

The Effect of Variation in Mesh-Base Design on the Shear Bond Strength of Orthodontic Brackets

Samir E. Bishara, BDS, DDS, DOrtho, MS^a; Manal M. A. Soliman, BDS, MS^b; Charuphan Oonsombat, DDS, MS^c; John F. Laffoon, BS^d; Raed Ajlouni, BDS, MS^e

Abstract: This study compared the shear bond strengths of two metallic orthodontic brackets, one with a single-mesh bracket base and the other with a double-mesh bracket base. The Transbond XT adhesive system was used to bond all brackets to the teeth. Two types of brackets were compared, ie, 20 Ovation metal bracket series, with a double-mesh base (Super-mesh) and an 81.50 gauge (0.126 inch), and 20 Victory series metal brackets that have a miniature single-mesh base. The teeth were bonded and debonded within half an hour from the initial bonding. The enamel surface was examined under 10× magnification to determine how much residual adhesive remained on the tooth. Student's *t*-test was used to compare the shear bond strength of the two groups. Chi-square test was used to compare the adhesive remnant index (ARI) scores for the two bracket types. The mean shear bond strength for the double-mesh brackets was 5.2 ± 3.9 MPa and for the single-mesh brackets was 5.8 ± 2.8 MPa. The *t*-test comparisons indicated that they were not significantly different from each other ($P = .157$). The ARI comparisons indicated that both bracket types had similar bracket failure modes and were not significantly different from each other ($\chi^2 = 2.0, P = .5$). These results indicated that single- and double-mesh bracket bases have comparable shear bond strength and bracket failure modes. (*Angle Orthod* 2004;74:400–404.)

Key Words: Bracket base; Mesh type; Shear bond strength

INTRODUCTION

To enhance the retention of the adhesive to the metal base of orthodontic brackets, various chemical and mechanical retentive designs have been suggested. Mechanical retention was enhanced by placing undercuts in the cast bracket bases or by welding different diameter mesh wires to the bracket base as well as incorporating different designs in the mesh itself. Other innovative approaches to improve retention included using laser-structured bases,¹ using metal plasma-coated bracket bases,² and fusing metallic or ceramic particles to the bases.³

Cucu et al⁴ investigated the in vitro shear bond strength of orthodontic brackets with 80- and 100-gauge (0.123 and 0.154 inches, respectively) mesh bases as well as mini and standard-size bases. They found no significant differences in the shear bond strength of any of the brackets compared.

Regan and van Noort⁵ found that machine integral bases were more retentive than foil-mesh bases. On the other hand, Thanos et al⁶ compared mesh-base and metal-base brackets and found that mesh-base brackets are more retentive in tension, whereas metal-base brackets were more retentive in shear.

MacColl et al⁷ evaluated the effects of sandblasting bracket base mesh surfaces, reducing base surface area, and etching enamel with various acid types. They found that sandblasting and microetching of foil-mesh bases increased the shear bond strength. In addition, they found no significant differences in the shear bond strength of bracket base surface areas between 6.8 and 12.4 mm² but decreased when the surface area was at 2.4 mm².

Smith and Reynolds⁸ evaluated the performance of fine-mesh, coarse-mesh, and undercut bracket bases. They found that the fine-mesh base had a higher tensile bond strength than the coarse mesh, and both performed better than the undercut base.

Using a validated model of finite element method of stress analysis for the bracket-cement-tooth system, Mid-

^a Professor, Department of Orthodontics, College of Dentistry, University of Iowa, Iowa City, Iowa.

^b Associate Lecturer, Department of Operative Dentistry, College of Dentistry, University of Almenia, Egypt.

^c Fellow, Department of Operative Dentistry, College of Dentistry, University of Iowa, Iowa City, Iowa.

^d Research Assistant, College of Dentistry, University of Iowa, Iowa City, Iowa.

^e Assistant Professor, General Dentistry Department, Baylor College of Dentistry, Dallas, Tex.

Corresponding author: Samir E. Bishara, BDS, DDS, DOrtho, MS, Department of Orthodontics, School of Dentistry, University of Iowa, S219 DSB, Iowa City, IA 52242 (e-mail: karla-starckovich@uiowa.edu).

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dleton et al⁹ and Knox et al¹⁰ evaluated the effect of varying the bracket base geometry, including incorporating single- and double-mesh designs. The combined mesh layers resulted in a decrease in the stress recorded in the most superficial (coarse) mesh layer and an increase in the stresses recorded in the deepest (fine) mesh layer when compared with the single-layer design. They also found that modification in the spacing and the diameter of the mesh wire influences the magnitude and distribution of the stress recorded.

Knox et al¹¹ evaluated different bracket base designs including 60-, 80-, and 100-gauge (0.093, 0.123, 0.154 inches, respectively) single-mesh bases, a double-mesh base, and integrated metal base. They concluded that the bonding agent significantly affects the shear bond strength and that particular base designs may allow improved adhesive penetration or improved penetration of the curing light.

The literature provides conflicting reports regarding the effect of using different retentive bracket base designs on the shear bond strength. The controversy also extended to the use of a single- or double-mesh bracket base and whether it affects the shear bond strength of orthodontic brackets.

This study compared the shear bond strength of two metallic orthodontic brackets, one with a single-mesh bracket base and the other with a double-mesh base.

MATERIALS AND METHODS

A total of 40 extracted human molars were collected and stored in a solution of 0.1% (wt/vol) thymol. The criteria for tooth selection included intact buccal enamel, no history of any pretreatment with chemical agents, eg, hydrogen peroxide, no cracks due to the presence of the extraction forceps, and no caries. The teeth were cleansed and polished with pumice and rubber prophylactic cups for 10 seconds and washed with water. The Transbond XT adhesive system (3M Unitek, Monrovia, Calif) was used to bond all brackets to the teeth.

Brackets used

Two types of brackets were used in this study. Twenty Ovation metal bracket series (GAC International, Bohemia, NY) with a double-mesh base (Super-mesh) and an 81.50 gauge (0.126 inches) were used. The surface area of the Ovation bracket was calculated to be 13.9 mm². Twenty Victory series metal brackets (3M Unitek) that have a miniature single-mesh base were used. The bracket base surface area was calculated to be 11.8 mm². All brackets used were for maxillary left central incisors.

Scanning electron microscopy photographs at different magnifications (from 20× to 200×) for the Ovation double-mesh and Victory single-mesh bracket bases, in the "as received" condition, are presented in Figures 1 and 2, respectively.

When evaluating mesh performance, Matasa¹² identified a number of variables that need to be considered, including

- Mesh number, ie, the number of openings per lineal inch measured from the center of wire to the center of wire.
- Wire diameter: If it is too thin it will break. If it is too thick it will limit the penetration of the adhesive.
- Size of the aperture (open area): The higher the percentage of the open area the better is the penetration of the adhesive.

The mesh-base specifications for the two brackets compared in this study were described by Matasa¹³ as presented in Table 1.

Bonding procedure

A 37% phosphoric acid gel was applied to the buccal surface of each tooth for 15 seconds. The teeth were then rinsed with a water spray for 30 seconds and dried with an oil-free air source for 20 seconds until the buccal surfaces of the etched teeth appeared to be chalky white in color. The sealant was applied on the etched surfaces. The Transbond XT adhesive was placed on each bracket base. The bracket was then properly positioned on the tooth and subjected to 300 g of force. Excess adhesive was removed using a sharp scaler. The bracket was then light cured for 20 seconds.

The teeth were embedded in acrylic placed in phenolic rings (Buehler Ltd, Lake Bluff, Ill). A mounting jig was used to align the facial surfaces of the teeth perpendicular with the bottom of the mold so that the labial surface would be parallel to the applied force during the shear test.

Shear bond strength testing

The teeth were debonded within half an hour from the time of initial bonding to approximate the timing of tying the initial archwires to the teeth. An occlusogingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. This was accomplished by using the flattened end of a steel rod attached to the crosshead of a Zwick test machine (Zwick GmbH & Co, Ulm, Germany). A computer electronically connected with the Zwick test machine recorded the results of each test in megaPascals (MPa). Shear bond strengths were measured at a crosshead speed of five mm/min.

Modified adhesive remnant index

After debonding, the enamel surface was examined under 10× magnification to determine how much residual adhesive remained on the tooth according to the following scale: 1 = all the composite remained on the tooth, 2 = more than 90% of the composite remained on the tooth, 3 = more than 10% but less than 90% remained on the tooth, 4 = less than 10% remained on the tooth, and 5 = no composite remained on the tooth.

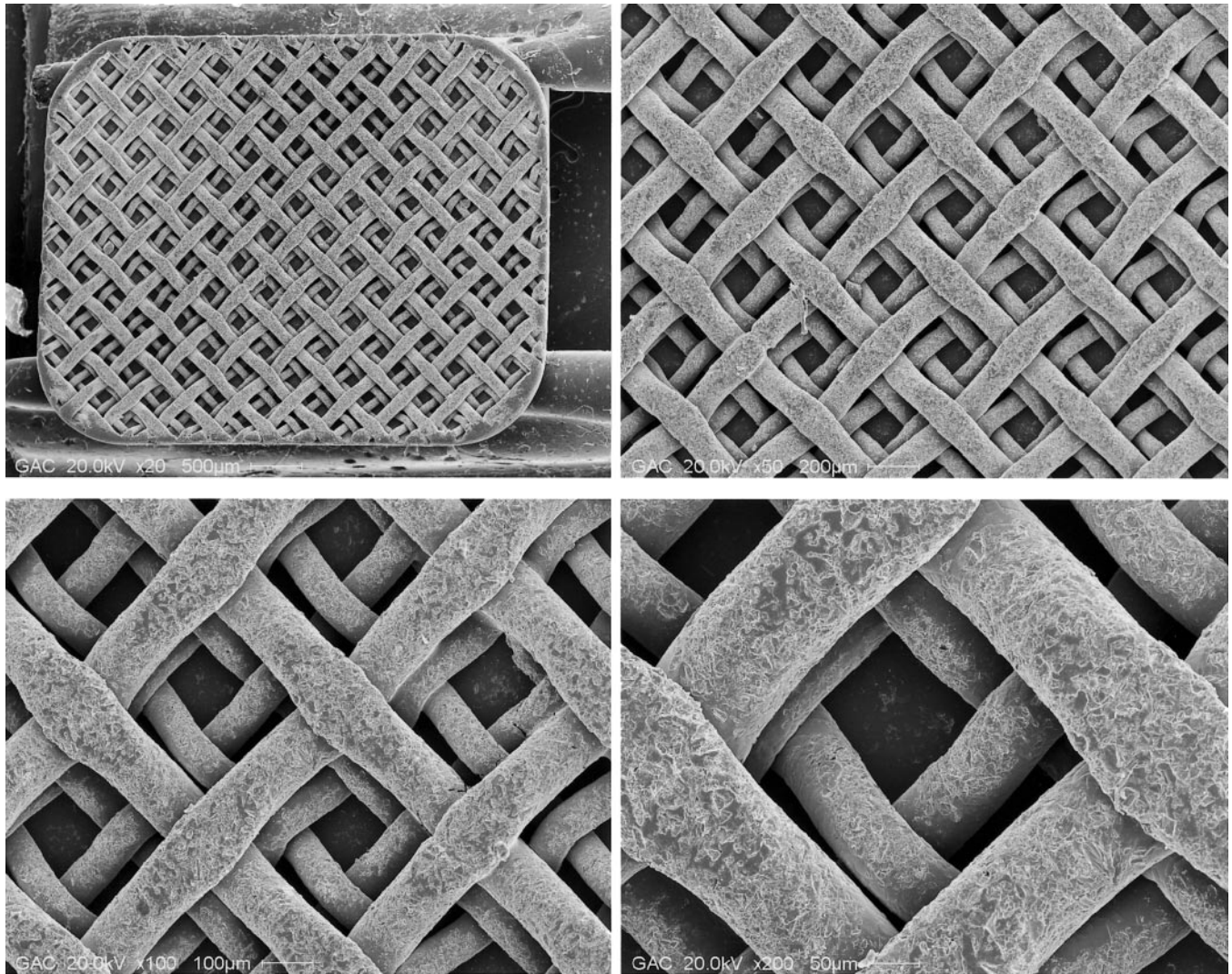


FIGURE 1. SEM photographs at different magnifications (from $\times 20$ to $\times 200$) for the Ovation double-mesh bracket bases, in the "as received" condition.

Statistical analysis

Descriptive statistics including the mean, standard deviation, and minimum and maximum values were calculated for the two bracket types tested. Student's *t*-test was used to compare the two groups. Chi-square (χ^2) test was used to compare the adhesive remnant index (ARI) scores for the two bracket types. For the purpose of the statistical analysis, the ARI scores for groups 1 and 2 and groups 4 and 5 were combined. Significance for all statistical tests was predetermined at $P \leq .05$.

RESULTS

Shear bond strength

The descriptive statistics for the two bracket types compared are presented in Table 2. The mean shear bond strength was 5.2 ± 3.9 MPa for the double-mesh brackets

and 5.8 ± 2.8 MPa for the single-mesh brackets. The *t*-test comparisons ($t = 2.09$) indicated that these values were not significantly different from each other ($P = .157$).

ARI scores

The failure modes of the two types of brackets are presented in Table 3. The ARI scores comparison indicated that both bracket types had similar bracket failure modes and were not significantly different from each other ($\chi^2 = 2.0$, $P = .5$). More specifically, at the time of debonding, most of the adhesive remained on the enamel surface. These results indicated that in general, in the first half hour, there was more adhesive attached to the enamel surface than the bases of both types of brackets (ARI scores of 1 and 2).

DISCUSSION

When evaluating the efficiency of the bracket base retention, some investigators found machine integral bases to

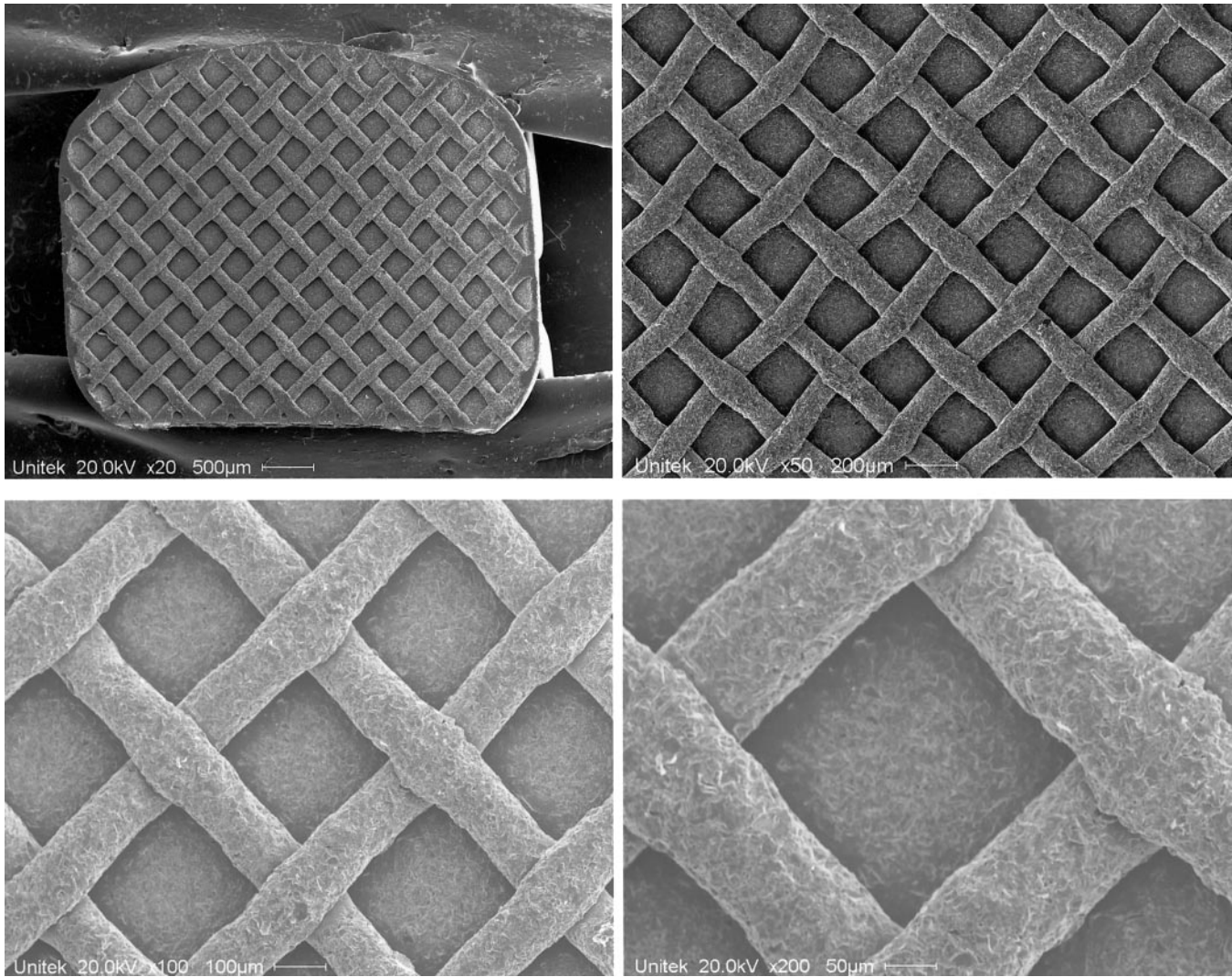


Figure 2. SEM photographs at different magnifications (from $\times 20$ to $\times 200$) for the Victory single-mesh bracket bases, in the “as received” condition.

TABLE 1. Mesh-Base Specifications of the Two Brackets Compared in This Study as Described by Matasa¹³

| Brackets | Pad ^a | Diameter (inch) ^b | Aperture, μ^c | Open Area (%) ^d |
|----------|---------------------|------------------------------|-------------------|----------------------------|
| Ovation | Super-mesh 200 | 0.0021 | 75 | 34 |
| Victory | Single-mesh 80 mesh | 0.0055 | 180 | 31.5 |

^a Mesh number (x) = number of openings per lineal inch from the center of the wire to the center of the wire.

^b Diameter of the mesh wire.

^c Aperture, size of the mesh aperture in micrometers.

^d Open area, total area available for the adhesive to penetrate.

be more retentive than foil-mesh bases,⁵ whereas others found the opposite.^{7,8} Similarly single- and double-mesh designs were evaluated using finite element analysis, and the stresses were found to differ according to the depth of the adhesive layer.^{9,10} In this study both the single- and double-

TABLE 2. Descriptive Statistics in Megapascals (MPa), and the Results of the Student’s t -Test Comparisons of the Shear Bond Strengths of the Brackets Tested^a

| Brackets | n | \bar{x} | SD | Range |
|-------------|----|-----------|------|----------|
| Single mesh | 20 | 5.8 | 2.8 | 1.0–11.2 |
| Double mesh | 20 | 5.2 | 3.9 | 1.0–13.8 |
| t -Test | | | 2.09 | |
| P | | | .157 | |

^a n, sample size; \bar{x} , mean; SD, standard deviation; P , probability.

mesh designs produced similar shear bond strength values and bracket failure modes.

What may explain these conflicting results? Majjer and Smith¹⁴ evaluated different bracket pads using scanning electron micrographs and identified a number of variables and observations that might affect the bond strength of brackets, including (1) weld spots could reduce the reten-

TABLE 3. Frequency Distribution and χ^2 Comparisons of the Modified Adhesive Remnant Index (ARI) Scores of the Two Groups

| Brackets | n | ARI Scores ^a | | | | |
|-------------|----|-------------------------|-----|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Single mesh | 20 | 10 | 10 | — | — | — |
| Double mesh | 20 | 12 | 5 | 3 | — | — |
| χ^2 | | | 2.0 | | | |
| P | | | .50 | | | |

^a 1, all the composite remained on the tooth; 2, more than 90% of the composite remained on the tooth; 3, more than 10% but less than 90% remained on the tooth; 4, less than 10% remained on the tooth; 5, no composite remained on the tooth.

tive area, (2) weld spurs could reduce bond strength with foil-mesh brackets, (3) weld spots on the edges of the attachments should be avoided to improve resin-mesh seal, (4) bracket bases should be designed to prevent air entrapment under the base, and (5) the best resin penetration and bond strength are obtained with a fine mesh of the woven type.

Knox¹¹ suggested that bracket base design needs to improve both the adhesive and light-curing penetrations. On the other hand, Matasa¹² observed that the manufacturer's efforts to improve bonding strength have traditionally focused on the bracket pad more than the adhesive and enamel conditioner. As a result, the bonding pad and bracket base evolved with time to incorporate a perforated mesh, mesh, grooves, dents, and pegs without too much effect on bond strength.

To improve bracket performance, Matasa¹³ suggested that because metals are hydrophilic, the use of a proper primer would help wet the surface and invite the adhesive to pass through the mesh. This can be accomplished either by mesh silanation or by polymer coating. In the absence of such a treatment it becomes critical to press the bracket after it is placed on the tooth to force the adhesive to pass through the mesh layer(s) and minimize the amount of air trapped in the mesh, enhancing bond strength.

CONCLUSIONS

The results indicated that the single- and double-mesh bracket bases evaluated in this study provided comparable

shear bond strengths and bracket failure modes. Whether these results will hold at 24 hours after the time of initial bonding or after thermocycling still needs to be determined.

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