Effect of the precrack preparation with an ultrasonic instrument on the ceramic bracket removal

Yen-Liang Chen, Hsing-Yu Chen, Yu-Chih Chiang, Hao-Hueng Chang, Chun-Pin Lin

Graduate Institute of Clinical Dentistry, School of Dentistry, National Taiwan University, Taipei, Taiwan
Department of Dentistry, National Taiwan University Hospital, National Taiwan University, Taipei, Taiwan

Received 1 May 2013; received in revised form 22 May 2013; accepted 4 June 2013

Background/Purpose: In terms of fracture mechanics, a precrack preparation may facilitate the propagation of a break through the expected fracture plane during the bracket debonding process. The purpose of this study was to evaluate the effect of an ultrasonic precrack preparation on the debonding force and failure modes of ceramic bracket removal.

Methods: Eighty extracted premolars were assigned to four groups: Inspire, precrack Inspire, Clarity, and precrack Clarity groups, with each group containing 20 teeth. The precrack preparations were made at the mesial gingival line angle of Inspire brackets and on the mesial side of Clarity brackets with an ultrasonic tip. Debonding force, failure modes, and bracket breakage score were measured and recorded. Fracture surfaces after bracket debonding were observed with scanning electron microscopy (SEM).

Results: We found that the ultrasonic precrack preparation could significantly decrease the average debonding force and the mean bracket breakage scores of both kinds of ceramic brackets. After bracket debonding, 80% of brackets in the precrack Inspire group and 100% of brackets in the precrack Clarity group showed no bracket failure. However, only 25% of brackets in the Inspire group and 75% of brackets in the Clarity group showed no bracket failure. SEM micrographs showed a precrack notch at the adhesive resin after precrack preparation, and no enamel damage was noted after the bracket debonding.
Introduction

The ceramic bracket was introduced in the 1980s.¹ It is more esthetic than other kinds of bracket and also resists distortion and discoloration. However, the hardness and brittleness of ceramics could cause a fracture of the bracket, and the fracture piece may remain on tooth surface. The removal of the bracket or residual adhesive resin is time-consuming and may require a high-speed machine.²,³ In addition, the high-speed bur used to remove the residual resin may sometimes damage the enamel.⁴⁻⁶

For facilitating the removal procedure of the ceramic bracket, some manufacturers use a modified ceramic bracket design such as the vertical debonding slot of the Clarity bracket (3M Unitek, Monrovia, CA, USA) and the ball-base of the Inspire bracket (Ormco, Orange, CA, USA). Ultrasonic instruments have been tried for the removal of brackets, and the results showed a significant reduction of the debonding strength and a favorable failure mode of the ceramic bracket. However, ultrasonic removal is time-consuming and is not generally accepted in clinical applications.⁷,⁸

Fracture mechanics is an engineering discipline; its aim is to give a quantitative description of the broken bracket by crack growth. Fracture mechanics is primarily used to prevent and predict catastrophic failure of the structures of man-made materials such as metals, plastics, and ceramics. The fracture mechanics theory assumes that the existence of a defect or crack in the solid can further grow or propagate to cause failure. It then considers the conditions of stress or energy under which propagation will occur.⁹

The bracket removal depends on the failure of the adhesive between the bracket and the enamel surface. According to the fracture mechanics, a surface crack or defect that is capable of propagation can cause the failure. Therefore, the precrack preparation may create a defect on the adhesive layer and facilitate adhesion fracture. The purpose of this study was to evaluate the effect of an ultrasonic precrack preparation on debonding force and failure mode of ceramic bracket removal.

Materials and methods

Eighty extracted premolars free of restorations and caries were collected and stored in 0.1% wt/vol thymol solution to prevent dehydration and bacterial growth. The teeth were randomly assigned to four groups: Inspire, precrack Inspire, Clarity, and precrack Clarity groups, with each group containing 20 teeth. The upper premolar ceramic brackets with 0.018-in. slots were used in this study. The characteristics of the brackets are summarized in Table 1.

Prior to bonding the ceramic bracket, each tooth was scaled and cleaned by a rubber cup with pumice on a low-speed handpiece. After rinsing, the teeth were etched with 37% phosphoric acid gel (gel etchant, Kerr, Orange, CA) for 30 seconds according to the instruction of the manufacturer. The etching gel was washed out with an air-water spray for 20 seconds, and then the teeth were dried with air until they showed a chalky-white appearance.

A bonding primer (Orthosolo; Ormco) was applied on the etched enamel surface and the teeth were dried with air. Next, the dual-cure adhesive (ENLight, Ormco) was applied between the bracket and the center of the etched enamel surface, and then cured with a light cure unit (L.E. Demetron I, Kerr, Orange, CA, USA) as close to the bracket as possible for 10 seconds (according to the instruction manual) with 800 mw/cm² output.

An ultrasonic tip (S13R, Satelec Acteon, Mierignac, France) powered by an ultrasonic device (Prophylax, Satelec Acteon) with a power setting of 10 was used for the preparation of the precrack notch. The precrack notch was made at the interface of the bracket and the enamel surface at the gingival line angles of the Inspire brackets (Fig. 1A) and on the mesial sides of the Clarity brackets (Fig. 1B). Each notch was carefully prepared with 10 strokes.

All brackets were removed with the pliers recommended by the manufacturers. The pliers used for debonding Inspire ceramic bracket were plastic pliers. However, Howe pliers were applied for Clarity bracket debonding. For measuring the debonding force, a universal test machine (Instron I, Kerr, Orange, CA) as close to the bracket as possible for 10 seconds

Table 1  The ceramic brackets used in this study and their characteristics.

<table>
<thead>
<tr>
<th>Material</th>
<th>Type of bond</th>
<th>Type of wing</th>
<th>Color</th>
<th>Base area (mm²)</th>
<th>Recommended instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M Unitek</td>
<td>Mechanical</td>
<td>Twin</td>
<td>Opaque</td>
<td>11.83</td>
<td>Howe or Weingart hand instrument</td>
</tr>
<tr>
<td>Ormco</td>
<td>Mechanical</td>
<td>Twin</td>
<td>Clear</td>
<td>11.67</td>
<td>A specifically designed plastic</td>
</tr>
<tr>
<td>Inspire</td>
<td>Mechanical</td>
<td>Twin</td>
<td>Opaque</td>
<td>11.83</td>
<td>Howe or Weingart hand instrument</td>
</tr>
<tr>
<td>Clarity</td>
<td>Mechanical</td>
<td>Twin</td>
<td>Clear</td>
<td>11.67</td>
<td>A specifically designed plastic</td>
</tr>
</tbody>
</table>

Conclusion: The ultrasonic precrack preparation can significantly decrease the debonding force and may guide the bracket debonding through a favorable fracture plane without damage to either the bracket or the enamel.

"Copyright © 2013, Elsevier Taiwan LLC & Formosan Medical Association. All rights reserved."
adhesive fracture at the ceramic–resin interface; and Type V, adhesive fracture at the resin–enamel interface. The degree of bracket damage was recorded using the bracket breakage score modified by Sinha and Nanda in 1997.11 The score range was from 0 to 6 and described as follows: 0, no bracket fracture; 1, one wing of bracket fracture; 2, two wings of bracket fracture; 3, three wings of bracket fracture; 4, bracket total fracture; 5, base of bracket fracture; and 6, fracture in other parts of a bracket.

The amount of residual adhesive on the enamel surface after bracket removal was evaluated with a digital image analysis system (Leica Quantinet 500 MC Plus Image Analysis System; Cambridge Ltd, Cambridge, England), and the percentage of residual adhesive was calculated. The record of the adhesive remaining after bracket removal was assessed using a modified adhesive remnant index.12 The range of scores were from 0 to 5 and described as follows: 0, no adhesive remained on the tooth surface; 1, <25% of the adhesive remained on the tooth surface; 2, >25% but <50% of the adhesive remained on the tooth surface; 3, >50% but <75% of the adhesive remained on the tooth surface; 4, >75% of the adhesive remained on the tooth surface; and 5, all adhesive remained on the tooth surface. The adhesion between the bracket and enamel surface after precrack preparation and the enamel surface after bracket removal were examined by scanning electron microscopy (SEM; S-2400; Hitachi, Tokyo, Japan).

The descriptive statistics were calculated, and the Student t test and Fisher’s exact test were used for comparison between the two groups with a significance level of p < 0.05 by SPSS version 11.0 (SPSS Inc., Chicago, IL, USA).

Results

The average debonding force was 25.7 ± 12.0 N for the Inspire group and 16.7 ± 4.2 N for the precrack Inspire group, with a significant difference between the two groups (p < 0.05). Moreover, the mean debonding force was 76.9 ± 23.5 N for the Clarity group and 39.0 ± 12.6 N for the precrack Clarity group; a significant difference was also found between the two groups (p < 0.05; Fig. 2).

Fig. 3 shows the failure modes of four tested groups.10 The percentage of Type I failure mode (the ceramic bracket fracture) was significantly higher in the Inspire group (75%) than in the precrack Inspire group (20%, p < 0.05); it also significantly decreased from 25% in the Clarity group to none in the precrack Clarity group (p < 0.05). There was no Type III failure mode (cohesive enamel fracture) in all brackets after the bracket removal. However, the incidence of Type IV failure mode (adhesive resin fracture at the ceramic–resin interface) was the highest in all four groups. The frequencies of Type V failure mode (adhesive resin fracture at the resin–enamel interface) were higher in the two groups without precrack preparation than in the other two groups with precrack preparation.

Table 2 presents the distribution of the bracket breakage score in four experimental groups.11 The average bracket breakage score was significantly higher in the Inspire group (3.8 ± 2.2) than in the precrack Inspire group (1.0 ± 2.1, p < 0.001). In addition, the mean bracket breakage score decreased significantly from 0.7 ± 1.5 in the precrack Clarity group to 0.0 ± 0.0 in the precrack Clarity group (p < 0.05).
Clarity group to zero in the precrack Clarity group (p < 0.05; Table 2).

The adhesive remnant index scores in four experimental groups are listed in Table 3. The average adhesive remnant index score was 4.7 ± 0.5 for the Inspire group and 4.9 ± 0.4 for the precrack Inspire group, with no significant difference between the two groups. Furthermore, the mean adhesive remnant index score was 4.9 ± 0.4 for the Clarity group and 5.0 ± 0.2 for the precrack Clarity group; there was also no significant difference between the two groups (Table 3).

During the precrack preparation procedure, a crack was prepared at the adhesive layer between the ceramic bracket and enamel surface with an ultrasonic instrument (Fig. 4A). A notch was created after ultrasonic precrack preparation (Fig. 4B). The SEM micrograph revealed that the adhesive resin was partially removed by the ultrasonic tip (Fig. 4C). The notch was not as sharp as a crack and was located at the adhesive resin shown by the high-magnification SEM micrograph (Fig. 4D). The crack preparation was initiated at the adhesive resin layer and propagated along the bracket–resin interface as shown by the SEM micrograph (Fig. 5). The precrack Inspire group showed some imprints and dislodgment of ball-base (Fig. 5A). The precrack Clarity group showed that the crack propagated toward the interface of the ceramic bracket base and the adhesive resin (Fig. 5B).

**Discussion**

Because of the different removal directions recommended by the manufacturers, the precracks were prepared on different adhesion locations of the Inspire and the Clarity ceramic brackets. The precrack preparation significantly decreased the debonding force in both kinds of ceramic brackets in this study (Fig. 2). The ultrasonic preparation created a notch at the adhesive layer, and the propagation of the notch facilitated the bracket debonding and decreased the debonding force. In general, the debonding force for the Inspire bracket was lower than that for the Clarity bracket with or without precrack preparation. The difference in the debonding force was probably due to the different bracket designs. The ball-base design of the Inspire bracket can reduce the mechanical bond between the adhesive resin and the bracket.

The incidence of Type I failure mode was lower in both kinds of ceramic brackets with precrack preparation than in brackets without precrack preparation (Fig. 3). This indicates that the precrack preparation can facilitate bracket removal without causing bracket breakage. However, the incidence of Type V failure mode was not obvious in the two groups with precrack preparation. This implies that precrack preparation may not successfully lead the fracture propagation along the resin–enamel interface. The fracture plane was largely determined by the position and depth of the crack made by the ultrasonic tip. In this study, the precrack was prepared at the adhesive resin (Fig. 4), and the propagation of the crack was along the bracket–resin interface (Fig. 5), indicating that the bonding between the bracket and the resin is weak and easy to break. If we could design a tip with one sharp edge toward the resin and a blunt edge toward the enamel, this might successfully debond the ceramic bracket and reduce the risk of enamel damage. Enhancing the bonding strength between the bracket and resin is another way that may lead to the propagation of the crack along the resin–enamel interface during the bracket debonding process.

Besides the Type I failure mode, bracket failure can be indicated by the bracket breakage score (Table 2). According to our findings, the incidence of bracket breakage score of zero (no bracket failure) was higher in both kinds of ceramic brackets with precrack preparation than in the brackets without precrack preparation. This means that precrack preparation can totally (for Clarity brackets) or partially (for Inspire brackets) prevent bracket damage. In the two precrack groups, because the lower debonding force was used to remove the brackets, the incidence of bracket breakage could be thus reduced.

Different failure modes may ensue after debonding the bracket from the enamel surface. The adhesive remnant index score can be used to analyze the composition of the failure modes. This study found that all adhesive remnant index scores were either 4 (>75% of the adhesive remained on the tooth) or 5 (all adhesive remained on the tooth) in all four experimental groups. These results suggest that during the
bracket debonding fractures occur predominantly at the resin—bracket interface, and further indicate that the bonding force between the adhesive resin and the ceramic bracket is weaker than that between the adhesive resin and the enamel.

The ultrasonic removal of ceramic bracket was studied in the 1990s. Bishara and Trulove\(^6\) found that the bracket fracture ratio can be reduced from 35% to 0% when an ultrasonic device was used to remove the brackets. Because using an ultrasonic device to remove a bracket can be time-consuming and uncomfortable to the patients, its clinical application is not generally accepted by clinicians. In this study, we used a very fine diamond ultrasonic tip for the preparation of a small crack on the adhesive resin. This precrack preparation took only a few seconds but allowed

---

**Figure 4**  (A) The precrack (arrow) was prepared at the gingival line angle of an Inspire bracket by an ultrasonic instrument. (B) A notch (arrow) was observed at the adhesive resin after the precrack preparation. (C) The SEM micrograph revealed that the adhesive resin was partially removed (arrow) by the ultrasonic tip. (D) At higher magnification, the notch (arrow) was not as sharp as a crack, and is located at the adhesive layer. EN = enamel; IN = Inspire bracket.

---

**Figure 5**  SEM micrographs demonstrating the crack initiation at the adhesive resin layer and propagation along the bracket—resin interface. (A) Precrack Inspire group, after bracket removal, the precrack preparation (arrow) toward the adhesive resin and some imprints and dislodgment of ball-base were found on the enamel surface (EN). (B) The precrack Clarity group showed that the crack (arrow) propagated toward the interface of adhesive resin and Clarity ceramic bracket base (\(^a\)). \(^b\)Remnants of the adhesive resin with imprints of the Clarity bracket base. \(^a\)Remnants of the adhesive resin with some imprints and dislodgement of ball-base of the Inspire bracket. SEM = scanning electron microscopy.
Ceramic bracket removal with precrack preparation

us to use a significantly lower debonding force to remove the bracket. In addition, it also guided the bracket debonding through a favorable fracture plane without damage to either the enamel or the bracket.

The design of the ultrasonic tip is an important issue, and the manufacture of the ultrasonic tip can be customized for specific uses. The ultrasonic tip used in this study is originally made for the retrograde root canal preparation after root end resection. Therefore, the characteristics of the tip such as shape, size, and coating material are specifically designed for the retrograde root canal preparation but not for the preparation of a crack on the adhesive resin. According to this study, an ultrasonic tip specifically designed for making a crack on the adhesive resin to guide the subsequent bracket debonding is necessary. The quality and the efficiency of the bracket debonding procedure could be improved by the help of an ultrasonic device equipped with a suitable tip. In conclusion, the ultrasonic precrack preparation can significantly decrease the debonding force and may guide the bracket debonding through a favorable fracture plane without damage to either the enamel or the bracket.

References