Original Article

Assessment of the Confidence of the Adhesive Remnant Index Score With Different Methods

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ABSTRACT

Objective: The purpose of this *in vitro* study was to investigate the reliability of the adhesive remnant index (ARI) score system with different assessment methods and to test the compatibility of the estimators.

Materials and Methods: Sixty-eight human premolars were used in this study. The premolar brackets (SmartClip, 3M Unitek, Monrovia, CA, USA) were bonded with a light cure adhesive (Transbond XT, 3M Unitek). Brackets were debonded using a Lloyd LRX testing machine (Lloyd Instruments Plc., Fareham, Hampshire, UK). Special image analysis software with ×20 magnification and naked-eye assessment methods were used to evaluate the adhesive remnant. Four different investigators scored the same samples according to a 4-point scale. The Kendall rank correlation coefficient was used to test the reliability of the estimator's scores. The Friedman test, followed by the Wilcoxon signed-ranks test, was used to investigate significant differences in the ARI scores between the different assessment methods

Results: The Kendall rank correlation coefficients revealed no significant difference between the scores assigned by the investigators in this study. However, the ARI scores were significantly different when the special image analysis program was used ($p < 0.05$).

Conclusion: The reliability of the ARI scores increased when quantitative measurement methods were used. (*Turkish J Orthod* 2013;26:149–153)

KEY WORDS: Adhesive Remnant Index, Quantitative Measurement

INTRODUCTION

The amount of residual bonding resin on the surface of the tooth or the bracket base is an important factor for clinicians in selecting an orthodontic adhesive. Although differences in adhesive remnant scores reflect the bonding strength, adhesive systems that show less residual resin are preferable because they are easier and safer to clean up after debonding procedures. As resin tags penetrate the enamel surfaces, reaching depths up to 50 μm,[1] they may exert irreversible effects on the enamel surfaces after orthodontic appliances are removed.[2] Thus, an assessment system to evaluate the adhesive remnant could be helpful for investigators. Årtun and Bergland first introduced the adhesive remnant index (ARI),[3] and most studies of bonding in orthodontics use this index.[4–6]

Many studies have changed or expanded the ARI system scores to provide more sensitive evaluation. Årtun and Bergland[3] separated the adhesive remnant criteria according to the following: 0 = the entire adhesive left on the bracket base, 1 = more than half of the adhesive left on the bracket base, 2 = less than half of the adhesive left on the bracket base, and 3 = no adhesive left on the bracket base. Other studies in the orthodontic literature have developed a 5- or 6-point scale.[7,8]

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Various qualitative and quantitative methods have been used to determine the ARI on enamel surfaces or bracket bases after bracket removal, such as scanning electron microscopy (SEM), visual inspection, photography, 3-dimensional profilometry, stereomicroscopy, and visual inspection with photography under magnification.[6,9–11] If remnants are not adequately detected, ARI scores could be inaccurate.

Therefore, the aim of this *in vitro* study was to evaluate the reliability of the ARI with different assessment methods and to investigate potential individual differences between estimators. The null hypothesis was that the ARI score would show no difference between the different assessment systems and that there would be no difference between the estimators when the 4-point ARI scales were used.

MATERIAL AND METHODS

Sixty-eight noncarious human premolars, which were extracted for orthodontic purposes from 14- to 17-year-old patients undergoing orthodontic treatment, were used in this study. Enamel structure of the teeth was examined at ×20 magnification, and teeth with surface irregularities or hypoplastic areas were excluded from the study. The extracted teeth were stored in distilled water, and the water was changed weekly to avoid bacterial accumulation. The teeth were mounted in casts, keeping the long axis of the tooth parallel to the bottom of the mold and the plastic molding cup filled with dental stone. Before the bracket bonding, all the teeth were cleaned with a flour of pumice slurry. The enamel surface was then rinsed with water and dried with compressed air. The premolar brackets (SmartClip 3M Unitek, Monrovia, CA, USA) were bonded with a light cure adhesive (Transbond XT, 3M Unitek) according to the manufacturer's instructions, and excessive adhesive was removed using a sharp scaler. Finally, the bracketed tooth was stored in distilled water at 37°C for 24 hours before the debonding test.[12,13] The samples were tested with a Lloyd LRX testing machine (Lloyd Instruments Plc, Fareham, Hampshire, UK) with a cross-head speed of 1 mm/min.

Scaled digital photographs of every bracket base were taken with a digital imaging system (Nikon Digital Sight DS-L1 Imaging system) connected to a stereo light microscope (Nikon SMZ 1500, Nikon, Tokyo, Japan). Photographs of the bases were taken from the same angle of view for each bracket, taking care to show the whole bracket base and the remaining adhesive in every image. Images were 1280 × 960 pixels with a color depth of 24 bits and were stored in joint photographic experts group (JPEG) file format.

After all the samples were tested, the brackets were debonded, and the records were collected, the images were transferred to a computer, and the digital photographs were randomly numbered. The bracket base and residual adhesive surface area were then digitized, and the number of pixels was counted automatically. The stained adhesive was measured quantitatively on color macrophotographs using a special computerized image analysis system (Fig. 1). The bracket base area covered with the residual adhesive and the total bracket base area were measured on the same digital photograph, and the percentage of the adhesive was calculated. The image analysis software automatically calculated the percentage of adhesive remnant surface area on the bracket base, and the researchers scored the ARI scale according to these records. The ARI evaluation used the 4-point scale of Årtun and Bergland (Fig. 2). After the image analysis software was used, the numbers of the samples and photographs were changed to maintain the blind nature of the design and to prevent bias. The adhesive remnant on the bracket base was then scored with the naked eye in daylight and in the photographs taken at ×20 magnification. The evaluation and scoring of the adhesive remnant were carried out by 4 researchers, and the scores were recorded.

The Kendall rank correlation coefficient was used to test the reliability of the estimators' scores in this study. The Friedman test, followed by the Wilcoxon signed-ranks test, was used to investigate significant differences in the ARI scores between the different assessment methods.

Results

The distributions of the ARI scores for the different assessment methods for each investigator are given in Table 1. The results of the Kendall rank correlation coefficients for the reliability of the estimators showed that their scores were compatible. The Kendall rank correlation coefficients were 0.736 for the naked eye, 0.829 for the ×20 magnification, and 0.863 for the image analysis program. When the scores were evaluated according to the 4-point scale, the Friedman test showed that the ARI scores were significantly different among the assessment methods (Table 2). The evaluation of the adhesive remnant with the special image analysis program showed a statistically significant difference com-



Figure 1. Measurement of percentage adhesive remnant area with digitized computerized image analysis system.

pared with the naked eye evaluation ($p \leq 0.05$). On the other hand, there was no statistically significant difference between the image program and the ×20 magnifications according to the three researchers in this study (S.A., S.Y., and A.O.).

Discussion

This *in vitro* bonding study was designed to investigate the reliability of the ARI with different assessment methods and to compare potential differences between the evaluators. Testing 24 hours after bonding is generally preferred, and 24 hours allows comparison with other *in vitro* bond strength studies.[12] Furthermore, polymerization is expected to be complete at the end of 24 hours.[13] Only a limited number of studies have addressed the reliability and reproducibility of ARI scores.[6,11] Montasser and Drummond[11] showed that there was significant difference between the ARI scores when the evaluation was done at different magnifications. In the

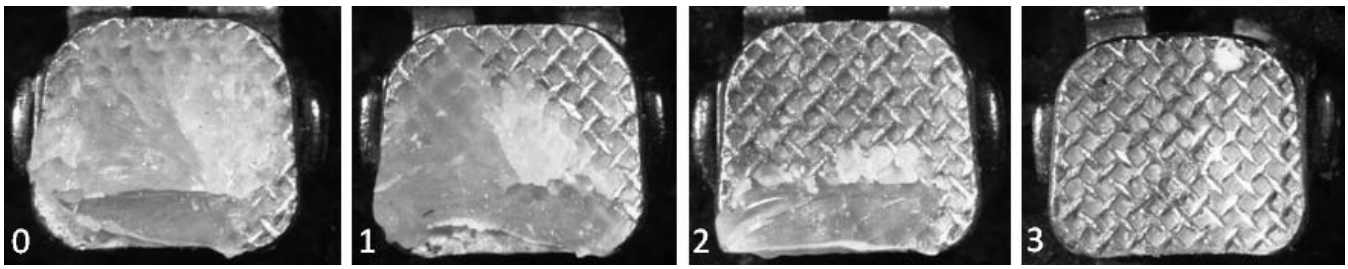


Figure 2. Adhesive remnant indexevaluation used a 4-point scale in which 0 = the entire adhesive left on the bracket base, 1 = more than half of the adhesive left on the bracket base, 2 = less than half of the adhesive left on the bracket base, and 3 = no adhesive left on the bracket base.

Table 1. Frequency of adhesive remnant index scores according to the estimators

	S.A.				N.A.				S.Y.				A.O.			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Naked eye	1	25	36	6	0	31	35	2	0	31	35	2	4	26	33	5
20× magnification	0	30	36	2	1	30	34	3	6	32	24	6	1	34	30	3
Computer	0	33	32	3	4	21	28	15	3	35	28	2	1	34	30	3

present study, use of a special computerized image analysis system resulted in significantly different ARI scores compared with those of the conventional assessment with the naked eye without any magnification. However, only one investigator (S.A.) reported a significant difference between the evaluations with the ×20 magnifications and the naked eye. The other investigators found similar results between the naked eye and the ×20 magnification assessment methods, and there was no significant difference between these two groups. It should be noted that personal bias could result in different estimators reaching different conclusions regarding the same samples. Montasser and Drummond[11] used the same evaluator, but our study included 4 different evaluators and 3 different methods. Therefore, we cannot compare our results with those of Montasser and Drummond. All the estimators in this present investigation reported compatible results, and there was no significant difference between the ARI scores of the different estimators. Therefore, the null hypothesis was rejected

When the naked-eye assessment was compared with the image program assessment, some samples with a score of 1 changed to a score of 2 or some with a score of 2 changed to a score of 1. The percentage of the adhesive remnant on these samples was about 50%. Because of the sensitivity of the naked eye, the estimators could not distinguish the ARI scores when the adhesive remnant was about 50%. All the estimators had normal vision. Therefore, the use of specialized software such as the image analysis program used in this study could be suitable for such samples.

The naked-eye evaluation is the easiest assessment method for detecting remnant adhesive. Most studies of the bonding strength of adhesives have used different evaluation techniques, for example, quantitative methods, to obtain more accurate results. However, these methods consume more time. The ARI scores for the percentage of the remnant adhesive have been calculated by software programs with standardized photographs.[14] Some studies have also examined the bracket base surfaces with SEM[15,16] as SEM images offer great possibilities for enamel or bracket-base surface investigation by providing high-quality results. Light stereomicroscopy and photomicrography have also been used to analyze ARI scores.[17,18] A past study also used weight of the bracket to quantify the residual adhesive after debonding, and weight produced statistically similar results to those based on measurements of area.[16] Arıcı et al. also used the same special computerized image analysis system to measure percentage dental plaque area and found that it was reproducible.[19]

CONCLUSIONS

On the basis of this *in vitro* study, the following conclusions can be drawn:

- Evaluation of remnant adhesive with the ARI (4-point scale) score is a reliable method according to this study, and there were no statistical differences between estimators' scores.
- Quantitative methods such as image analysis programs may be useful for assessing residual adhesive after debonding.

Table 2. Comparisons of the 3 methods using Wilcoxon tests

	Significance			
	S.A.	N.A.	S.Y.	A.O.
Naked eye, 20× magnification	.007*	.850	.072	.467
Naked eye, computer	.020*	.004*	.008*	.046*
Computer, 20× magnification	.317	.040*	.796	.484

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