Bonding Brackets to Porcelain - *In Vitro* Study

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The aim of this research was to verify, *in vitro*, the effect of various porcelain surface treatments on the shear strength of orthodontic brackets bonded to porcelain and the mode of fracture after debonding. Eighty-eight samples of metallic supported feldspathic porcelain were randomly divided into four groups according to their surface preparation as follows: the porcelain was maintained intact (GI), roughened with a diamond bur (GII), etched with 10% hydrofluoric acid (GIII), or sandblasted with aluminum oxide (GIV). The specimens were treated with silane (Scothprime) and brackets were bonded with Concise. Each sample was subjected to a shear load at a crosshead speed of 1 mm/min and a recording was made at the point of failure. Bond strengths, adequate to withstand the application of orthodontic forces, were achieved in all groups. The Kruskal-Wallis statistical test showed no significant differences in bond strength between the groups ($p > 0.05$). However, many more porcelain fractures occurred on deglazed porcelain. This study indicates that with the appropriate material selection, the silane/composite procedure alone may be adequate for bonding.

Key Words: bonding, brackets, porcelain, orthodontics.

INTRODUCTION

Direct bonding brackets on etched enamel surfaces have been widely documented in orthodontic literature and are clinically successful. Over the past few years, the demand for orthodontic treatment in adults has greatly increased and the orthodontist faces the necessity of bonding accessories to already existing restorations. Although bands can be placed on single porcelain crowns, this is not possible on the abutment teeth of fixed bridges (1). Furthermore, esthetics is an important factor for adults and therefore bonding to porcelain must be considered (2).

When dealing with bonding brackets to porcelain there are at least 3 variables that are exclusive to this material and therefore should be mentioned to better understand the complexity of the subject: composition, surface integrity and resistance. The chemical composition constitutes a problem due to the fact that it is virtually impossible for an orthodontist to differenti-

ate between various types and brands of porcelain in a clinical situation (3,4). Many of these materials are similar in chemical formula, but there are differences in components, crystalline structure, particle size, sintering behavior, and microtopography created by etching (5). Calamia et al. found that the bond strength of composite resin to aluminous porcelain was inferior to that of feldspathic porcelain (6). Although alumina increases the strength of porcelain, it is highly resistant to chemical attack and therefore does not etch well (5). The surface integrity depends on finishing procedures (glazed or polished porcelain) and to reach maximum resistance, technique and material used to fabricate the restauration must necessarily be considered. Furthermore, it is highly important that the porcelain is well supported by the tooth or the metallic structure.

Conventional acid etching is ineffective in the preparation of porcelain surfaces for the mechanical retention of orthodontic attachments (2). When trying to obtain mechanical or chemical retention of brackets

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on porcelain, materials and techniques, which were mostly derived from bonding systems to repair porcelain, were developed to resist orthodontic and mastigatory forces. These procedures should keep the accessories bonded throughout the orthodontic treatment and ideally not damage the porcelain surface during debonding. The aim of this research was to verify, *in vitro*, the effect of various porcelain surface treatments on the shear strength of orthodontic brackets bonded to porcelain and the mode of fracture after debonding.

MATERIAL AND METHODS

One hundred and ten metal-porcelain samples (Biobond II-Ceramco II, Dentsply Indústria e Comércio Ltda., Petrópolis, RJ, Brazil) in standardized sections of 10 x 10 x 2 mm were produced according to manufacturer recommendations. Before glazing, each surface was flattened on a metallurgical wheel (Isomet 11-1180 Low Speed Saw, Buehler Ltd., Dusseldorf, Germany) using 400- and 600-grit silicon carbide paper (Lixa d'água Waterproof, Carborundum Abrasivos, São Paulo, SP, Brazil) producing a 1.5-mm thickness of porcelain for all specimens. After this, a fine layer of glaze (Fine Grain Stain Incolor and Fine Grain Stain Liquid, Ceramco II, Dentsply Indústria e Comércio Ltda.) was applied and those with visible flaws were rejected.

In order to proceed with the shear bond test, 88 assemblies were mounted vertically and centrally to the base of PVC tube segments (27 mm in height; Tigre, Joinville, SC, Brazil) which were used to retain the plaster (Empresa e Indústria Gesso Mossoró SA, Rio de Janeiro, RJ, Brazil) that embedded the metallic extensions (sprues) of the specimens. The procedure was made possible with the help of a specially designed template.

Each porcelain surface was pumiced with a rubber prophylaxis cup (Viking, São Paulo, SP, Brasil) in a low-speed conventional handpiece (Kavo do Brasil S.A. Indústria e Comércio, Joinville, SC, Brazil), washed for 20 s and dried with a mild continuous stream of oil-free compressed air. The specimens were then numbered, randomly divided into four groups and subjected to one of the following conditions: GI: the glaze was maintained; GII: the glaze was removed with diamond burs (8835 314 014 Gebr. Brasseler, Lemgo, Germany); GIII: etched with 10% hydrofluoric acid (Dentsply

Indústria e Comércio Ltda.) for 4 min; GIV: sandblasted with 50 µm aluminum oxide (Microetcher II Dental Bonding System, Denville Enginneering Inc., San Ramon, CA, USA) under 90 psi air pressure, with the nozzle held 10 mm from the porcelain surface until it appeared completely frosted.

The GII, GIII and GIV porcelain specimens were thoroughly rinsed with a steady stream of water for 15 s and dried with oil- and humidity-free compressed air. Three coats of the primer (Scotchprime Ceramic Primer, 3M Unitek, Monrovia, CA, USA) were painted onto the porcelain surface with a disposable brush and allowed to dry. With a special gadget, Concise System was used to bond the brackets (Mini Standard Edgewise, Superior Central Incisor, American Orthodontics, Sheboygan, WI, USA) with the slot vertically positioned onto the center of each assembly (Figure 1). The technical procedures for precisely fixing the brackets followed exactly the same pattern for all groups.

The assemblies were then stored in distilled water at 37°C for 24 h, then thermocycled 500 times (5°-55°C) with a dwell time of 20 s per bath. After termocycling, the slight excess of adhesive material outside the bracket bases was carefully removed with a small round tungsten-carbide bur (H7S314009 Gebr. Brasseler, Lemgo, Germany) to standardize the surface area for bond strength testing (3). The assemblies were again stored in water at 37°C and were submitted to the shear load test 8 days after the bonding procedure.

Each sample was subjected to a shear load in a Universal Testing Machine with a knife-edged blade (DL-10.000, EMIC model) at a crosshead speed of 1 mm/min. The force was applied parallel to the porce-
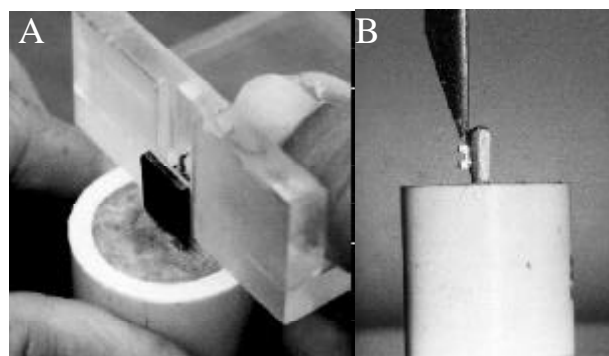

Figure 1. A) Special acrylic apparatus used to fix the bracket into position and removed after resin polymerization. B) Shear test jig. Blade was located parallel to long axis of the porcelain.

lain surface close to the bonded area and a recording made of the shear load at the point of failure (Figure 1). The force per unit area required to dislodge the bracket was then calculated and reported as the shear bond strength in megapascals (MPa). After debonding, an optic microscope (Leiz-Wetzlar, D.F. Vasconcellos SA, Leitz, Brazil) with 10X magnification was used to examine all bonding sites and classify them according to the Adhesive Remnant Index (ARI) (7) and porcelain fracture. The most representative specimens of each group were placed on stubs, coated with a conductive layer of gold and palladium (about 300 Å) and examined with a scanning electron microscope (Stereo Scan 250 MK3, Cambridge Instruments, Cambridge, England).

RESULTS AND DISCUSSION

Dental literature presents studies where surface roughening is done to increase the area available for chemical and/or mechanical retention (2,3,8-12) to the porcelain. Therefore, an increase in bond strength between composite and porcelain is expected. It is known that the esthetic and structural qualities of the porcelain may be irreversibly lost with surface roughening. The glaze is effective in strengthening the porcelain, thereby reducing crack propagation (8). Thus, it is imperative to find techniques that do not destroy the restoration while debonding. Based on this, one of the aims of this research was to promote different ways of preparing the

porcelain surface before bonding and determine which one has the least deleterious effect on the porcelain surface after debonding.

Microscopic evaluation revealed that roughening with a coarse diamond bur gave a random pattern of porcelain removal that corresponded to the irregular arrangement of the cutting edges on the abrasive instrument. The sandblasting procedure with aluminium oxide gave the porcelain surface a frosted appearence very similar to that observed by Zachrisson et al. (3). Scanning electron microscopy also showed that the abrasion produced by the Microetcher and diamond burs removed the glaze of the porcelain. However, the conditioning with hydrofluoric acid (HF) revealed the same pattern reported by Tylka et al. (13): a three-

Table 1. Shear bond strength (MPa) comparison of GI, GII, GIII and GIV.

Descriptive statistics	Groups			
	I	II	III	IV
Number	22	22	22	22
Mean	17.68	17.11	16.12	18.64
S.D.	8.11	7.37	7.77	7.61
Minimum	6.30	7.07	4.63	6.06
Maximum	28.43	28.36	26.83	28.83

Kruskal-Wallis test
Test statistics = 1.827; p-value = 0.609

Table 2. Adhesive remnants on porcelain samples, scored according to the ARI System and number of fractured porcelain after shear load test.

	Ari Score				P. F.
	0	1	2	3	
GI	0	1	5	8	8
GII	1	0	2	4	15
GIII	0	1	4	5	12
GIV	0	0	4	7	11

Score 0 = No adhesive left on the porcelain.
Score 1 = Less than half of the adhesive left on the porcelain.
Score 2 = More than half of the adhesive left on the porcelain.
Score 3 = All adhesive left on the porcelain, with distinct impression of the bracket mesh.
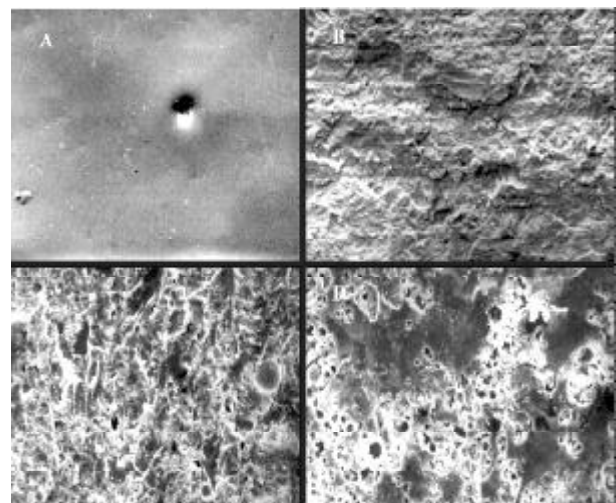P.F. = Porcelain fractured.

Figure 2. SEM photomicrographs: A) Intact porcelain; B) glaze removed with diamond burs; C) sandblasted with microetcher; D) hydrofluoric acid etched. Original magnification 200X.

dimensional lattice of voids and channels, together with intact islands of glazed porcelain not affected by the etchant (Figure 2). It has been shown that, depending on the concentration of HF, there is preferential dissolution of the glassy or crystalline phase of the porcelain. Differences in these two phases and the varying particle sizes of the different porcelains appear to be the cause of different etch patterns (14). This study shows the effectiveness of HF in promoting microretention for bonding. However, extreme care should be taken during intra-oral application of HF due to severe tissue irritation when the acid comes in contact with soft tissues.

The data for bond strength (MPa) comparison of groups are listed in Table 1. The Kruskal-Wallis test was run on the data and showed no significant differences in bond strength among the groups (p>0.05). In this research, the shear force necessary to dislodge the brackets from the porcelain surface ranged from 4.63 (GIII) to 28.83 MPa (GIV) with a mean average of 17.83 MPa. Knoll et al. (15), who studied the shear

bond strength of metallic brackets bonded with Concise to dental enamel, found a value that ranged from 11.21 to 21.37, with a mean average value of 16.11 MPa. Reynolds (16) reported that values between 5.88 and 7.85 MPa are enough to withstand orthodontic forces. From the 88 assemblies used in this experiment, only 3 remained below Raynold's range. Therefore, the results achieved in this research are in agreement with those observed while bonding to dental enamel.

Different modes of fracture could be observed under microscopic inspection (Figure 3) and are listed in Table 2. A great number of cohesive fractures of the porcelain could be seen (Figure 4) and, most of the time they were directly associated with higher shear bond strength necessary to dislodge the bracket. However, there were assemblies that fractured at lower levels of strength. This could probably be justified by the presence of voids and surface cracks occurring during the process of fabrication of the porcelain and/or while promoting microretention over the porcelain surface, but not detectable under clinical inspection. Cracked surfaces, even those of microscopic size, can act as stress concentrators leading to dental porcelain fractures. The concentrated stress can easily exceed the strength of the porcelain body and, as the depth of the crack increases, a brittle fracture occurs rapidly. Thus, it is highly important to minimize surface irregularities
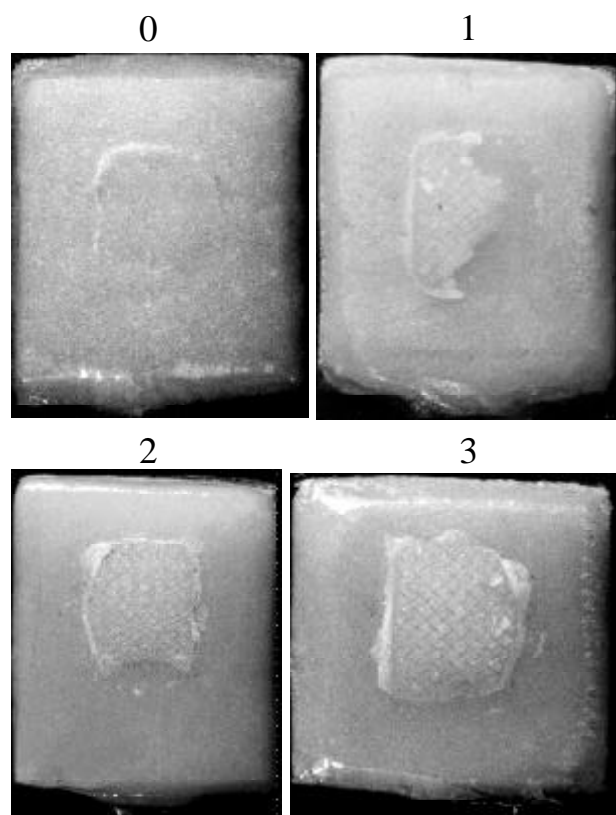

Figure 3. Samples illustrating the different patterns of bracket debonding and representative of all ARI scores. See Table 2 for explanation of scores.
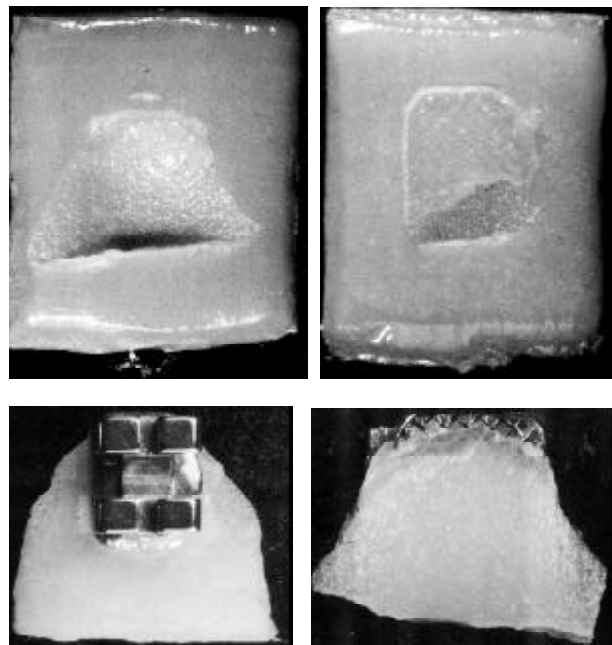

Figure 4. Porcelain fracture pattern commonly found in all groups.

and for that reason glaze is effective in reducing crack propagation (8).

When comparing the results, the lowest incidence of porcelain surface destruction could be seen in glazed porcelain (GI: 36%), followed by the assemblies where roughening of the porcelain was promoted (GII: 68%, GIII: 54%, GIV: 50%). Phillips has shown that if the glaze is removed by grinding, the transverse strength may be only half of that with the glaze present (8). Findings of the current research support this view. In the present study, the roughening of the porcelain (GI, GII and GIII) did not significantly improve composite retention. Therefore, the higher index of porcelain fractures produced on debonding may be due to the weakening of the porcelain structure rather than an increase in bond strength. A higher incidence of porcelain fracture was found when porcelain roughening was promoted with diamond burs (GII). The porcelain structure was weakened, probably due to vibrations of the low-speed straight handpiece. The same could be seen when Eustaquio et al. reported that abrasion with greenstone produced microcracks on the porcelain surface (9). Based on this, the use of a sandblaster to deglaze the porcelain was suggested (3). Among the groups in which microretention was undertaken, GIV had the lowest index of porcelain destruction.

Zelos et al. (17) found 42% of glazed porcelain destruction after the shear mode test of ceramic brackets bonded to porcelain. In this research, we found 36% of glazed porcelain fractures after the shear bond test. This finding is identical to that of the work of Nebbe and Stein in which they tested metallic brackets bonded to glazed porcelain (11). Winchester and Orth (12) reported that the promotion of microretention on the porcelain surface does not appear to be necessary for orthodontic purposes. The results of this research confirm this statement.

As previously described by Zachrisson et al., thermocycling simulates the temperature fluctuations in the mouth by subjecting the bonds to alternating hot and cold water baths. The differences in thermal expansion coefficients between porcelain, resin, and metal result in stresses that cause fatigue. In this research, rigorous thermocycling of the bonds to porcelain was used due to the fact that recent experiments have shown that it is necessary to approximate clinical reality (3).

The issue of bond reliability using organosilanes has been a concern in previous studies in this area as can be seen by the great standard deviation that appears to be the result of many factors (10,18). Major et al. (10) have shown that the operating technique must be such that solutions and bonding surfaces do not become contaminated in any way that may interfere with the principal bonding mechanism. Also, the nature of the bond is such that water can greatly interrupt the ability of the silanol to react to the porcelain surface. Furthermore, the resin must be able to set undisturbed to eliminate weakening of resin during curing (10). In orthodontics, one requires a silane that is effective for the entire treatment, which could take up to two years (12). To test the real efficacy of silane-treated porcelain bonds, it is important that new investigations be carried out with long-term water storage before debonding.

In this study, the shear bond test was performed 8 days after bonding procedures, thus respecting the initial period of chemical reactions among silane/composite/porcelain. This could be confirmed by higher mean values (17.68 MPa) when bonding to glazed porcelain (GI), proving the efficacy of the silane as a coupling agent.

Nebbe and Stein (11), studying brackets bonded to glazed and deglazed porcelain over different time intervals, found that bonding strengths to roughened porcelain were significantly higher in the first 10-min interval. However, there was a progressive increase in bond strengths of the glazed group until it reached a mean value of 18.22 MPa compared to 18.70 of the deglazed group, after 72 h. In view of these findings, they suggest microretentions when immediate force application is necessary after bracket placement. In these cases there is a lack of time for maximum bond strength to develop when bonding to glazed porcelain that may lead to bond failure (11). The orthodontist could consider bonding the brackets on the first appointment and have the patient return the following day to have the arch wire fitted. This would allow the organosilane and the orthodontic adhesive bonds to mature and achieve greater bond strength to resist the forces imparted by the arch wire. In case of bond failure, the porcelain surface can be roughened to increase the bond strength but the incidence of porcelain damage is much more likely (10). This is an *in vitro* study and although clinical evaluations have brought forth useful information (19,20), more research of porcelain exposed to the oral environment may be needed to provide accurate answers.

ACKNOWLEDGMENTS

RESUMO

Sant'Anna EF, Monnerat ME, Chevitarese O, Stuani MBS. Colagem de brackets em porcelana: estudo *in vitro*. Braz Dent J 2002;13(3):191-196.

Este estudo foi realizado com o objetivo de verificar, *in vitro*, a influência de vários tratamentos da superfície da porcelana sobre a resistência ao cisalhamento de "brackets" ortodônticos colados sobre porcelana e o modo de fratura após a descolagem. Oitenta e oito peças de porcelana feldespática suportadas por metais foram divididas aleatoriamente em 4 grupos: a porcelana foi mantida intacta (GI), tornada áspera com broca diamantada (GII), condicionada com ácido HF a 10% (GIII) ou jateada com óxido de alumínio (GIV). Os corpos de prova foram tratados com silano (Scotchprime) e "brackets" foram colados com o Concise. Após ser processado, cada espécime foi submetido ao ensaio de cisalhamento com velocidade de 1 mm/min. Em todos os grupos alcançaram-se forças adequadas para suportar as forças ortodônticas. O método estatístico de Kruskall-Wallis foi aplicado sobre os dados e demonstrou não haver diferenças significativas na resistência de colagem entre os grupos (p>0.05). Entretanto, um maior número de fraturas ocorreu nas porcelanas onde o "glaze" foi removido. Este estudo demonstrou que, selecionando-se apropriadamente os materiais, a utilização somente de silano e compósito pode ser adequada para promover a colagem.

Unitermos: colagem, brackets, porcelana, ortodontia.

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