Original Article

Enamel Integrity: Base Morphology and Clarity of Debonded Modern Ceramic Brackets

Omar S. Mohammed[1]*

Abstract

Objective: To evaluate the effectiveness of base morphology and clarity of modern ceramic orthodontic brackets on adhesion of brackets with enamel surface and enamel surface integrity after debonding.

Methods: The Scan Electron Microscopy (SEM) was used at high magnification 1000x, and the images were taken for a retentive base of three types of ceramic brackets (Pure, Encore, and Reflections). The degree of light transmission was evaluated, and shear bond strength and adhesive remnant index were evaluated.

Results: SEM exhibited differences in surface morphology of retentive base between tested ceramic brackets. Optical Characteristic showed Pure brackets were significant differences with all tested brackets but not significant between them. One-way ANOVA revealed a significant difference at ($p < 0.05$) in shear bond strength. The reflections and Encore gave the highest bond strength, while the Pure gave the lowest value.

Conclusions: The morphology of the base and clarity of ceramic brackets directly affect the adhesion brackets with enamel surface under the same condition. In addition, the mode of retention plays an important role in the damage of the enamel surface after debonding.

Keywords: *Orthodontic ceramic brackets, Clarity, SEM, Shear bond strength, Mode of failure.*

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1. *Department of Preventive Dentistry, Orthodontics, Pedodontics, College of Dentistry, Mosul University, Mosul, Iraq.*

** Corresponding author: omarsabah2003@yahoo.com*

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Introduction

The bond strength and debonding of the ceramic brackets should be considered due to their hardness in relation to the enamel. The manufacturer effort is concentrated on this part, and recently three kinds of ceramic bracket bases are available. The first bracket base is formed with undercuts or grooves that provide a mechanical interlock to the adhesive. The mechanical retention of such brackets is less as compared to other bracket base having both micromechanical retention and chemical adhesion[1,2]. The second type of bracket base has a smooth surface and relies on a chemical coating to enhance bond strength, and the third type is a mixture between the mechanical and chemical way. A silane coupling agent is used as a chemical mediator between the adhesive resin and the bracket[3]. It has been claimed that chemical adhesion provided higher bond strength than mechanical retention[4].

Recently, the ceramic bracket base developed in two ways has come from polycrystalline alumina with a rough base containing randomly oriented sharp crystals or spherical glass particles. These brackets provide only micromechanical interlocking with the orthodontic adhesive[2].

Many efforts have been made to overcome the potential damage of enamel during debonding; a ceramic bracket with a thin polycarbonate laminate coating on the base has been manufactured (CeramaFlex, TP Orthodontics). The bond to the enamel, therefore, is not through an adhesive to the ceramic base but to the thin polycarbonate laminate. It has been suggested that these brackets are as easy to remove as metallic brackets[5]. The adhesive system also has an important role in shear bond value; Al-Saleh M, El-Mowafy (2010)[6] shown the conventional adhesive system used with metallic and ceramic brackets exhibited high shear bond strength value compared with new adhesive cement. The orthodontists always are looking to find good retentive brackets with less damaging surfaces during the debonding of brackets.

Improvements in bracket base and clarity make the debonding methods more difficult. Yet, enamel damage during the debonding of ceramic brackets continues to be a matter of concern for orthodontists.

Patients and methods

Three commercially available orthodontic ceramic brackets were selected for the study (Table 1). All brackets were for upper central incisors and had Roth 0.022-inch (0.56 X 0.75 mm/22 X 30) slots size

This study was conducted in Erbil City/Kurdistan region/ Iraq from Sep 1st, 2018, till May 1st, 2019. all laboratory tests were done at the University of Athens/College of Dentistry/Biomaterial department.

Morphology of retentive Base

The base of each examined brackets was sputter-coated with a thin carbon layer and then examined by scanning electron microscopy (Quanta 200 SEM, FEI, USA) under the following conditions; high vacuum, 10KV accelerating voltage, 90µA beam current, and secondary electron detector (ETH) at 1000X magnification.

Optical properties

The tested brackets (no:10 per brand) were tested using a light-curing unit (Elipar TriLight, ESPE GmbH, Germany) with emitting 800 mW/cm^2 at 400-515 nm. The standard mode of exposure was used at 20s exposure time. This type of light cure has a specific area for testing alight to promote the user to re-calibrate the light intensity.

The amount of light intensity emitting from light cure at a distance between the light guide and sensor was tested at a distance proximately equal to the average thickness of the brackets. It's about 750 mW\cm^2 without any brackets as standardization criteria.

In addition, the direction of light through the brackets was in the same way during the fixation of the bracket in the oral cavity. As normal fixation of the brackets to the tooth surface, the tested bracket was placed in the sensor in the way that the labial surface of brackets looking toward the light cure tip. Then, measurement of the light transmission through the brackets was calculated in a way that the light passed through the face of the brackets toward the base of it.

The measurement was repeated ten times for each bracket. The data got it excluded from the 750 mW\cm^2 (without bracket), and the statistic analysis was done.

Shear bond strength and mode of failure (adhesion with enamel)

Three types of modern ceramic brackets were used in this study, shown in (Table 1). The brackets have different types of mechanical retention in their bases.

Intact central incisors extracted for periodontal reasons were selected. Teeth were scaled with an ultrasonic scaler to remove tissue tags, and the plaque was then kept in water at 4^{o}C with the addition of 0.5% sodium azide. The crowns were sectioned, embedded in epoxy resin, leaving the labial surfaces free and horizontally oriented. Following normal bracketing procedure and according to the instruction of adhesive materials, the exposed tooth surfaces were cleaned with fluoride-free slurry, etched with a 37% phosphoric acid gel (Super-etch gel, SDI, AUS) for 15sec, rinsed with water spray for 10s, and thoroughly air-dried for 5sec. A thin film of a primer (Transbond XT Primer, 3M Unitek, USA) was applied on acid-etched surfaces. A light-cured orthodontic adhesive was applied on bracket bases (Transbond XT, 3M Unitek). Simulation to bracketing procedure in the oral cavity, the brackets (n:10 per brand) were pressed against the central part of the labial surfaces; the excess paste was carefully removed, light-cured with a LED unit (Radii Plus, SDI, 1200 mW/cm^2 light intensity) for 5s through the bracket and then from apical and incisal edges (10s each), stored in distilled water (2-weeks/37°C)[7].

The universal testing machine was used to debond brackets (Tensometer 10, Monsanto, UK) under a shear load applied at the bracket base-enamel interface, at a crosshead speed of 2mm/min (Figure 3B). The debonding forces were recorded in N and transformed to MPa after measuring the bracket dimensions with a digital caliper. The failure mode of debonded tooth surfaces was examined under a reflected light video-microscope (MS-500C, Moritex, UK) at 25X magnification and classified according to the modified adhesive remnant index scores (ARI). The ARI index includes Score 1: no adhesive left on the tooth; Score 2: <25% adhesive left; Score 3: 25%- 50% adhesive left; Score 4: 50%-75% adhesive left; Score 5: >75% adhesive left; and Score 6:100% adhesive left, with adhesive failure at the bracket-adhesive interface.

Results

SEM

In high magnification at (1000x), Pure (Figure 1A) exhibited waves of high and low protruding peaks; some of them appeared very sharp and another rounded protruding peaks and valleys. Reflection and Encore(Figures 1B, C, respectively) revealed features represented by forming ridges of varying intensity randomly spread in different directions, creating a very specific relief.

Optical Properties:

Table 2 shows the degree of light transmittance obtained from measuring the degree of absorption of light through the brackets. The results showed a significant difference between groups at ($p \leq 0.05$).

Shear Bond Strength and Mode of failure:

The shear bond strength exhibited Encore and Reflections presented the highest debonding force and the lowest values in Pure (Table 3). The failure mode analysis showed (Tables 4, Figure 2) that tooth surface covered with composite resin in Encore about (62%), Reflection about (75%), and Pure about (25%). The main failure mode occurred at the adhesive tooth interface (Pure 80%, Encore 25%, and Reflection 30%).

Discussion

Bonding of an adhesive to a ceramic bracket is typically mechanical and is achieved by indentations or undercuts in the bracket base. Although many means of ensuring mechanical interlocking have been used in the past few years, efficient penetration of bonding materials into brackets base could be limited by manufacturing difficulties or deficiencies or improper design[8]. Some studies concentrated on various techniques that were used for enhancing bracket bonding by different mechanical techniques, like sandblasting[9]. allowing penetration of the adhesive to provide adequate bond strength[10]. Ansari MY et al. (2016)[11] showed that bracket base design significantly affects shear bond strength. The tested brackets presented differences in morphological and textural of the brackets bases design.

Clinically, the role of the design of the retentive part is involved with three issues: Firstly to enhancing the micromechanical interlocking between the adhesive material and the bracket, secondly to provide satisfactory bonding with the enamel of the tooth, and thirdly to facilitate the debonding of the bracket from the tooth structure after an efficient period of clinical performance.

Although of methodological limitation[12], the results of the shear bond strength test for the tested bracket are within the range that was reported for metallic brackets except for Pure[13]. Pure ceramic bracket exhibited lower value, which may be related to the reduced size and number of retentive base protrusions from both depth and area width, but the value higher than plastic and nearly to metallic brackets[14]. Gwinnett[15] reported the mean bond Strength values for metal brackets to be 12.1 ±4.6 MPa.

Table 1: The commercial tested ceramic brackets.

Commercial Bracket Name	Composition*	Types of Slot	Manufacturer
Pure	Monocrystalline	Ceramic	Ortho Technology-USA.
Encore	Monocrystalline	Metallic	Ortho Technology-USA.
Reflections	polycrystalline	Ceramic	Ortho Technology, USA.

*Composition according to the manufacturing information.

Table 2: In-Line Transmission of The Activation Light

For Tested Brackets *(Means And Standard Deviations)**.

PRODUCTS	MEANS/ (750 mW\cm^2)**	% D.L***
Pure	130.66 (2.60) [a]	17%
Encore	210.10 (8.02) [b]	28%
Reflections	233.13 (4.12)[b]	31%

*Same superscripts imply mean values with no statistically significant differences.

* * light intensity emitting from of light cure without brackets (standardization criteria).

*** Percentage is representing the decrease in density of light transmission (scattered or absorbed).

Table 3: Results of shear bond strength with enamel (means and standard deviations)*.

PRODUCT	BOND STRENGTH (N)	BRACKET AREA (mm^2)	BOND STRENGTH (MPa)
Pure	111,12(1,2) [a]	14,7	7.56 (1,5) [a]
Encore	172,15(2,8) [b]	14,8	11,63(1,1) [b]
Reflections	176,10(3,2) [b]	14,8	11.89(1,6) [b]

* Same superscripts imply mean values with no statistically significant differences

Table 4: Results of the ARI score index*.

PRODUCT	SCORE 1	SCORE 2	SCORE3	SCORE 4	1	SCORE 6
Pure	0	6	3		0	0
Encore	0	1	2	5	2	0
Reflections	0	1	1	4	4	0

*Score 1: no adhesive left on the tooth; Score 2: <25% adhesive left; Score 3: 25%- 50% adhesive left; Score 4: 50%-75% adhesive left; Score 5: >75% adhesive left; and Score 6:100% adhesive left, with adhesive failure at the bracket-adhesive interface

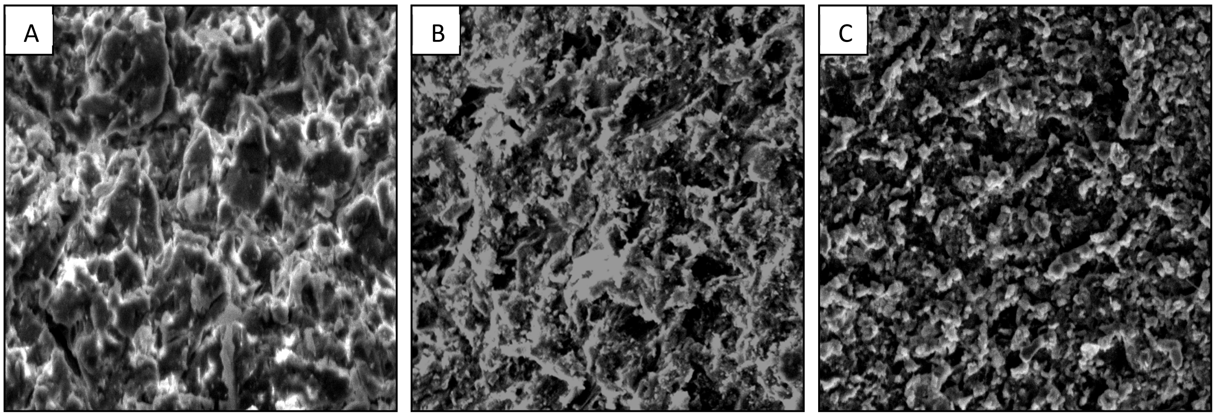

Figure 1: Secondary electron images of brackets base at 1000 X magnification, A) Pure. B) Reflection and C) Encore ceramic brackets.

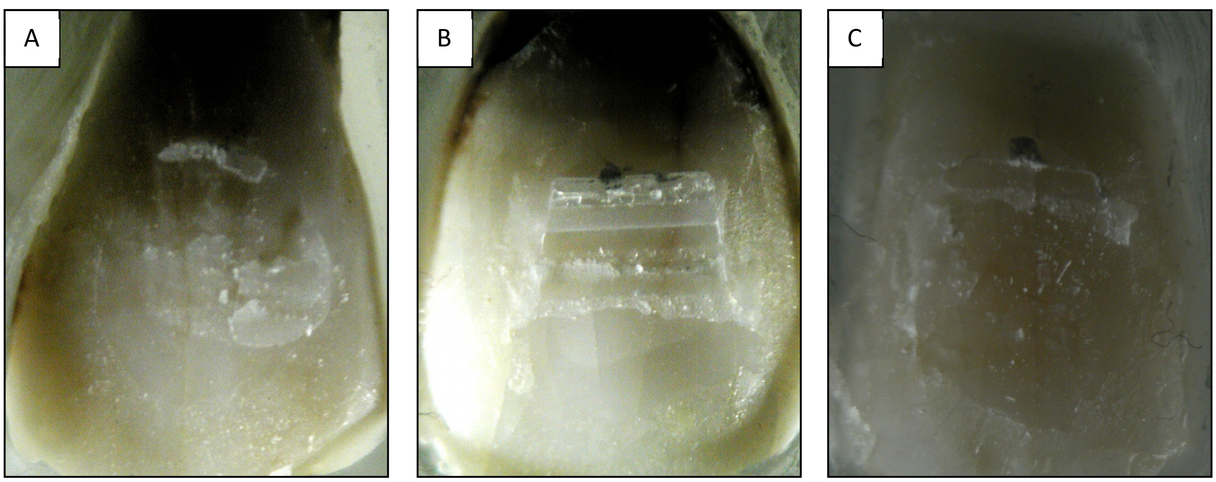

Figure 2: Enamel surfaces after brackets debonding. A: Encore, B: Reflection, and C: Pure ceramic brackets.

Most bond strength values found in the present study are above the minimal force levels suggested by Reynolds[15,16] for a successful clinical bonding (5.9 to 7.8 MPa). Brackets with excessively high bond strength may not be advantageous because of the higher risk of enamel damage during debonding. Retief[17] reported enamel fractures in specimens within vitro bond strength values of 9.7 MPa. Despite aging that occurred intra oral may reduce the strength and modify the failure mode, the results obtained from most brackets are promising, taking into account that no base primer was used. The debonding values were given both in load (Newton) and pressure units (Mega Pascal). The calculation of the bonding area based only on bracket length/width leads to a significant error. The ranking of the debonding values in N and MPa were almost the same, implying a standard effect of the bonding bases.

The failure mode analysis manifested ARI scores of 2 and 3 (enamel-covered up to 50% with adhesive resin) in most products, which complies with the failure mode of metallic brackets[18]. Winchester LJ[19] and Buzzitta et al. [20] reported that metal brackets tend to fail predominantly at the bracket-adhesive interface, which leaves the residual adhesive to be removed from the enamel surface. Ødegaard J and Segner (1988)[21] concluded that Bond failure with the ceramic bracket occurred predominantly in the enamel/adhesive interface; the failure site for the metal bracket was mainly in the bracket/adhesive interface. Kitahara-Céia et al. (2008)[22] showed that the damage evaluation comparing the same surface before bonding and after debonding showed no significant statistical difference between the mechanical retention group and the polymer base retention group.

The clarity of ceramic brackets also may be one of the factors that affect the bond strength and mode of failure (mention above). The Pure exhibited low bond strength and a high Percentage of adhesive remaining on the bracket. These values may be coming from a high Percentage of polymerization light pass through the Pure bracket due to the high translucency of polymer used, which affected the complete polymerization of the adhesive material bracket base. Although Encore has a metallic slot, due to the translucency of polymer bracket was used, leading to a minor loss of polymerization light making these brackets exhibited high bond strength with proximately 50% of adhesive remaining on the tooth.

Considering that the clinical debonding procedure of ceramic and plastic brackets involves bending distortion of the wings, just like in the metallic brackets[23], it can be concluded that the ceramic brackets tested are safe regarding enamel integrity.

Conclusions

1. New Pure, Encore, and Reflection are presented a clinically acceptable shear bond strength value (14,50,13.37 MPa), respectively, that could be compared to bond strength values for metal brackets.

2. Most of the specimens failed at the bracket-adhesive interface, which may indicate a reduced chance of enamel damage.

3. Pure gave the lowest shear bond strength, and this result may be related to the type of retentive feature not successfully like that presented in Ecore and Reflections.

4. None of the central incisors examined in this study indicated any gross enamel damage as evaluated by the enamel structure's loss.

5- The base morphology and clarity of ceramic brackets have a direct effect on shear bond strength.

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