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ORIGINAL ARTICLE

# A Comparative Study of Shear Bond Strength of Three Different Bracket Bases Bonded to Porcelain Surfaces

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## Abstract

Previous studies showed that the bonding strength of brackets to porcelain restorations and the failure model depend on many variables including bracket base design. The aim of this in-vitro study was to investigate Shear Bond Strength (SBS) of different bracket base designs on porcelain surfaces and to evaluate the sites of adhesive fracture with the Adhesive Remnant Index (ARI). Sixty feldspathic porcelain discs were randomly divided into three different groups each of twenty. Maxillary right incisor metal brackets with three different base designs (Victory series, 3M Unitek, Monrovia, California; Dyna-Lock, 3M Unitek, Monrovia, California and Mini Topic, Dentaurum, Inspringen, Germany) were bonded on the deglazed and conditioned porcelain surfaces in group 1, 2 and 3 respectively. Brackets were debonded and SBS was calculated in Mega Pascal (MPa). ARI scores were recorded after debonding. SBS forces calculated for group 1, 2 and 3 were 20,57 (± 7,18), 16,84 (± 6,20), 18,55 (± 5,46) MPa respectively. ANOVA and Multiple Comparison test revealed no significant difference in ARI scores between groups. Porcelain fractures after debonding were observed in groups 1 and 3. All brackets tested provided acceptable SBS. However, only Dyna-Lock brackets did not cause any porcelain fractures at debonding. This finding could be an acceptable reason to use this kind of brackets during orthodontic treatment of patient having porcelain restorations.

**Keywords:** Orthodontics, bracket base, dental porcelain, shear bond strength.

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## Introduction

Direct bonding of orthodontic brackets to teeth has been a common procedure for more than 30 years (1,2). Because most bracket bases do not chemically bond to enamel or resin, efforts have been made to improve mechanical retention with various designs. A mechanical undercut provides a place for the orthodontic adhesive to extend before polymerization (3). Mechanical retention of most metal brackets is achieved by the welding of different diameter mesh wires to the bracket base as well as incorporating different designs in the mesh itself (4). Other bracket bases have a milled undercut or are sandblasted, chemically etched, sintered with porous metal powder (3,5). Another innovative approach to improve retention is using laser-structured bases (6).

An increase in the number of adults seeking orthodontic treatment presented new problems to the orthodontist. Adult orthodontic treatment frequently requires bonding brackets onto various types of dental restorations. Metal ceramic and all-ceramic restorations are widely used to restore damaged or missing teeth in adults (7). Previous studies showed that bonding strength of brackets to porcelain restorations and the failure model depend on many variables; porcelain type and surface conditioning, bracket material, base design and retention mode, composition and physical properties of bonding of the bonding adhesive, and the light-curing source (7).

The literature contains many reports on bonding to porcelain surfaces for orthodontic purposes (8,9). Numerous conditioning methods have been suggested for pre-treating ceramic surfaces such as roughening the porcelain surface with a diamond drill or sandpaper discs (8-10), sandblasting with aluminum oxide particles (11,12), chemical preparation with hydrofluoric (HF) acid (11-14) and use of silane (gamma-methacryloxypropyltrimethoxy-silane) which provides a chemical link between porcelain and composite resin and increase the wettability of the porcelain surface (12,15,16).

Many studies have been performed to compare shear bond strength (SBS) of metal brackets with different retentive bases to enamel (17-19), but there are no investigations showing the effect of using different bracket base designs on porcelain surfaces regarding SBS.

Therefore the aim of this in-vitro study was to investigate SBS of different metal bracket base designs on porcelain surfaces, to determine the behavior of the porcelain surface after de-bonding and also to evaluate the sites of adhesive fracture with the adhesive remnant index (ARI).

## Materials and Methods

### 1. Porcelain specimen preparation and fabrication:

One hundred and eighty porcelain discs were prepared. For the compaction route, 0.7 g of porcelain powder (Vita VMK 95, Vita Zahnfabrik, Bad Säckingen, Germany) was mixed with 0.25 g of it's special liquid to form slurry. The slurry was transferred in a metallic mold (15 mm in diameter and 2.5 mm in thickness). The mould was overfilled with the slurry and condensed on a vibrating table for 90 s and excess water brought to the surface of the sample was blotted away using an absorbent tissue. The specimen surface was leveled using a razor blade to provide specimens of uniform thickness prior to removal from the mould. The condensed disc specimens were sintered and glazed in accordance with manufacturer's instructions.

### 2. Bracket bonding to porcelain surfaces:

Three types of maxillary right central incisor metal brackets with different base structures selected for this study were: miniature single-mesh (Victory Series, 3M Unitek, Monrovia, California); integral (Victory Series, 3M Unitek, Monrovia, California); and laser structured brackets (Dentaurum, Inspringen, Germany) with a surface diameter of 8.97 mm2, 9.25 mm2 and 12 mm2 respectively. 60 brackets for each type were used. Digital Scanning microscopy investigations were conducted on the gold-coated brackets using HitachiTM TM-1000 Tabletop Digital Microscope (Hitachi–High Technologies Corporation, Japan). Digital photographs at different magnifications (100X and 200X) for the bracket structures of Victory, Dyna-Lock and Mini-Topic brackets in "as received" condition, are presented in figure 1.

To stimulate the moisture and temperature changes in the oral environment, all porcelain specimens were stored in deionized water at 37ºC for 30 days, and then thermal cycled in deionized water at 5±2ºC to 55±2ºC for 5000 cycles. The total period of exposure to both 5±2ºC and 55±2ºC was 10 seconds, with a dwell time of 5 seconds in each bath. Before surface conditioning procedures all discs were kept in distilled water at 37ºC for six weeks. The water was changed weekly. The specimens were embedded in acrylic moulds, remaining the glazed surfaces exposed. All specimens were randomly divided into three groups, each containing 60. This is the minimum number recommended previously for laboratory bond strength testing (20). The porcelain surfaces were deglazed by aluminum oxide sandblasting with an air abrasion device (Microetcher II Intraoral Sandblaster, Danville Engineering) filled with aluminum oxide (Danville Engineering) with a diameter of 50-µm, from a distance of approximately 5 mm for five seconds. After sandblasting the deglazed porcelain surfaces were cleaned with water and dried with oil-free compressed air to remove the remaining powder. They were then etched with 5-per-cent hydrofluoric acid gel (IPS Ceramic Etchant Gel, Ivoclar Vivadent AG, Schaan, Lichtenstein) for 120 seconds, rinsed with distilled water for 15 seconds, and dried before application of the silane primer. Reliance Porcelain Conditioner (Reliance Orthodontic Products Inc. Unite. 3M Unitek) was applied on the etched surface for 60 seconds.

Victory, Dyna-Lock and Mini-Topic brackets were applied to porcelain surfaces in groups 1, 2 and 3 respectively. All brackets were bonded to the prepared porcelain surfaces with a light cure composite resin (Transbond XT, 3M UNITEK, Monrovia, California, USA) in accordance with manufacturer's recommendation directions. A 300 g weight was then placed on the brackets for 15 seconds and excess cement was carefully removed from the porcelain surface around the bracket base with a dental probe and the adhesive was light cured for 40 seconds using a visible light-curing unit (Optilux™ XT, 3M Unitek, Monrovia, California, USA). All brackets were placed by a single operator. All specimens were stored in 37ºC-distilled water for one week and subjected to thermo cycling before SBS testing.

The specimens were mounted in a jig of the universal test machine (Instron 3345) so that the bracket base parallel to the direction of the shear force. A standard knife-edge blade was positioned to make contact with the bonded specimen. Shear force was applied to the porcelain-bracket interface with a crosshead-speed of 1-mm-per-minute until de-bonding occurred. The bond strength values were calculated by dividing the maximum load (in Newton) by the area of the bracket to convert the results to MPa.

After de-bonding, the bracket bases and porcelain surfaces were examined visually by a single operator under 24X by using a stereo microscope (Stereo Microscope, Leica, MZ 12.5) to determine amount of residual adhesive remained on the porcelain surface according to the Adhesive Remnant Index (ARI) (21).

### 3. Statistical analysis:

Statistical analyses were performed with SPSS 17.0 for MS Windows. Descriptive statistics such as mean, standard deviation, minimum and maximum values were calculated. One-way ANOVA test was used to compare the means differences between the three groups and Post Hoc Tukey HSD tests were conducted for significance differences between pairs of means. One-way ANOVA test was used to compare ARI scores between and within groups. Statistical significance level was established at p<0,05 with a confidence interval of 95%.

## Results

Mean SBS of Victory, Dyna-Lock and Mini-Topic groups were, 20,57 (±7,18), 16,84 (±6,20) and 18,55 (±5,46) MPa respectively (Table 1). The One-Way ANOVA test showed that there were no statistically significant differences between groups (p>0,05) in terms of MPa (Table 2). One-Way ANOVA test showed that there were no statistically significant differences between ARI scores in terms of different bracket groups (p>0,05, Table 3). All brackets remained remnants (Fig. 1). However, the degree of remnants remained as scored 3 for Dyna-Lock, Mini-Topic and Victory groups were 95%, 75% and 50% respectively.In both Victory and Mini-Topic groups, porcelain fractures were observed in three specimens in each group, while no fracture was observed in the Dyna-Lock group.

**Table 1.** Descriptive statistics of Shear Bond Strength (MPa) and Nominal Area ($mm^2$).

| Bracket | Area ($mm^2$) | N | Mean (MPa) | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Victory Series | 9.25 | 60 | 20.57 | (±7.18) | 10.98 | 33.23 |
| Dyna-Lock | 8.97 | 60 | 16.84 | (±6.20) | 5.22 | 31.27 |
| Mini-Topic | 12 | 60 | 18.55 | (±5.46) | 8.67 | 27.89 |

SD: Standart devaiation.

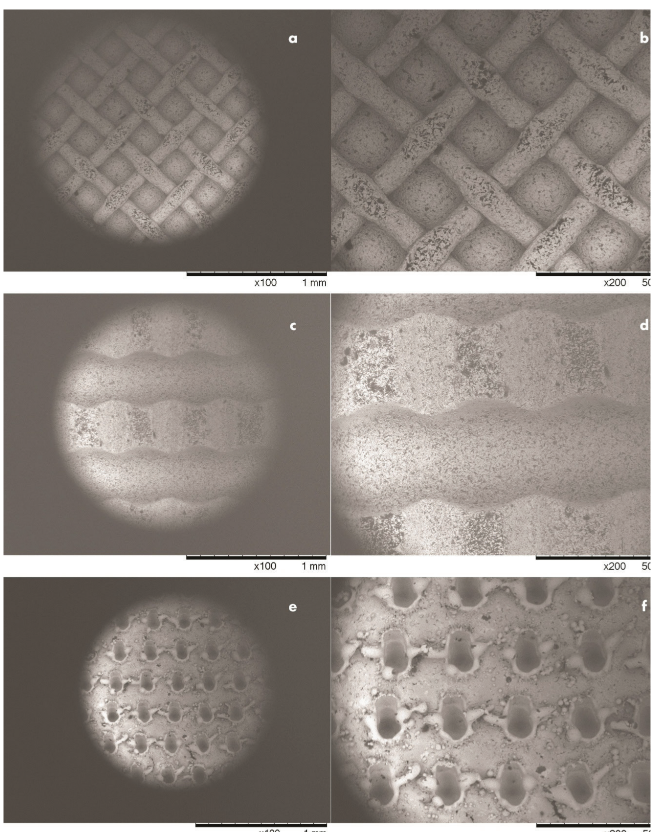
**Table 2.** One-Way ANOVA and Post Hoc Tests (Tukey HSD) for MPa

| Groups | | | Significance (p>0.05) |
|---|---|---|---|
| Victory | - | Dyna-Lock | 0.158 |
| Victory | - | Mini-Topic | 0.933 |
| Dyna-Lock | - | Mini-Topic | 0.293 |

**Table 3.** One-Way ANOVA test for ARI scores between and within groups.

| | Sum of Squares | df | Mean Square | F | Sig. (p>0.05) |
|---|---|---|---|---|---|
| **Between Groups** | 2.500 | 2 | 1.250 | 1.264 | 0.290 |
| **Within Groups** | 56.350 | 57 | 0.989 | | |
| *Total* | 58.850 | 59 | | | |

**Figure 1:** SEM photograph of Victory bracket at 100X (a) and 200X (b) magnifications; Dyna-Lock bracket at 100X (c) and 200X (d) magnifications; Mini-Topic bracket at 100X (e) and 200X (f) magnifications.




## Discussion

As porcelain restorations are widely used to restore damaged or missing teeth in adults, the orthodontic treatment for such patients must take into consideration the difficulty in bonding brackets to porcelain, whose glazed surface is not amenable to resin penetration and on the other hand must consider a safe removal of brackets to reduce to a minimum if any possible damage to the restoration surface (7).

The orthodontist might not know whether the dental ceramic is feldspathic porcelain, aluminous porcelain, or glass ceramic. It is very common to find feldspathic porcelain in ceramic-fused-to-metal restorations[13]. In the present study lecute containing feldspathic porcelain was used as described in the study of Sinmazisik et al. (21). Optimal bracket adhesion to a porcelain surface requires that orthodontic forces can be applied without bond failure during treatment, and that porcelain integrity not be jeopardized during the de-bonding procedure. Unfortunately, little is known about the bond strengths of various bracket base designs when bonded to porcelain restorations.

The aim of this study was to evaluate SBS of different base structured metal bracket to porcelain surfaces.

Bonding brackets to porcelain surfaces is a double challenge. On one hand, optimal bonding shown to be 6 to 10 MPa must be achieved to prevent bond failure during treatment (22,23). On the other hand, de-bonding must leave the porcelain as functionally and esthetically perfect as it was before treatment (11). However, considerable risk exists for porcelain fracture on de-bonding. The adhesive strength between porcelain and resin, especially when a silane primer is used to roughen porcelain, could exceed the cohesive strength of porcelain, resulting in porcelain fracture on debonding (23, 24).

Thurmond et al. (25) stated that de-bonding forces higher than 13 MPa could cause cohesive fractures. In the present study, in all groups the SBS was above 13 MPa. The highest MPa values were observed in the Victory groups and the lowest MPa values were observed in the Dyna-Lock group. This finding was similar to the results of the study of Cozza et al. (26). Cohesive fractures were observed in Victory and Mini-Topic groups. For all three groups ARI scores indicated that bracket-adhesive interface, which is mechanical and depends on the base structure of the bracket, was weaker than the adhesive-porcelain interface, which is a chemical link and depends on the porcelain surface preparation and adhesives, preventing cohesive fractures of the porcelain. Cohesive failures within the ceramic could be interpreted so that the composite-resin-ceramic compound was stronger than the ceramic layer itself (15, 27). In Dyna-Lock group the percentage of ARI score 3 was higher then the other two groups (95%), which shows that more resin was left on the porcelain surface compared to the other groups. This kind of residual may require further treatment to remove adhesive traces from the porcelain surface, a procedure that could cause additional damage to porcelain restoration surface. Although several studies have reported that polishing can produce surfaces as smooth as the original glaze (28), Sinmazisik et al. (29), indicated that glazed specimens have significantly higher flexural strength than polished specimens. In the same study the authors suggested that small porcelain corrections might be polished without effecting the ceramic restoration negatively.

The morphology of the base is an important variable for the retention of a bracket (3, 30, 31). In previous literature it was suggested that the base design could improve penetration of the adhesive material (3, 30, 31). The size of the base is also an important factor (17). Merone et al. (31) and Cucu et al. (32) indicated that clinicians could select smaller brackets with no reduction in effectiveness of the treatment procedure.

With the exception of Victory series brackets, all brackets used in this study were "integral brackets", in which the body and the retentive base are a unique piece.

Victory series brackets present with an 80-G-mesh foil, which seems to be the most retentive size providing large spaces for the penetration of the adhesive and curing light (33). Therefore, in the present study Victory series brackets were used to test SBS of mesh based bracket bases to porcelain surfaces.

The retentive system of Dyna-Lock brackets consists of the retention groove base, which is characterized by horizontal undercut channels open at the medial and distal extremities, with a "V" grooved pattern running vertically on the surface of the base. This design should reduce the chances of air entrapment because excess material can escape. This type of retention showed the lowest MPa in the present study similar to other studies (26).

In Mini-Topic brackets, the retentive system is characterized by a laser-structured base in which the retention is obtained with many hole-shaped cavities on the bottom of the brackets that are realized by a laser beam scanned over the base surface. Although the surface area of these brackets was larger, in the present study it was observed that the bond strength to porcelain of Mini-Topic brackets were lower when compared with Victory series brackets.

Many studies indicated that methods that provide a sufficient bond with less roughening should be used (8, 34). The rough ceramic surface should be polished after de-bonding the brackets; this is possible with ceramic polishing kits and diamond polishing pastes (11, 34, 35). In this study, deglazing was performed with sandblaster and not with a green stone, in order to avoid micro cracks (11, 36), which could lead to porcelain fractures at de-bonding.

Calamia[36] suggested that the use of strong acids to etch porcelain may produce increased bond strength since the action of an acid such as 9.6 per-cent HF is to create a series of surface pits by preferential dissolution of the glass phase from the ceramic matrix (37). However, HF is extremely corrosive, and is capable of causing severe trauma to soft tissues and tooth substances (38, 39). Therefore HF acid must be used with great care. Previous research recommended that 5 per-cent hydrofluoric acid could be used for intra-oral applications in order to prevent tissue irritation without a loss in bond strength[39)]. In the previous study 5 per-cent HF acid was used for 120 seconds.

Kocadereli et al. (12) indicated that silane application after surface roughening of porcelain surfaces, which provide a chemical link between porcelain and composite resin (15), increases the bond strength of orthodontic attachments. In previous studies it was indicated that silanization with Reliance showed lower bond strength between the bracket surface and composite resin leaving more adhesive on the porcelain surface, which may prevent porcelain fractures at de-bonding (40). In this study silanization was performed with Reliance.

During orthodontic treatment brackets with higher SBS are more preferable although when treating patients with porcelain restorations, it should be considers that porcelain material is britable and too high SBS could cause fractures in porcelain materials during de-bonding which will lead to renewal of the porcelain surfaces.

## Conclusion

Orthodontic bonding forces to porcelain were evaluated in-vitro with three different brackets with different base designs and within the limitations of this study and it could be concluded that:

1. All brackets tested provided acceptable bond force levels.

2. Higher SBS between metal brackets and porcelain surfaces may cause porcelain fractures during de-bonding.

3. Dyna-Lock brackets, could be used safely to overcome cohesive fractures in porcelain during de-bonding of orthodontic patients, which have porcelain restorations, clinically, however, it is not always possible to make extrapolations from in-vitro studies to clinical situations.

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