https://doi.org/10.26682/sjuod.2022.25.2.22
Journal of University of Duhok., Vol. 25, No.2 (Pure Engineering Sciences), Pp 231-243, 2022

SHEAR BOND STRENGTH OF DIFFERENT TYPES OF STAINLESS STEEL ORTHODONTIC FIXED RETAINERS: AN IN VITRO STUDY

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(Received: August 20, 2022; Accepted for Publication: October 19, 2022)

ABSTRACT

Background and Objectives: This in vitro study was performed to assess the shear bond strength (SBS) of three different fixed lingual retainers using two types of different adhesive systems and fracture modes (Adhesive Remnant Index -ARI) of different retainer's wire-adhesive combination.

Materials and methods: one hundred eighty (180) extracted sound human upper premolar teeth were divided into two groups (90 for each group). Then each group subdivided to three subgroups (30 for each subgroup) bonded with three different fixed lingual retainers (Straight-8 strand braided flat soft wire 0.028 x 0.008 inches db UK, 3M Unitek coaxial multi strand 0.0195-inch wire USA and Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA), which were bonded to the lingual surface of the teeth using two types of different adhesive systems (3M™ Transbond™ LR Adhesive USA and HeyTec Flow SE Composite, Heydent Germany).

To assess the shear bond strength, the samples were debonded using a Universal testing machine (Instron). For each specimen, the site of failure was examined using a Stereomicroscope. One-way analysis of variance was used for the statistical analysis.

Results: There was a high statistically significant difference between the two study groups ($p < 0.001$). Straight-8 strand braided flat soft wire combined with 3M Transbond LR Adhesive had the strongest shear bond strength (14.0 ± 4.0 MPa)

whereas the minimal SBS was noted in Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm bonded with HeyTec Flow SE Composite (4.5 ± 2.7 MPa). The site of failure in group one was predominantly at the wire composite interface (cohesive failure), while in group two was in enamel/composite interface (adhesive failure).

Conclusion: The simplified bonding procedures (self-etching composite) resulted in unfavorable reduction in shear bond strength. There is still support for the traditional multi-step adhesive technique.

KEY WORDS: fixed lingual retainer, shear bond strength, one step self-etched adhesive, conventional multistep adhesive.

INTRODUCTION

In clinical orthodontics, a strong bond between orthodontic retainers and tooth enamel is critical (Kartal and Kaya, 2019). To accomplish this, a strong, safe bond between the tooth structure and the various orthodontic materials is required (Jedliński et al., 2021).

The mechanical retention of an adhesive between the retainer wire and irregularities in the tooth enamel caused by surface preparation is the basis for fixed retainer bonding (Proffit et al., 2018). Pretreatment of the surface is required to improve bond strength to the enamel (Tahmasbi et al., 2019). As a result, following treatment, the outcome must remain properly, ensuring the success of treatment (Johnston and Littlewood, 2015).

The main factors to consider for a longterm s uccessful lingual retainer are the material used in its fabrication (stainless steel, FRC, etc.), the adhesive material used for retainer bonding, the number of teeth bonded, and the location on t he lingual site of the teeth where the retainer is bonded (Kučera et al., 2021).

Despite all the good consequences of the retainer staying in place for a long time and good impact it has on the treatment result, a break in the adhesive material may occur more frequently and the retainer separates from the surface of the tooth, leading to unsatisfactory results if the problem is not addressed rapidly, which is what usually happens and leads to clinical retainer failure (Iliadi et al., 2015).

Retainer bonding became more popular after the introduction of acid etching in orthodontics. The most generally used etching method is to use 37 % phosphoric acid for 30 seconds. (Brauchli et al., 2010, Gu et al., 2018).

Because of its uneven surface and greater flexibility, multistranded wires are ideal for fixed lingual retainers because they provide superior mechanical retention and allowing for physiologic tooth movement (Annousaki et al., 2017). Microcracks within the adhesive might cause bonded lingual retailer to fail. As a result, the success of bonded lingual retainers may be attributed to the wire-composite combination (Shafiei et al., 2019).

Placement of a fixed bonded retainer is a technique sensitive procedure and clinicians commonly encounter troubles. We used a self-etchant flowable composite (HeyTec Flow SE Composite, Germany). It took away the steps of etching, priming and bonding. Hence, simplifying the sensitive multistep of conventional composites (Giannini et al., 2015). We investigated a self-etching flowable adhesive in this study to simplify clinical procedure and replace technique sensitive, multistep adhesive systems in lingual retainer placement.

Objectives of the study

1.Evaluation and comparison of shear bond strength (SBS) of three different fixed lingual retainers using two different types adhesive systems.

2. Analyzing the fracture modes (Adhesive Remnant Index-ARI) of different retainers' wire-adhesive combination.

MATERIAL AND METHODS

A total of one hundred eighty (180) extracted human upper premolars were gathered from private orthodontic clinics in the governorate of Duhok. The following criteria were used to choose teeth were included in this study: intact lingual surfaces free of caries, restorations and cracks. Teeth with carries, restorations and Enamel defects (like erosion, fluorosis, enamel crack and enamel hypoplasia) were excluded.

The teeth were then kept at room temperature in distilled water with thymol (0.1% weight/volume). The water was changed every week until they were ready for the experiment in order to prevent bacterial development and dehydration (Berk et al., 2008; Türköz and Ulusoy, 2012).

Sample Preparation and Mounting

To make it easier to embed the crown in a plastic mold before bonding, the roots will be removed 2 mm below the cementenamel junction by disk bur under water cooling (Figure 1). The remaining crowns will next be cleaned, plaque and soft tissue remnants removed using an adjustable ultrasonic scaler, and polished with fluoride-free pumice. utilizing a rubber cup linked to a slow headpiece, followed by air/water rinsing and oil-free compressed air drying.

Fig. (1): Teeth Before And After Root Cutting.

Rapid polymerization of self-curing acrylic resin allowed the teeth to be mounted and inserted horizontally in a cubic plastic mold (10x 10x 10mm in size). Each mold was constructed with proximal contact and a pair of teeth placed after acrylic reached the doughy stage. This left the whole lingual surface of the crowns exposed and parallel to the mold's base, ensuring that the retainer would be perpendicular to the long axis of the crown. (Reicheneder et al., 2014). (Figure 2).

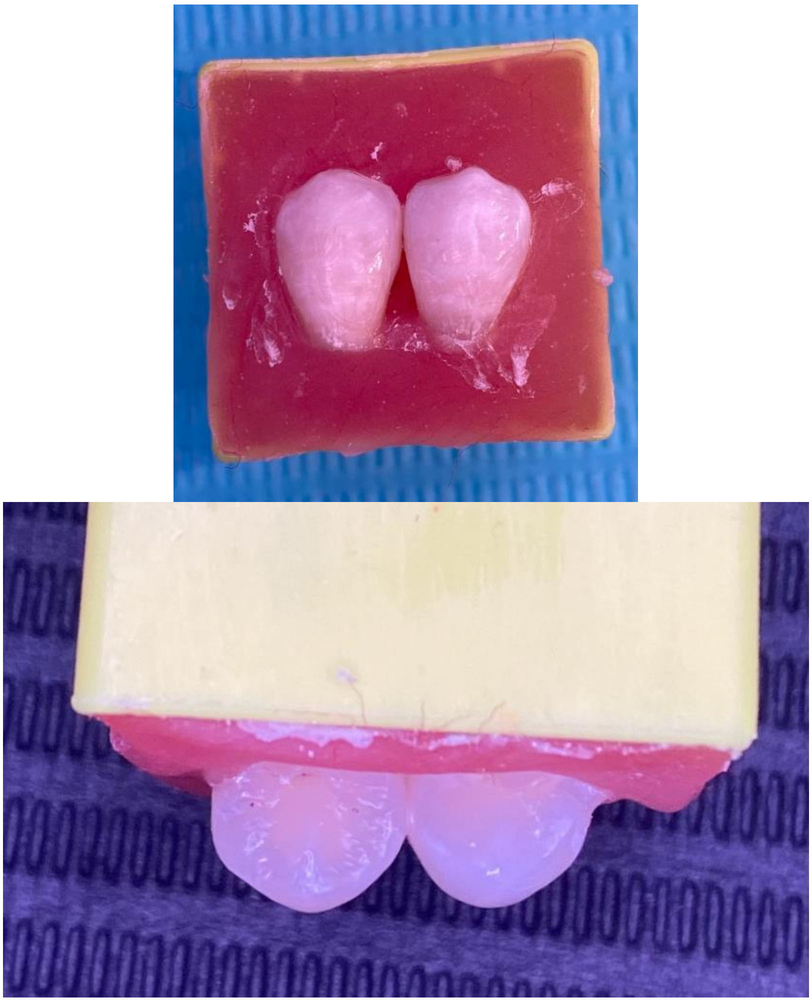

Fig. (2): Teeth Embedded In A Cubic Plastic Mold.

The extracted teeth then randomly divided into two test groups of forty-five (45) samples for each group. The two groups then subdivided into three subgroups (15 samples) for each subgroup. Groups will be as follow:

Group 1: Conventional bonding system using 3M™ Transbond™ LR Adhesive USA. Then subdivided into 3 subgroups using three different types of stainless steel orthodontic fixed retainers as follows:

A. 3M™ Transbond™ LR Adhesive USA with 3M Unitek coaxial 0.0195" wire USA.

B. 3M™ Transbond™ LR Adhesive USA with Straight-8 braid flat soft wire 0.028 x 0.008 inches db UK.

C. 3M™ Transbond™ LR Adhesive USA with Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA.

Group 2: Self-etchant bonding system using HeyTec Flow SE Composite, Heydent Germany. Then subdivided into 3 subgroups using three different types of stainless steel orthodontic fixed retainers as follows:

A. HeyTec Flow SE Composite, Heydent Germany with 3M Unitek coaxial 0.0195" wire USA.

B. HeyTec Flow SE Composite, Heydent Germany with Straight-8 braid flat soft wire 0.028 x 0.008 inches db UK.

C. HeyTec Flow SE Composite, Heydent Germany with Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA.

Bonding Procedure

Group 1 – Conventional Bonding System

The lingual teeth surfaces of each tooth that is used with Transbond LR were etched with a 37% phosphoric acid gel (dLine, Lithuania) for 30 seconds according to the manufacturer's instruction. Teeth then were rinsed with water from a triple syringe for 30 seconds and dried with air source from triple syringe for 20 seconds. For all teeth were etched, frosty white appearance of etched enamel should be noticed. (Figure 3A & B).

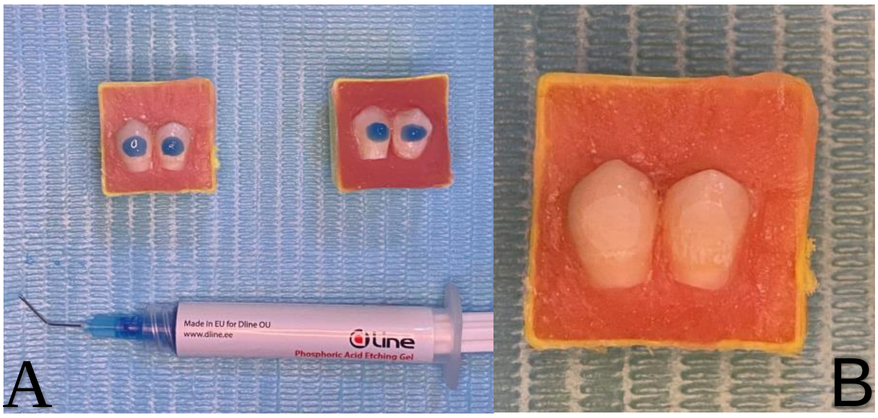

Fig. (3A): Application Of The 37% Phosphoric Acid Gel. **Fig. (3B):** Frosty White Appearance Of Etched Enamel.

A small amount of Transbond XT (3M, USA) adhesive primer was put in a previously etched and dried enamel surface by microbrush for about 5 seconds, then the tooth is lightly blown with a stream of oil-free compressed air to evaporate solvent and to ensure a uniform layer of primer remained on enamel surface (Richardson and Pyšek, 2010). Then light curing for 20 seconds as suggested by manufacturer using light cure machine (Noblesse E LED, Germany) (Scribante et al., 2011; Sfondrini et al., 2014; Sfondrini et al., 2021). (Figurr 4).

Fig. (4): Appling Transbond XT Adhesive Primer**.**

To standardize the bonding procedure, all retainers will have a length of 15 mm. Then the wire was gently placed at the middle part of the lingual surface without any bend so that it will be parallel to the base of the plastic mold and perpendicular to the long axis of the crown. The amount of composite used for bonding the wire segment will be standardized using commercially available dome-shaped mold, Mini-Mold. The dimension of the composite dome will be 4 mm in diameter with a maximum depth of 2 mm located at least 4 mm away from each other (Samson et al., 2018). (Figure 5).

Excess composite will be removed by a probe from the margins of the mini-mold before curing the composite. Composite will be cured for 40 seconds according to manufacturer instructions placed at the mesial, distal, occlusal and gingival surfaces using orthodontic light cure unit (Scribante et al., 2011; Sfondrini et al., 2014; Sfondrini et al., 2021).

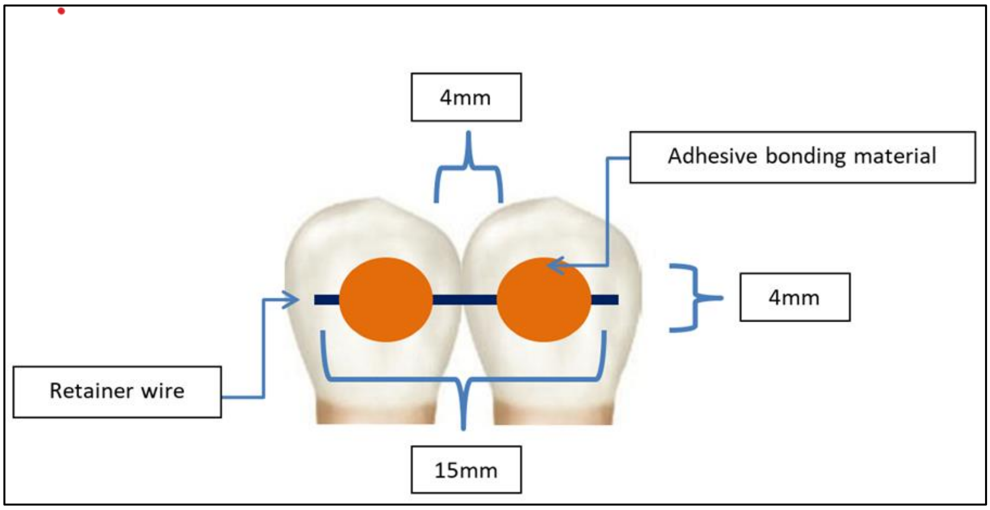

Fig. (5): Schematic Drawing of Experimental Design

Group 2 – Self Etchant Bonding System

Inside acrylic blocks, the exposed enamel surface (lingual) of the teeth was polished using a rubber cup linked to a slow-speed handpiece for ten seconds. The teeth were then washed for 15 seconds with a triple spray of air and water, then dried for 10 seconds with a compressed air stream that was oil-free. In accordance with the manufacturer's guidelines, the HeyTec Flow SE Composite was then applied directly to the retention wires without any enamel surface preparation so it doesn't need to be primed, etched, or bonded to enamel. Following that, the identical procedures of the bonding technique used for group 1 were used for this group, including composite standardization and light curing.

Storage

After that, all of the samples were kept in distilled water for 24 hours at room temperature until the next stage of the experiment (Sfondrini et al., 2021).

Shear Bond strength Testing

At Salahadin University, College of Engineering, Department of Mechanics, and Material Strength Lab, measurements of shear bond strength (SBS) were performed using a Universal testing machine (Instron). The samples were secured within an Instron holding device, this allowed the samples to be positioned so that the long axis of the teeth would be parallel to the shearing force.

Until the bonded wire segment fails, force was applied perpendicular to it. When an occlusal-gingival load was applied, a shearing blade hit the bonded wire's midpoint at a speed of 0.5 mm/min, creating a shear force until the bond failed and the wires debonded from the teeth. (Figure 6A & B). The computer, which was linked to the Instron, recorded the debonding force in Newton (N). The maximum load (N) was recorded and then divided by the surface area (mm2) of the matrix to determine bond strength in Mega Pascal (MPa).

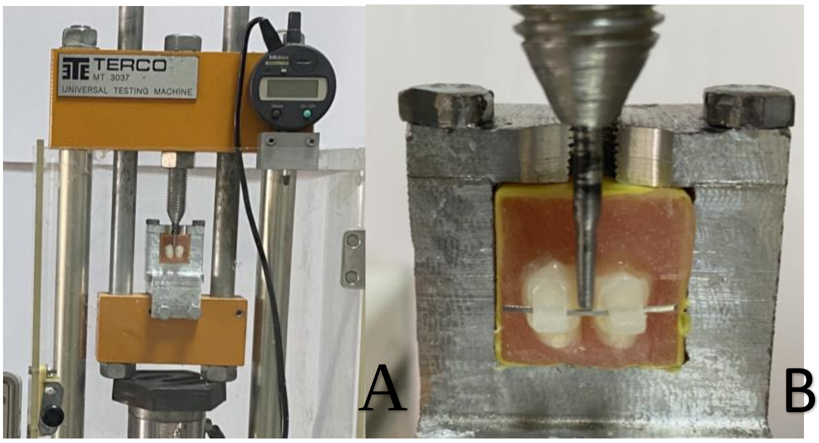

Fig. (6A): Universal Testing Machine (Instron) Holding The Sample. Figure (6B) Relationship Of Instron Head To The Wire Segment (B).

Evaluation of adhesive failure

The amount of adhesive resin remaining on each tooth's enamel surface was measured using the Adhesive Remnant Index (ARI) in a specimen where the bond had failed (Henkin et al., 2016). The assessment of the ARI for this study was carried out utilizing a stereomicroscope (LEICA EZ4) with a 35x LED. The ARI score were recorded and then the data will be analyzed. The ARI had the following scales: 0 = no adhesive retained on the enamel. 1 = less than 50 per cent of adhesive retained on the enamel. 2 = more than 50 per cent but less than 100 per cent of adhesive retained on enamel. 3 = all adhesive retained on the enamel with an impression of the wire (Bilal and Arjumand, 2019).

Statistical Analysis

Descriptive statistics, including the mean, the standard deviation (SD), standard error (SE) and the range, were done for groups. The comparisons of the Shear bond strength (SBS) in groups 1 and 2 were performed in ANOVA one-way test. The pair-wise comparisons of the SBS between retainers were examined in Tukey post hoc test. The Comparisons of SBS applied by retainers between study groups were examined in an independent t-test. The significant level of difference was determined in a p-value of less than 0.05 The statistical calculations were performed in JMP Pro 14.3.0.

RESULTS

Shear bond strengths

Group 1 – Conventional Bonding System

Maximum shear bond strength was observed in subgroup B (db Straight-8 strand braided flat soft wire, UK) yielded the highest mean debonding force (14.0±4.0 MPa), this was followed by subgroup A (3M Unitek coaxial multi strand 0.0195-inch wire USA) which was (13.1±2.5 MPa), and then followed by the minimum observed debonding force subgroup C (Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA) (9.6±0.7 MPa) (Table. 1).

On inter group comparison of the mean shear bond strength among the three retainers of this group, one-way ANOVA revealed statistically high significant difference between the three lingual retainers with respect to bond strength ($P \leq 0.05$) especially in subgroup B and A which showed significantly higher results when compared to subgroup C.

Table (1): Shear bond strength (SBS in Mega Pascal) of different stainless steel orthodontic fixed retainers in group 1.

	SBS (MPa)						
Subgroup	**Number**	**Range**	**Mean**	**SD**	**SE**	**P-value**	**Inter group comparison**
A (3M)	15	8.5-15.6	13.1	2.5	0.7	**0.0196**	3M vs. db: P=0.7227
B (db)	15	8.5-21.2	14.0	4.0	1.0		3M vs. IOS: **P=0.0177**
C (IOS)	15	5.7-14.2	9.6	2.6	0.7		db vs. IOS: **P=0.0016**

SD: standard deviation; SE: standard error. ANOVA one-way was performed for statistical analyses.
Tukey test was performed for post hoc comparisons.
The red bold numbers show the significant differences.

Group 2 – Self Etchant Bonding System

Maximum shear bond strength was observed in subgroup A (3M Unitek coaxial multi strand 0.0195-inch wire USA) yielded the highest mean debonding force (6.3±4.1 MPa), this was followed by subgroup B (db Straight-8 strand braided flat soft wire, UK) which was (5.4±2.8 MPa), and then followed by the minimum observed debonding force subgroup C (Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA) (4.5±2.7 MPa) (Table. 2).

On inter group comparison of the mean shear bond strength among the three retainers of this group, one-way ANOVA revealed no statistically significant difference between three lingual retainers with respect to bond strength ($P \leq 0.05$).

Journal of University of Duhok., Vol. 25, No.2 (Pure Engineering Sciences), Pp 231-243, 2022

Table (2): Shear bond strength (SBS in Mega Pascal) of different stainless steel orthodontic fixed retainers in group 2.

	SBS (MPa)					P-value	Inter group comparison
Subgroup	**Number**	**Range**	**Mean**	**SD**	**SE**		
A (3M)	15	1.27-15.56	6.3	4.1	1.1	0.3344	3M vs. db: P=0.7046
B (db)	15	1.13-9.9	5.4	2.8	0.7		3M vs. IOS: P=3019
C (IOS)	15	1.42-9.9	4.5	2.7	0.7		db vs. IOS: P=0.7662

SD: standard deviation; SE: standard error.
ANOVA one-way was performed for statistical analyses.
Tukey test was performed for post hoc comparisons.

Comparison of the same retainers between the same subgroups of both study groups are summarized in Table 3. Using an independent t-test, there was a statistically high significant difference observed among all the retainers. The highest statistically significant difference was observed in db retainer (db Straight-8 strand braided flat soft wire, UK) followed by 3M retainer (3M Unitek coaxial multi strand 0.0195-inch wire, USA) then followed by IOS retainer (Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm IOS USA) which had a minimal statistically significant difference.

Table (3): Comparison of Shear bond strength (SBS in Mega Pascal) of retainers between study groups.

	SBS (MPa)				
Groups	Number	Mean	SD	SE	P-value
3M					**<0.001**
Group 1	15	13.1	2.5	0.7	
Group 2	15	6.3	4.1	1.1	
IOS					**<0.001**
Group 1	15	9.6	2.6	0.7	
Group 2	15	4.5	2.7	0.7	
db					**<0.001**
Group 1	15	14.0	4.0	1.0	
Group 2	15	5.4	2.8	0.7	

An independent t-test was performed for statistical analyses.
The red bold numbers show the significant differences.

Adhesive Remnant Index (ARI) after debonding

Table 4 represents the site of the bond failure of both groups. ARI of the bond site that firstly failed in each study group was analyzed by Pearson chi-squared test. On inter group comparison of both groups there was no statistically significant difference between the distribution of the ARI scores of the lingual retainers.

Table (4): Contingency analysis of Adhesive Remnant Index (ARI) scores of both group 1 and group 2.

Group 1	ARI				P-value
	0	1	2	3	
A (3M)		1	13	1	
B (db)		4	6	5	0.1328
C (IOS)		3	9	3	

	ARI				
Group 2	**0**	**1**	**2**	**3**	**P-value**
A (3M)	10	5			0.0668
B (db)	14	1			
C (IOS)	14	1			

Pearson chi-squared test was performed for statistical analyses.

Comparison of the same retainers between the same subgroups of both study groups are summarized in Table 5. Using a Pearson chi-squared test, there was a statistically high significant difference observed among all the retainers.

Table (5): Comparisons of ARI of same retainers between group 1 and 2.

Groups	ARI				
	0	**1**	**2**	**3**	**P-value**
3M					**<0.0001**
Group 1	10	5	0	0	
Group 2	0	1	13	1	
IOS					**<0.0001**
Group 1	14	1	0	0	
Group 2	0	3	9	3	
db					**<0.0001**
Group 1	14	1	0	0	
Group 2	0	4	6	5	

Pearson chi-squared test was performed for statistical analyses.
The red bold numbers show the significant differences.

DISCUSSION

In the group one (conventional bonding system) a greater force was required for debonding of db Straight-8 braid flat soft wire subgroup which show the highest SBS value (14.0 MPa) followed by coaxial 0.0195 multi-strand stainless steel subgroup (13.1 MPa) and the last subgroup was Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm which had a lowest SBS value (9.6 MPa), and there was a high significant difference between IOS subgroup and other two subgroups (P<0.001).

According to Reicheneder et al, (2014) they hypothesized that increasing the retainer wire's strand count would typically improve its clinical stability. Due to its interlaced nature, softness, and flat design, which adapted to the lingual surface of the teeth when bonded. Straight 8 is a dead-soft wire, which implies that when it is suited to the tooth surface, it is passive and does not exert any active force, indicating that no accumulated force and stress contributed to the failure of the retainer bond, here our finding is similar to the study done by Singh A et al, (2019).

Conversely, coaxial 0.0195 multi strand stainless steel wire is a simple coaxial wire that may experience residual stresses throughout the fabrication and application processes. The accumulation of stresses at the areas of mastication caused by these stored stresses might result in debonding and failure of the bond between the wire and adhesives (Scribante et al., 2011; Sifakakis et al., 2015).

This finding was consistent with a research done by Baysal et al, (2012), who found no significant difference between dead-soft eight-braided wire and 0.0195-inch dead-soft coaxial wire. Cooke and Sherriff (2010) came to the conclusion that the in vitro bond strength (SBS) of flat dead braided soft wire and coaxial 0.0195 inch multistranded round wire when bonded with transbond LR may express some SBS value difference but it's not significantly.

But there was a significant difference when comparing both straight 8 dead soft flat and coaxial 0.0195 multi strand with Ultra-Flex Lingual Retainer. These differences could be attributed to the nature of the retainer material (Scribante et al., 2011).

The combination of Transbond LR and db Straight-8 braid flat soft wire subgroup produced a higher shear bond strength value than the other two subgroups of retainers. In addition to the flexibility of the soft db straight wire that better fitted to the tooth enamel surface, it may be because of the superior flowability and viscosity of the Transbond adhesive surrounding the wire that increased mechanical retention. The same finding was obtained by Reicheneder et al, (2014) and Mudhir (2021). The result of this group was disagreed with a study done by Sifakakis et al, (2011) They reported that when used as a fixed orthodontic retainer, rounded coaxial multistranded wire had a greater success rate and bond strength than flat dead braided soft wire. However, this might be because a different adhesive (Flow Tain, Reliance) was used with 0.0195-inch wire and that the retainer was attached from canine to canine on an orthodontic mold rather than to two teeth as was the situation in our research, which could have an effect on the results.

The lowest SBS value was recorded (obtained) by Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm. Same results obtained by Pasha et al. (2020). In an in-vitro study, they conclude that the Ortho Flextech Reliance Orthodontics SS (0.974mmx 0.402mm) which is equivalent to Ultra-Flex Lingual Retainer had the lowest SBS when bonded with 3M Transbond LR Adhesive in compressing with OrthoClassic flat dead soft wire and Custom made twisted wire 0.010 SS Ligature.

In group 2 we used a self-etchant flowable composite (HeyTec Flow SE Composite, Heydent Germany). Placement of a fixed bonded retainer is a technique sensitive procedure and clinicians commonly encounter troubles. It took away the steps of etching, priming and bonding. Hence, simplifying the sensitive multisteps of conventional composites (Giannini et al., 2015). We investigated a self-adhering flowable adhesive in this study to simplify clinical procedure and replace technique sensitive, multistep adhesive systems in lingual retainer placement.

In the group two (Self-etchant bonding system) a greater force was required for debonding of coaxial 0.0195 multi-strand stainless steel subgroup which show the highest SBS value (6.3 MPa) followed by db Straight-8 braid flat soft wire subgroup (5.4 MPa) and the last subgroup was Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm which had a lowest SBS value (4.5 MPa), and there was no significant difference between their debonding forces ($P>0.3344$).

This could be caused by the wires' surface properties. The five-stranded coaxial wires had the greatest force values under SEM photomicrographs, followed by the three-stranded wires, with the flat rectangular wire displaying the lowest value. The largest pieces of composite debris were retained in the three-stranded wires and were spaced out along the wire surface. The five-stranded coaxial wires also had significant amounts of smaller pieces of composite present, but the flat rectangular wire had only occasionally small pieces of composite. It is possible to hypothesize that the wire's surface characteristics may have an impact (effect) on how well the wire is retained in the composite (Bearn et al., 1997; Baysal et al., 2012).

Indeed, HeyTec Flow SE Composite has been developed for restorative procedures and It was our own idea to use it in bonding lingual retainers. There is only one study available which use a self-etching flowable composite (Vertise Flow, Kerr) to bond lingual retainer. According to Veli et al, (2014), Vertise Flow, a resin-based, self-adhering flowable composite, significantly decreased the shear bond strength when used to attach lingual retainers to unetched enamel. Our study's findings are on the same line with those of this study.

When comparing both study groups together, there is a large significant difference in SBS between them (P<0.001). all three types of retainer wires bonded with 3M Transbond LR composite had higher (larger) SBS (db 14.0, 3M 13.1, IOS 9.6 MPa) respectively than the same retainer wires when bonded with HeyTec Flow SE Composite (3M 6.3, db 5.4, IOS 4.5 MPa). All retainers bonded with conventional multi-step adhesive system produced the greater bond strength than the same retainers bonded with the self-adhesive system.

The lowest values of bond strength were gained with the self-adhesive system. This suggests that the streamlined (simplified) bonding procedures produced an undesired reduction in shear bond strength. The findings indicate a remarkable low shear bond strength of the self-adhesive system, which may be caused by reasons other than the etching pattern, such as the adhesive's viscosity, its surface tension, how acidic monomers interact chemically with enamel, and the water concentration (Kanemura et al., 1999; De Munck et al., 2005).

According to Katona and Long (2006), the shear bond strength of a single adhesive is significantly lower than that of a multistep adhesive. This may be due to the load, structural factors and the strengths of the structural components of composites to resist such stresses. The findings of the Meerbeek et al, (2003) experiment showed that the way in which enamel was prepared before bonding processes had a major effect on the bonding efficiency of both the etch-and-rinse and the self-etch adhesives.

SEM (Scanning Electron Microscope) was used by Iijima et al. (2008) to measure the etching depth of the bonding agent at the interface between the adhesive resin and enamel. Due to a minor etching effect, SEM revealed that the resin penetration of self-etch bonding into sound enamel was relatively shallow. In contrast the tiny resin tags were longer in traditional acid etch. Additionally, self-etching primers had pH values that were substantially less acidic whereas 35 percent phosphoric acid, which has an acidic pH value, had the greatest etching effects on enamel. Additionally, phosphoric acid etching produced a stronger relationship between the adhesive and tooth enamel, according to Pamira et al, (2012).

Finally, it can be concluded from the discussion and comparison of all the strength tests that the bond strength between the self-etching bonding system and the traditional etch and rinse bonding system clearly differed. Compared to self-etchant adhesives, traditional adhesives had a significantly better shear bond strength, (Iijima et al., 2008; Elekdag-Turk et al., 2008; Ostby et al., 2008; Minick et al., 2009; Yuasa et al.,2009; Abdelnaby and Al-Wakeel, 2010; Al-Saleh and El-Mowafy, 2010; Yonekura et al., 2011). Additionally, resulted in stronger etching of enamel surface than the mild etching caused by the self-etch adhesives (Pamir et al., 2012; Sofan et al., 2017). These finding was in agreement to our study. From our study, the combination of Straight-8 strand braided flat soft wire with 3M Transbond LR Adhesive had the highest SBS among all combinations. Followed by 3M Unitek coaxial multi strand 0.0195-inch wire with 3M Transbond LR Adhesive. These findings show that the bonding strength and clinical stability of Transbond LR are much higher than that of all other adhesive systems tested independent of the retainer wire used. Same results had been obtained by Baysal et al. (2012), Reicheneder et al. (2014), Ousehal et al. (2016) and Singh et al. (2019). Combination of Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm with HeyTec Flow SE Composite had the lowest SBS among all combinations.

Adhesive remnant index after debonding (ARI)

After debonding, adhesive remnant index (ARI) scores as explained by Årtun and Bergland (1984) used to assess the sites of bond failure within the wire adhesive enamel complex can occur; between the wire-adhesive, within the adhesive, and between the adhesive and the tooth surface (Littlewood et al., 2000).

in group 1 most of the adhesive retained on the enamel (ARI scores 1 to 3) the failure was at the wire composite interface (cohesive failure), that most of the composite left on the enamel surface at different degrees. There was only mechanical retention between the two materials, stainless steel wire and composite resin, which could be the cause of this, same results obtained by Mudhir (2021). Even with different wire diameters, there was no significant difference in the ARI score for the three tested retainer wires in this group.

In group 2 (self-etchant composite) least amount of adhesive retained on the enamel (ARI scores 0 to 1). The failure was at the composite tooth surface interface (adhesive failure). This results were somewhat similar to those of Foek DL et al, (2009), who demonstrated that while utilizing self-etchant composite, there was an adhesive failure between the enamel and the composite.

There was no significant difference in ARI score for all three tested retainer wires. Higher ARI numbers reflect a move to cohesive failure, while lower ARI numbers mostly reflect adhesive failure (Valizadeh et al., 2020). This result was resembling to the findings of Veli et al, (2014), who used a self-etchant composite, demonstrated that the adhesive failure occurred between the enamel and the composite (Vertise Flow).

When comparing both groups together, there was a large significant difference between them (p<0.0001). In group 1 (conventional bonding system) most common failure sites was between the wire and composite pads (cohesive failure). This could be due to bonding between two different materials which are composite and wire, there is only a mechanical retention between them. Same results obtained by Veli et al, in a study done in 2014. While in group 2 (self-etching bonding system) the majority of failure sites were between the composite and tooth surface (adhesive failure). This may be due to a weak bond of self-etchant composite with the tooth surface due to lack of the pretreatment enamel surface. Due to the modest etching action, the resin penetration of the self-etch bonding into sound enamel was relatively shallow. In contrast to the tiny resin tags were longer in traditional acid etching (Iijima et al, 2008).

CONCLUSIONS

Within the limitations of this in vitro study, the present study showed:

1. Straight-8 strand braided flat soft wire combined with 3M Transbond LR Adhesive had the strongest shear bond strength (SBS).
2. The combination of Ultra-Flex Lingual Retainer 0.9 mm x 0.4 mm with HeyTec Flow SE Composite showed the lowest SBS value.
3. HeyTec Flow SE Composites (self-etching bonding system) significantly reduced the shear bond strength when used to bond fixed lingual retainers.
4. There were variations in the study groups failure characteristics that were statistically significant. Failures at the tooth/composite contact happened more frequently in the self-etchant group. While failures at the wire/composite contact were more prevalent in the traditional (conventional) composite group.
5. The simplified bonding procedures (self-etching composite) resulted in unfavorable reduction in shear bond strength. There is still support for the traditional multi-step adhesive technique.

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