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Effect of different surface treatments on microtensile bond strength of two types of composite substructures with ceramic by resin cements

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ABSTRACT

Introduction: The aim of this study was to investigate the effect of different surface treatments on the microtensile bond strength (µTBS) of two types of composite substructures with Vita Mark II ceramics by resin cement.

Materials & Methods: Sixty-four substructure specimens were molded from two dual-cure composites Core.it and Build-it, equally, and cured by LED light. The specimens of each group were randomly divided into 4 subgroups (n=8) treated by one of HF acid 10%, air abrasion, Er: YAG laser, and one group without any treatment (control group), and then the specimens of each group were bonded to Vita Mark II CAD/CAM ceramic blocks using two Duo-Link and Panavia F 2.0 resin (n=4 and 20 slice in any group). Each final specimen was thermocycled between 5 °C and 55 °C for 2500 cycles and then cut by a slow speed saw to obtain 5 sticks with cross-section dimensions of about 1×1 mm². The µTBS test was done at a speed of 0.5 mm/min by Universal Testing Machine. The fracture pattern was then determined using a stereomicroscope. Statistical differences between groups were determined by one-way ANOVA using Tukey's multiple comparison tests.

Results: Among all 16 groups, the highest µTBS was observed in the group with Core.it substructure composite and Duo-link resin cement without any surface treatment and after that in the second step in build-it substructure composite group and Panavia resin cement without surface treatment. The most common fracture pattern in all groups was cohesive in resin cement (P<0.05).

Conclusion: According to this study, composite substructure surface treatment by hydrofloridric acid, laser and air abrasion reduced µTBS between substructure- ceramic and so is not recommended.

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Introduction

The goals of restorative dentistry are the restoration of lost tooth tissues caused by caries and fractures to restore the functional, mechanical, physical, biological properties and cosmetics to the teeth. Typically, teeth which have been undergone root canal therapy would be lost a great amount of the crown tissue due to high caries, fractures, or access cavity preparation that need to be reconstructed in some way to be able to preserve remained tooth structure. [1]

Some of the most commonly used core build-up materials are amalgams, resin composites, glass ionomers, etc. The material used as core build-up must have suitable mechanical properties to overcome the forces are applied during chewing. [2] Substructures are often made of metals. Casting metallic posts and cores have a long success due to their superior physical properties; but because of the growing demand for all-ceramic restorations, their use has been limited owing to the gray color. [3] For this reason, tooth-colored materials such as composites, ceramics, glass ionomer cements, and compomers are used as substructures. [4, 5]

The use of all-ceramic restorations has become highly desirable because of the improvement of ceramic materials properties and subsequently its advantages such as light transmittance, biocompatibility, resistance to accumulation of bacterial plaques, neutral taste, and the absence of corrosion and dark metal margins. [5] Despite these advantages, the weakness of these materials is their fragile nature. Therefore, the success of using these restorations is dependent on obtaining a reliable bond that could integrate all parts of components including substructure, luting cement, and ceramics into a single structure.[6] Reaching this goal depends on the durability of the bond and the tight bonding between the substructure, cement, and ceramic restoration.[1] Clinical and laboratory evidence shows that the use of adhesive resin cement can enhance ceramic restorations properties and provide optimal clinical durability.[7]

In recent years, resin cement has gained popularity due to its good physical and chemical properties such as translucency, insolubility, high mechanical strength, chemical and micromechanical bonding to dental, composite, and porcelain structures. [8-10] Therefore, the type of substructure material and resin cement is very important for ceramic durability. Dual-cure resin composites are recently introduced materials for use in posts, because of their close elastic module to dentin and fiber post and the resin cement. [11]

Nowadays, CAD/CAM (computer-aided design/ computer-aided manufacturing) has also become a popular technique in restorative dentistry for the preparation of casts and dies and temporary and final restorations. This system makes it possible to design the office restoration and deliver it in one session. The benefits of CAD/CAM systems include better accuracy and providing clean and efficient designing methods, allowing the dentist to view the cavity from different angles and opposite teeth on the computer's monitor while designing the restoration on it without the complexity of many conventional elastomeric molding materials. [12]

While surface roughness and wear of machinable ceramics [13], the effect of hydrofluoric acid concentration and etching time on the surface roughness [14] and microtensile bond strength (μTBS) of two types of aged composite substructures with Vita Mark II ceramic [15] have been done. This study aimed to investigate the effect of different surface treatments (HF acid etching, laser, and air abrasion) on the μTBS of two types of composite substructure (Core.it and Build-it) with Vita Mark II ceramics by resin cement (Panavia F2.1 and Duo-Link).

Materials & Methods

This study was approved by code 9134815 in 03.10.1391 in the Research Council of Babol University of Medical Sciences.

Substructures preparation: Sixty-four substructure specimens were made from two dual-cure composites (32 specimens Core.it (Spident, Incheon, Korea) and 32 specimens Build-it (Pentron, Orang CA, USA)) in transparent polyethylene molds with 10 mm in diameter and 5 mm in height. The composites were bulked in the molds according to the manufacturer's instructions and hardened by LED light (Valo, Ultradent, South Jordan, USA) with a 1000 mw/cm² intensity for 40 seconds. All composite blocks were made in less than one hour and stored in 37 °C water. The surface of all samples was then polished with 600-grit silicon carbide paper for 30 seconds to achieve a uniform bonding surface. Specimens in each of two upper groups were then randomly divided into 4 subgroups (n=8) and treated in one of four ways, HF acid 10% (hand-made from dilute of hydrofluoric acid 40%, Merck KGaA, 64271Darmstadt. Germany), air abrasion, or Er:YAG laser (Dr. Smile, Italy, 2980 nm) surface treatments or without surface treatment (control group) (Table 1).

Table 1. Surface treatment procedures for substructure specimens.

Group 1	Etching with HF acid 10% for 60 seconds then washing for 20 seconds and drying + silane (Pulp Dent, USA) application.
Group 2	Applying air abrasion with aluminum oxide particles (50µm) at 2.5 bar pressure.
Group 3	Applying Er:YAG laser with 1.5 Watts power continuously and 30% water and 60% air by Erbium tip □600 with 8mm in length at a 0.5 mm gap from the surface.
Group 4	without surface treatment for the control group

The surface of the specimens was applied silane (silane, PulpDent, Watertown, USA) and Porcelain bonding resin (BISCO, Illinois, USA),

Ceramic treatment and bonding procedure: Vita Mark II CAD/CAM ceramic blocks (Vita, Zahnfabrik, Germany) were etched using HF acid gel 10% (hand-made) for 60 seconds, then were washed, dried, and applied silane. Moreover, 8 substructures in each subgroup were divided equally (n=4) and were bonded to treated ceramics(14x12 mm) using two different resin cement (Duo-Link (BISCO, Illinois, USA) and Panavia F 2.0 (Kuraray, Tokyo, Japan)) under 75 N load (use of a 7.5Kgf weight) and light-cured for the 40s with a 1000 mw/cm² intensity.

Microtensile bonding test: Test groups were consisting of cylindrical substructures made of Core.it and Build-it undergoing 3 types of surface of treatment bonded with Panavia F 2.1 and Duo-Link cements to ceramic blocks (12 groups). Cylindrical substructures materials without surface treatment served as control groups (4 groups).

After the preparation of specimens they were maintained in 37° C water for 24 hours then were thermo cycled at 5 °C and 55 °C for 2500 cycles. The cutting was done by a slow speed saw (ISOMET) and 5 slices with cross-section dimensions of about 1×1 mm² were obtained from each specimen (20 slices in any group). Two ends of each slice were bonded to the arms of a Micro Tensile Tester (Bisco, Schaumburg, IL, USA) with cyanoacrylate adhesive (Mitreapel, Istanbul, Turkey) and stretched at a speed of 0.5 mm/min and the required pressure to create the first fracture was calculated in MPa according to cross-section area. The dimensions of each slice were measured with a micrometer (Mitutoyo micrometer code103–137 graduations 0.01 mm, Illinois, USA).

Failure mode test: The fracture mode was then determined using a stereomicroscope (Olympus®, Center Valley, USA) and reported as follows: 1. Adhesive detachment in the ceramic- resin cement interface (adhesive fracture), 2. Cohesive fracture in adhesive resin cement, 3. Cohesive fracture in composite, 4. Adhesive detachment in the resin cements-composite interface (adhesive fracture).

Statistical analysis: The raw data were analyzed by SPSS ver. 18 software. The µTBS in different groups was reported as mean±SD. Each fracture pattern in groups was reported as a percentage. Statistical differences between groups were determined by one-way ANOVA using Tukey's multiple comparison test. P <0.05 was considered significant.

Results

Table 2 shows the mean and standard deviation of µTBS between the tested groups with two types of resin cement by various treatments and composite types.

Different uppercase letters show significant differences in µTBS between various resin cement in two composite core build-up composites in each raw and different lowercase letters show significant differences in µTBS between various surface treatments in each column.

Table 2. Comparison of the mean (MPa) of µTBS of CAD/CAM ceramic blocks to core build-up composites disaggregated with various treatments method and resin cement.

Build up composites / Cements / Treatment groups	Core.it		Build-it	
	Panavia F2	Duo-link	Panavia F2	Duo-link
HF*	$24.1{\pm}8.1^{Aa}$	15.5 ± 1.7^{Ba}	18.2 ± 3.8^{ABa}	17.5 ± 3.06^{Ba}
Airabrasion	25.2 ± 5.8^{Aa}	19.8 ± 3.4^{Bb}	21.8 ± 10^{ABab}	17.6 ± 4.1^{Bab}
Laser	21.12 ± 4.8^{Aa}	22.4 ± 8.6^{Ab}	22.5 ± 7.2^{Aab}	20.3 ± 5.5^{Aab}
Control	25.7 ± 3.7^{Aa}	28.2 ± 3.5^{Ab}	26.9 ± 4.7^{Ab}	23.2 ± 3.2^{Ab}

*HF: Hydrofluoric acid. Different lowercase letters indicate a significant difference (P<0.05) among columns. Different capital letters show a significant difference (P<0.05) among rows.

As shown in Table 2, in groups with Core.it composite as substructure there was a significant difference between µTBS in using of two types of Panavia and Duo-link resin cement with HF and air abrasion treatments but there was no significant difference between groups with Laser and Control treatments. In groups with Build-it composite as substructure, there was no significant difference between µTBS of groups in the use of two resin cement with any of the three different treatment and control groups.

The highest tensile strength between all 16 groups was observed in the group with Core.it substructure composite and Duo-link resin cement without any surface treatment and after that in the second step in build-it substructure composite group and Panavia resin cement without surface treatment.

Table 3 shows the distribution frequency of fracture patterns in studied groups. As could be seen, the most fracture pattern was observed in all groups was type 2 (cohesive fracture in resin cement).

Table 3. Failure mode in studied groups

Composite	Cement	Surface treatment / Failure mode	HF* n(%)	Air abrasion n(%)	Laser n(%)	Control n(%)
Core.it	Panavia F2	1	0	2(10)	0	0
		2	16(80)	18(90)	20(100)	20(100)
		3	0	0	0	0
		4	4(20)	0	0	0
	Duo-link	1	0	0	0	0
		2	15(75)	20(100)	17(85)	20(100)
		3	0	0	0	0
		4	5(25)	0	3(15)	0
Build.it	Panavia F2	1	0	2(10)	0	0
		2	17(85)	15(75)	18(90)	20(100)
		3	0	0	0	0
		4	3(15)	3(15)	2(10)	0
	Duo-link	1	0	0	0	0
		2	15(75)	15(75)	19(95)	20(100)
		3	0	0	0	0
		4	5(15)	5(25)	1(5)	0

*HF: Hydrofluoric acid.

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Discussion

A crucial factor in the clinical success of ceramic restorations is the bonding strength of the luting agent to the internal surface of the restoration and residual tooth structure. [16] In this study, in the comparison between the two groups with different core composite (Core.it, Build-it) and without considering surface treatments, in group bonded with Panavia F2.1 resin cement μTBS was significantly higher than the group bonded with Duo-Link resin cement. These changes were similar in both core materials.

The higher bond strength of Panavia resin cement (self-etch technique) than Duo-Link (etch and rinse technique) is in contrast to Tezvergil et al. [17] and Yesilyurt et al.'s [18] studies' results that reported the bond strength values obtained with aged composites in self-etch systems were significantly lower than those of etching and rinse systems. There are three possible mechanisms for the effect of adhesive on aged composites: 1. Chemical bond formation with matrix, 2. Chemical bond formation with exposed filler particles, and 3. Micro-mechanical involving via penetration of monomeric components into the matrix micro-irregularities. It seems that the adhesive agent's matrix structure is probably an important factor in the bonding to the old composite matrix and affects the bond strength; for example, the polar nature of the phosphate groups could be effective in bonding to composites' inorganic filler.[18] On the other hand, in Gresnigt's study, in comparison of the bond strength between two various types of resin cement (etch and rinse and self-etch systems) with old composite, were not significantly different.[19] But, this study had two major differences from our study. First, in Gresnigt's et al. study the composite surfaces were prepared by the tribo-chemical silica coating process, but in our study were prepared by air-abrasion with aluminum oxide particles, laser, and HF. Second, the composites in Gresnigt's study underwent an aging process, which was not done in the current study.[19]

There was no significant difference in μTBS between the two types of used substructure composites in this study, which was similar to other studies such as Bitter et al. [20] Bozogullari et al. also didn't find significant differences in the bond strength of the three resin-based cores (Clearfil AP-X, Photocore, Coremax) with ceramic. [5] In this study, there was no significant difference between investigated resin cement and composites interaction. Cekic-Nagas et al. [21] reported that the bond strength of Smile resin core with Bifix QM resin cement was significantly higher than Bis-Core resin core. They commented this difference is because of various filler content between two composites and the Smile composite passed better-polymerized light due to lower filler weight (75% to 78%) resulting in a higher degree of conversion that provides higher bond strength with resin cement. In the present study, despite the difference in the filler content of the two composites, no such difference was observed. However, the difference in the μTBS between two resin composites in the Cekic-Nagas et al. study could be due to the differences in their polymerization method that there was not in this study; Bis-Core is a dual-cure composite and Smile is a light cure composite.[21]

Zeinalabdeen et al. in contrast with this study showed that sandblasting and laser prepared bond strength better than the control group without treatment. [22] They used lava ultimate and Vita Enamic hybrid ceramics that is different from this study.

Adhesive fracture is not commonly finding during μTBS testing. This type of fracture usually occurs during the sample cutting process, which indicates a weak bond. HF acid-treated ceramic specimens usually show a fracture that begins at the adhesive-ceramic interface and then either expands into the adhesive or reaches the adhesive-composite interface or returns to the ceramic-adhesive interface. These types of fractures are considered cohesive. [23] In this study, most of the fractures investigated by stereomicroscope were cohesive. Observation with light microscopy is generally not sufficient to determine the fracture pattern in the adhesive interface, and the use of SEM is much more appropriate to provide a complete and accurate description of the fracture pattern type. For this reason, in future studies, using electron microscopy is recommended. Most of the observed fracture patterns were type 2 (cohesive fracture in adhesive resin), which were consistent with high obtained bond strength values.

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Conclusion

According to this study, composite substructure surface treatment by hydrofloridric acid, laser and air abrasion reduced μTBS between substructure- ceramic and so is not recommended.

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Conflicts of Interest

There is no conflict of interest

Authors' Contribution

Negin Tabar contributed to the conception, design, definition of intellectual content, literature search, experimental studies, data acquisition and critically revised the manuscript.
Seyedkamal Seyedmajidi contributed to experimental studies and critically revised the manuscript.
Toloo Jafari contributed to experimental studies, data acquisition and critically revised the manuscript.
Soraya Khafri contributed to Data acquisition, Data analysis and critically revised the manuscript.
Homayoon Alaghehmand contributed to the conception, design, definition of intellectual content, literature search, experimental studies, data acquisition, Manuscript preparation, Manuscript editing, Manuscript review, and critically revised the manuscript.

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