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A Comparative Evaluation of Debonding Properties for Three Types of Directly Bonded Orthodontic Lingual Retainer Wires: An In Vitro Study

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Abstract

Objectives: To Evaluate and Compare Debonding Properties (Detachment Force, Magnitude of Deformation, Adhesive Remnant Index and Pull out Force) for Three Types of Directly Bonded Lingual Retainer Wires.

Materials and Method: 36 pairs of extracted mandibular incisors were embedded in Acrylic blocks proximally in contact with each other. The wires used were 0.0195-inch Stainless Steel (SS) Dead soft coaxial (Group A), 0.008-inch x 0.033-inch SS Flat woven (Group B), and the 0.0175-inch SS Multistranded 1 x 6 (Group C).

An 8 mm sectioned wire from each category was bonded directly onto the lingual surface of the tooth. The Detachment force was tested using a Universal Testing Machine (UTM) followed by the assessment of the

Magnitude of Deformation in the debonded wire and the Adhesive Remnant Index on the enamel surface.

For the Pull out Test using UTM, another 36 blocks were prepared. The free end of a 5 cm sectioned wire was embedded in the centre with composite and cured.

Results: Group A showed the maximum mean detachment force and pull out force. The maximum deformation was seen in Group B. The amount of deformation was significantly different among groups ($p < 0.05$). The least ARI was observed for Group C.

Conclusion: Based on the values of Detachment Force and Pull out test force values, Group A was found to be a better wire amongst the others. Based on the magnitude of deformation and ARI, Group C was found to be a better choice as a retainer wire.

Keywords: Retention, Lingual retainers, Multistranded, Coaxial, Flat woven.

Introduction

Despite major advances in orthodontic diagnosis and treatment planning, retention remains a major problem. The ***biologic considerations*** to be kept in mind when choosing a retainer include maintenance of periodontal fibers in their changed position, ease of access, and maintaining optimal oral hygiene; and conservation of functional forces on the dentition.

Bonded retainers are widely used after completion of orthodontic treatment. ***Lingual Bonded Retainers (LBR)*** are preferred over removable ones because they are invisible and esthetic hence are well-tolerated by patients. Initial versions of bonded retainers were made of larger diameter, round wire bonded merely to the two canines. Later, a thicker wire of dimension 0.032-inch was used for the same purpose. Thinner and multistranded wires of dimension 0.0175-0.0215-inch became more commonly used[1]. The flexible property of the wire eases the concentration of stress inside the adhesive used for bonding diminishing the chance of resultant failure.

LBRs do not require patient compliance, provide better esthetics than removable retainers, and can be used for lifelong retention. But they have certain disadvantages like debonding, breakage of retainer wire, difficulty in retainer placement, precise bonding technique, tendency to cause periodontal problems, and the risk of bringing about inadvertent tooth movement as a result of the distortion of the wire or absence of passivity in the wire.

Most debonding failures are encountered at the enamel-composite junction[2] and have been related to the contamination from lack of moisture/salivary control while carrying out the bonding procedures, and/or poor maintenance of dryness on the enamel surface before bonding. Failures at the composite-wire interface are comparatively less common. Placement of insufficient adhesive and material loss due to abrasion has been implicated in the detachment of the wire from the surface of the composite.

The core thickness of the wire also plays an important role in detachment properties as wires with larger diameters offer a greater surface area for bonding and thus, requires a higher pull out force.

Materials and Methods

This in-vitro study to test the debonding properties of lingual retainer wires was carried out on extracted teeth after approval by the Institutional Review Committee at the Bharati Vidyapeeth Deemed to be University Dental College and Hospital, Navi Mumbai with the Ref. No. BVDU/Exam/973/2019-20. Informed consent was not obtained as the study did not involve patients. A total of 72 Extracted Human Mandibular Permanent Incisors were collected. They were stored in plastic containers under standardized conditions in Normal Saline.

Ultrasonic Scaling was done to remove any hard deposits on the surface of the teeth. An air rotor bur (Tungsten Carbide Bur, 8 fluted, Double cutting, Dentsply, India) was used to make grooves on proximal aspects of the root. These grooves aided in retention while embedding the teeth in Self-Cure Acrylic Resin (Acralyn 'R', Asian Acrylates, Mumbai, India).

The acrylic covered the entire root till the Cemento Enamel Junction and the entire crown of the tooth remained exposed. Leuckhart's Mould was used for preparing the Acrylic Blocks of 10 x 10 x 15 mm such that they were aligned and proximally in contact with each other. A total of 36 such blocks were prepared. The samples were divided into 3 Groups. (Table 1) (Fig.1).

Table 1**:** Samples for each group

Group	Wire Used	No. of Samples for assessing Debonding Force	No. of Samples for Pull-out test
Group A	0.0195" SS Dead soft Coaxial Wire (Respond; Ormco Corp., USA)	12	12
Group B	0.008" x 0.033" SS Flat Woven Wire (Leone S.P.A., Italy)	12	12
Group C	0.0175" SS Multi stranded 1 x 6 Wire (Libral Traders, India)	12	12

SS: Stainless Steel

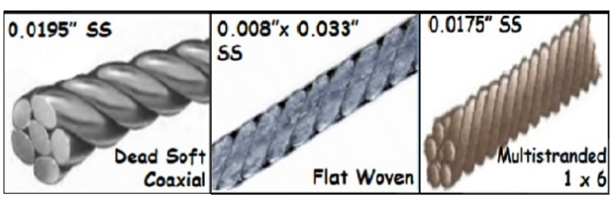

Figure 1: Three groups of wire taken

An 8 mm piece of wire was taken from each category of LBR wire to be bonded on the tooth surface. The mid-point and another marking of 2 mm from both the terminal edges of the wire were done. It was made sure that the composite did not extend beyond this marking on both ends to maintain uniformity of the adhesive applied on all the bonded samples. (Fig.2)

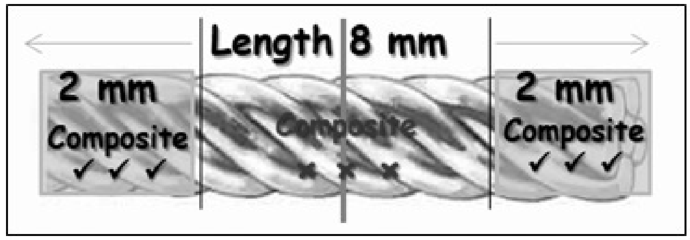

Figure 2: Bonding area on the wire sample

The lingual surfaces of the teeth were etched using Ortho-phosphoric Acid, 37% (Etch-Rite, Pulpdent Corp., USA) for 30 seconds and then rinsed with water from a 3-way syringe for 20 seconds. The primer (Transbond XT, 3M Unitek, USA) was then applied and cured using Light-emitting diode curing unit (Coltolux, Coltene Whaledent, Mumbai, India). A layer of composite (Transbond XT, 3M Unitek, USA) was first placed on the teeth on which the wire was stabilized; another layer of composite was then applied on the wire and cured again. Care was taken so that composite does not go beyond the 2 mm mark from the edges. (Fig.3)

For the Pull out Test, 36 Acrylic blocks of 10 x 10 x 15 mm was prepared. 3 mm x 2 mm hole was made in the center of each block and filled with composite in increments and curing was done. The free end of a 5 cm sectioned wire was embedded in the composite and cured. The samples were kept in distilled water at room temperature for a day. (Fig.3)

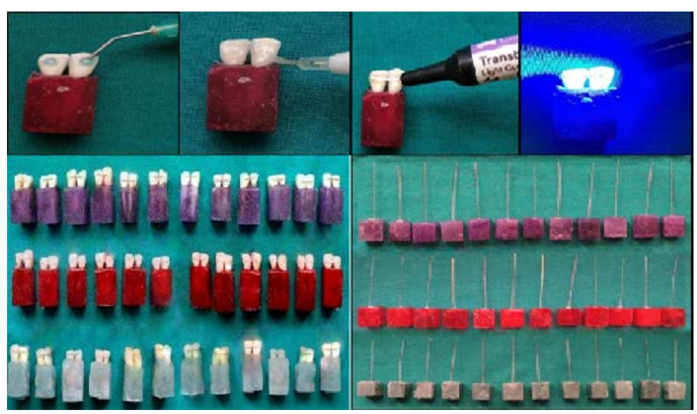

Figure 3: Steps of bonding and samples ready for testing

Detachment Force

The block was held in a jig which was in turn attached to the base plate of the Universal Testing Machine (Instron, USA) with a crosshead speed of 10 mm/min[3]. The maximum load required to debond the wire from the enamel surface was recorded. (Fig.4)

Figure 4: Testing under progress

Magnitude of Deformation

After debonding, the remaining composite was removed using a tungsten carbide bur. The wire was then placed on graph paper and the magnitude of deformation was assessed using a Stereomicroscope (Almicro, Haryana, India) at x20 magnification. The assessment was done in millimeters.

Adhesive Remnant Index (ARI)

The fracture was examined at the site where the Initial bond failure occurred. ARI scoring was done and the overall score was calculated as 0, 1, 2, 3 where:

Score 0: no adhesive left on the tooth,

Score 1: less than half of the adhesive left on the tooth,

Score 2: more than half of the adhesive left on the tooth

Score 3: all adhesive is left on the tooth with a distinct impression of the wire on its surface[4]

Pull Out Test

The Universal Testing Machine was placed in tensile mode with crosshead speed set to 10 mm/min[3]. Test blocks were placed in the machine and force was applied along the long axis of the wires. The force used to detach the wires from the composite was recorded. (Fig.4)

Statistical Analysis

Normality testing was done using Shapiro-Wilk test.

Data for debonding force and pull-out tests were normally distributed. Hence, parametric tests were used for the analysis of these parameters.

Data for ARI and the magnitude of deformation failed normality testing. Hence, non-parametric tests were used for analysis of these parameters.

For normal data, the study parameters were compared between the three groups using a one-way analysis of variance (ANOVA). Post-hoc Dunnett's test was used for pairwise comparisons in the sub-groups.

For non-normal data, the three groups were compared using Kruskal-Wallis test (Non-parametric ANOVA). Post-hoc Wilcoxon test was used for pairwise comparisons in the sub-groups.

All testing was done using two-sided tests at alpha 0.05 (95% confidence level). Thus, the criteria for rejecting the null hypothesis was a 'p' value of <0.05.

Statistical Software

All data were entered into a Microsoft Office Excel (version 2013) in a spreadsheet which was prepared and validated for the data form. Data were entered and checked for errors and discrepancies. Data analysis was done using windows based 'MedCalc Statistical Software' Version 17.8.2 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2017)

Data Expression

Data for Detachment Force, Magnitude of Deformity, Adhesive Remnant Index and Pull out Force is expressed as Mean, Median, Range, Standard Error of Mean (SEM), and Standard Deviation as applicable. The 95% Class Interval values are also presented as applicable.

Results

Detachment Force: Group A showed the maximum mean debonding force of 50.5017 N followed by Group C with 43.4017 N and Group B with 41.2117 N. (Figure 5)

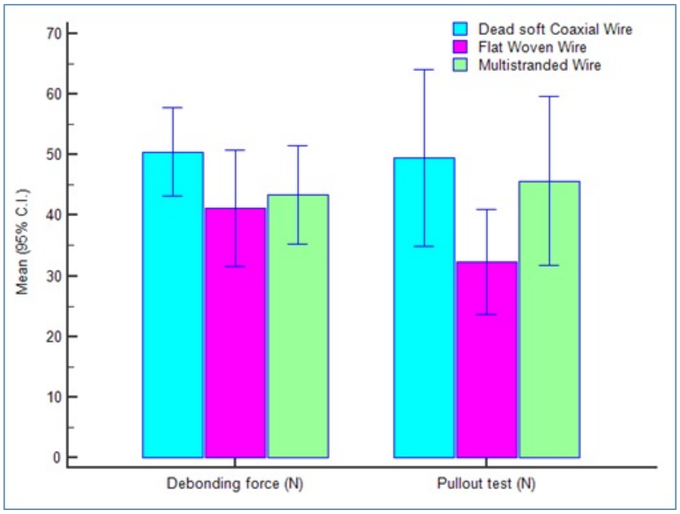

Figure 5: Graph comparing the mean debonding and Pull out forces

There was no statistically significant difference in detachment force among test groups.

Magnitude of Deformation

Group B showed the maximum mean amount of deformation of 2.625 mm followed by Group A with 1.25 mm and Group C with 0.75 mm. (Figure 6)

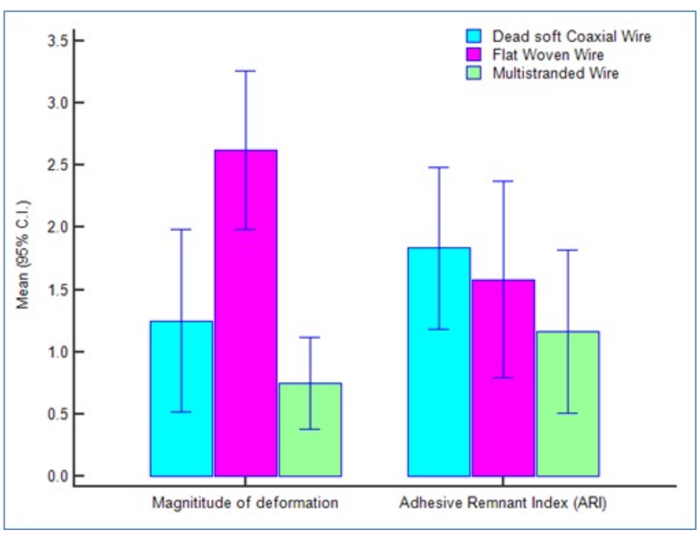

Figure 6: Graph comparing the mean magnitude of deformation and ARI

There was statistically significant difference among the groups ($p < 0.05$).

Adhesive Remnant Index

Group A showed the maximum mean ARI of 1.833 followed by Group B with 1.583 mm and Group C with 1.166 mm. (Figure 6)

There were no statistically significant differences among test groups.

Pull out test

Group A had the maximum mean pull out force of 49.5067 N**,** Group B had 32.3092 N and Group C had a mean pull out force of 45.6733 N. (Figure 5)

There was no statistically significant difference in pull out forces among test groups.

Table 2 shows the Comparison of Significance level of the properties.

Table 2: Comparison of significance level of the properties

	Debonding Force	Magnitude of Deformation	ARI	Pull out test
Dead coaxial wire	50.5017	1.2500	1.8333	49.5067
Flat woven wire	41.2117	2.6250	1.5833	32.3092
Multi stranded wire	43.4017	0.7500	1.1667	45.6733
Significance level	P=0.215 Not Significant	P=0.000506 Significant	P=0.336555 Not Significant	P=0.101 Not Significant

Discussion

The era of bonded retainers commenced with the bonding of fixed lingual retainer to mandibular anterior teeth by ***Knierim*** in ***1973***[5]. This established bonded retainers as an essential part of orthodontic treatment to prevent relapse or secondary crowding of mandibular incisors.

The choice of wire based on its cross-section, material, thickness, flexibility, etc. determines the success rate of the retainer.

This concept of LBRs evolved from direct splinting of contact points of anterior teeth using sealants and composite resins. Initially, single-stranded wires with a round or rectangular cross-section were used as LBRs[6]. This was then modified and a 0.0115-inch to 0.0195-inch wire in the form of a triple-stranded wire was used. Multistranded wires were preferred as their spiral cross-section gave a good surface retention to the bonding agent. Failures in the form of loosening or wire breakages were still reported frequently. In ***1977***, ***Zachrisson***[7] described the advantages of using multi-stranded wires for retention. Later, in ***1982, Artun and Zachrisson***[1] introduced the technique of bonding multi-stranded wires from canines to canines only. Finally in ***1991, Dahl and Zachrisson***[8] reported 0.0215-inch 5-stranded wire to be the most optimal fixed retainer wire as it had the lowest failure as compared to the wires used previously. The reason for utilizing more flexible or adaptable wire is to permit physiological development of teeth, specifically those with periodontal complications. In a study on the clinical efficacy of two types of retainer wires: 0.0175-inch SS Multistranded wire and Single-stranded ribbon Titanium LBR, both the wires had the same clinical effects when bonded but it was shown that the ribbon wire had less failure in terms of detachments[9].

In the present study, debonding properties of three different types of retainer wires, namely, multistranded, coaxial, and flat woven were measured. These wires were chosen because they were the most frequently used wires by clinicians. The multistranded SS wire has been studied extensively in the literature as compared to flat wires[1,8,10,11]. Dead-soft wires and flat wires are preferred as they adapt passively to the anterior arch form, therefore reducing unintentional tooth movement. Flat wires also provide more surface area for the adhesive to bond on.

In another study[12], it was observed that when a vertical force is applied to a bonded wire, tension, shear, and torsion forces may occur at the interface concurrently. Accordingly, other factors like the age of the enamel, morphology of the lingual surface, and size of the tooth also come into play. Bond strength studies comparing various lingual retainer wires are difficult to perform as there is no gold standard method for the preparation of samples and testing. There is also no minimum bond strength value that has been quoted for lingual retainers, unlike orthodontic attachments.

In the present study, 0.0195-inch SS Dead soft coaxial wire showed the maximum mean detachment force of **50.5017 N** followed by the 0.0175-inch SS Multistranded 1 x 6 wire with **43.4017 N** and 0.008-inch x 0.033-inch SS Flat Woven wire showed **41.2117 N**. Although the inter-group variation was statistically insignificant, there was a difference of almost 7 N between the Dead soft coaxial and the Flat woven wire which can be deemed as clinically significant. The value obtained in the present study is similar to the detachment force values obtained in a study where they demonstrated that the Coaxial/Transbond™ LR group amongst others was statistically significantly stronger than the other combinations[11]. Another study which evaluated the bond strengths of various wire-composite combinations found that the 0.0195-inch dead soft coaxial wire/ Tetric N-Flow composite showed similar detachment force values as in the present study. [13]

The masticatory forces and any attempt at cleaning the area beneath the wire with interdental aids may serve as a source of repetitive deformations in the bonded wire which result in the fracture of the retainer wire. The multistranded wire has a lesser extent of deformation which causes the force to be transmitted to the teeth. Wires that get easily deformed are also at a higher risk of breakage.

0.008-inch x 0.033-inch SS Flat woven wire showed the maximum mean amount of deformation of 2.625 mm followed by 0.0195-inch SS Dead soft coaxial wire with 1.25 mm and 0.0175-inch SS Multistranded 1 x 6 wire with 0.75 mm. There was statistically significant difference among the groups ($p < 0.05$). The findings of the present study are in accordance with the study where the coaxial wire exhibited a lesser amount of mean deformation[12].

Fractures or debonding can occur at either the wire-composite or the composite-enamel interface. The literature shows evidence for both. The stresses induced in the wire can also give rise to fractures in the long run. In a study, it was observed that most of the fractures occurred at the adhesive-enamel interface than at the adhesive-wire interface[14]. On the other hand, in another study it was shown that the failure at the composite-wire interface dominated most of the debondings[12].

In the present study, the mean ARI value for 0.0195-inch SS Dead soft coaxial wire was **1.8333**, for 0.008-inch x 0.033-inch SS Flat woven wire was **1.5833**, and for the 0.0175-inch SS Multistranded 1 x 6 wire was **1.1667**. The inter-group variation was statistically insignificant. Scoring of the ARI is necessary as it plays a major role in the wire and composite selection. Adhesives which leave behind lesser remnant on the enamel surface after debonding are preferred. The wire-adhesive interface is considered better, as most of the adhesive remains on the enamel surface itself thus, there is a reduced chance of enamel fracturing.

Pull-out tests helped in the evaluation of the micromechanical adhesion between the adhesive and the retainer wire. In this study, it was found that the larger diameter wire i.e. the 0.0195-inch SS Dead soft coaxial wire had the maximum mean pull out force of **49.5067;** followed by the lesser diameter 0.0175-inch SS Multistranded 1 x 6 wire which had a mean pull out force of **45.6733** and the least diameter 0.008-inch x 0.033-inch SS Flat Woven wire had a mean pull out force of **32.3092.** The inter-group variation was statistically insignificant. These findings are similar to a study where they found that the six-stranded coaxial wires gave the best retention in the composite as compared to three-stranded and 0.0215-inch multistranded wire. They concluded that wires with larger diameters have more surface area hence require greater force to pull the wire out from composite[15]. The values of the pull out tests shown by the coaxial wire and the flat woven wire are higher than the ones obtained in another study[16].

Thus, investigating the right kind of retainer wire helps us combat retention failures that lead to relapse. With the wide array of retainer wires available at our disposal, it is very important to choose the appropriate wire as per our needs considering the ability of the wire to resist the forces and various factors at play in the oral environment.

Even the best designed In-Vitro Study is unlikely to replicate the conditions at play In-Vivo. The potential influence of the oral environment on the bonding material and the composite-wire interface was a non-existing factor here. Saliva is a powerful surfactant that can percolate between interfaces and force them apart. The testing may not accurately replicate the forces generated by the intra-oral stresses and orthodontic appliance adjustments. In the present study, detachment force testing was done at the rate of 10 mm/min. In an In-Vivo situation, it is unlikely for the functional loading on the LBR to be limited to this specific value.

Further studies can be carried out using different composite and wire combinations used in routine practice and thus the best composite-wire combination can then be adopted. Variables such as saliva, temperature, microbes, and the cyclic loading from mastication should also be taken into consideration.

Conclusion

The following observations were made:

Detachment Force: 0.0195-inch SS Dead soft coaxial wire showed the maximum mean detachment force (**50.5017 N**) followed by the 0.0175-inch SS Multistranded 1 x 6 wire (**43.4017 N**) and 0.008-inch x 0.033-inch SS Flat Woven wire (**41.2117 N)** showed the minimum force. The inter-group variation was statistically insignificant.

Magnitude of Deformation: 0.008-inch x 0.033-inch SS Flat woven wire showed the maximum mean amount of deformation of **2.625 mm** followed by 0.0195-inch SS Dead soft coaxial wire with **1.25 mm** and 0.0175-inch SS Multistranded 1 x 6 wire with **0.75 mm**. There was statistically significant difference among the groups ($p < 0.05$).

Adhesive Remnant Index: The mean ARI value for 0.0195-inch SS Dead soft coaxial wire was **1.8333**, for 0.008-inch x 0.033-inch SS Flat woven wire was **1.5833**, and for the 0.0175-inch SS Multistranded 1 x 6 wire was **1.1667**. The inter-group variation was statistically insignificant.

Pull out Test: 0.0195-inch SS Dead soft coaxial wire had a mean pull out force of **49.5067;** followed by the 0.0175-inch SS Multistranded 1 x 6 wire which was **45.6733** and the 0.008-inch x 0.033-inch SS Flat Woven wire had a mean pull out force of **32.3092.** The inter-group variation was statistically insignificant.

Based on the values of Detachment Force and Pull out test force values, 0.0195-inch SS Dead soft coaxial wire was found to be a better wire amongst the others. On the basis of the magnitude of deformation and ARI, 0.0175-inch SS Multistranded 1 x 6 wire was found to be a better choice as a retainer wire.

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