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Research Article

The shear bond strength of the sapphire bracket bonded to composite restoration using different bonding agents

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Abstract: This study aimed to determine the most effective bonding system of sapphire brackets bonded to composite restoration. **Materials and Method**: Thirty composite discs (3M Filtek™ Z250) were stored in deionized water for nine days then conditioned with 37% phosphoric acid and divided into three groups based on the bonding agent: group (A) conventional bonding agent (Transbond XT™), group (B) Scotchbond™ and group (C) Assure Plus® were used, then the conventional adhesive (Transbond XT™) was applied to the base of sapphire brackets then bonded to composite discs. After bonding the composite discs, they were thermocycled for 5000 cycles, the shear bond strength (SBS) was measured, and the adhesive remnant index (ARI) was determined. **Results**: One-way ANOVA revealed no significant difference, although Assure Plus and Scotchbond showed higher SBS than Transbond, and the Kruskal-Walli's test revealed no significant difference in the ARI scores between the groups. **Conclusion**: All bonding agents produced more than the clinically acceptable shear bond strength (SBS), and all groups caused composite restoration surface fracture, indicating high SBS.

Keywords: Aged composite, Assure Plus, Orthodontics, Shear bond, Universal bonding agent

INTRODUCTION

Since bonding to restorative and prosthetic surfaces does not follow a single procedure, modifications in procedures and materials are needed to establish reliable bonding to non-enamel surfaces in a large number of adults undergoing orthodontic treatment [1]. Composite resins are widely used for decayed teeth, pit and fissure caries, abfraction defects, diastema closure, building up peg laterals, and composite veneers due to their superior esthetics [2]. Thus, maxillary incisors and posterior teeth often have composite restorations on their buccal surfaces. Methacrylate groups in the non-polymerized resin layer that is oxygen-inhibited on the composite surface help the composite resin adhere to the surface [3]. The cohesive strength of the composite is the same as the new composite, and incremental composite repair is possible, the methacrylate layer is absent from polished, aged, or saliva-contaminated composites[4]. Since traditional bonding techniques for bonding orthodontic brackets to restoration surfaces are ineffective in multiple studies, researchers have focused on adhesion to restoration surfaces and tested various techniques and materials [5]. Multiple surface preparation techniques have been indicated to deal with the problems of bonding orthodontic brackets to an aged composite, such as mechanical methods, which include diamond bur roughening, laser, and sandblasting [6]. Silanation, hydrofluoric acid etching, and prolonged phosphoric acid etching are examples of chemical processes [7]. Scotchbond™, a multi-mode adhesive, can be used for self-etching and etch and rinse [8], which can bond to enamel, dentin, composite, amalgam, and porcelain, according to the manufacturers. Assure Plus, a new product, is claimed to bond to amalgam, porcelain, composite, and any tooth surface, including normal and abnormal enamel [9]. A few trials have shown that Assure Plus, a new adhesive, improves SBS [10]. More evidence-based research is required because the product is relatively new and there are not enough of these studies available [11].

It's important to create treatment protocols that are as efficient as possible and time-saving for a successful workflow. In the prosthetic field of dentistry, one-step adhesives were created due to the necessity for materials to produce acceptable bonding strength; these materials may reduce orthodontic equipment costs and time [12].

Enhancing the bond strength of the bracket to composite resin depends more on the kind of bracket rather than the kind of bonding agent, sapphire brackets have the best shear bond strength when compared to other brackets because sapphire brackets' translucency provides a better opportunity for the adhesive to fully polymerize with light curing [13]. The bond must be strong enough to withstand the stresses in the wet oral environment and be able to be removed at the end of the procedure without

leaving behind any residue or damaging the surface [14]. SBS between 4 and 10 Mega Pascal (MPa) have been recommended for bonding to enamel, but there are no recommendations for bonding to various restorative materials [12]. From a clinical perspective, restorative materials should have SBS at least as high as enamel to reduce bracket loss [12]. Constant loads on brackets are applied by chewing stresses and temperature changes in the oral environment, but these loads are smaller than the static bracket bond strength, because bracket debonding can occur when subjected to such periodic stresses repeatedly throughout treatment, studies assessing bond strength between brackets and tooth enamel in a laboratory setting are necessary [15].
Orthodontic research is currently focused on reducing the amount of working time spent during bonding and debonding without compromising the ability to keep a clinically effective bond strength **[16]**. Therefore, the purpose of this study was to determine the most effective bonding agent (Scotchbond, Assure Plus, or Transbond) for bonding sapphire brackets to composite restoration. The null hypothesis was that the type of the bonding agent has no significant effect on the SBS and the ARI of sapphire bracket bonded to composite restorative material.

MATERIALS AND METHODS

The present study was an *in vitro* experimental investigation that involved the use of 30 composite discs (3M™ Filtek™ Z250, St. Paul, USA), constructed with a plastic mold (10 mm diameter and 4 mm length). The composite was loaded on a glass slide in two layers of 2mm and the last layer was loaded in the mold and covered by a celluloid strip and glass slide, and slightly pressed; each layer was cured by a light-emitting diode (Woodpecker® China) for 20 seconds [**2**] to obtain composite discs with a flat surface (figure 1). The sample size was calculated with the statistical package G* power (3.1.9.4) using α=0.05, β=0.2 and 80% study power (each group had 10 samples).

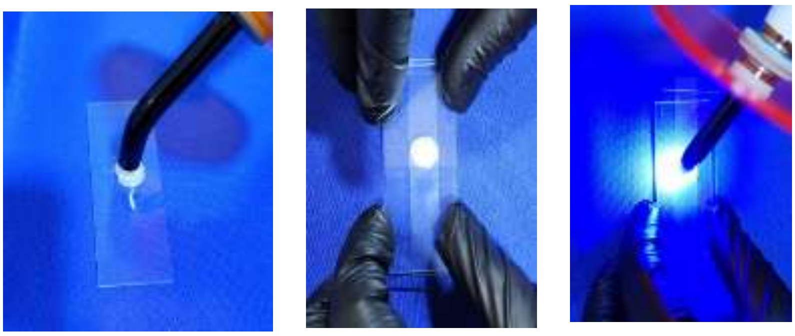

Figure (1): Construction of composite disc

Acrylic blocks were constructed from cold cure acrylic to hold the sample, the blocks were made by using a silicone mold with a cylindrical projection of 10 mm diameter and 4 mm to make a depression for embedding the composite discs, the depression in the acrylic block was painted with a thin layer of cyanoacrylate adhesive so that the composite disc was fitted closely in the depression made in it then a load of 200gm was placed over it with force gauge to extrude the excess adhesive, the surface of composite discs was polished with silicone polishing burs for composite [12], after that the samples were stored in deionized water at 37° for 9 days [17].

The composite discs were acid-etched by phosphoric acid gel 37% for 30 seconds and then divided into three groups:

1. Group A (n=10): Transbond XT (3M Unitek, Monrovia, Calif, USA) primer was applied to the composite disc and cured for 10s [12]
2. Group B (n=10): Scotchbond Universal (3M Deutschland, Gmbh, Neuss, Germany) was coated with one layer, rubbed for 20s, air dried for 5s, and light cured for 10s [18]
3. Group C (n=10): Assure Plus (Reliance Orthodontic Products, Itasca, Illinois, USA) was coated and air-dried for 5s and light cured for 10s [**19**]

Small amount of the adhesive paste (Transbond XT, 3M Unitek, Monrovia, Calif, USA) was applied onto the bracket base (upper right central IOS sapphire bracket) and placed in the center of the composite discs with a clamping tweezer.

A surveyor applied 200 gm to the bracket for 10 seconds (Figure 2) to ensure uniform adhesive thickness. Any excess bonding material was carefully removed from around the bracket base with a dental probe without disturbing the seated bracket and the bonding material [20]. The adhesive was then light-cured for 40 seconds (20 seconds on each side of the bracket) [21]. A curing light meter (Woodpecker® China) was used periodically to check the curing light's intensity before use [22].

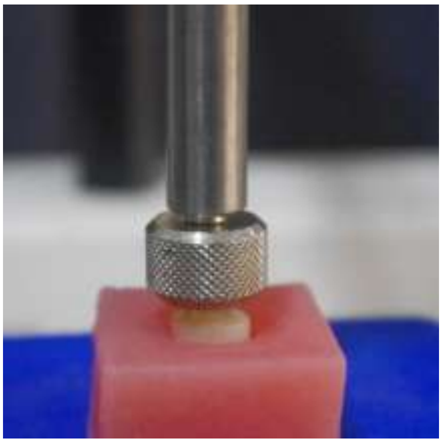

Figure (2): bracket bonding

After bracket bonding, samples were incubated in distilled water at 37°C for 24 h. After that, they were thermocycled 5000 times between 5°C and 55°C in cold and hot water baths with a dwell time of 30 s [23]. A universal testing device (Tinius Olsen universal testing machine, China) with a 50 KgF load cell and 0.5 mm/min crosshead speed at College of Dentistry performed the shear bond strength test, the test was accomplished in laboratories of the University of Technology/ Department of materials engineering [24]. The shearing force was applied in an occlusal gingival direction at the bracket/composite surface interface until debonding occurred (Figure 3). The bond strength was determined in MPa by dividing the maximal force in Newton by the bonding surface area in mm^2. The shear bond strength was calculated using the equation S = F/A. To calculate the adhesive remnant index, the debonded bracket and composite disc blocks were retained in the labelled containers.

Figure (3): Debonding of the bracket

The stereomicroscope (Meiji™, Japan) was used to check the composite disc surfaces and bracket base at tenfold magnification [25]. According to Artun and Bergland, the site of bond failure was scored depending on the amount of remaining adhesive [26]. The range is between 0 and 4 as follows [**12**] (Figure 4): score 0 = no adhesive remains on the tooth, score 1 = less than 50% adhesive remains on the tooth, score 2 = more than 50% adhesive remains on the tooth, score 3 = all adhesive is remaining on the tooth, score 4 = surface fracture.

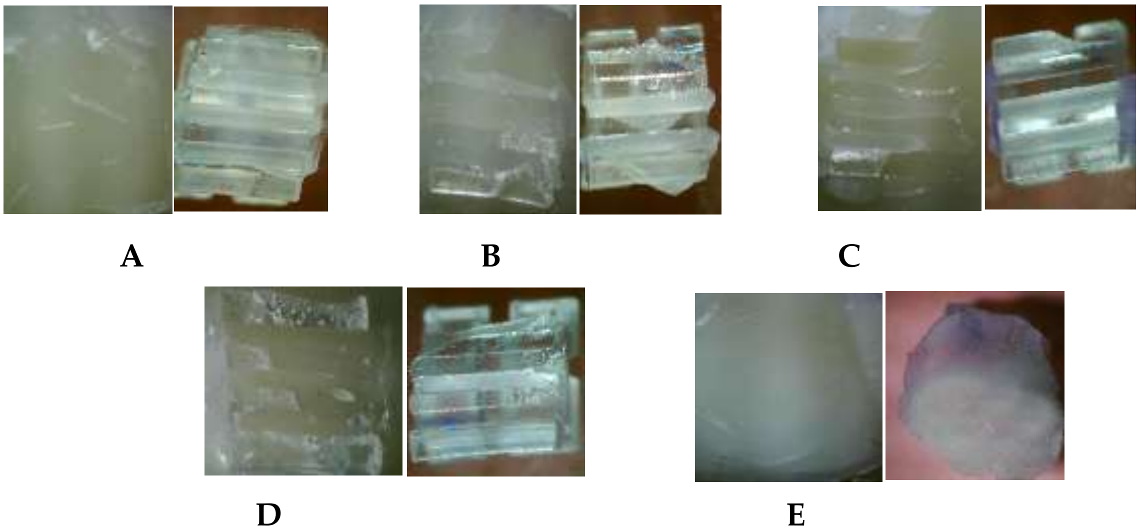

Figure (4): ARI Scores: A (score0), B (score1), C (score2), D (score3), and E (score4)

Regarding the estimation of the bond failure site, the researcher examined 10 specimens, and re-examination of the same specimens was made after one month for intra-examiner calibration and then well-trained orthodontist examined the same specimens to evaluate inter-examiner calibration.

The intra and inter-examiner calibration's excellent reliability is shown in Table 1).

Table (1): Intraclass correlation coefficient (ICC) to evaluate the intra-examiner and inter-examiner reliability of ARI measurements.

Calibration	ICC	95% CI
Intra- examiner	0.98	0.92- 0.99
Inter -examiner	0.95	0.83- 0.98

ICC value < 0.5 = poor reliability
ICC value 0.5-0.75= moderate reliability
ICC value 0.75 and 0.9 = good reliability
ICC value > 0.90 = excellent reliability

Statistical analysis

1- Testing the normality of data distribution, the distribution of the data will be evaluated for normality using the Shapiro-Wilk's and Kolmogorov-Smirnov tests.
2- Descriptive statistics of the shear bond strength test, The means, standard deviations, minimum and maximum values of the shear bond strength.
3- Inferential statistics of the shear bond strength test
a- One-way analysis of variance (ANOVA): To test any statistically significant difference among the shear bond strength of the groups.
b- The Kruskal Wallis test: used to determine significant differences in the ARI scores among the groups.

In the statistical evaluation, the following levels of significance will be used:

Non-significant NS P > 0.05
Significant S 0.05 ≥ P > 0.01
Highly significant HS P ≤ 0.01

The data collected from the experimental study were managed statistically to test the shear bond strength and the adhesive remnant index (ARI) after debonding of sapphire brackets. Data were analyzed using the statistical package of social science, SPSS (IBM Company, New York, USA) software version 26.

RESULTS

The Shapiro-Wilk and Kolmogorov-Smirnov tests determined data distribution normality (P-value>0.05) (Table 2); the data were normally distributed.

Table (2): Normality tests

	Kolmogorov-Smirnov	Shapiro-Wilk
A	.200	.932
B	.200	.568
C	.200	.740

* A (Transbond™), B (Scotchbond™) and C (Assure Plus®).

Descriptive statistics of SBS in the studied groups are presented in (Table 3), among all groups, the highest shear bond strength was revealed by Assure plus (19.68 MPa) followed by Scotchbond (19.36 MPa) while Transbond produced the lowest SBS (17 MPa).

Table (3): Descriptive statistics of the shear bond strength test of the groups

Group	Mean [MPa]	SD	Min	Max
A	17	3.78	10.86	23.59
B	19.36	5.34	11.57	26.71
C	19.68	4.88	12.46	29.38

*SD (standard deviation), Min (minimum), Max (maximum), A (Transbond™), B (Scotchbond™) and C (Assure Plus®).

The data were normally distributed, so one-way analysis of variance (ANOVA) was used to compare the average differences in SBS between groups. The results showed no significant difference in the mean value of SBS between all studied groups (F=0.965, P-value>0.05) (as shown in Table 4):

Table (4): Comparison of shear bond strength means between and within groups by ANOVA

shear bond	Sum of Squares	df	Mean Square	F	p-value
Between Groups	42.835	2	21.418	.965	.394
Within Groups	599.120	27	22.190		
Total	641.955	29			

*d.f. (degree of freedom)

The frequencies of the adhesive remnant index as shown in Table 5, score 0 did not appear in any group, and score 1 had 6.6% which was observed only in the Transbond and Assure plus groups, while scores 2 and 3 had the highest percentage of 33.3%, and score 4 of 26.6% was observed in Transbond group in less percentage than Scotchbond and Assure plus groups.

Table (5): The Frequency distribution and percentages of ARI scores in the groups.

Group	Score 0	Score 1	Score 2	Score 3	Score 4
A	0(0%)	1(10%)	3(30%)	4(40%)	2(20%)
B	0(0%)	0(0%)	4(40%)	3(30%)	3(30%)
C	0(0%)	1(10%)	3(30%)	3(30%)	3(30%)
Total	0(0%)	2(6.6%)	10(33.3%)	10(33.3%)	8(26.6%)

*A (Transbond™), B (Scotchbond™) and C (Assure Plus).

The Kruskal–Wallis's test showed no statistically significant differences in the adhesive remnant index between the groups (P-value>0.05) (Table 6):

Table (6): Comparison of the ARI scores between groups using the Kruskal-Wallis's test

	df	**P-value**
Kruskal-Wallis test	2	.922

*df= (degree of freedom)

DISCUSSION

In the adult population, there has been a gradual increase in the need for orthodontic treatment who have had their teeth restored using different restorative materials, such as composite resin, amalgam, and porcelain. When bonding orthodontic attachments to certain surfaces, orthodontists are more likely to encounter issues. Due to improvements in the esthetic filling materials' qualities, posterior teeth now receive composite resin restorations more frequently [27]. The sapphire bracket is used by patients who want their orthodontic appliances to be almost indistinguishable [28].

The orthodontic adhesive cannot form a chemical bond with an old composite restoration because it lacks the reactive layer of unpolymerized methacrylate groups on its surface [29]. In order to improve the bond between existing composite restorations and orthodontic brackets, a number of chemical and mechanical procedures were suggested [3].

Intraorally, composite resin restorations remain wet, and the water absorption of composite resin restorations results in various adverse effects, including surface degradation, softening of the resin matrix, loss of filler particles, microcrack formation, and chemical degradation of the resin [30]. A systematic review and meta-analysis of orthodontic bonding studies found that most in vitro studies store specimens in distilled water, and some use artificial saliva [31], but the aging media did not significantly affect SBS and ARI [**32**]. Junior et al. (2009) calculated the number of days it would take to saturate an 8mm x 8mm x 4mm block of composite resin (FiltekTM Z250) using the water diffusion coefficient and reported that nine days are required for studies concerning the surface of the composite resin [17]. This study artificially aged composite resin restorations in deionized water for nine days before orthodontic bracket bonding because surface studies only required nine days.

All groups in this study demonstrated SBS more than 6-8 MPa, which is the same value reported by Reynold [33]. According to another research, the detachment of brackets is observed in 5% of cases where brackets are bonded with 5.4 MPa SBS [34]. The clinical approach of optimal bond strength requires (1) reducing unexpected debonding during treatment and (2) achieving an intact surface after debonding. Moreover, it is essential to evaluate the bonding efficacy in clinical settings because of various factors associated with the oral environment [35]. Assure Plus revealed the highest SBS, followed by Scotchbond, while Transbond produced the lowest SBS [36].

Papacchini et al. (2007) found that composite repair with bonding resin had 38.2 MPa bond strength compared to 24.5 MPa without it [37]. Staxrud et al. 2011 found that bonding resin increased composite-composite bond strength from 9.9 MPa to 26 MPa, which is consistent with our findings [4]. There were no statistically significant differences in the mean values of bond strengths for the three bonding agents tested in this study but the SBS of Assure Plus and Scotchbond was higher than the conventional primer. This may be because unfilled, low-viscosity liquid monomer bonding resins can penetrate substrate microporosities deeper than highly filled, viscous orthodontic adhesives [38].

Bayram et al., 2011, found that Transbond with phosphoric acid etching had the lowest SBS which agrees with our findings, however, the authors have documented a bond strength of 3.71 MPa, which was observed to be considerably lower than the findings of our investigation. This could potentially be attributed to the utilization of metal brackets and a faster crosshead speed (1mm/min) during the debonding process [2].

Buyukcavus et al., 2022 also noted that Transbond produced the weakest bond (7.52 MPa) but also lower than our reported result which may be due to using a nano-filled resin composite (Filtek Supreme Ultra 3M ESPE), faster crosshead speed (1mm/min) and using molar tubes with different base design instead of sapphire bracket [11].

A previous study by Hadrous et al., 2019, showed that the SBS of Assure Plus and conventional primers were approximately the same which disagrees with our findings in which Assure Plus showed higher SBS than the conventional primer this may be attributed to that the study was performed on enamel not on composite resin [39].

Farhadifard et al., 2020 did not report clinically acceptable range of SBS in the control group bonded with Transbond primer (5.07 MPa), which disagrees with our results this may be due to the different aging procedure of composite discs [40].

After SBS testing, determining the material failure site and assigning ARI scores is necessary [41]. Some authors prefer bracket-adhesive failure to reduce tooth or restorative surface fracture [42]. The removal of adhesive material is more extensive in cases of bond failure occurring at the interface between the bracket and adhesive (score 3) as compared to restoration-adhesive failure (score 0). The best bonding methods lower bond strength while maintaining it within a clinically acceptable range and leaving no or little adhesive remnant to reduce enamel damage [43].

This study's ARI scores showed that adhesive-bracket interface bond failure was the most prevalent. Bond failure at the restoration-adhesive interface was reduced, reducing damage risk. Tse (2012) found that Scotchbond™ and Assure Plus® had a higher incidence of surface fracture than orthodontic bonding resin Transbond™, which is consistent with our findings [44]. While Bayram et al. (2011) showed an ARI score of 0 in all samples bonded with Transbond™ XT without surface preparation, which disagrees with our finding in which higher scores were seen, this may be attributed to the different aging procedure of the composite resin restoration [2].

It is important to keep in mind that oral clinical circumstances, where there is significant variation in humidity, stress, temperature, and acidity, do not exactly express in vitro conditions. Long-term clinical trials are required to verify the bonding effectiveness of the items evaluated in this research under laboratory conditions.

CONCLUSIONS

Within the constraints of the current study, it is possible to conclude that:

1. Sapphire brackets that had been bonded showed surface fracture, indicating an extremely strong bond between the bracket and composite.
2. Assure Plus and Scotchbond primers produced shear bond strength higher than Transbond.
3. All tested groups produced above the clinically acceptable range of SBS.

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Ethical statement: The College of Dentistry at the University of Baghdad's Research Ethics Committee gave its approval to the study (Reference number: 612/612422).

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

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قوة الترابط لقوس الياقوت الملتصق بالترميم المركب باستخدام عوامل ربط مختلفة

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الملخص

الاهداف: الهدف من هذه الدراسة هو تحديد نظام الترابط الأكثر فاعلية لحاصرات الاسنان التقويمية نوع الياقوت الملتصقة على حشوة الكومبوزت. **المواد وطرائق العمل**: تم تخزين ثلاثين قرصًا مركبًا (3M Filtek ™ Z250) في ماء منزوع الأيونات لمدة تسعة أيام ثم تمت تهيئتها بحمض الفوسفوريك بنسبة 37٪ وتم تقسيمها إلى ثلاث مجموعات بناءً على عامل الترابط: المجموعة (أ) عامل الترابط التقليدي (Transbond XT ™) ، المجموعة (ب) تم استخدام Scotchbond ™والمجموعة ®Assure Plus (C) ، ثم تم وضـــع المادة اللاصـــقة التقليدية (Transbond XT ™) وتم ربط حاصرات التقويم الياقوتية بأقراص حشوة الكومبوزت. بعد الترابط ، تم تدوير الأقراص المركبة حرارياً لمدة 5000 دورة ، وتم قياس قوة رابطة القص (SBS) ، وتم تحديد مؤشر بقايا المادة اللاصقة(ARI) **النتائج**: كشف ANOVA أحادي الاتجاه واختبار Tukey اللاحق أنه لا يوجد فرق كبير على الرغم من أن اختبار Assure Plus و Scotchbond أظهروا SBS أعلى من Transbond ، كشف اختبار Kruskal-Wallis عدم وجود فرق كبير في درجات ARI بين المجموعتين. **الاســـتنتاجات**: أنتجت جميع عوامل الترابط قوة رابطة القص مقبولة ســـريريًا (SBS) وتســـبب جميع المجموعات كسرًا في السطح يشير إلى ارتفاع.SBS