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Original Research Article

Comparison of shear bond strength and adhesive remnant index score of three different orthodontic adhesive systems with and without primer: An in vitro study

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ABSTRACT

Aim: The purpose of this study was to evaluate and compare shear bond strength and ARI score of orthodontic brackets bonded with three different orthodontic adhesive systems with and without primer.
Objective: To assess and compare the shear bond strength and adhesive remnant index score of three different orthodontic adhesive systems with and without primer.
Materials and Methods: The samples comprised 150 healthy premolars extracted for orthodontic purposes. All the teeth were mounted on an acrylic block and divided into 5 groups (30 samples in each group). Group A (Transbond XT Primer + Adhesive); Group B (Transbond XT Adhesive); Group C (Bracepaste Primer + Adhesive); Group D (Bracepaste Adhesive); Group E (Aqualine LC Adhesive). Stainless steel (3M Unitek) premolar brackets were used. Once the brackets are bonded. The bonding strength values were measured by a universal testing machine.
Results: Distribution of mean values in Intergroup overall, pairwise, comparison of shear bond strength and in Intergroup overall and pairwise comparison of adhesive remnant index scores of three different orthodontic adhesive systems with and without primer, showed a highly statistically significant difference ($p<0.001$) between the groups as the $p<0.05$.
Conclusion: Group A has got the best and the highest shear bond strength of all the groups. No statistically significant difference was seen between Group A and B; Group C and D have got the least shear bond strength. Group E has got clinically acceptable shear bond strength that is almost equal to that of Group A and B. Group A has got the best and the highest ARI score of 2 and 3 of all the groups. Group C and D have got the highest ARI score of 0 and 1.

1. Introduction

As aesthetics is the highest priority in this 21st Century, the number of adults seeking orthodontic care increased from 14% to 27% between 2010 and 2014, based on a survey conducted by the american association of orthodontics back in 2015.[1] Aesthetic and functional considerations have led to a paradigm shift from soldered brackets on bands on individual teeth to the present times of direct and indirect bonding of brackets.

Bonding in orthodontics has revolutionized fixed appliance therapy by allowing attachments to bond directly to teeth's enamel surfaces, enhancing efficiency and comfort for both patients and clinicians. Buonocore opened a new horizon in dentistry when he discovered the acid etching technique in 1955.[2] Newman heralded the onset of direct bonding in orthodontics by combining acid etching with composite resins for improving their mechanical retention along the tooth surface.[3] This led to the development of modern adhesive materials and their extensive use to

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bond attachments i.e., brackets and molar tubes in fixed orthodontic appliances.

Buonocore advocated the use of phosphoric acid etching to improve the adhesion of acrylic resin filling materials to enamel as early as 1955.[2] This procedure involves the dissolution of the organic component of the enamel matrix, creating microporosities in the enamel surface.[3] Buonocore, Bowen, Wilson, and Tavas' innovative work enabled this crucial advancement in methodology. Research has significantly influenced the development of orthodontic adhesives, which use three agents: an enamel conditioner, a primer solution, and an adhesive resin, to bond orthodontic brackets to enamel.[4,5]

One distinctive feature of several modern bonding systems in operative dentistry is that they combine the conditioning and priming chemicals into a single acidic primer solution for simultaneous use on both enamel and dentin.[4,5] Combining conditioning and priming into a single treatment step results in an improvement in both time and cost-effectiveness to the clinician and, indirectly, to the patient.

Currently, a one-step adhesive technique is available and employed in restorative dentistry. Etchant, primer, and resin are all included in the paste. It provides a number of benefits, such as reducing the chance of contamination during bonding procedures and conserving chair time.[6,7] The strength of a bond in orthodontic brackets is determined by factors like enamel surface nature, enamel conditioning, adhesive type, bracket shape, and bracket recycling need.According to Reynolds, resistances of 5.9–7.8 MPa are adequate to withstand masticatory force.[8] Bishara et al. observed mean bond strengths of 10.4 and 11.8 MPa, respectively.[9]

In our study, we compared the shear bond strength and adhesive remnant index of three different adhesive systems with and without primer. The three different orthodontic adhesive systems used were Transbond XT (3M Unitek, Monrovia, CA, USA), Bracepaste (American Orthodontics) and Aqualine LC. Transbond XT bond strength has been well-researched and documented in past literaturs. Bracepaste is also a comparatively new orthodontic adhesive. Its main active components are BisEMA, Ethoxylated bisphenol A-Di methacrylate and TD: Tetramethylene Di methacrylate. The manufacturer claims comparable bond strength to Transbond XT as the Bis-GMA and Quartz Silica components are similar. The Aqualine LC adhesive has been recently launched onto the market its main active components are methacrylate monomers, inorganic fillers, and photoinitiators. This material claims to achieve a strong bond to etched enamel without a priming step as required by most other orthodontic adhesives.

We conducted this comparison to ascertain the most effective and simple way of bonding the orthodontic brackets. Another reason was to evaluate if the bonding bracket without primer has ideal qualities comparable to bonding brackets with primer and whether they are able to withstand all the shear and tensile forces. Our aim for this study was to devise a technique that is most efficient and economical for the patients and the orthodontist.

2. Materials and Methods

The study involved 150 healthy premolars extracted for orthodontic purposes, cleaned with non-fluoridated pumice, stored in artificial saliva, and mounted on an acrylic block. The teeth were randomly divided into 5 groups, with 30 samples in each group, after 18 months of ethical clearance.

2.1. Inclusion criteria

The inclusion criteria include intact buccal enamel, non-carious teeth, non-restored teeth, no cracks, no chemical pre-treatment, and no enamel defects.

2.2. Exclusion criteria

Not applicable.

The study involved grouping 150 extracted premolars using various tools such as a mouth mirror, straight probe, tweezer, bracket positioning plier. ScotchBond Etchant 32% Ortho Phosphoric Acid, Transbond XT Primer, Transbond XT Adhesive, bracepaste primer, Aqualine LC Etchant Gel, and Aqualine LC Bonding Paste (Figure 1 A,B,D). The fixed appliance 0.022 X 0.028 bracket system, 3M S10 ELIPAR Light Curing Unit (Figure 1 E), Universal Testing Machine(Figure 2 C), Stereo Microscope (Figure 1 C), Stereo Microscope and Image Analysis System (Figure 3 A), Sputter Coater(Figure 1 F) and Field Emission Scanning Electron Microscope (Figure 3 B), were used. The results showed that the process was accurate and efficient, with the accuracy of the machine being +/-1%). The use of various equipment and tools ensured accurate results.

The teeth were randomly divided into 5 groups:-

Group A: The teeth were etched with 32% phosphoric acid for 15secs (3M Scotchbond), washed with water, and dried to a chalky white appearance. An adhesive primer (Transbond XT) was applied to the etched surface and then cured for 10secs; an adhesive (Transbond XT) was applied to the bracket and placed on the tooth and then light cured.

Group B: the teeth were etched with 32% phosphoric acid for 15secs (3M Scotchbond), washed with water, and dried to a chalky white appearance. An adhesive (Transbond XT) was applied to the bracket and placed on the tooth and then light cured.

Group C: The teeth were etched with 32% phosphoric acid for 15secs (3M Scotchbond), washed with water, and dried to a chalky white appearance. An adhesive primer (Bracepaste)was applied to the etched surface and then cured for 10secs. An adhesive (Bracepaste) was applied to

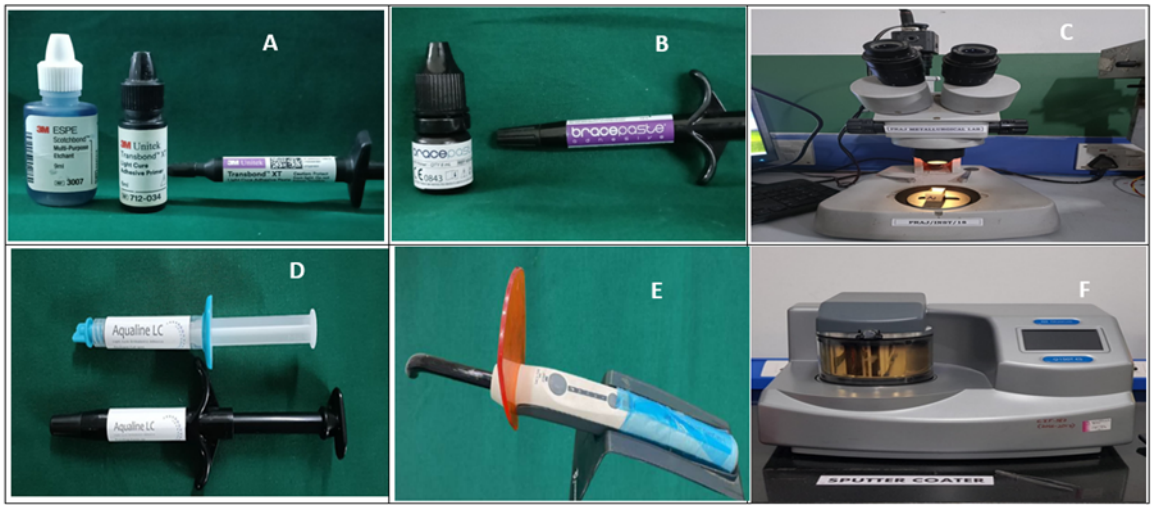

Figure 1: A): ScotchBond Etchant 32% Orthophosphoric acid,Transbond XT Primer, Transbond X Adhesive; **B)** Bracepaste Primer,Bracepaste Adhesive; **C)**: StereoMicroscope; **D)** : Aqualine LC Etchant gel, Aqualine LC Bondingpaste; **E)**: 3M S10 ELIPAR Light Curing Unit (3M Unitek); **F)**Sputter coater Quorum Q150T ES (UK) for gold sputteringof samplesAcrylic jigs with color tags were used for easyidentification and shear bond strength measurement, exposing only the toothcrown and paralleling labial force.

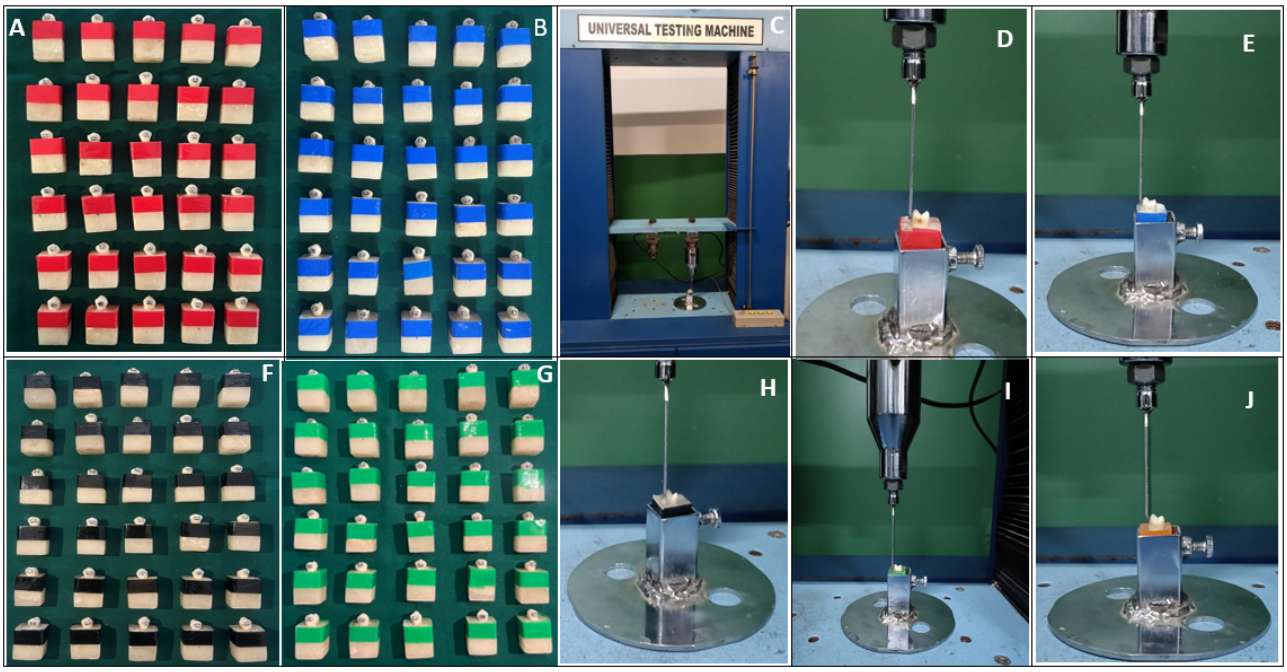

Figure 2: A) ,B),F),G): Acrylic jigs withcolor tags; **C)**: ACME Universal Testing Machine; **D),E),H),I),J)**: Evaluation of Shear Bond Strength of groups.

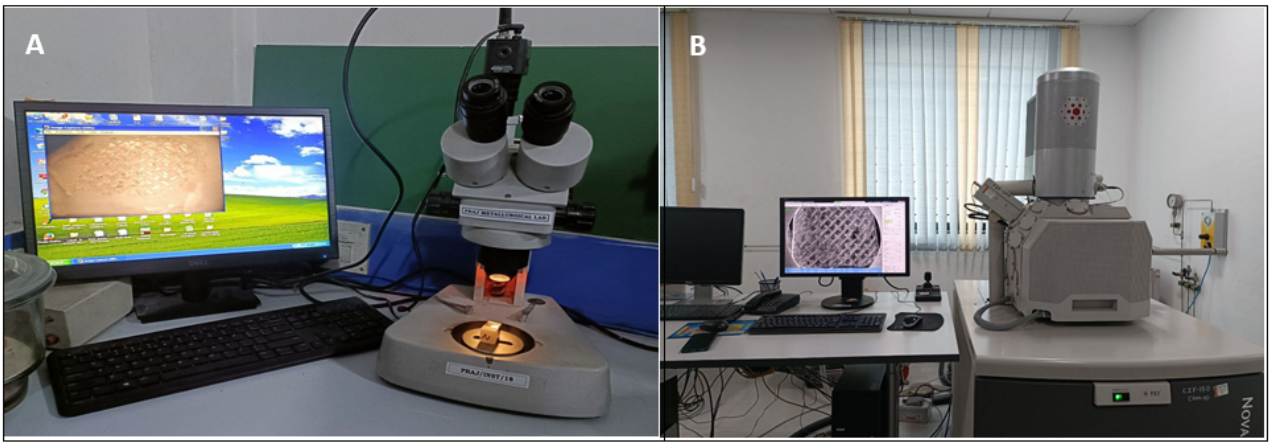

Figure 3: A): StereoMicroscope and Image Analysis System; **B)**: Field Emission Scanning Electron Microscope for Assessment of Remnant atBracket Surface

the bracket and placed on the tooth and then light cured.

Group D: The teeth were etched with 32% phosphoric acid for 15secs (3M Scotchbond), washed with water, and dried to a chalky white appearance. An adhesive (Bracepaste, American Orthodontics) was applied to the bracket and placed on the tooth and then light cured.

Group E: The teeth were etched with Aqualine LC etchant gel for 30secs, washed with water, and dried to a chalky white appearance. An adhesive (Aqualine LC adhesive paste) was applied to the bracket and placed on the tooth and then light cured.

Stainless steel (3M Unitek) premolar brackets were used, bonded and debonded at 37°C for one minute. Bonding strength values were measured, and residual adhesive on teeth was examined using trans-illumination and fibre optic light magnification lens.

Scanning electron microscope: Brackets were examined under Field emission scanning electron microscope (FESEM: FEI Nova Nano SEM 450) from each group at each level to compare the amount of adhesives left on the bracket surface. The specimens were prepared for better resolution by sputtering gold-palladium in a Quorum Q150T ES sputter coater unit. This technique enhances secondary electron emission and prevents charging. After gold sputtering, the images were examined under FESEM at 15KV and 20mm distance.

3. Results

The data on continuous variables are presented as mean and standard deviation (SD). The intergroup statistical comparison of means of continuous variables was done using analysis of variance (ANOVA). Tukey's Post-Hoc test for multiple group comparisons. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference clearly. Data obtained was compiled on MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States). Data were subjected to statistical analysis using Statistical package for social sciences (SPSS v 26.0, IBM). Descriptive statistics like Mean & SD for numerical data have been depicted.

3.1. The statistics showed

Descriptive statistics of Shear Bond Strength of three different orthodontic adhesive systems with and without primer respectively. It represents the descriptive statistics of the shear bond strength of three different orthodontic adhesive systems with and without primer with mean and standard deviation. Group A mean is 13.18+5.71. Group B mean is 11.28+6.0. Group C mean is 6.83+2.81. Group D mean is 9.61+4.06. Group E mean is 10.05+4.0.(Table 1)

Table 1: Descriptive statistics of shear bond strength of three different orthodontic adhesive systems with and without primer respectively

Groups	Mean	SD	SE	Mini.	Maxi.
Group A (Transbond XT Primer + Adhesive)	13.18	5.71	1.04	3.98	23.09
Group B (Transbond XT Adhesive)	11.28	6.0	1.09	2.07	24.61
Group C (Bracepaste Primer + Adhesive)	6.83	2.81	0.51	2.07	14.15
Group D (Bracepaste Adhesive)	9.61	4.06	0.74	4.23	19.93
Group E (Aqualine LC Adhesive)	10.05	4.0	0.73	3.39	17.89

In (Table 2) intergroup overall comparison of Shear Bond Strength of three different orthodontic adhesive systems with and without primer respectively represents that there

is a highly statistically significant difference (p<0.001) between the groups as the p<0.05.

Table 2: Intergroup overall comparison of shear bond strength of three different orthodontic adhesive systems with and without primer respectively

	Mean	SD	One way Anova F test	P value
Group A (Transbond XT Primer + Adhesive)	13.18	5.71	F = 7.495	p < 0.001**
Group B (Transbond XT Adhesive)	11.28	6.0		
Group C (Bracepaste Primer + Adhesive)	6.83	2.81		
Group D (Bracepaste Adhesive)	9.61	4.06		
Group E (Aqualine LC Adhesive)	10.05	4.0		

In (Table 3) data represents the Inter group pairwise comparison of the shear bond strength of three different orthodontic adhesive systems with and without primer. There is a highly statistically significant difference (p<0.001) between Group A and Group C. While a significant difference (p<0.05) was seen between Group A and Group D and also between Group B and Group C. No significant difference (p>0.05) was seen between other groups.

In (Table 4) statistics represents the descriptive statistics of the Adhesive Remnant Index score of three different orthodontic adhesive systems with and without primer which shows the percentage distribution of ARI score after the shear bond strength test.

In (Table 5) represents the intergroup overall comparison of the adhesive remnant index scores of three different orthodontic adhesive systems with and without primer. There is a highly statistically significant difference (p<0.001) between the groups (p<0.05).

In (Table 6) represents the Inter group pairwise comparison of the adhesive remnant index scores of three different orthodontic adhesive systems with and without primer. There is a highly statistically significant difference (p<0.001) between Group A and Group C. While a significant difference (p<0.05) was seen between Group B and Group C, between Group C and Group D and also between Group C and Group E. No significant difference (p>0.05) was seen between other groups.

3.2. Result summary

Distribution of mean values in Intergroup overall comparison of shear bond strength of three different

Table 5: Comparative statistics of mean adhesive remnant index score of three different orthodontic adhesive systems with and without primer respectively

	Mean	SD	One-way Anova F test	P value
Group A (Transbond XT primer + adhesive)	2.06	0.96	F = 7.832	p < 0.001**
Group B (Transbond XT Adhesive)	1.73	0.86		
Group C (Bracepaste primer + adhesive)	0.76	1.0		
Group D (Bracepaste adhesive)	1.43	0.81		
Group E (Aqualine LC adhesive)	1.56	0.93		

Table 6: Intergroup pairwise comparison of adhesive remnant index score of three different orthodontic adhesive systems with and without primer respectively

Tukey's post hoc test for pairwise comparison

Group	Comparison Group	Mean Difference	P value
Group A (Transbond XT primer + adhesive) vs	Group B (Transbond XT adhesive)	0.3	p =0.715
	Group C (Bracepaste primer + adhesive)	1.26	p<0.001**
	Group D (Bracepaste adhesive)	0.6	p=0.091
	Group E (Aqualine LC adhesive)	0.46	p=0.289
Group B (Transbond XT adhesive) vs	Group C (Bracepaste primer + adhesive)	0.96	p =0.001*
	Group D (Bracepaste adhesive)	0.3	p =0.715
	Group E (Aqualine LC adhesive)	0.16	p=0.956
Group C (Bracepaste primer + adhesive) vs	Group D (Bracepaste adhesive)	0.66	p=0.045*
	Group E(Aqualine LC adhesive)	0.8	p=0.009*
Group D (Bracepaste adhesive) vs	Group E (Aqualine LC adhesive)	0.13	p =0.980

p>0.05 – no significant difference *p<0.05 – significant

Table 3: Inter group pairwise comparison of shear bond strength of three different orthodontic adhesive systems with and without primer respectively

Tukey's post hoc test for pairwise comparison			
Group	**Comparison group**	**Mean difference**	**P value**
Group A (Transbond XT primer + adhesive)	Group B (Transbond XT adhesive)	1.89	p =0.516
	Group C (Bracepaste primer + adhesive)	6.35	p<0.001**
	Group D (Bracepaste adhesive)	3.57	p=0.029*
	Group E (Aqualine LC adhesive)	3.13	p=0.076
Group B (Transbond XT adhesive)	Group C (Bracepaste primer + adhesive)	4.45	p =0.003*
	Group D (Bracepaste adhesive)	1.67	p =0.636
	Group E (Aqualine LC adhesive)	1.23	p=0.844
Group C (Bracepaste primer + adhesive) vs	Group D (Bracepaste adhesive)	2.78	p=0.149
	Group E (Aqualine LC adhesive)	3.21	p=0.064
Group D (Bracepaste adhesive) vs	Group E (Aqualine LC adhesive)	0.43	p =0.996

Table 4: Descriptive statistics of adhesive remnant index score of three different orthodontic adhesive systems with and without primer respectively

Groups	**Score 0 N (%)**	**Score 1 N (%)**	**Score 2 N (%)**	**Score 3 N (%)**
Group A (Transbond XT primer + adhesive)	2 (6.6%)	7 (23.3%)	9 (30%)	12 (40%)
Group B (Transbond XT adhesive)	3 (10%)	7 (23.3%)	15(50%)	5 (16.6%)
Group C (Bracepaste primer + adhesive)	16 (53.3%)	8 (26.7%)	3 (10%)	3 (10%)
Group D (Bracepaste adhesive)	2 (6.6%)	17 (56.6%)	7 (23.3%)	4 (13.3%)
Group E (Aqualine LC adhesive)	4 (13.3%)	10 (33.3%)	11 (36.6%)	5 (16.6%)

orthodontic adhesive systems with and without primer shows a highly statistically significant difference (p<0.001) between the groups as the p<0.05.

Distribution of mean values in Intergroup pairwise comparison of shear bond strength of three different orthodontic adhesive systems with and without primer shows a highly statistically significant difference (p<0.001) between Group A and Group C while a significant difference (p<0.05) was seen between Group A and Group D and also between Group B and Group C and no significant difference (p>0.05) was seen between other groups.

Distribution of mean values in Intergroup overall comparison of adhesive remnant index of three different orthodontic adhesive systems with and without primer shows a highly statistically significant difference(p<0.001) between the groups as the p<0.05.

Distribution of mean values in Intergroup pairwise comparison of adhesive remnant index scores of three different orthodontic adhesive systems with and without primer shows a highly statistically significant difference (p<0.001) between Group A and Group C while significant difference (p<0.05) was seen between Group B and Group C, between Group C and Group D and also between Group C and Group E and no significant difference (p>0.05) was seen between other groups.

4. Discussion

Enamel bonding for orthodontic applications was introduced in 1965 and was considered a significant milestone in orthodontic treatment. Numerous adhesives have been commercialised and introduced to the market with claims of achieving an ideal bond strength. The light cure resins used in this study were Transbond XT, Bracepaste, and Aqualine LC. Transbond XT bond strength has been well-researched and documented in past literature.[10–12] This investigation found that Transbond XT (with and without primer) showed higher values of shear bond strength 13.18+5.71 MPa and 11.28+6.0 MPa respectively (Table 2) comparable with values reported by Falter Meir[7] who concluded that Transbond XT with primer has the highest strength of 8.67 ± 1.21 MPa, Bishara.[13] (10.40MPa ± 2.1MPa). Other studies also showed the similar result Arnold[14] (9.7 ± 3.1MPa and 8.0 ±1.3MPa) Tecco et al.(23.23 MPa + 5.23 MPa), Rock and Abdulla (8-23MPa) respectively.

Bracepaste is also a comparatively new orthodontic adhesive. Its main active components are BisEMA, Ethoxylated bisphenol A-Di methacrylate and TD: Tetramethylene Di methacrylate. The resin's increased viscosity has been proposed to aid in positioning and prevent 'the drifting' of the brackets. In this study Bracepaste (with and without primer) showed the shear

bond strength of 6.83+2.81 MPa and 9.61+4.06 MPa respectively which was significantly lower than Transbond XT (with and without primer) (Table 2) and this is in agreement with the study reported by Samaneh Shams (16.83 MPa).[15]

The Aqua line LC adhesive has been recently launched onto the market its main active components are methacrylate monomers, inorganic fillers, and photo initiators. This material claims to achieve a strong bond to etched enamel without a priming step as required by most other orthodontic adhesives. Aqua line LC which is available without primer shows the mean shear bond strength of 10.05+4.0 MPa was lower than Trans bond XT (with and without primer) but the difference was not statistically significant (p>0.05) but shear bond strength was greater than that of Bracepaste (Table 2).

On intergroup pairwise comparison of shear bond strength between Transbond XT (3M), Bracepaste (AO) and Aqualine LC (Table 3). The shear bond strength of Group A was highest when compared with Group B, Group C, Group D, and Group E. There was a highly statistically significant(p<0.001) difference between Group A and Group C. There was a statistically significant difference(p<0.05) between Group A and Group D. No statistically significant(P>0.05) difference between Group A, Group B and Group E. On comparing the shear bond strength of Group B with Group C, Group D and Group E. There was a statistically significant(p<0.05) difference between Group B and Group C. No statistically significant difference(p>0.05) was seen between Group B, Group D and Group E. On comparing the shear bond strength of Group C with Group D and Group E. There was no statistically significant difference(p>0.05) between Group C, Group D and Group E. On comparing the shear bond strength of Group D and Group E. There was no statistically significant difference(p>0.05) between Group D and Group E.Group C (Bracepaste with primer) and Group D (Bracepaste adhesive) as compared to the other two adhesives showed the least shear bond strength. ARI, developed by Artun and Berglund, has been used to help standardize the bond failure analysis. For the present study, the ARI scores used in this study adhere to the original standards established by Artun and Berglund.

On intergroup pairwise comparison of adhesive remnant index score of Transbond XT, Bracepaste, Aqualine LC (Table 6). In the comparison of Group A with Group B, Group C, Group D and Group E. It is a highly statistically significant(P<0.001) difference seen between Group A and Group C. No statistically significant(p>0.05) was seen between Group A, Group B, Group D and Group E. In the comparison of Group B with Group C, Group D and Group E. There is a statistically significant difference (p<0.05) between Group B and Group C. No statistically significant difference was seen between Group B, Group D, and Group E. In the comparison of Group C with Group D and Group E. It is a statistically significant (p<0.05) difference between Group C, Group D and Group E. In the comparison of Group D with Group E. There is no statistically significant difference between Group D and Group E.

This is an in vitro study; care should be taken in the interpretation of the results, which may differ from those results obtained in the oral environment. Studies developed in vivo or in situ may provide additional evidence to these findings, thus enhancing knowledge of bond strength in Orthodontics.

5. Conclusion

Based on the results of this study, we conclude as follows:

1. Group A (Transbond XT with primer) has got the best and the highest shear bond strength of all the groups.
2. No statistically significant difference was seen between Group A (Transbond XT with primer) and Group B (Transbond XT adhesive).
3. Group C (Bracepaste with primer) and Group D (Bracepaste adhesive) have got the least shear bond strength.
4. Group E (Aqualine LC adhesive) has got clinically acceptable shear bond strength that is almost equal to that of Group A (Transbond XT with primer) and Group B (Transbond XT adhesive).
5. Group A (Transbond XT with primer) has got the best and the highest ARI score of 2 and 3 of all the groups.
6. Group C (Bracepaste with primer) and Group D (Bracepaste adhesive) have got the highest ARI score of 0 and 1.

6. Conflict of Interest

None.

7. Source of Funding

None.

8. Ethical Approval

This study was conducted after taking approval from institution ethical committee (Ref. No. MCBS/EC/641/2021).

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