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Comparative evaluation of effect of heat treatment of three different types of lingual retainer wires on their shear bond strength an *in-vitro* study

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Abstract
Aim: To evaluate and compare the shear bond strength of three different lingual retainer wires before and after heat treatment.
Materials and Methods: A total of 120 human extracted premolar teeth were mounted in pairs and 60 blocks were made and divided into 6 groups (n=10) and colour coded. Retainer wires used were Orthodirect Braided retainer wire ™ (0.016” x 0.022”), Modern Co-axial wire™ (0.0175”) and Custom-made twisted Stainless-steel ligature wire (0.010”) of 10 mm length on each specimen. Piezo gas burner was used for heat treatment of the retainer wires. Three groups were boned with as manufactured retainer wires and other three groups were bonded with heat treated wires using Tetric-N-Flow flowable composite. After storage in artificial saliva for 24 h, the samples were subjected to shear bond strength test at a speed of 1 mm/min until debonding of retainer to determine shear bond strength in Newtons. Data were analyzed using the one-way ANOVA.
Results: The result demonstrated that there was significant difference in shear bond strength of Co-axial retainer wire after heat treatment while non-significant difference for Orthodirect Braided retainer wire and Custom-made twisted Stainless-steel ligature wire. The mean shear bond strength of as manufactured Custom-made stainless-steel twisted ligature wire was found to be the highest.
Conclusion: The finding of this investigation indicates that coaxial wire after heat treatment and as manufactured custom-made stainless-steel twisted ligature wire might be better retained on the teeth and would provide the efficient result.

Keywords: Shear bond strength, retainer wire, heat treatment

Introduction
Orthodontic treatment involves the movement of teeth to correct malocclusion. There is, however, an inherent tendency for teeth to relapse to their pretreatment position. To counter relapse, the fixing of bonded retainers to the mandibular or maxillary incisors has become an established part of Orthodontic practice. Retaining teeth in its aligned position ensures reorganization of periodontal tissues, minimizes changes due to growth, allows neuromuscular adaptation to the new position of the teeth and holds teeth in stable positions with good contact points. The gingival fibers and supra-crestal fibers reorganize at an extremely slow pace and hence produce enough forces to cause relapse.
Retention protocols include fixed and removable retainers. Removable retainers have the disadvantages of aging, reduced wearing comfort such as impaired patient speech, and their clinical success depends on sufficient patient compliance. Fixed orthodontic retainers is made of thin, flexible multistrand wires, usually 0.0195" or 0.0215", and is bonded to each tooth in the anterior segment. Booth *et al.* [1] evaluated 60 patients who had permanent retainers in place for more than 20 years and concluded that orthodontists might recommend permanent retention to maintain the alignment of lower incisors.
The fixed retainers used in orthodontic treatments must be passive towards teeth, without developing any stress.
This characteristic is challenging to achieve due to the mechanical properties of the materials the retainers are manufactured from. Residual stress might be generated because of them

flexibility and chemical composition of the stainless-steel wires. Zachrisson described the use of flexible spiral wire applied to all teeth in the labial segment and the advantages of using this new design, which prevented teeth from rotational relapses and allowed the physiological movements of the attached teeth [2].

Adverse effects of bonded flexible spiral wire retainers include insufficient passiveness of the wire, elastic deflection caused by the clinician during insertion or repair, mechanical deformation of the wire due to trauma, or untwisting of single strands of round flexible spiral wires. Elastic deformation incorporated into the wire during its manipulation and mechanical deformation from masticatory forces can lead to unwanted tooth movements. Since round flexible spiral wires are produced by twisting multiple strands to form one spiral wire, forces within the wire might be generated through an untwisting of these single strands.

In the oral cavity, lingual retainers undergo cyclic stresses due to mastication, occlusion, and parafunctional habits. The shear bond strength of retainers must be high enough to resist masticatory stresses. Bond failure increases the chair time and the costs and is inconvenient for patients. Artun *et al.* [3] and Bearn *et al.* [4] found that the most common mode of failure was loosening between the wire and composite. Because bonded lingual retainers are intended to serve for long periods of time in the mouth, attempts should be made to increase the success rate of these devices. Attempts were made to enhance the retention of lingual fixed retainer including right-angle bend, using adhesive promoters, micro-etching and sandblasting. Bearn *et al.* [4] found that there must be at least 1 mm of composite material over the retainer wire to provide a balance between sufficient composite strength and excess intraoral bulk.

Wires with a high degree of annealing are described in the literature as dead soft.[5] Heat treatment increases the malleability of the wire while improving its properties by relieving the stresses retained from archwire formation. These stored forces can lead to the accumulation of stresses at the points of masticatory overloads, causing fatigue and failure of the bond between wire and adhesive. In office heat treatment of retainer wires with a flame is frequently used by orthodontists to anneal the wire and create passivity.

Only conflicting and insufficient information is available regarding the alterations induced by the heat treatment, which makes this treatment a controversial choice in orthodontics. These factors, allied with the existence of only a small number of reported studies regarding this subject, were the rationale for the present study. There are very few studies in the literature that shows the effect of heat treatment on bond strength of lingual retainer wires. So, the present study was designed to compare and evaluate effect of heat treatment of three different types of lingual retainer wires on shear bond strength.

Materials and Methods

Study sample: This *in vitro* study evaluated 120 extracted human premolars.

Sample size calculation: The sample size was calculated using G*Power software version 3.1 to be 10 in each group (a total of 60) according to a study by A Baysal *et al.* [6]

Inclusion criteria: The inclusion criteria were that the teeth should be with intact enamel surfaces with no cracks caused by the extraction forceps and no pretreatment with any chemical agents.

Exclusion criteria: the exclusion criteria were decayed teeth, fluorosed teeth, attired teeth, restored teeth, hypoplastic teeth and fractured teeth.

Intervention: 120 Extracted human premolar were collected, cleaned using ultrasonic scaler and store d in 10% Formalin solution and mounted in acrylic blocks in set of two. The acrylic blocks were then randomly divided into six groups (n=10) and colour coded as white, blue, purple, red, green and pink (Fig: 1)

In white, blue and purple group, non-heated treated retainer wires used to bond were Orthodirect Braided retainer wire ™ (0.016” x 0.022”), Modern Co-axial wire™ (0.0175”) and Custom-made twisted Stainless steel ligature wire (0.010”) respectively and in red, green and purple group, the heat treated retainer wires bonded were Orthodirect Braided retainer wire ™ (0.016” x 0.022”), Modern Co-axial wire™ (0.0175”) and Custom-made twisted Stainless steel ligature wire (0.010”) respectively.

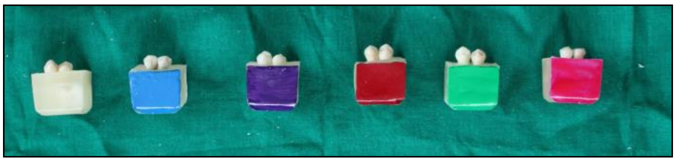


Fig 1: Colour coded pair of Extracted Premolars mounted in Self-Curing Acrylic Resin.

The enamel surfaces of the two premolars in each specimen was acid-etched with 37% phosphoric acid for 30 seconds followed by rinsing for 15 seconds, and then was dried until the enamel had a faintly white appearance (Fig:2). The bonding agent (Ivoclar, Switzerland) was applied and light cured for 20 seconds with a visible light curing unit (woodpecker curing light, Germany). (Fig: 3)

Fig 2: Acid etching of tooth

Fig 3: Application of Bonding agent (Ivoclar, Switzerland)

For custom made twisted wire, two stainless steel 0.010" ligature wires were twisted using Mathieu plier to form a passive bundle. (Fig:4) In white, blue and purple specimen block the respective 10 mm wire length was gently curved to give passive fit to the tooth surface and center point of wire was marked using marking pen. In red, green and pink specimen block the wire was annealed very briefly using Piezo gas burner (Thermo gas torch, India) at 850^{o} F and then quenched under water at room temperature followed by gently curving a 10 mm wire length to give passive fit to the tooth surface and marking center point. (Fig: 5) The wire was bonded with light cure adhesive Flowable composite (Tetric-N-Flow, Ivoclar, Switzerland) between the pairs of teeth in each specimen block and was light cured for 20 seconds with a visible light curing unit (Woodpecker curing light, Germany) and stored in artificial saliva at room temperature for 24 hours before debonding procedure. (Fig: 6)

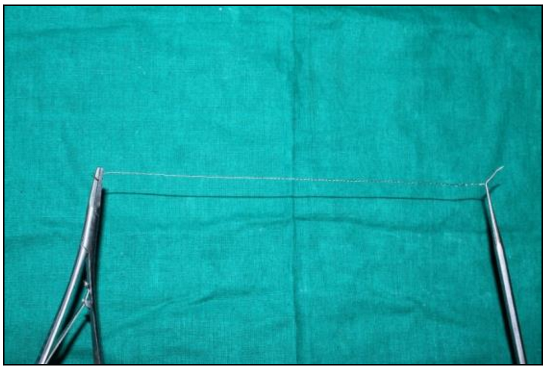


Fig 4: Twisting of two stainless steel ligature wires.

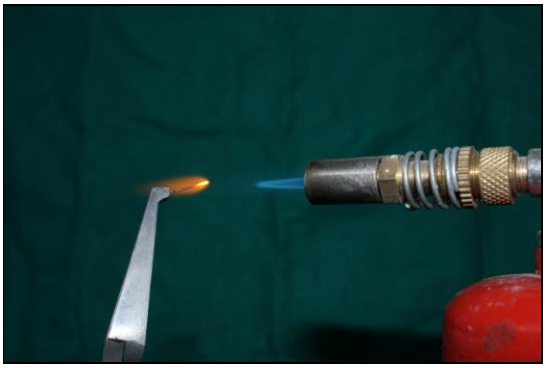


Fig 5: Heat treatment of retainer wire using Piezo gas burner. (Thermo gas torch, India)

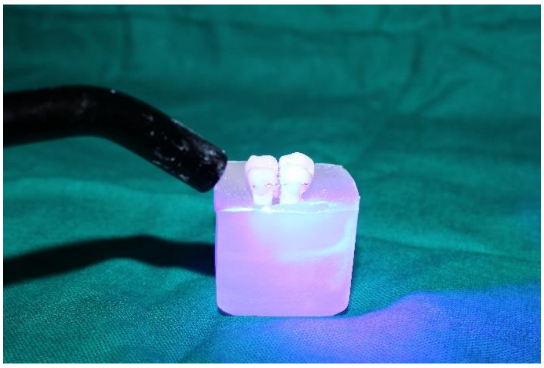


Fig 6: Light curing

Shear bond strength: Each specimen block was placed in the testing machine so that the vertical force was applied with the chisel edge to the midpoint of the interdental wire segment on the marked point at crosshead speed of 1mm/min. The load applied to the wire was gradually increased until debonding occurred, and the shear bond strength was recorded in Newton (N). (Fig:7)

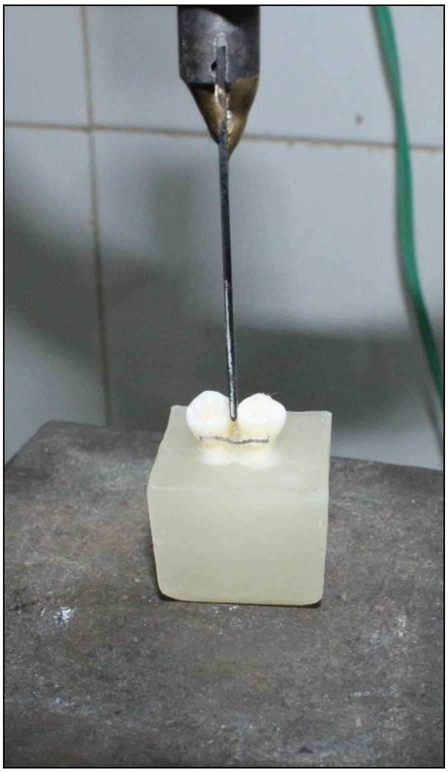


Fig 7: Debonding of Retainer wire using Universal Testing Machine.

Statistical analysis: Comparison of shear bond strength among three different wires was done using One-way ANOVA test followed by Post hoc Tukey test, Kruskal Wallis test, post hoc Mann Whitney test and intergroup comparisons of fracture load were performed by Independent t test.

Results

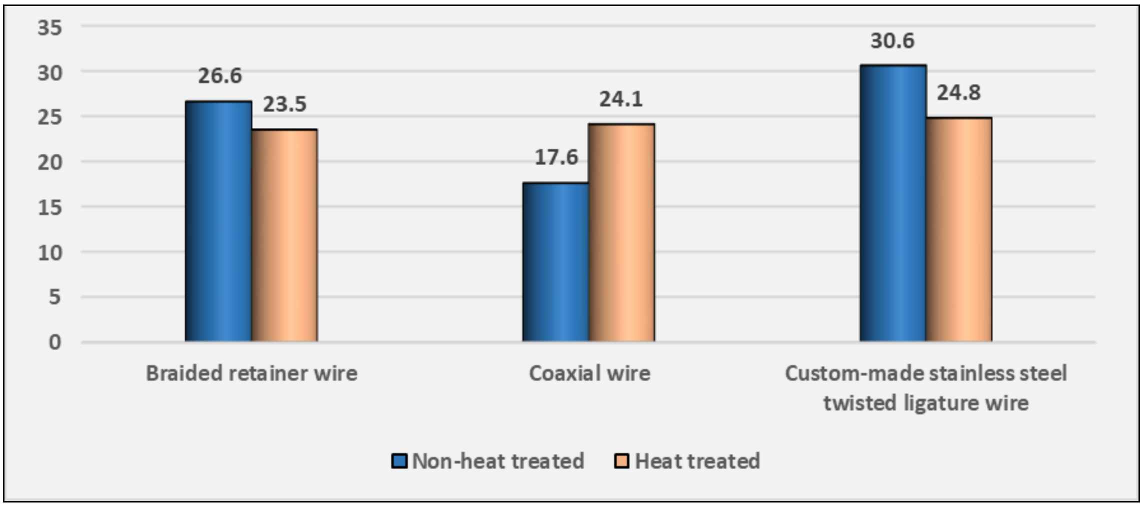
Significant statistical difference was noted between the groups, with the highest bond strength attained by Custom-made stainless-steel twisted ligature wire group (30.60±10.26 N) followed by Braided Retainer wire group (26.60±16.32 N) and the lowest by Coaxial wire group (17.60± 6.08 N) in non-heat treated group.

On comparison of heat treated group, Kruskal Wallis test revealed non-significant difference in the shear bond strength among three different heat-treated wires with highest bond strength attained by Custom-made stainless steel twisted ligature wire group (24.80±11.01 N) followed by Coaxial wire group (24.10±4.70 N) and the lowest by Braided Retainer wire group (23.50±13.72 N).

Independent t test and Mann Whitney test for comparison of shear bond strength between non-heat treated and heat treated wires revealed that heat-treated coaxial wires showed a significantly greater shear bond strength as compared to the non-heat-treated coaxial wire whereas there was a non-significant difference between non-heat-treated and heat-treated braided retainer wires and custom-made stainless steel twisted ligature wires. (Table 1 and Graph 1)

Table 1: Comparison of shear bond strength between non-heat treated and heat treated wires

Wire	Non-heat treated		Heat treated		Difference (MPa)	p-value
	Mean (N)	SD	Mean (N)	SD		
Braided Retainer wire	26.60	16.32	23.50	13.72	3.10	0.423#
Coaxial wire	17.60	6.08	24.10	4.70	-6.50	0.015*
Custom-made stainless-steel twisted ligature wire	30.60	10.26	24.80	11.01	5.80	0.239



Graph 1: Comparison of shear bond strength between non-heat treated and heat-treated wires

Discussion

Once a phase of orthodontic treatment has been completed to straighten teeth, there remains a life-long risk of relapse. By using retainers to hold the teeth in their new position for a length of time, the surrounding periodontal fibres adapt to changes in the bone which can help minimize any changes to the final tooth position after the completion of orthodontic treatment. Bonded retainers have been commonly used to prevent relapse. However, occlusal changes have been observed in patients with long term fixed retention, such as unexpected torque changes between the adjacent teeth or opposite inclinations of contralateral mandibular canines.

Under clinical conditions, lingual retainers are subjected to cyclic stresses because of mastication, occlusion, and intraoral habits. This repeated subcritical loading induces fatigue and may cause partial or total failure of one or more components of the retainer complex. Singh *et al.* [5] in a study stated that heat treatment of wire relieves the stresses retained from archwire formation and improves malleability and stability of arch wire. However, excessive heat should be avoided, because it could damage the wire and increase the risk of fracture.

Although the previous studies evaluated different lingual retainer wires adhesive systems or their combinations [7, 8, 6, 9, 10, 11, 12, 13] torque characteristic [14, 15, 16] and residual stress release of heat-treated wire,[5]when heated using different methods but no studies of other authors have been found to evaluate the shear bond strength of heat-treated retainer wires. Thus, this study was conducted to evaluate the effect of heat treatment of three types of lingual retainer wires bonded using a single composite type on shear bond strength.

In the present study statistically, significant difference was found in shear bond strength of three types of lingual retainer wires. The greater force was required for debonding of custom-made stainless steel twisted ligature wire group which showed the highest shear bond strength value followed by braided retainer wire group and the least was coaxial wire group. The value range of bond strength for custom-made stainless steel twisted ligature wire was in accordance with the study done by Ranjita *et al.* [17] The investigation protocol was similar where the force was applied to the interdental wire segment but the test was performed on lower anterior teeth.

The shear bond strength value obtained for coaxial wire in this study is less than the values obtained in study done by Radlanksi *et al*, [22] Shahji *et al.* [8] and Asli baysal *et al.* [6] This difference could be attributed to the lower anterior teeth being used as well as vertical pressure applied at bond site and use of different adhesives and composite resins in their study whereas the present study was performed on premolar teeth and vertical load was applied on interdental segment of wire.

The results of Golshah *et al.* [19] were in line with the present findings that higher number of strands in the retainer wire does not increase the bond strength. The obtained result for braided retainer wire was in accordance with the study by Mudhir [21] and Shahji *et al.* [18] where shear bond strength of braided retainer wire was found more than that of coaxial wire. The residual forces while twisting the strands during manufacturing process could be the reason for decreased strength.

After heat treatment, there was significant difference in shear bond strength of three types of lingual retainer wires. The heat treatment leads to reduction in shear bond strength of braided retainer wire and custom-made stainless-steel twisted ligature wire whereas the shear bond strength of coaxial wire was increased.

Various studies have contributed to the general understanding of the phenomena involved but no detailed investigation of the effects of heat-treating orthodontic wires has been done. Engeler *et al.* [16] noted in a study that heat treatment was found to have no statistical effect on torsional load transfer on retainer wires whereas Arnold *et al.* [15] reported in a study that heat treatment reduced the stiffness of the wire and lead to a non-uniform and non-reproducible effect**.** Carsten [21] performed a study on heat treatment of stainless steel archwires and reported that the heat treatment of archwire should be performed at 350^0-375 ^{0}C for 20-25 minutes for

resolution of internal stresses introduced during the cold working of the wire. In a study carried on heat treatment of stainless steel by Michael [22], exposure of the stainless-steel springs to a stress relief heat treatment of 750^0 F for 11 minutes showed improved spring properties.
In a study by Bellini *et al*. [23], the heat treatment of titanium wire led to precipitation of titanium and reduced super elasticity by producing changes in the chemical composition of the matrix. Thus, in present study this could be the reason for decreased shear bond strength of braided retainer wire. Gupta *et al.* [24] in a study on orthodontic stainless-steel brackets stated that direct flaming increased the temperature leading to disintegration of metal alloy and weakened its structure which accounted for the decreased bond strength. So, this could be the reason for decreased strength of custom-made stainless steel twisted ligature wire.
The significantly increased force required to dislodge the heat treated co-axial wire from composite appear to be due to the enhanced surface characteristic of wire that is increased micro-mechanical retention, release of the stored forces within the cold drawn wire due to heat treatment and easy adaptation of wire on tooth surface must have prevented accumulation of stress on single area leading to lack of any force exertion.
Clinical failure rates are needed to confirm the usefulness of heat treated co-axial retainer wire but the result of the study is encouraging. Investigations into bond strength are difficult to compare and interpret with previous work. This is because there is no standard protocol for preparation and testing of materials. Individual variation in tooth anatomy, mineralization as well as adaptability of the wire segments usually leads to variability in bond-strength values and the wide age group of the teeth donors, varied morphology of lingual surface, tooth size, masticatory force, saliva, diet, and oral habits etc. could have also influenced the results.
Since orthodontic retainers are commonly bonded to anterior teeth, the bond-strength values achieved by using human premolars in this study should not be extrapolated directly to clinical applications. Another drawback was that the investigative protocols differed among studies and hence, comparison of the results with other studies was difficult. Clinical studies are needed to validate the preliminary *in vitro* performance of retainers bonded.
The results and conclusion of *in vitro* investigations must be extrapolated to the clinical situation with care and further in-vivo trials with these materials are indicated to confirm the validity of the conclusions drawn in this *in-vitro* investigation.

Conclusion
Under the limitations of this *in vitro* study, following conclusions were obtained:

1. The difference in shear bond strength among three different lingual retainer wires before heat treatment was significant and the difference in the shear bond strength among three different heat-treated wires was not significant.
2. There was a non-significant difference between non-heat-treated and heat-treated braided retainer wires and stainless-steel wires whereas heat-treated coaxial wires showed a significantly greater shear bond strength as compared to the non-heat-treated coaxial wire.

The finding of this investigation indicates that coaxial wire after heat treatment might be better retained on the teeth and provide an optimum performance in bonded fixed retainers. Also, as manufactured custom-made stainless steel twisted ligature wire would provide the efficient retention without heat treatment.

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