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Research Article

Shear Bond Strength of Metallic and Ceramic Brackets Bonded With Different New Generation Composite Systems

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Abstract

Objective: The aim of this study was to compare the Shear Bond Strength (SBS) of six different adhesive systems including Transbond XT (3M ESPE) and Light Bond Kit (Reliance) as orthodontic bonding system; Fusion Xtra (Voco) and Xtrafil (Voco) as bulk-fill composites; Nexus (Kerr) and Maxcem Elite (Kerr) as adhesive-resin cements for bonding of metal and ceramic brackets.

Methods: Sixty permanent maxillary premolars were randomly divided into twelve equal groups. Stainless steel (Gemini bracket; 3M Unitek) and ceramic (Radiance, American Orthodontics) maxillary premolars brackets with a 0.022 inch slot, were bonded to the teeth using six different adhesive systems according to manufacturers' instructions. Shear bond strength of the samples were done by Shimatsu instron instrument. Following the shear bond test, samples were evaluated under stereomicroscope for Adhesive Remnant Index (ARI) scores. The data were analyzed using analysis of variance (ANOVA), post hoc Tukey HSD and chi-square tests.

Results: Analysis of variance test showed a significantly differences among the various group. Brackets bonded with Light Bond Kit and Fusion Xtra in metallic brackets showed a significantly lower SBS than other groups ($P<0.05$). Additionally, teeth bonded with Tranbond XT ceramic brackets showed a significantly higher SBS than the other groups. Moreover, significant differences in debond locations (ARI scores) were found among the various groups.

Conclusion: The bond strength of ceramic brackets was significantly higher than metallic ones except Xtrafil and the adhesive-resin cement.

Clinical Significance: Bulk-fill composites can successfully be used for bracket bonding.

Keywords: Bracket; Bulk Fill Composite; Shear Bond Strength

Introduction

For over past 50 years, adhesives and their bonding properties to enamel and dentine has greatly progressed in the fields of dentistry and orthodontics [1]. Direct bonding has a main role in modern orthodontics. Easy bracket placement, acceptable clinical success rate, and reduction in chair side time are the advantages of this technique. Significant bond failure has varied in the literature (0.5-16%) [2]. Orthodontic adhesives ideally should provide adequate bond strength and aesthetic appearance after debonding of the enamel. With this in mind, the highest quality and bonding ability of orthodontic brackets have been at the forefront for researchers and engineers [3,4].

While various types of composites such as micro filled, micro hybrid, flow able are available [5], another development in this field has been the introductions of nanocomposites that claim to have achieved higher wear resistance and appropriate mechanical properties. Nanocomposites enhance the hybrid layer, increase marginal seal, and reduce polymerization shrinkage due to their higher filler content. Furthermore, nano-filler bandings have shown satisfactory bond strength to enamel and dentin, and can be utilized for direct and indirect restorations [6,7]. Despite the extensive applications of nanocomposites in restorative dentistry, there is inadequate data regarding the possibility of using them for bonding orthodontic brackets. The "bulk fill" resin nanocomposites are light-curing and are cured to a maximum increment thickness, which is generally cured at a thickness of 4mm [8,9].

Good composite should provide sufficient bond strength to maintain the restoration in position even at high masticatory load [10]. Various types of cements are available, which include total-etch resin cement that is a multi-step adhesive system. These are sensitive and time-consuming [11]. In the attempt to simplify the application procedures, the self-etching adhesive system was developed in which the smear layer is preserved and altered [12]. With this adhesive system, primer and bonding agent can be applied to the tooth without prior etching and rinsing the tooth [13,14]. According to the manufacturer, NX3 Nexus® cement is dual-cure resin cement that can be used with both as a total-etch and self-etch adhesive.

The main concern for adhesive research and engineering is the overall Shear Bonding Strength (SBS). In addition, the SBS must be accounted for when applied to an orthodontic bracket, because it must withstand routine forces endured by the mouth. Interestingly, low shear strength can result in higher costs and prolonged treatment times. Furthermore, low SBS can cause damage to the enamel and dentin when the bracket loses its adhesion.

Presently, self-etching adhesives have a wide range of resistant forces that range from 2.8 to 16.6 MPa. Previously published reports have shown that resistances forces of 5.9-7.8 MPa are sufficient for orthodontic adhesives [15], while others have determined it to have a higher range (10.4-11.8 MPa) [16,17]. Newer design aesthetic plastic or ceramic brackets has become popular and a need to determine SDS for these models is necessary [18]. In addition, bonding and adhesive properties as well as their durability are a topic of debate in the clinic [19]. The objective of this report was to compare the SBS of six different bonding agents for bonding of ceramic and metallic brackets.

Materials and Methods

Sixty extracted non-carries human maxillary premolars were used in this *in vitro* study. The extracted premolars were stored at room temperature in distilled water. The inclusion criteria for this study dental enamel without caries, or cracks. Each premolar was vertically embedded in an acrylic resin block in a way that the crown was exposed. The buccal enamel surface of the molar was polished with a non-fluoridated pumice powder, washed, and dried with a stream of air. Randomly, the premolars were categorized into groups (n=12). All adhesive materials are shown in Table 1. Bonding of the metallic and ceramic brackets was performed by the same orthodontist according to the (Nuri Mert Topbasi) procedures.

Table 1: Adhesives materials used in this study.

Adhesive Material	Adhesive Type	Manufacturer	Composition
Transbond XT	Light-cure	3M Unitek, USA	35% phosphoric acid, silane-treated quartz, bisphenol A diglycidyl ether dimethacrylate, bisphenol A bis-(2-hydroxyethyl)-ether dimethacrylate, silane-treated silica
Light Bond Kit	Light-cure	Reliance Orthodontic Products, Inc, Itasca IL, USA	Fused Silica, Urethane Dimethacrylate, Triethylene glycol dimethacrylate
Fusion X-tra	Light cure (Ormocer based bulk fill composite)	Voco GmbH, Cuxhawen	Nanohybrid ORMOCER , organically modified silicic acid
X-trafil	Light cure (methacrylate based Bulk fill composite)	Voco GmbH, Cuxhawen	Bis-GMA, UDMA, TEGDMA, Inorganicfillers, fumedsilica, CQ Photoinitiator; photoaccelerator;
Nexus	Dual cure (resin cement)	Kerr, Orange, CA, USA	2-hydroxyethyl methacrylate 2-hydroxy-1,3-propanediyl bismethacrylate (1-methylethylidene)bis[4, 1-phenyleneoxy(2-hydroxy- 3,1-propanediyl)] bismethacrylate
Maxcem Elite	Dual cue (self etch and self adhesive resin cement)	Kerr, Orange, CA, USA	Resinmatrix: GPDM, co-monomers (mono-, di-, andtri-functionalmethacrylatemonomers), proprietary self-curingredoxactivator, photoinitiator CQ, stabilizer Filler load 67%wt: fluoroaluminiosilicateglass, fumedsilica, bariumglass, ytterbiumfluoride
Futurabond U	Universal adhesive Light cure	Voco GmbH, Cuxhawen	2-HEMA, Bis-GMA, HEMA, acidic adhesive monomer, urethane dimethacrylate, catalyst, silica nanoparticles, ethanol
Solobond Plus	Etch &rinse adhesive Light cure	Kerr, Orange, CA, USA	Ethyl alcohol, alkyl dimethacrylate resins, Barium aluminoborosilicate glass, Fumed silica (silicon dioxide), Sodium hexafluorosilicate.

GPD	:	Mglycerol Dimethacrylate Dihydrogen Phosphate
CQ	:	Camphorquinone
TEGDMA	:	Triethylenglycoldimethacrylatebis
EMA	:	Ethoxylated Bisphenol A Glycol Dimethacrylate
Bis-GMA	:	Bisphenol A-Glycidylmethacrylate
UDMA	:	Urethane Dimethacrylate
ORMOCER	:	Organic Modified Ceramic
HEMA	:	2-Hydroxyethyl-Methacrylate

Group 1: Etching of the enamel surfaces were done using a solution of 37% phosphoric acid (Gel Etch, 3M Unitek, Monrovia, USA) and air-dried following a water rinse, all for 15 seconds. The Transbond XT primer (3M Unitek, Monrovia, USA) was then used to treat the enamel followed by Transbond XT adhesive application to the base of the bracket. Maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) were bonded using a standard protocol.

Group 2: The enamel on the molars were etched with Reliance Etching Agent (Reliance Orthodontic Products, Inc, Itasca IL, USA) and a sealant treatment was performed with Light Bond Sealant (Reliance Orthodontic Products, Inc, Itasca IL, USA) . Then, the adhesive Light Bond Kit (Reliance Orthodontic Products, Inc, Itasca IL, USA) was used to treat the bracket base. Maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) were adhered using the manufacturer's protocol.

Group 3: Enamel etching was done using phosphoric acid (Vococid, Voco GmbH, Cuxhawen) for 15 seconds, aspirate acid, and a rinse with water for 15 seconds. Without overdrying, removal of excess moisture with compressed air was done to produce a silky matte surface. Activation of a single dose adhesive package (Futrabond U, Voco GmbH, Cuxhawen) and adhesive application to the cavity surface using the Voco Single Tim brush and rub adhesive in for 20 seconds was also performed. A dry adhesive, with dry and oil-free air, was done for at least 5 seconds followed by a light cure for 10 seconds. The Fusion Xtra, ormocer based Bulk fill (Voco GmbH, Cuxhaven) composite was then administered to the bracet base and a light cure was done for 10 seconds. Maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) were bonded using the manufacturer's directions.

Group 4: Enamel etching was done using phosphoric acid (Vococid, Voco GmbH, Cuxhawen) for 15 seconds, aspirate acid, and a rinse with water for 15 seconds. Without overdrying, removal of excess moisture with compressed air was done to produce a silky matte surface. Activation of a single dose adhesive package (Futrabond U, Voco GmbH, Cuxhawen) and adhesive application to the cavity surface using the Voco Single Tim brush and rub adhesive in for 20 seconds was also performed. A dry adhesive, with dry and oil-free air, was done for at least 5 seconds followed by a light cure for 10 seconds. (Voco GmbH, Cuxhaven) composite was applied to the bracet base and light cure for 10s.The X-tra fil bulk fill (Voco GmbH, Cuxhaven) composite was then administered to the bracet base and a light cure was done for 10 seconds. Maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) were bonded using the manufacturer's directions.

Group 5: Etching of the enamel surfaces were done using a solution of 37% phosphoric acid (Vococid, Voco GmbH, Cuxhawen), rinsed thoroughly for 20 seconds, and blotted-dry with a cotton swab for a glistening surface. Generous amounts of adhesive (Solobond Plus, Kerr, Orange, CA, USA) were applied using light brushing motion to thoroughly wet the surface for 15 seconds. A high-volume evacuation tip was placed over the enamel for 1–2 seconds to evaporate the solvent after an air-dry for 3 seconds with clean, dry air. The Surface should have a uniform glossy appearance upon light-cure for 20 seconds. Lastly, apply an auto-mixed cement (Nexus, Kerr Orange, CA, USA) and light-cure for 20 seconds. Maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) were bonded using a standard protocol.

Group 6: Etching of the enamel surfaces were done using a solution of 37% phosphoric acid (Vococid, Voco GmbH, Cuxhawen), rinsed thoroughly for 20 seconds, and blotted-dry with a cotton swab for a glistening surface. Maxcem Elite (Kerr orange CA, USA) was used as a dual cure resin cement that self-etches and self-adheres. No adhesive were applied on enamel surfaces. Only auto mixed cement (Maxcem elite, Kerr Orange CA, USA) were applied on bracket surface a maxillary premolar metallic brackets (Gemini bracket, 3M Unitek, USA) and were bonded using manufacturer's protocol.

Group 7: Etching of the enamel surfaces were done using a solution of 37% phosphoric acid (Vococid, Voco GmbH, Cuxhawen), rinsed thoroughly for 15 seconds, and blotted-dry with a cotton swab for a glistening surface. After Transbond XT primer (3M Unitek, Monrovia, USA) was applied to the enamel surfaces. Then, Transbond XT adhesive was administered to the base of the bracket base. Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were bonded using a standard protocol.

Group 8: The enamel on the molars were etched with Reliance Etching Agent (Reliance Orthodontic Products, Inc, Itasca IL, USA) and a sealant treatment was performed with Light Bond Sealant (Reliance Orthodontic Products, Inc, Itasca IL, USA) . Then, the adhesive Light Bond Kit (Reliance Orthodontic Products, Inc, Itasca IL, USA) was used to treat the bracket base. Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were adhered using the manufacturer's protocol.

Group 9: Enamel etching was done using phosphoric acid (Vococid, Voco GmbH, Cuxhawen) for 15 seconds, aspirate acid, and a rinse with water for 15 seconds. Without overdrying, removal of excess moisture with compressed air was done to produce a silky matte surface. Activation of a single dose adhesive package (Futrabond U, Voco GmbH, Cuxhawen) and adhesive application to the cavity surface using the Voco Single Tim brush and rub adhesive in for 20 seconds was also performed. A dry adhesive, with dry and oil-free air, was done for at least 5 seconds followed by a light cure for 10 seconds. (Voco GmbH, Cuxhaven) composite was applied to the bracet base and light cure for 10s.The X-tra fil bulk fill (Voco GmbH, Cuxhaven) composite was then administered to the bracet base and a light cure was done for 10 seconds. Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were bonded using the manufacturer's directions.

Group 10: Enamel etching was done using phosphoric acid (Vococid, Voco GmbH, Cuxhawen) for 15 seconds, aspirate acid, and a rinse with water for 15 seconds. Without overdrying, removal of excess moisture with compressed air was done to produce a silky matte surface. Activation of a single dose adhesive package (Futrabond U, Voco GmbH, Cuxhawen) and adhesive application to the cavity surface using the Voco Single Tim brush and rub adhesive in for 20 seconds was also performed. A dry adhesive, with dryand oil-free air, was done for at least 5 seconds followed by a light cure for 10 seconds. (Voco GmbH, Cuxhaven) composite was applied to the bracet base and light cure for 10s.The X-tra fil bulk fill (Voco GmbH, Cuxhaven) composite was then administered to the bracet base and a light cure was done for 10 seconds. Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were bonded using the manufacturer's directions.

Group 11: Etching of the enamel surfaces were done using a solution of 37% phosphoric acid (Vococid, Voco GmbH, Cuxhawen), rinsed thoroughly for 20 seconds, and blotted-dry with a cotton swab for a glistening surface. Generous amounts of adhesive (Solobond Plus, Kerr, Orange, CA, USA) were applied using light brushing motion to thoroughly wet the surface for 15 seconds using light brushing motion. A high-volume evacuation tip was placed over the enamel for 1–2 seconds to evaporate the solvent after an air-dry for 3 seconds with clean, dry air. The Surface should have a uniform glossy appearance upon light-cure for 20 seconds. Lastly, apply an auto-mixed cement (Nexus, Kerr Orange, CA, USA) and light-cure for 20 seconds. Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were bonded using a standard protocol.

Group 12: Etching of the enamel was done for at least 15 seconds with 37% ortho-phosphoric acid (Vococid, Voco GmbH, Cuxhawen), followed by a rinse for 20 seconds and drying with a cotton swab for a glistening surface. The Maxcem Elite (Kerr orange CA, USA) is dual cure resin cement, with self-etching and self-adhesive capabilities. No adhesive were applied on enamel surfaces. Only auto mixed cement (Maxcem elite, Kerr Orange CA, USA) were applied on bracket surface Maxillary premolar ceramic brackets (Radiance, American Orthodontics, USA) were bonded using a manufacturer's directions.

All metallic and ceramic brackets were polymerized by using a LED light unit (VALO, Ultradent Products, South Jordan, USA) for 20 seconds each on both the mesial and distal sides. All premolars placed in distilled water at 37°C until debonding occured. The SBS of the samples were done by Shimatsu Instron (AGS-1000kGW; Instron, Shimadzu Corp., KYOTO, Japan) instrument with a cross-head speed of 0.5 mm/min and 1KN load cell (Figure 1). The force, measured in Newtons (N), was determined for removal of the brackets and SBS values were calculated by converting Newtons into Megapascals (MPa) by Trapezium X (Shimadzu Corp., Kyoto, Japan).

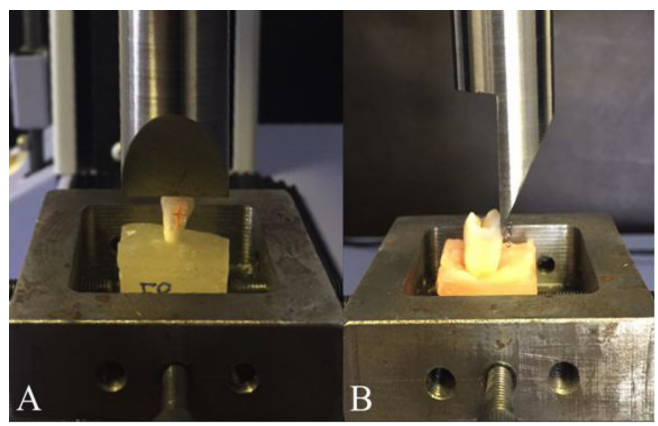

Figure 1: Tooth positioned in the universal testing machine. A: frontal view, B: lateral view.

After debonding procedure, all teeth buccal surfaces and metallic and ceramic brackets were analyzed with a stereomicroscope (Leica M27.5, Heerbrugg, Switzerland) at a magnification of 40X. This was done in order to evaluate the adhesiveness on the enamel surfaces. The ARI (Adhesive remnant index) scoring was done according to the modified ARI score (Figure 2) [20].

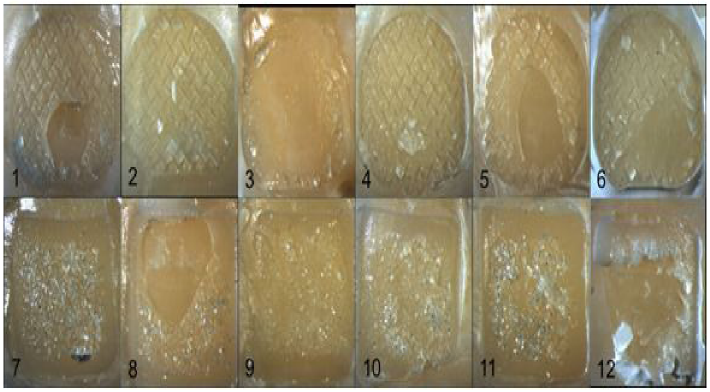

Figure 2: Stereomicroscopic images of ARI scores at 10X magnification. 1: Transbond XT metallic bracket, 2: Light Bond Kit metallic bracket, 3: Fusion Xtra metallic bracket, 4: Xtrafil metallic bracket, 5: Nexus metallic bracket, 6: Maxem Elite metallic bracket, 7: Transbond XT ceramic bracket, 8: Light Bond Kit ceramic bracket, 9: Fusion Xtra ceamic bracket, 10: Xtrafil ceramic bracket, 11: Nexus ceramic bracket, 12: Maxem Elite ceramic bracket.

Modified ARI scores ranged from 1 to 5 where: 1- the entire composite remained on the molar; 2- composite of 90% or greater remained on the molar; 3- a composite 90% or less but more than 10% was left on the molar; 4- a composite of less than 10% was left on the molar; 5- no composite remained.

Statistical Analyses

All statistics were performed using the SPPS (SPSS Inc., version 21.0, Chicago, IL, USA). After performing Shapiro-Wilks homogeneity test to assess the normality of the data, statistical analyses were done by a parametric tests. Descriptive statistics included mean, standard deviation, maximum, and minimum values that were calculated for each group. One-way variance analysis (ANOVA) and post hoc Tukey HSD tests were performed for multiple comparisons of SBS values among the groups. Modified ARI scores were compared with the chi-square test among the groups. A p-value of less than 0.05 was considered significant.

Results

The statistical analysis of the SBS values for the study of metallic and ceramic bracket groups are shown in Table 2and3, respectively. Xtrafil demonstrated the highest SBS value (11.80 ± 0.72 MPa), while no significant difference was observed between the Xtrafil and Nexus (11.09 ± 0.83 MPa) group for metallic brackets. Transbond XT demonstrated the highest SBS value (21.59 ± 0.71 MPa) in ceramic bracket groups. Brackets bonded with Light Bond Kit (7.39 ± 0.55 MPa) and Fusion Xtra (7.59 ± 0.70 MPa) in metallic brackets had reduced SBS compared to the other groups ($p < 0.05$). Also, Light Bond Kit demonstrated the lowest SBS value (11.62 ± 1.34 MPa) in ceramic bracket groups.

Table 2: Comparison of SBS (MPa) values in metallic brackets.

Groups	Subgroups	Mean	SD	Minimum	Maximum	*P*
Orthodontic Adhesives	Transbond XT	10.54^{B}	0.45	10.04	11.16	<0.001
	Light Bond Kit	7.39^{C}	0.55	6.53	7.97	
Bulk Fill Composites	Fusion Xtra	7.59^{C}	0.70	6.85	8.52	
	Xtrafil	11.80^{A}	0.72	10.88	12.80	
Adhesive-Resin Cements	Nexus	11.09^{AB}	0.83	10.36	12.22	
	Maxcem Elite	10.24^{B}	0.37	9.85	10.68	

A,B,C Different capital letter indicate that as regards One-way ANOVA/Tukey tests SBS valuesare significantly different at P<0.001, SD: Standard Deviation.

Table 3: Comparison of SBS (MPa) values in ceramic brackets.

Groups	Subgroups	N	1	2	3	4	5
Orthodontic Adhesives	Transbond XT	5	2 (40 %)	1 (20 %)	0	2 (40 %)	0
	Light Bond Kit	5	0	3 (60 %)	1 (20 %)	1 (20 %)	0
Bulk Fill Composites	Fusion Xtra	5	0	1 (20 %)	2 (40 %)	2 (40 %)	0
	Xtrafil	5	3 (60 %)	2 (40 %)	0	0	0
Adhesive-Resin Cements	Nexus	5	0	1 (20 %)	4 (80 %)	0	0
	Maxcem Elite	5	2 (40 %)	2 (40 %)	1 (20 %)	0	0
All groups that are not significantly different from each other (*P*>0.05). A,B,C,D Different capital letter indicate that as regards ANOVA/Tukey tests SBS values are significantly different at *P*<0.001, SD; Standard Deviation.							

Table 4: Distribution of Adhesive Remnant Index (ARI) scores among the study groups in metallic brackets.

Groups	Subgroups	N	1	2	3	4	5
Orthodontic Adhesives	Transbond XT	5	0	3 (60 %)	2 (20 %)	0	0
	Light Bond Kit	5	0	4 (80 %)	1 (20 %)	0	0
Bulk Fill Composites	Fusion Xtra	5	0	2 (40 %)	3 (60 %)	0	0
	Xtrafil	5	0	1 (20 %)	2 (40 %)	2 (40 %)	0
Adhesive-Resin Cements	Nexus	5	0	3 (60 %)	2 (40 %)	0	0
		5	0	1 (20 %)	4 (80 %)	0	0

Table 5: Distribution of Adhesive Remnant Index (ARI) scores among the study groups in ceramic brackets.

Groups	**Subgroups**	**Mean**	**SD**	**Minimum**	**Maximum**	***P***
Orthodontic Adhesives	Transbond XT	21.59A	0.71	20.57	22.34	<0.001
	Light Bond Kit	11.62D	1.34	9.73	12.68	
Bulk Fill Composites	Fusion Xtra	12.42CD	0.63	11.6	13.12	
	Xtrafil	12.91CD	0.59	12.18	13.62	
Adhesive-Resin Cements	Nexus	18.28B	0.59	17.56	19.02	
	Maxcem Elite	13.74C	0.31	13.39	14.10	

All groups that are significantly different from each other (χ^2=29.051 ; P<0.001).

Discussion

In this study, we have compared the new materials for bonding of both metallic and ceramic brackets. We used two different orthodontic resin cements; bulk fill composites including methacrylate and ormocer based; resin cements including dual cure and self-adhesives. As an integral part of orthodontic therapy, maxillary premolar teeth are typically removed by extraction. For this reason, we used these extracted teeth for clinical outcomes and comparison with the current literature [21,22].

According to a study by Reynolds and von Fraunhofer [15] an appropriate adhesive for orthodontic purposes should meet a SBS value of at least 5.9-7.8 MPa. Presently, etching with acid is the preferred method for bonding brackets in orthodontics. Interestingly, there are a few studies that have shown an increased rate of bracket loss due to self-etching primers [18]. Other reports demonstrated SBS yields and rates of failure consistent with the conventional etching procedure [23-25]. We used 37% orthophosphoric acid (Vococid) on the molar surface before application of the orthodontic cement, bulk fill composites, and resin cements. We have reached the SBS scores 7.59-11.80 for metallic brackets and 11.62-21.59 for ceramic brackets.

Tight adhesion to the molar has been made possible since the use of phosphoric acid was introduced in dentistry by Buonocore. This procedure later became the pretreatment option started by Newman for orthodontists performing bonding experiments. Self-etching primers are another method used in the place of acid-etching and include hydrophilic monomers such as Hydroxyethylmethacrylate (HEMA). Acid monomers, however, have been created to reduce the bonding steps and minimize errors [26]. Both adhesives we used are made of silanized inorganic particles and a resin made of dimethacrylate. Multiple reports have demonstrated the Bis GMA adhesive physical properties and bonding strengths on metal brackets [27-29]. In our study, we have selected to use new generation adhesive system as Futurabond U is a universal adhesive material. This material can be used both as etch & rinse system and self-etch system. It has HEMA, Bis-GMA, HEDMA, acidic adhesive monomer, urethane dimethacrylate, catalyst, silica nanoparticles. In resin cement groups OptiBond Solo Plus was used with Nexus resin cement. This adhesive has Barium aluminoborosilicate glass, alkyl dimethacrylate resins, fumed silica (silicon dioxide), and sodium hexafluorosilicate. Futurabond U and Solobond Plus have etanole-based solvents. In this present study, an etch-and-rinse technique was preferred to standardize all the adhesive applications of brackets.

In this report, the mean SBS of Transbond XT was 21.59 Mpa, and was the highest average compared to the other groups. Multiple reports have shown various force strengths 15.49 MPa [17], 11.2 MPa [30] and 9.7 MPa [31] for the acid-etch adhesives and Transbond XT, respectively. However, Scougall Vilchis et al [32]. Compared Transbond XT with Transbond Plus and other three self-etching adhesives and found that the SBS of Transbond XT was highest (19.0 MPa), followed by Transbond Plus (16.6 MPa) and three other self-etching adhesives.

In our study reliance light kit showed the lowest SBS results in both metal and ceramic groups. Controversy to our results, Sorake et al. showed that the Reliance self-etching primer demonstrated the most bond strength followed by Clearfil Protect bond, Clearfil SE bond, and Tran bond Plus. The Clearfil Protect Bond primers, which contain MDPB, have been demonstrated to have antimicrobial effects on the enamel surface [33]. This may be due to the test method and other materials differences. Continuous evaluation of composites will help to understand discrepancies with the literature of SBS tests [34].

The filler typically aids in the mechanical properties of the resin. However, there is no evidence that the quantity of the filler directly proportional to the material's SBS level. In addition, the materials submitted for testing have a known strength value for force evaluation [35]. However, our study showed that filler rate has affected SBS results. Bulk fill composites and dental resin cements have fumed silica in their inorganic structure. Xtrafill has 87% filler rate, and this material has the highest SBS (11.80) score in metal brackets and second highest SBS (12.91) score in porcelain brackets. Transbond XT has 84% filler and it showed the highest SBS (21.59) score in porcelain brackets.

In our study bulk fill composites showed as good SBS scores as orthodontic adhesives. Chalipa et al. reported that the nanocomposites can be successfully used for bonding orthodontic brackets [36]. Therefore, in addition to Transbond XT, both Supreme XT and AELITE Aesthetic Enamel are appropriate for orthodontic purposes and could be utilized for bonding, despite not dis- playing any additional advantages compared to Transbond XT [15]. Since various studies regarding bond strength of composites have utilized adhesives with different size/concentration of filler, it is difficult to compare their results accurately [37]. This is further complicated by different medians and thermocycling rounds [38]. The data shown here are consistent with that of Bishara and colleagues [16]. There was no statistical difference between the SBS value of Transbond XT and a restorative nanocomposite, and both materials were considered applicable in orthodontics.

Conclusions

Within the limitations this laboratory study showed;

1) The bond strength of ceramic brackets were significantly higher than metallic ones except Xtrafil.

2) The adhesive-resin cement and bulk-fill composites can successfully be used for bracket bonding.

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