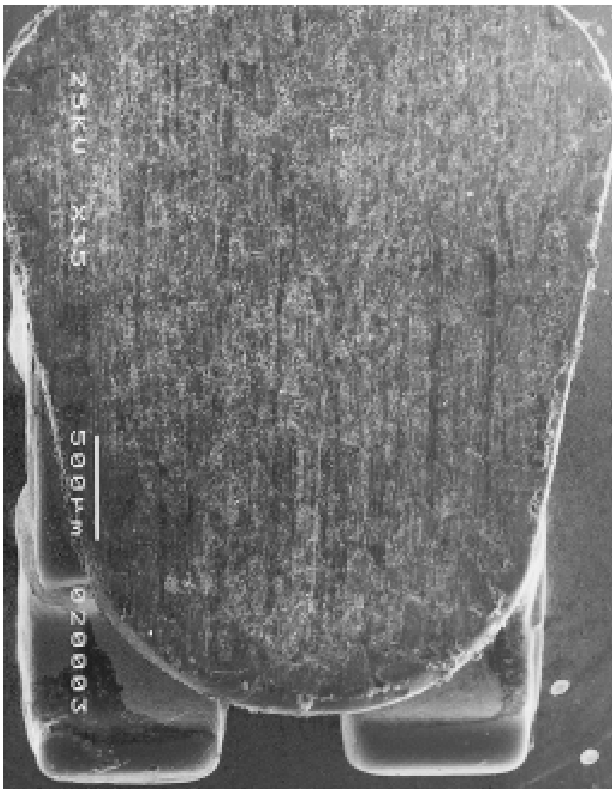
FIG. 2 Application of shear/peel force to a bonded bracket held in a customized mounting jig and positioned on the compression plate of the Instron machine.

TABLE 2 *Mean (SD) of bracket slot width and inter-wing gap measurements (μm) for each group*

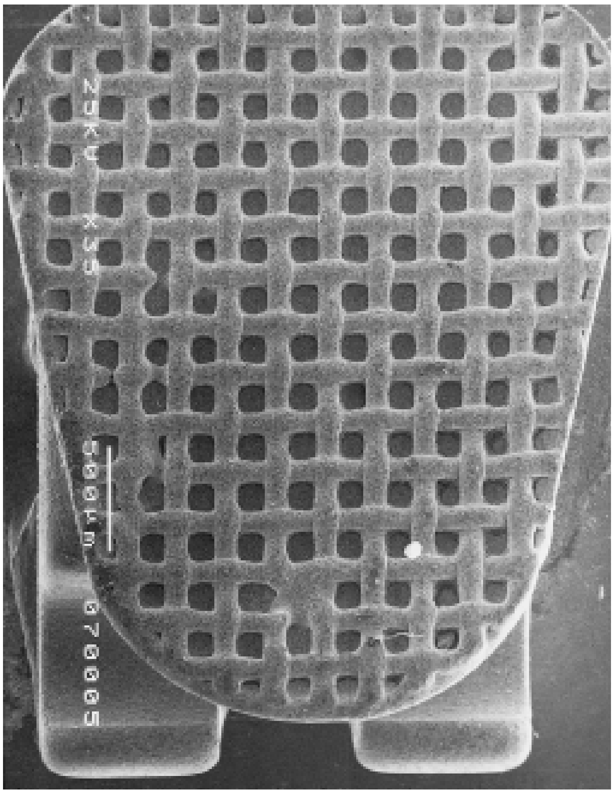
| Measurements | Groups | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| Slot width | 562·80 (8·76) | 560·00 (8·56) | 560·04 (7·38) | 561·76 (6·44) | 565·86 (17·94) | 583·86 (14·30) |
| Inter-wing gap | 694·22 (6·36) | 695·62 (5·18) | 696·68 (8·64) | 696·46 (6·37) | 698·44 (19·04) | 722·36 (15·61) |



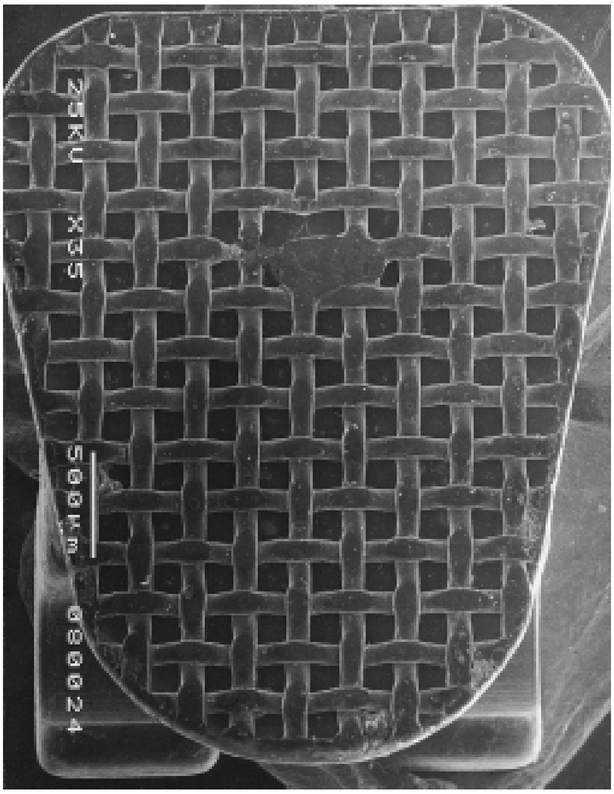

**(a)**




**(b)**

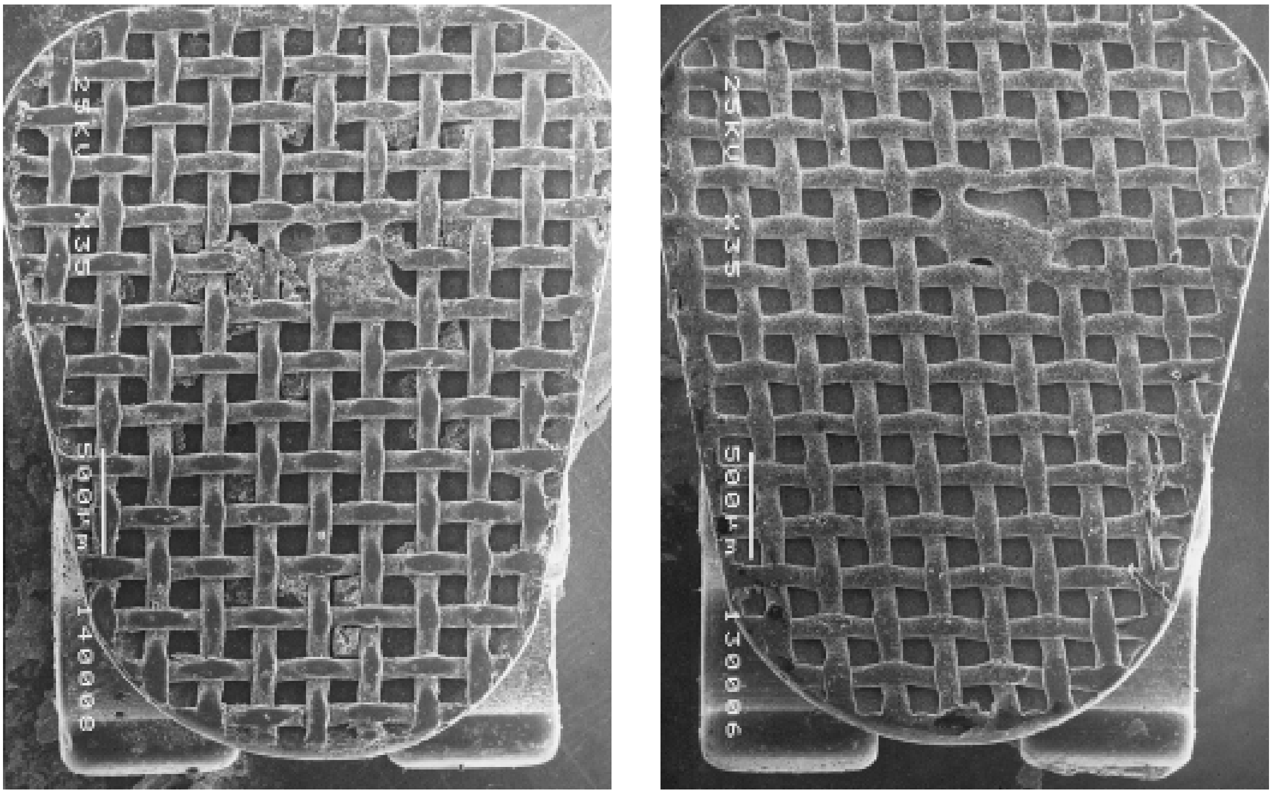



**(c)**




**(d)**

FIG. 3 Scanning electron micrographs of bracket bases of: (a) Group I ( the control) showing a multi-stranded wire structure and clean retentive areas; (b) Group II showing a continuous resin coverage that blocks all retentive areas; (c) Group III showing rough intact and clean base; (d) Group IV showing smooth intact wiremesh and clean retentive areas; (e) Group V showing intact wiremesh with few adhesive remnants; (f) Group VI showing intact, but slightly rough wiremesh with clean retentive areas.




(e) (f)

FIG. 3 (*Continued*)

representatives of Group II that had been reconditioned mechanically using green stone. It is clear that all available undercuts were filled with the adhesive with a nearly continuous resin coverage above the level of the wire mesh intersections. The sandblasted bracket bases were dull and rough with an intact multi-stranded structure, and the retentive areas were less well-defined (Figure 3c). Some of brackets that were directly flamed, were similar to the control, while others had some of the retentive areas filled with the adhesive (Figure 3d). With the naked eye, only three brackets in Group V had a few white specks, that is adhesive remnants attached to the bracket base. The remaining 22 brackets appeared very similar to the control bracket, but with very few adhesive-filled retentive areas (Figure 3e). None of the Buchman group brackets had adhesive remnants when viewed under the light microscope. However, the bases were slightly dull and rough when viewed under SEM (Figure 3f).

### *Shear Peel Bond Strength Testing*

Most specimens exhibited failure at the bracket base/adhesive interface. The shear/peel bond strength (SPBS) means and standard deviations are given in Table 3. When this data were analysed with a one-way ANOVA, a significant difference in the mean SPBS of the groups ($P < 0{\cdot}00001$) was found. Multiple comparison range testing revealed that that the mean SPBS of the group of brackets prepared by grinding (Group II) is significantly different from all the other groups, at the 0·05 level of significance.

TABLE 3 *Means (SD) for shear peel bond strength for each group of brackets*

| Measurements | Groups | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| Bond strength (Mpa) | 21·8 (3·3) | 15·7 (3·1) | 21·5 (4·6) | 19·7 (2·8) | 21·8 (4·8) | 19·7 (3·4) |

## Discussion

One of our findings was that Buchman method resulted in an increase 21·06 and 28·14 µm for slot width and inter-wing gap, respectively. However, these amounts can be considered clinically insignificant.

It was evident from the analysis of the shear/peel bond strength (SPBS) data that the mean SPBS of Group II (grinding with green stone) is significantly lower than all other methods. From a mechanical point of view, this is not surprising because preparing the brackets for rebonding by removal of the adhesive with a green stone, leaves a composite surface devoid of undercuts (Figure 3b).

The optimal bond strength required for orthodontic clinical use is as yet unknown. Ideally, the brackets should be easily bonded to the enamel, not undergo any in-service bond failures and yet be easily removed at the end of treatment without damage to the enamel surface (Ireland and Sheriff, 1997). The highest number given as an optimal bond strength required clinically, 7·85 Mpa, was cited by

Reynolds (1975). In this study, all brackets tested cleared this requirement. However, extrapolation of laboratory data to the clinical situation should always be done with caution.

### *Which is the Most Effective Method of Chairside Conditioning?*

When we consider the clinical value of our finding. It appears that mechanical adhesive grinding is quick, simple and easy to perform as a chairside in-office procedure. Unfortunately, this results in a reduction in bond strength. When the Buchman method or BigJane machine is used, the procedure is complex and takes more time. Sandblasting and direct flaming methods appear to offer the clinician a viable, simple, easy method to immediately reuse previously failed brackets. However, it should be emphasized that the composite incineration process is known to produce toxic fumes that might be inhaled (Klaassen, 1996). Nevertheless, the amount of adhesive remnants burned during the in-office bracket reconditioning process is small and with wearing a facemask in an open room space, the produced vapour is considered as a very low hazardous material.

## Conclusions

1. The in-office bracket reconditioning methods employed in this study seem to have no effects on the slot width and inter-wing gap measurements of the brackets.
2. All reconditioning methods tested in the present study were efficient. However, grinding the adhesive attached to the bracket base with green stone seems to be the least efficient method.
3. Sandblasting alone and direct flaming alone are viable, time saving, and convenient in-office bracket reconditioning methods. On the other hand, Buchman method and reconditioning with the BigJane machine are not very strongly recommended because they are relatively complicated and require longer times to perform.
4. The in-office bracket reconditioning methods described caused no damage to the multi-stranded structure of the meshwire.

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