RESEARCH

Does Surface Treatment With Different Primers Increase The Shear Bond Strength Between Metallic Bracket and Monolithic Zirconia?

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ABSTRACT

Does Surface Treatment With Different Primers Increase The Shear Bond Strength Between Metallic Bracket and Monolithic Zirconia?

Background: This was aimed to investigate the effect of surface treatment with different primers on the shear bond strength (SBS) between metallic brackets and monolithic zirconia crowns.

Methods: Sixty-five monolithic zirconia molar crowns were fabricated with CAD-CAM technology. All crowns underwent thermal cycling. After aging, crowns were randomly divided into five groups (n = 13) according to cementation procedures: orthodontic bonding system; primer/composite paste: Transbond XT (TXT) (control); Group M: Monobond Plus (MP) was applied on crowns surfaces then TXT composite paste; Group MT: MP was applied on crown surface then primer/composite paste of TXT; Group Z: Z-Prime Plus (ZP) was applied on crown surface then TXT composite paste; Group ZT: ZP was applied on crown surface then primer/composite paste of TXT was used for bonding the metallic brackets. The bracket-bonded crowns were tested for SBS using a universal testing machine. Results were analyzed using analysis of variance.

Results: A statistically significant difference was found between all groups regarding SBS values ($p=0.001$). Group MT showed the highest SBS value, the control group showed the lowest SBS value ($p<0.05$).

Conclusion: It can be concluded that all bracket-bonded crowns were sufficient to withstand orthodontic forces. Surface treatment with primers contributes to increase the shear bond strength between metallic bracket and monolithic zirconia.

KEYWORDS

Metallic Brackets, Monolithic Zirconia, Shear Bond Strength, Zirconia Primer.

ÖZ

Primerlerle Yüzey İşlemi, Metalik Braket ve Monolitik Zirkonya Arasındaki Makaslama Bağlanma Dayanımını Arttırır mı?

Amaç: Bu çalışma, farklı primerlerle yapılan yüzey işleminin, metalik braketler ve monolitik zirkonya kronlar arasındaki makaslama bağlanma dayanımı (SBS) üzerindeki etkisini değerlendirmeyi amaçladı.

Gereç ve Yöntemler: Altmış beş monolitik zirkonya molar kron CAD-CAM teknolojisi ile üretildi. Tüm kronlara termal döngü uygulandı. Yaşlandırma işlemi sonrası kronlar, yüzey işlemlerine göre rastgele beş gruba (n = 13) ayrıldı: ortodontik bonding sistemi; primer/kompozit rezin: Transbond XT (TXT) (kontrol); Grup M: kron yüzeylerine Monobond Plus (MP), ardından TXT kompozit rezin uygulandı; Grup MT: kron yüzeyine MP uygulandıktan sonra TXT'nin primer/kompozit rezin; Grup Z: kron yüzeyine Z-Prime Plus (ZP), ardından TXT kompozit rezin uygulandı; Grup ZT: kron yüzeyine ZP uygulandı, ardından metalik braketlerin yapıştırılması için TXT'nin primer/kompozit rezini kullanıldı. Braket yapıştırılan kronlar, Universal test cihazı kullanılarak SBS için test edildi. Sonuçlar, varyans analizi kullanılarak analiz edildi.

Bulgular: SBS değerleri açısından tüm gruplar arasında istatistiksel olarak anlamlı fark vardı ($p=0.001$). Grup MT en yüksek SBS değerini, kontrol grubu en düşük SBS değerini gösterdi ($p<0.05$).

Sonuç: Kronlara yapıştırılan tüm braketlerin ortodontik kuvvetlere karşı yeterli dayanıklılıkta olduğu sonucuna varılabilir. Primerlerle yüzey işlemi, metalik braket ve monolitik zirkonya arasındaki makaslama bağlanma dayanımını artırmaya katkıda bulunmuştur.

ANAHTAR KELİMELER

Makaslama Bağlanma Dayanımı, Metalik Braketler, Monolitik Zirkonya, Zirkonya Primer.

INTRODUCTION

The number of adults demanding orthodontic treatment has been increasing in recent years. Although clear aligners have started to take place of fixed orthodontic appliances with its high popularity, they are still insufficient for treatment of complex cases and they are still not as common as fixed appliances. Moreover, the clear aligners cannot always be an affordable option for every patient due to their availability and price. Therefore, the bond strength of traditional fixed braces is still an important issue for an effective and convenient treatment process. However, the clinicians confront with an important number of dental restorations due to missing, malformed, attritated, and weared teeth.[1] Previous restorations have been one of the major causes of frequent bracket failure which can lead to increased orthodontic treatment duration, increased number of visits, and long chairtime.

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On the other hand, the use of zirconia in dental restorations has been gaining popularity owing to the developments in CAD/CAM technology. However, lower bond strength of orthodontic brackets to zirconia compared to the tooth enamel requires surface treatment on zirconia as well as other restorative materials.[2-4] Hydrofluoric acid etching can be less effective when used on zirconia surface due to its acid-resistant feature.[5-7] Besides, tribochemical silica coating or air abrasion are the methods that can improve the bond strength to zirconia surface.[7,8] However, in case of aging processes, the attachment of silica on the zirconia surface is unpredictable.[7]

Another surface treatment method that improves the bond strength in zirconia is the application of bonding systems or primers with functional monomers such as 10-MDP.[7,9-11] However, currently, there is no consensus concerning the most effective primer for producing optimal bond strength of orthodontic brackets to zirconia surface due to different primer brands and different application procedures.

This study was aimed to investigate the shear bond strength (SBS) of orthodontic metallic brackets bonded with different primers and different application procedures to monolithic zirconia crowns. The null hypothesis tested was that no difference would be found in the SBS between metal brackets and monolithic zirconia crowns regardless of the used primers and application procedures.

MATERIALS AND METHODS

Monolithic zirconia molar crowns (Vita YZ T, Vita Zahnfabrik, Bad Sackingen, Germany) were fabricated with CAD-CAM technology (Yenamak D50, Yenadent Ltd, Istanbul, Turkey). For the thermocycling before bracket bonding, the cold tank was set to 5°C and the hot tank to 55°C, and a total of 3911 cycles were completed simultaneously with 90 seconds of immersion and 10 seconds of holding. After the thermal aging procedure, zirconia crowns were randomly divided into five groups (n = 13) and mandibular molar metallic orthodontic brackets (Mini 2000 Ormco Corp., Glendora, California, USA) were bonded to these crowns. Five groups were described in the flow chart as seen in Fig.1.

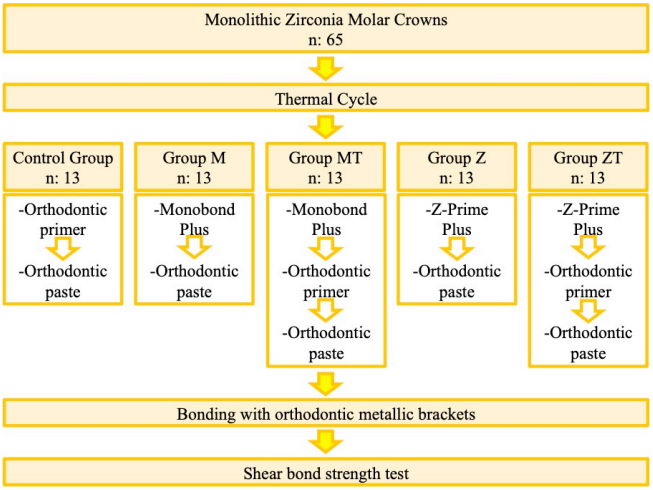

Figure 1

Flow chart of the study.

Control: Orthodontic bonding system (primer/composite paste) (Transbond XT, 3M/Unitek, Monrovia, CA, USA) was used for bonding the brackets.

Group M: Monobond Plus (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the zirconia surface then Transbond XT composite paste was used for bonding the brackets.

Group MT: Monobond Plus (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the zirconia surface then primer/composite paste of Transbond XT was used for bonding the brackets.

Group Z: A zirconia primer Z-Prime Plus (Bisco Inc, Schaumburg, IL, USA) was applied on the zirconia surface then Transbond XT composite paste was used for bonding the brackets.

Group ZT: Z-Prime Plus (Bisco Inc, Schaumburg, IL, USA) was applied on the zirconia surface then primer/composite paste of Transbond XT was used for bonding the brackets.

The composition of materials applied to zirconia crowns is presented in Table 1.

Table 1.

Composition of Materials Applied to Monolithic Zirconia Crowns.

Trade Name	Functional Monomer	Manufacturer
Transbond XT primer	TEGDMA, Bisphenol A diglycidyl ether dimethacrylate, Hydroquinone, Camphorquinone, Triphenylantimony, 4-(Dimethylamino)-Benzene ethanol	3M Unitek, USA
Transbond XT paste	Bisphenol A diglycidyl ether dimethacrylate, Bisphenol A Bis(2-hydroxyethyl ether) dimethacrylate, Silane treated quartz, Silane treated silica	3M Unitek, USA
Z-PRIME Plus	Organophosphate and carboxylic acid, biphenyl dimethacrylate and hydroxyethyl methacrylate	Bisco, Inc., Schaumburg, IL, USA
Monobond Plus	10-Methacryloyloxydecyl dihydrogen phosphate, silane methacrylate, ethanol, sulfide methacrylate	Ivoclar Vivadent AG, Schaan, Liechtenstein

The primers were applied according to the manufacturers' recommendations. The same operator bonded the brackets into the middle of the buccal surfaces of the zirconia crowns. The brackets were firmly pressed, and the remaining paste around the bracket base was removed with a dental probe. The specimens were light-cured from all four directions at a 45-degree angle and a distance of 10 mm after bracket placement. Each light curing session lasted 15 seconds (Woodpecker, Guilin Woodpecker Medical Instrument, Guilin, Guangxi, China).

Prior to SBS measurement, the crowns were embedded in an epoxy resin (Pattern Resin Ls, Gc America Inc.) and were stored at 100% relative humidity for 24 h. The bracket-bonded crowns were placed parallel on the Universal testing machine (Universal testing machine, Besmak, Ankara, Turkey) with a load applied parallel to the buccal surface of the crown in a gingivo-occlusal direction.(Fig.2) Debonding was ensured by a knife-edged rod moving at a constant rate of 1 mm/ min. The force needed to debond the brackets was measured in Newtons, and the results were converted to MPa.

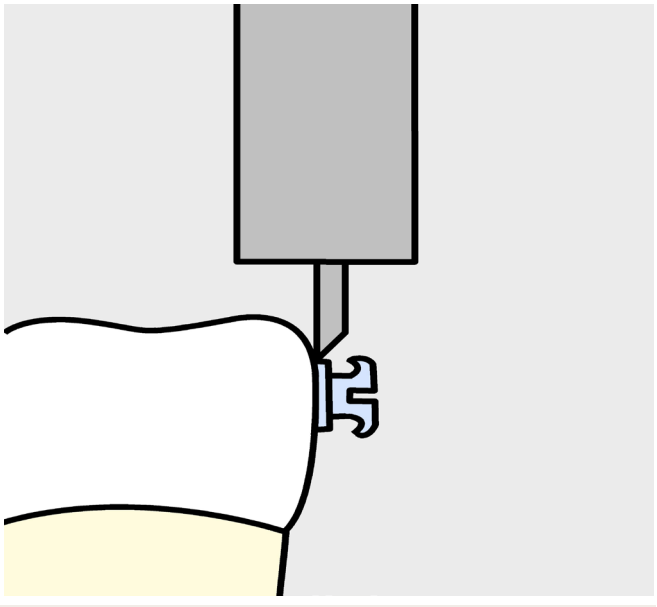

Figure 2

Schematic illustration of SBS testing.

Power analysis was performed with the G Power program (G * Power 3.1 software; Heinrich Heine University, Düsseldorf, Germany) which indicated a requirement of 65 samples for 5 group12 with a power of 0.90 with 0.51 effect size. Statistical analyses were carried out using the SPSS 23.0 package program (SPSS Inc., Chicago, IL, USA) at a level of significance of $\alpha = 0.05$. Normal distribution of data was tested using one sample Shapiro-Wilks test. The one-way analysis of variance (ANOVA) was used to analyze the data. The Bonferroni test was used for Post-hoc analysis ($p < 0.05$).

RESULTS

The mean, standard deviation, maximum and minimum values of the data obtained from the SBS test for each group are given in Table 2.

Table 2.

Descriptive Statistics of The Shear Bond Strength (Mpa) For All Groups

Groups	N	Mean±Std. Dev	Min	Max
Control (a)	13	8.36±3.78b,c	3.47	15.62
Group M (b)	13	13.35±4.02a	8.35	21.16
Group MT (c)	13	16.70±2.66a,d,e	13.55	24.46
Group Z (d)	13	12.04±5.83c	4.55	21.40
Group ZT (e)	13	12.08±3.11c	7.77	18.21

The letters represent the comparison between the groups. Each group differs statistically with the exponential letters indicated in the Mean±Std. deviation values.

A statistically significant difference was found between all groups regarding SBS values ($p = 0.001$). Group MT showed the highest SBS value while where the control group showed the lowest SBS value.

According to the results of the post-hoc test, the control group (8.36±3.78 MPa) showed a statistically significant difference with Group M (13.35±4.02 MPa), and Group MT (16.70±2.66 MPa) ($p < 0.05$). Group MT showed statistically significant differences with Group Z (12.04±5.83 MPa), and Group ZT (12.08±3.11 MPa) as well as control group ($p<0.05$).

After SBS test, the failure modes were evaluated with the magnification of stereomicroscope (SZTP; Olympus Optical Co, Tokyo, Japan) under a 10X magnification and classified into one of the following types: adhesive failure 1: between monolithic zirconia crown and composite resin; adhesive failure 2: between bracket and composite resin, and mixed failure: adhesive and cohesive. Only five specimens of the Group MT showed a mixed failure, where less than half of the composite resin was left on the crown surface. All the other specimens showed a complete adhesive failure between the monolithic zirconia and the composite resin, with no adhesive left on the crown surface. The failure mode of each group was shown in Table 3.

Table 3.

Distribution of failure modes following the shear bond strength test.

Groups	Adhesive failure 1	Adhesive failure 2	Mixed failure	Total
Control	13	-	-	13
Group M	13	-	-	13
Group MT	8	-	5	13
Group Z	13	-	-	13
Group ZT	13	-	-	13
Total	60	-	5	65

DISCUSSION

This study assessed the effect of different zirconia primer treatments with different application methods of orthodontic adhesive system (TXT) on the SBS between monolithic zirconia and the metal brackets. According to the results of this study, the null hypothesis tested was that no difference would be found in the SBS between metal brackets and monolithic zirconia crowns regardless of the used primers and application procedures was rejected. The use of dental zirconia has become popular due to its excellent mechanical strength and optimal aesthetics compared to porcelain fused to metal restorations.[12,13] Clinical studies have shown that despite the survival rates of zirconia-based restorations exceeding 90%, the chipping problem is prevalent in veneer ceramics.[14,15] Therefore, the use of monolithic zirconia is recommended, especially in cases where the interocclusal distance is limited.[16] Therefore, in this study, molar crowns were produced from monolithic zirconia in CAD-CAM.

Previous studies reported better SBS of metal brackets rather than the ceramic brackets to zirconia surface.[17,18] This can be attributed to the design of the metallic bracket base, creating a better mechanical coupling with zirconia. Therefore, the metallic brackets were used in the current study.

It is known that the chemical bond of the primer is obtained between the metal ions of the ceramic surface and the functional monomer, like 10-MDP.[19-21] There have been remarkable studies for zirconia bonding with the use of MDP-containing primers. Previous researches have successfully shown its significant effect in increasing SBS of metallic brackets on zirconia.[22,23]

Bracket bonding to previous zirconia restoration requires different surface treatment techniques to provide optimum bond strength.[24,25] Air abrasion is an effective and simple way to form micromechanical retention and increase bond strength, but is known to have the potential to reduce the mechanical properties of zirconia.[26,27] Generally, patients seeking orthodontic treatment refer to the orthodontist with restorations they already have. Therefore, air abrasion cannot always be a suitable method for patients with previous zirconia restorations. On the other hand, chemical bonding techniques such as application of zirconia primer before bracket bonding can improve the bond strength by creating chemical bonds.[20,28] Another method to ensure chemical bond with zirconia is to use several primers that seem more suitable for use with Transbond XT which is the gold standard for orthodontic adhesive systems, consisting of primer and composite paste.[29-31] Monobond Plus (Ivoclar Vivadent, Schaan, Liechtenstein) is known as a universal primer which is suitable for all types of restorative materials.[32] Another zirconia primer that has been described to be highly impressive in obtaining durable resin bond to zirconia surface is Z-Prime Plus usage are clear, there are different application procedures for orthodontic adhesive systems when used right after the surface treatment agents. In previous studies different zirconia primers were used with; paste of the TXT solely[11,25] or different zirconia primers were used with primer and composite resin paste of the TXT consecutively.[10,11,31] Therefore, in the present study, both application methods of Transbond XT were also investigated.

In this study, the mean SBS values of control group and the groups which were treated with MDP-containing primer (M, MT, Z, and ZT groups) were higher than the clinically adequate bond strength (6-10 MPa) that is enough to withstand the orthodontic and masticatory force.[33-35] These results were consistent with the previous studies.[10,30,36] This means the adhesive systems that were used in this study can resist shear stress to sufficient levels. Control group showed the lowest value of the mean SBS among all the groups.

The lower bond strength of Z-Prime Plus compared to other MDP-containing primers has been reported in a previous study.[37] Similarly, in the current study, the SBS values of Group Z and Group TZ were lower than other MDP-containing primer groups (Group M and Group TM). This can be explained by the carboxylic acid monomer which is thought to weaken the bond with the resin cement's methacrylate group.[37]

The groups with Monobond Plus showed the highest SBS values among the other groups in the current study. The reason for this can be the effect of sulfide methacrylate monomer exists in Monobond Plus.[38]

Some authors suggested the use of either universal primer or ceramic primers combined with orthodontic primers rather than using solely ceramic primers.[10,11] According to the results of this study, the bond strength was significantly increased with the use of Transbond XT primer/adhesive paste in combination with the primer application (Group TM, Group TZ), so it is conceivable that chemical bonding could have actually occurred.

In daily practice, generally glazed restorations already exist in dentition when bracket bonding is needed. The usage of non-glazed restorations in the current study could be a limitation for this study. However, glazed restorations require deglazing with a burr before bracket bonding which also could affect the result of in-vitro study. Therefore, non-glazed restorations were used to ensure standardization.

Aging process of monolithic zirconia samples was not considered in previous studies.[39,40] Considering the aging process before bracket bonding can be a superiority for the current study. Moreover, the selection of monolithic zirconia as the main restorative material can be another superiority compared to other traditional ceramic and zirconia materials. Producing monolithic zirconia by using CAD-CAM technology enabled the authors to use exactly the same type of tooth for each sample which is advantageous for standardization. Because this new generation material is expected to become more popular in the future, current study can contribute to clinical practice by means of presenting different surface conditioning agents for enabling proper bond strength of orthodontic brackets.

CONCLUSION

Within the limitations of this in vitro study, according to the mean shear bond strength values of the all tested groups, it can be concluded that all bracket-bonded crowns were sufficient to withstand orthodontic forces. Surface treatment with primers contributes to increase the shear bond strength between metallic bracket and monolithic zirconia.

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