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Shear-bond strength of orthodontic brackets to nano-hybrid composite resin using different protocols

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Abstract
Objective: The objective of this study was to test the effect of different bonding agents and surface preparation techniques on the shear bond strength values of metal orthodontic brackets on to polished nano-hybrid composite resin surface in vitro.
Materials and methods: 90 composite resin discs were prepared and thermocycled, then they have been randomly divided into six groups, metallic orthodontic brackets were bonded to these composite discs using three bonding agents: Transbond XT primer, plastic conditioner and Assure Plus, each material was used with and without sandblasting with aluminum oxide particles. After thermocycling the samples again, Shear bond strength testing was done for all six groups using universal testing machine.
Results: ANOVA test revealed a significant difference between the groups. Sandblasting significantly increased bond strength values for all three materials, moreover, Assure plus produced significantly higher bond strength values than the other two materials.
Conclusion: sandblasting and using universal bonding agents like Assure Plus are both effective methods to increase bond strength values of orthodontics brackets to composite surface.

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I. Introduction

Classically Orthodontics has been a specialty dealing mainly with children. However, recently there has been a gradual and steady increase in the number of adult patients seeking orthodontic treatment (1). As many of these patients present with fillings on the labial surfaces of anterior teeth and the buccal surface of posterior teeth, the orthodontist is a faced with the problem of bonding orthodontic brackets to these restored surfaces.

Amalgam has been the gold standard for restoring teeth for many decades, and many practitioners still use till now. However, because of its appearance, lack of proper bonding technique to tooth structures and concerns about mercury toxicity, there has been a dramatic decline in its use in the last few decades (2, 3). On the other hand, dental composite resins have greatly developed in recent years and almost replaced amalgam as a universal filling material (4). Although composite resins were initially used on anterior teeth only, nowadays they are increasingly used on posterior teeth as well because of the improved physical properties of this esthetic material (5).

Direct bonding of orthodontic attachments to enamel surface has been a regular part of fixed orthodontic therapy since 1965, when Newman has, for the first time, applied the technique of acid etching and epoxy resin bonding to directly bond orthodontic attachment to the buccal surface of teeth (6). Orthodontic Bonding techniques have quite developed since then, and now a predictable bond strength can be routinely achieved when bonding brackets to enamel (7). Unfortunately, bonding orthodontic attachment to other surfaces, including composite resin, has not been as successful.

Many chemical and mechanical surface preparation techniques have been suggested To overcome the relatively weak shear bond strength of orthodontic brackets to the composite resin and other restorative materials, (8). The aim of this study was to test the best combination of mechanical and chemical techniques to bond metal orthodontic brackets onto a polished and aged nano-filled composite resin.

II. Materials and Methods

Composite Preparation

Ninety composite resin discs were prepared from a nano-filled resin composite (Filtek nanohybrid Z- 350 3M ESPE, St Paul, Minnesota, USA), 7 mm in diameter and 2 mm in height by conventional condensation methods using a Teflon mold. A glass slab was placed on the other side to get a smooth surface. The composite was light polymerized with a light-emitting diode device (LED – conventional light-cure machine) at an intensity of 1500 mW/cm2 for 20 seconds through the glass slap at a 90-degree angle at the top of the surface.These discs were then embedded in a cylindrical acrylic mold to facilitate handling, Fig. 1. All specimens were stored in distilled water for one day at 37°C and then thermo-cycled (1000 cycles, 5–55°C). During thermocycling, the dwell time for the specimens in each well was 30 seconds and the transfer time between the wells 4 seconds.

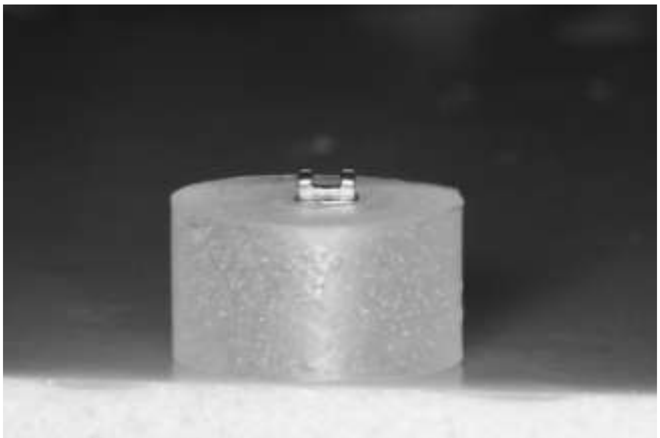

Fig. 1, bracket bonded to composite disc which is embedded in an acrylic mold

Composite surface preparation methods

The specimens (90 discs) were randomly assigned into one of the six groups of 15 discs each, as follows:

Non-sandblasted groups:

1- Transbond Group (Transbond, TB)

Following the manufacturer's instructions, a thin uniform coat of Transbond XT primer was applied using a brush.

2- Plastic Conditioner Group (Plastic Conditioner, PC)

Following the manufacturer's instructions, a coat of Plastic Conditioner was applied using a brush. The surface was allowed to air dry for 60 seconds. A thin uniform coat of Transbond XT primer was applied using a brush.

3- Assure Plus Group (Assure Plus, AP)

Following the manufacturer's instructions, one coat of assure plus Universal bonding resin was rubbed onto the surface for 20 seconds. The surface was dried for five seconds using an air-water syringe, and then light-cured with a LED light-curing unit for 10 seconds.

Sandblasted groups:

The discs were sandblasted with 50 mm AI2O3 particles for 10 seconds using a Microetcher (Danville Engineering Inc., Danville, California, USA) at a distance of 10 mm. Then these groups were treated with same agents as the first three groups and as follows:

4- Sandblasting and Transbond Group (SB + TB)

Following the manufacturer's instructions, a thin uniform coat of Transbond XT primer was applied using a brush.

5- Sandblasting and Plastic Conditioner Group (SB + PC)

Following the manufacturer's instructions, a coat of Plastic Conditioner was applied using a brush. The surface was allowed to air dry for 60 seconds. A thin uniform coat of Transbond XT primer was applied using a brush.

6- Sandblasting and Assure Plus Group (SB+ AP)

Following the manufacturer's instructions, one coat of Assure Plus Universal bonding resin was rubbed onto the surface for 20 seconds. The surface was dried for five seconds using an air-water syringe, and then light-cured with a LED light-curing unit for 10 seconds.

Bonding Procedure

An orthodontic adhesive (Transbond XT, 3M Unitek) was used to bond the metal brackets to the surface of the composite discs; the brackets were central incisor bracket (Gemini 3M Unitek brackets). According to the manufacturer, the surface area for the brackets were 10.52 mm^2. After bonding procedure, the specimens were stored in distilled water for one week then thermo-cycled (1000 cycles, 5–55°C) again before SBS testing.

SBS testing was performed using a universal testing device. For shear testing, the specimens were stressed in an occluso-gingival direction at a crosshead speed of 0.5 mm/minute, as illustrated in Fig. 2. The maximum load necessary to debond was recorded in Newtons and then converted to megapascals (MPa) as a ratio of Newtons to the surface area of the bracket base.

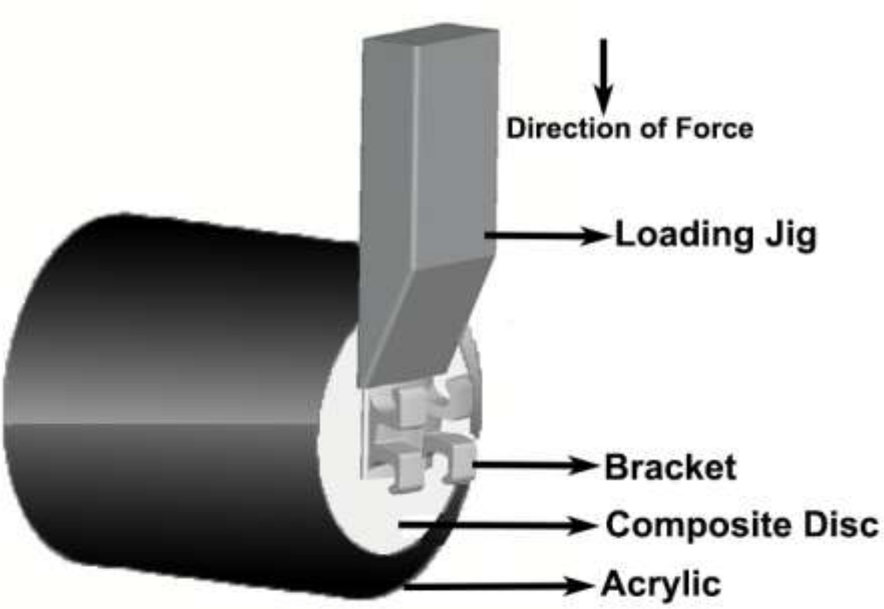

Fig 2 Schematic illustration of the SBS testing

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 23 (IBM Corp., Armonk, N.Y., USA). One-way analysis of variance was used to determine whether there is a significant difference in shear bond strength among the groups, a post hoc Tukey's test was then used to test if there is a significant difference between each individual pairs of the six groups.

Results

Descriptive statistics are shown in Table 1. Mean SBS values for all groups are also represented graphically in Figure 3. The lowest mean shear bond strength can be seen in Transbond group (6.27 MPa), The highest mean SBS value strength achieved in sandblast + assure plus group (12.04) MPA.

ANOVA testing revealed that there is a statistically significant difference in mean SBS values among the groups (F= 16.023, P = 0.000), so the null hypothesis that there is no difference in shear bond strength between the groups was rejected.

The result of post-hoc Tukey test (last column of Table 1) revealed that there is no statistical difference between TB group and PC group. Also, there was no statistical difference between SB + TB group, SB + PC and AP groups. However statistical differences were found between SB + AP and all other groups.

Table 1 Desriptive statistics (Mean, standard deviation, standard error and range) of SBS values for all groups, and the result of comparion between groups.

Groups	Mean (MPa)	SD (MPa)	SE (MPa)	Range (MPa)	Tukey*
TB	6.27	2.09	0.54	2.85 - 10.46	A
SB+TB	9.00	2.12	0.55	4.75 - 11.41	B
PC	6.40	1.81	0.47	2.85 - 9.51	A
SB+PC	9.38	1.64	0.42	6.65 - 12.36	B
AP	8.87	1.59	0.41	5.70 - 11.41	B
SB+AP	12.04	2.89	0.75	7.61 - 16.16	C

* Each letter represents a category of groups without significant difference, while groups with different letters are significantly different from each other according to Tukey's test.

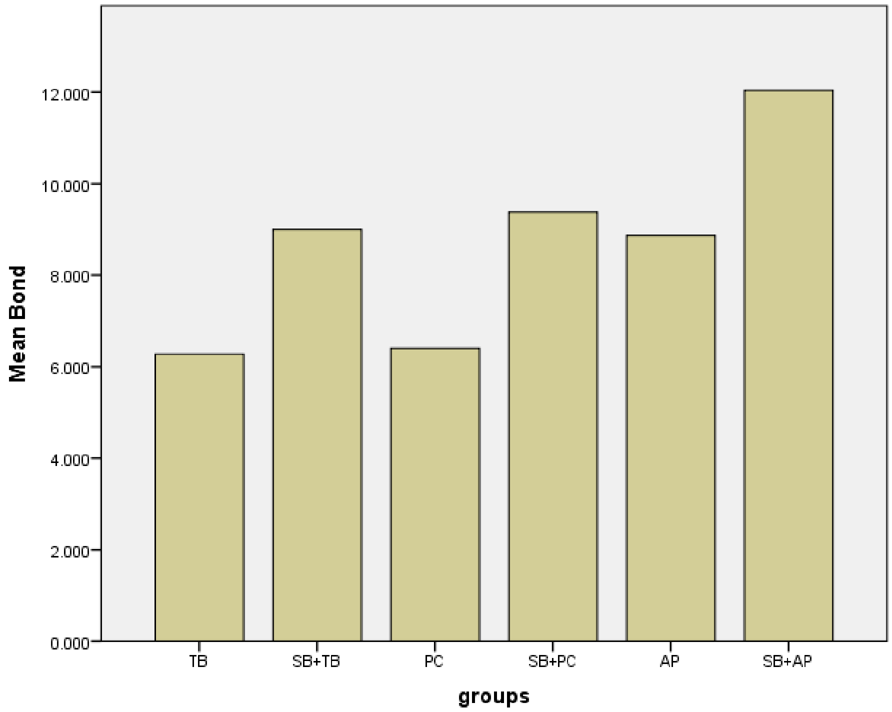

Fig. 3 Chart showing SBS values in MPa of orthodontic brackets to composite resin surface prepared with different methods.

III. Discussion

Bonding orthodontic brackets to composite resins using an intermediate adhesive is possible through two main mechanisms: First, Chemical bonding of the adhesive to the matrix or exposed filler particles of the composite resin, second micromechanical retention caused by penetration of the monomer components to microcracks in the matrix (9).

However, both chemical and micromechanical bonding to an existing old polished composite restoration can be a challenging task. Regarding chemical bonding, It is known that chemical bonding of two layers of composite resins depends on the presence of a reactive layer of unpolymerized methacrylate groups on the surfaces (10). Old composite restorations do not have this layer of unpolymerized resin because it is diminished with time, making chemical bonding to old composite more difficult than bonding to fresh composite(11, 12). Micromechanical retention to old composite, on the other hand, is also difficult to achieve because conventional acid etching technique with a phosphoric acid used routinely to modify enamel surface, has been proved to be quite ineffective when used on the composite surface (13, 14). That is why we decided to disregard acid etching technique from our study.

Composite restoration and bonded brackets in the oral cavity are subjected to the harsh conditions of the intra-oral environment. The absorption of water by the composite resin from the inherently wet oral cavity will greatly affect physical and chemical properties of the composite resin(15). In addition, the constant fluctuation of the intra-oral temperature also affect the properties of the composite and disregarding this fact could lead to serious errors and prevent honest simulation of this environment in in-vitro studies which is necessary to get clinically relevant results.

Two of the commonly used techniques to simulate these conditions in in-vitro studies are thermocycling and immersion in water (16). Both of these methods has been employed in our study. Thermocycling has been shown to adversely affect shear bond strength of orthodontic brackets(17, 18) However there is no agreement regarding the exact protocol that will produce the most accurate results. In our study, we chose to thermocyle the samples for 1000 times before bracket bonding and another 1000 times after bonding.

Our study was conducted to compare the effectiveness of three bonding agents, Transbond XT primer, Plastic Conditioner and Assure plus with and without sandblasting for each one of them. Transbond XT is a widely used orthodontic adhesive resin; it is used in most studies regarding orthodontic bonding as a standard material. Plastic Conditioner is an adhesion promoter, and is applied to the surface of a composite resin or acrylic appliance prior to bonding. Assure plus is marketed as a universal orthodontic bonding resin,or “All Surface Bonding Resin” to enhance orthodontic bonding to a variety of surfaces including enamel, atypical enamel, metal, composite resin, ceramics and amalgam. No other studies that we aware of has compared between these three materials with and without sandblasting.

During the clinical function, bonded brackets are subjected to relatively heavy mechanical stresses, and the bond strength must be enough to withstand these functional stresses and resist bond failure, which is a frustrating experience for both the clinician and the patient. Reynolds (19) suggested that a shear bond strength value of 6 – 8 Mpa is clinically acceptable. However, we should be careful when we compare shear bond strength values from in-vitro studies to those of Reynolds, because it is known that shear bond values in in-vitro studies are generally higher than their counterparts obtained in-vivo.(20). In our study, all groups exceeded the minimum bond strength values suggested by Reynolds, although TB and PC groups were close to the lower limit.

According to our results, lower shear bond strength values were found in all the groups without micromechanical roughening when compared with the corresponding groups using the same material but with micromechanical roughening via sandblasting. These findings are in agreement to what has been found by Bayram et al(21), who found lower shear bond strength value when using Transbond XT primer alone when compared with the same material but with roughening either by bur or sandblasting with aluminum oxide particles. These results also come in agreement with results of Demirtas et al. (14), who used micro-hybrid composite but reached the same conclusion: mechanical roughening with a bur or sandblasting lead to significant increase in bond strength. These consistent findings should not be surprising, because as we have mentioned any method that creates micro-holes and cracks on the surface of the composite, which can be penetrated by unfilled resin, will lead to increase in shear bond strength. Several other studies have confirmed these findings. (8, 22-25). Since diamond bur and sandblasting with aluminum oxide particles are both proved methods to achieve mechanical roughening on the composite surface, we have opted to include only sandblasting in our study as we believe it is gentler to the composite surface and more controllable.

Among the three materials that we have tested the Transbond group and the plastic conditioner group got significantly lower shear bond strength values than the Assure Plus group both with and without sandblasting.

No direct comparisons to other studies can be made, as past studies have not examined the bond strengths of Assure Plus to existing composite resin restorations. This significant difference can not easily explained because the exact chemical formula of Assure Plus, as well as many commercial bonding agents, is proprietary and not well known (26). It could be a component added to the bonding agent that increases the chemical bond to the matrix or filler particles in the composite, or it could an increase in the penetrability of the bonding agent due to using a monomer with a small molecular weight which will lower the viscosity, or these better bond strength values could be attributed to altering the composition of the solvent.

One of the interesting points that may have clinical relevance is that Assure Plus without mechanical roughening produced nearly similar bond strength values to Transbond and plastic conditioner groups with mechanical roughening. This similarity could provide the clinician with a choice of using Assure Plus (or may be a similar universal bonding product) without mechanical roughening or using traditional Transbond or Plastic Conditioner with mechanical roughening and get similar acceptable bond strength values.

IV. Conclusions

Within the limitation of this study, we can conclude the following:

1- Sand blasting with aluminum oxide particles is quite an effective yet simple and nonagressive method for increasing bond strength to composite resin regardless of the material used.

2- Assure plus universal bonding agent provided a significantly more bond strength than other conventional method and it is recommended to use when we want to bond brackets to composite surface.

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