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Influence of different orthodontic brackets and chemical preparations of ceramic crowns on shear bond strength

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RESEARCH

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ABSTRACT

Background
Bonding to ceramic restorations remains a major challenge to orthodontists, especially due to an increasing number of adults seeking orthodontic treatment.

Aims
The objective of this research was to investigate the influence of two chemical methods used for surface conditioning of ceramic crowns, on shear bond strength (SBS) of metallic and ceramic orthodontic brackets bonded to ceramic surfaces.

Methods
The study was conducted on 48 prepared specimens of metallic and ceramic orthodontic brackets bonded to ceramic crowns, conditioned with two different etching materials: hydrofluoric acid (HFA), or phosphoric acid, and subsequently, silane. SBS was tested using Universal Testing Machine. The samples were analysed using Scanning Electron Microscope, to determine adhesive remnant index (ARI). Statistical data was processed with ANOVA, and ARI was evaluated using x^2 test, with level of significance α=0.05.

Results
SBS values of the groups etched with HFA and silane, compared to the groups etched with phosphoric acid and silane, are not significantly increased. However, ceramic brackets show significantly higher SBS values than metallic brackets.

Conclusion
Both types of ceramic surface conditioning procedures have similar features and provide strong enough SBS values to realize the orthodontic treatment. Also, the assumption that only the type of bracket significantly affects the SBS value can be accepted.

Key Words
Orthodontic brackets, dental ceramic restorations, SBS, HFA, phosphoric acid, silane

What this study adds:

1. What is known about this subject?
Considering the increasing number of adults asking for orthodontic treatment, further studies are required to assess SBS of orthodontic brackets to dental ceramic restorations.

2. What new information is offered in this study?

Ceramic surface etching with HFA doesn't increase SBS of orthodontic brackets compared to etching with phosphoric acid, which is safer to use in clinical conditions.

3. What are the implications for research, policy, or practice?

There is still no consensus regarding the most efficient conditioning protocol for gaining optimal bond strength of orthodontic brackets to ceramic restorations.

Background

With the introduction of the acid-etching bonding technique, by Buonocore in 1955, and with the improvements made later by Newman, the bonding of orthodontic brackets has been highly advanced.[1,2] Nevertheless, due to the increased interest in an aesthetic facial appearance by adult patients and the wide use of ceramics as dental restorations, bonding to ceramics remains a major challenge to orthodontists because of its higher level of failure than bonding to enamel.[3] This is mostly owing to the surface conditioning, the ceramic type, the bracket material, the bonding adhesive, the light-curing source used, as well as the skill of the clinician. Therefore, in order to obtain sufficient bond strength, the need to find a reliable and safer method for bonding orthodontic brackets to ceramic crowns arises. However, the bond strength should be also adequate for easy and safe removal of the bracket, in order to reduce the possibilities of damaging the restoration surface.[3,4]

Various techniques have been presented for bonding brackets to ceramic surfaces, which differ in terms of the surface preparation. Some methods have suggested the use of hydrofluoric acid (HFA), phosphoric acid, or acidulated phosphate fluoride, while others described mechanical roughening procedures, such as sandblasting and diamond stone burs. Obtaining sufficient bond strength is difficult when using only mechanical conditioning procedures with diamond stone burs, sandblasting, or sandpaper discs, and all these procedures damage the glazed surface of the ceramic restoration.[4-11] A combination of acids and silane coupling agent is recommended for chemical preparation of the glazed ceramic surface before bonding.[12-14] Silane enhances bond strength by increasing the chemical bond between the resin composite and the ceramic material.[12-17] Other attributes including the duration of acid etching of the surface, as well as the concentration of the acid applied are also relevant.[17-20]

HFA, best known for its ability to dissolve glass, is mostly applied at concentrations of 5–9.6 per cent for 120 s to ensure optimal bond strength. However, gingival barriers should be used before application to eliminate the very negative effects of HFA to soft tissues, tooth substance and the corneas of the eyes.[5,6,9,12,16] Consequently, the need for a safer procedure for bonding brackets to ceramics has arised.

The bracket material and the bracket's base surface design or the retention mode should also be considered when bonding brackets to ceramic surfaces. Some investigations have found that the shear bond strength (SBS) of ceramic brackets is higher than that of metallic brackets because of the stronger adhesion obtained with ceramic brackets. Furthermore, the higher bond strength of ceramic brackets is due to the increased light availability for photo-polymerization because of greater light transmission, resulting in a higher degree of polymerization and reduced stresses at the adhesive/bracket interface.[7,13-15,19]

Considering that feldspar ceramics provide excellent aesthetics, good biocompatibility and mechanical properties,[21] and are still widely used as restorative materials, as veneers, crowns and bridges, the objective of this study was to examine factors affecting the SBS of orthodontic brackets bonded to ceramic crowns, such as the influence of different surface conditioning materials and of orthodontic brackets made of different materials. Another objective of this study was to overcome the need for etching with HFA, which is highly noxious, with phosphoric acid and silane application as pre-treatment procedures of the ceramic surface prior to bonding.

Method

The sample included 48 prepared specimens of feldspar-based porcelain fused to metal (PFM) crowns (VITA Zahnfabrik, Bad Säckingen, Germany), where orthodontic brackets were bonded to, equally metallic (Mini 2000, Ormco Corporation, Glendora, CA, USA) and ceramic brackets (Glam Forestadent, Bernhard Forster GmbH, Pforzheim, Germany). The bonding surface of the specimens was conditioned with two different etching materials: 5 per cent HFA (IPS Ceramic Etching Gel, Ivoclar Vivadent AG, Schaan, Lichtenstein), or 37 per cent phosphoric acid (Etching solution, Ormco Corporation, Glendora, CA, USA), and subsequently silane (Prosil, Dentscare, Joinville, Brazil) was applied. All brackets were bonded with a two-component (primer and adhesive) composite resin-based bonding system (Tranbond XT, 3M/Unitek, Monrovia, CA, USA). The ceramic crowns were produced by the same technician, and were in the shape of a maxillary premolar, and then embedded in a two-component epoxy filling (Epoxy Repair, Bison International, Goes, Netherlands). Subsequently, the specimens were washed with alcohol (95 per cent) and distilled water. The surface conditioning of the ceramic samples was conducted with etching materials (either 37 per cent phosphoric acid or 5 per cent HFA) for 120s,[15] followed by application of silane. All brackets were bonded by the same operator and positioned in the middle of the ceramic sample. They were pressed firmly, and the excess adhesive was removed from around the bracket base using a dental probe. The adhesive was light cured for 40s,[7] using a light-emitting diode (LED; Ledition, Ivoclar Vivadent AG, Schaan, Lichtenstein). After polymerization, the specimens were thermocycled (5800 cycles, 5ºC to 55ºC in distilled water, 10s dwelling time) in order to simulate the moisture in the oral environment.

The impact of the two etching methods of the ceramic surface and of the two types of brackets on the SBS and ARI was tested using different combination in four groups (n=12): 1. Metal bracket bonded after surface conditioning with 37 per cent phosphoric acid and silane; 2. Metallic bracket bonded after surface conditioning with 5 per cent HFA and silane; 3. Ceramic bracket bonded after surface conditioning with 37 per cent phosphoric acid and silane; and 4. Ceramic bracket bonded after surface conditioning with 5 per cent HFA and silane. As illustrated in Figure 1, SBS was tested in a Universal Testing Machine (Erichsen 0-2000 N, ISO 7500-1:1, AM Erichsen GmbH Corporation KG, Hemer-Sundwig, Germany), with a load applied parallel to the buccal surface of the restoration in gingival-occlusal direction, using a knife-edged rod moving at a fixed rate of 1mm/min, until debonding occurred. The force applied to debond the brackets was recorded in Newton, and SBS values were calculated in megapascal (MPa).

After shear bond testing, the samples were analysed using a Scanning Electron Microscope (Vega TS5136MM, Tescan, Brno, Czech Republic), in order to evaluate the type of bond failure at the bracket-adhesive interface in each test group, to visualize the adhesive remnant and ceramic condition after the brackets removal. Before SEM, the samples were dehydrated over a period of 5h, in increasing concentrations of alcohol (70 per cent and 95 per cent). Subsequently, ceramic brackets and all ceramic crowns were coated with gold and palladium sputter (SC7620 Mini Sputter Coater, Quorum Technologies Ltd, UK). To determine the adhesive remnant index (ARI), the measurements were performed according to Bishara et al., using scores from 1–5.[19] 1—All adhesive remaining on the ceramic crown surface with the impression of the bracket base; 2—More than 90 per cent of the adhesive remaining on the ceramic crown surface; 3—Less than 90 per cent, but more than 10 per cent of the adhesive remaining on the surface; 4—Less than 10 per cent of the adhesive remaining on the ceramic crown surface; 5—No adhesive remaining on the ceramic crown surface.

Statistical analysis of data was based on the hypothesis that SBS and ARI (dependent variables) were not dependent on the type of bracket and the etching method used (independent variables). The Kolmogorov-Smirnov method was used to test the normality of distribution of the SBS data. Since SBS is a continuous variable, the hypothesis was tested using two-way analysis of variance (ANOVA). The ARI index was tested using the chi-square test. The level of significance was set as 0.05. The data were analysed using SPSS Statistics 20.0 (IBM, Armonk, NY, USA).

Results

The Kolmogorov-Smirnov test revealed that the SBS data were normally distributed. Descriptive statistics of SBS are presented in Table 1.

The mean values of SBS for metallic brackets were almost equal for both types of etching methods, i.e., around 10 MPa. For ceramic brackets, the mean value for both types of etching methods was slightly higher than 14 MPa; the difference in the SBS between the types of brackets was significant (*p*=0.013) as presented in Table 2. The observed significant difference in the SBS between the two types of brackets was independent of the type of etching used (*p*=0.616).

Based on our results, the type of bracket influenced the ARI value significantly (*chi-square*=10.626, *df*=4, *p*=0.031). The third ARI category was the predominant category for the ceramic brackets (58.3 per cent), while for the metallic brackets, the data were equally distributed across all categories. The etching method did not significantly affect the ARI index (*chi-square*=2.088, *df*=4, *p*=0.720). The frequency of ARI categories according to the type of brackets and surface conditioning are presented in Figure 2. Some of SEM images of the brackets after debonding from ceramic surfaces are presented in Figure 3.

Discussion

In the present study we hypothesized that the SBS of orthodontic brackets bonded to ceramic surfaces is affected by the bracket material but is not affected by the type of etchant applied, and that phosphoric acid in combination with silane is a reliable conditioning alternative for ceramic surfaces prior to bonding.

It has been recommended that the methods providing sufficient bond strength with less roughening should be used to avoid microcracks on the ceramic surface.[6,12,16] Consequently, in this study, no sandblasting or other mechanical roughening was applied, and the brackets were bonded to a glassed ceramic surface after chemical conditioning. It has been reported that silane application after ceramic surface roughening provides a chemical link between porcelain and composite resin, and increases the bond strength of orthodontic attachments.[13] Phosphoric acid (37.0 per cent) cannot etch a ceramic surface, but has the ability to neutralize the alkalinity of the absorbed water layer, which is present on ceramic restorations in the mouth and thereby improve the chemical activity of the silane primer that is subsequently applied.[4] Furthermore, being aware that in clinical situations etching with HFA, must be used with great caution as it is extremely corrosive and capable of causing severe trauma,[5,6,9,12,16] we aimed to devise an alternative protocol involving etching with less dangerous materials, such as phosphoric acid in interaction with silane.

Previous studies have shown that optimal bond strength ranges from 6–10MPa.[10] Nevertheless, this is not universally accepted in clinical situations, because the bracket-ceramic surface bond is affected by many environmental factors.[4] The present study was performed under *in vitro* conditions, and in all groups, the mean SBS values were above 9.9MPa, but less than 14.8MPa, which might clinically cause cohesive fractures. Since the difference between these groups was not significant concerning the etchant, where all the groups showed high bond strengths, our results may therefore indicate that there is no need to use HFA and that a combination of phosphoric acid with silane is sufficient to achieve higher bond strength when bonding to glassed ceramic surfaces. This is in accordance with previously reported findings.[4,12] However, this is in disagreement with other reports, where the combination of silane and phosphoric acid is very little or in no expression. [3,5,6]

Also, the findings of this study are concurrent with other studies,[7,15] indicating that the bond strength of ceramic brackets was higher than that of metallic brackets, due to stronger adhesion to ceramics and better light transmission, which leads to a higher degree of polymerization and stress reduction on the adhesive-bracket joint. This is promising for adult orthodontics, due to better aesthetics of the ceramic brackets during orthodontic treatment. The opposite has been reported when bonding to all-zirconia ceramic, indicating that the bond strength of metallic brackets was higher than that of ceramic brackets, highlighting the role of bracket base design, when the chemical coupling is weak.[22]
A modification of the ARI, which divided the scale into 5 scores to provide an accurate evaluation of the adhesive remaining on the ceramic surface, has previously been reported.[19] In the present study, ARI scores indicated that there were mixed, adhesive and cohesive types of bond failure in metal bracket groups, independent of the etchant applied, as well as adhesive type of failure in the ceramic bracket groups, also independent of the etchant. These findings are in accordance with some previously reported findings,[6,11] while does not agree with 2010 study of Abu Alhaija et al.[15]

In addition, because of the complexity of the oral environment, it should be regarded that there are some limitations of *in vitro* studies, and that there might be differences between *in vivo* and *in vitro* bond strengths, especially when bonding to other restorative materials. However, despite the limitations, SBS testing remains a relevant methodology to compare bonding protocols by providing important information regarding bracket debonding in clinical situations.[23] Further studies using different combinations of influencing factors are required.

Conclusion

Since there was no significant interaction of the factors in the study, the assumption that only the type of bracket significantly affects the SBS value can be accepted. The bond strength of ceramic brackets to feldspar ceramic crowns is higher than the bond strength of the metallic brackets.

Furthermore, we conclude that the use of hydrofluoric acid for etching purposes does not cause a significant increase in the SBS values as compared to etching with phosphoric acid and silane.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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ETHICS COMMITTEE APPROVAL

Approved by Ethical Committee of School of Dental Medicine, University of Zagreb
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Figure 1: Schematic illustration of SBS testing

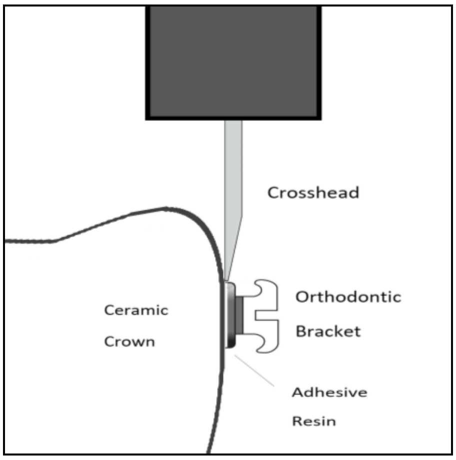

Figure 2: The frequency of Adhesive Remnant Index (ARI) categories by the type of brackets and surface conditioning

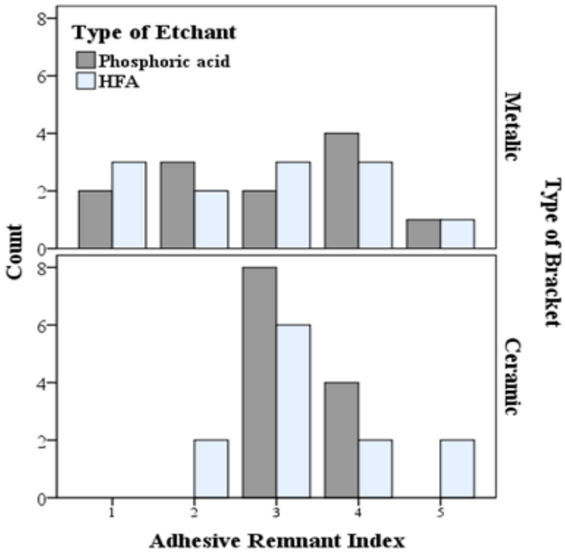

Figure 3: SEM images of ceramic (upper row) and metallic (lower row) brackets after debonding for ARI evaluation

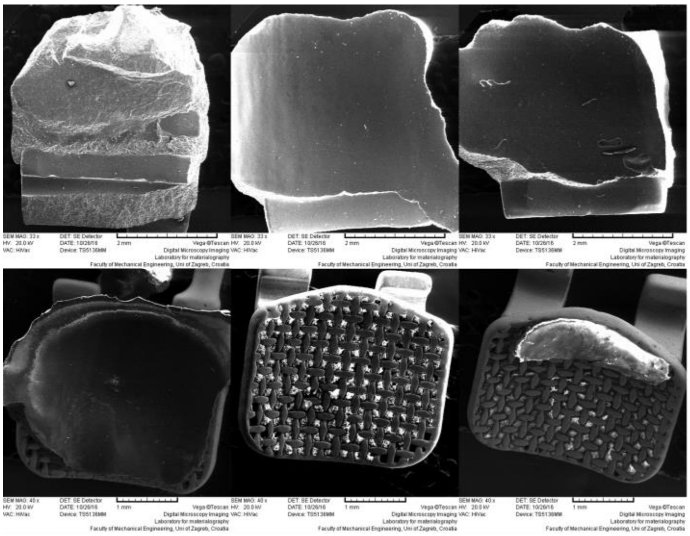

Table 1: Descriptive Statistics of Shear Bond Strength (MPa)

Type of bracket	Type of etchant	N	Mean	SD
Metallic	Phosphoric acid	12	9.90	(4.95)
	HFA	12	10.82	(5.92)
	Total	24	10.36	(5.36)
Ceramic	Phosphoric acid	12	14.10	(4.35)
	HFA	12	14.75	(6.27)
	Total	24	14.43	(5.29)
Total	Phosphoric acid	24	12.00	(5.04)
	HFA	24	12.79	(6.29)
	Total	48	12.39	(5.65)

N- sample number; SD- standard deviation

Table 2: Univariate test of significance for Shear Bond Strength (MPa)

Source	Sum of squares	df	Mean square	F	p
Type of bracket	198.655	1	198.655	6.752	**0.013**
Type of etching	7.508	1	7.508	0.255	0.616
Interaction	0.219	1	0.219	0.007	0.932
Error	1294.501	44	29.420		
Total	8871.654	48			

df- degrees of freedom; F- distribution