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Comparison of the Direction of Enamel Microcracks in Five Different Debonding Methods: An in Vitro Study

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Abstract

Background: Debonding of orthodontic metal bracket is a routine part of fixed orthodontic treatment. The purpose of this in vitro study was to evaluate the direction of enamel cracks before and after debonding the metal orthodontic brackets in five different techniques.
Methods: Two hundred extracted human premolars were randomly divided into five groups in this in vitro study. Metal brackets were bonded with Transbond XT (3 M Unitek, Monrovia, CA, USA) light-cured adhesive. Then the brackets were removed with one of these methods: ultrasonic scaler, ligature cutter plier, bracket removal plier, how plier, crown remover. Direction of the enamel cracks were examined by stereomicroscope and compared. Statistical analysis was done with Paired *t*-test and Chi-squared test. $P < 0.05$ was considered as significant.
Results: After debonding, mixed type had the highest frequency (80.9 %) and no specimens were observed with horizontal crack. There was no significant change in the pattern of directions in before-after comparison (p=0.007. Mixed pattern was less common in ultrasonic group compared to crown remover and ligature cutter groups (p=0.007 and 0.035 respectively).
Conclusion: All of the five debonding methods in the current study had no significant change on the microcrack patterns and there were no horizontal cracks after debonding. Ultrasonic device had the least number of mixed cracks after debonding.

Keywords: Debonding, Direction of microcrack, Enamel, Metal brackets, Orthodontics

1. Introduction

The introduction of bonding to orthodontics had a dramatic effect on the profession. Bonding attachments has many advantages like aesthetic improvement, detailed tooth movement, higher quality of life, ease of use and less periodontal impairment (1, 2). Improvement of oral hygiene due to easier access to interproximal area, less coverage of tooth structures and discoloration are the other advantages (3-5)

Bonding of brackets and other orthodontic attachments is one of the most important stages of the whole treatment process. Most bond failures are a consequence of inconsistencies in the bonding technique, bonding resins quality, inadequate bond strengths, or the quality of the brackets being used. (6, 7)

The retention of metal brackets relies on mechanical retention and a mesh structure is the most common method of providing this (8). Debonding may be encountered amid the treatment (inadvertent bond failure by patient or bracket repositioning by clinician) or at the end of the treatment in removal of the appliance.

In debonding process the clinician must remove the bracket and composite resin without or with the least amount of damage to enamel and underlying structures. (9) Therefore choosing of correct debonding technique is of importance. Debonding may

be unnecessarily time consuming and damaging to the enamel if carelessly performed or performed with an improper technique. Another possible implication which necessitate pretreatment examination of the teeth for crack evaluation is to find and detect enamel microcracks. Without such examination the patient may blame the orthodontic treatment for creation of these microcracks. (10)

Several factors, including the type of the bracket and adhesive resin, instruments used for debonding and prophylaxis dictates the amount of enamel actually removed, but the final surface topography is not influenced by different clean-up methods.(11)

In the long term, Enamel cracks might lead to tooth fracture, demineralization and caries development or esthetic problems. (12).

Bond failure may take place within the composite, between bracket and adhesive or between adhesive and enamel (13). Zarrinia et al. and Oliver recommended that the earlier type is harmful for the enamel (9, 10). There are few reports in the literature that examined direction of enamel cracks after debonding of the metal brackets. The aim of this study was to evaluate and compare the effects of five method of bracket debonding on direction of enamel microcracks before and after debonding the metal orthodontic brackets.

2. Methods

Preparation of the samples

This in vitro study was performed on the human premolar teeth which were extracted for orthodontic purposes. Two hundred recently extracted teeth which met our inclusion criteria were selected. The inclusion criteria were intact buccal enamel surface, no previous caries, no previous restorations and no enamel lesions or hypoplasia.

The specimens were rinsed with copious water then maintained in 0.1% thyme for seven days at room temperature. This prevents the samples from bacterial habitation and growth. Then, the teeth were stored in distilled water at 4°C. The sample were not stored more than three months and the water was replaced every week. (14) Selected teeth were randomly divided into five groups each containing forty premolars (N=40). The root of the teeth were embedded in self-cured acrylic resin up to cementoenamel junction and the clinician can handle and control the specimens easily.

Enamel surface of the teeth were cleaned using a fluoride-free pumice and water at low speed before bonding of the brackets, then the enamel surface was rinsed with water spray and dried with an oil-free air compressor for 10 seconds. (15) Enamel surface was etched with 37% phosphoric acid gel (3M/Unitek, Monrovia, CA, USA) for 20 seconds, rinsed for 15 seconds and dried with air spray to obtain a chalky appearance. Transbond XT primer (3 M Unitek, Monrovia, CA, USA) was applied to the enamel surface. Light-cured adhesive Transbond XT (3 M Unitek, Monrovia, CA, USA) then was added on the bracket base (Gemini, 3M/Unitek, Monrovia, USA) and placed on the standard location on the buccal surface and the excess resin was removed. The composite was light-cured using a conventional QTH curing light (Litex 680A, Dentamerica Inc, California, and USA) for 40 seconds, ten seconds from each side (distal, mesial, gingival and occlusal). (15)

Debonding process

After bonding the bonded attachments were removed through one of these five methods:

Group I: ultrasonic device. In this group, we used an ultrasonic scaler (UDS-k,Woodpecker, Guilin, China) for bracket removal .G1 scaler tip was placed on the bracket base and water cooling was on and the power set up was at 6. The clinician did not exerted lateral hand force.

Group II: How pliers. In this group, we used How plier (Dentaurum, Ispringen, Germany) for debonding of the brackets by placing the blades on the wings and applying a squeezing force in a mesio-distal direction.

Group III: Bracket removal pliers. In this group, we used a bracket removal plier (Dentaurum, Ispringen, Germany) to debond the brackets. Peeling force was exerted by placing the blades under the gingival and occlusal tie-wings. The peeling force was applied in an occlusion-gingival direction.

Group IV: Crown remover. In this group, we used a crown remover (Perfection plus, Southhampton, UK) for removal of the brackets by placing the blade of the crown remover at the bracket base with a peeling force in occluso-gingival direction.

Group V: Ligature cutter. In this group, we removed the brackets with a ligature cutter plier (Dentaurum, Ispringen, Germany). The blades was placed under the occlusal and gingival tie-wings with a mesio-distal peeling force. Removal of the brackets in all groups was done with the same clinician.

Direction of the microcracks:

Before bonding, the direction of enamel cracks were assessed for all 200 samples were evaluated under an optical stereomicroscope SMZ800 (Nikon, Tokyo, Japan) at ×40 magnification. As Figure 1 shows the microscope is connected to a digital camera DS-V1 (Nikon, Japan, Tokyo) which has the ability of linear measurements for evaluation of the enamel microcracks [figure 2]. The distance from the buccal surface to the lens was the same for all of the measurements. (14) The directions of the enamel cracks were classified as: Vertical, Oblique, Horizontal and Mixed.

Sample size calculation

The sample size was calculated based on previous research (28). Sample size determination was performed using G. power 3.1 software. A total of 200 samples (40 in each group) were required for power of 80% at the 0.05 level of statistical significance.

Statistical analysis

The comparison of direction of the cracks before and after debonding was done using Paired *t*-test. We used Chi-squared test to compare before-after differences between the groups. All_Statistical analysis was done with SPSS (version 25.0, Chicago, IL) and $P < 0.05$ was considered significant.

Figure 1. Stereomicscope connected to the digital camera

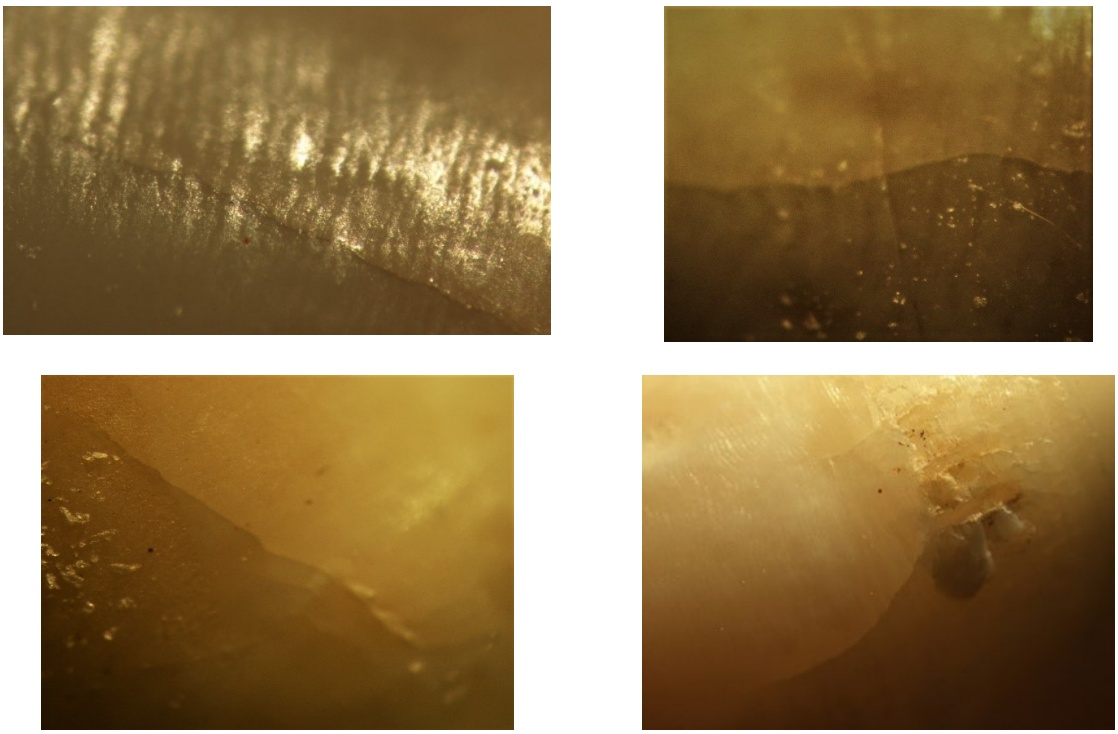

Figure 2. Direction of the crack at 40x magnification. Oblique (a), horizontal (b), vertical (c), mixed (d)

3. Results

The direction of enamel cracks before and after debonding in the groups has been shown in table I. Before bonding, the highest frequency for cracks direction was mixed type (62.6%) and the lowest frequency for cracks direction was Horizontal type (0.6%). 14.4% of the cracks were vertically and 22.4 % were oblique. There was no statistically significant difference between the directions of cracks before bonding in different groups.

After debonding, the highest frequency for cracks direction was mixed type (80.9 %) and the lowest frequency for cracks was horizontal type (0%). 12.9% and 6.2% of the cracks were oblique and vertical respectively. There was a statistically significant difference between the directions of cracks after debonding in different groups (p=0.007). Ultrasonic group showed significantly lower mixed cracks compared to ligature cutter and crown remover groups (p=0.007 and 0.035 respectively)

There was no statistically significant difference between the directions of cracks of teeth with no crack before bonding and after debonding between the different groups.

Table 1. Directions of enamel cracks before and after debonding

	Type of crack	Ultrasonic	How Plier	Ligature Cutter	Bracket Removal	Crown remover	Total	P-value
Before	Mix	19(47.5)	24(60)	25(62.5)	20(50)	21(52.5)	109(54.5)	0.671
	Vertical	6(15)	7(17.5)	4(10)	3(7.5)	5(12.5)	25(12.5)	
	Oblique	9(22.5)	5(12.5)	6(15)	10(25)	9(22.5)	39(19.5)	
	Horizontal	0	0	0	0	1(2.5)	1(0.5)	
	No cracks	6(15)	4(10)	5(12.5)	7(17.5)	4(10)	26(13)	
After	Mix	26(65)	35(87.5)	33(82.5)	26(65)	37(92.5)	157(78.5)	0.007
	Vertical	3(7.5)	2(5)	0	5(12.5)	2(5)	12(6)	
	Oblique	10(25)	1(2.5)	6(15)	7(17.5)	1(2.5)	25(12.5)	
	Horizontal	0	0	0	0	0	0	
	No cracks	1(2.5)	2(5)	1(2.5)	2(5)	0	6(3)	
P-value		0.089	0.124	0.058	0.075	0.068	0.053	

4. Discussion

The main goal of the orthodontic treatment in general is to improve dentofacial aesthetics. (16) Removal of the bracket, which creates a clean surface of the enamel, increases the risk of the enamel damage during debonding. (17) Therefore, removing the brackets from the tooth is as important as its placement. This way, the use of instruments and preservative techniques assumes great importance. (18)

There are various techniques such as transillumination, ultrasound,optical coherence tomography (OCT), scanning electron microscopy (SEM), stereomicroscopy, confocal optical profilometry (COP), three dimensional (3D) scanning methods that can be employed to evaluation of enamel microcracks (line measurements of enamel cracks such as length, number and direction of cracks or depth of enamel crack and volumetric enamel loss). Advantage of using the stereomicroscope consist of non-destructive technique, direct evaluation of enamel cracks and no necessity for specific sample preparation. Common disadvantages of other method include the following: requirements for sample preparation and indirect measurement. (19)

In this study, we compared direction of propagation of the enamel cracks before and after debonding orthodontic brackets between How plier, bracket removal plier, ligature cutter plier, Crown remover and ultrasonic scaler.

We found that ultrasonic appliance had lower mixed pattern after bracket removal compared to ligature cutter and crown remover groups. This may be attributed to the gentle force of the ultrasonic device .furthermore vibration entity of ultrasonic force prevents from concentration of the stress on a certain point and crack propagation.

There are several factors influencing enamel fractures such as fluoride content, composition of enamel surface and age .therefore we used extracted teeth from younger patients in order to reduce the chance of enamel cracks and fractures(20).

Bonding system Transbond XT (3M Unitek) was chosen due to its great physical properties and wide clinical use, demonstrating satisfactory longitudinal results. (7, 21) Bracket debonding was performed 24 hours after bonding, when the resin bonding systems achieve their maximum strength, with no statistically significant difference after longer periods. (6)

There was no significant in before-after comparison and no horizontal crack was seen after debonding. This shows that all five techniques can be used safely. Similarly to the reports of Heravi et al, (22) the directions of the

enamel cracks changed during debonding. In contrast to Zachrisson (23) who reported that the majority of the enamel cracks were vertically before bracket placement, we found that only about a 15% of the enamel cracks were vertical and the majority of the cracks were mixed. This controversy can be due to the fact that debonding method and cracks evaluation technique (optical stereomicroscope versus fiber optic light) was different in the studies. We found that after debonding the directions of more than 80% of the enamel cracks were mixed. Thus, during debonding a crack may extend in a new direction.

In contrast to the findings of the present study, Yeon et al (24), concluded that all kinds of cracks were significantly increased, especially increase rate of oblique crack reached 54.9%. In our study only mixed cracks were increased (80.9%) while oblique cracks were decreased (12.9%). The increase in mixed pattern and concurrent decrease in oblique cracks means that some of oblique cracks has been changed to mixed pattern.

Zachrisson (23) reported that detection of cracks in a predominantly horizontal direction, is an indication that the bonding and/or debonding technique used may need improvement. In our study, there were no horizontal cracks after debonding. The results showed that all of the five debonding method in current study, caused the least damage to enamel.

It is cleared that in the oral environment teeth are exposed to various factors such as forces of mastication, saliva, acid, the stresses exerted by the archwires, and patient abuse. (25) Hajrassie et al, showed that in-vitro debonding force were significantly higher than in-vivo debonding force. This indicated that in-vivo bond strengths and frequency of new enamel cracks are lower than those recorded in-vitro. (26)

Knosel et al and Khan et al, do recommend the crown remover for debonding the brackets because they cause less damage to the enamel. While in our study, the lowest and highest number of mixed cracks after debonding was seen in ultrasonic and crown remover, respectively. (27-28)

After debonding the metal bracket, residual adhesive could be removed with minimal damage to the enamel by the careful use of a tungsten carbide bur, followed by finishing procedures, but adequate clean-up without enamel loss is difficult to achieve. Several factors, including the instruments used for prophylaxis and debonding and the type of adhesive resin used, dictates the amount of enamel actually removed, but the final surface topography is not influenced by different clean-up methods. (29-30)

The concept of ideal debonding consists of failure in the bracket-adhesive interface, with adhesive remaining on enamel surface to be cautiously removed with adequate instruments, resulting in less enamel loss. On the other hand, If no adhesive remained on the enamel surface after bracket removal (ARI=0) bond failure occurred at the adhesive-enamel interface, entailing greater damage risks for the tooth enamel (11).

Limitations and suggestions

The present study just like other in vitro studies has the inherent limitation of no mimicking oral environment exactly. Furthermore the authors recommend the measurement and comparison of the depth of enamel microcracks following bracket removal process. We declares that one of the limitation of the present study was ignoring the remaining adhesive and the pattern of bond failure. The authors recommend considering ARI in future studies.

Conclusion

All of the present debonding techniques do not produce horizontal cracks. Debonding procedure increase the presence of mixed pattern of enamel crack.

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