An Image Analysis of Adhesive Remnant Index between Metal and Ceramic Brackets: A Clinical Study

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Abstract

The objectives of this cross-sectional study are 1) to compare the Adhesive Remnant Index (ARI) score between metal and ceramic brackets and 2) to compare the mean percentage of the adhesive remnant on the bracket base.

The data were obtained from patients who required debonding of fixed orthodontic appliances. The patients were allocated into three groups; 1) conventional metal brackets, 2) self-ligating metal brackets, and 3) self-ligating ceramic brackets. All brackets were mechanically debonded using recommended pliers. After debonding, dental disclosing solution was applied on the adhesive remnant, and ARI score was recorded based on the image analysis measurement of the photograph. All debonded brackets were evaluated under a stereomicroscope, and the percentage of the adhesive remnant on the bracket base was calculated using image analysis. The data was analysed using SPSS version 24.0 and the level of statistical significance set at $p < 0.05$.

A total of 192 brackets which comprised of 64 brackets in each group were evaluated for this study. There was statistically significant difference ($p<0.05$) between three types of brackets in the ARI assessment on the tooth surface. The result was consistent with the image analysis of the mean percentage of adhesive remnant on the bracket base. The result showed a statistically significant difference between self-ligating metal brackets and other types of brackets.

The self-ligating metal brackets had most adhesive remain on the tooth surface and had the smallest mean of percentage adhesive remnant on the bracket base.

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Introduction

Malocclusion had impacted the psychological discomfort domain in oral health quality of life.[1] The most common reason patients request for orthodontic treatment was to improve self -esteem and correct dental aesthetics. Furthermore, patients opted to choose aesthetic brackets compared to stainless steel or metal brackets. The metal bracket is known for its unaesthetic appearance.[2]The ideal criteria for brackets are good aesthetic for the patient and adequate technical performance for the clinician in each stage of an orthodontic treatment.[3] All orthodontics procedures during treatment should be performed with precautions including the bracket selection. Brackets with a mechanical retention are preferable since bond failures are more common at the bracket-adhesive interface than at adhesive-enamel interface during debonding. Therefore, it will reduce the risk of enamel damage.[4] Metal brackets with mesh bracket base design showed more adhesive on the tooth surface upon debonding.[5] Previous studies also showed more adhesive on the

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enamel after debonding of ceramic brackets with mechanical retention. This debonding characteristic has the advantage of protecting the enamel surface.[6] Several researchers have also reported the pattern of bond failure of ceramic brackets with mechanical retention that debonded mechanically. In their in-vitro studies, they found more bond failures at bracket-adhesive interface, no enamel fracture, and it is safer to remove ceramic brackets using recommended pliers.[7,8] However, there is a contradicting in-vitro finding where metal and ceramic brackets with mechanical retention of higher debonding strength compared to that of ceramic bracket with chemical retention. The site of bond failure is at the enamel-adhesive interface.[9] The risk of producing enamel cracks after debonding of metal brackets was the same as ceramic brackets with mechanical retention.[10] One orthodontic case reported enamel fracture after debonding metal brackets.[11] The authors urged to examine enamel cracks on the tooth surface prior to the bond up procedure.

The outcome of the clinical study might be different due to complex oral environment.[9] The debonding strength, tooth structure, and adhesive might be different in the clinical study. Based on the previous in vitro studies, enamel fracture was more likely to occur due to the nature of enamel which is drier than vital teeth in the oral cavity.[12] Shear bond strength in wet condition was more clinically acceptable than in dry condition.[13] This is proven by an in-vivo study which showed lower mean bond strength.[14] Systematic review and meta-analysis by Finnema et al. reported the factors affecting in-vitro orthodontic bond strength testing. They concluded that experimental conditions, water, photopolymerization time, and crosshead speed influence the in-vitro bond strength. Furthermore, the test conditions were not documented accurately in many studies, which could affect the outcome.[15] In previous studies, most of the brackets were debonded individually without working archwire in the bracket and this has influenced the shear bond strength value and debonding characteristic.[6,9,16,17]

These contradicting findings and confounding factors in previous studies led us to identify the debonding characteristics between metal and ceramic brackets especially in the oral environment. To date, there is a lack of clinical study to evaluate debonding characteristics between these two types of brackets. The objectives of this cross-sectional study are 1) to compare the Adhesive Remnant Index (ARI) score between metal and ceramic brackets and 2) to compare the mean percentage of the adhesive remnant on the bracket base.

Methodology

This cross-sectional study was conducted after receiving approval from Research Ethics Committee, Universiti Teknologi MARA; Reference: 600-RMI (5/1/6).Two proportions formula in power and sample size program was used based on the data from in-vitro studies regarding the debonding characteristics of metal and ceramic orthodontic brackets on enamel surface.[5,17] “Cluster Effect 2” was applied in this study to avoid an underestimation of the required sample size[18]. Sixty-four (64) orthodontic brackets per group were required to demonstrate debonding characteristics of the brackets with a power of 80% chance of detecting ARI score of 3 and significance at the 5% level. P0: 0.9 [5] and P1: 0.6 [17]. Patients who fulfilled the inclusion and exclusion criteria were recruited from the postgraduate and specialist orthodontics clinics, Universiti Teknologi MARA (Shah Alam, Puncak Perdana, and Sungai Buloh). Informed consent through written information sheet were obtained from the patients or the guardians (patients under 17-year old). The inclusion and exclusion criteria were as listed in Table 1:

Inclusion Criteria	Exclusion Criteria
1. Required debonding fixed orthodontic appliance.	1. Orthodontic retreatment cases
2. Sound orthodontically treated teeth.	2. Poor oral hygiene
3. Bonding agent (Transbond™ Plus) self-etching primer and Transbond™ XT (3M Unitek) light cure adhesive used for bonding.	3. White spot lesion of enamel
4. Ceramic and metal brackets with MBT prescription and 0.022 inch slot	4. Abnormal formation of enamel (hypomineralization and hypoplastic teeth).
	5. Restoration on labial surface of the tooth
	6. Fracture bracket.
	7. Recondition or reposition of bracket

Table 1. Inclusion and exclusion criteria of the samples.

A total of 192 brackets were allocated and divided into three groups depending on the type of brackets: Group 1) 64 conventional metal brackets (Gemini, 3M Unitek), Group 2) 64 self-ligating metal brackets (Smart Clip SL3, 3M Unitek), and Group 3) 64 self-ligating ceramic brackets (Empower Clear Bracket, American Orthodontic) with MBT prescription and 0.022 x 0.028 inches slot (Table 2 and Figure 1).All brackets from the subjects were mechanically debonded by the same operator using metal bracket debonding pliers (Task Inc, Japan) and ceramic bracket debonding pliers (YDM, Japan). The debonding procedures and protocols are as follows: 1) Archwire were in place during debonding. 2) Adhesive flash was removed from surrounding edge of the brackets using probing instrument. 3) Debonding instrument was placed at mesial/distal of the ceramic brackets or occlusal/gingival of the metal brackets. 4) Handle of pliers was squeezed slowly until bracket was released from tooth.5) Lateral torque was applied to the metal bracket and shearing off was applied to the ceramic bracket.

Types of Brackets	Brand and Bracket Names	Manufacturers	Base Designs
A) Conventional metal brackets	Gemini	3M, Unitek	80 gauge micro etch pad
B) Self-ligating metal brackets	Smart Clip SL3	3M, Unitek	80 gauge micro etch pad
C) Self-ligating ceramic brackets	Empower	American Orthodontic	Quad Matte base

Table 1. Inclusion and exclusion criteria of the samples.

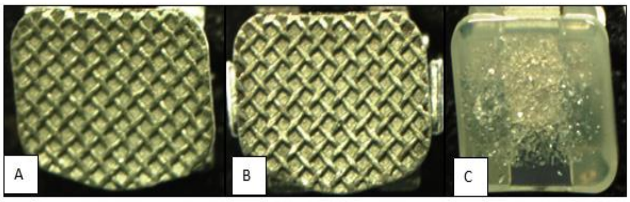

Figure 1. The type of base design of three (3) different brackets. A: Conventional metal bracket, B: Self-ligating metal bracket, and C: Self-ligating ceramic bracket.

After the debonding procedure, a cheek retractor was placed to retract buccal mucosa away from the tooth surface. Teeth were dried using 3-way syringe and dental disclosing solution (D&C #28 1.5%w/w, Sunstar Americas, Inc, Chicago) was applied in a thin layer to the adhesive remnant on the enamel surface using a microbrush. After the solution dried up 30 seconds, intraoral photographs of each bracket were taken with the macro-lens (Canon 100mm 1:2.8L) of DSLR camera (Canon 70D) and camera flash (Canon MR-14EX II Macro Ring Lite) from the front view and side views (both right and left). The setting of the camera was international standard organization (ISO) of 200, aperture (F) of 32, and shutter speed (S) of 200 while the setting of camera flash was Evaluative Through the Lens (ETTL) with light metering of 0.ARI scores were recorded based on image analysis (Olympus Cell B, Version 3.3) measurement of photograph (Figure 2). Comparison of ARI scores between ceramic and metal brackets were analysed using statistical analysis.

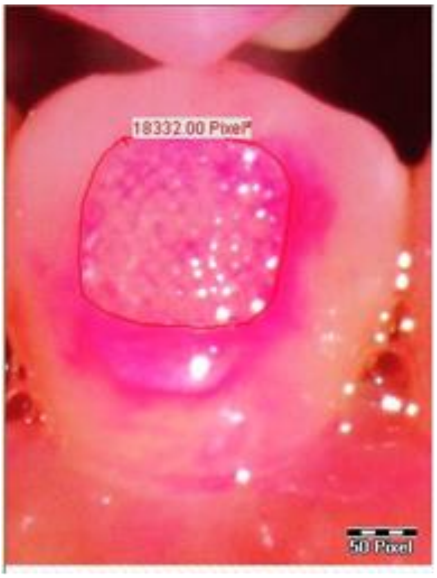

Figure 2. Example of image analysis of clinical photograph of self-ligating metal brackets after debonding

All debonded brackets were cold-sterilised using cleaner and disinfectant (Dentasept SH Pro). The brackets were kept outside and dried for 10 minutes prior to microscopic evaluation. The aim of the microscopic evaluation was to evaluate the percentage of adhesive remnant on the bracket base. Dental disclosing solution (D&C #28 1.5%w/w, Sunstar Americas, Inc, Chicago) was applied to the adhesive remnant on the bracket base. It was used to differentiate between the bracket base and the adhesive and to facilitate the surface area measurement. Each bracket was evaluated under a stereomicroscope at 20 x magnification (Olympus Stereo Microscope: SZ61) (Figure 3). The percentage of adhesive remnant on the bracket base was calculated using image analysis (Olympus Cell B, Version 3.3). The mean percentage of adhesive remnant in each type of brackets was compared using statistical analysis. Data management and statistical analysis were carried out using IBM SPSS version 24.0. The level of statistical significance was set at *p*< 0.05.

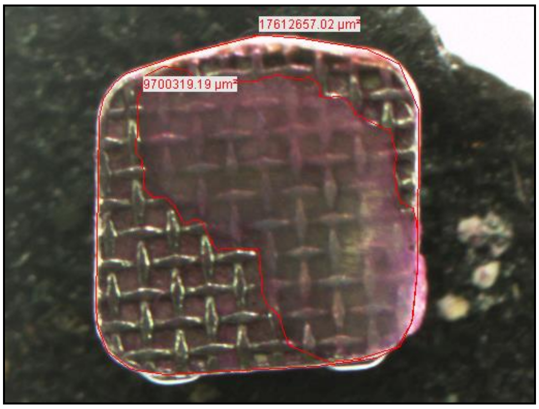

Figure 3 Example of image analysis of microscopic measurement with magnification x 20 of self-ligating metal brackets after debonding.

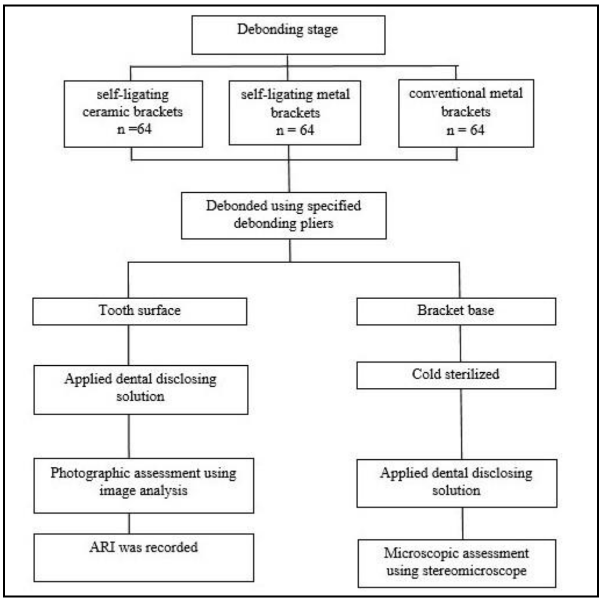

Figure 4. Flow chart of the methodology.

Results

The debonding characteristics of brackets can be determined by using the ARI. The ARI scores for three types of the brackets are shown in Table 3. This study found a statistically significant difference (*p* = 0.001) in the ARI scores between three different types of brackets. The ARI score of 3 was higher in self-ligating metal brackets (60.9%) followed by self-ligating ceramic brackets (35.9%) and lastly the conventional metal brackets (26.6%). However, conventional metal brackets showed the highest ARI score of 0 (21.9%) compared to self-ligating ceramic brackets (10.9%) and self-ligating metal brackets (9.4%). Self-ligating ceramic brackets showed the highest in the ARI score of 1 (42.2%) followed by the conventional metal brackets (35.9%). Most of these brackets showed less than half adhesive that remained on the tooth surface. In the ARI score of 2, self-ligating metal and ceramic brackets showed the same result as score of 0 (10.9% and 9.4% respectively). On the other hand, the highest percentage in ARI score of 2 was the conventional metal brackets (15.6%) compared to other brackets.

	Adhesive Remnant Index (ARI)				
Brackets (n=192)	n (%)				*p*-value
	0	1	2	3	
Self-ligating ceramic brackets (n=64)	7 (10.9)	28 (43.8)	6 (9.4)	23 (35.9)	
Self-ligating metal brackets (n=64)	6 (9.4)	11 (27.2)	8 (12.5)	39 (60.9)	*p* = 0.001
Conventional metal brackets (n=64)	14 (21.9)	23 (35.9)	10 (15.6)	17 (26.6)	

Table 3. The ARI scores between three different types of brackets.
*Note: 0 = no adhesive left on the tooth; 1 = less than 50% of adhesive remained on the tooth; 2 = more than 50% of the adhesive remained on the tooth; and 3 = all adhesive remained on the tooth with distinct impression of the bracket base (Artun & Bergland, 1984).
*Statistical analysis: Chi Square test. Significance at p< 0.05.

Table 4 demonstrated the associate factor (types of brackets) of ARI by Logistic Regression. This analysis used conventional metal bracket as control. It demonstrates score 2 and score 3 with less risk of enamel damage. For self-ligating metal brackets, the result showed 95% CI (1.563-6.738) which did not include 1, the coefficient was positive (1.177), and self-ligating metal brackets were significant to the model (p = 0.002). Based on the odd ratio result, self-ligating metal brackets are likely to have 3.25 times more than 50% adhesive remnant on the tooth surface compared to conventional metal brackets. On the other hand, for self-ligating ceramic brackets, the result showed 95% CI (0.602-2.430) which included 1 and self-ligating ceramic brackets were not significant to the model (p= 0.594).

Brackets	Regression Coefficient (B)	Crude Odds Ratio (95% CI)	Wald Stats	*p*-values
Conventional metal brackets (n=64)	0	1		
Self-ligating metal brackets (n=64)	1.177	3.25 (1.563-6.738)	9.977	0.002
Self-ligating ceramic brackets (n=64)	0.190	1.21 (0.602-2.430)	0.284	0.594

Table 4. Association between the types of brackets and ARI.
*Note: Scores of 2 and 3 were considered as preferable ARI score in this study.
*Statistical analysis: Simple Logistic Regression
*Hosmer and Lemeshow test: p = 1.00. Assumption is met. The model is fit
*Significance at p< 0.05

The percentage of adhesive remnant on the bracket base among three types of orthodontic brackets was shown in Table 5. Homogeneity of variances was tested and it showed no significant difference (p = 0.255). There was a statistically significant difference between the three types of orthodontic brackets (p = 0.001). The study found that self-ligating metal brackets had the smallest mean of percentage adhesive remnant on the bracket base (27.1%) compared to the conventional metal brackets (53.9%) and self-ligating ceramic brackets (46.2%). This finding proves that more teeth in the self-ligating metal brackets presented with ARI scores of 2 and 3. Based on post-hoc Tukey's test result, the self-ligating metal brackets showed a statistically significant difference ascompared to the self-ligating ceramic brackets (p= 0.001) and the conventional metal brackets (p = 0.02) with mean differences of 19.10 and -26.80, respectively.

Variables	N (n=192)	Percentage of Adhesive (%) Mean (SD)	F statistic [a] (df)	*p*-value
Types of Brackets				
Self-ligating ceramic	64	46.2 (39.2)		
Self-ligating metal	64	27.1 (38.4)	7.73 (2, 189)	p = 0.001
Conventional metal	64	53.9 (41.4)		

Table 5. The percentage of adhesive remnant on the bracket base among three types of orthodontic brackets.
*One-way ANOVA test. Significance at p< 0.05
* Data were normally distributed
*All pairs of mean scores are significantly different by post-hoc test (Tukey test) except between self-ligating ceramic and conventional metal brackets (p = 0.515 with mean difference = -7.72).

Discussion

The adhesive remnant index (ARI) scoreshave been used to evaluate the adhesive remnant on the tooth surface and the bracket base.In previous in-vitro studies, the ARI scores were evaluated by scanning electronic microscope, finite element analysis, and three-dimensional profilometry.[19] They evaluated without any colour agent or dental disclosing solution to assess ARI. ARI assessment using dental disclosing solution is a new intervention. In clinical examination, the ARI assessment on the tooth surface was difficult due to the lack of contrasting colour in the orthodontic adhesive. The dental disclosing solution application is a viable new approach for further clinical studies to evaluate adhesive remnant on the tooth surface either by visual inspection or photography.

Furthermore, the application of disclosing solution is beneficial to clinical and laboratory investigation due to its effectiveness, simplicity, non-toxic, cheap, and time-saving advantages.[20,21,22]

In clinical orthodontics, an adequate bond strength between an adhesive and the bracket base should be strengthened to prevent bonding failure during orthodontic treatments. Bond strength should also not be too strong because it may increase the risk of enamel damage during debonding.[16] Even though there is no universally accepted minimum shear bond strength (SBS) for clinical orthodontic, SBS of 8-9 megapascals (MPa) was adequate for orthodontic bracket bonding.[23] In the previous studies, in-vitro results of bond strength were generalised to in-vivo conditions. Nevertheless, the bond strength determined by the laboratory examinations cannot be the accurate indicator for the functioning of different orthodontic materials or systems in a clinical setting. Some researchers suggested that in-vitro results must be interpreted with caution when applied in clinical situations.[25]

There was an agreement that the metal brackets did not show any problem in the clinical set-up due to low bond strength between the metal bracket base and the adhesive.[25] In this clinical study, 60.9% of the self-ligating metal brackets showed ARI score of 3. It was found that there was a significant difference in ARI scores compared with the self-ligating ceramic and conventional metal brackets group ($p < 0.05$). In other words, more than half of the samples in self-ligating metal brackets group had all adhesive left on the tooth surface. This finding is supported by our microscopic results whereby the mean percentage of adhesive remnant on the bracket base was 27.1%. It indicated that the bond failure pattern of self-ligating metal brackets occurred more at the bracket-adhesive interface than at another interface, entailing minimal risk of enamel damage.[4] However, the result was different from the conventional metal brackets group. The mean percentage of adhesive remnant on the bracket base was 53.9% while ARI was score 0 (21.9%) and score 1 (35.9%). Therefore, more than half conventional metal brackets showed less than half adhesive on the teeth surface. Previous in-vitro study found the mean debonding strength for the metal brackets (30.73 MPa) was significantly higher than that of ceramic brackets (13.87 MPa).[9,10] It was contradicted withother in-vitro study where they found 85% of self-ligating and conventional metal brackets showed ARI score of 3.Their result showed no statistically significant difference.[5] In our study, self-ligating metal brackets showed more ARI score of 3 (60.9%) followed by self-ligating ceramic brackets (35.9%) and finally the conventional metal brackets (26.6%).

The early ceramic brackets used silane coupling agent to act as a chemical mediator between the ceramic bracket base and the adhesive resins. This chemical interaction resulted in extremely strong bonds that caused the enamel-adhesive interface to be stressed during debonding. It predisposed enamel risking irreversible damage in the form of crack and delamination that often-required dental restorations.[5] This is proven by in-vitro studies that the chemical retention of ceramic brackets had a risk for enamel damage during debonding.[4,17] However, the result was different when the researchers used mechanical retention in ceramic brackets. This bracket exhibited the least damage on the enamel surface.[6,8]A previous in-vitro study showed 60% of mechanical retention ceramic brackets scored 3 and 0% scored 0 in ARI score. It was shown that this type of bracket had more bond failures at the bracket-adhesive interface which minimized the risk of enamel damage.[17]In this study, the self-ligating ceramic brackets showed no significant different with conventional metal brackets. This finding is supported by other previous in-vitro studies which compared ARI scores between metal and ceramic brackets. No significant difference was shown in ARI scores between the mechanically retained metal and ceramic brackets. Habibi et al. observed that none of the ceramic brackets and metal brackets scored 0. Most of the brackets showed ARI scores of 2 and 3.[9] Recently, an in-vitro study also found no significant difference between metal and ceramic brackets. They found only 1.8% of metal brackets and 3.5% of ceramic brackets scored 0.[24]

The debonding characteristics of self-ligating ceramic and conventional metal brackets were different with self-ligating metal brackets due to dimension and design of the bracket base.[25] Previous in-vitro studies showed the mean shear bond strength (SBS) of new, recycled and repeated recycled conventional metal bracket were more than that recommended by Reynolds in 1975.[23,28] SBS was also different among the brackets with the mesh base. The bracket with a larger mesh size showed higher mean of SBS compared to the smaller mesh size. In addition, different mesh designs will give different debonding characteristics due to different bond strengths; the larger the mesh spacing, the greater the bond strength between brackets, adhesive, and enamel.[26,29] Our findings are different from the previous in-vitro results due to several factors: 1) different regimen for load application and 2) different adhesive and material preparation.[24] The clinical study gave different debonding characteristics because of the complex oral environment. The presence of ions, minerals, fluctuating pH and temperature in the mouth could adversely affect the adhesive and the material of the brackets by biodegradation process which could create a different bond strength between the bracket base and the adhesive.[30,31]Another study reported that in-vivo group had significantly lower mean bond strength as compared to in-vitro group.[14] Furthermore, the retention mechanism, the geometric form of the bracket base, and the condition of the enamel surface might give varied results for the study.[8]It could also be due to the impaired light access afforded by the mesh disc model, incomplete polymerization, and compromised adhesion.[27]

Most of the previous in-vitro studies are correlated with the ARI assessment and pattern of bond failure with the risk of enamel damage. This cross-sectional study was conducted mainly to compare the debonding characteristics between ceramic and metal brackets. Therefore, randomized clinical trial is recommended for future studies to investigate the association between ARI scores and enamel damage in orthodontic patients. Assessment of enamel structure before bonding the brackets and after debonding the brackets can be evaluated using a transilluminator or any advanced instrument such as optical coherence tomography.[32]

Conclusion

Based on the results of this study, the following conclusions are drawn:

1. There is a variation of debonding characteristics among three types of brackets. Based on the ARI assessment, most adhesive remain on the tooth surface in the self-ligating metal brackets and was statistically significant difference when compared to the self-ligating ceramic and the conventional metal brackets.
2. There is a similar result between microscopic and the clinical assessment. The self-ligating metal brackets showed a statistically significant difference in mean percentage of adhesive remnant on the bracket base compared with other types of brackets.

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