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Comparison of Shear Bond Strength of Self-Adhesive Resin Cement and Conventional Resin Cement Bonded to Lithium Disilicate Glass Ceramic with Different Surface Treatments: In Vitro Study

Mumtaz A. Sadeeq *[1], Abdulkareem R. Ibrahim [2]

[1, 2] Department of Conservative Dentistry, College of Dentistry, University of Duhok/ Iraq

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***Correspondence:**
E-mail: mumtaz.abdulazeez.sadeeq @gmail.com

Abstract

Aims: to measure the shear bonding strength of self-adhesive resin-cement bonded to lithium disilicate glass-ceramic with different surface treatments and compare it with that of conventional resin-cement. **Materials and Methods:** eighty circular blocks (10mm-diameter x 3.0mm-thickness) of IPS e-max Press ceramic, were fabricated in accordance with the manufacturer's instructions. The samples were divided into four main groups (n=20) according to surface treatments: group A no surface treatment, group B sandblasting with 50-µm alumina particles for five seconds under two bars of pressure using a sandblasting device, group C acid-etching with 9% hydrofluoric acid for 20-seconds, followed by rinsing with distilled water, group D combination by sandblasting with 50-µm alumina particles as in group B and then were etched with 9% hydrofluoric acid as in group C. For the bonding procedure, each main group was divided into two subgroups (n=10) according to the types of resin cement that were used: sub-group1: specimens were prepared by applying one layer of silane on the ceramic surface. The single bond universal was applied by micro-brush. Then specimens were light cured, next, 2-mm-long transparent plastic tubes with 4-mm diameter were placed on the ceramic surface, and filled with conventional resin-cement, it was light-cured, sub-group2: 2-mm-long transparent plastic tubes with 4-mm diameter were placed on the ceramic surface and filled with self-adhesive resin-cement, then were light-cured, and the shear bond strength was tested using the universal testing machine. The results were analyzed statistically. **Results:** Comparisons of shear bonding strength between total conventional and self-adhesive groups show that the highest mean was in the conventional adhesive group (49.13 ±3.05), while the lowest mean was in the self-adhesive group (26.51 ±2.16). **Conclusions:** With all surface treatments, self-adhesive resin-cement had a lower mean shear bond strength than conventional resin-cement.

مقارنة بين قوة رابطة القص للأســمنت الراتنجي ذاتي اللصــق والأســمنت الراتنجي التقليدي المرتبط بالســيراميك الزجاجي ثنائي ســيليكات الليثيوم مع معالجات ســطحية مختلفة: دراسة في المختبر

الملخص

الأهداف: قياس قوة الربط الانزلاقي للأسمنت الراتينج ذاتي اللصق المرتبط بالسيراميك الزجاجي ثنائي سيليكات الليثيوم مع معالجات سطحية مختلفة ومقارنتها مع تلك الخاصة بأسمنت الراتينج التقليدي. **المواد وطرائق العمل:** تم تحضير ثمانون عينة دائرية (قطر 10 مم × سمك 3 مم) من السيراميك المضغوط (IPS e-max)، وفقًا لتعليمات الشركة المصنعة. تم تقسيم العينات بشكل عشوائي إلى أربع مجموعات رئيسية (ع = 20) حسب معاملات السطح على النحو التالي: (1) المجموعة أ: بدون معالجة سطحية، (2) المجموعة ب: استعمال رشاش الرمل (sandblasting) مع جزيئات اوكسيد الالمنيوم حجم 50 مايكرون، (3) المجموعة ج: استعمال حامض الهايدروفلوريك 9% لمدة 20 ثانية، (4) المجموعة د: استعمال رشاش الرمل كما في المجموعة ب مع حامض الهايدروفلوريك 9% كما في المجموعة ج. لغرض اللصق، تم تقسيم كل مجموعة رئيسية إلى مجموعتين فرعيتين وفقًا لأنواع الأسمنت الراتينج المستخدم وعلى النحو التالي: (1) المجموعة الفرعية 1 (ع: 10): تم تحضير العينات في هذه المجموعة الفرعية عن طريق تطبيق طبقة واحدة من (silane) على سطح السيراميك. ثم تم تطبيق مادة اللاصق (single bond universal) بواسطة فرشاة دقيقة. تم بعد ذلك معالجة العينات بالضوء ، بعد ذلك ، تم وضع أنابيب بلاستيكية شفافة بطول 2 مم بقطر داخلي 4 مم على سطح العينات ، وتم ملئ الانابيب بمادة إسمنت الراتينج المعالج بالضوء (Variolink Esthetic LC)، وثم معالجته بالضوء، (2) المجموعة الفرعية 2 (ع: 10): تم وضع أنابيب بلاستيكية شفافة بطول 2 مم بقطر 4 مم على سطح العينات وتم تعبئتها بأسمنت الراتينج ذاتي اللصق (Speed CEM Plus) ، تم معالجته بالضوء ، وتم اختبار قوة الرابط الانزلاقي لكل عينة باستخدام جهاز(universal testing machine). وثم تم تحليل النتائج إحصائيا. **النتائج:** تُظهر مقارنات قوة الربط الانزلاقي بين مجموع المجموعات التقليدية واللصق الذاتي أنه تم اكتشاف أعلى متوسط لقوة الرابط الانزلاقي في مجموعة اللصق التقليدية (49.13 ± 3.05) ، بينما تم اكتشاف أدنى متوسط في مجموعة اللصق الذاتي (26.51 ± 2.16). **الاستنتاجات:** مع جميع المعالجات السطحية ، كان للأسمنت الراتينج ذاتي اللصق (Speed CEM Plus) متوسط قوة رابطة قص أقل من الأسمنت الراتينج التقليدي المعالج بالضوء (Variolink Esthetic LC).

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INTRODUCTION

Lithium disilicate ceramics have become popular because they combine strength, longevity, biocompatibility, esthetics, and treatment predictability in a single restoration [(1)]. Unlike conventional feldspathic ceramic or leucite-reinforced ceramic, the seventy percent crystal phase of this distinct glass ceramic material inherently refracts light. It imparts superior structural support and superior flexural strength [(2,3)].

The success of ceramic restoration relies on a numeral of variables, including the cementation process and the ceramic material's ingredients [(4)]. The main function of the cementation is to make reliable retention and a tough seal of the space between the tooth and the restoration. Depending on the chemical composition of the cementing agent and the nature of pretreatment of both the tooth surface and the indirect restoration, adhesion may be gained by a chemical or micromechanical retention, or both [(5)]. To improve the adhesion of resin to ceramic, various ceramic surface treatments have been developed. It may be adhesively cementing a lithium disilicate glass-ceramic, however, if the retentive region is tiny, adhesion may be insufficient [(4)]. Before cementing lithium disilicate crowns, it is recommended that they be etched with hydrofluoric acid [(6)]. The second crystal phase and the glass matrix are eliminated by hydrofluoric acid, producing irregularities within the lithium disilicate crystals of the IPS e.max Press for bonding [(4,7)].

Airborne abrasion using 50-um alumina particles is another advocated procedure for ceramic surfaces in order to improve mechanical retention [(4)]. An appropriate silane must be applied to the ceramic surface after air abrasion to make chemical interactions between the ceramic's inorganic phase and the resin cement's organic phase [(4,7)].

Silane has been successfully used in dentistry to enhance the bonding capacity between ceramic and resin cement [(8,9)]. Nevertheless, excessive surface modifications can reduce the flexural strength of materials owing to surface defects that encourage the development of cracks [(10 - 12)].

Permanent luting cements involve those substances characterized by adhesive properties to different dental and/or prosthetic substances. Traditionally, luting resin cements need the implementation of a primer or a surface pre-treatment of the bonding substrates [(13)]. Resin-based luting cement was introduced first in a multistep process with inherent technique sensitivity. Later self-adhesive systems were launched to reduce potential drawbacks and reduce application time as well [(14)].

The current study aims to measure the shear bonding strength of self-adhesive resin-cement bonded to lithium disilicate glass-ceramic with different surface treatments and compare it with that of conventional resin-cement, as the use of self-adhesive resin cement aims to simplify the bonding process between the teeth structure and the indirect lithium disilicate ceramic restorations with minimal surface treatments because of severe surface modifications can reduce the flexural strength of ceramic due to surface defects that encourage the propagation of cracks. Also, to decrease the clinical time needed for the cementation process.

MATERIALS AND METHODS

Ceramic Blocks Fabrication

According to the manufacturer's specifications, a total of eighty circular blocks of IPS e-max Press ceramic, shade MT BL3 (IPS e.max Press; I voclar Vivadent, Schaan, Liechtenstein), measuring 10 mm in diameter by 3 mm in thickness, were manufactured using ceramic press technique. Polysiloxane mold was used to create the circular wax patterns, which had a 10-mm diameter and 3-mm thickness. These wax patterns were then sprued and connected to the muffle base with a surrounding paper cylinder.

Wax patterns were invested with phosphate-bonded investment material (HinnriVEST KB, Germany) using a size 1 ring. 100g of powder was mixed with 28ml of pure Ernst Hinrichs GmbH Rapid Cure Investment liquid and was allowed to set for 45 minutes. The mold was prepared using the lost wax technique. The ring was heated from 200°C to 900°C in one hour for the burnout in the furnace (Vulcan a-550; Degussa-Ney, Yucaipa, Ca, USA). It was then kept at the higher temperature for 30 min. Meanwhile, the pressing furnace (EP 600; Ivoclar Vivadent, Germany) was pre-heated to 700°C for 45-min. IPS-Empress ceramic ingots and the plunger were then heated in the burnout furnace for 5-10 min. The heated ingots and plunger were inserted in the heated mold and put in the pressing furnace. The temperature was elevated at the rate of 60°C/min until it reached 1075°C and was sustained for 20-min. At the finish of this cycle, the plunger pushed the ingots into the mold which was accomplished in 6-7 min. The ring was then sited under the fan cooling for a period of 45 min. The ceramic casting was divested to retrieve the pressable ceramic discs.

After cooling, to simplify handling the circular ceramic blocks during the polishing procedure custom-built plastic molds were manufactured by using plastic tubes which were cut into eighty small tubes (20-mm diameter x 20-mm length), and each ceramic block was put on glass slap, and fixed by using two-sided adhesive tape to avoid movement of the ceramic block during acrylic pouring and the plastic tube was put on the block and filled with cold-cure acrylic resin (Acrosun, Tahran, Iran).

The samples were manually wetly polished using 600, 800, 1000, and 1200 grit silicon carbide abrasive papers (Smiradix, Greece) to provide a flat and polished surface (2 minutes per each carbide abrasive paper by the same operator) [15].

Samples Grouping

The ceramic blocks were randomly divided into four main groups according to surface treatments (20 samples per group):

Group A: no surface treatment.

Groups B Sandblasting: the surfaces of ceramic blocks were treated by air abrasion with 50-um alumina particles for 5 sec under two bars of pressure by means of a sandblasting appliance (Air Abrasion Master, Stardent Equipment Co., Limited, Guangdong, China) maintained at a distance of 10 mm and perpendicular to the treated surface [16]. The distance between the nozzle and the surface was standardized with the help of a custom-made tool (Figure 1).

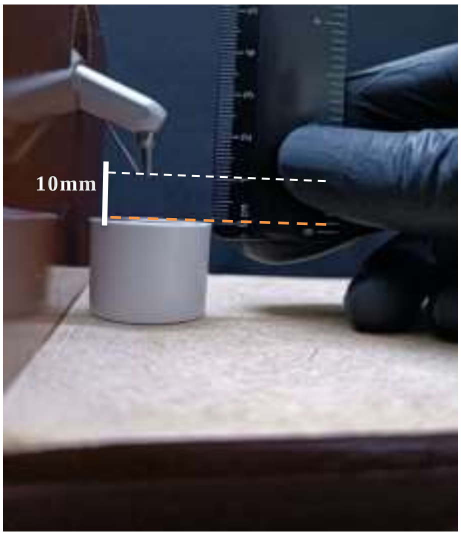

Figure (1): Custom-made tool showing the distance (10mm) between ceramic surface and nozzle and its perpendicular to the surface.

Group C Acid-etching: the test surfaces of ceramic blocks were etched with 9% hydrofluoric acid (HF) (Porcelin Etch 9%, Ultradent Products Inc., USA) for 20 sec [16,17], after which rinse for a minute with distilled water.

Group D: the test surface of ceramic blocks was combination by air particle abrasion with 50-um alumina particles as in group B and then were etched with 9% HF as in group C.

After rinsing, the samples were cleaned using ultrasonic equipment (Digital Ultrasonic Cleaner, iSonic, China) in distilled water for 20 minutes, and then dried with compressed air [18].

Bonding Procedures

A two-sided adhesive tape with a 4-mm hole in diameter was fixed on the ceramic surface of the samples to restrict the bonding area to a 4-mm diameter in order to achieve a uniform bonding procedure. Each main group were divided into two subgroups (n=10) according to the types of resin cement that were used and as follows:

Sub-group 1: specimens in this sub-group were prepared by applying one layer of silane (Monobond N, Ivoclar Vivadent, Schaan, Liechtenstein) on the surface of ceramic, allowing 1 min, and drying with air spray for 10 seconds such it's surface will no longer shiny. Then the single bond universal (Tetric N-Bond Universal, Ivoclar Vivadent, Schaan, Liechtenstein) was applied by microbrush, and after 10-15s, it was dried with gentle air spray for 5s. The specimens were then light-cured using an LED curing unit (NOBELESSE.E, MAX DENTAL Co., Ltd., Gyeonggi-do, Korea) operating at 1000mW/cm^2 energy density (measured by a radiometer) for 10s [16].

Next, 2-mm-long transparent plastic tubes (Clear PVC tube, Shangdong, China) with 4-mm interior diameter [19] were sited on the surface of the specimens, and a light cured resin cement (Variolink Esthetic LC, Ivoclar Vivadent, Schaan, Liechtenstein), transparent color, was applied until it fills up, it was light cured using an LED curing unit (NOBELESSE.E, MAX DENTAL Co., Ltd., Gyeonggi-do, Korea) running at 1200 mW/cm^2 in high power mode for 30s [20].

Sub-group 2: 2-mm-long transparent plastic tubes (Clear PVC tube, Shangdong, China) with 4-mm interior diameter were sited on the surface of the samples [19] and fill with self-adhesive resin cement (Speed CEM Plus, Ivoclar Vivadent, Schaan, Liechtenstein), transparent color shade, it was light-cured using an LED curing unit (NOBELESSE.E, MAX DENTAL Co., Ltd., Gyeonggi-do, Korea) running at 1200 mW/cm^2 in high power mode for 30s (Figure 2).

The ceramic/resin cylinder interfaces were examined for bonding defects before the test using a 20x optical microscope. Cement cylinders with evident bubble inclusion, interfacial gap creation, or other flaws were discarded, and new ones were substituted in their place [20]. One hour following cementation, samples were kept in distilled water in a dark container at room temperature for 24 hours [21].

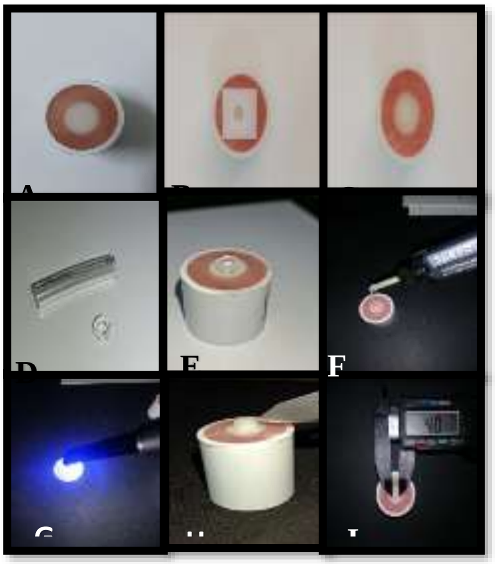

Figure (2): Bonding procedure, A: Ceramic sample, B: Two-sided adhesive tape was fixed on the ceramic surface, C: Two-sided adhesive tape after external cover removal, D: Transparent plastic tube, E: Plastic tube was fixed on the ceramic surface, F: The plastic tube was filled with resin cement, G: Curing the resin cement, H: Removing the plastic tube, I: Checking the diameter of cement cylinder.

Shear Bond Strength (SBS) Testing

The mounted specimens have undergone SBS testing in a universal testing machine (WP 300, GNUT, Geratebau GmbH, Hamburg, Germany) (Figure 3a). The machine's knife-edge chisel metal attachment applied shear stresses at the cement-ceramic interface (Figure 3b), operating at a cross speed of 1mm/min, until total failure [17]. The shear bond strength (in MPa) was obtained by dividing the maximum load to failure (measured in Newtons) by the bonding area (measured in mm^2), which was determined by measuring the cement cylinder's diameter at two points using a digital caliper.

(MPa) = (N) Force / (mm^2) Area.

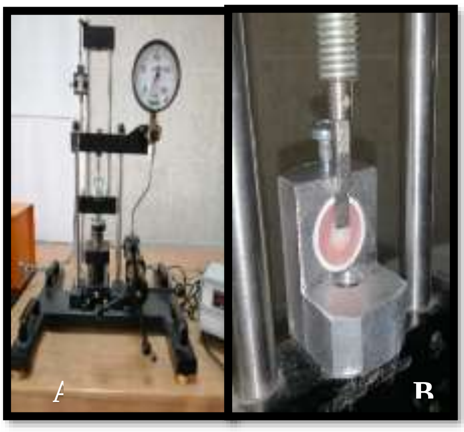

Figure (3): A: Universal testing machine, B: Knife-edge chisel applied force.

Statistical Analysis

The data were subjected to normality and analyzed with one-way ANOVA followed by Tukey post hoc at 0.05 level of significance using the statistical package JMP®: JMP Pro, Version 14 Software; SAS Institute Inc., Cary, North Carolina, USA).

RESULTS

Shear Bond Strength (SBS)

Table (1) and Figure (4) illustrate the maximum mean of shear bonding strength was noticed in group C_1 (16.48±1.19), while the minimum mean was noticed in group B1 (7.32±1.63). It also, illustrates that the variance in shear bonding strength for the groups (A_1, B_1, C_1, D_1) was statistically extremely significant.

Table (1): Comparisons of shear bonding strength among study groups with conventional adhesive.

Study groups	Statistics		p-Value
	Mean (SD)	95% CL	
Group A1	11.86 (1.03)	11.13-12.60	0.0001 VHS
Group B1	7.32 (1.63)	6.16-8.49	
Group C1	16.48 (1.19)	15.63-17.33	
Group D1	13.46 (1.43)	12.44-14.48	

ANOVA one-way was performed for statistical analyses. The size of each group is 10. VHS: very highly significant.

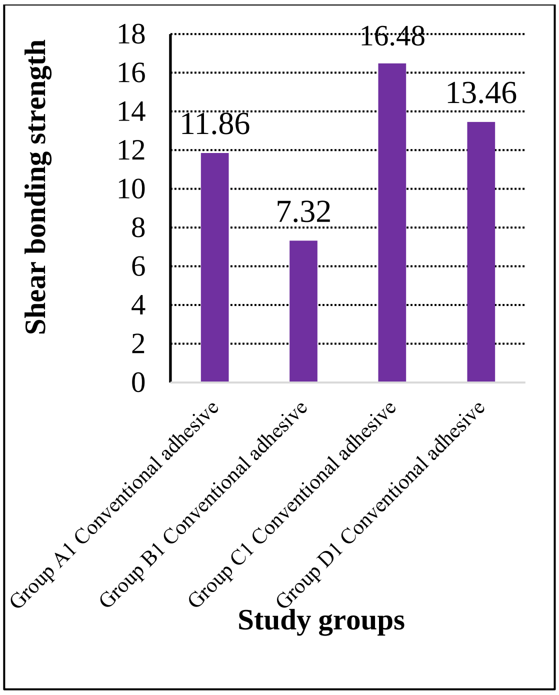

Figure (4): Bar chart showing the comparisons of shear bonding strength among study groups with conventional adhesive.

Table (2) illustrates that the variance in shear bond strength for the groups (A_1, B_1) and (A_1, C_1) was statistically extremely significant, whereas the variance in shear bond strength for the groups (A_1, D_1) was statistically not significant. Also, reveals that the variance in shear bond strength for the groups (B_1, C_1), (B_1, D_1), and (C_1, D_1) was statistically extremely significant.

Table (2): Pairwise comparisons of shear bonding strength between study groups with conventional adhesive

Level	- Level	Difference (95% CL)	p-Value
Group A1	Group B1	4.54 (2.93 to 6.15)	0.0001
Group A1	Group C1	-4.62 (-3.01 to -6.23)	0.0001
Group A1	Group D1	-1.59 (+0.02 to -3.20)	0.0534
Group B1	Group C1	-9.16 (-7.55 to -10.77)	0.0001
Group B1	Group D1	-6.13 (-4.52 to -7.74)	0.0001
Group C1	Group D1	3.03 (1.42 to 4.64)	0.0001

Tukey test was performed for pairwise comparisons. The last column shows the significant differences (VHS).

Table (3) and Figure (5) illustrate the maximum mean of shear bond strength was noticed in group C_2 (13.0±1.26), while the minimum mean was noticed in group A_2 (1.99±0.56). It also, illustrates that the variance in shear bonding strength for the groups (A_2, B_2, C_2, D_2) was statistically extremely significant.

Table (3): Comparisons of shear bonding strength among study groups with self-adhesive

Study groups	Statistics		p-Value
	Mean (SD)	95% CL	
Group A2	1.99 (0.56)	1.59 to 2.39	0.0001 VHS
Group B2	2.07 (0.56)	1.67 to 2.47	
Group C2	13.06 (1.26)	12.16 to 13.96	
Group D2	9.39 (1.39)	8.40 to 10.39	

ANOVA one-way was performed for statistical analyses. The size of each group is 10.

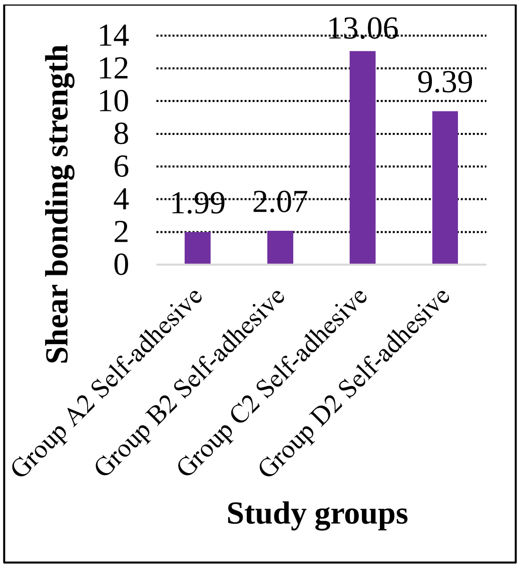

Figure (5): Bar chart showing the comparisons of shear bonding strength among study groups with self-adhesive

Table (4) illustrates that the variance in shear bonding strength for the groups (A_2, B_2) was statistically not significant, whereas the variance in shear bonding strength for the groups (A_2, C_2) and (A_2, D_2) was statistically extremely significant. Also, illustrates that the variance in shear bonding strength for the groups (B_2, C_2), (B_2, D_2) and (C_2, D_2) was statistically extremely significant.

Table (4): Pairwise comparisons of shear bonding strength between study groups with self-adhesive

Level	- Level	Difference (95% CL)	p-Value
Group A2	Group B2	-0.08 (+1.15 to -1.31)	0.9980
Group A2	Group C2	-11.07 (-9.84 to -12.30)	0.0001
Group A2	Group D2	-7.41 (-6.18 to -8.63)	0.0001
Group B2	Group C2	-10.99 (-9.76 to -12.22)	0.0001
Group B2	Group D2	-7.33 (-6.10 to -8.55)	0.0001
Group C2	Group D2	3.66 (2.44 to 4.89)	0.0001

Tukey test was performed for pairwise comparisons. The last column shows the significant differences (VHS).

Table (5) illustrates the maximum mean of shear bond strength was noticed in group C_1 (16.48±1.19), while the minimum mean was noticed in group A_2 (1.99±0.56). Also, illustrates that the variance in shear bonding strength for the groups (A_1, A_1, B_1, B_1, C_1, C_2, D_1, and D_2) was statistically extremely significant.

Table (5): Comparisons of shear bonding strength between conventional and self-adhesive groups

Study groups	Statistics			p-Value
	Mean	SD	95% CL	
Group A1 (C.A.)	11.86	1.03	11.13 to 12.60	0.0001
Group A2 (S.A.)	1.99	0.56	1.59 to 2.39	
Group B1 (C.A.)	7.32	1.63	6.16 to 8.49	0.0001
Group B2 (S.A.)	2.07	0.56	1.67 to 2.47	
Group C1 (C.A.)	16.48	1.19	15.63 to 17.33	0.0001
Group C2 (S.A.)	13.06	1.26	12.16 to 13.96	
Group D1 (C.A.)	13.46	1.43	12.44 to 14.48	0.0003
Group D2 (S.A.)	9.39	1.39	8.40 to 10.39	

An independent t-test was performed for statistical analyses.
C.A.: Conventional Adhesive; S.A.: Self-Adhesive.

Table (6) shows that the maximum mean of shear bond strength was noticed in the conventional adhesive group (49.13±3.05), whereas the minimum mean was noticed in the self-adhesive group (26.57±2.16). It also, illustrates that the variance in shear bonding strength for the groups (Conventional adhesive and self-adhesive) was statistically extremely significant.

Table (6): Comparisons of shear bonding strength between total conventional and self-adhesive groups

Experimental groups	Statistics				p-Value
	No.	Mean	SD	95% CL	
Conventional adhesive	40	49.13	3.05	46.94 to 51.31	0.0001
Self-adhesive	40	26.51	2.16	24.97 to 28.05	

An independent t-test was performed for statistical analyses; No.: Number.

DISCUSSION

A ceramic restoration's clinical effectiveness is dependent on the strength and longevity of the link between the ceramic and the resin cement [26]. The bonding processes, which are partially managed by the precise surface modification employed to improve micromechanical or chemical retention to the ceramic substrate, determine the quality of this bond [27 & 28]. Following surface preparation, resin cement is applied to the ceramic surface, and bonding is achieved by the cement's penetration and polymerization [29 & 30].

Hydrofluoric acid etching and the use of a silane compound are the proven methodologies for cementing lithium disilicate-based ceramics [31]. Etching with hydrofluoric acid is very important in the cementing of lithium disilicate-based ceramics to enhance irregularities and generate a surface with microporosity by moderately dissolving the glass phase and leaving behind an effective surface rich in silica [32]. The silane agent induces adherence between the organic resin cement phase and the inorganic ceramic phase, resulting in the creation of a siloxane bond [33,9].

The advantages of the shear bond strength (SBS) test achieved by applying parallel force to the binding interface are easy specimen preparation and simple test protocol and yielding dependable results [36,38,40-43].

In the current study, different surface modifications were used, simplified or not (etching with 9% hydrofluoric acid, air abraded with 50-um alumina particles and a combination of them), and the outcomes illustrated that various surface treatments and adhesive procedures promoted considerable variations in shear bond strength.

This study demonstrated that etching the ceramic bonding surface with hydrofluoric acid 9% developed the maximum rates of shear bond strength for both types of resin cement (Conventional adhesive and Self-adhesive) with a statistically highly significant variance when compared with the air abrasion with 50-um alumina particles group, combination of their group or no surface treatment group.

By using 9% hydrofluoric acid to etch the ceramic surface, the specimens' glassy matrix was gradually dissolved to a deepness of a few microns, allowing the lithium disilicate crystals to protrude from the glass matrix. The modification of the surface morphology generated by the application of 9% hydrofluoric acid increased the surface area, increased the surface energy, and made it easier for resin cement to penetrate and adhere to the micro retentions of the treated surface (9,28,46 & 47).

The finding of the present study corroborates with those of Özdemir and Aladağ (48), Maruo *et al.* (49), and Guimaraes *et al*. (50) who revealed that etching the bonding surface of lithium disilicate glass-ceramic with 9.5% hydrofluoric acid permitted higher values of shear bond strength than the surface prepared by sandblasting with 50-μm alumina particles.

Although air abrasion with 50-µm alumina particles generates superficial irregularities in the ceramic surface, helping the interaction with cement (53,54,55), but the present outcomes show that this treatment does not give a retentive surface that is as effective as etching with hydrofluoric acid, and this is owing to a significantly lower biaxial flexural strength found after sandblasting with 50-µm alumina for lithium disilicate which leads to reduce in bonding potency between lithium disilicate ceramic and resin cement (56).

The results of the present study are in agreement with those of Ayad et al. (29) who demonstrated that compared to a ceramic surface etched with 10% hydrofluoric acid, the shear bond strength shear was reduced when the ceramic surface was air abraded with 50-um alumina particles.

In the current study when comparing the shear bond strength of self-adhesive resin cement, with conventional light-cured resin cement, the outcomes revealed that self-adhesive resin cement (Speed CEM Plus) had a lower mean of shear bond strength than conventional light-cured resin cement (Variolink Esthetic LC) with all types of surface treatments and the variance in shear bond strength for two types of resin cement was statistically extremely significant. the findings of the current study concur with those of Roy et al. (62) who found that there was a substantial variance between the average shear bond strengths of conventional resin cement and self-adhesive resin cement when bonded to lithium disilicate disks.

CONCLUSIONS

Based on the current study's findings and limitations, it was determined that, with all surface treatments, self-adhesive resin cement (Speed CEM Plus) had a lower mean shear bond strength than conventional resin cement (Variolink Esthetic LC). Furthermore, the 9% hydrofluoric acid surface modifications illustrated superior shear bonding strength values when related to the samples treated by other surface treatments.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication and/or funding of this manuscript.

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