ORIGINAL ARTICLE

Three-dimensional quantification of adhesive remnants on teeth after debonding

Yong-Keun Lee[a] and Yong-Kyu Lim[b]
Seoul, Korea

Introduction: The objective of this study was to determine 3 dimensionally the amount of adhesive remaining on teeth after debonding orthodontic brackets. **Methods:** Three kinds of adhesives were investigated. Metal brackets were bonded to 45 extracted premolars (15 for each adhesive). Labial surfaces of the teeth were scanned before bonding and after debonding. Remaining volume, maximum height, mean maximum height, and mean height of the adhesive remaining on the tooth after debonding were determined, and adhesive remnant index (ARI) scores were measured. Data were analyzed with the Kruskal-Wallis test. Regression analysis was performed between each parameter for the remaining adhesive and the ARI. **Results:** Scanned profiles of the tooth surfaces after debonding showed the remaining adhesive clearly. Volume and mean height were significantly different by the type of adhesive ($P < 0.05$). For the ARI scores, 2 resin-based adhesives showed similar trends; however, a smaller portion of the resin-modified glass ionomer adhesive remained on the teeth. Parameters for remaining adhesive and ARI scores showed significant correlations ($r = 0.332$-0.486; $P < 0.05$). **Conclusions:** Quantitative data for the remaining adhesive provides more detailed information about the debonded enamel surface. (Am J Orthod Dentofacial Orthop 2008;134:556-62)

The adhesive remnant index (ARI) is generally used to monitor the remaining adhesive on the enamel or bracket base after debonding an orthodontic bracket.[1-3] It provides a rank score, not a true numerical value. It is also a surface-area assessment, not a 3-dimensional (3D) volumetric measure.

In addition to the ARI system, stereomicroscopic[4] and scanning electron microscopic (SEM) evaluations[5-8] were used for the remaining adhesive. Direct measurement with models,[9] planer surfometer,[10] and quantitative weight and area data evaluations[3] were other measurement protocols. In a quantitative study, the amount of adhesive remnant was expressed as a percentage of the mean bracket area.[11] Optical coherence tomography was used to acquire optical cross sections of the occlusal topography nondestructively before bonding and after debonding.[12] Various protocols were applied to determine the enamel surface damage after bracket debonding, such as enamel detachment index,[6] calcium remnant index,[8] composite remnant index, and surface roughness index.[13]

Various qualitative and quantitative protocols have been developed to evaluate the remaining adhesive after debonding the bracket. However, true quantitative data, based on the comparison between the unbonded and debonded tooth surface, were not found. The null hypothesis assumed in this study was that the adhesives remaining on the enamel surfaces were the same regardless of the type of adhesive. The objective was to determine the amount of remaining adhesive quantitatively with a 3D profilometer (MTS, St Paul, Minn) by the type of orthodontic adhesives. With this instrument, the quantitative data on the volume and height of adhesive remaining on a tooth by comparing the surface before bonding the bracket and after debonding, and the qualitative data on the location of the changes in surface profile were recorded by digital mapping of the surface.

MATERIAL AND METHODS

Extracted premolars were stored in 0.01% sodium azide (batch no. 095K0119, Sigma, St Louis, Mo) solution before scanning. For scanning, the root part of each tooth was removed with a disk, and the crown part was embedded in a resin block (20 × 20 mm acrylic resin block with a 10-mm diameter hole at the center) with chemically cured acrylic resin to expose the labial surface at the upper part of the block. This embedding made a nearly flat measuring surface without depres-

[a]Professor, Department of Dental Biomaterial Science and Dental Research Institute, College of Dentistry, Seoul National University, Seoul, Korea.
[b]Professor, Department of Orthodontics, Graduate School of Clinical Dentistry, Korea University, Seoul, Korea.
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Reprint requests to: Yong-Keun Lee, Department of Dental Biomaterial Science, College of Dentistry, Seoul National University, 28 Yeongeon-dong, Jongro-gu, Seoul, Korea; e-mail, ykleedm@snu.ac.kr.
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Table I. Orthodontic adhesives investigated in this study

Code	*Brand name*	*Description*	*Batch number*	*Manufacturer*
LB	Light Bond	Small particle, glass-filled resin composite	0600624	Reliance Orthodontic Products, Itasca, Ill
TB	Transbond XT	Silane-treated quartz filler: 70%-80% Bis-GMA: 10%-20% Bisphenol A Bis (2-hydroxyethyl ether) dimethacrylate: 5%-10% Dichlorodimethylsilane reaction product with silica by weight: <2%	5RC	3M ESPE, St Paul, Minn
FO	GC Fuji ORTHO LC	Powder Alumino-silicate glass: 100% Liquid Polyacrylic acid: 20%-22% 2-hydroxyethyl methacrylate: 35%-40% Proprietary ingredient: 5%-15% 2,2,4, Trimethyl hexamethylene dicarbonate: 5%-7% Triethylene glycol dimethacrylate: 4%-6%	0510041	GC Corporation, Tokyo, Japan

sions that block the movement of the scanning probe of the profilometer.

After embedding, the labial surface of each tooth was scanned with the 3D profilometer for the area of 5 mm in the occlusogingival direction and 7 mm in the mesiodistal direction. The interval for each line scan (scan across mesiodistal direction) was 100 μm, and the number of points in each line scan was 70 at 10 μm intervals.

A metal bracket for maxillary premolars (Gemini bracket, 0.018-in twin, 7° torque, 0° angle, 3.35 mm in occlusogingival and 3.75 mm in mesiodistal directions, 3M Unitek, Monrovia, Calf) was bonded to the labial surface of a tooth based on the protocols recommended by the manufacturers of the adhesives. Details are shown in Table I. Fifteen specimens for each of the 3 adhesives were fabricated.

For the Light Bond (Reliance Orthodontic Products, Itasca, Ill) (LB) and the Transbond XT (3M ESPE, St Paul, Minn) (TB) adhesives, the enamel surfaces were cleaned with pumice and etched with 32% phosphoric acid (Uni-etch, batch no. 0400003743, Bisco, Schaumburg, Ill) for 15 seconds. The etchant was washed with water for 10 seconds and dried for 5 seconds. Then light cure adhesive primer (Transbond XT, batch no. 5CG, 3M Unitek) was applied on the etched enamel surface. LB or TB adhesive was applied on the bracket base, and the bracket was pressed firmly on the enamel surface. Excess adhesive was removed around the bracket margins with a probe. Light curing was performed for 10 seconds from the mesial and the distal sides with a halogen unit (VIP, Bisco) with an intensity setting of 600 mW/cm^2. The intensity of the unit was periodically monitored by using a hand-held dental curing light radiometer (model 100, Demetron Research, Danbury, Conn) with an accuracy of ± 2%.

For the Fuji Ortho (GC, Tokyo, Japan) (FO) adhesive, the enamel surfaces were cleaned with pumice and conditioned with GC Fuji PLUS conditioner (batch no. 0509061, GC) for 20 seconds. The etchant was washed with water and dried. Then the powder and liquid were mixed at a ratio of 1:1 and applied on the bracket base, and the bracket was pressed firmly on the enamel surface. Excess adhesive was removed around the bracket margins with a probe. Light curing was performed for 10 seconds from the mesial, distal, occlusal, and gingival sides with the same halogen unit and the same intensity setting.

Bracket bonded specimens were stored in 37°C distilled water for 24 hours. Debonding was performed with a universal testing machine (model 4465, Instron, Canton, Mass) with a crosshead speed of 1 mm per minute, and the bond strength was determined.

The debonded enamel surfaces were scanned with the same protocols as for the unbonded enamel surfaces. Based on the results from the 3D profilometer, the amount of remaining adhesive was determined.

Four parameters to quantify the remaining adhesive were measured.[14] Remaining volume (mm^3) was the total volume of the remaining adhesive on the enamel surface based on the comparison of unbonded and debonded surfaces. Maximum height (μm) was the distance from the reference (unbonded) surface to the highest point of remaining adhesive after debonding. Mean of the maximum height (μm) was the mean of the values of the height from the reference line to the highest point after debonding based on each line scan. Mean height (μm) was the mean value of the height of remaining adhesive from the reference surface based on each measuring point (50 × 70 points).

The ARI score was also calculated by using the criteria of Årtun and Bergland,[1] in which the scores

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