

Effect of Adhesive Type on the Shear Bond Strength of Metal Brackets to Two Ceramic Substrates

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Abstract

Objective: Increased number of adult patients requesting orthodontic treatment result in bonding bracket to ceramic restorations more than before. The aim of this study was to evaluate and compare the shear bond strength of orthodontic brackets bonded to two types of ceramic bases with conventional orthodontic bonding resin and a new nano-filled composite resin.

Materials and Methods: Twenty four feldspathic porcelain and 24 lithium disilicate ceramic disks were fabricated. All of the samples were conditioned by sandblasting, hydrofluoric acid and silane. Maxillary incisor metal brackets were bonded to half of the disks in each group by conventional orthodontic bonding resin and the other half bonded with a nano-filled composite. The samples then were thermocycled for 2000 cycle between 5-55° C. Shear bond strength was measured and the mode of failure was examined. Randomly selected samples were also evaluated by SEM.

Results: The lowest bond strength value was found infeldspathic ceramic bonded by nano-filled composite ($p<0.05$). There was not any statistically significant difference between other groups regarding bond strength. The mode of failure in the all groups except group 1 was cohesive and porcelain damages were detected.

Conclusion: Since less damages to feldspathic porcelain was observed when the nano-filled composite was used to bond brackets, the use of nano-filled composite resins can be suggested for bonding brackets to feldspathic porcelain restorations.

Key Words: Dental Porcelain; Orthodontic Brackets; Shear Strength, Composite Resins , Nanocomposites

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INTRODUCTION

In recent years there has been an increase in the number of adults seeking orthodontic treatment which increase the probability of patients having ceramic restoration.

Therefore, orthodontists are often faced with the challenge of effectively bonding orthodontic brackets to esthetic restorations such as laminate veneers or metal-ceramic restorations in adult patients.

Ideally, direct bonding of orthodontic brackets would achieve a satisfactory and reversible bond for the duration of treatment without the need for toxic materials or irreversible damage to the porcelain restoration. Although ceramic restorations are used frequently the problem of acceptable composite bonding on porcelain surface has been reported [1-5]. In bonding brackets to ceramic substrate, double challenges exist. On the one hand optimal bond strength of 6 to 10 MPa is desired to minimize bond failure during the treatment period [6-8], on the other hand after debonding procedure, the ceramic restorations should be returned to their ideal esthetic and function. In recent years with advancement in nanotechnology, nano filled composites are introduced in dentistry which showed higher mechanical properties [9, 10].

Pre-treatment of ceramic surfaces is necessary to obtain sufficient bond strength of orthodontic brackets to all-ceramic restorations. Several options have been described which are generally combinations of various mechanical and chemical conditioning methods, such as bonding to glazed ceramic with a coupling agent (silane), deglazing the ceramic by roughening the surface by means of diamond burs and/or air particle abrasion, and chemical preparation of the ceramic with acids, such as phosphoric, hydrofluoric, acidulated phosphate fluoride [4, 6, 11-14].

A current literature review revealed that by evolving techniques and materials, roughening the porcelain with a bur, removing the glaze, and using hydrofluoric acid as pretreatment procedure, can be avoided [15].

Damage to the ceramic due to roughening during surface conditioning should be minimized since the restorations ordinarily remain in the mouth following orthodontic treatment [16]. Only a limited number of studies exist concerning the bond strength of orthodontic brackets to all-ceramic restorations, and in most of them, mainly feldspathic ceramic was employed [17].

Furthermore, insufficient information exists concerning the bond strength of other all-ceramic materials to orthodontic brackets.

The objective of this study was to evaluate and compare the shear bond strength of orthodontic brackets to two types of ceramic bases bonded with conventional orthodontic bonding resin and new nano-filled composite resin.

MATERIALS AND METHODS

A total of 48 ceramic discs were fabricated with a diameter of 9 mm and thickness of 3mm. specimens were made up from two types of ceramic; feldspathic porcelain (Vitadur Alpha; Vita Zahnfabrik, Bad Säckingen, Germany), and lithium disilicate-base ceramic (E-max; Ivoclar Vivadent, Schaan, Liechtenstein). All specimens were fabricated according to the manufacturer's instructions. Then all specimens were embedded in autopolymerizing acrylic resin (Meliodent; HeraeusKulzer Ltd, Newbury, Berkshire, UK) with their glazed surfaces facing upward. All samples were conditioned first by sandblasting using 50 µm aluminium trioxide (Al₂O₃) (GAC, Bohemia, NY) with an intra-oral air abrasion device (Microetcher II, Danville Materials, San Ramon, Calif) a distance of approximately 10 mm and a pressure of 2 bars for 4 seconds, then etched with 9.6 per cent HFA gel (Pulpdent Porcelain Etch Gel; Pulpdent Corp., Watertown, Mass) for 2 minutes. Subsequently Silane (ESPE-SIL, ESPE, Seefeld, Germany) was applied to the surface of the ceramics and then dried.

Each ceramic group were randomly divided in two subgroup in order to use either Transbond light curing adhesive paste (TransbondTM XT; 3M Unitek, Monrovia, Calif) or Superemano-nano-filled composite (3M Unitek, complete manufacturer's information). Bonding procedures were carried out by same operators (HS). The light cure adhesive systems were applied to the mesh base of a maxillary central incisor bracket (Ultratrim, Dentarum, Pforzheim, Germany).

Subsequently, the brackets were seated and positioned manually on the ceramic surfaces. Excess composite was carefully removed from the periphery of the bracket base with an explorer. The adhesive paste was cured for 20 seconds from two directions using a visible light-curing unit (XL300;3M/Unitek Dental Products,Monrovia,Calif). All specimens were stored in distilled water at 37 °C for 24 hours and then they were thermocycled in a custom-made device (Malek-Teb Co., Tehran, Iran) for 2000 times between 5°C and 55°C with a dwelling time of 20 seconds. The shear bond test was performed using a universal testing machine at a crosshead speed of 1 mm/minute. The bond strengths were calculated in mega-Pascal (MPa).The test design and examined groups are summarized in Table 1. Fractured surfaces were examined with an optical microscope (Stereomicroscope, SMZ800, Nikon Instrument Inc., Kawasaki, Kanagawa 210-0005, Japan) at x20 to determine mode of

failure and the amount of adhesive resin remaining on the porcelain surface was scored according to the modified adhesive remnant index (ARI) [18].

In order to assess the probable damage to the ceramic substrate which may have occurred during debonding the brackets, five specimens were randomly selected and examined by scanning electron microscope (SEM) Topcon ABT-150S, Topcon Co., Tokyo, Japan) before conditioning, after conditioning and after debonding procedures.

The surface morphology of test specimens also was observed using a scanning electron microscope (SEM).

Collected data was subjected to the descriptive statistical analysis. After examining the normal distribution of results, one way and two way analysis of variance (ANOVA) was used to evaluate the differences in shear bond strength values between groups. Benferoni analysis was used to compare paired groups.

Table 1. Summarized descriptions of study groups

Groups	Descriptions
1	Vitadur Alpha feldspathic porcelain + Superem nano-filled composite
2	Vitadur Alpha feldspathic porcelain + Transbond light curing adhesive paste
3	E-max lithium disilicate-base ceramic+ Superem nano-filled composite
4	E-max lithium disilicate-base ceramic+ Transbond light curing adhesive paste

Table 2. Descriptive statistics of shear bond strength test

Groups	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Group 1	9.2817	1.96069	.56600	8.0359	10.5274	6.54	13.22
Group 2	18.1833	3.61184	1.04265	15.8885	20.4782	12.23	24.66
Group 3	16.3933	2.46138	.71054	14.8294	17.9572	11.86	19.59
Group 4	19.4950	3.22732	.93165	17.4445	21.5455	14.77	25.96

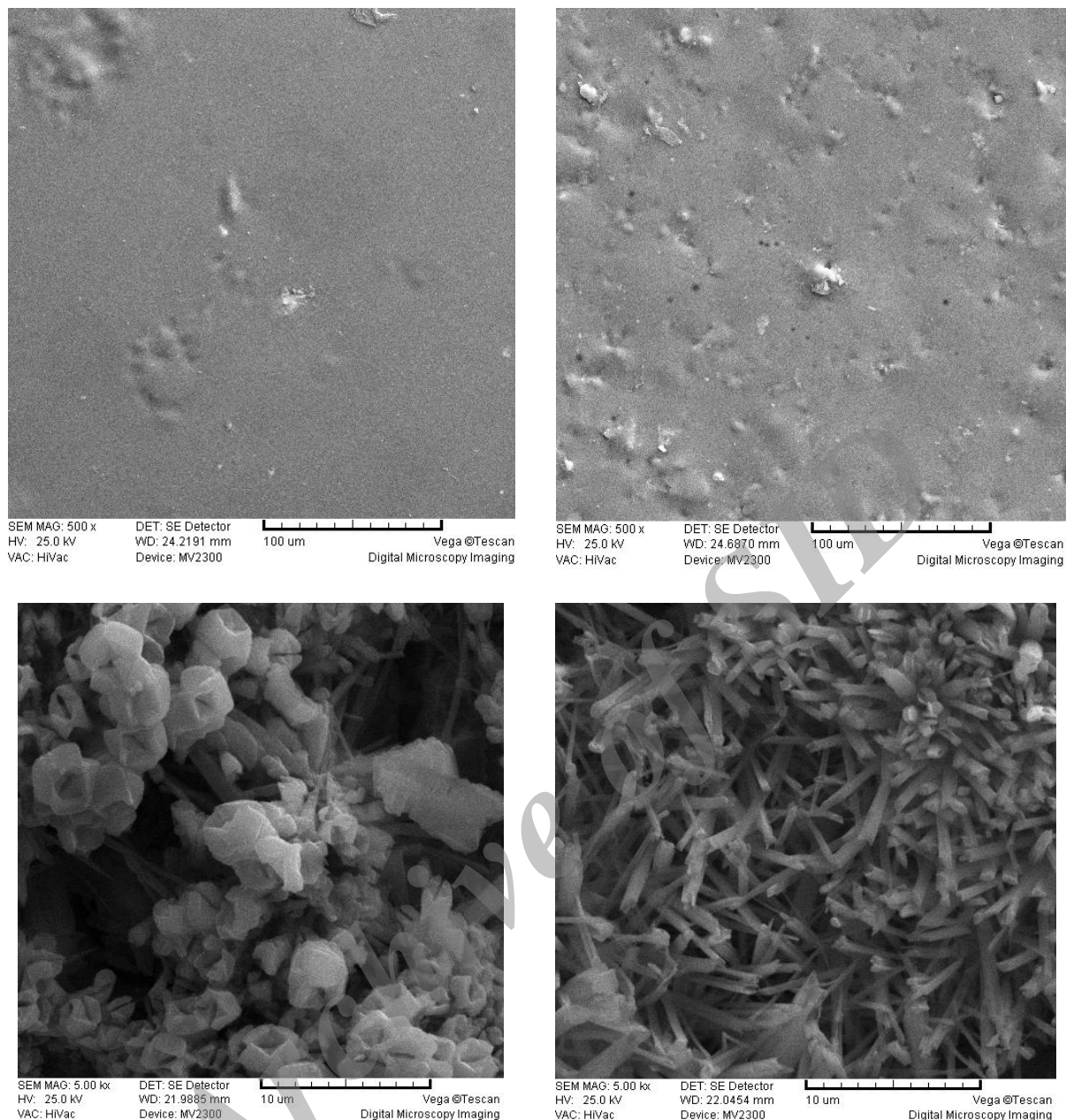


Fig 1. Ceramic substrates before conditioning; A: lithium disilicate ceramic (E-max) and B: feldspathic porcelain ($\times 500$); C and D represent lithium disilicate and feldspathic ceramic after conditioning respectively ($\times 5000$)

RESULTS

Descriptive statistics including mean, minimum and maximum values, and standard deviations of each group, are summarized in Table 2. The lowest SBS (9.28 MPa) was observed when Supreme nano-filled composite was used to bond brackets to the feldspathic

porcelain surfaces (group 1) which was significantly different from other groups ($P < 0.05$). Although the mean shear bond strengths were varied in other groups, statistical analysis showed no significant differences. Regardless of the type of ceramic substrate, statistical

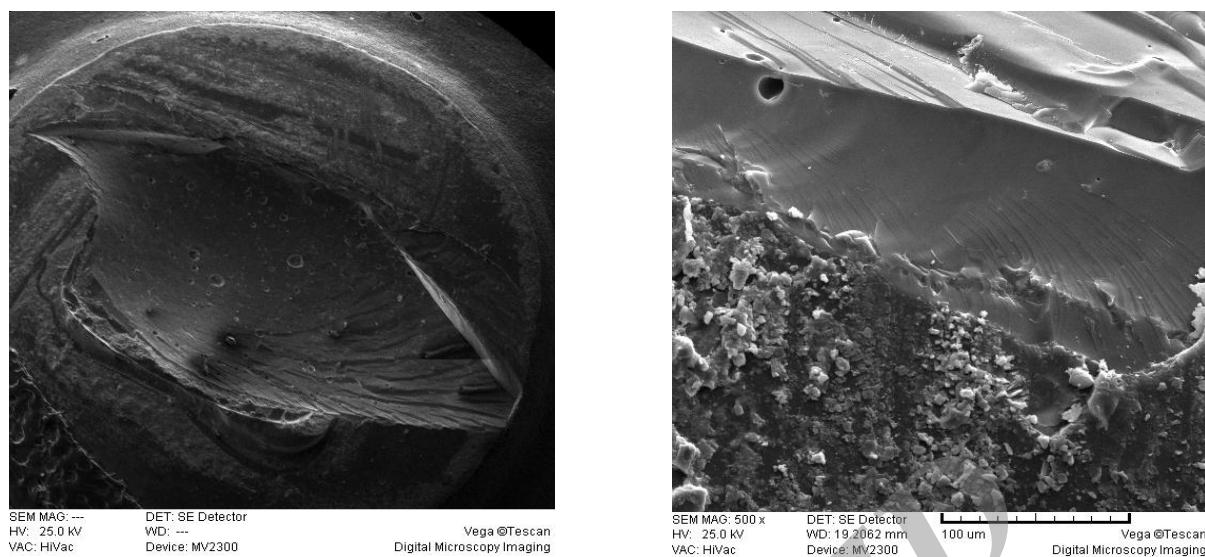


Fig 2. Damages observed at the debonding area in the lithium disilicate ceramic substrates; (A: $\times 50$ magnification and B $\times 500$ magnification)

analysis showed that Transbond light curing adhesive paste produced higher shear bond strength than Superemnano-filled composite. Evaluating the impact of ceramic type on the bond strength revealed that in the similar condition and regardless of bonding system, E-max lithium disilicate-base ceramic generates higher bond strength comparing to feldspathic porcelain. The ARI scores for all groups were 5 which mean no adhesive were remained on the ceramic surfaces. SEM examination of ceramic before conditioning showed smoother surfaces in E-max lithium disilicate-base ceramic compare to Vitadur Alpha feldspathic porcelain (Fig 1A and B).

After conditioning, E-max exhibited different pattern from feldspathic porcelain (Fig 1C and D). SEM evaluation of debonded specimens showed damages at the debonding area in the ceramic substrates except in group 1 which no damages was observed (Fig 2).

DISCUSSION

Most dental ceramics are usually similar in chemical elements and components but have

distinct differences in particle size and crystalline structure, therefore different results are expected to obtain regarding the bonding to ceramic surfaces [19].

There are limited studies in evaluation of nanocomposite to porcelain surface specially all-Ceram one [14, 16]. In order to induce artificial aging by simulating thermal stresses in oral environment which result in various amount of thermal expansion in metal brackets, thermocycling was recommended [20-22]. Although studies showed thermocycling cause decrease in bond strength, in order to imitate oral environment, thermocycling is required.

The numbers of cycles are varied in different study and are usually between 500 to 5000 cycles [16, 22-24]. In the present study all specimens were thermocycled for 2000 times between 5°C and 55°C with a dwelling time of 20 seconds. Surface roughening by abrading the glaze layer results in higher bond strength [25], however it has been reported that removal of the glaze by grinding diminishes the transverse strength of the ceramics to half of that when the glaze is present [26].

Several studies have recommended that the glaze not be removed by grinding for safety reasons [3, 11, 27]. Therefore grinding the ceramic surfaces is not recommended and was not employed for pre-conditioning the specimens in the present study. In order to remove glaze layer, many studies recommended sandblasting, since this method produced less damage to the ceramic surface [28, 29]. The use of HF usually consider as an important factor to increase the bond strength in ceramic substrate by increasing the micromechanical retention [2, 13, 30-32].

It has been reported that the use of silane without any other treatment would not affect bond strength to the ceramics, however the application of silane after etching with HF significantly increase the bond strength [33-35]. As it has been recommended by many investigators, in the present study, all specimens were conditioned first by sandblasting then etched with 9.6 percent HFA gel and subsequently Silane was applied to the glazed surface of the ceramics. Preferable bond strength in restorative dentistry is different from that is desirable in orthodontics. In restorative dentistry usually the higher bond strength is more desirable, while in orthodontics an optimum bond is required. A reduced amount of bond strength can lead to debonding the brackets, whereas an increase in bond strength value can cause damages to substrate during the debonding procedure. It has been reported that the optimum bond strength of 6-10 MPa is required for clinically adequate adherence of bracket in orthodontic treatments [7, 29, 36].

All SBS values in the present study were above this optimal range except for group 1 in which metal brackets were bonded to Vitadur Alpha feldspathic porcelain by Superemnano-filled composite. The result of this study showed that SBS of metal bracket bonded to ceramic substrate could highly influenced by the type of adhesive and the type of ceramic, which was in agreement with the previous studies [34, 37, 38].

Regardless of the ceramic type, metal brackets bonded to ceramic substrate bonded with Transbond light curing adhesive paste showed higher SBS than specimens bonded with Superemnano-filled composite.

Composites used in this study had different filler properties which led to differences in viscosity and flow properties of resin composites. Superem nano-filled composite had higher viscosity than Transbond light curing adhesive and it could be demonstrating that resin composites with higher viscosity intend to penetrate less to the etched surfaces which can result in lower bond strength.

The SEM photographs of the post-conditioned of two kind of ceramics showed different surface morphologies (Fig 1 C, D). E-max ceramic displayed fewer pits and more unchanged surface than Vitadur Alpha feldspathic porcelain. These different microscopic appearances substantiate the SBS values. Not considering the resin composites which used for bonding, the bond strength values were higher in feldspathic porcelain than E-Max group probably due to the more roughening of the ceramic surface. Assessing the brackets and fractured surfaces showed that the ARI scores for all groups were 5 which mean no adhesive were remained on the ceramic surfaces.

However except in group1 which Superem nano-filled composite used for bonding brackets to feldspathic porcelain, other groups showed the cohesive mode of failure in the ceramic substrate which was concomitant with the damages to the ceramic surface. Considering all SBS values in the present study were above the optimal range except for group 1, these results were predictable.

Thumb et. al, [39] reported that increasing the SBS up to 13 Mpa increase the probability of cohesive fracture in ceramic substrate and damages to ceramic restoration. Preservation of esthetic aspects in ceramic restorations is one of the main considerations in orthodontic treatment and damage to the ceramic restorations is not acceptable in this regard.

The types of the composite and bonding materials or the type of ceramic restorations are not the sole cause of this problem. According to some researches one of the major contributor factors in damaging to ceramic is the kind of debonding procedure which employed. Kloaket. al., [40] demonstrated that changing the load direction cause significant differences in SBS values obtained from in vitro studies [40]. Mojtahedzadeh et. al., [41] revealed that method of SBS testing has an impact on the obtained value. They observed that by wire loop method, higher SBS and lower standard deviation would be attain [41]. Littlewood et. al. [42] speculated that wide variation of results was due to the lack of directional control of the debonding force. Debonding procedure in the clinic is different from laboratory condition and less cohesive debonding could be observed compare to invitro conditions [29, 4]. However, debonding in clinic should be done very gently to reduce cohesive failure in ceramic substrate as much as possible.

CONCLUSION

The new nano-filled composite produced adequate bond strength in order to use to bond metal brackets to ceramic restorations. Since less damage to feldspathic porcelain was observed when the nano-filled composite was used to bond the brackets, the use of nano-filled composite resins can be suggested for bonding brackets to feldspathic porcelain restorations. However, as a general recommendation, debonding should be done carefully to reduce the risk of ceramic damage.

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