Dental Research Journal

Original Article

Shear bond strength of orthodontic brackets to porcelain surface using universal adhesive compared to conventional method

Soodeh Tahmasbi[1], Amin Shiri[2], Mohammadreza Badiee[3]

[1]Department of Orthodontics, Dentofacial Deformities Research Center, Dental School, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran, [2]Department of Endodontics, School of Dentistry, Shahed University, of Medical Sciences, Tehran, Iran, [3]Dentofacial Deformities Research Center, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

ABSTRACT

Background: Considering the increase in demand for orthodontic treatment in adults, bracket bond to restored teeth is a clinical challenge. This study sought to compare the shear bond strength (SBS) of orthodontic brackets to feldspathic porcelain using universal adhesive and conventional adhesive with and without silane application.

Materials and Methods: In this *in vitro* study Fifty-six feldspathic porcelain discs were roughened by bur, and 9.6% hydrofluoric acid was used for surface preparation. Samples were divided into the following four groups ($n = 14$): Group 1: universal adhesive, Group 2: universal adhesive/silane, Group 3: conventional adhesive, and Group 4: conventional adhesive/silane. Mandibular central incisor brackets were bonded, and SBS was measured by Instron® machine. To assess the mode of failure, adhesive remnant index (ARI) score was determined. The data were analyzed using SPSS software and two-way ANOVA, Bonferroni test, and Kruskal–Wallis test ($P < 0.05$ considered significant).

Results: The highest SBS was noted in the universal adhesive/silane group (12.7 MP) followed by conventional adhesive/silane (11.9 MP), conventional adhesive without silane (7.6 MP), and universal adhesive without silane (4.4 MP). In the absence of silane, the conventional adhesive yielded significantly higher SBS than universal adhesive ($P = 0.03$). In the presence of silane, the two adhesives showed SBS values significantly higher than the values obtained when silane was not applied, while the two adhesives were not significantly different in terms of SBS in the presence of silane ($P = 0.53$). Based on ARI score, there were statistically significant differences between Groups 1 and 4 ($P = 0.00$) and Groups 2 and 4 ($P = 0.023$).

Conclusion: Based on the current results, SBS of bracket to porcelain mainly depends on the use of silane rather than the type of adhesive. Both universal and conventional adhesives yield significantly higher SBS in the presence of silane compared to that in the absence of silane.

Key Words: Orthodontic bracket, porcelain, shear bond strength, universal adhesive

Received: July 2018
Accepted: May 2019

Address for correspondence:
Dr. Mohammadreza Badiee, Dentofacial Deformities Research Center, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail: mohammadreza.badiee@yahoo.com

INTRODUCTION

Considering the increase in demand for orthodontic treatment in adults, bracket bond to restored teeth is a clinical challenge.[1] Ceramic restorations are extensively used to replace the lost or severely

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480

How to cite this article: Tahmasbi S, Shiri A, Badiee M. Shear bond strength of orthodontic brackets to porcelain surface using universal adhesive compared to conventional method. Dent Res J 2020;17:19-24.

damaged teeth due to optimal biocompatibility and favorable esthetics.[2,3] Because ceramic surfaces cannot easily bond to other dental materials particularly composite resin, ceramic surface preparation is a necessity before bonding.[4,5]

Several mechanical and chemical methods and a combination of both are used to alter ceramic surface's properties.[2,6,7] Sandblasting and surface roughening by bur are among the commonly used mechanical methods for ceramic surface preparation. Hydrofluoric (HF) acid is also used for surface etching.[8,9] Laser, as an alternative surface treatment modality, has been evaluated as well.[6] Etching of the ceramic surface with HF acid can yield a bond strength value as high as that obtained by enamel etching; however, the clinical application of HF acid must be done with caution because it has adverse effects on oral soft tissue and thus, contact with oral mucosa must be avoided.[7,9]

Silane application has also been suggested to increase composite bond strength to porcelain surface. Silane is a coupling agent which can enhance the bond to bracket. Silane is composed of bifunctional molecules which bond to resin on the one end to porcelain on the other end. Moreover, silane increases the wettability of ceramic surface.[10]

In general, bracket bonding to porcelain surfaces in orthodontics is done by the application of fifth generation of bonding material such as Single Bond 2, after etching with HF acid with or without silane.[1] Universal adhesives, introduced in the recent years, enable bracket bond to different surfaces such as enamel, dentin, composite resin, porcelain, and amalgam, all with the use of a single adhesive.[11] They contain many ingredients, such as bisphenol A-glycidyl methacrylate, hydroxyethyl methacrylate, 10-methacryloyloxydecyl dihydrogen phosphate (MDP), and/or silane.[12,13] As MDP is a versatile amphiphilic functional monomer, it is the most important component in multi-mode universal adhesive (MUAs) for practical use. MDP has the potential to bond chemically to metals, zirconia, and tooth tissue.[12,14] However, little is known regarding the bonding efficiency of universal adhesives to orthodontic bracket and artificial surfaces, Thus, this study aimed to assess and compare the shear bond strength (SBS) of orthodontic metal brackets to feldspathic porcelain by the use of universal adhesive in comparison with Single Bond 2 as a conventional adhesive.

MATERIALS AND METHODS

In this *in vitro* study total of 56 feldspathic porcelain discs measuring 5 mm in thickness and 8 mm in diameter were fabricated. Samples were randomly divided into four groups of 14 to receive the following surface treatments:

- Group 1 – HF acid + universal adhesive
- Group 2 – HF acid + silane + universal adhesive
- Group 3 – HF acid + conventional adhesive
- Group 4 – HF acid + silane + conventional adhesive.

The discs were fabricated in desired dimensions and glazed. Disc surfaces in all groups were roughened by a long-fissure diamond bur (Tizkavan, Tehran, Iran) for 5 s. All discs were then etched with 9.6% HF acid for 90 s (FGM HF, Avisa, Brazil), rinsed with water spray for 30 s, and dried by air spray for 30 s to obtain a chalky white appearance.

Next, in Group 1, one layer of Scotchbond™ Universal adhesive (3M™ ESPE™, Seefeld, Germany) was applied on the surface of discs by a microbrush for 20 s, thinned by air spray for 5 s, and light cured for 10 s using Optilux light-curing unit (Kerr, Danbury, CT, USA) with a light intensity of 650 mW/cm^2.

In Group 2, silane (FGM Silane, Avisa, Brazil) was applied on disc surfaces for 1 min by a microbrush and after 30 s of drying by air spray, one layer of Scotchbond Universal adhesive (3M ESPE, Seefeld, Germany) was applied for 20 s followed by 5 s of air spray and light curing for 10 s.

In Group 3, two layers of Single Bond 2 conventional adhesive (3M ESPE, Conway, USA) were applied on the surface for 20 s, air sprayed for 5 s, and light cured for 10 s.

In Group 4, silane was applied on disc surfaces by a microbrush for 1 min and dried with air spray for 30 s. Two layers of Single Bond 2 conventional adhesive were then applied by a microbrush for 20 s, dried with air spray for 5 s, and light cured for 10 s.

Mandibular central incisor brackets (American Orthodontics, CA, USA) were bonded to the disc surfaces using Transbond XT composite (3M ESPE Dental Products, CA, USA) by a single operator and light cured for 40 s. The discs were then mounted on autopolymerizing acrylic resin (Parsdental, Tehran, Iran) such that the bracket slot was parallel to the horizon. All samples were stored in distilled water for 24 h. Prior to SBS testing, the samples were subjected to 500 thermal cycles between 5°C and 55°C within 24 h, and shearing force was then measured in universal testing machine (Instron UTM, Zewic/Roell Z020, Germany) with a crosshead speed of 0.5 mm/min. The SBS was calculated using the following formula:

SBS = Load at failure (N)/bracket cross-section (mm^2).

To assess the mode of failure, all samples were evaluated under a stereomicroscope (ZSX9, Olympus, Tokyo, Japan), and the Adhesive Remnant Index (ARI) score was determined as suggested by Artun and Bergland[15] as follows:

- Score 0 – No adhesive remaining on the surface [Figure 1]
- Score 1 – About 25% of adhesive remaining on the surface
- Score 2 – About 50% of adhesive remaining on the surface
- Score 3 – About 75% of adhesive remaining on the surface
- Score 4 – The entire surface is covered with adhesive [Figure 2].

Statistical analysis

The data were analyzed using SPSS software version 18 (SPSS Inc, Chicago, IL, USA). Normal distribution of data was assessed using Kolmogorov–Smirnov test. Two-way ANOVA followed by Bonferroni test was used to compare SBS in the four groups. In addition, Kruskal–Wallis test was applied to compare the mode of failure in the four groups ($P < 0.05$ considered significant).

RESULTS

Kolmogorov–Smirnov test confirmed the normal distribution of data in the following four groups: Group 1: ($P = 0.810$), Group 2 ($P = 0.126$), Group 3 ($P = 0.588$), and Group 4 ($P = 0.621$). Table 1 shows the descriptive statistics of SBS in the four groups. Maximum bond strength was noted in universal adhesive plus silane group followed by conventional adhesive plus silane, conventional adhesive without silane, and universal adhesive without silane groups.

Table 1: Mean and standard deviation of shear bond strength (MPa) in different groups

Adhesive	Silane	Mean±SD
Conventional	Yes	11.9 (5.0)
	No	7.6 (3.5)
Universal	Yes	12.7 (2.9)
	No	4.4 (2.8)

SD: Standard deviation

Two-way ANOVA was applied to assess the effect of type of adhesive and use of silane on the mean SBS which showed that the interactive effect of type of adhesive and silane on SBS was statistically significant ($P = 0.047$).

Because the effect of silane on SBS of universal and conventional adhesives was significant, Bonferroni test was applied, which showed a statistically significant difference between the two adhesives in terms of SBS when silane was not applied ($P = 0.03$). In other words, in the absence of silane, conventional adhesive yielded significantly higher SBS than universal adhesive, whereas the two adhesives were not statistically significantly different in terms of SBS in the presence of silane ($P = 0.53$). Although

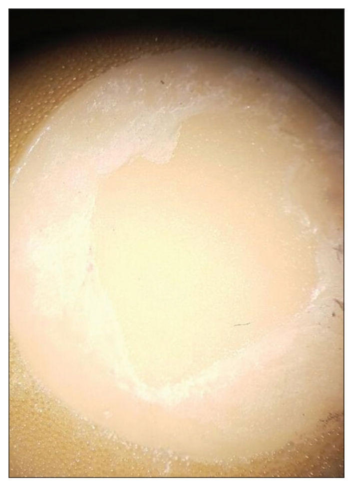

Figure 1: Score 0: No adhesive remaining on the surface.

Figure 2: Score 4: The entire surface is covered with adhesive.

Table 2: Adhesive Remnant Index score in different groups

Adhesive	Silane	ARI score				
		0 (%)	1 (%)	2 (%)	3 (%)	4 (%)
Universal	No	0 (0)	0 (0)	1 (7.1)	3 (21.4)	10 (71.4)
	Yes	2 (14.3)	0 (0)	1 (7.1)	5 (35.7)	6 (42.9)
Conventional	No	2 (14.3)	0 (0)	4 (28.6)	3 (21.4)	5 (35.7)
	Yes	6 (42.9)	4 (28.6)	2 (14.3)	0 (0)	2 (14.3)

ARI: Adhesive Remnant Index

in the presence of silane, the mean SBS of universal adhesive group was slightly higher than that of conventional adhesive group, this difference did not reach statistical significance.

The ARI score was determined in the four groups under a stereomicroscope. Table 2 shows the mode of failure and ARI scores in the four groups. In Group 1, 71% of the samples had ARI score of 4. In Group 2, 40% of the samples showed ARI score of 3. The ARI score in Group 3 was the same as that in Group 2. In Group 4, most samples showed ARI score of 0.

The Kruskal–Wallis test was applied to compare the mode of failure in the four groups. Based on the results, significant differences were noted between Groups 1 and 4 ($P = 0.00$) and Groups 2 and 4 ($P = 0.023$); no other significant differences were noted in this respect ($P > 0.05$).

DISCUSSION

Bracket bond to ceramic surfaces is a major challenge in this respect. Bond to ceramic requires surface preparation. Several methods have been suggested for ceramic surface preparation in literature. By advances in the production of different types of ceramics, the conventional preparation techniques may no longer be able to provide a strong bond to ceramic surfaces.[4,5]

Several mechanical and chemical methods and a combination of both are used to alter the surface properties of ceramics.[2,6,7] Sandblasting and surface roughening by bur are among the mechanical techniques used for this purpose.[16,17] The results of previous studies on superiority of one technique over the other are controversial. Elsaka reported that sandblasting with aluminum oxide particles yielded results superior to surface preparation by bur,[17] whereas Najafi *et al.* indicated that surface roughening by bur yielded higher bond strength compared to sandblasting.[16] In the current study, disc surfaces were roughened by bur; the method whose efficacy has been previously confirmed and requires no additional equipment.

HF acid can be used for the chemical alteration of ceramic surface.[8,9] Trakyali *et al.* evaluated the effect of acid concentration and type of silane on SBS of orthodontic brackets to ceramic surfaces and demonstrated that the use of 9.6% HF acid (instead of 5% HF acid) yielded the highest SBS.[18] In the current study, 9.6% HF acid was used for 90 s to etch the ceramic surfaces.[19]

In addition to surface roughening and deglazing the ceramic surface by HF acid, silane application on the ceramic surface has been recommended as a reinforcing chemical agent to enhance the bond strength.[19] The results of previous studies on the efficacy of silane to increase the SBS of bracket to ceramic surfaces have been controversial.[1,10,18,19] Thus, in the current study, silane was used in two out of the four groups for bracket bonding. The results showed that silane application significantly increased the SBS compared to no application of silane.

Kukiattrakoon and Thammasitboon suggested the hypothesis that SBS is determined not only by surface roughness but also by other factors such as silanization, especially when the porcelain has been previously etched with HF acid.[19]

Gonçalves *et al.* assessed the effect of bonding agent, duration of etching, and presence/absence of silane on SBS of orthodontic brackets to ceramics and reported that the highest SBS was obtained by the use of Transbond XT along with silane following 60 s of etching.[20] Girish *et al.* reported that the highest SBS was obtained following sandblasting and use of silane for ceramic surface preparation.[6] Türk *et al.* evaluated the bond strength of brackets to ceramic surfaces with different surface preparations and noted the highest SBS following etching with 9.6% HF acid and application of silane,[3] which was similar to our finding. However, Abdelnaby *et al.* and Karan *et al.* reported that the use of silane did not have any advantage.[21,22]

Introduction of universal adhesives in the recent years has enabled bracket bond to different surfaces namely enamel, dentin, composite resin, porcelain, and amalgam, with the use of one single adhesive. A study by Hellak *et al.* evaluated the SBS of orthodontic brackets to ceramic surfaces by the use of universal and conventional adhesives.[14] Thus, the current study evaluated the SBS of metal brackets to feldspathic porcelain by the use of universal adhesive and Single Bond 2 as a conventional adhesive and showed that, in the presence of silane, universal adhesive yielded higher SBS compared to Single Bond 2; however, this difference was not statistically significant. In other words, in the presence of silane, universal adhesive can serve as a suitable alternative to Single Bond 2, whereas in the absence of silane, SBS provided by Single Bond 2 was higher than that provided by universal adhesive. The three groups (all except the universal adhesive without silane group) showed SBS values that satisfied or were greater than the minimum value required by Reynolds (5.9–7.8 MPa) for the clinical use of brackets.[23] These results show that the presence of silane and its coupling function is more important than the type of adhesive. Other studies have proven the positive effect of silane on SBS of brackets to ceramic surfaces.[3,21-23] Isolan *et al*. evaluated the bond strength of composite to feldspathic porcelain using universal adhesives compared to conventional adhesives and reported that universal adhesives yielded higher SBS compared to conventional adhesives.[24] They used Scotchbond as universal and Single Bond 2 as conventional adhesives, similar to the current study. Hellak *et al*. evaluated the SBS of brackets to the enamel and restorations using three bonding systems. They showed that Scotchbond Universal provided the highest SBS of brackets to feldspar ceramic surfaces, whereas the conventional adhesive (Transbond XT) was the best in bonding to enamel.[14]

During debonding of brackets, four types of fractures may be seen, namely cohesive within the porcelain, cohesive within the adhesive layer, adhesive at the porcelain–adhesive interface, and adhesive at the adhesive–bracket interface. Assessment of ARI scores showed that, in the group of universal adhesive without silane, 71% of the samples showed adhesive fracture at the adhesive–bracket interface with no obvious remnant composite on the base of the bracket. ARI score in Groups 2 and 3 was similar. In both groups, more frequent ARI score was 4. However, in the last group (conventional with silane), ARI score of 0 was frequent that showed the adhesive fracture at the porcelain–adhesive interface. ARI score and mode of failure cannot be predicted based on the bond strength value because it depends on several factors such as bracket base design and type of adhesive.[24] The mode of failure is crucial in damage to porcelain restorations. Thus, it is important to minimize the risk of damage to porcelain as much as possible.[25] Naseh *et al*. showed that cohesive porcelain fracture had the lowest frequency in the lithium disilicate/Assure Plus group (one type of universal bonding).[26] Golshah *et al*. showed that the group of Transbond XT bonding plus silane and universal adhesive plus silane had the highest frequency of ARI score of 3, whereas groups Transbond XT bonding alone and universal adhesive alone had the highest frequency of ARI scores 0 and 1,[27] which is partially according to our study result. In general, the results of *in vitro* experiments are never precisely comparable with those of *in vivo* situations. However, the results of *in vitro* experiments can provide important information for *in vivo* situations and are of decisive value for clinical practice and day-to-day clinical use.

CONCLUSION

1. The SBS provided by universal adhesive is not significantly different from that provided by conventional adhesive in the presence of silane
2. In the absence of silane, conventional adhesive yields significantly higher SBS compared to universal adhesive
3. In the presence of silane, both adhesives provide significantly higher SBS compared to no use of silane
4. SBS of brackets to porcelain surfaces is mainly influenced by the use or no use of silane rather than type of adhesive.

Acknowledgment

The authors would like to acknowledge the Dentofacial Deformities Research Center, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Financial support and sponsorship

This study was funded by the Dentofacial Deformities Research Center, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial, in this article.

REFERENCES

1. Saraç YŞ, Külünk T, Elekdağ-Türk S, Saraç D, Türk T. Effect s of surface-conditioning methods on shear bond strength of brackets bonded to different all-ceramic materials. Eur J Orthod

2011;33:667-72.
2. Abu Alhaija ES, Al-Wahadni AM. Shear bond strength of orthodontic brackets bonded to different ceramic surfaces. Eur J Orthod 2007;29:386-9.
3. Türk T, Saraç D, Saraç YS, Elekdağ-Türk S. Effects of surface conditioning on bond strength of metal brackets to all-ceramic surfaces. Eur J Orthod 2006;28:450-6.
4. Kim MJ, Lim BS, Chang WG, Lee YK, Rhee SH, Yang HC. Phosphoric acid incorporated with acidulated phosphate fluoride gel etchant effects on bracket bonding. Angle Orthod 2005;75:678-84.
5. Ajlouni R, Bishara SE, Oonsombat C, Soliman M, Laffoon J. The effect of porcelain surface conditioning on bonding orthodontic brackets. Angle Orthod 2005;75:858-64.
6. Girish PV, Dinesh U, Bhat CS, Shetty PC. Comparison of shear bond strength of metal brackets bonded to porcelain surface using different surface conditioning methods: An *in vitro* study. J Contemp Dent Pract 2012;13:487-93.
7. Schmage P, Nergiz I, Herrmann W, Ozcan M. Influence of various surface-conditioning methods on the bond strength of metal brackets to ceramic surfaces. Am J Orthod Dentofacial Orthop 2003;123:540-6.
8. Gillis I, Redlich M. The effect of different porcelain conditioning techniques on shear bond strength of stainless steel brackets. Am J Orthod Dentofacial Orthop 1998;114:387-92.
9. Kao EC, Boltz KC, Johnston WM. Direct bonding of orthodontic brackets to porcelain veneer laminates. Am J Orthod Dentofacial Orthop 1988;94:458-68.
10. Blatz MB, Sadan A, Kern M. Resin-ceramic bonding: A review of the literature. J Prosthet Dent 2003;89:268-74.
11. Alex G. Universal adhesives: The next evolution in adhesive dentistry? Compend Contin Educ Dent 2015;36:15-26.
12. Chen L, Suh BI, Brown D, Chen X. Bonding of primed zirconia ceramics: Evidence of chemical bonding and improved bond strengths. Am J Dent 2012;25:103-8.
13. Fukegawa D, Hayakawa S, Yoshida Y, Suzuki K, Osaka A, Van Meerbeek B. Chemical interaction of phosphoric acid ester with hydroxyapatite. J Dent Res 2006;85:941-4.
14. Hellak A, Ebeling J, Schauseil M, Stein S, Roggendorf M, Korbmacher-Steiner H. Shear bond strength of three orthodontic bonding systems on enamel and restorative materials. Biomed Res Int 2016;2016:6307107.
15. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984;85:333-40.
16. Zarif Najafi H, Oshagh M, Torkan S, Yousefipour B, Salehi R. Evaluation of the effect of four surface conditioning methods on the shear bond strength of metal bracket to porcelain surface. Photomed Laser Surg 2014;32:694-9.
17. Elsaka SE. Influence of surface treatments on bond strength of metal and ceramic brackets to a novel CAD/CAM hybrid ceramic material. Odontology 2016;104:68-76.
18. Trakyali G, Malkondu O, Kazazoğlu E, Arun T. Effects of different silanes and acid concentrations on bond strength of brackets to porcelain surfaces. Eur J Orthod 2009;31:402-6.
19. Kukiattrakoon B, Thammasitboon K. Optimal acidulated phosphate fluoride gel etching time for surface treatment of feldspathic porcelain: On shear bond strength to resin composite. Eur J Dent 2012;6:63-9.
20. Gonçalves PR, Moraes RR, Costa AR, Correr AB, Nouer PR, Sinhoreti MA, *et al.* Effect of etching time and light source on the bond strength of metallic brackets to ceramic. Braz Dent J 2011;22:245-8.
21. Karan S, Büyükyilmaz T, Toroğlu MS. Orthodontic bonding to several ceramic surfaces: Are there acceptable alternatives to conventional methods? Am J Orthod Dentofacial Orthop 2007;132:144.e7-14.
22. Abdelnaby YL. Effects of cyclic loading on the bond strength of metal orthodontic brackets bonded to a porcelain surface using different conditioning protocols. Angle Orthod 2011;81:1064-9.
23. Reynolds IR. Letter: 'Composite filling materials as adhesives in orthodontics'. Br Dent J 1975;138:83.
24. Isolan CP, Valente LL, Münchow EA, Basso GR, Pimentel AH, Schwantz JK *et al*. Bond strength of a universal bonding agent and other contemporary dental adhesives applied on enamel, dentin, composite, and porcelain. Appl Adhesion Sci 2014;25:2-10.
25. O'Brien KD, Watts DC, Read MJ. Residual debris and bond strength – Is there a relationship? Am J Orthod Dentofacial Orthop 1988;94:222-30.
26. Naseh R, Afshari M, Shafiei F, Rahnamoon N. Shear bond strength of metal brackets to ceramic surfaces using a universal bonding resin. J Clin Exp Dent 2018;10:e739-45.
27. Golshah A, Mohamadi N, Rahimi F, Pouyanfar H, Tabaii ES, Imani MM. Shear bond strength of metal brackets to porcelain using a universal adhesive. Med Arch 2018;72:425-9.