Original Article

How is the Enamel Affected by Different Orthodontic Bonding Agents and Polishing Techniques?

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Abstract
Objectives: The objective of this study was to assess the effect of new bonding techniques on enamel surface.
Materials and Methods: Sixty upper central incisors were randomly divided into two equal groups. In the first group, metal brackets were bonded using Transbond XT and in the second group, the same brackets were bonded with Maxcem Elite. The shear bond strength (SBS) of both agents to enamel was measured and the number and length of enamel cracks before bonding, after debonding and after polishing were compared. The number of visible cracks and the adhesive remnant index (ARI) scores in each group were also determined.
Results: There were significantly more enamel cracks in the Transbond XT group after debonding and polishing compared to the Maxcem Elite group. There was no significant difference in the length of enamel cracks between the two groups; but, in each group, a significant increase in the length of enamel cracks was noticeable after debonding. Polishing did not cause any statistically significant change in crack length. The SBS of Maxcem Elite was significantly lower than that of Transbond XT (95% confidence interval).
Conclusion: Maxcem Elite offers clinically acceptable bond strength and can thus be used as a routine adhesive for orthodontic purposes since it is less likely to damage the enamel.
Keywords: Maxcem; Dental Enamel; Dental Bonding; Dental Polishing
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INTRODUCTION

Many studies have shown that bracket debonding can cause enamel loss, particularly when the fracture occurs at the enamel-adhesive interface. Enamel damage may be in the form of enamel cracks, which may propagate during debonding [1-3]. These cracks can jeopardize the integrity of enamel and cause esthetic problems for patients [4]. Acid-etching, rinsing, drying and applying resin and bonding agents are the routine steps of conventional orthodontic bracket bonding. Concurrent with studies on the efficacy of the conventional technique, many studies, aimed at reducing the number of steps necessary for adhesion, have examined new bonding techniques with clinically adequate bond strength but shallower etching depth [5,6].

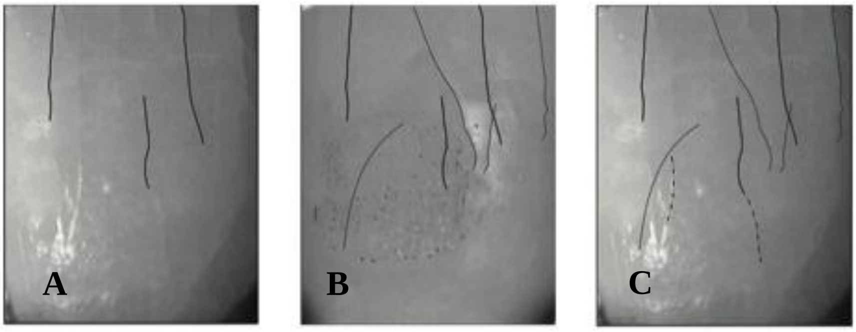

Fig. 1. Enamel cracks before bracket bonding (A), after deboning (B) and after polishing (C). Note the new cracks.

Traditional methods of bonding orthodontic brackets to teeth rely on acid etching to achieve adequate retention. However, maintaining a sound enamel surface after bracket removal is of primary concern to clinicians. Bond failure at the bracket-adhesive interface or within the adhesive is generally considered safer than a fracture at the enamel-adhesive interface; this is because studies have demonstrated that enamel fracture can occur during debonding [7]. On the other hand, if a considerable amount of adhesive remains on the tooth surface after debonding, more chair time is required to remove the residual adhesive. In addition, the process of removing the residual adhesive results in further enamel loss [8].

All-purpose or multi-purpose self-adhesive resin cements are now commercially available in the market. They are capable of bonding to different substrates such as enamel, dentin, amalgam, metal and porcelain [9,10].

These cements require no surface pretreatment due to their monomer and filler content and initiation technology. Their organic matrix consists of newly developed multifunctional phosphoric acid methacrylates. The phosphoric acid methacrylates react with basic fillers in the luting cement and the hydroxyapatite of the tooth structure [11,12].

These self-adhesive cements do not require an "etch and rinse" phase as they are capable of conditioning the tooth surface and simultaneously preparing it for adhesion. This not only shortens the clinical application time, but also significantly reduces technique-sensitivity and risk of errors during application or manipulation [13]. The aim of the current study was to assess the enamel cracks after debonding of brackets bonded with two different adhesive systems and also to evaluate enamel cracks after removing adhesive remnants and enamel polishing.

MATERIALS AND METHODS

Sixty upper central incisors, extracted due to periodontal disease, were selected and stored in normal saline at room temperature until required.

The teeth had no carious lesions or enamel defects. The study design was approved by the ethics committee of Mashhad University of Medical Sciences. Using a stereomicroscope (Blue Light Industry, Waltham, MA, USA) and digital camera (Exwave HAD, Sony Corporation, Tokyo, Japan) a magnified image (×23.9) was taken of the buccal surface of each tooth.

The number of enamel cracks and the length and direction of each crack were assessed with the aid of Adobe Photoshop CS software (Adobe Systems Incorporated, San Jose, CA, USA) (Fig. 1).

The number of visible cracks (i.e. cracks visible to the naked eye) was also recorded [14].

The teeth were then randomly divided into two equal groups.

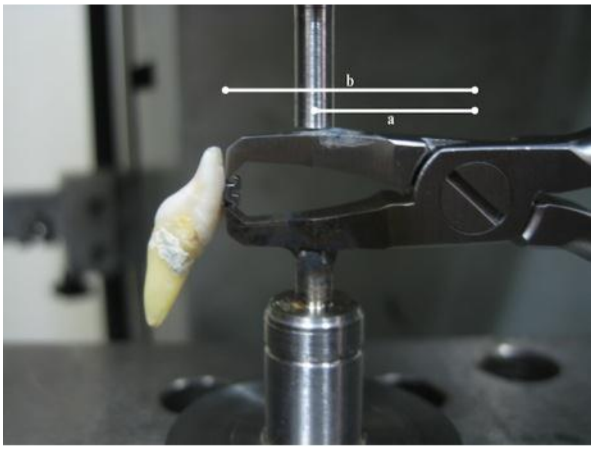

Fig. 2. Force application simulating clinical use of debonding pliers mounted on Zwick. (a) The distance from the point of force application to the fulcrum of the pliers. (b) The distance from the point of actual force application to the fulcrum of the pliers

In the first group, the buccal surface of each central incisor was conditioned with 35% phosphoric acid (Dent Zar Inc., Tarzana, CA, USA).

A standard edgewise twin metal bracket (Dentaurum, Pforzheim, Germany) was bonded with Transbond XT (3M ESPE, St. Paul, MN, USA) to the center of the labial surface of each tooth. In the second group, the same bracket was bonded with self-adhesive composite cement (Maxcem Elite, Kerr, Orange, CA, USA). In both groups, the adhesive was cured for 40 seconds (10 seconds for each side of the bracket). The teeth were then incubated in distilled water at 37°C for 24 hours to allow the material to set [3]. All the brackets were debonded with RMO i-546 remover pliers (RMO, Frankfurt, Germany). The blades of the pliers were placed at the bracket-adhesive interface and a gentle squeezing force was applied to the pliers by a Zwick Z250 testing machine (Zwick/Roell, Ulm, Germany) at a speed of 0.5 mm/min until bond failure occurred. The present method of force application was modified from a diametric compression test for tension that indirectly measures tensile strength. This approach was used because it simulates the usual clinical method of applying debonding forces [15]. The debonding force recorded by the Zwick is not equal to the actual force applied at the bracket–adhesive interface because the force was applied at a predetermined distance on the pliers' beaks. These forces, however, are proportional and can be expressed in the following ratio: The actual force (F) equals the measured force (f) multiplied by (a) divided by (b): F= f (a/b). In this ratio, (a) is the distance from the point of force application to the fulcrum of the pliers and (b) is the distance from the point of actual force application to the fulcrum of the pliers. The calculated ratio was 0.77 (Fig. 2). Deboning force was measured in Newton and was then converted to MegaPascal (MPa). Surface area under the base of bracket was 9.8mm^2. After debonding, the buccal surfaces of the teeth in each group were examined by the same stereomicroscope and the magnified images (×23.9) were taken with the same digital camera. The number of enamel cracks and the length and the direction of each crack were assessed with the aid of the same software. The number of visible cracks in each tooth was also recorded (Fig. 1).

The adhesive remnants on each tooth were then assessed using the ARI in a 0-3 scale: 0 indicates no composite left on the tooth; 1 indicates less than half of the composite left on the tooth, 2 indicates that more than half of the composite is left on the tooth surface and 3 shows that all the composite is left on the tooth surface with a distinct impression of the bracket base [16]. The buccal surface of each tooth was polished with 12-blade tungsten carbide bur (G&H Orthodontics, Franklin, IN, USA) under water coolant. We used a new bur for each tooth. The enamel surface was examined for the third time in the same way (Fig. 1). All procedures were carried out by the same operator. The amount of shear bond strength in each group was compared with independent t-test. The enamel cracks in each group were compared before bonding, after debonding and after polishing using repeated measures ANOVA. Independent t-test was used for inter-group comparisons. Mann-Whitney U test was applied for comparing ARI between the two groups and Friedman and its post hoc test for within-group comparisons.

RESULTS

Debonding forces

The result of the independent t-test indicated that the mean shear bond strength of Maxcem Elite (the self-adhesive composite cement) was significantly lower than that of Transbond XT (the adhesive composite) (P<0.001). The mean SBS of Maxcem Elite and Transbond XT was 10.29±1.14 and 11.48±1.09, respectively.

Number of Cracks

There were no significant inter-group differences in the number of enamel cracks before debonding (P=0.155). However, after debonding this difference was significant (P<0.001). There were significantly more enamel cracks in the Transbond XT group after debonding and polishing compared to the Maxcem Elite group (P<0.001). In the Maxcem Elite group, the difference in the number of enamel cracks before and after debonding was statistically significant (P<0.001).

The difference, however, was not significant after debonding and after polishing (P=0.06). The Transbond XT group showed the same results (Tables 1 and 2). The number of visible enamel cracks followed a similar pattern. In each group, before and after debonding, a significant intra–group difference was seen (P<0.001).

Length of cracks

There was no significant difference in the length of enamel cracks between the two groups (P=0.813). In each group, however, a significant increase in the length of enamel cracks was obvious after debonding. After polishing, the difference was not statistically significant (Table 3) (P=0.801).

ARI

The Mann-Whitney-U test showed that the differences were statistically significant among the groups (P=0.001) (Table 4).

DISCUSSION

The main objective of this study was to evaluate the enamel cracks after debonding brackets, bonded with two different bonding systems followed by polishing. The SBS of Maxcem Elite, a self-adhesive cement, and Transbond XT, a conventional adhesive composite, was also compared. The number and length of enamel cracks before bonding, after debonding and after polishing were also compared as well as the ARI following the removal of orthodontic brackets. Before bonding, no significant differences were seen in the number of enamel cracks. After debonding, however, the number of cracks significantly increased in both groups. Zachrisson and Arthun [17] showed that debonding of brackets created enamel cracks, which were different in size and direction.

Table 1. Number of enamel cracks before bonding, after debonding and after polishing.

	Before bonding Mean ± SD	After debonding Mean ± SD	After polishing Mean ± SD	Within group P †
Maxcem Elite	2.17 ± 0.83 [a]	6.07 ± 0.87 [b]	6.37 ± 1.03 [b]	<0.001*
Transbond XT	2.53 ± 1.01 [a]	7.62 ± 1.07 [b]	7.70 ± 1.18 [b]	<0.001*
Between groups P value	0.155**	<0.001**	<0.001**	

†: Friedman test
**: Mann Whitney test
SD: Standard deviation
*: Significant difference
Significant difference between a and b (Wilcoxon test)

Table 2. Number of visible cracks before bonding, after debonding and after polishing

	Before bonding Mean ± SD	After debonding Mean ± SD	After polishing Mean ± SD	Within group P †
Maxcem Elite	0.73 ± 0.64 [a]	1.87 ± 0.68 [b]	2.03 ± 0.61[b]	<0.001*
Transbond XT	0.90 ± 0.76 [a]	2.27 ± 0.69 [b]	2.50 ± 0.68 [b]	<0.001*
Between groups P value	0.435**	0.028**	0.007**	

†: Friedman test
**: Mann Whitney test
SD: Standard deviation
*: Significant difference
Significant difference between a and b (Wilcoxon test)

Table 3. Length of enamel cracks before debonding, after debonding and after polishing.

	Before bonding Mean ± SD	After debonding Mean ± SD	After polishing Mean ± SD	Within group P †
Maxcem elite	5.20 ± 1.52 [a]	9.23 ± 1.41 [b]	9.59 ± 1.68 [b]	<0.001*
Transbond XT	5.60 ± 1.48 [a]	9.33 ± 1.83 [b]	9.70 ± 1.76 [b]	<0.001*
Between groups P value	0.305**	0.813**	0.801**	

†: Repeated measures test
**: Independent t- test
SD: Standard deviation
*: Significant difference
Significant difference between a and b (Wilcoxon test)

Table 4. The Adhesive Remnant Index (ARI)

ARI	**Transbond XT**	**Maxcem Elite**
	N (%)	**N (%)**
0	0	0
1	2 (6.7)	16 (53.3)
2	8 (26.7)	10 (33.3)
3	20 (66.7)	4 (13.3)
Total	30 (100)	30 (100)

0, No composite left on the tooth; *1*, Less than half of the composite left on the tooth; *2*, More than half of the composite left on the tooth; *3*, All the composite left on the tooth with a distinct impression of the bracket base

Heravi et al. [14] reported a significant increase in the number and length of enamel cracks after debonding with different pliers.
Bishara et al. [15] stated that 82% of the teeth studied did not show significant increase in the number of enamel cracks after debonding and the teeth showing increased number of cracks had significantly greater mean bond strength. After polishing, the number and length of enamel cracks increased in all groups, although there were no differences among the groups. According to Zarrinnia et al, [18] debonding pliers cause resin fracture at the adhesive-bracket interface, and using a tungsten carbide bur accompanied by water coolant effectively removes all adhesive remnants.
Gwinnett and Gorelick [19] evaluated enamel morphology after six different polishing procedures. MonoLok™ 2 was used as the bonding system. They showed that the smoothest surface was obtained with the gloss polishing paste.
A direct correlation between ARI and bond strength was shown. The current study found significant differences among the ARI scores and concluded that, in the Transbond XT group, debonding was mostly of cohesive type, in contrast to the adhesive mode in the Maxcem Elite group.
Radovic et al. [20] reported that self-adhesive cements had satisfactory bond strength to dentin and restorative materials, but their bond strength to enamel was weak. Vicente et al. [21] showed that Rely X Unicem (a self-adhesive resin cement) possessed significantly lower bond strength than Transbond XT. Rely X Unicem also left significantly less adhesive remnant compared to Transbond XT.
Bishara et al. [22] reported low bond strength for Rely X Unicem and suggested that the SBS of this self-adhesive universal cement needs to be increased for its successful use for bonding orthodontic brackets.
Faltermeier et al. [23] showed that one-component adhesives (Rely X Unicem and Maxcem) had significantly lower SBS than two- or three-component adhesives. Bishara et al. [22] reported that Maxcem had significantly lower bond strength than Transbond XT. In the current study, Maxcem Elite (a new self-adhesive system) was employed. The mean bond strength in the Transbond XT group was significantly greater than that in the Maxcem Elite group, although the SBS of the latter was 10.29±1.14 MPa, which is clinically acceptable [24].

CONCLUSION

1. Debonding brackets bonded with Maxcem Elite resulted in less enamel cracks.
2. Removing adhesive remnants and polishing with a 12-blade tungsten carbide bur did not increase enamel cracks.
3. Maxcem Elite provides clinically acceptable bond strength and can be used as a routine adhesive for orthodontic purposes.

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