Correlation between shear bond strength and degree of conversion of four orthodontic adhesives

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Background and objective: The aim of the study is to assess the correlation between degree of monomer conversion (DC) and shear bond strength (SBS) of the different adhesives. The objective of the present study was to determine the efficiency of four orthodontic adhesives regarding shear bond strength (SBS), debonding characters and degree of conversion (DC) and to correlate SBS to the DC.
Methods: Forty human upper first premolars, divided into four Groups (n = 10) were bonded with metal brackets using four different adhesives. Brackets were debonded in shear on an Instron universal testing machine with a crosshead speed of 1 mm per minute. The mode of bond failure was determined by the adhesive remnant index (ARI) index and the DC was determined by fourier transform infrared spectroscopy (FTIR) analysis.
Result: There was a statistically significant difference between the SBS of only Transbond XT and Orthobond plus color change adhesive while the two remaining adhesives showed no significant difference. All groups of the adhesives showed cohesive type of bond failure according to the ARI results. A statistically significant lower percentage of DC was noted for Orthobond plus (63 %) than Transbond XT (70.2 %) but it was within the accepted range reported in the literature (55-75%). Pearson's correlation was significantly positive between SBS and DC for Smart Ortho, Heliosit Orthodontic and Orthobond Plus adhesives and insignificantly positive for Transbond XT.
Conclusion: Within the limitations of this in vitro study it can be concluded that the Transbond plus color change has significantly higher fluoride release as well as recharge properties when compared to other ortho-adhesive material.
Keywords: Orthodontic Adhesive, Shear Bond Strength, Degree of conversion

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Introduction

The clinical practice of orthodontics has been improved by the direct bonding of orthodontic brackets to the enamel surface in terms of aesthetics, comfort, better dental hygiene, decreased gingival irritation, and less chairside time. The development of Bowen's resin BIS-GMA (bis-phenol A glycidyl dimethacrylate) for restorative purposes in 1962 and Buonocore's innovative work on the acid etch technique in 1955 both made significant contributions to the direct bonding technique and were crucial in the development of new procedures and materials.[1] The acid-etch technique was first used in general dentistry, but when George Newman, [2] started bonding plastic brackets tothe tooth enamel as an addition to metal bands in his orthodontic practice, it was accepted into orthodontics. For many reasons, bonding brackets directly to tooth enamel proved advantageous for both the dentist and the patient. With the help of this technique, dentists may use smaller brackets and do rid of the issue with post-treatment band gaps. In comparison to circumferential bands, directly bonded brackets for the patient were much more clean, esthetic, and produced less soft tissue discomfort. [3] The bond between orthodontic devices and tooth surfaces is strengthened by etching enamel, allowing orthodontic appliances to resist pressures applied during orthodontic therapy and stay connected

to teeth. The most popular technique used in orthodontics nowadays to prepare tooth enamel before bracket installation is acid-etching using 37% phosphoric acid. Numerous in vitro and in vivo investigations are conducted on a range of orthodontic bonding and adhesive procedures. The three primary factors that must be taken into consideration for successful orthodontic bonding are the bonding agent itself (material composition and shear bond strength), enamel preparation and morphology, and the individual base of the orthodontic attachment (material and mechanical properties). [4] To minimize white spot lesions and dental cavities below and around the brackets, the main goal is to achieve a good marginal seal and use the least amount of bonding material possible. [5] The appropriate adhesive strength for bonding orthodontic devices is difficult to measure. It is understood that low bond strength may cause frequent debonding while very high bond strength may cause enamel fracturing during appliance debonding. [6] According to some studies, it's crucial that the enamel integrity be maintained following the removal of orthodontic brackets in order to achieve a successful outcome in orthodontic treatment. [7]
Bonding of orthodontic bracket to be clinically successful, it must be able to withstand displacement forces of at least 6 to 8 megapascal (MPa). [8] In order to assess how much adhesive was still adhered to the tooth after debonding, Artun and Bergland used the Adhesive Remnant Index (ARI) method. [9] The following criteria were used to establish this index system, which was based on a pilot study of 20 extracted teeth: From 0 to 3, the index score is as follows:
0= No adhesive remains on the tooth
1= less than half of the adhesive remains on the enamel
2= more than half of the adhesive remains on the tooth
3= all the adhesive remains on the tooth
Studies have debated if the differences in ARI scores reflect a difference in the bond strength between the enamel and the adhesive for the various adhesive systems. [10-13] However, adhesive systems with less adhesive remnant on the tooth have been favored for easier and safer removal of residual resin after debonding. [14,15] To successfully remove the adhesive residue and return the enamel surface to its pretreatment state as closely as feasible, the final stage of the debonding process of cleaning the enamel requires an accurate evaluation of the adhesive remnant. Although laboratory studies intended for evaluating the enamel surface after debonding and cleaning of the surface have used more sophisticated techniques like scanning electron microscope, finite element analysis, and 3 -d modeling. The majority of laboratory studies on the bond strength of orthodontic brackets have examined teeth and brackets under 10 magnification (Mag) to assess and score the adhesive remnant. [11, 16-18] After bracket debonding and enamel cleaning, clinical examination of the adhesive residue and the enamel surface is often performed by visual inspection under a dental operating light. [19,20]
Degree of conversion (DC), which impacts the mechanical, physical, and biological aspects of resins, measures how much the carbon double bonds (C=C) in an orthodontic adhesive resin's monomer are converted to carbon-carbon single bonds (C-C) in the polymer. [21] Because there is a link between DC and the shear bond strength of bonded brackets, a high DC value just after resin polymerization is regarded as ideal. [21] Optimal mechanical qualities demand a high monomer to polymer conversion. [22] According to one study, there is a direct link between increasing DC and increasing tensile strength, compressive strength, and elastic modulus. [23] According to Kauppi and Combe the clinically accepted limit of DC of orthodontic adhesive ranges from 55% to 75%. [24]
Insufficient conversion has been linked to the elution of substances from RBCs with potentially toxic effects, including hormonal disruption. [22]
The main goal of this study is to compare and evaluate the debonding strength and degree of conversion of the orthodontic adhesives that are bonded to stainless steel brackets.

Materials and methods

For the conduction of this study, forty sound human upper first premolars that had been extracted for orthodontic reasons collected from private clinics have been used. Blind randomized sampling technique was used to divide the teeth into four equal groups.

Following extraction, they were cleansed of debris and kept in distilled water at room temperature until the research started and for the duration of the research to avoid dehydration. Using a square metal mold, teeth were immersed in a pink self-curing acrylic resin, leaving the buccal surface of the teeth visible (Figure 1).

Figure1: extracted upper first premolar embedded in acrylic resin.

The labial surface of each tooth was positioned parallel to the shearing force. Specimens of teeth were sorted into four groups of ten at random. Orthodontic stainless steel maxillary first premolar brackets equilibrium® 2 with roth 22 prescription (Dentaurum, ispringen, germany) are utilized in this study because of their universality that can be used on left and right maxillary first or second premolars. Four different types of orthodontic adhesives were tested in this research including Transbond™ XT Light cure adhesive paste (3M Unitek, Monrovia,California, USA), Heliosit® Orthodontic (Vivadent, Schaan, Liechtenstein), Orthobond plus color change adhesive (Morelli Ortodontia, Alameda Jundiaí ,Brazil) and Smart Ortho Adhesive bond (Dongtancheomdansaneop 1-ro, Hwaseong-si, Gyeonggi-do, Korea). Each tooth was blindly assigned to one of the experimental groups. Teeth were etched for 30 seconds with a gel containing 37 percent phosphoric acid, then the acid was washed away with water spray for 5 seconds. The tooth surface was then dried by air using moisture-free until the surface had a white chalky appearance. After applying a thin layer of TransbondTM XT primer (3M Unitek, Monrovia, California) made of Bis-GMA and Triethylene Glycol Dimethacrylate (TEGDMA) in a 1:1 ratio with a photoinitiator on the etched enamel, the brackets were bonded using orthodontic resin composite adhesive to completely cover the mesh surface of the brackets. The brackets were then placed on the tooth surface and pressed firmly into place on the tooth's facial surface. A dental probe was used to remove excess adhesive from the bracket base's borders before polymerization. Then, brackets were exposed to a visible light-curing unit O-Light curing light (woodpecker, China) for 5 seconds on each side (total cure time 20 seconds), held 1mm away from the bracket-tooth interface. The output intensity of the curing light is calibrated using LED (light-emitting diode) radiometer (COXO, china) (Figure 2).

Following bonding, all samples were kept in distilled water at room temperature for 24 hours before being examined using a universal testing machine in the shear mode (Terco MT-3037, USA) (Figure 3).

Figure 2: Calibrating light output intensity with radiometer.

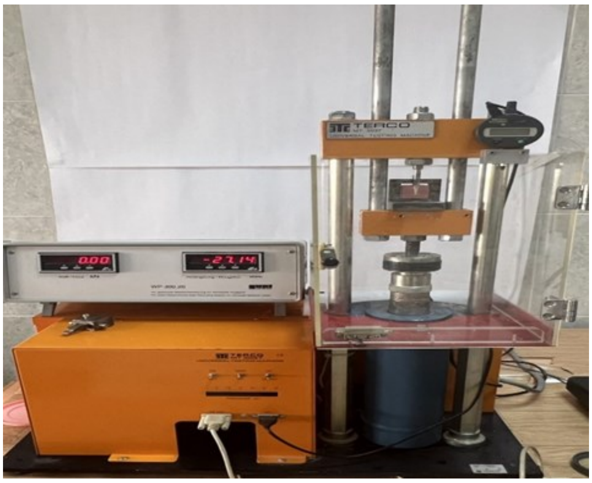

Figure3: Universal instron testing machine and WP system .

The bonded bracket base was aligned with the direction of the shear force by positioning the tooth embedded in acrylic on the specimen holder and stabilizing it with a locking screw on the platform of the universal testing machine. Similar to other investigations, specimens were strained in the occlusogingival direction at a crosshead speed of 1 mm per minute. [25] The highest load required to debond or start a bracket fracture was measured in newtons by WP 300.20 system for data acquisition (Gunt Hamburg, Germany) (Figure 3), and the MPa value was obtained by converting the number of newtons to the bracket's surface area. The following equation was used to determine the shear bond strength: Shear Strength (MPa) = Debonding Force (N) / the surface area of the bracket base (mm^2), where the bracket base surface area is calculated as the sum of the width and height of the bracket base (mm). [26] The bracket bases and enamel surfaces were investigated upon bond failure using an optical microscope (optika, Ponteranica, Italy) set to a 10x magnification. The quantity of adhesive still present on the enamel surface was measured using the adhesive remnant index (ARI) . This scale has a 0 to 3 range. A score of 0 means that there is no adhesive left on the tooth in the bonding region; a score of 1 means that there is less than half of the adhesive on the enamel; a score of 2 means that there is more than half of the adhesive left on enamel ; and a score of 3 means that all the adhesive is left on the enamel. FTIR spectroscopy was executed using the ATR accessory (Alpha II compact ftir spectrometer Billerica, Massachusetts, United States) (Figure 3).

Figure 4: FTIR/ATR accessory.

Uncured adhesive material was placed on the ATR (attenuated total reflectance) crystal ensuring that the crystal was fully covered by the material, the FTIR spectra of the uncured samples were then collected. A 2 mm portion of each adhesive was placed on a microscopy glass slide (26 mm x 76 mm x 1 mm) and covered with a polyester strip. Next, a metal orthodontic bracket identical to the one used in the previous test was pressed onto the polyester strip, simulating the light pressure applied clinically during bracket bonding. Between each set of monomer/polymer spectra, the crystal plate of the ATR accessory was cleaned with an absorbent paper and ethyl alcohol and then dried with tissue paper. The samples were exposed to the same polymerization and light exposure protocols as used for the shear test. After removal of the bracket and the polyester strip, the discs were created and used to assess the degree of conversion.

Results

It's clear from table (1) that Transbond XT shows the highest mean of SBS which is 20.34 MPa followed by Smart Ortho 17.14 MPa , heliosit Orthodontic 13.98 MPa and Orthobond Plus 11.5 MPa.

Post Hoc Tukey's test results showed statistically significant difference between Transbond XT and Orthobond Plus and the rest of the adhesives showed no significant difference as shown in table 2.

Table 1: SBS values of the adhesives

Adhesive	Mean	N	Std. Deviation	Minimum	Maximum
Heliosit	13.9840	10	6.19472	4.10	28.00
Orthobond Plus	11.5060	10	4.91460	2.00	18.70
Smart Ortho	17.1450	10	6.94513	8.30	31.20
Transbond XT	20.3440	10	8.94468	9.36	33.00
Total	15.7447	40	7.43991	2.00	33.00

Table 2: Post Hoc Tukey's test (Multiple Comparisons).

(I) material	(J) material	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Transbond XT	Smart ortho	3.19900	3.08844	.730	-5.1189	11.5169
	Heloist	6.36000	3.08844	.186	-1.9579	14.6779
	Orthobond plus	8.83800*	3.08844	.034	.5201	17.1559
Smart ortho	Transbond XT	-3.19900	3.08844	.730	-11.5169	5.1189
	Heloist	3.16100	3.08844	.737	-5.1569	11.4789
	Orthobond plus	5.63900	3.08844	.278	-2.6789	13.9569
Heloist	Transbond XT	-6.36000	3.08844	.186	-14.6779	1.9579
	Smart ortho	-3.16100	3.08844	.737	-11.4789	5.1569
	Orthobond plus	2.47800	3.08844	.853	-5.8399	10.7959
Orthobond plus	Transbond XT	-8.83800*	3.08844	.034	-17.1559	-.5201
	Smart ortho	-5.63900	3.08844	.278	-13.9569	2.6789
	Heloist	-2.47800	3.08844	.853	-10.7959	5.8399

The ARI scores were established with 10x magnification under the stereomicroscope and the ARI scores for each group is shown in Table (3).

Table 3: ARI distribution

		material				Total
		Transbond XT	Smart Ortho	Heloist	Orthobond PLus	
ARI	0	1	0	1	1	3
	1	2	1	7	0	10
	2	5	9	1	5	20
	3	2	0	1	4	7
Total		10	10	10	10	40

Chi-square test shows that there was a non-significance relation between the groups and ARI scores as shown in table (4).Table (5) shows the DC values obtained for the materials used in the study. Transbond™ XT light cure adhesive paste. showed the highest DC followed by Heliosit® Orthodontic, then Smart OrthoAdhesive bond, and Orthobond plus color change adhesive.

Table 4: chi-square test results

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	69.654[a]	69	.455
Likelihood Ratio	61.647	69	.723
Linear-by-Linear Association	.261	1	.609
N of Valid Cases	40		

Table 5: DC values of the adhesives

adhesives	Mean	N	Std. Deviation	Minimum	Maximum
Transbond XT	70.20	10	3.271	67	75
Smart Ortho	65.80	10	2.864	62	69
Orthobond Plus	63.00	10	2.739	60	67
heliosit	65.80	10	1.789	64	68
Total	66.20	40	3.636	60	75

Discussion

One of the most common complications faced in patients undergoing orthodontic treatment with fixed appliances are white spot lesion. In spite of the efforts for maintaining excellent oral hygiene during orthodontic treatment, WSLs are still seen in some patients.[11] Fluoride releasing orthodontic adhesives are potentially one of the methods to prevent WSL.[24] Storage media is one of most common factor that affecting the amount of fluoride release, as acidic solutions lead to more release fluoride than water and artificial saliva.[25,26] Also fluoride release in artificial saliva lower than in distal water. This perhaps due to the present of organic components in saliva, which may act as a barrier and could impede with the fluoride release of ortho-adhesive.[27]

Fluoride release of ortho-adhesive resin.
Fluoride can inhibit production of glucosyltransferase, which prevents the glucose from forming extracellular polysaccharides and reduces bacterial adhesion.[21] During fixed orthodontic treatment, orthodontic adhesive resin that contain fluoride in their composition important to prevent caries and WSL development. Studies for fluoride release measurement have been generally used distilled water,[28] deionized water,[12,26,29] artificial saliva[23] and DDW.[18] The storage media for the present study was used distilled deionized water (DDW) to evaluate the fluoride release of the orthodontic adhesive resin samples. DDW water was used to provides a baseline of fluoride release potential in unstimulated environments. It is a medium with no minerals or organic molecules and it was easily water achievable and more fluoride is released in DDW than in artificial saliva.[29] The amount of fluoride release in deionized water could be different from the one found in the oral cavity, because saliva is analways changing medium, with respect of temperature, pH, protein content and many other factors.[30]

In the present study the ion selective electrode was used to measure fluoride release, DDW was changed 24h before fluoride release measurement days, this measurement was taken to detect the amount of fluoride release in this period at each time point, not cumulative fluoride release This is to avoid fluoride saturation of the samples by continued fluoride release,[31] TISAB II was added to the solutions (standard and sample solutions) to de-complex fluoride ions,[20] and to adjusting the pH value of the solution in range of 5-7 and to prevent complex formation between H+ and F- in acidic solution.[32] Standard solution also was used to calibrate the

Conclusion

Within the limitations of this in vitro study it can be concluded that the Transbond plus color change has significantly higher fluoride release as well as recharge properties when compared to other ortho-adhesive material.

Conflicts of interst

The authors reported no conflicts of intersts.

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