Efficiency Evaluation Of Four Differentorthodonticbonded Retainers - An In Vitro Study

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ABSTRACT

Introduction: Orthodontic retention ensures teeth remain in their treated positions post-treatment to maintain results. Bonded lingual retainers are preferred for their aesthetic appeal and reliability in preventing relapse. The aim of the study was to analyze & compare the efficiency of four different types of orthodontic bonded lingual retainers

Material and Methods: The study examined 60 orthodontic bonded lingual retainers grouped by material: 0.0195" SS coaxial wire (Group A), flat braided multi-stranded SS wire (Group B), 0.012" SS double twisted ligature wire (Group C), and fiber-reinforced composite (Group D). These retainers were bonded to 60 pairs (120 teeth) of extracted human premolars using Tetric N Flow adhesive. After subjecting the specimens to thermocycling, debonding force (SBS) was measured with a UTM. Fracture mode (ARI scores) and retainer deflection were evaluated using an optical stereomicroscope. Statistical analyses included ANOVA,Chi-Square test, and Post Hoc Tukey test.

Results: The study outcomes indicated that all orthodontic bonded retainers in the four study groups remained intact after undergoing thermocycling.The SBS (50.54 ± 2.86N) of the FRC group surpassed that of the other groups and also highly significant difference of SBS among groups($p<0.05$). ARI scores 1 & 2 were in majority among the groups with 36.6% and 30.0% respectively. Group D had the highest incidence of 53.3% of adhesive failure at the enamel-composite interface.the amount of deflection was highest in Group C with 2.81 ± 0.24mm whereas Group D had least mean deflection of 0.08 ± 0.06mm with highly significant results ($p<0.05$).

Conclusion: FRC is a persuasive option for lingual retainer bonding compared to traditional stainless steel wires, weighing its merits and limitations. Nevertheless, the choice between FRC and conventional methods should be a joint decision with a dental professional, considering each patient's specific needs and treatment objectives.

Keywords: Bondedretainers,Retention,Orthodonticretaine rwires, FRC.

INTRODUCTION

Orthodontic retention is defined as "the holding of teeth following orthodontic treatment in the treated position for the period necessary for the maintenance of the result" .[20] It addresses the natural tendency of teeth to revert to their original positions due to the elasticity of periodontal fibers and changes in alveolar bone remodeling post-treatment. Among the various retention methods explored, bonded lingual retainers have gained prominence for their effectiveness in maintaining lower incisors in their corrected positions over the long term.[8] Initially, these retainers consisted of thick, round wires bonded only to the canines, but this design exhibited notable failure rates due to its limited scope of coverage.[2]The evolution of bonded lingual retainers saw the introduction of multi-strand wire designs pioneered by Zachrisson in 1983.[4] Multi-strand wires offer several advantages over single-strand designs, including increased mechanical retention for the composite without needing additional retentive loops. Moreover, their flexibility allows for physiological tooth movement, minimizing the risk of root resorption or other complications associated with fixed retention methods.[4] Factors influencing the longevity and effectiveness of lingual retainers include the type of composite resin used, its application technique, and the specific conditions in the oral cavity.[17]To address some of these challenges, fiber-reinforced composite (FRC) materials have emerged as promising alternatives to metal wires. FRC retainers offer advantages such as biocompatibility, aesthetic appeal (especially beneficial for patients allergic to metal), and improved flexibility that accommodates natural tooth movement.[14]In this study, weanaly sed & comparedthefailure of thre edistinct varieties of wires & Fiber reinforcedcomposite used for bondedlingualretainerfabricationon the basis of debonding force (SBS),fracture mode (adhesiveremnantindex), fatigueres is tance & amount of de formation.

MATERIAL & METHOD

A total of 120 human premolar teeth that were extracted for orthodontic purposes with intact lingual surfaces were collected and used in the study. To prevent dehydration and surface damage to the teeth, these teeth were kept in distilled water for storage. The study included sixty orthodontic bonded retainers which were segregated into four groups based on distinct types of orthodontic bonded retainer being used i.e. 0.0195" SS Coaxial wire, Flat braided multi-stranded SS wire, 0.012" SS double twisted ligature wire (custom made) & Fiber reinforced composite retainer (Interlig), with 15 samples in each group. These samples were then bonded to sixty pairs (120) of extracted human premolars, which were embedded in acrylic blocks. The cold cure acrylic blocks were fabricated using a custom made mould of bioplast sheet with dimensions of 50mm×25mm×25mm in which roots of premolar teeth were embedded so that the long axis of the teeth were perpendicular to the base of the moulds.(Figure 1)

FIGURE 1:Materials used for custom made assembly fabrication

Each acrylic block contained premolars which were matched to form the contact area that mimicked intraoral situation. The acrylic blocks were colour coded to demarcate four different orthodontic bonded retainer.(Table 1 &Figure 2,3)

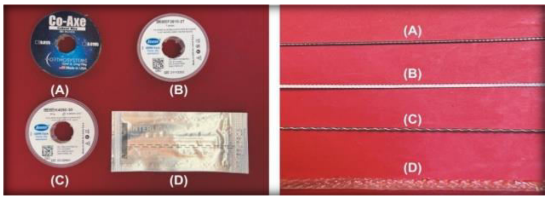


FIGURE 2:Orthodontic lingual bonded retainers

FIGURE 3: Fabrication of acrylic blocks: Group A, Group B, Group C, Group D

GROUPS	ORTHODONTIC BONDED RETAINER	TEETH No	COLOUR CODING
A	0.0195"SSCoaxialwire bonded to natural teeth	30	**Green**
B	Flat braided multi-stranded SS wire bonded to natural teeth	30	**Yellow**
C	0.012" SS double twisted ligature wirebonded to natural teeth (Custom-made)	30	**Blue**
D	Fiber reinforced composite (Interlig) bonded to natural teeth	30	**Red**

TABLE 1:Acrylic blocks color- coded to represent the four different groups

FIGURE 4: **Groups after bonding orthodontic retainers**

FIGURE 5: **Thermocycler**

The lingual aspects of the teeth were polished with fluoride-free pumice, etched for 30 seconds with 37% ortho-phosphoric acid, rinsed with water for 30 seconds using a three-in-one syringe and dried for 20 seconds using an oil-free air source. A thin coat of primer was applied to the etched tooth surface and cured for 10 seconds using LED curing light. A 10mm length of retainer wires and 10mm×2.0mm×0.2mm for FRC were cut and the midpoint of the retainers were marked with a pencil. The testretainer was then placed on the primed tooth surface. Great care was taken to position the retainer parallel to the base of the mould and below the point of contact between the teeth in the mould using condenser or ball burnisher. The Tetric®-N-Flow composite was applied and cured for 10 seconds with a light emitting diode curing unit. The light curing unit's tip was positioned as near as feasible to the tooth's surface. After curing, the teeth were immersed in distilled water at room temperature for 24 hours before testing.(Figure 4)

All specimens were exposed to thermal cycles between 55°C & 5°C using a thermo-cycling machine, with a dwell time of 60 seconds & a transition time of 15 seconds which simulates a period of six months in the patient’s oral environment. Any failure during the thermocycling process was recorded.(Figure 5)

Following fatigue formation, the specimens were tested for shear bond strength by using Universal Testing Machine (UTM). The embedded specimens were secured in a jig attached to the base plate of an Universal Testing Machine. A chisel-edge plunger was mounted in the movable crosshead of the testing machine and positioned along the occluso-apical axis of the teeth so that the leading edge was aimed perpendicular to the marked midpoint of the retainer. The chisel-edge was carefully positioned to prevent any contact with other parts of the specimen. The crosshead speed was set to 1mm/min and the maximum load necessary to debond the wire was recorded. Eachtooth-bonded retainer assembly is tested once to eliminate the influence of wear. The values for debonding forces were recorded in Newtons from the electronic monitor display in universal testing machine for each tooth-bonded retainer assembly.(Figure 6)

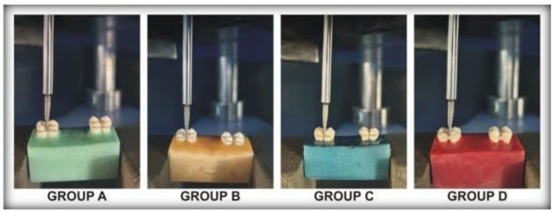


FIGURE 6: Orthodontic bonded retainer under maximum load in Universal Testing Machine

The fracture mode of the retainer was evaluated using Adhesive Remnant Index (ARI) system. The Adhesive Remnant Index (ARI) was employed to evaluate the amount of adhesive resin retained on the enamel surfaces of each tooth in a specimen pair where failure of the bond had occurred (Årtun and Bergl and, 1984). The evaluation of the composite and enamel surfaces in this study was done using a stereomicroscope at ×20 magnification. Since each specimen had two bonding sites, the ARI score for both sites were documented. Subsequently, the data pertaining to the first bond failure was examined. In cases where both bonds failed simultaneously, the lower score was recorded.(Figure 7)

The ARI has a scale range between 0 and 3:

- 0 = no adhesive retained on the enamel (adhesive failure at composite-enamel interface)
- 1 = less than 50% of adhesive retained on the enamel (adhesive failure predominantly at composite-enamel interface)
- 2 = more than 50% but less than 100 % of adhesive retained on enamel (cohesive failure predominantly at the wire-composite interface)
- 3 = all adhesive retained on the enamel with an impression of the wire (cohesive failure at the wire-composite interface)

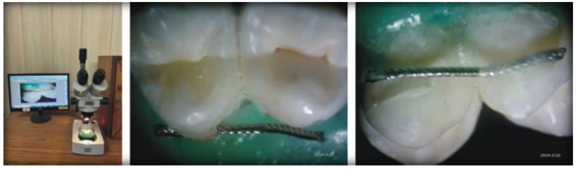


FIGURE 7: GROUP A Orthodontic bonded retainer under Stereomicroscope

The extent of retainer deflection after failure was evaluated by gently removing the composite over the retainer using a tungsten carbide bur, provided that the retainer was not broken in two halves and only bond failure had occurred on either one site or both. The retainer was then placed on a graph paper and an optical stereomicroscope with a ×20 magnification was used to measure its deflection. Millimetres were used to measure the amount of deflection.(Figure 8)

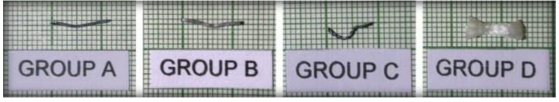


FIGURE 8: Orthodontic bonded retainer positioned on graph paper

STATISTICAL ANALYSIS

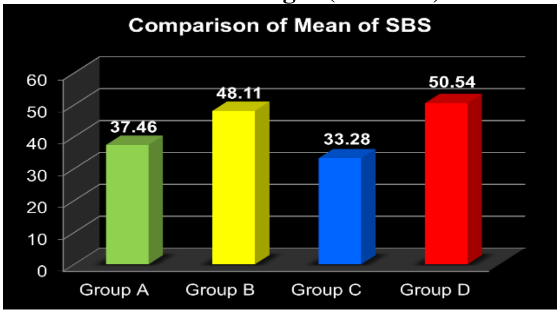
The Shear Bond Strength (SBS) and Adhesive Remnant Index (ARI) of all groups were compiled and statistically examined through Statistical Package for the Social Sciences (SPSS). The descriptive statistics were calculated for mean, range and standard deviation for SBS and ARI. The comparison of SBS among study groups was done using ANOVA and the Chi-square test was employed to assess ARI. Post-Hoc Tukey' s test was performed for multiple comparisons of statistically significant results. a p value ,0.05 was considered Statisticallysignificant.

RESULTS

SBS: In the study, all orthodontic bonded retainers across the four groups demonstrated resilience during thermocycling without any failures. The highest mean shear bond strength of 50.54 ± 2.86N was observed with Fiber Reinforced Composite (Group D), followed by Flat braided multi-stranded SS (Group B) with 48.11 ± 2.60N. (Table 2 & Graph 1)Statistical analysis via ANOVA revealed highly significant differences in shear bond strength among the study groups ($p < 0.05$, $p = 0.00$).

Groups	Mean	Std. Deviation	Std. Error	'P' value	Inference
A	37.46	3.48	0.09	0.00	Highly Significant
B	48.11	2.60	0.67		
C	33.28	3.23	0.83		
D	50.54	2.86	0.73		

TABLE2:Comparison of Shear Bond Strength (Newtons) of all Groups using ANOVA



GRAPH 1: **Comparison of Shear BondStrength Group A, Group B, Group C and Group D in Newtons**

ADHESIVE REMNANT INDEX (ARI)

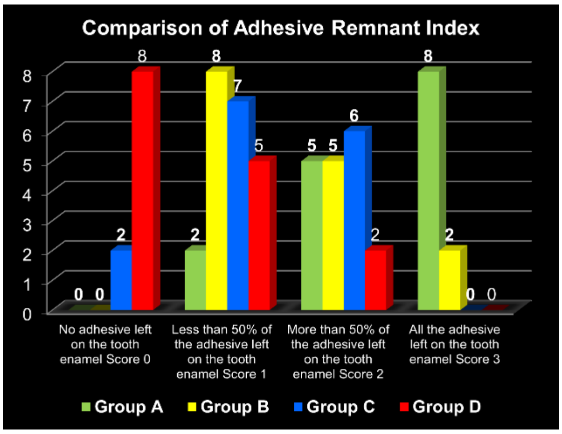
While the ARI scores revealed non-uniform distribution across all groups, with the majority falling under ARI Score 1 that is 36.6% (indicating less than 50% adhesive left on tooth enamel) and ARI Score 2 that is 30.0% (indicating more than 50% adhesive left on tooth enamel), no group exhibited entirely uniform scores.(Table 3& graph 2).The Pearson Chi-square test was used to analyze the ARI scores across the four study groups..The most comparisons revealed no significant variability (p>0.05) in ARI scores across the study groups, Group B and Group D exhibited a potential trend towards differing adhesive remnant index values.(Table 4)

Adhesive Remnant Index (ARI)			Group A	Group B	Group C	Group D	Total
Score 0	No adhesive left on the tooth enamel	Count	0	0	2	8	10
		%	0.00 %	0.00 %	13.4 %	53.3 %	16.7 %
Score 1	Less than 50% of the adhesive left on the tooth enamel	Count	2	8	7	5	22
		%	13.4 %	53.3 %	46.6 %	33.3 %	36.6 %
Score 2	More than 50% of the adhesive left on the tooth enamel	Count	5	5	6	2	18
		%	33.3 %	33.3 %	40.0 %	13.4 %	30.0 %
Score 3	All the adhesive left on the tooth enamel	Count	8	2	0	0	10
		%	53.3 %	13.4 %	00.0 %	00.0 %	16.7 %
TOTAL		Count	15	15	15	15	60

TABLE 3: Frequency and percentage of Adhesive Remnant Index scores of all study groups

Study Group	Comparison Group	Mean Diff.	P value	Inference
A	**B**	0.8	0.914	**Non-Significant**
A	**C**	1.2	0.364	**Non-Significant**
A	**D**	1.8	0.914	**Non-Significant**
B	**C**	0.4	0.621	**Non-Significant**
B	**D**	1	**0.052**	**Significant**

TABLE 4: Comparison of Adhesive Remnant Index scores among study groups using Chi-square test



GRAPH 2: Comparison of ARI scores of Group A, Group B, Group C, Group D

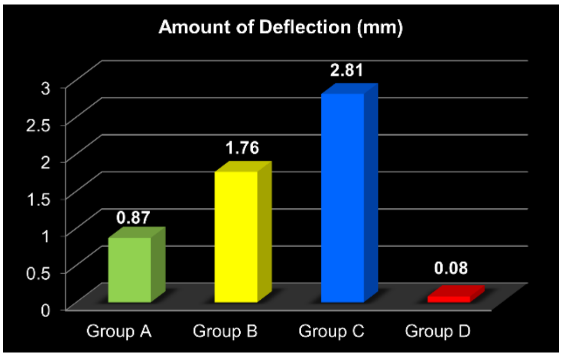
The primary location of cohesive failures was at the wire-composite interface, as indicated by a cumulative 83.3% occurrence of ARI scores 1, 2, and 3 (36.6%, 30.0%, and 16.7%, respectively. In contrast, Group D, using Fiber Reinforced Composite material, exhibited the highest percentage (53.3%) of adhesive failures at the enamel-composite interface.

AMOUNT OF DEFLECTION

The Group C, employing 0.012" SS double twisted ligature wire, showed the highest mean deflection at 2.81 ± 0.24mm. ANOVA analysis showed a statistically significant difference in the degree of deformation among all four study groups ($p < 0.05$, $p = 0.00$).(Table 5 & Graph 3)

Groups	Mean	Std. Deviation	Std. Error	'P' value	Inference
A	0.87	0.075	0.04	0.00	Highly Significant
B	1.76	0.179	0.02		
C	2.81	0.242	0.06		
D	0.08	0.062	0.01		

TABLE5: The Comparison of amount of deflection (millimeters) among the groups using ANOVA



GRAPH 3: **Comparison of amount of deflection (millimetres) of in Group A, Group B, Group C, Group D**

DISCUSSION

Stability is vital throughout orthodontic treatment, including retention, aiming to achieve proper occlusion by repositioning teeth within normal muscle balance. The relationship and integrity of the apical bases play a crucial role in ensuring long-term stability .[15]

Maintaining optimal tooth alignment is essential for oral health and stability. When teeth are in their ideal positions, it facilitates reorganization and adaptation of gum (gingival) and supporting bone (periodontal) tissues, minimizing changes due to ongoing growth and development. This alignment also allows the neuromuscular system—including muscles and nerves—to adjust to new tooth positions, ensuring firm tooth stability and proper contact points between adjacent teeth.

Following orthodontic treatment, the periodontal ligaments undergo prolonged reorganization, not reverting immediately to their normal state while teeth remain rigidly positioned. Allowing each tooth to respond independently to chewing forces is crucial once desired movements are achieved, typically taking 3-4 months. This process reduces residual tooth mobility post-appliance removal. However, slow reorganization of gingival and supracrestal fibers can generate forces leading to potential relapse toward original tooth positions, necessitating extended retention strategies to maintain corrected tooth alignment.[20]

Lingual bonded retainers are commonly used post-orthodontic treatment to prevent relapse, but their efficacy relies heavily on the strength of the bond between the wire and composite material. The primary concern is potential failure due to wire breakage or bond failure, highlighting the critical importance of ensuring robust bond strength for successful retention.[19]

Bonded lingual retainers are designed in various configurations, including combinations of multiple wires differing in size, composition, and physical structure[18]. Multi-stranded round wires are favored for lingual retention due to their interwoven structure, which enhances mechanical retention and accommodates physiological tooth movement effectively. Their resilience to stress fractures contributes to higher success rates in lingual bonded retainers.[25]

Fiber Reinforced Resin Composite (FRC) is a recent advancement in dentistry, involving the incorporation of fibers like polyethylene, aramid, carbon, or glass into resin composites to enhance their strength and durability.[23] This technique is widely utilized across various dental procedures to improve material properties and clinical outcomes.

The effectiveness of FRC retainer systems depends significantly on their intricate internal structure. The resin matrix and adhesive system collaborate to integrate the fibers, creating a cohesive composite. This integrated design allows for the absorption and dispersion of mechanical stresses, thereby enhancing the overall durability and performance of the retainer system.[29]

Fiber Reinforced Resin Composites (FRCs) are used in orthodontics for both active and passive purposes, enhancing anchorage and preserving tooth position after orthodontic treatment. They provide mechanical strength comparable to metal alloys, aesthetic advantages due to fiber translucency, and are biocompatible without containing metals. This makes them particularly suitable for adult patients with metal allergies who desire inconspicuous treatment.[23]

The present in vitro study was conducted to assess the performance of four different varieties of bonded orthodontic lingual retainers based on fatigue resistance, SBS, mode of failure and amount of deflection. A sample of 60 orthodontic bonded lingual retainers were utilized, with 15 samples allocated to each of the four study groups. The study groups were distinguished by the type of retainer material that is Group A: 0.0195" SS coaxial wire with green colour coding; Group B: Flat braided multi-stranded SS wire yellow colour coding; Group C: 0.012" SS double twisted ligature wire with blue colour coding; and Group D: Fiber-reinforced composite with red color coding. The groups were compared and analysed statistically to obtain results.

In this study, maxillary and mandibular premolars were utilized to bond orthodontic lingual retainers. The teeth were embedded in acrylic blocks with their long axes perpendicular to the base, mimicking intraoral conditions for contact area consistency.[2]

Research by Cookie & Sheriff[7] highlighted that factors such as enamel age, lingual morphology, and tooth size influence bonding interface forces. Radlanski & Zain[19] criticized the use of human lower incisors in research due to individual variability based on donor age, a view supported by Goldshah & Simkooei[10] who noted variations in tooth anatomy and mineralization affecting bond strength. To address these concerns, human premolars were chosen for uniform bonding areas in this study, aligning with Bryan & Sheriff'sfindings that larger tooth crowns enhance bonding effectiveness by distributing load over wider enamel areas.[5]

In this in vitro study, all orthodontic bonded lingual retainers across the four groups successfully withstood the thermo cycling process without failure, a positive outcome attributed to the specific properties of the specimens.[1] Thermo cycling assesses whether temperature variations affect the bond strength of lingual bonded retainers.

Similar outcomes were observed in studies conducted by Goldshah & Simkooei[10] and Elsorogy et al. ,[8] where various types of orthodontic bonded retainers underwent thermal cycles simulating six months of oral conditions without experiencing failures. However, these studies noted variations in failure forces and locations among different materials. According to Lie Sam Foek et al.,[13] in vitro studies provide a controlled environment that is easier to manage compared to the complexities encountered in clinical settings. Any discrepancies identified in vitro are likely to be magnified in real-world applications.

In this investigation, we applied vertical force at the midpoint of interdental retainers, creating complex multi-directional forces across both bonding sites in each sample. This method potentially induced horizontal tensile forces. Using a Universal Testing Machine (UTM), we measured the Shear Bond Strength (SBS) of orthodontic bonded retainers under these conditions. This approach provided valuable insights into how well these retainers withstand diverse force applications. The interdental area was selected for force application based on previous studies by Radlanski & Zainand Aldress et al., which demonstrated that bond strength is typically lowest in this specific region.[19,2]

In our study, we reported Shear Bond Strength (SBS) values for four types of orthodontic bonded retainers in Newtons rather than Pascals. This decision was based on findings from research on bracket loading by Katona & Moore,[12] which showed that force distribution across bond surfaces is not uniform.According to Shulz et al. ,[21]orthodontic bonds should withstand forces ranging from 0.5 to 4 Newtons. These forces encompass a spectrum from the minimal forces during chewing to the higher forces required for orthodontic tooth movement within the bone.

In our study, Group D, employing Fiber Reinforced Composite (FRC), achieved the highest Shear Bond Strength (SBS) at 50.54N, followed closely by Group B with 48.11N. The difference in SBS between these groups was not statistically significant. In contrast, Group A, using a 0.0195" stainless steel coaxial wire, exhibited a lower SBS of 37.46N compared to other retainer wires. This disparity is likely due to residual stresses from fabrication and application processes, potentially leading to bond failure at stress points during mastication.[22,24]

Research by Lucchese et al. on Fiber Reinforced Polymer (FRC) versus Stainless Steel (SS) orthodontic retainers supports our findings, showing FRC's ability to withstand higher loads before debonding and exhibiting less deflection compared to stainless steel wire. These studies collectively demonstrate that FRC retainers offer superior mechanical performance compared to traditional stainless steel wires.[14]

Our study corroborates findings by Cacciafesta et al. and Tahmasbi et al. , indicating that Fiber Reinforced Composite (FRC) requires higher debonding forces due to effective reinforcement with long fibers. FRC proves to be a practical alternative to stainless steel wires for bonding dental segments, offering both strength and aesthetic advantages.[6,27]

Regarding Adhesive Remnant Index (ARI) scores across the four groups, results were mostly non-significant ($p > 0.05$), except for Groups B and D ($p = 0.05$). Group D showed the highest enamel-composite adhesive failure rate at 53.3%, with an ARI score of 0, indicating complete adhesive detachment from the enamel. These findings align with Foek et al. and Nagani et al., underscoring adhesive failure as common with FRC retainers.[9,17]In our study, we observed higher ARI scores indicating cohesive failures and lower scores indicating adhesive failures, consistent with findings from various studies.[7,8,28]

Retainer failures typically result from specific issues such as breakage at the wire-composite interface or detachment of resin pads from the enamel-composite interface. Adhesive failure at the enamel-composite interface often stems from inadequate bonding procedures or conditions like widened Periodontal Ligament (PDL) spaces or insufficient bone support .[9]

The selection of Tetric N flow as the standardized adhesive for lingual retainer wires was based on its superior bonding properties and improved polishing characteristics compared to other adhesives and micro-filled composites. This choice was supported by research from various studies highlighting a methodical approach to material selection in dental applications.[26,19]A study by Aksakalli et al. emphasized the importance of prioritizing bond strength when selecting orthodontic bonded lingual retainers, rather than focusing solely on the choice of composite material.[1]

In our study, we used an optical stereo microscope to measure wire deflection by placing the retainer on graph paper, a method akin to that used by Baysal et al.[3] Understanding wire deflection is crucial as it significantly impacts the stability of teeth under functional loads and natural movements. Our findings are consistent with those of Milhero et al., who employed the Finite Element Method (FEM) to analyze retainer debonding. They reported a deflection of 0.6mm for Fiber-Reinforced Composite (FRC) retainers, while twisted ligature retainers showed a higher deflection of 2.9mm. In our study, Group C demonstrated a comparable deflection of 2.8mm.[16]

Fiber Reinforced Composite (FRC) has emerged as a promising alternative to traditional stainless steel retainer wires in dentistry, particularly for anchorage units. Offering superior aesthetics, biocompatibility, flexibility, and bonding capabilities, FRC addresses many drawbacks associated with metal wires. Its corrosion resistance and lighter weight further enhance its appeal, providing both strength and durability alongside aesthetic benefits.

However, FRC presents challenges such as higher costs and increased technique sensitivity compared to conventional retainers. Moreover, FRC retainers may require larger bonding surfaces on teeth than conventional wires, potentially complicating repairs. Additionally, non-self-cleaning areas could contribute to additional periodontal concerns. These factors underscore the need for careful evaluation and selection when considering FRC for dental procedures. Collaboration with a dental professional is essential to assess specific patient needs and treatment goals for making informed decisions.

Our study has limitations due to the difficulty in replicating clinical conditions in vitro accurately. Therefore, caution is needed when applying our findings to practice. Factors like saliva, oral humidity, temperature variations, masticatory forces, tongue pressure, tooth movements, and oral bacteria cannot be fully simulated in the lab.

Additionally, our study did not fully replicate periodontal tissue properties, including their viscoelasticity and dynamics of the periodontal ligament and alveolar bone. We used a limited sample size of teeth, representing a shorter retainer complex compared to typical cases. Furthermore, we focused on one type of fiber reinforced composite for a relatively brief observation period.

Future research should explore a wider range of retainer wires, designs, and bonding techniques to provide deeper insights and improve orthodontic retention strategies

CONCLUSION

The versatility and efficacy of FRC, coupled with its aesthetic appeal, position it as a promising material in this landscape of advancing orthodontic technologies. The disadvantages of FRC include high expense, increased technique sensitivity compared to conventional retainers, larger tooth bonding surface, difficulty in repair and potential contribution to periodontal conditions due to non-self-cleanable areas. However, the choice between FRC and conventional methods should be made in collaboration with a dental expert, taking into account the unique needs and treatment objectives of each patient.

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