Adhesive Remnants in Orthodontic Brackets: A Microscopic Study

S Vikram¹, Shiji M Kunjappan², P Vasanthan³, S Sabitha⁴, Ajeetha Gomathi Selvarajan⁵, V Saranya⁶

Contributors:
1Professor and Head of the Department, Department of Orthodontics & Dentofacial Orthopedics, Vinayaka Mission’s Sankarachariyar Dental College, Salem, Tamil Nadu, India; 2Reader, Department of Orthodontics, Vinayaka Mission’s Sankarachariyar Dental College, Salem, Tamil Nadu, India; 3Professor, Department of Orthodontics, Vinayaka Mission’s Sankarachariyar Dental College, Salem, Tamil Nadu, India; 4Reader, Department of Oral and Maxillofacial surgery, Vinayaka Mission’s Sankarachariyar Dental College, Salem, Tamil Nadu, India; 5Former Professor and Head of the Department, Department of Orthodontics, Vivekananda Dental College for Women, Elayampalayam, Tiruchengode, Namakkal, Tamil Nadu, India; 6Post-graduate Student, Department of Oral and Maxillofacial Pathology, Ragas Dental College, Chennai, Tamil Nadu, India.

Correspondence:
Dr. Vikram S, Department of Orthodontics & Dentofacial Orthopedics, Vinayaka Mission’s Sankarachariyar Dental College, Salem, Tamil Nadu, India. Phone: +91-9444383777. Email: srevikram@hotmail.com

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Abstract:
Background: The concept of bonding resins to enamel has enjoyed applications in all fields of dentistry, including the bonding of orthodontic brackets. In the process of bonding orthodontic brackets to enamel, conventional adhesive systems use three different agents: An enamel conditioner, a primer solution, and an adhesive resin. The bonded brackets should have enough bond strength to withstand masticatory forces, the forces applied during orthodontic treatment and should enable easy debonding, clean up procedure at the end of the treatment without causing iatrogenic damage such as cracks and loss of enamel. Depending on the mode and direction of the loading force different types of bond strengths are evident. Thus, the aim of the study is to evaluate the adhesive remnant index (ARI) of Metal-Chrome Cobalt TP Nu-edge L N bracket system with Primekote base and to compare it with that of 3M Gemini Metal-Stainless Steel bracket with woven mesh base and Ormco Metal-Stainless Steel bracket with the Optimesh base.

Materials and Methods: Three commercially available pre-adjusted edgewise premolar brackets with different base designs were used for the study on 54 premolar teeth. An optical microscope was used to determine the enamel crack after debonding. Scoring was done to calculate the ARI. Statistical analysis: Chi-square test was performed.

Results: Varying fracture sites were noted for 3M Gemini and TP Primekote brackets, with 44% of bond failure occurring at the bracket/adhesive interface. Ormco Optimesh brackets had bond failure site at bracket adhesive interface in about 66% of the samples. The difference in ARI scores noted was statistically significant. The bond failure for tensile bond strength test group occurred at the bracket/adhesive interface.

Conclusion: Sites of bond failure after tensile bond strength test was mostly at the bracket/adhesive interface or within the adhesive. None of the brackets showed failure at the enamel/adhesive interface. Hence, tensile stress can be used for debonding.

Key Words: 3M Gemini wovenmesh bracket, adhesive remnant index, ORMCO optimesh bracket, TP Primekote bracket group

Introduction

In 1955, Buonocore introduced a technique of acid-etching. The concept of bonding resins to enamel has enjoyed applications in all fields of dentistry, including the bonding of orthodontic brackets. In the process of bonding orthodontic brackets to enamel, conventional adhesive systems use three different agents: An enamel conditioner, a primer solution, and an adhesive resin. A unique characteristic of some new bonding systems in operative dentistry is that these systems combine the conditioning and priming agents into a single acidic primer solution for simultaneous use on both enamel and dentin.1,2 These relatively new systems were used originally on dentin.1,3 Essentially, the acidic part of the primer dissolves the smear layer and incorporates it into the mixture. Acidic primer solutions also demineralize the dentin and encapsulate the collagen fibers and hydroxyapatite crystals.2 This simultaneous conditioning and priming allow penetration of the monomer into the dentin. The adhesive resin component will then diffuse into the primed dentin, producing a “hybrid layer.”3 These new systems were also found to be effective when bonding to enamel.4

Basically, 4 types of orthodontic attachments are available for bonding, i.e., plastic (polycarbonate), plastic with metal reinforcing, metal, and ceramic. Metal bracket rely on mechanical retention since adhesives used for bonding do not bond to metals. A variety of bracket bases, therefore, has been introduced as a retention aid. They are:

1. Perforated base
2. Sintered base-metallic or ceramic particles are fused onto the bracket base to achieve a porous layer into which resin can penetrate
3. Mesh foil bracket base-different gauges which are either spot welded, brazed, photo etched, laminated, laser welded, or finely woven. The mesh bases may also be further modified by sand blasting or polymer coating
4. Undercut bases-brackets with undercuts are milled and
cast into bases as an integral part of the bracket. The bracket and base are a single unit, which is more stable and prevents distortion. Micro and Macro undercuts may also be generated by computer aided laser cutting process (Titanium brackets)

5. Omesh brackets base-bracket base with foil mesh treated by a thermal spraying process, in which a highly corrosion resistant metal alloy particles are sprayed at an extremely high velocity to the mesh pad

6. Primekote base-bond strength is enhanced by the application of a surface silicon layer prior to application of polymer coating. Primekote polymer has high specific adhesion to orthodontic adhesives, because of its ability, it is not only metal to adhesive but also polymer to the adhesive; the reliability of bond is substantially improved.

The present study was, therefore, undertaken to compare the debonding character and site of bond failure among three bracket systems, evaluating it by modified adhesive remnant index (ARI) using an optical microscope.

**Aim of the study**
To study the debonding character and site of bond failure of brackets with three different designs in mesh base.

**Materials and Methods**
The debonding character was evaluated.

Samples-brackets
Substrate
Premolar teeth-54 numbers

**Armamentarium**
Leica optical microscope (LEICA Cambridge Ltd., Cambridge, ENGLAND) with x1000 magnifying power was used to screen adhesive remnants on the tooth surface and the bond failure sites (Figure 1).

**Procedure**
The selected brackets were bonded to the extracted premolar teeth to test the ARI.

**Sample size**
A total of 54 premolar teeth were obtained from the Department of Oral Surgery. Informed consent was obtained from patients.

**Eligibility criteria**

**Inclusion criteria**
- Premolar extracted for orthodontic treatment.
- Both first and second premolars were taken.

**Exclusion criteria**
- Teeth with evidence of decay or restoration.
- Teeth with clinically visible enamel defects

The selected teeth were screened for enamel defects or damages, using the Optical microscope. To examine the teeth under the optical microscope, all the teeth were fixed in a self-cure acrylic block. The teeth fixed to the acrylic blocks were divided into 3 groups of 18 samples each. Individual groups were color coded. 3M Gemini bracket group-White Color, TP Primekote bracket group-Pink Color and Ormco Omesh bracket group-Green color.

The selected brackets types were then bonded to the teeth mounted on the respective color coded acrylic blocks (Figure 2). Transbond XT light cure adhesive system (Figure 3) was used for bonding the brackets. Enamel on the buccal surface of the tooth was etched with 37% phosphoric acid solution for 30 s. After etching, the enamel surface was rinsed with water for 20 s and dried with oil-free air spray. Transbond-XT bonding primer was applied to the etched enamel surface and light cured for 10 s. Transbond-XT adhesive was uniformly applied to the base of the bracket, and the bracket was positioned on the tooth surface. Excessive flash around the brackets were removed. Light curing using...
Dentaurum LC unit was done for 10 s on all four sides of the bracket to bond the bracket. The above procedure was done for all 54 samples, which were to be tested. The bonded teeth were then stored in water for 24 h prior to testing. Instron Machine was used to apply Shear and Tensile stress to debond the brackets. A special blade in cast iron was custom made with a beveled edge to apply shear force, and 0.010 double stranded ligature was used for applying tensile force. 18 samples in each group were subdivided further into two for applying shear and tensile stress to debond the brackets.

**Test for debonding character (adhesive remnants)**
The debonded specimens were screened using an optical microscope ×50 magnification for scoring according to modified ARI index. The scoring was in the following range between 1 and 5.
1. Indicates all of the composite remained on the tooth surface, along with the impression of the bracket base.
2. More than 90% of composite remained on the tooth surface.
3. More than 10% but <90% of the composite remained on the tooth surface.
4. <10% of composite remained on the tooth surface.
5. Indicates that no composite remained on the tooth surface.

The scores for all the samples were tabulated and subjected to statistical evaluation.

**Statistical analysis**
Chi-square test was done to evaluate the results.

**Results**
From Table 1 and Graph 1 show the percentage distribution of ARI score for 3M Gemini, Ormco Optimesh and TP Primekote brackets after shear bond strength test. It is evident that varying fracture sites were noted for Gemini and Primekote brackets, with 44% of bond failure occurring at the bracket/adhesive interface (score no.1). One the other hand, Optimesh brackets had bond failure site at bracket/adhesive interface in about 66% of the samples (score no.1). The difference in ARI scores noted was statistically significant.

Optical microscopic appearance for the site of bond failure at bracket/adhesive interface, within the adhesive and at the enamel/adhesive interface are shown in Figures 4-6, respectively.

**Discussion**
Bonding of brackets to enamel has been an important issue in orthodontics, since the introduction of direct bonding technique.
Orthodontic bond strength assessment and failure patterns can be studied in various ways. In vitro tests are usually performed with the aid of a mechanical testing machine or by simulation of clinically applied debonding procedure in the laboratory, where failure modes are evaluated by microscopic examination. In vivo tests are done usually by bonding the brackets on the patients who come for orthodontic treatment. Measurement of failure rates of brackets and failure sites are assessed at each appointment. Bond strength can also be assessed using finite element analysis, modeling components of the enamel-adhesive-bracket system and finding the stress distributions on it.\(^2\)

Bracket base design varies from a metal bracket to a ceramic and polycarbonate bracket. Metal brackets usually have a mechanical retentive base while ceramic and plastic bracket have a chemical retentive base. Though ceramic bracket and plastic brackets have better esthetic appearance than metal brackets, the disadvantage like fracture of bracket or enamel damage while debonding is more. Metal brackets mildly flexes while debonding leading to less enamel damage or crack. It has also less frictional properties, which can be advantageous for the clinician to preserve anchorage. Metal brackets are also cost-effective with better qualities. Hence, in this study, three different metal brackets with different mesh base designs were chosen. Improvements in bracket base designs have been undertake since the introduction of direct bonding attachments. Among the different types of brackets, stainless steel brackets although has been widely used, has a disadvantage of nickel hypersensitivity. Park et al. and Hammula et al. have reported in vitro release of nickel and chromium from orthodontic appliances. The release of nickel results in allergic reactions, which are manifested on the skin as dermatitis and urticaria and in mouth as hypertrophied gingivae, glossitis, metallic tastes and tooth staining. Pure titanium brackets were subsequently introduced which was found to exhibit low co-efficient of friction and provide an alternative to stainless steel. However, Titanium brackets tested by Kusy et al. were 0.002 larger than normal bracket slot size stated. Being oversized, it facilitated engagement of all wires, but at the expense of loss of torque control.

**Figure 4:** Bond failure at bracket/interface. The adhesive remaining on the tooth surface with impression of brackets base is evident (Score - 5).

**Figure 5:** Bond failure within the adhesive. The arrow indicates area of tooth surface without adhesive.

**Figure 6:** Bond failure at enamel/adhesive interface.
TP Nu-edge LN brackets have been designed with Primekote technology to improve bond strength both mechanically and chemically. It also encompasses substantial improvements in bracket design with torque built in base and reduced frictional properties. Nu-edge brackets incorporate prime coast polymer coating integrally bonded to the bracket base by a unique coating process in the factory. The durability of the bond is enhanced by the application of a surface silicon layer prior to application of polymer coating. Primekote polymer has high specific adhesion to orthodontic adhesives, because of its ability to form polymer/polymer covalent interface. Since the mechanism of bonding is not only metal to adhesive but also polymer to the adhesive, the reliability of bond is substantially improved. The reported enhanced properties of Nu-edge brackets essentially with reference to improved bond strength chemically and mechanically with a low nickel content prompted to undertake this study. Hence, a comparative evaluation of bond strength and debonding characters of Primekote bracket with that of Gemini and Optimesh brackets made of stainless steel but with different types of bases was undertaken.\textsuperscript{2,3}

Gemini brackets have 80 gauge woven mesh base. The manufacturer of this product (3M, Unitek) claim that 80 gauge mesh is better than 100 gauge mesh size in retentive bond strength.

Optimesh bracket (Ormco, Sds) has a foil mesh base, which is treated by a thermal spraying process, in which a highly corrosion resistant metal alloy particles are sprayed at an extremely high velocity to the mesh base. These metal particles sintered on the mesh base, provide large surface area and intricate microscopic network giving a micro-mechanical locking and an additional mechanical retentive aid.

One of the important considerations in testing the bond strength of bonded attachments is its debonding character with reference to site of bond failure and site of damage to the enamel.

Bond failure is determined in debonded specimens by evaluating the amount of residual adhesive left on the tooth surface either with a stereomicroscope or an optical microscope. In this present study, optical microscope was used. Artun et al. described ARI scores has a more complex means of defining the site of bond failure between enamel, adhesive and at the bracket base. The adhesive remnant score ranged between 0 and 3. The index was subsequently modified with a score of 1-5 by Bishara, et al.\textsuperscript{1}

The debonding character of each specimen in the present study was determined with modified ARI using an optical microscope. Modified ARI index gives a better description about site of bond failure.

One of the findings in this study was the differing amount of residual adhesive on the tooth surface obtained for various bracket base/adhesive combinations.

Bond failure, however, can occur in any one of the following interfaces, namely:

- a. At the bracket/adhesive interface
- b. Within the adhesive itself
- c. At the enamel/adhesive interface
- d. Within the enamel.

3M Gemini brackets mostly had bond failure at the bracket/adhesive interface and within the adhesive. Only in 2 samples bond failure occurred at the enamel/adhesive interface.

Ormco Optimesh brackets had failure site mostly at the bracket/adhesive interface and remaining few within the adhesive itself. None of the brackets tested had any failure at enamel/adhesive interface (score of 5-no adhesive left on the tooth surface).

The site of bond failure after shear bond strength test for TP Primekote brackets was mostly along the bracket/adhesive interface and within the adhesive. Only one sample failed at the enamel/adhesive interface. 3M Gemini, Ormco Optimesh, and TP Primekote brackets site of bond failure were in a heterogeneous way similar to the finding noted by for stainless steel metal brackets.\textsuperscript{4,5}

Bond failure sites for the three different metal brackets used in this study after tensile bond strength test showed almost similar failure sites. Ormco Optimesh, 3M Gemini and TP Primekote brackets site of bond failure were at the bracket/adhesive interface and within the adhesive. No brackets had failure site at the enamel/adhesive interface after testing tensile bond strength. This suggests that a tensile force can be the most suitable for debonding brackets without any damage or crack to the enamel.

When residual adhesive was more on the tooth, enamel damage was less, but when no adhesive remained on the tooth surface it can cause enamel damage or crack.

Only 3 samples, 2 bonded with 3M Gemini bracket and 1 bonded with TP Primekote bracket had no adhesive remaining on the tooth surface (score of 5). These three samples did not have any visible crack or defect clinically or when viewed through optical microscope prior to bonding.

**Summary and Conclusion**

This study was undertaken to evaluate debonding character in reference to site of bond failure was studied.

The following conclusions were drawn from the study:-

1. Site of bond failure for Ormco Optimesh brackets after
shear bond strength test was at the bracket/adhesive interface and within the adhesive. 3M Gemini brackets site of bond failure were equally at the bracket/adhesive interface, within the adhesive and in the enamel/adhesive interface. TP Primekote brackets had failure sites on the bracket/adhesive interface and within the adhesive

2. Site of bond failure after tensile bond strength test was mostly at the bracket/adhesive interface or within the adhesive in all three difference bracket types. None of the brackets failed at the enamel/adhesive interface. Hence, tensile stress can be used for debonding these brackets and avoid enamel damage.

References