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# Comparative Assessment of the Shear Bond Strength of Ceramic Brackets Bonded to the Enamel Surface with a Self-adhesive System

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**ABSTRACT**

**Objectives:** This study aimed to evaluate the shear bond strength of ceramic brackets bonded to the enamel surface using Vertise Flow, with or without the application of phosphoric acid.

**Materials and Methods:** Forty-five extracted human premolar teeth were randomly assigned to three groups (N=15) based on the adhesive used for bonding: 1) Transbond XT, etch, and bond; 2) Vertise Flow; 3) Etch and Vertise Flow. After a 500-round thermocycling procedure, the shear bond strength was measured using a universal testing machine. The samples were then evaluated under a stereomicroscope to determine failure modes, and the Adhesive Remnant Index (ARI) was measured for each group. The data were analyzed with one-way ANOVA and post-hoc Tamhane at a significance level of $P<0.05$.

**Results:** The highest shear bond strength values were observed in the Transbond XT (13.5±5.38MPa), acid etch and Vertise Flow (11.2±2.89MPa), and Vertise Flow (6.2±3.16MPa) groups, respectively, in descending order. The Vertise Flow group exhibited a significantly lower shear bond strength value compared to the other two groups, with no significant difference between the latter two.

**Conclusion:** While all three study groups demonstrated clinically acceptable shear bond strength values, Vertise Flow showed lower values compared to the other two adhesives. The Vertise Flow composite resin system, whether used alone or with acid etching, remains a suitable choice for bonding ceramic brackets, offering the advantage of a simplified bonding procedure.

**Keywords:** Dental Cements; Shear Strength; Orthodontic Brackets

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## INTRODUCTION

Ceramic brackets were introduced to meet patients' aesthetic demands as they closely match the color of the teeth and do not draw much attention. Since these brackets are not very visible, they are suitable for individuals who prefer not to have metallic appliances in their mouth during treatment [1,2].

The bonding process of orthodontic brackets to tooth surfaces has been significantly modified over the past 60 years due to the introduction of new materials and techniques. These advancements have made it possible to bond brackets to tooth surfaces more effectively. With rapid advances in various scientific fields, the field of orthodontics has also witnessed significant developments in materials and tools [3]. Dental adhesives and the ability to bond orthodontic brackets and appliances to the enamel surface, previously achieved with bands around the teeth, are considered a significant development in orthodontic treatments. The shear bond strength (SBS) of orthodontic brackets is one of the most critical factors in the bonding process. The bond strength of orthodontic brackets must be sufficient to withstand the forces applied during treatment, yet not so high as to cause enamel damage during bracket removal [4]. A bond strength of 6–8 MPa is sufficient to resist masticatory forces [5].

An important issue is bracket debonding during orthodontic treatment. One of the goals of developing new and different bonding systems is to design and produce materials that provide the fastest, easiest, and highest quality bond [6]. Over the past decade, several studies have investigated the efficacy, durability, and resistance of new bonding agents by evaluating their Shear Bond Strength (SBS) and tensile bond strength [6-8]. Typically, SBS tests are preferred over tensile bond strength tests due to the similarities in the oral cavity conditions in terms of loading and force application conditions [9].

The practice of bonding orthodontic appliances to the enamel surface was introduced in 1965 [10]. Since then, various bonding systems have been introduced for bonding orthodontic brackets. Older systems involved many steps, including etching for 30 seconds, rinsing with water, drying, and applying a resin primer before bonding the bracket with resin cement [11].

Recently, new self-adhesive composite resins have been introduced to the dental industry. These composite resins have reduced the number of bonding steps, thereby facilitating the bracket bonding process. Vertise Flow is the first material introduced as a self-adhesive composite resin that does not require the etching and adhesive process as a restorative material. The application of self-adhesive systems only requires the cleaning of the enamel surface and removal of remaining debris and pellicles. The manufacturers claim that Vertise Flow is the first self-adhering composite, which makes it time-consuming [12]. In addition to its routine use as a pit and fissure sealant, a good restorative material for small Class I and Class II cavities, and repair of ceramics, it can potentially be used for bonding brackets. In contrast to conventional bracket bonding procedures, using this material can be easier and faster, which is considered advantageous in crowded orthodontic offices and clinics [13]. Only a few studies have evaluated Vertise Flow self-adhesive composite resin for bonding orthodontic brackets [5,14]. Studies on self-adhesive composite resins have not reported adequate SBS values for metallic orthodontic brackets [5,6,14]. However, in studies where the tooth surface has been etched with phosphoric acid before placing the composite resin, significantly higher bond strengths have been reported, reaching clinically acceptable levels [15–17]. There is limited research on the use of Vertise Flow self-etch composite resin in bonding ceramic brackets.

Therefore, the purpose of this study was to assess the Shear Bond Strength (SBS) of ceramic brackets bonded to the enamel surface with Vertise Flow self-adhesive composite resin.

## MATERIALS AND METHODS

### *Ethical Approval:*

This study was conducted under the approval of the Ethical Committee of the Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1397.131).

Forty-five intact human maxillary or mandibular first premolars, extracted for orthodontic reasons, were included in the study based on the following inclusion criteria: caries-free buccal surfaces, absence of enamel hypoplasia, no prior restorations, and no visible cracks. After cleaning the residual tissues from the surfaces, all teeth were stored in distilled water at 37ºC for a maximum of three months. Before beginning the study procedures, the samples were immersed in a 0.5% chloramine T solution for one week. After rinsing, the buccal surface of each tooth was cleaned with a rubber cup in a low-speed handpiece with fluoride-free pumice mixed with water for 10 seconds. The buccal surfaces of the teeth were dried with an oil-free air stream after rinsing to remove pumice and water residues. All 45 samples were randomly assigned to three groups (N=15) using a random numbers table. In each group, the ceramic brackets (Transcend Bracket, Unitek Corp, Monrovia, CA, USA) with a similar base, measuring 14.2 $mm^2$, were bonded to the enamel surface as follows:

***Group 1 (etch + bond + Transbond XT):*** The enamel surface was etched with a 37% phosphoric acid gel (Ultra-Etch, Ultradent Products Inc., UT, USA) for 20 seconds, according to the manufacturer's instructions. The etched enamel surface was rinsed with a water spray for 20 seconds and dried with an air syringe under mild pressure for 10 seconds. A layer of Transbond XT Primer (3M Unitek, Monrovia, CA, USA) was applied and thinned with an air spray, followed by light-curing for 20 seconds with a Dental LED light-curing unit (Woodpecker, China). A small amount of Transbond XT (3M Unitek, Monrovia, CA, USA) composite resin was then placed on the ceramic bracket base. The bracket was immediately placed at the mesiodistal and occlusogingival center of the buccal surface using tweezers with mild pressure and firmly positioned with a scaler. Excessive composite resin was removed, and the bracket and composite resin were light-cured separately from four sides (occlusal, gingival, mesial, and distal) for 10 seconds with a Dental LED light-curing unit (Woodpecker, China).

***Group 2 (Vertise Flow):*** A 0.5mm uniform layer of Vertise Flow self-etch composite resin (Kerr, Orange, CA, USA) A 0.5mm uniform layer of Vertise Flow self-etch composite resin (Kerr, Orange, CA, USA) was applied to the middle area of the enamel surface and thinned with a microbrush for 15–20 seconds. Then, a small amount of Vertise Flow was placed on the bracket base. Following positioning with a scaler, the excessive composite was removed and light-cured similar to Group 1.

***Group 3 (etch + Vertise Flow):*** After etching the enamel surface with 37% phosphoric acid gel, Vertise Flow composite resin was applied and brackets were bonded, similar to the procedure described for Group 2.

The samples were placed in three separate groups in a glass container and were subjected to thermocycling (TC300, Vafaei Industrial Company, Iran) after 24 hours of storage in 37ºC distilled water. All the samples in the study groups underwent a 500-round thermocycling procedure consisting of 30 seconds of heat and 30 seconds of cold, with 10 seconds for transfer at 5ºC/55ºC. Each tooth was mounted and fixed within an acrylic resin block. To this end, the teeth were placed in self-cured acrylic resin (Acropars, Iran) in a prefabricated metallic mold. The buccal surfaces of the teeth were situated perpendicular to the mold base so that the bonding surface would be parallel to the applied forces during the SBS test. After the setting process of the acrylic resin, the teeth and the acrylic resin blocks were removed from the metallic mold.

At the end of this stage, the samples were ready for debonding. For the debonding step, a steel rod with a smooth end was attached to the universal testing machine (Zwick, Germany). The samples were connected to the machine's jig so that the bracket base was parallel to the shearing force application direction. A shearing force at an occlusogingival direction was used on the samples at a crosshead speed of 1 mm/min until debonding occurred.

The force necessary to debond the brackets was recorded in Newton, and the bond strength was calculated in MPa by dividing the force in Newton by the bracket base surface area in $mm^2$ (13.5±0.2 $mm^2$). After debonding, the bracket base and enamel surfaces were evaluated under a stereomicroscope (Leica, EZ4D, Germany) at ×10 magnification. The Adhesive Remnant Index (ARI) was used to evaluate the adhesive remaining on the enamel surface, which was classified as follows: 0: No adhesive on the enamel surface; 1: Less than half of the adhesive remained; 2: More than half of the adhesive remained; and 3: All the adhesive remained.

Data were analyzed using one-way ANOVA to compare SBS among the study groups. The post hoc Tukey test was used for two-by-two comparisons of the groups at a significance level of $P<0.05$.

## RESULTS

Since the data were distributed normally, the mean SBS values of the study groups were compared with one-way ANOVA at a significance level of $P<0.05$. Table 1 presents the means and standard deviations of SBS in different study groups. The highest and lowest values were recorded in the Transbond XT (13.35±5.38 MPa) and Vertise Flow groups (6.23±3.16 MPa), respectively. Since one-way ANOVA revealed significant differences in the mean SBS values between the three study groups (P=0.0001), post hoc Tukey tests were used for two-by-two comparisons a 0.05 acceptable type I error.

As shown in Table 1 and Figure 1, the mean Shear Bond Strength (SBS) in the Vertise Flow group was significantly lower than the other two groups, i.e., Etch + Bond + Transbond and Etch + Vertise Flow (P<0.001). However, there were no significant differences in SBS between the Etch + Bond + Transbond and Etch + Vertise Flow groups (P=0.464). Evaluation of the Adhesive Remnant Index (ARI) with the Kruskal-Wallis test showed significant differences between the study groups (P=0.013). Therefore, the appropriate post hoc tests (Bonferroni) were applied for two-by-two comparisons of the mean ARI values. According to the results, a significant difference was noted only between the Etch + Vertise Flow and Vertise Flow groups (P=0.01) (Table 1 and Figure 2).

## DISCUSSION

This study evaluated the Shear Bond Strength (SBS) of ceramic brackets bonded to the enamel surface with a self-adhesive system (Vertise Flow). Currently, clinicians aim to decrease chair time as much as possible. Therefore, Vertise Flow self-adhesive composite resin might be a suitable choice to replace currently available materials, given its characteristics. This composite resin can directly bond brackets to tooth surfaces without the need for etching and bonding steps. If this system can provide the necessary bond strength for brackets, it can help facilitate bracket bonding procedures, decrease bonding time, and increase patient comfort and satisfaction.

In addition, considering the increased rate of orthodontic treatments, it is important to pay attention to problems with brackets that might be a source of concern with these appliances during orthodontic treatment, including the failure of bracket bond to the enamel surface, residual resin on the enamel after bracket debonding, increased demineralization, etc. [18].

Ceramic brackets are used in patients with aesthetic demands. They are almost tooth-colored, and their appearance draws less attention; therefore, they are more favorable for patients [1]. Several studies have evaluated the differences between metallic and ceramic brackets, indicating that ceramic brackets exhibit a higher mean of SBS to tooth enamel than metallic brackets [2,19]. Regarding the etching of the enamel surface before placing self-adhesive composite resins, some studies have shown [15–17,20,21] that etching the enamel before placing self-adhesive composite resins improves the bond between the enamel and the adhesive, thereby increasing the bond strength. This is because acid etching before placing the adhesive increases the micro-retentive porosities on the enamel surface, resulting in a better bond [15]. This is consistent with the present study and a study by Goracci et al., in which a stronger bond was achieved between the tooth and bracket with acid etching [5]. Some studies have evaluated bonding systems, using the available adhesives with different particle sizes, viscosity, and filler contents, which have addressed the problem of the bond strength of brackets to tooth surfaces. Currently, Transbond XT composite resin is used as the gold standard for bonding brackets [22]. The current study aimed to leverage the characteristics of the self-adhesive Vertise Flow composite resin in bonding ceramic orthodontic brackets to the enamel surface. Considering that

**Table 1.** Means and standard deviations of shear bond strength (MPa) and ARI scores in the three study groups

| Groups | Mean±SD | Minimum | Maximum | ARI (N) | | | |
|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 |
| Etch+Bond+Transbond | 13.35±5.38$^{a}$ | 7.57 | 25.12 | 5$^{c}$ | 10 | 0 | 0 |
| VertiseFlow | 6.23±3.16$^{b}$ | 2.21 | 11.09 | 13$^{c}$ | 2 | 0 | 0 |
| Etch+VertiseFlow | 11.20±2.89$^{a}$ | 7.04 | 16.65 | 5$^{d}$ | 10 | 0 | 0 |

The similar superscript letter indicates no significant difference between the study groups
SD: standard deviation; ARI: adhesive remnant index

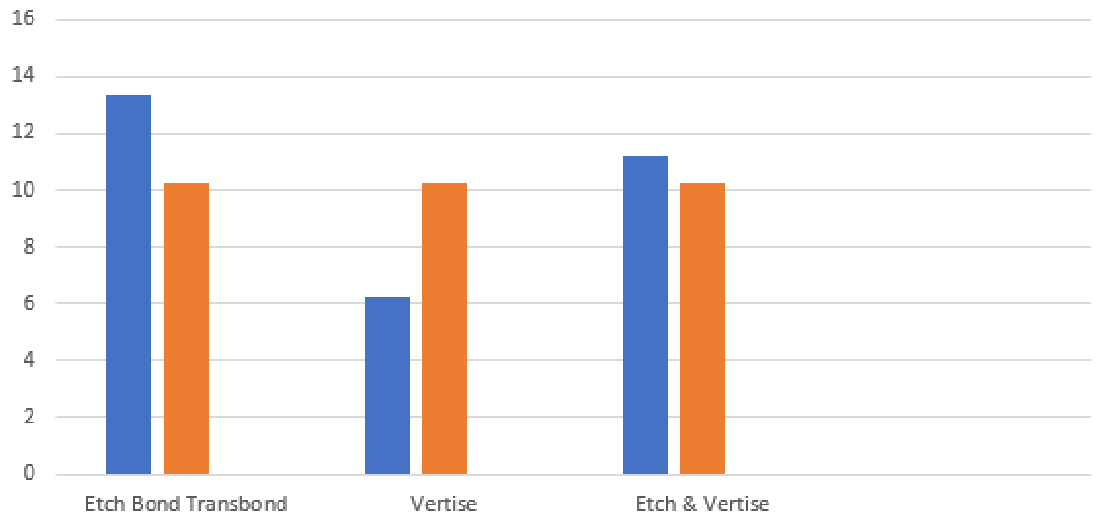


**Fig. 1.** Mean bond strength values (MPa) in the three study groups (blue) and comparison with the total means (orange)

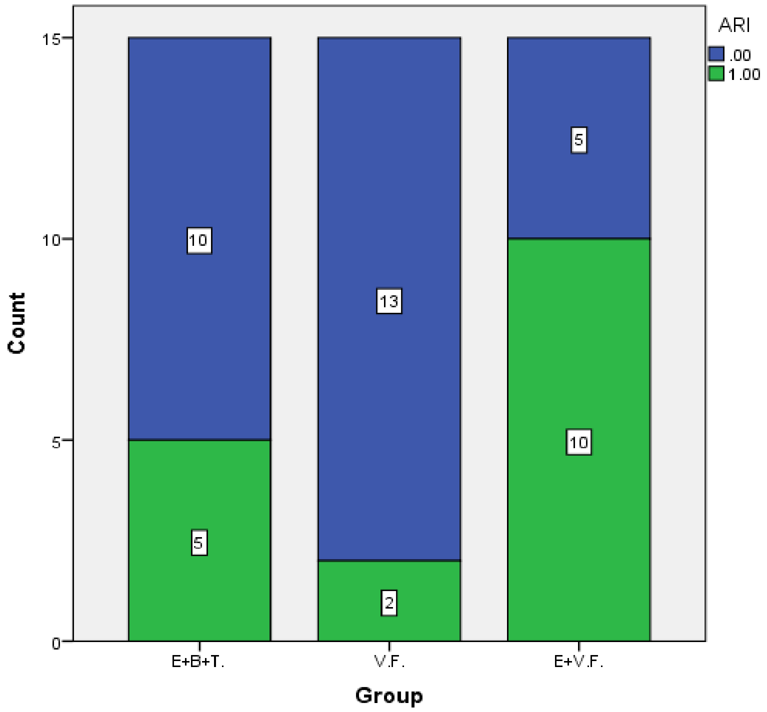


**Fig. 2.** Frequency distribution of adhesive remnant index scores in the study groups

the research was conducted in vitro, it's important to note that the oral cavity presents varied conditions, encompassing a mix of tensile, shear, and rotational forces, as well as a blend of stresses such as thermal fluctuations, moisture, acidity, and microbial plaque. Simulating these conditions in vitro is challenging. Consequently, the findings should be interpreted with an awareness of the limitations inherent in the present study [23]. Based on our results, the SBSs of the adhesives to enamel were highest in group 1 (etch+bond+Transbond XT), followed by groups 3 (etch+Vertise Flow) and 2 (Vertise Flow) respectively. According to two-by-two comparisons, the SBS in group 2 was significantly lower than the other two groups, with no significant difference between groups 1 and 3. The weaker performance of Vertise Flow compared to the other adhesives may be attributed to its minimal adaptation to the enamel surface [12].

In a study on metallic brackets, Isman et al. [6] showed that the mean bond strength of Vertise Flow without etching was significantly lower than that of the conventional Transbond XT etch-and-rise system. However, there was no significant difference between Transbond XT and Vertise Flow applied after etching. Therefore, it was concluded that the new self-adhesive composite resin system requires the application of additional phosphoric acid to achieve an SBS comparable to conventional orthodontic bonding agents (Transbond XT) [6]. These results were different from our findings, which might be due to the use of ceramic brackets instead of metallic brackets. Ceramic brackets have been suggested to increase the SBS [2].

In a study by Gungor et al., the bond strength of metallic brackets bonded with Vertise Flow composite resin to tooth enamel was 5.90±0.90MPa, which is lower than the optimal level [14]. The different findings may be related to the use of metallic vs. ceramic brackets. The 5.90±0.90MPa mean SBS of metallic brackets bonded with Vertise Flow composite resin in the study by Gungor et al. was close to that in the present study (6.2MPa). However, since Reynolds reported that the minimum SBS necessary to resist masticatory forces is approximately 6MPa [24], and 5.90±0.90MPa is just below 6MPa, different conclusions have been reached from the results of these two studies. It should be noted that some studies have advocated not using a fixed numeric range as an acceptable range for bond strength for all studies [25,26].

In a study by Goracci, the mean bond strength of metallic brackets bonded with Vertise Flow to the enamel without etching decreased significantly to amounts lower than the optimal level [5]. However, in the group where the enamel surface had been etched before placing Vertise Flow composite resin, the bond strength was at an acceptable level both before and after thermocycling. High bond strength to the enamel can lead to complications such as enamel cracks and fractures during bracket debonding [5]. Considering the use of ceramic brackets in the present study and the higher SBS of ceramic brackets compared to metallic brackets [19,2], it might be concluded that the higher SBS in the present study could be related to the use of ceramic brackets.

Valizadeh et al. evaluated the bond strength of metallic brackets bonded by Vertise Flow composite resin to composite resin disks [27]. The mean bond strength in all the study groups, including the Vertise Flow group, was >6MPa. It was concluded that bonding brackets to composite resin restorations with Vertise Flow adhesive might replace conventional orthodontic adhesives [27], a finding consistent with the present study examining the bond of ceramic brackets to enamel using Vertise Flow adhesive. With lower ARI values, the bond failure tends to be of the adhesive type. Elevated ARI values signify more cohesive failures, indicating a greater amount of adhesive remaining on the enamel. The presence of excess adhesive may necessitate removal using a bur, thereby raising the likelihood of surface roughness and potential trauma to the tooth surface during the removal process. Conversely, diminished ARI values amplify the strain on the enamel surface during bracket debonding, escalating the likelihood of stress concentration and the potential for surface cracks or fractures.

With lower ARI values, the need to eliminate residual adhesive from the enamel surface diminishes, reducing the risk of trauma to the tooth surface during the adhesive removal process. In the present study, the ARI index demonstrated the greatest amount of adhesive remaining on the enamel to be in the Etch + Vertise Flow group. There was a significant difference in the ARI index between the Etch + Vertise Flow and Vertise Flow groups, and there were no significant differences between the Transbond XT and the other two groups. Therefore, considering that the ARI index in the Etch + Vertise Flow group is significantly higher than in the other two groups, an important consideration in this group will be the absence of trauma to the enamel surface while removing the composite resin using a bur. However, due to the lower ARI index for the Vertise Flow group, there is no concern about potential damage to the enamel surface during the debonding procedure, especially considering its mean SBS (i.e., 6.2 MPa). ARI is an important consideration for clinicians in selecting orthodontic adhesives [28]. Some investigations have reported no significant differences in ARI value distributions between different study groups [29-32]. However, in studies by Gungor et al. [14] and Goracci [5], there was a significant difference in the distribution of ARI values between the Transbond XT and Vertise Flow groups. As the removal of ceramic brackets requires higher debonding strength and is more prone to enamel damage [33], using Vertise Flow could be a rational route to prevent this undesirable outcome.

While the bonding procedure for ceramic brackets with Vertise Flow self-adhesive composite resin is simplified by its one-step process and reduced potential for technical errors, caution is crucial during bracket placement due to its lower viscosity and flowable consistency. Additionally, meticulous care is needed to remove excess bonding agent. If etching precedes bracket bonding, the absence of a bonding agent, a departure from conventional adhesives, streamlines procedural steps, resulting in a more straightforward process with reduced chairside time.

## CONCLUSION

Within the limitations of the present study, it may be concluded that employing the self-adhesive Vertise Flow composite resin for bonding ceramic brackets to the enamel surface yields a shear bond strength slightly lower than the control group (Transbond XT), yet it remains within clinically acceptable limits. Notably, when Vertise Flow is utilized without etching, there is reduced residual composite resin on the enamel compared to the control group (Transbond XT), leading to less enamel damage during the removal of excess composite resin. However, this approach results in a reduction in shear bond strength.

## CONFLICT OF INTEREST STATEMENT

None declared.

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