Effect of Flowable Composite Intermediate Layer on Bond Strength of Intra-Oral Porcelain Repair: An *In-Vitro* Study

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Abstract

Aims: The aim of this study was to investigate the effect of flowable composite, as an intermediate layer between feldspathic porcelain and composite, on bond strength during intra-oral porcelain repair and its potential role in providing a long-lasting repair. ***Methods:*** Forty feldspathic porcelain (VMK 95) specimens were fired in metal ingots. They were airborne-particle abraded, etched with 4% hydrofluoric acid gel (Porcelain Etch), and then silane (Porcelain Primer) was applied. Specimens were randomly allocated to one of three study groups or to the control group (ten to each of the four groups). After the application of the bonding agent (One-step), one of the following flowable composites was applied using a brush to specimens in each study group: Filtek Flow, Tetric Flow, or Aelite Flo LV. Flowable composite was not used in the control group. a hybrid composite (Z-100) was applied to the bonding surfaces of specimens in all groups. Specimens were stored in distilled water at 37ºC for 24 hours and then subjected to shear testing (MPa) using a universal testing machine at 0.50mm/min. Treatment effect was tested by analysis of variance (one-way ANOVA). ***Results:*** Mean MPa ±SD values for each test group were as follows: Filtek Flow, 16.40 ±4.19; Tetric Flow, 13.75 ±4.0; Aelite Flo LV, 15.03 ±4.34; for the control group, 15.37 ±2.20. The fractured surfaces showed cohesive failures in the porcelain, with the exception of those treated wtih Aelite Flo LV which exhibited adhesive failures. ***Conclusion:*** Flowable composite does not appear to enhance the shear bond strength of intra-oral porcelain repair.

Key Words: Intra-Oral Porcelain Repair, Flowable Composite, Bond Strength

Introduction

Ceramic and metal-ceramic restorations are essential for the restoration of damaged or missing teeth. They also enhance the aesthetics of the natural dentition. Ceramics have been used to provide aesthetic restorations for several decades, but the use of metal-ceramic restorations is also common. In view of the difference of the physical properties of metal alloys and ceramic materials used, it is not surprising that mechanical failures of metal ceramic systems occasionally occur. Clinically, such mechanical failures are often seen as porcelain fractures, which may be caused by inappropriate abutment preparation, poor framework design, technical errors during prosthesis fabrication, occlusal forces, physical trauma, iatrogenic factors, and surgical operations [1-6]. The majority of the metal-ceramic restoration failures are seen in the anterior region and predominantly at the labial surface of the maxillary teeth [6]. Therefore, these fractures may not only raise aesthetic concerns, but may also lead to functional problems. Their repair is an expensive procedure requiring considerable time and effort [5]. Removal of restorations from the mouth is arduous and may cause trauma to the abutment tooth, thus increasing the possibility of subsequent endodontic therapy [7]. Moreover, it may end up with the fracture of the abutment tooth or an increase in the number of the fractures. Additionally, it is not always possible to remove the restoration, thus necessitating *in situ* repair. Indeed, both patients and dentists would prefer intra-oral repair without removal of the restorations [3,4,8,9]. Intra-oral repair provides acceptable aesthetics, saves time, and is less costly both for the dentist and the patient [4,8,10-15].

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Note: Product manufacturers' details listed at end of paper.

Numerous intra-oral repair systems, including bonding systems, are now available. Composite resin is commonly used in conjunction with these repair systems [10,16-19]. To enhance bond strengths, ceramic surfaces are roughened prior to silane application [4,20-23]. Roughening may be accomplished using rotary instrumentation [22] or chemical etching of porcelain surfaces [4,5,17,18,23-25]. Surface roughening creates irregularities and facilitates the penetration of repair materials [4,18,25-27]. In practice, chemical and mechanical surface treatments also appear to facilitate the spread of low-viscosity repair materials [8,28].

Low-viscosity flowable composites were first introduced in 1996. They have a filler size similar to hybrid composites but a lower filler content. Owing to their stress absorption during polymerisation and favourable fatigue behaviour against occlusal forces, they may be used for composite restorations. Some studies have shown positive results for flowable composites [25,29,30] whereas others have reported no benefit from this material [31,32]. Their properties have led to the investigation of flowable composites in porcelain repair. These materials may provide an intermediate elastic layer between the composite and the rigid porcelain, which may absorb the stress arising from occlusal forces and enhance the durability of the repair.

Aim

The aim of the present study was to investigate the use of flowable composites as an intermediate layer between feldspathic porcelain and composite in intra-oral porcelain repair procedures, in an attempt to enhance the success of porcelain repair. The null hypothesis was the absence of any difference between study groups and controls in terms of bond strength.

Methods

Forty identical cylinder-shaped metallic ingots (Wirolloy) with a diameter of 8 mm and length of 15 mm were used to support the porcelain. A cavity with a 6 mm diameter and a depth of 1.5 mm was carved at one end of each ingot using a carbide bur in a drill press under water-cooling (Type 29, Comm Wo 3564, Masch no. 524). Feldspathic porcelain (VMK 95) was fired into the cavities *(Figure 1).* Each porcelain specimen's upper surface was ground (Ecomet Grinder) using a series of abrasive papers (silicon carbide grit sizes 240 through 320). The specimens were then subjected to airborne-particle abrasion with 50 μm aluminium oxide particles at a pressure of 2.5 atm. for three seconds, in order to increase surface roughness. They were divided into four groups, with each group containing ten specimens. Specimens were randomly allocated into the three study groups according to the different flowable composite and the control group that used no flowable composite *(Table 1).*

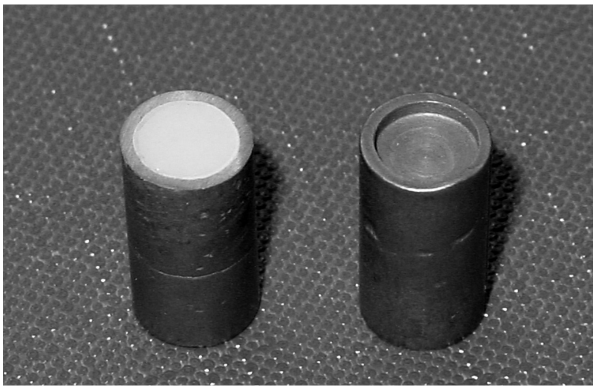

Figure 1. *Drilled metal ingots and porcelain specimens fired in metal ingots.*

Following abrasion, specimens were cleaned for 15 seconds using a pressured stream device (Triton SLA). The porcelain surface of each specimen was etched by the application of 4% hydroflu-

Table 1. *Treatment protocols for each experimental group and the control group*

Group 1	**Group 2**	**Group 3**	**Control group**
Airborne-particle abrasion	Airborne-particle abrasion	Airborne-particle abrasion	Airborne-particle abrasion
Etching	Etching	Etching	Etching
Silane application	Silane application	Silane application	Silane application
Bonding	Bonding	Bonding	Bonding
Filtek Flow	***Tetric Flow***	***Aelite Flo LV***	**-**
Hybrid composite	Hybrid composite	Hybrid composite	Hybrid composite

oric acid gel (Porcelain Etch) for four minutes, according to the manufacturer's instructions. After the completion of the etching procedure, specimens were thoroughly rinsed for 15 seconds using an air/water (triple-function syringe) spray and dried for five seconds. In order to provide a uniform area for the bonding test, a 90 μm thick plastic adhesive tape with a hole of 5 mm in diameter was used. Silane (Porcelain Primer) was applied for 60 seconds to the etched porcelain surfaces. The surface was then air-dried with a mild stream of oil-free air. A bonding agent (One-Step) was applied to the entire surface and thinned to a uniform film using a gentle oil-free air stream. The bonding was light-cured for ten seconds (Polylux II, 650 mW/cm^2). The repair methods and treatment protocols used in the study are presented in *Tables 1* and *2*. No flowable intermediate material was used in one of the four groups, which served as the control. For each of the remaining three groups, one of the following flowable composites was used: Filtek Flow, Tetric Flow, or Aelite Flo LV.

The flowable composite was applied using a brush and cured for 20 seconds. In order to obtain a standard thickness of flowable composite, care was taken to level it with the top surface of the plastic adhesive tape. After placing a 4 mm thick translucent plastic ring on the prepared surface, a 2 mm thick hybrid composite (Z-100) was filled into the ring and polymerised for 40 seconds with a halogen light-curing device. Then, a second layer of 2 mm hybrid composite was applied and light-cured for 40 seconds.

The adhesive tape and the translucent plastic ring were removed with a sharp knife after the polymerisation of the composite *(Figure 2).* The specimens were stored in distilled water for 24 hours at 37°C. Shear bond tests between the ceramic specimens and repair systems were performed in a mechanical testing machine [AVK Buckpest MH-1) with a cross-head speed of 0.5 mm/min. Shear bond strengths were calculated and recorded in megapascal units. Mean shear bond strength values (MPa) were submitted to one-way ANOVA signif-

Table 2. *Adhesive systems and composites used in the study*

	Adhesive	Manufacturer	Composition	Application procedure
Etch	Porcelain Etch	Bisco, USA	4% hydrofluoric acid gel	Porcelain surface etched for 4 minutes, rinsed for 15 seconds with air-water, dried for 5 seconds.
Silane	Porcelain Primer	Bisco, USA	Ethanol, acetone, silane	Brush application for 30 seconds, waited for 60 seconds and dried with air-blow
Bonding	One-step	Bisco, USA	Bisphenyl dimethacrylate, hydroxyethyl methacrylate, aceton, glass frit	Brush application, light-cured for10 seconds
Flowable composite	Filtek Flow	3MESPE, St Paul, MN USA	BisGMA, TEGDMA, 47% vol; zirconia/silica, 1.5μm	Brush application, light-cured for 20 seconds
	Tetric Flow	Ivoclar-Vivadent Liechtenstein	BisGMA, UDMA, TEGDMA 39.7 % vol; Barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, 0.7μm	Applied with brush, light-cured for 20 seconds
	Aelite Flo LV	Bisco, USA	Ethoxylated Bisphenol A, dimethacrylate, triethylene-glycol dimethacrylate 52% vol; Barium glass, 0.7μm	Applied with brush, light-cured for 20 seconds
Hybrid composite (A3)	Z-100	3MESPE, St Paul, MN, USA	BisGMA, TEGDMA, 71% vol; zirconia/silica, 0.01-3.5μm	Light-cured for 40 seconds

icant difference tests (alpha=.05). Each specimen was examined under an optical microscope (OPMI pico microscope) with x25 magnification, and mode of failure was classified as adhesive, cohesive, or a combination of both.

Figure 2.*The test specimen*

The mean shear bond strength values and the standard deviations were calculated for each group. The difference between groups was analysed using analysis of variance (one-way ANOVA). Results were interpreted at 95% confidence level and a *P* value of <0.05 was considered significant.

Results

The mean shear bond strengths of the groups were as follows: Filtek Flow, 16.40 ±4.19 MPa; Tetric Flow, 13.75±4.09 MPa; Aelite Flo LV, 15.03 ±4.34 MPa; and the control group, 15.37±2.20 MPa *(Tables 3* and *4).* No statistically significant difference was found between groups, with similar shear bond strengths for the three flowable composite groups and the control group. The mode of failure was cohesive (fracture of the porcelain) for 38 specimens; only two adhesive failures occurred in the Aelite Flo LV group.

Table 4.*Mean shear bond strengths in megapascals. No statistically significantly difference was found between groups (*P>*0.05)*

	Mean	SD
Group 1	16.40	4.19
Group 2	13.75	4.09
Group 3	15.03	4.34
Control group	15.37	2.20

Discussion

Intra-oral porcelain repair may be a suitable procedure for small fractures. A large fracture involving multiple porcelain teeth requires repair and reconstruction by the technician using an indirect method. It should be emphasised that the causes of the fracture should be established before the repair. Intra-oral porcelain repair should be regarded as a temporary treatment option, especially in situations where the patient's time and financial resources are limited [4].

The present study investigated the effect of flowable composites on bond strength of a hybrid composite to feldspathic porcelain. The study showed that flowable composites did not increase the bond strength of composite to porcelain.

Early-generation, multipurpose adhesive systems involve several treatment steps and agents for such a repair [15]. Various single- or multi-component bonding systems consistently providing high bond strengths are available [3, 5, 9-11, 15, 20, 21].

Table 3.*Values of shear bond strengths for the specimens*

Specimens	**Group 1 Filtek Flow (MPa) n=10**	**Group 2 Tetric Flow (MPa) n=10**	**Group 3 Aelite Flo (MPa) n=10**	**Control group (MPa) n=10**
1	21.78	11.83	9.49	16.00
2	22.79	11.68	17.00	14.98
3	18.82	16.15	21.67	14.31
4	15.14	13.74	19.39	11.87
5	10.80	13.73	11.92	15.68
6	12.52	11.01	17.85	18.28
7	17.67	11.45	9.22	17.89
8	14.21	24.50	18.21	14.34
9	18.67	11.18	12.58	17.80
10	11.59	12.26	13.01	12.58
	10.80-22.79	11.01-24.50	9.22-21.67	11.87-18.28

In the present study, a single-component bonding system was used for bonding to porcelain. The mean shear bond strengths obtained ranged between 13.75 ±4.09 MPa and 16.40 ±4.19 MPa. These values are lower than those found in two previous studies [10, 14] but similar to the results reported in two others [17, 27]. Due to the lack of a standard research method, the reported bond strength values vary widely from 3.0 to 25.0 MPa, making it difficult to determine the best option for repair [5, 10, 13, 14, 26].

The filler level in a composite material determines its mechanical strength and physical properties. Flowable composite liner material and an overlying hybrid composite material can combine the advantages of each material to provide better marginal adaptation, mechanical strength, stress reduction, and wear resistance in operative dentistry [25, 28, 29]. Taking these advantages into consideration, we applied flowable composite as an intermediate layer between the porcelain and the composite resin in order to reduce the stress between these two layers, and hence increase the shear bond strength. However, the flowable composite-applied groups did not show any difference in terms of bond strength, compared to the control group. The relation between degree of conversion and shrinkage strain of flowable resin composites is material-dependent and cannot be generalised to all flowable composites [31, 32]. De Goes *et al.* (2008) [31] reported that the effect of the addition of an intermediate flowable composite layer on microtensile to dentine was material dependent and increased the adhesion of all materials, but only one material was significantly increased. Cadenaro *et al.* (2009) [32] reported that the use of flowable materials did not lead to evident stress reduction and the risk of debonding at the adhesive interface as a result of polymerisation contraction was similar for both types of materials.

The authors of a number of studies have recommended the use of hybrid composite in porcelain repair [4, 12, 15, 17], because it exhibits less polymerisation shrinkage and water absorption, and a lower tendency for macroscopic fracture under high stress. Therefore, in the present study hybrid composite (Valux Plus) was used under the flowable composite.

There have been reports that porcelain repair systems demonstrate cohesive porcelain failure [5,14,15]. In one of these, as far as the porcelain substrate is concerned, some research groups have shown 100% cohesive failure. In another group, 100% of the failures were cohesive, but with 80% in the porcelain and 20% in the repair system, all of which were due to adhesive failure. Some groups presented 80% cohesive failure in the porcelain, showing a 10% combination and 10% adhesive failures. In the present study, the failure mode between the composite resin cylinders and the porcelain was primarily cohesive in the porcelain, except for the Aelite Flo LV specimens where there were cohesive failures in eight specimens and adhesive failures in two specimens. Dos Santos *et al.* (2006) [5] suggested that all types present porcelain cohesive fracture, indicating that the bond strength between the repair material and the substrate is superior to the strength of the substrate itself. In addition, Della Bona and Van Noort (1995) [33] have suggested that experimental design and types of test are more important when evaluating the mode of failures.

All the test specimens were stored in distilled water at 37°C for 24 hours before testing. Twenty-four hour immersion in a 37°C water bath is classified as short-term storage. Although thermocycling and long-term storage are important for simulating clinical conditions, bond strength results with short-term storage may give an indication *in vitro;* however, final evaluation should be determined using clinical studies. The effects of thermal cycling and long-term storage on bond strength were not evaluated in this study and this may be considered a limitation.

This study was conducted under controlled laboratory conditions, so the results may not accurately predict the clinical performance of various porcelain repair techniques. In this study, shear bond test, which is the commonly used method for measuring bond strength, was preferred. It is easy to perform, achieves results quickly, and reflects the clinical situation [5, 8, 10, 13].

Conclusion

The present experimental study did not find any difference between the three flowable composite groups and the control group, in terms of shear bond strength. In conclusion, flowable composite does not seem to enhance the shear bond strength of porcelain repair.

Acknowledgments

The authors wish to thank Bisco (Schaumburg, IL, USA), Ivoclar-Vivadent (Lichtenstein), and 3M ESPE (USA MN) for their free supply of commercial products.

Product Manufacturer Details

Aelite Flo LV: Bisco, Schaumburg, IL, USA.

AVK Buckpest MH-1: AVK International A/S,

Litomerice, Czech Republic.
Carbide bur: Werkzeugmaschinenfabrik, Heilbronn, Neckar, Germany.
Ecomet Grinder: Buehler, Lake Bluff, IL, USA.
Filtek Flow: 3M ESPE, St Paul, MN, USA.
One-Step: Bisco, Schaumburg, IL, USA.
OPMI pico microscope: Carl Zeiss, Essen, Germany.
Polylux II: KaVo, Germany
Porcelain Etch: Bisco, Schaumburg, IL, USA.
Porcelain Primer: Bisco, Schaumburg, IL, USA.
Tetric Flow: Ivoclar-Vivadent, Liechtenstein.
Triple function syringe: KaVo, Germany.
Triton SLA Steam Cleaner: Bego, Bremen, Germany.
Valux Plus: 3M ESPE, St Paul, MN, USA.
Vita VMK 95: Vita, Bad Säckingen, Germany.
Wirolloy: Bego, Bremen, Germany.
Z100: 3M ESPE, St Paul, MN, USA.

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