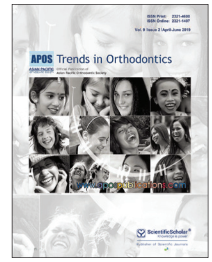
ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.apospublications.com

APOS Trends in Orthodontics

Article in Press



Original Article

Comparison of shear bond strength of metallic orthodontic brackets bonded to zirconia models underwent different surface conditioning methods and different primer systems

Amena Raafat Khaled[1], Enas Talb Al-Jwary[2]

[1]Department of Nineveh Health, Ministry of Health, [2]Department of Pedodontic, Orthodontic and Preventive Dentistry, College of Dentistry, University of Mosul, Mosul, Iraq.

***Corresponding author:**
Enas Talb Al-Jwary,
Department of Orthodontics,
College of Dentistry/University of Mosul, Mosul, Iraq.

enastallb@uomosul.edu.iq

Received: 22 June 2024
Accepted: 07 October 2024
EPub Ahead of Print: 11 December 2024
Published:

DOI
10.25259/APOS_154_2024

Quick Response Code:

APOS
ASIAN PACIFIC
ORTHODONTIC SOCIETY

ABSTRACT

Objectives: This study aimed to compare the shear bond strength (SBS) of metal brackets bonded to zirconia models with different surface treatment methods and two types of primers and to determine the adhesive remnant index (ARI). With the increase in demand for orthodontic treatment by adults and most adult patients having acrylic resin, amalgams, gold, composite resin, zirconia, or porcelain restorations, bonding of orthodontic braces to these surfaces is now a necessity. Brackets bonding to zirconia prostheses are a challenge in orthodontics because they need special surface conditioning.

Material and Methods: In this *in vitro* study, 60 zirconia models were divided randomly into two groups of 30 models according to the primer material used (Assure® Plus and Transbond™ XT). The labial surface of each model was subjected to one of the following three surface preparation: No surface treatment (control group), sandblasting with 50 µm aluminum oxide (Al_2O_3) particles, and acid etching with 9.6% hydrofluoric acid (HF). Metal orthodontic brackets (Dentaurum) were bonded to zirconia models using Assure® Plus or Transbond™ XT adhesives. The SBS was measured using a universal testing machine at a crosshead speed of 0.5 mm/min. The labial surfaces of models were inspected under a stereomicroscope, and the ARI scores were determined. Raw data were analyzed using Statistical Package for the Social Sciences program through analysis of variance and the Kruskal–Wallis test ($P \leq 0.05$).

Results: The Al_2O_3 air abrasion with the Assure® Plus group had the highest mean of SBS values, while HF groups with Transbond™ XT adhesive or Assure® Plus gave rise a significantly lower SBS values than that obtained for the Al_2O_3 group. A significant difference was noted among the groups in the ARI scores. In Al_2O_3 group bonded with Transbond™ XT had scores 1 and 2, which was designated as a mix-type failure, indicating a favorable failure mode.

Conclusion: This study showed that air abrasion of zirconia models had a significant effect on the SBS of metal brackets bonded to zirconia surface, and the Transbond™ XT adhesive is a suitable primer material.

Keywords: Orthodontic metal bracket, Zirconia models, Surface conditioning method, Shear bond strength

INTRODUCTION

Direct bonding in orthodontics has decreased enamel decalcification, improved gingival health, and made the placement of orthodontic appliances more comfortable for orthodontists and patients.[1] Nowadays, patients seek esthetic dentistry, so ceramic, zirconia, E.max crowns, or other types of fixed partial prosthesis meet their needs. With the increase in demand for orthodontic treatment for adult patients, orthodontists are often challenged with the problem of bonding orthodontic brackets to different types of prosthesis.[2] Based on this evidence, numerous methods to improve bracket bonding to such restoration have been suggested, like mechanical (diamond bur, abrasive discs, air-particle abrasion, or laser), chemical (orthophosphoric acid, hydrofluoric acid [HF], maleic acid, or silane), or combinations of both methods to alter the surface characteristics of porcelain to withstanding orthodontic forces and provide sufficient bond strength.[3,4] HF acid etching is typically utilized to improve the bracket bonding to traditional ceramics.[5] Quentin *et al*.[6] concluded that 40% HF is the most appropriate concentration for conditioning zirconia at ambient temperature because it forms the fastest and most uniform etching. Air particle abrasion is a technique in which aluminum oxide (Al_2O_3) particles, generally 50 µm, are projected to create abrasion by high air pressure on the surface of ceramic or another fixed prosthesis.[7] During brackets bonding, the use of primer is highly recommended; many commercial porcelain or zirconia primers are available that are used to treat glazed surfaces and provide a strong bond by increasing the wettability of the ceramic or zirconia surface for bonding of adhesive material.[8] The manufacturer claims that Assure® Plus is a recently introduced universal adhesive with high bond strength to normal enamel as well as to irregular metal surfaces such as gold, amalgam, stainless steel, ceramic, zirconia, and e.max pontics. Assure® Plus can be polymerized by chemical curing, light-curing, and dual-curing systems.[9-11] As already said, providing reliable bonding between the bracket and the surface of restoration is necessary. This connection should be strong enough to prevent bonding failure by orthodontic force or by masticatory force and to protect the integrity of restoration during the deboning of brackets at the end of orthodontic treatment.[12] The objective of this study was to compare the shear bond strength (SBS) of metal brackets bonded to glazed zirconia models using the two surface conditioning methods and two different primer materials.

MATERIAL AND METHODS

The ethical approval with Ref. no. (UoM.Dent.23/33) for this research was obtained from the Research Ethics Committee of the College of Dentistry/Mosul University.

The sample

The investigated sample included 60 Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) glazed zirconia models; each model consisted of two parts [Figure 1]; the upper part of the model is a crown of upper left central incisor with a diameter determined according to Ash and Nelson[13] and Sangalli *et al*.[14] The cylindrical base with a diameter of 10 mm in height and a radius length of 10 mm. The sample size was calculated using sample size calculation formulas by Charan *et al*.[15] and based on a study done by Mehta *et al*.[16]

Zirconia models fabrication

A three-dimensional program (Exocad Galawy) was used to design the samples. Subsequently, the zirconia models were milled using the Go2dent digital software (Go2dental program) and a CAD/CAM milling machine (Maxx200, Korea). All the steps of laboratory processes for the model's design, construction, and glazing are carried out according to the manufacturer's recommendations by a single dental technician to ensure consistency. All the models were cleaned with a polishing paste without fluoride and then thoroughly washed and dried by the air for 5 seconds.

Criteria of sample selection

The labial surface of models was examined by a stereomicroscope (Japan/Union/ME3138) under ×10 magnification power [Figure 2] to confirm that selected

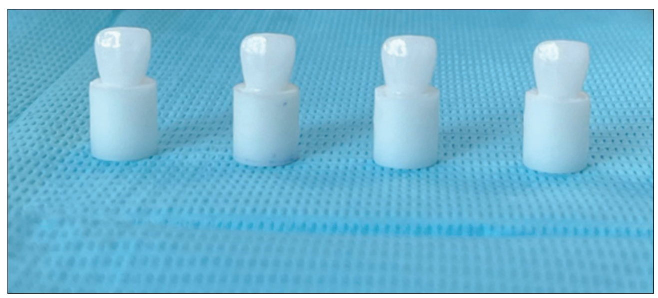


Figure 1: Zirconia models.

Figure 2: Evaluation of zirconia models by stereomicroscope.

models were clear of any impurities, porosities, cracks, or irregularities.[17]

Sample grouping

The models were randomly divided into two main groups according to adhesive type: Assure® Plus bonding group and Transbond™ XT adhesive group. Then, each group was subdivided into three subgroups according to surface treatment methods: follow control group, HF treatment group, and Al_2O_3 air abrasion group.

Surface treatment procedure

For HF groups, the middle third of the labial surface of the models was treated with 9.6% HF acid for 1 min, then rinsed for 30 s and air-dried.[18]

For Al_2O_3 groups: The models are fixed in a special design base to ensure standardization of distance and direction between microetcher (Ortho Technology, Emergo Europa) and model surface, as shown in [Figure 3]. Then, the middle third of the labial surface of models underwent air abrasion with 50 µm Al_2O_3 particles using the microetcher at a distance of 10 mm and in a direction perpendicular to the labial surface of specimens with the pressure of 0.25 Mps for 15 s. Then, the models were rinsed thoroughly under tap water to remove Al_2O_3 particles and then air dried.[19]

Bonding the brackets

For the groups of Transbond™ XT orthodontic primer, a thin layer of adhesive primer (Transbond XT; 3 M Unitek®, Monrovia, CA, USA) was applied and well-distributed on the center of the middle third of the labial surface of the crown of the model and left for 30 s and then dry with oil-free air for 10 s to remove excess Then, curing started using LED light curing device for 10 s according to manufactured instruction.

Figure 3: Air abrasion of models.

For the Assure® Plus groups, a single coat of the Assure® Plus primer was applied and well distributed on the center of the middle third of the labial surface of the crown of the model and left for 2 min, then thoroughly dry for 3–5 s and then curing started using LED light curing device for 10 s. All these procedures followed the manufactured instructions.

In all groups, the adhesive paste Transbond™ XT (Transbond XT; 3 M Unitek®, Monrovia, CA, USA) was applied over the base of the upper central incisor bracket (standard Edgewise 0.022 inch slot metal bracket, Dentaurum). Subsequently, the brackets were positioned at the treated center of the labial surface of the crown of the model at a distance of 4 from the incisor edge. Boons gauge was used to ensure the correct bracket position [Figure 4]. After that, the model is insulted on a customized mold and transferred to the stage of the universal testing machine. A universal testing machine applied a load of 200 g at a bracket slot for 10 s to confirm uniform adhesive thickness[20] [Figure 5]. A sharp dental explorer removed the excess resin. Then, the adhesive

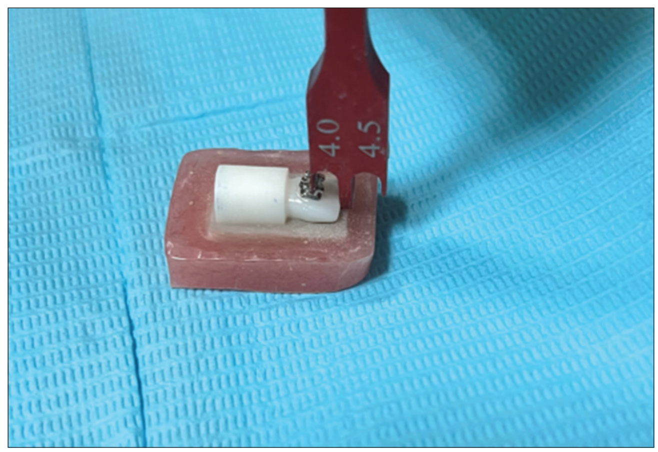


Figure 4: Bracket positioning.

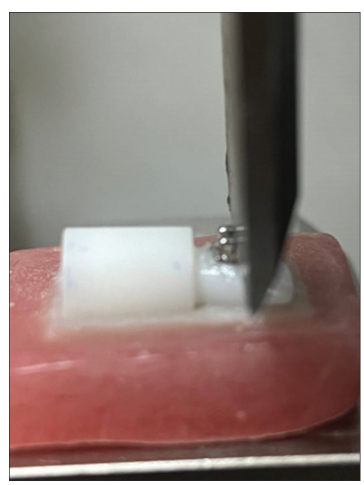


Figure 5: A stable pressure is applied to the bracket.

was photopolymerized using an LED light curing device with a wavelength of (420–480 nm) and an illumination of (1200–1500) mw/cm^2. The curing light was applied for 20 seconds for the mesial side and 20 seconds for the distal side; the tip of the curing device was at a distance of 2mm from the mesial and distal edges of the bracket base.[21] The specimens were allowed to bench rest for 30 min and then placed in a sealed container containing distilled water and stored in an incubator at 37°C for 24 h before testing.[22]

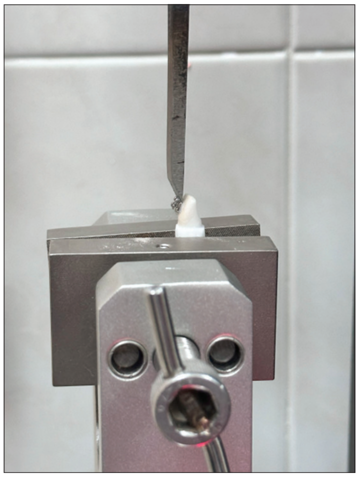


Figure 6: Shear bonding strength measurement by universal testing machine.

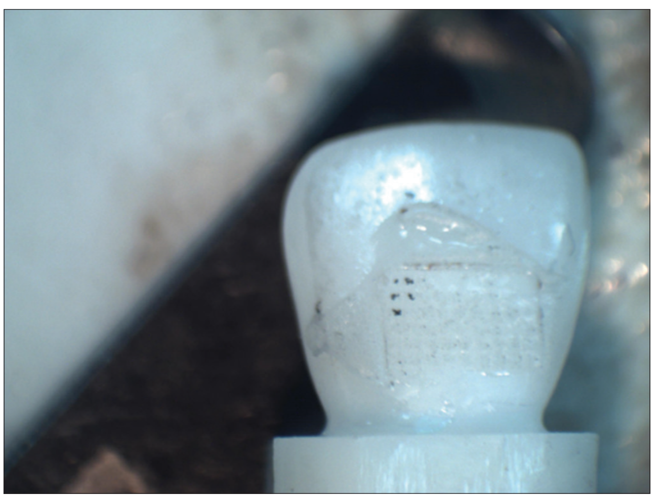


Figure 7: Adhesive remnant index score 3.

SBS measurement

The SBS test was measured using the universal testing machine (GESTER, Fujian, China) at the postgraduate laboratory, College of Dentistry, University of Mosul, with a crosshead speed of 0.5 mm/min. A prefabricated holder for the specimens has been constructed to ensure proper and secure seating of the specimen so that the bracket base is parallel to the direction of the shear force [Figure 6]. The chisel-shaped blade was directed toward the tooth-–bracket interface in an occlusal-gingival direction. The necessary load to debond or initiate bracket failure was recorded in the Newton unit and converted to the MPa unit by dividing the failure load or force in the Newton unit by the surface area of the bonded bracket base (mm^2).

Adhesive remnant index (ARI) measurement

After debonding of the brackets, the labial surface of the crown of the models was examined under Stereomicroscope at ×10 magnification power (Optica, Italy) to assess the amount of adhesive material left on the model's surfaces. The criteria that were used for measuring ARI scores were as follows:[10]

- Score 0 = No adhesive score remnant on the labial surface of the model.
- Score 1 = Less than half of the adhesive remained on the labial surface of the model.
- Score 2 = More than half of the adhesive remained on the labial surface of the model.
- Score 3 = All of the adhesive remained on the labial surface of the model, with a distinct impression of the bracket's mesh [Figure 7].

Statistical analysis

The Statistical Package for the Social Sciences Statistics V.19 software (New York, USA) was used to perform statistical

Table 1: Descriptive statistics and one-way analysis (ANOVA) of SBS (MPa) for all groups of zirconia models.

	Primer type	Surface treatment method	*n*	Minimum	Maximum	Mean	Std. deviation	F	Sig.
Zirconia models	Assure® Plus	Control	10	2.78	3.70	3.3039	0.31672	1.037E4	0.000
		HF	10	3.90	4.30	4.0989	0.14546		
		Al_2O_3	10	17.02	17.98	17.6450	0.25779		
	Transbond™ XT	Control	10	2.87	3.49	3.1865	0.22104	8.958E3	0.000
		HF	10	3.80	4.12	4.0182	0.10698		
		Al_2O_3	10	14.66	15.60	15.0527	0.29435		

ANOVA: Analysis of Variance, SBS: Shear bond strength, HF: Hydrofluoric acid, Al_2O_3: Aluminum oxide, F:F value, Sig.: Statistical significance analyses. The Shapiro–Wilk test showed that the SBS raw data were normally distributed, and Levene's test confirmed homoscedasticity. One-way analysis of variance (ANOVA) was used to compare the mean SBS values of the groups at a significance level of $P \leq 0.05$, followed by Duncan's Multiple Range test. The non-parametric data of ARI scores were compared by the Kruskal–Wallis test.

RESULTS

Descriptive statistics and one-way analysis (ANOVA) of the SBS values of each group is shown in [Table 1]. The Al_2O_3 with Assure® Plus group had the highest mean value and revealed a significant difference between the means of SBS values of the groups at $P \leq 0.05$. Using Duncan's Multiple Range test for SBS [Table 2], significant discrepancies were detected in Assure® Plus groups and Transbond™ XT primer groups. The highest SBS was found in Al_2O_3 groups. The mean SBS for HF groups for Transbond™ XT adhesive and Assure® Plus was lower than that one's obtained by Al_2O_3. Conversely, the control groups had the lowest mean SBS values [Table 2]. The independent *t*-test [Table 3] revealed that there was a significant difference at $P \leq 0.05$ between Assure® Plus and Transbond™ XT primer type in Al_2O_3 groups, and there was no significant difference among other groups.

The distribution of the ARI scores among groups is illustrated in [Table 4]. The majority of the models in control and HF had scores of 0 and score 1 (all adhesive remained on the bracket base), while most of the samples of Assure® Plus with Al_2O_3 groups had scores of 2 and 3 (all the adhesive remained on the zirconia surface). The Kruskal–Wallis test revealed significant differences in the ARI scores among the groups at $P \leq 0.05$, as shown in [Table 5].

Table 2: Duncan's multiple range tests for SBS (MPa).

	Zirconia models	
	Assure® Plus	**Transbond™ XT**
Control		
Mean	3.3039^c	3.1865^c
n	10	10
Std. deviation	0.31672	0.22104
HF		
Mean	4.0989^b	4.0182^b
n	10	10
Std. deviation	0.14546	0.10698
Al_2O_3		
Mean	17.6450^a	15.0527^a
n	10	10
Std. deviation	0.25779	0.29435

SBS: Shear bond strength, HF: Hydrofluoric acid, Al_2O_3: Aluminum oxide, MPa: Megapascal, $^{a,b\ and\ c}$Different letters vertically means statistical significant.

DISCUSSION

Esthetic restorations such as zirconia crowns are highly requested for adults, new challenges are presented, like the bonding of orthodontic braces to zirconia surfaces. The ideal property of bonding material must be high enough to withstand the orthodontic forces during treatment and also allow debonding of the brackets at the end of treatment to maintain the integrity of the zirconia surface.[3,23]

In the present study, when the zirconia models were roughened by 9.6% HF, the SBS was 4.0182 MPa for Transbond™ XT and 4.0989 MPa for Assure® Plus, which is lower than 5.9 and 7.8 MPa which is the reasonable clinical bond strength values of SBS that stated by Reynolds *et al.*[24] The use of HF acid was investigated by several previous studies and reported that the application of HA on zirconia surface is not sufficient to provide adequate adhesion, as zirconia has a low silica content, which makes it resistant to acid etching and difficult to create porosities.[1,25] According to Faria *et al.*,[26] the HF provides no effect on the zirconia surface but provides adequate adhesive strength on glass ceramics, and this is due to differences in the composition of ceramics materials, which produce distinct topographical features after etching.

Table 3: Independent t-test for SBS means (MPa) between adhesive types.

	n	**Mean**	***t*-value**	**sig**	**Std. deviation**	**Std. error mean**
Zirconia						
Control						
Assure® Plus	10	3.3039	0.961	0.349	0.31672	0.10016
Transbond™ XT	10	3.1865	0.961		0.22104	0.06990
HF						
Assure® Plus	10	4.0989	1.413	0.175	0.14546	0.04600
Transbond™ XT	10	4.0182	1.413		0.10698	0.03383
Al_2O_3						
Assure® Plus	10	17.6450	20.951	0.000*	0.25779	0.08152
Transbond™ XT	10	15.0527	20.951		0.29435	0.09308

SBS: Shear bond strength, HF: Hydrofluoric acid, Al_2O_3: Aluminum oxide, MPa: Megapascal, sig.: Statistical significance, *: significant difference.

While Quentin *et al.*[6] found that the used of high concentration of HF 40% is appropriate for conditioning of zirconia specimens because it leads to uniform and fast etching. Furthermore, our result is in contrast with Zhang *et al.*[5] who considered HF acid as a promising surface conditioning method to promote bracket-zirconia bonding without excessive zirconia damage. However, intraoral etching by HF can be dangerous and considered toxic. Hence, alternatives to HF can be used like orthophosphoric acid, sandblasting, and carbon dioxide laser.[27,28]

Several researchers have sandblasted zirconia specimens with Al_2O_3 particles to provide higher mechanical retention[9,10,16,29] by increasing the surface roughness of zirconia.[30] Farag[31] used Al_2O_3 particle sizes for sandblasting (40, 80, and 110 μm) and observed that the use of coarser Al_2O_3 particles led to an increase in surface irregularities and then increased the surface area available for adhesive, improving the micro-mechanical retention and finally increasing the bond strength values.

The effectiveness of sandblasting in increasing the SBS between the bonding materials and the zirconia specimens is similar to the study of Ourahmoune *et al.*[32] They showed that air abrasion increases surface roughness and wettability of the zirconia materials, and the contact angle increases, increasing the mechano-retention and enhancing the bond strength.

Table 4: Distribution of ARI scores among groups.

Group	0	1	2	3
Assure® Plus				
HF	4	6	0	0
Control	5	5	0	0
Al_2O_3	0	1	6	3
Transbond™ XT				
HF	3	7	0	0
Control	9	1	0	0
Al_2O_3	1	5	4	0

ARI: Adhesive remnant index, HF: Hydrofluoric acid, Al_2O_3: Aluminum oxide

Mehta *et al.*[16], in their study, concluded that bonding brackets to sandblasted zirconia surfaces with Reliance Assure Plus resulted in higher SBSs than the retention between the orthodontic attachment and the adhesive.

Kwak *et al.*[1] observed that when air abrasion was done with 30 μm Al_2O_3 on the glazed zirconia, producing a randomized rough surface and providing acceptable bonding of metal bracket to glazed zirconia.

The values of SBS obtained by Assure® Plus and Transbond™ XT with zirconia specimens did not differ significantly in the control and HF groups. In contrast, the SBS of orthodontic brackets bonded to zirconia using Assure® Plus was significantly higher than those bonded by Transbond™ XT for Al_2O_3 groups because of the higher flowability of Assure® Plus, which provides adequate SBS. The same conclusions were concluded by Amirabadi *et al.*[33], wherein the adhesion of the orthodontic bracket to ceramic that bonded by Assure® Plus was significantly superior to that when bonded with Transbond™ XT.

In contrast to these studies, Mehta *et al.*[16] reported a similar bonding strength of Assure® Plus and Transbond™ XT for zirconia specimens. Furthermore, Douara *et al.*[29] revealed no significant differences between the use of Transbond™ XT and Assure® Plus on zirconia specimens.

ARI was used to determine the position and mode of adhesive failure. Several studies have advocated that it is preferable for the occurrence of adhesion failure at the tooth adhesive interface so that the resin remnants on the surface can be cleaned safely with rotary instruments.[30,34-36]. When debonding orthodontic brackets from the enamel surface, it is important to avoid enamel damage and with minimal adhesive remaining on the teeth surface. Likewise, for all restorations, the aim is for the debonded area to have minimal cohesive damage to ceramic or zirconia and, at the same time, have minimal residual adhesive left.[16]

The adhesive failure in the control and HF group bonded by Transbond™ XT or Assure® Plus had a score of 0 and 1, which was designated to adhesivezirconia interface failure. Contrarily, most of the models in the Al_2O_3 group

Table 5: Descriptive statistics and Kruskal–Wallis test of ARI.

Zirconia models	Primer type	Group	*n*	Minimum	Maximum	Mean	Std. deviation	Kruskal–Wallis Test		
								Chi-square	Df	Asymp. Sig.
	Assure® Plus	Control	10	0.00	1.00	0.3000	0.48305	19.262	2	0.000
		HF	10	0.00	1.00	0.5000	0.52705			
		Al_2O_3	10	1.00	3.00	2.0000	0.66667			
	Transbond™ XT	Control	10	0.00	1.00	0.1000	0.31623	14.783	2	0.001
		HF	10	0.00	1.00	0.3000	0.48305			
		Al_2O_3	10	1.00	2.00	1.5000	0.52705			

ARI: Adhesive remnant index, HF: Hydrofluoric acid, Al_2O_3: Aluminum oxide, DF: degree of freedom, Asymp. Sig.: significant difference at $P \leq 0.05$.

bonded with Assure® Plus had a score of 2 and 3, which was designated to adhesivebracket interface failure, while in Al_2O_3 group bonded with Transbond™ XT had a score of 1 and 2, which was designated as mixtype, indicating a favorable failure mode. This result suggests that the Transbond™ XT is a suitable adhesive for use with zirconia material.

Limitation of the study

These *in vitro* studies were applied to evaluate the effect of two types of adhesive material and two surface treatment methods on SBS, but the effect of other factors that intervene in the oral environment was not considered in our investigation. These contributing variables affect the SBS values in the oral environment, such as the pH level of saliva, complex microflora, temperature, stress generated by the orthodontic archwire, and masticatory force.

CONCLUSION

The SBS obtained when bonding metal orthodontic brackets using the Transbond™ XT adhesive or Assure® Plus with air abrasion by Al_2O_3 particles were satisfactory for zirconia restoration. On the other hand, inadequate SBS values were achieved when using HF treatment of zirconia surface, so acid etching of zirconia models by HF had no significant effect on SBS of metal brackets bonded to zirconia specimens. According to the ARI result, Transbond™ XT is a suitable adhesive for use with zirconia material.

Ethical approval

The research/study was approved by the Institutional Review Board at the research ethics committee of the College of Dentistry/Mosul University, number UoM.Dent.23/33, dated 4th June 2023.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI.

REFERENCES

1. Kwak JY, Jung HK, Choi IK, Kwon TY. Orthodontic bracket bonding to glazed full-contour zirconia. Restor Dent Endod 2016;41:106-13.
2. Pouyanfar H, Mani M, Tabaii E, Bakhtiari M, Falah K, Teimourian H. Shear bond strength of metal brackets to zirconia following different surface treatments using a universal adhesive. J Clin Diagn Res 2019;13:20-3.
3. Mehmeti B, Azizi B, Kelmendi J, Iljazi-Shahigi D, Alar Z, Anić Milošević S. Shear bond strength of orthodontic brackets bonded to zirconium crowns. Acta Stomatol Croat 2017;51:99-105.
4. Manne PR, Krishna CV, Sekhar GC, Reddy J. Comparison of shear bond strength of orthodontic brackets bonded to zirconia surfaces underwent different surface treatments using different primers: An *in vitro* study. J Contemp Orthod 2021;5:31-6.
5. Zhang C, Yao C, Yuan C, Zhang H, Liu L, Zhang H, *et al*. Evaluation of surface properties and shear bond strength of zirconia substructure after sandblasting and acid etching. Mater Res Express 2020;7:095403.
6. Quentin F, Fernando M, Joan R, Marc A. Hydrofluoric acid etching of dental zirconia. Part 1: Etching mechanism and surface characterization. J Eur Ceramic Soc 2016;36:121-34.
7. Labunet A, Kui A, Voina-Tonea A, Vigu A, Sava S. Orthodontic attachment adhesion to ceramic surfaces. Clin Cosmet Investig Dent 2021;13:83-95.
8. Debnath S, Wunder SL, McCool JI, Baran GR. Silane treatment effects on glass/resin interfacial shear strengths. Dent Mater 2003;19:441-8.
9. Toodehzaeim MH, Haerian A, Safari I, Arjmandi R. The effect of assure plus resin on the shear bond strength of metal brackets bonded to enamel and surface of porcelain and amalgam restorations. Biosci Biotechnol Res Commun 2017;10:82-7.
10. 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.
11. Pulido P, Pereira MP, Pitschielller R, Proença L, Bugaighis I. Comparison of shear bond strength of metallic brackets bonded to ceramic surfaces utilizing different adhesive systems: An *in vitro* study. J Orthodont Sci 2023;12:73.
12. Mokhtarpur H, Nafisifard M, Dadgar S, Etemadi A, Chiniforush N, Sobouti F. Shear bond strength of the metal bracket to zirconium ceramic restoration treated by the Nd: YAG laser and other methods: An *in vitro* microscopic study. J Lasers Med Sci 2020;11:411-6.
13. Ash M, Nelson S. Wheeler's dental anatomy, physiology, and occlusion. United States: Saunders/Elsevier; 2010.
14. Sangalli L, Dalessandri D, Bonetti S, Mandelli G, Visconti L, Savoldi F. Proposed parameters of optimal central incisor positioning in orthodontic treatment planning: A systematic review. Korean J Orthod 2022;52:53-65.
15. Charan J, Kaur R, Bhardwaj P, Singh K, Ambwani S, Misra S. Sample size calculation in medical research: A primer. Ann

Natl Acad Med Sci (India) 2021;57:74-80.
16. Mehta A, Evans C, Viana G, Bedran-Russo A, Galang-Boquiren M. Bonding of metal orthodontic attachments to sandblasted porcelain and zirconia surfaces. Biomed Res Int 2016;2016:5762785.
17. Lee MH, Son JS, Kim KH, Kwon TY. Improved resin-zirconia bonding by room temperature hydrofluoric acid etching. Materials (Basel) 2015;8:850-66.
18. Riowruangsanggoon D, Riddhabhaya A, Niyomtham N, Sirisoontorn I. Shear bond strength of polypropylene fiber in orthodontic adhesive on glazed monolithic zirconia. Polymers 2022;14:4627.
19. Ahrari F, Boruziniat A, Alirezaei M. Surface treatment with a fractional CO_2 laser enhances shear bond strength of resin cement to zirconia. Laser Ther 2016;25:19-26.
20. Degrazia FW, Genari B, Leitune VC, Arthur RA, Luxan SA, Samuel SM, *et al*. Polymerisation, antibacterial and bioactivity properties of experimental orthodontic adhesives containing triclosan-loaded halloysite nanotubes. J Dent 2018;69:77-82.
21. Blöcher S, Frankenberger R, Hellak A, Schauseil M, Roggendorf MJ, Korbmacher-Steiner HM. Effect on enamel shear bond strength of adding microsilver and nanosilver particles to the primer of an orthodontic adhesive. BMC Oral Health 2015;15:42.
22. Babaee Y, Neshandar H, Falahchai M, Safary S. Effect of different surface treatments and orthodontic bracket type on shear bond strength of high-translucent zirconia: An *in vitro* study. Int J Dent 2022;18:9884006.
23. Khanehmasjedi M, Naseri MA, Khanehmasjedi S, Basir L. Comparative evaluation of shear bond strength of metallic brackets bonded with two different bonding agents under dry conditions and with saliva contamination. J Chinese Med Assoc 2017;80:103-8.
24. Reynolds IR. A review of direct orthodontic bonding. Br J Orthod 1975;2:171-8.
25. García Sanz V, Paredes Gallardo V, Bellot Arcís C, Mendoza Yero O, Doñate Buendía C, Montero J, *et al*. Effects of femtosecond laser and other surface treatments on the bond strength of metallic and ceramic orthodontic brackets to zirconia. PLoS One 2017;12:e0186796.
26. Faria R, Leite P, Bottino A, Araújo J. Shear bond strength between different resinous cements and lithium disilicate ceramic. Rev Íbero Am Prótese Clín Lab 2004;6:556-81.
27. Alzainal AH, Majud AS, Al-Ani AM, Mageet AO. Orthodontic bonding: Review of the literature. Int J Dent 2020;2020:8874909.
28. Mageet O, Aziz S, Osman A, Al-Haideri H. The effect of surface treatments on shear bond strength between orthodontic metal bracket and porcelain face. Azerbaijan Pharm Pharmacother J 2024;23:22-9.
29. Douara YE, Abdul Kader S, Kassem HE, Mowafy MI. Evaluation of the shear bond strength of ceramic orthodontic brackets to glazed monolithic zirconia using different bonding protocols. Egypt Orthod J 2019;56:9-20.
30. Pathak A, Nandan H, Sthapak R, Sharma S, Dubey M. Comparative assessment of hydrofluoric acid and sandblasting etching technique on porcelain crowns. Asian Pac J Health Sci 2019;6:175-81.
31. El-Farag SA. The influence of different surface treatments on bond strength of cad/cam fabricated ceramic restorations. Egypt Dent J 2024;70:1727-39.
32. Ourahmoune R, Salvia M, Mathia T, Mesrati B. Surface morphology and wettability of sandblasted peek and its composites. Scanning 2014;36:64-75.
33. Amirabadi GE, Shirazi M, Shirazi Z. Microshear bond strength of transbond XT and assure universal bonding resin to stainless steel brackets, amalgam and porcelain. J Islam Dent Assoc IRAN 2015;27:1-5.
34. Türk T, Saraç D, Saraç YŞ, Elekdağ Türk S. Effects of surface conditioning on bond strength of metal brackets to all ceramic surfaces. Eur J Orthod 2006;28:450-6.
35. Yadav S, Upadhyay M, Borges GA, Roberts WE. Influence of ceramic (feldspathic) surface treatments on the micro shear bond strength of composite resin. Angle Orthod 2010;80:765-70.
36. Pignatta LM, Lugato IC, Bertoz FA, Santos EC. Evaluation of Adhesive Remnant Index using conventional mesh bases and sandblasted orthodontic bracket bases and three bonding systems. Rev Dent Press Ortod Ortop Facial 2009;14:117-23.

How to cite this article: Khaled AR, Al-Jwary ET. Comparison of shear bond strength of metallic orthodontic brackets bonded to zirconia models underwent different surface conditioning methods and different primer systems. APOS Trends Orthod. doi: 10.25259/APOS_154_2024