Bond strength assessment of metal brackets bonded to porcelain fused to metal surface using different surface conditioning method

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ABSTRACT

Introduction: Bonding of orthodontic brackets to porcelain surfaces always remain a challenge to the clinicians. Various modalities have been suggested for improving the bonding of the brackets onto the porcelain surfaces however none have been conclusive. Hence the aim of the study was to compare the bond strength achieved by metal brackets bonded to porcelain fused to metal surface by different surface conditioning methods.

Material & Method: 64 porcelain fused to metal discs were used to assess the shear bond strength and surface roughness tests were used to examine the effect of 4 different surface conditioning methods: Group I: Silane coupling agent, Group II: Sandblasting (APA- Air Particle Abrasion), Group III: 9.6% Hydrofluoric acid (HFA), Group IV: Fine diamond bur for bonding metal brackets to ceramic surfaces. Metal brackets were bonded to the ceramic substrates with a light cure composite. The samples were stored in 0.9% NaCl solution for 24 hours and then thermocycled (5000 times, 5°C to 55°C, 30 seconds). Shear bond tests were performed with a universal testing machine (Instron).

Result: All shear bond strength (SBS) values in present study were above optimal range except for Group I (Silane coupling agent) and Group III (9.6% hydrofluoric acid), rendering them clinically acceptable.

Conclusion: Diamond bur and sandblasting showed the highest bond strength. Increased damage to the ceramic surfaces was noted with the use of diamond bur and sandblasting. Hence sandblasting (APA) can be clinically used as it gives acceptable results in terms of bond strength and surface roughness, but the health risks should be considered.

INTRODUCTION

With the increase in number of adult patients seeking orthodontic treatment, bonding brackets onto various types of dental restorations has become a routine dental practice. Patients are increasingly demanding dental restorations that are both aesthetic and functional. One of the materials that particularly has presented problems to both the operative dentist as well as the orthodontist is porcelain surfaces. Whether the purpose is to repair a porcelain crown or to bond a bracket to such a restoration, the difficulty that clinicians face in both situations is that the porcelain surface essentially is inert i.e., it does not bond (adhere) readily to other materials.[1]

Since glazed porcelain surfaces are not amenable to resin penetration for orthodontic bonding, mechanical or chemical pre-treatment of the surface is essential for successful direct bonding. However, as the conventional acid-etching technique is not effective in pre-treatment of non-enamel surfaces, four types of surface-conditioning techniques have been suggested:

- Roughening the porcelain surface with a diamond drill or sandpaper discs.
- Sandblasting with aluminium oxide particles (APA- Air Particle Abrasion).
- Chemical preparation with hydrofluoric acid (HFA).
- Use of silanes (gamma-methacryloxypropyl-trimethoxy silane) which provide a chemical link between porcelain and composite resin and increase the wettability of the porcelain surface.

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Conflicting results exist in the literature on the effects of the above conditioning methods and various adhesives.[2]
There has been no consensus in the literature regarding the best surface conditioning method for optimum brackets-porcelain bonding. The effect of different surface treatments on the roughness of the porcelain restorations was not assessed. Hence the aim of this study was to compare the bond strength achieved by metal brackets bonded to porcelain fused to metal surface by different surface conditioning methods and evaluate the effect of surface-conditioning methods on the ceramic surfaces.

MATERIAL AND METHOD

64 porcelain fused to metal discs of standard dimension of 10mm diameter, 2mm thickness of porcelain and 0.5 mm thickness of metal casting were used. The discs were manufactured with the help of a self-made dye and Feld spathic Vita porcelain (Vita, Bad Sackingen, Germany) of desired thickness was fired on them. Later on the

ceramic was glazed. The specimens were embedded in acrylic moulds, so that only the glazed surface of the disc remained uncovered. These acrylic templates would fit into the jig of the universal testing machine, Instron which was used to determine the shear bond strength.

The sample blocks were colour coded in 4 different colours (white, blue, orange, green) for easy differentiation of the 4 different groups and each colored group consists of 16 specimens of the discs and the respective bracket used. Each group was subjected to different surface conditioning treatment. Shear bond strength of 15 specimens in each group was assessed and 1 specimen in each group was used for assessing the surface roughness after the surface conditioning treatment using the scanning electron microscope.

In group I (white), silane was applied to specimens without any roughening procedure.

In group II (blue), Air Particle Abrasion (APA) was performed using aluminium trioxide with an air abrasion device (Microetcher II Intraoral Sandblaster, Danville Engineering), filled with 50 µm aluminium oxide particles (Danville Engineering), at a distance of approximately 10mm and a pressure of 2.5 bars for 4 seconds.

In group III (orange), porcelain surfaces were etched with 9.6 per cent HFA (Pulpdent, Watertown, Massachusetts, USA) for 2 minutes, rinsed with a water/ spray combination for 30 seconds, and dried.

In group IV (green), mechanical roughening was performed with fine diamond burs. The cylindrical diamond burs, with shaft parallel to specimens, were rotated at 40,000 rpm with water coolant.

After chemical and mechanical roughening, the specimens were washed and rinsed thoroughly to remove debris, and then air dried. Subsequently, silane was applied on the porcelain surface with a microbrush and allowed to dry for 5 minutes. A thin uniform layer of sealant was applied on the porcelain surface with a microbrush and cured for 20 seconds (Transbond XT; 3M Unitek). The light cure adhesive paste (Transbond XT; 3M Unitek) was applied to mesh of the central incisor brackets (0.018 inch slot-from Ormco, Glendora, CA, USA). The bracket base surface area was calculated using the ImageJ software (developed by National Institute of Health, Maryland, U.S.A). The bracket was then properly positioned on the ceramic and subjected to 300 g of force. The test samples were stored in 0.9% NaCl solution for 24 hours. All samples were thermocycled 5000 times between 5°C and 55°C with a dwelling time of 30 seconds.

Shear bond strength

The acrylic block with embedded porcelain disc and bonded bracket was positioned in the jig to measure the force of debonding. An occluso-gingival load was applied to the bracket, producing a shear force at the bracket-tooth interface. A computer electronically connected with the Instron test machine recorded the results of each test in megaPascals(MPa) Fig:1. Shear bond strengths was measured at a cross-head speed of 1 mm/min

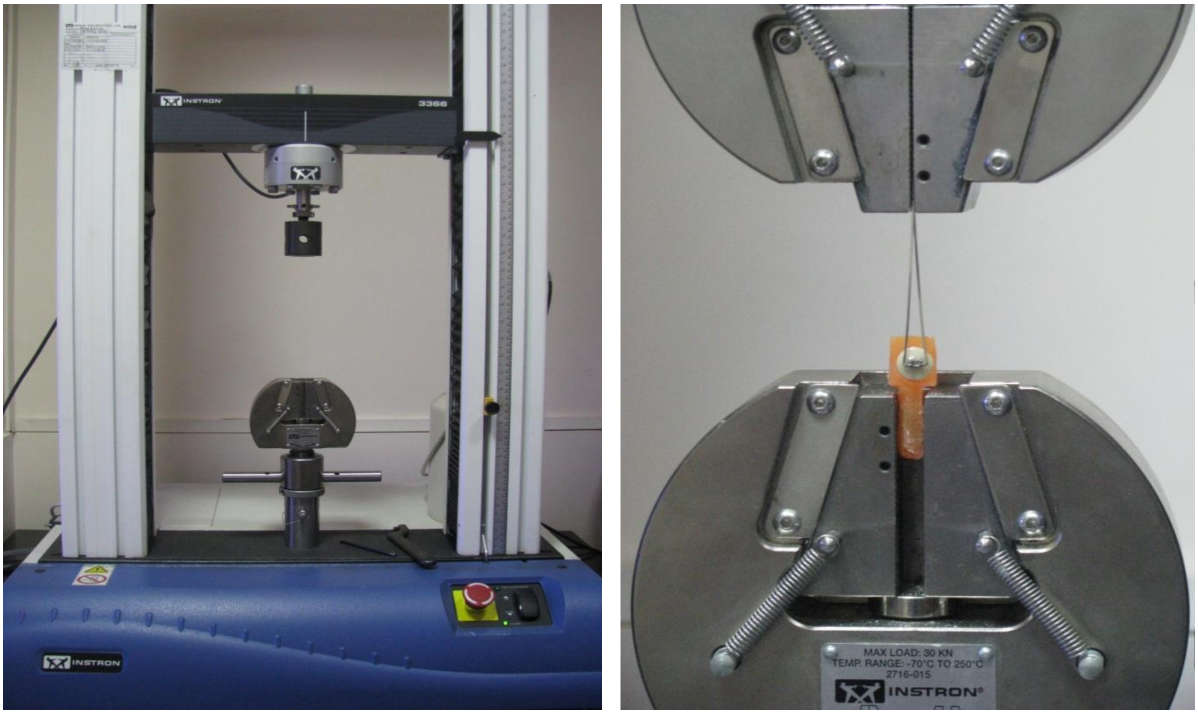

Fig: 1 Instron / Universal testing machine model no 3366 (instron corporation.) Shear bond strength testing

Scanning Electron Microscopy

To evaluate the effect of surface-conditioning methods on the ceramic surfaces, the surfaces of one specimens of each group were then conditioned with the same experimental protocol described above. One roughened specimens for each group was gold sputtered with a sputter coater and examined under a field emission scanning electron microscope (SEM, Carl Zeiss, EVO 18 Special Edition). The SEM photomicrographs were taken at 150x and 750x magnification.(Fig:2,3,4,5).

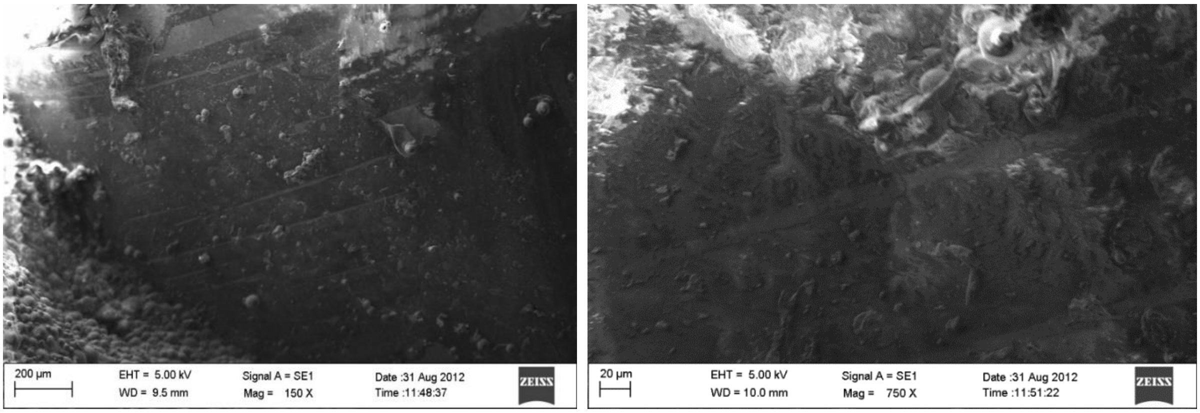

Fig: 2 Scanning electron microscopy photographs of an intact, glazed porcelain surface treated with silane at 150x, 750x showed no abrasion or peeling of the porcelain surfaces.

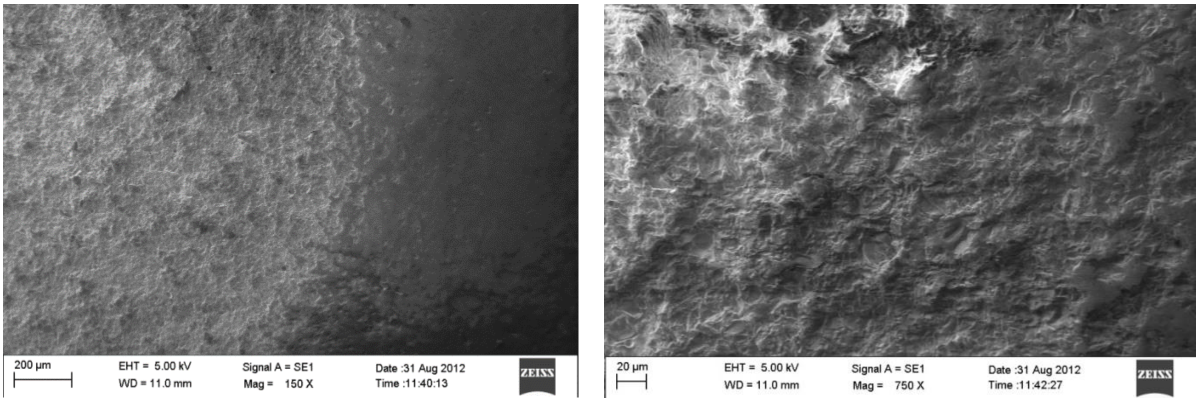

Fig: 3 Scanning electron microscopy photographs of a porcelain surface treated with sandblasting at 150x,750x showing uniform peeling with shallow undercuts on the porcelain surface

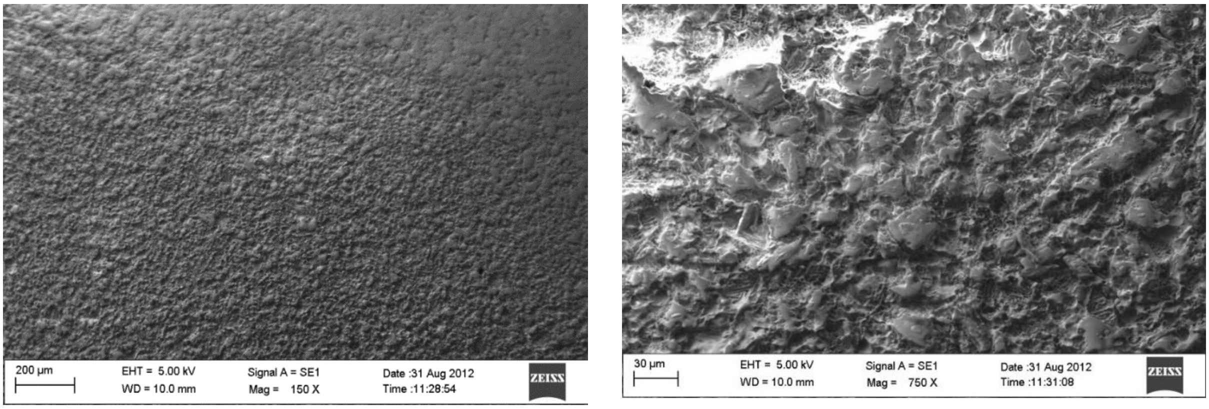

Fig: 4 Scanning electron microscopy photographs of a porcelain surface treated with hydrofluoric acid at 150x,750x showing pits with deeper undercuts and more loss of glazed surface

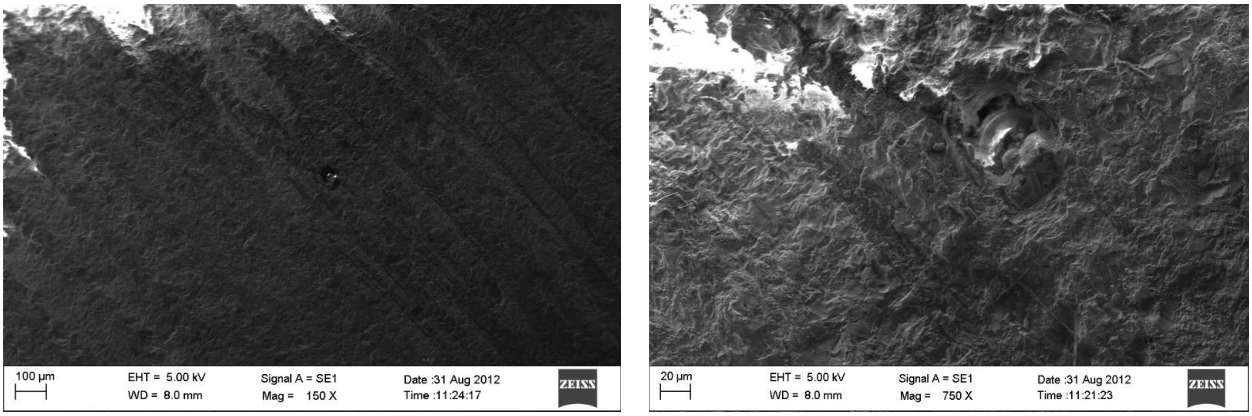

Fig: 5 Scanning electron microscopy photographs of a porcelain surface treated with diamond bur at 150x,750x showing roughened morphology- peeling and erosive appearance with deeper grooves and undercuts and loss of porcelain structure.

STATISTICAL ANALYSIS

The test statistics was performed using SPSS version 13. Descriptive statistics including the mean, standard deviation and confidence interval for mean were calculated for each group of sample tested. Analysis of variance (ANOVA) was used to determine whether significant differences existed between the various groups with significant difference. Significance of level was predetermined to p value <0.001.

The Bonferroni multiple comparison test was applied to find the group with significant difference. Significance of level was predetermined to p value <0.05.

RESULT

The mean, standard deviation and 95% confidence interval of shear bond strength value for all the groups were calculated.

Group I samples (white) , samples using silane only , showed mean, minimum and maximum bond strength of 3.7 MPa, 0.7 MPa and 7.5 MPa respectively (Table: I).

Group II samples (blue), samples roughened by sandblaster, showed mean, minimum and maximum bond strength of 10.52 MPa, 8.10 MPa and 14.56 MPa respectively (Table:I).

Group III samples (orange), samples etched with hydrofluoric acid showed mean, minimum and maximum bond strength of 5.82 MPa, 1.79 MPa and 13.19 MPa respectively (Table:I).

Group IV samples (green) showed mean, minimum and maximum bond strength of 11.81 MPa, 9.74 MPa and 15.91 MPa respectively. (Table:I)

ANOVA showed that p-value < 0.001 for comparison of all Groups suggesting that significant differences in mean bond strength existed (Table:I). The Bonferroni test showed that statistically highly significance difference existed between all the groups (Table:II). All SBS values in present study were above optimal range except for Group I (only silane) and Group III (9.6% hydrofluoric acid + silane), rendering them clinically acceptable.

Comparison of Shear bond strength

Table I: Descriptive statistics of the four groups and comparison of shear bond strength by anova tests. Significance of level was predetermined to p value <0.001.

	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p value
				Lower Bound	Upper Bound	.001
Silane	15	3.7	1.9	0.7	7.5	
Hydrofluoric acid	15	5.82	2.59	1.79	13.19	hs
Sandblasting	15	10.52	3.22	8.10	14.56	
Diamond bur	15	11.81	3.43	9.74	15.91	

Stress at maximum load (MPa)

Multiple Comparisons

Table II: Multiple comparison of shear bond strength between four groups using Bonferroni test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	p
Silane	Hydrofluoric acid	-6.104733(*)	1.808343	.008
	Sandblasting	-5.555467(*)	1.808343	.020
	Diamond bur	-5.982400(*)	1.808343	.010
Hydrofluoric acid	Silane	6.104733(*)	1.808343	.008
	Sandblasting	.549267	1.808343	1.000
	Diamond bur	.122333	1.808343	1.000
Sandblasting	Silane	5.555467(*)	1.808343	.020
	Hydrofluoric acid	-.549267	1.808343	1.000
	Diamond bur	-.426933	1.808343	1.000
Diamond bur	Silane	5.982400(*)	1.808343	.010
	Hydrofluoric acid	-.122333	1.808343	1.000
	Sandblasting	.426933	1.808343	1.000

* Significance of level was predetermined to p value <0.05.

DISCUSSION

The aim of this study was the evaluation of effectiveness of different surface-conditioning methods on shear bond strength of metal brackets bonded to porcelain fused to metal surface (feldspathic porcelain). Reynolds (1975)[3] stated that clinically adequate bond strength for a metal orthodontic bracket to enamel ranged from 6 to 8 MPa. All SBS values in present study were above optimal range except for Group I (only silane) and Group III (9.6% hydrofluoric acid + silane), rendering them clinically acceptable (Table: I).

In the present study, it was observed that the shear bond strength of Groups II and IV was above that suggested to be adequate. Group I samples, samples in which only silane was applied without any mechanical or chemical roughening got debonded with low bond strength. This could be because of high water solubility of silane. This showed that only silane cannot be used and hence it should be combined with chemical or mechanical roughening.

Chemical roughening with 9.6% HFA showed low SBS. Studies by Turk et al[4] and Sarac et al[5] showed the same. However, Kamada et al[6], Huang et al[7] and Harai et al[8] found HFA to be effective for improving both bond strengths. HFA is applied to increase micromechanical retention creating surface pits by preferential dissolution of glass phase from the ceramic matrix and to acidify the porcelain surface before silane application. The high aluminium oxide containing glaze and the increasing strength of porcelain makes its more resistant to chemical attack and reduces the effect of HFA etching.

The SBS achieved with APA was higher than that produced by HFA. However there is a disagreement concerning the effectiveness of APA with alumina in literature. Schmage et al[9], Ozcan et al[10] found APA with alumina particles to be more effective than chemical etching with HFA. Harari et al[8], Turkkahraman et al[2] and Karan et al[11] found that application of HFA was more effective than microetching with alumina.

It has been found that mechanical roughening with diamond burs and sandblasting provoked crack initiation and propagation within the ceramic. Since the crowns generally remain in the mouth after de-bonding, any damage to the ceramic surface should be avoided.[12] On the other hand, HFA has been found to be a harmful and irritating compound for soft tissues. Organosilane coupling agents are suggested to enhance bonding brackets to porcelain surfaces, but they fail to provide clinically sufficient bond strengths when used alone.[13] The result of the present study is in concordance with that of Zachrisson et al.

The SEM photomicrographs of the ceramic surface etched with 9.6% hydrofluoric acid revealed fewer pits and more loss of glazed surfaces. For the ceramic abraded with alumina, loss of glazed surface and mild roughening was seen. Uniform peeling or an erosive appearance with shallow penetrations and undercuts was observed when compared with chemical etching. The ceramic surface roughened with diamond bur showed more roughened morphology- uniform peeling or an erosive appearance with deeper grooves and additional undercuts were observed when compared to HFA and APA.(Fig:2,3,4,5).

These different microscopic appearances corroborate the SBS values. The bond strength gradually increased due to the gradual increase in roughening of the ceramic surface. Although roughening of the ceramic surface results in higher bond strength, removal of the glaze by grinding diminishes the transverse strength of the porcelain to half of that when the glaze was present. Cracks created during roughening lead to porcelain damage during debonding.

CONCLUSION

Under the conditions of this in-vitro study, it was concluded that

1. For minimal surface roughness, HFA or silica coating should be preferred as diamond bur and APA created higher surface roughness. The bond strength gradually increased due to the gradual increase in roughening of the ceramic surface
2. For optimal or higher bond strength, APA or diamond bur could be used, however use of diamond bur could lead to fracture of the ceramic surface.
3. Use of APA can be clinically recommended as it increases the bond strength with less surface damage.

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