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Methods of Porcelain Conditioning and Their Influence over Bond Strength and Surface Integrity-A Comparative Study

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ABSTRACT

Objective: to compare four different methods of porcelain conditioning for bracket bonding and the impact of these methods on bond strength and surface integrity of ceramics after debonding.

Methods: four experimental groups(n=25) were set up depending on the ceramic conditioning method: G1= 37% phosphoric acid gel etching followed by silane application; G2= 37% liquid phosphoric acid etching followed by silane application; G3= 9.6% hydrofluoric acid etching followed by thorough washing; and G4= 9.6% hydrofluoric acid etching followed by silane application. After surface conditioning metal brackets were bonded to porcelain by 3M Unitek Transbond XT adhesive. Samples were submitted to shear bond strength tests in a universal testing machine and the surfaces were later assessed with a microscope under 10X magnification. ANOVA test was performed to establish the difference between groups ($\alpha=0.05$)

Results: the highest shear bond strength values were found in groups G4 and G3(6.84 ± 1.93MPa and 5.01 ± 2.05 MPa respectively), followed by G1 (4.71 ± 2.19MPa) and G2 (4.42 ± 1.77 MPa). Regarding the surface evaluation after bracket debonding, the use of liquid phosphoric acid followed by silane (G2) produced the least damage to porcelain. G4 increased the risk of porcelain fracture.

Conclusion: acceptable levels of bond strength were reached by all methods tested, however, G2 showed the least damage to the ceramic surface.

Keywords: Ceramic conditioning, Orthodontic brackets, aluminium oxide, veneers.

I. INTRODUCTION

With the advent of biocompatible, non-metallic and esthetically pleasing ceramic materials, an increase has been seen in the demand and use of all-ceramic materials for the restoration of damaged teeth and to replace lost teeth, particularly in adult patients who seek the treatment for esthetic purpose[1,2]. Thus, orthodontists are faced with the challenge to fix the orthodontic attachments to the teeth that have been replaced with ceramic restorations.

Being an inert material, ceramic does not bond chemically to any of the available bonding resins. A number of methods like sand blasting[3], using diamond burs to roughen the surface, etching[4] , using silane coupling agents, etching with lasers[5] and curing with halogen and plasma arc lights[6] have been advocated to increase the bond strength. However, mechanical alterations like sand blasting and diamond burs roughen the surface of porcelain and can cause irreversible damage to the porcelain..[7] It has been seen that chemical agents like phosphoric acid and hydrofluoric acid along with silane provide with sufficient bond strength[6, 8, 9]. However, there is still scientific consensus about which technique would be ideal for bonding brackets to porcelain.[10]

As there has been an increase in adult patients seeking orthodontic treatment, more evidence is required for method of bonding orthodontic attachments to ceramic. Hence the purpose of the present study was to compare the methods of porcelain conditioning on bond strength and to evaluate the surface integrity of porcelain by four different chemical methods.

II. MATERIAL AND METHOD

This research had an experimental in-vitro study design. Hundred feldspathic porcelain were mounted on PVC tubes with the help of cold cure resin. A metal mould was made with the help of CAD/CAM machine. It was designed to have two plates which had 1.2cm diameter and 1.7mm thickness.

VITA dentin body powder was mixed with vita modeling fluid and condensed into the mould space and the excess water was blotted with a clean tissue. This ensured lower firing shrinkage and less porosity in the sintered porcelain. Then after this, the mould was carefully removed to leave back the ceramic specimens which were left on the cobalt-chromium plate which acted as base sintering.

Later on, after condensation, the ceramic specimens along with the metal base plate were placed in the furnace and fired at 930° C for 7min. The ceramic specimens after firing were removed and finished using sintered diamonds, stone bur and finishing points. All specimens were cleaned with steam cleaner followed by cleaning in an ultrasonic cleaner for 10mins. Finally, glaze in (VITA AKZENT) was applied and fired at 920°C for 5 mins.

After porcelain build-up, porcelain cylinders were mounted into PVC tubes with the help of cold cure acrylic resin taking care that samples should be centrally placed. During embedment, ceramic samples were pressed against a wax sheet so that they remained stationary.

Orthodontic stainless steel pre-adjusted edgewise brackets having standard (022 X .028). American Orthodontist (AO) were used for evaluating the shear bond strength. These brackets have a flat base which allowed stable positioning on the samples.

The Bonding agent used was 3M Unitek Transbond XT adhesive and 3M Unitek Transbond light cure adhesive paste. All samples were equally divided into four groups. Each group contains 25 samples. Each group underwent a different surface conditioning process.

Each sample was submitted to a shear bond strength test performed by universal testing machine (ACME engineers, India, UNITEST 10, Crosshead speed: 0.5mm/min). The force per unit of area required to debond brackets was recorded in Newtons and converted into Megapascal(1MPa=1 N/mm²) and named shear bond strength. After debonding, the adhesive remnant index (ARI) was assessed under 10x magnification (Wuzhou New Found Instrument Co. Ltd, China Model: XTL 3400). Scores ranged from 0 to 3: 0= absence of adhesive remnant; 1= less than half of the adhesive remnant; 2= more than half of the adhesive remnant; 3= all adhesive remnant attaches to the sample.

A similar method was used to assess the damage caused to the ceramic surface. The ceramic surface damage index(CSDI) used was: 0= no damage to the surface; 1= absence of glaze on ceramic surface; 2= presence of glaze and crack on ceramic surface; 4= fractured ceramic surface.

Statistical analyses were performed using SPSS V22.0 at a level of significance at ≤ 0.05 and analysis of variance (ANOVA)was performed to establish the difference between groups.

III. RESULTS

Table 1 displays results for the difference found in mean bond strength values. The ARI values are displayed in table 2 and CSDI is displayed in table 3.

Group G3 and G4, yielded the highest bond strength values whereas G2 showed the lowest values.

G2 group showed the best preservation of ceramic surface.

Table 1-Shear bond strength values

Group	N	Mean	SD	Minimum	Maximum	F	P-value.
I	25	4.71	2.19	1.63	9.55	7.544	0.001
II	25	4.42	1.77	2.59	8.75		
III	25	5.01	1.93	4.13	9.78		
IV	25	6.85					

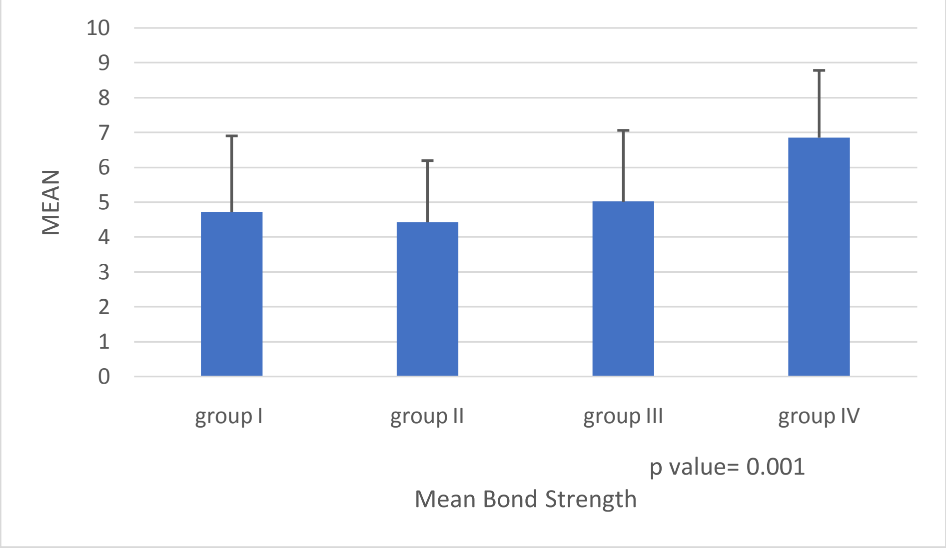

Table 2: mean adhesive remnant index

Group	N	Mean	SD	Minimum	Maximum	F	P value.
I	25	2.32	0.69	1.00	3.00		
II	25	2.56	0.65	1.00	3.00		
III	25	2.28	0.68	1.00	3.00	2.48	0.066
IV	25	2.72	0.61	1.00	3.00		

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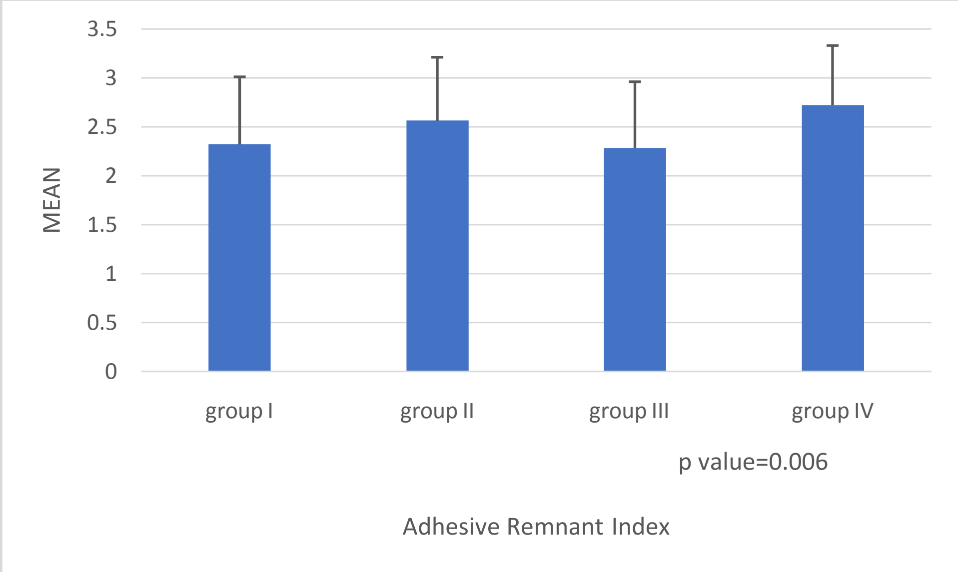
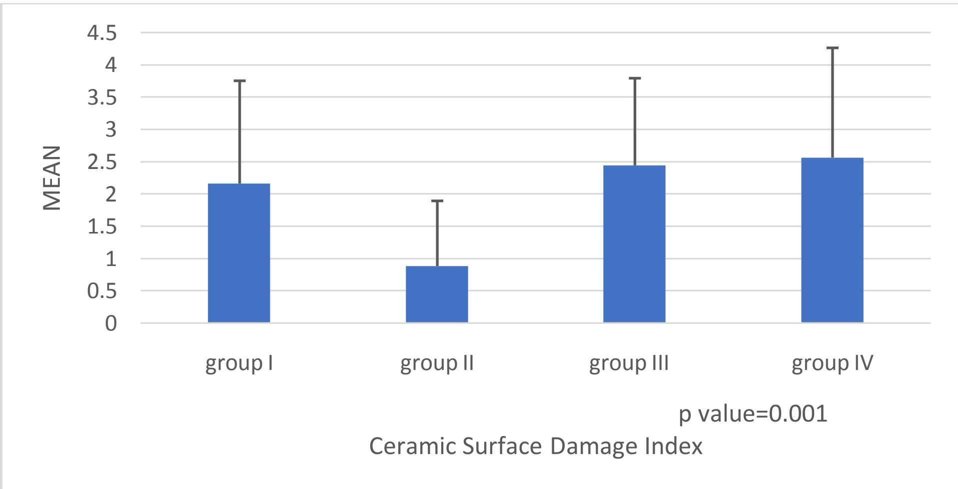


Group	N	Mean	SD	Minimum	Maximum	F	P-value.
I	25	2.16	1.59	0	4	7.136	0.001
II	25	0.88	1.01	0	4		
III	25	2.44	1.35	0	4		
IV	25	2.56	1.70	0	4		

Table 3-Ceramic surface damage index



IV. DISCUSSION

The number of adult patients seeking orthodontic treatment is increasing [21, 22]. This has encouraged orthodontists to test several different protocols concerning bonding brackets to different dental restorations (specifically porcelain/ceramic restorations). Bonding orthodontic brackets to porcelain/ceramic surfaces present a higher degree of failure when compared to bonding to enamel. Many times, this is granted to the porcelain type and surface conditioning, bracket material (base design, retention mode), properties of the bonding adhesive, and the light-curing source, as well as the skill of the clinician.[22, 23]

The shear bond strength results obtained in each group of our study were 4.70 MPa, 4.41 MPa, 5.01 MPa, and 6.84 MPa, pertaining to surfaces etched with 37% phosphoric acid gel etching followed by silane application (G1), 37% gel phosphoric acid liquid etching, followed by silane application (G2), 9.6% hydrofluoric acid etching alone (G3), 9.6% hydrofluoric acid etching followed by silane application (G4), respectively. Hydrofluoric acid etching with silane application was found to be necessary for direct bonding, which corroborates previous findings since similar shear bond strength results were found.

When shear bond strength, AR,I and CSDI values were analytically compared, the following was noted: G1 showed intermediate bond strength values, minimum adhesive left on most of the sample surface, and moderate (presence of glaze and cracks on the surface) to slight (absence of glaze) damage to the ceramic surface;

G2 showed the lowest shear bond strength values, although it also achieved minimal clinical requirements, the highest rate of surface preservation of samples left intact and only slight damage (presence of glaze and crack), and none of the samples fractured despite the high concentration of samples with score 0 in ARI; G3 showed good shear bond strength values, but with a high rate of surface damage, presenting with fractures cracks and lack of glaze; G4 also showed high bond strength values, but similarly to G3, there were high levels of surface fracture and lack of glaze and cracking.

Rambhiaet al.[24] used two different adhesives: Fuji Ortho LC and Ortho Bracket Adhesive. Kitayama et al[13]. used three adhesives: Concise as a chemically cured composite resin, Fuji Ortho as a chemically cured resin-modified glass ionomer cement, and Fuji Ortho LC as a light-cured resin-modified glass ionomer cement. Both studies concluded that there was no alteration among the different adhesives. The studies that focused on analyzing porcelain surfaces treated with silane concluded that the bond strength of brackets to porcelain surfaces was improved by the application of silane. In our study, we have used 3M silane as adhesive for determining the shear bond strength. The reason is that silane forms chemical bonds with inorganic and organic surfaces, which ultimately increases the bond strength.[14, 15, 18]

The studies that tested different acid concentrations concluded that the use of a strong acid to etch porcelain increases the bond strength because the acid creates a series of pits on the surface by the dissolution of the glass phase from the ceramic matrix.[16] Throughout the studies, it is apparent that the use of hydrofluoric acid greatly increases the bond strength. This is due to the acid's ability to react with the silica phase, which creates micro-mechanical retention through microchannels. Over time, the glassy matrix partially dissolves and increases the formation of retentive channels. The etching of HFA ultimately increases the surface area, which helps penetrate the resin cement into the micro-channels created.

Using 9.6% hydrofluoric acid gel and 3M silane combination had the highest shear bond strength(6.84MPa) which was perTrakyalii G, Malkondu O, Kazazoglu E, Arun T[16]who stated that the lowest shear bond strength was with 5% hydrofluoric acid gel and Pulpdent silane and the highest bond strength was noted with 9.6% hydrofluoric acid gel and Reliance silane combination.

Till today there have been no studies conducted regarding 3M silane as a bonding agent, so in our study, our objective was to check the shear bond strength (SBS), adhesive remnant index (ARI) and ceramic surface damage index (CSDI) using 3M silane agent. Results from the study by Trakyalii G, Malkondu O, Kazazoglu E, Arun T[16], and Costa AR,Correr AB, Puppin-Rontani RM[19]proved that there was a difference between the bond strength that resulted from the various brands of silane. The conclusion proved that silanization with Reliance resulted in higher bond strengths than Pulpdent.

In our study, we used a glazed porcelain surface to check the Shear bond strength. The prosthesis made with porcelain should have a glazed surface so it was necessary to check the bond strength on the same. Barcelo Santana HF, Hernandez MR, Acosta Torres SL, Sanchez Herrera LM, Fernandez Pedrero AJ, Ortiz Gonzalez R[14]concluded that the deglazed porcelain surface would yield the highest shear bond strength.

As mentioned above Group IV samples showed maximum adhesive left on the bracket base followed by Group III, Group I, and Group II respectively

The porcelain surfaces of group IV were etched with 9.6% hydrofluoric acid for one minute followed by water rinsing for another minute then by gentle air drying followed by silane application by another one minute.

In our study group IV samples had almost all adhesive left on bracket base when conditioned with 9.6% HF acid gel in combination with silane which was similar to the study done by, Brian Nebbe, and Errol Stein[7], Elham S. J. Abu Alhaija, Issam A. Abu AlReesh and Ahed M.S. AlWahadni, Pinar Cevik, NejlaKaracam, OguzEraslan&Zafer Sari.[20]

The study done by B. M. Bourke, W.P. Rock[12]stated that etching phosphoric acid for 60 seconds and prime with silane provided the highest amount of adhesive remnant on bracket base which was dissimilar with our study.

Along with the highest bond strength revealed with etching of 9.6%HF acid gel in combination with silane treatment the ceramic surface damage too was noted on the ceramic surface. Similar results were noted in the studies done by Immanuel Gillis and Meir Redlich[11] in which surface damage was maximum when HF acid was used along with silane + concise as adhesive. Another study was done by RaedAjlouni; Samir E. Bishara; CharuphanOonsombat; ManalSoliman; John Laffoon[6] in which they concluded that microetching + HF acid produced the greatest damage to porcelain surface when compared with self-etch/silane/adhesive combinations and B. M. Bourke, W.P. Rock[12] in their study which found that etching with HF acid +silane was associated with a higher incidence of severe porcelain damage as compared to phosphoric acid+silane+Scothbond dental adhesive.

This study contains many limitations, which makes it difficult to apply the results to clinical practice. Since the studies found were in vitro, the conclusions do not hold direct value, and to employ these methods on humans could be unsafe. The results cannot be universally accepted since many environmental factors could have influenced the determination of the most efficient method in bonding the brackets to porcelain surfaces.

One more limitation of the present study is related to sample storage. The shear bond strength results and surface damage may be related to the lack of thermal cycling.

V. OBSERVATIONS AND CONCLUSION

1. Assessment of shear bond strength reveals that, 9.6% hydrofluoric acid, when applied on porcelain disks for one minute followed by washing and drying of surface and application of silane for another minute, provided highest bond strength. 9.6% hydrofluoric acid etching alone for one minute provided lesser bond strength values followed by 37% phosphoric acid gel etching followed by silane application and 37% gel phosphoric acid liquid etching followed by silane application.
2. The brackets bonded using 9.6% hydrofluoric acid with silane treatment resulted in more amount of residual adhesive left on the bracket base. Whereas other groups of brackets bonded resulted in a minimum amount of residual adhesive left on samples.
3. The greatest amount of porcelain damage was noted with 9.6% hydrofluoric acid with silane treatment followed by 9.6% hydrofluoric acid etching, 37% phosphoric acid gel etching with silane application and 37% phosphoric acid liquid etching and silane application.

In conclusion,

- G4 (9.6% hydrofluoric acid +silane) provided highest bond strength among four groups.
- G2 (37% liquid phosphoric acid + silane) provided least bond strength among four groups.
- G4 (9.6% hydrofluoric acid + silane) caused greatest amount of porcelain damage among four groups.
- G2 (37% liquid phosphoric acid + silane) caused least damage to the porcelain surface.

Thus G2 provided acceptable amount of bond strength with least ceramic damage.

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