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Deflection Load of Different Orthodontic Fixed Lingual Retainers: An *in-Vitro* Study

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ABSTRACT

Background & Objective: Fixed retainer success is reported to increase with passive adaptation of the retainer wire to the tooth surface, reducing saliva contamination during bonding. Flexible wires minimize bond failures by reducing stress concentration inside the bonding compound; therefore, the ideal fixed orthodontic retainer should be passive and semi-rigid. This *in-vitro* study aimed to evaluate the deflection load of different orthodontic fixed lingual retainers, and evaluate the bending properties of a chain type stainless steel fixed retainer comparing it with the other types.

Materials & Methods: Five types of fixed bonded lingual retainers were flat metallic wire (FMW), round metallic wire (RMW), braided chain wire (BCW), and Fiber-reinforced composite with spot (SF) and full (FF) techniques were used to be tested. A three-point bending test was done at 0.1, 0.2, and 0.3 mm, and maximum deflection with an acrylic Frasaco mandibular model. These forces were measured using a Universal Instron testing machine.

Results: The FF retainer showed significantly higher load deflection values than other retainer types at 0.1, 0.2, and 0.3 mm and at the maximum load deflection. On the other hand, there were no significant differences between the remaining types of fixed retainers, except for the significant differences between FMW and RMW, SF groups at 0.2 and 0.3 mm.

Conclusion: The FMW retainer showed the lowest load deflection values, the BCW retainer would be an e xcellent choice for retaining tooth positionas it had an intermediate load deflection values compared with other retainer types; and the FF retainer had the largest values of load deflection.

Keywords: Lingual, Wire, Relapse, Retention, Deflection Load, Chain Type Stainless Steel

1. Introduction

The term "orthodontic retention" refers to keeping teeth in their best aesthetic and functional positions after treatment (1). Lower anterior crowding has been reported to have a higher rate of relapse following orthodontic treatment than other malocclusion-related characteristics (2). Fixed retainers are most frequently utilized throughout the orthodontic retention phase, as a result of their many benefits, including greater aesthetics, the lack of patient cooperation required, effectiveness, and suitability for lifelong retention (3). The metal wires used to create orthodontic splints often come in a variety of sizes, shapes, and diameters (4). The mechanical characteristics of these wires need to be studied in order to better understand whether specific types of retainer wires are to blame for unforeseen tooth movements (5).

The plain (solid) and multistrand wires are the two types of retainer wires that are frequently used in orthodontics. Multistrand wires have a round or rectangular cross-section and are made up of a predetermined number of thin wire sections that have been wound around one another. When compared to simple stainless steel wires, they feature a strong springback and low stiffness (6). Additionally, they have high resilience, which enables them to hold energy that would otherwise evaporate over time as weak forces (7).

Stainless steel retainer wire (Braided) is a type of permanent lingual retainer made of a braided wire that does not need to be bent or shaped to accommodate the anatomy of the lingual surface. This will save the clinician's time to take an impression and shape the permanent retainer on the mold to accommodate the shape of teeth. Stainless steel retainer wire (Braided) is made from a special medical-grade stainless wire, it will not rust or break if applied correctly (8).

About 50 years ago, fiber-reinforced composite (FRC) materials were first employed in dentistry (9). These materials are translucent and have high aesthetic criteria, so patients may favor FRC over metallic fixed retention in some situations due to the greater aesthetic requirements; they have high tensile strength and low extensibility (10). Furthermore, metal can interfere with the quality of a magnetic resonance imaging (MRI), so patients who require one should not wear metallic splints. Additionally, individuals with nickel allergies or sensitivities should not use metallic splints (11).

Fixed retainer success is reported to increase with passive adaptation of the retainer wire to the tooth surface, reducing saliva contamination during bonding (12). Flexible wires minimize bond failures by reducing stress concentration inside the bonding compound (13); therefore, to maintain natural tooth mobility, the ideal -semi fixed orthodontic retainer should be passive and rigid (14). The number of strands of wire, the location of the wires, the diameter of the wire, its flexibility, as well as the bonding strength with composite, are the key determinants of the success of these fixed retainers. Unexpected tooth movements can, however, result from elastic deformation included in the wire during its manipulation and mechanical distortion from masticatory forces (15). Additionally, Zachrisson advises utilizing wire widths that permit physiologic tooth movement, risk-particularly in cases of high periodontal (16). The dimension of the periodontal ligament gap and the amount of supporting alveolar boneare two specific anatomic factors that affect the physiologic tooth mobility,in the periodontal elastic properties of-addition to the visco tissues (17).

Maximum load and rigidity (or bending stress) are two criteria used to assess the lifespan of retainers. The load value in N with the specified magnitude of deflection was used to describe the rigidity of the retainer (18). The three-point bending test has been widely utilized by researchers to assess the mechanical properties of orthodontic wires and to investigate the connection between wire deflection and load. This test is a controlled and standardized testing method that provides a high level of repeatability and allows for comparison with other studies (19).

Previous studies reported the differences in the deflection load for different types of retainers, but they did not study the deflection load of braided chain wire (stainless steel chain retainer wire) and compare it with other types. Therefore, the purpose of the present report was to evaluate the deflection load of different orthodontic fixed lingual retainers and evaluate the bending properties of a chain-type stainless steel fixed retainer by comparing it with the other types. The null hypothesis of the present study was that there were no significant differences among the various groups tested.

2. Materials and Methods

In the current study, flat metallic wire (ORTHO TECHNOLOGY®, West Columbia, USA), round metallic splint (6 strands of coaxial wire) (ORTHO TECHNOLOGY®, Pet Lane Lutz, USA), braided chain wire (stainless steel retainer wire) (International Orthodontic Services, Stafford, USA), and Fiber-reinforced composite Angelus Interlig® types (Angelus Interlig®, Rua Waldir Landgraf, Brazil) were used to be tested (Table 1).

All four types of fixed lingual retainer materials were separated into coded groups of six specimens each (length: 28 mm) (20):

(i) FMW: Flat metallic wire (Braided retainer wire).

(ii) RMW: Round metallic wire (6 coaxial stranded wire).

(iii) BCW: Braided chain wire (stainless steel wire).

(iv) SF: Spot-bonded fiber-reinforced composite.

(v) FF: Full-bonded fiber-reinforced composite.

2.1 Preparation of samples

An acrylic Frasaco mandible model was used to simulate a canine-to-canine splint by bonding all of the specimens to it (21). The acrylic mandibular teeth were rigidly fixed into the appropriate holes (acrylic sockets) with screws to prevent vertical movement of the teeth. The lingual aspect of the six acrylic lower teeth was etched with blue etch (38% Phosphoric acid, "International Orthodontic Services, Stafford, USA") for 30 s, then washed with water, and finally dried (22). A thin uniform coat of the bonding agent was applied by brush (G-Premio Bond) (one component light-cured adhesive) and cured for 10 seconds (23). All four types of coded fixed lingual retainers (flat metallic wire "braided retainer wire", round metallic wire "6 strands coaxial wire", braided chain wire "stainless steel wire", and FRC splints) with 28 mm length were cut and prepared to be in good adaptation on the lingual surface of acrylic teeth from canine to canine (20). Then, fix the cut pieces with G-aenial universal light-cured radiopaque flowable composite. Commercially supplied dome-shaped wire bonder mold tips were used to control the amount of composite glue (Mini-Mold; Ortho-Care Ltd., Bradford, UK) (24, 25). The interproximal portions of the splint were left visible, and the flowable composite covered the retainer only where it lined up with each tooth (the support diameter is approximately 2 mm). Interproximal part of wire at the region between two adjacent bonding spot of lingual surface of two adjacent central incisors (the span length is 3-4 mm apart) that will be overpowered by vertical force in midpoint. On the other hand, in full-bonded FRC splints, composite covering was also carried out in interproximal gaps. Each tooth was given 40 seconds (20 seconds mesially and 20 seconds distally) (26, 27) to undergo light curing on all specimens using 1200 mW/cm2 of light intensity at a wavelength between 430 and 480 nm (20, 28). In the procedures of bonding BCW, it should be made sure that the lingual surface is clean and free of any residue, cut the BCW retainer to the desired length using a straight cutter, etch the lingual surface for 30 seconds, rinse and dry thoroughly. Apply a thin layer of bond and cure for 10 seconds. Apply a thin layer of flowable composite. Place the permanent retainer in place using a plier and position it in the proper vertical position. Note that if the retainer is too flexible for you to handle, you might wet the retainer with a primer to make it less flexible (8). All specimens were prepared by a single operator to reduce variability (Figure 1).

2.2 Deflection load test

The Tinius-Olsen universal testing machine was used to carry out the deflection load test after the bonding procedures using a 5 KN load cell with a crosshead speed of 1 mm/min and a customized chisel rod (25, 29, 30). A special clamping device was utilized to hold the specimen in the lower jaw of the Universal testing machine, and the load was applied vertically on the retainer in the occluso-gingival direction by using a custom-made plunger with a round head of 1 mm in diameter (which was fixed inside the upper arm of the Universal testing machine) until retainer failure occurred (25). The bending force at 0.1, 0.2, and 0.3 mm deflection and at the maximum deflection before the failure occurred (represents wire fracture, debonding, or composite cracking) were registered in computer software that was electronically linked to the Universal testing machine, and the force was recorded in Newton (N) (Figure 2) (27).

Data were submitted for statistical analysis using SPSS version 27. The data distribution was evaluated for normality using the Shapiro-Wilks test, so as to assign the related statistical tests. Descriptive statistics including Mean, Standard deviation, Standard error, Minimum, and Maximum were calculated for all groups. An analysis of variance (ANOVA) was used. A post hoc test was used for the assessment of the significance of differences between pairs (multiple comparisons). A p-value of < 0.01: Highly significant; $P > 0.05$: Non-significance; $0.05 \geq P > 0.01$: Significance. Intraclass Correlation Coefficient (ICC) to evaluate the intra-examiner (0.989) and inter-examiner (0.961) reliability of deflection load variations was excellent reliability.

Table 1. Materials grouping of different types of fixed retainers that were used.

Designation	Flat metallic wire N=6	Round metallic wire N=6	Braided chain wire N=6	Fiber reinforced composite N=6	Fiber reinforced composite N=6
Code	FMW	RMW	BCW	SF	FF
Manufacturer	Ortho-technology®	Ortho-technology®	International Orthodontic Services IOS	Angelus Interlig®	Angelus Interlig®
Name	Braided Retainer Wire	6 coaxial stranded wire	Stainless Steel Retainer Wire (Braided)	Fiber reinforced composite	Fiber reinforced composite
Design	Rectangular 3 stranded	Round 6 stranded	Rectangular	Intertwined scaffold fiber bundle	Intertwined scaffold fiber bundle
Dimensions	0.25 x 0.71 mm	0.44 mm	0.40 x 0.90 mm	2 x 0.2 mm	2 x 0.2 mm
Material	Stainless steel	Stainless steel	Stainless steel	Resin impregnated with glass fibres	Resin impregnated with glass fibres
Bonding technique	Conventional spot	Conventional spot	Conventional spot	Conventional spot	Conventional full

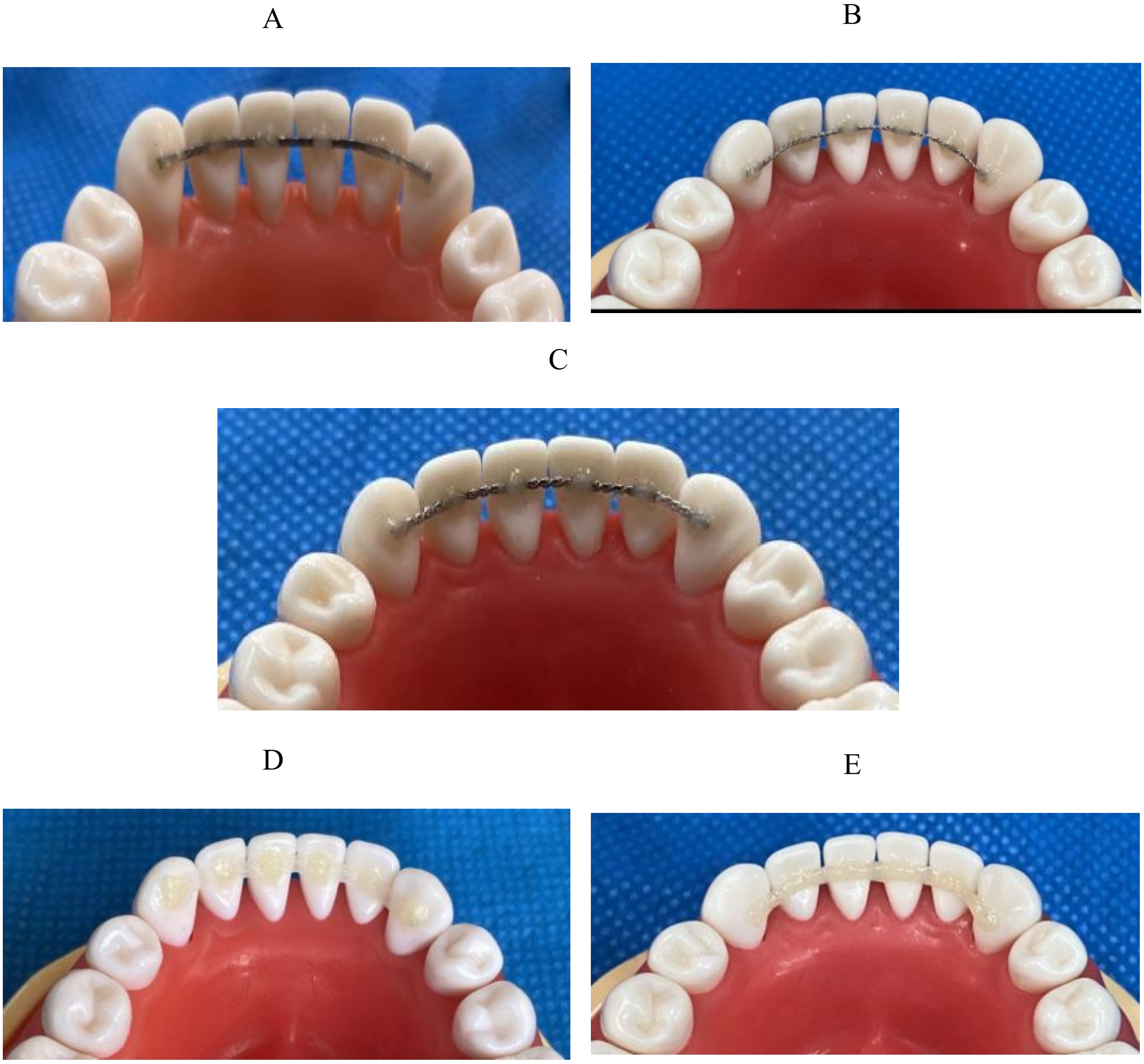

Figure 1. Four types of fixed retainer materials, and five bonding techniques. **A:** Flat metallic retainer wire, **B:** Round metallic retainer wire, **C:** Braided chain retainer wire, **D:** Spot-bonded fiber reinforced composite retainer, **E:** Full-bonded fiber reinforced composite retainer (**Prepared by Authors, 2025**).

Figure 2. Deflection load test (the bending force in the loading cell) (**Prepared by Authors, 2025**).

3. Result

The descriptive statistics (mean, standard deviation, standard error, minimum, and maximum) were performed for the five types of fixed retainer wires (FMW, RMW, BCW, SF, and FF) at 0.1, 0.2, and 0.3 mm and maximum load deflection. The load values of all tested samples were expressed in Newton (N) as shown in Table 2, Figure 3. At 0.1mm deflection, the FF showed higher mean values of load than the other retainer wires; the FMW and BCW showed intermediate load values; and the RMW and SF showed the lowest values of load (Figure 3.A). At 0.2 mm deflection, the FF showed higher mean values of load than the other retainer wires, the FMW retainer wire showed the second value after the FF; the BCW showed an intermediate value; and the RMW and SF showed the lowest values (Figure 3.B). At 0.3 mm deflection, the FF showed higher mean values of load than the other types of retainers; the second highest values were the FMW and BCW, the RMW and SF showed the lowest values (Figure 3.C). At maximum deflection, the FF showed higher mean values of load than the other retainer types; the second values were the BCW and RMW; the FMW showed an intermediate value; and the SF showed the lowest values (Figure 3.D).

Inferential statistics included the comparison of the mean load values (N) within groups that were determined using One-way analysis of variance (ANOVA) as presented in Table 2, indicating that there was a highly significant difference between all types of fixed retainers ($P < 0.01$).

The Post-hoc Tukey's HSD test of the mean load values (N) at 0.1 mm deflection between different fixed retainer types revealed that there were highly significant differences ($P<0.01$) between FF and FMW, RMW, BCW, and SF retainer types, and there were no significant differences ($P> 0.05$) between the remaining retainer types (Table 3).

The Post-hoc Tukey's HSD test at 0.2 mm deflection between different fixed retainer types revealed that there were highly significant differences ($P<0.01$) between FF and FMW, RMW, BCW, and SF retainer types, furthermore there were significant differences ($0.05 \geq P > 0.01$) between FMW, and RMW and SF groups, while there were no significant differences ($P> 0.05$) between the remaining groups (Table 4).

The Post-hoc Tukey's HSD test at 0.3 mm deflection between different fixed retainer types revealed that there were highly significant differences ($P< 0.01$) between FF and FMW, RMW, BCW, and SF groups, furthermore there were significant differences ($0.05 \geq P > 0.01$) between FMW and RMW, and SF groups, while there were no significant differences ($P> 0.05$) between the remaining fixed retainer types (Table 5).

The Post-hoc Tukey's HSD test of the mean load value at maximum deflection between different types of fixed retainers revealed that there were highly significant differences ($P < 0.01$) between FF and FMW, RMW, BCW, and SF groups, on the other hand there were non-significant differences ($P > 0.05$) between the remaining types of fixed retainers (Table 6).

Table 2. Descriptive statistics (N) of mean load deflection values at 0.1, 0.2, 0.3 mm and maximum load and ANOVA test.

No.	Code	Deflection	Mean	SD	SE	Min	Max	ANOVA	
								F	Sig
1	FMW	0.1	10.00	1.90	0.77	8.00	13.00	**8.593**	**0.001****
2	RMW	0.1	8.17	1.72	0.70	6.00	11.00		
3	BCW	0.1	9.00	1.55	0.63	7.00	11.00		
4	SF	0.1	8.00	1.79	0.73	5.00	10.00		
5	FF	0.1	13.00	1.55	0.63	11.00	15.00		
6	FMW	0.2	15.50	1.38	0.56	14.00	17.00	**11.200**	**0.001****
7	RMW	0.2	12.17	2.86	1.16	8.00	16.00		
8	BCW	0.2	14.17	2.99	1.22	12.00	18.00		
9	SF	0.2	12.17	3.25	1.32	7.00	16.00		
10	FF	0.2	20.83	2.14	0.87	18.00	23.00		

11	FMW	0.3	21.33	2.07	0.84	19.00	24.00	**18.317**	**0.001****
12	RMW	0.3	17.00	3.22	1.31	13.00	21.00		
13	BCW	0.3	20.00	3.95	1.61	17.00	26.00		
14	SF	0.3	16.00	3.85	1.57	10.00	20.00		
15	FF	0.3	30.83	3.43	1.40	27.00	35.00		
16	FMW	Max load	50.67	7.79	3.25	40.00	60.00	**30.883**	**0.001****
17	RMW	Max load	63.50	17.34	7.08	45.00	88.00		
18	BCW	Max load	72.00	15.40	6.29	50.00	85.00		
19	SF	Max load	39.17	4.58	1.87	35.00	44.00		
20	FF	Max load	201.67	60.27	24.61	107.00	271.00		

**P < 0.01: Highly significance.

Table 3. Multiple comparison (Post-hoc Tukey's test) of the mean load value at 0.1 mm deflection between different types of fixed retainers.

Materials grouping	Materials grouping	Mean Difference	P-value
FMW	RMW	1.83	0.075
	BCW	1.00	0.320
	SF	2.00	0.053
	FF	-3.00	0.005**
RMW	BCW	-0.83	0.406
	SF	0.16	0.867
	FF	-4.83	0.001**
BCW	SF	1.00	0.320
	FF	-4.00	0.001**
SF	FF	-5.00	0.001**

**P < 0.01: Highly significance. P > 0.05: Non-significance.

Table 4. Multiple comparison (Post-hoc Tukey's test) of the mean load value at 0.2 mm deflection between different types of fixed retainers.

Materials grouping	Materials grouping	Mean Difference	P-value
FMW	RMW	3.333	0.037*
	BCW	1.333	0.385
	SF	3.333	0.037*
	FF	-5.333	0.002**
RMW	BCW	-2.000	0.197
	SF	0.000	1.000
	FF	-8.666	0.001**
BCW	SF	2.000	0.197
	FF	-6.666	0.001**
SF	FF	-8.666	0.001**

**P < 0.01: Highly significance. * 0.05 ≥ P > 0.01: Significance. P > 0.05: Non-significance.

Table 5. Multiple comparison (Post-hoc Tukey's test) of the mean load value at 0.3 mm deflection between different types of fixed retainers.

Materials grouping	Materials Grouping	Mean Difference	P-value
FMW	RMW	4.333	0.035*
	BCW	1.333	0.500
	SF	5.333	0.011*
	FF	-9.500	0.001**
RMW	BCW	-3.000	0.136
	SF	1.000	0.612
	FF	-13.833	0.001**
BCW	SF	4.00	0.060*
	FF	-10.833	0.001**
SF	FF	-14.833	0.001**

**P < 0.01: Highly significance. * 0.05 ≥ P > 0.01: Significance. P > 0.05: Non-significance.

Table 6. Multiple comparison (Post-hoc Tukey's test) of the mean load value at maximum deflection between different types of fixed retainers.

Materials grouping	Materials grouping	Mean Difference	P-value
FMW	RMW	-12.833	0.453
	BCW	-21.333	0.217
	SF	11.500	0.501
	FF	-151.000	0.001**
RMW	BCW	-8.500	0.618
	SF	24.333	0.161
	FF	-138.166	0.001**
BCW	SF	32.833	0.063
	FF	-129.666	0.001**
SF	FF	-162.500	0.001**

**P < 0.01: Highly significance. P > 0.05: Non-significance.

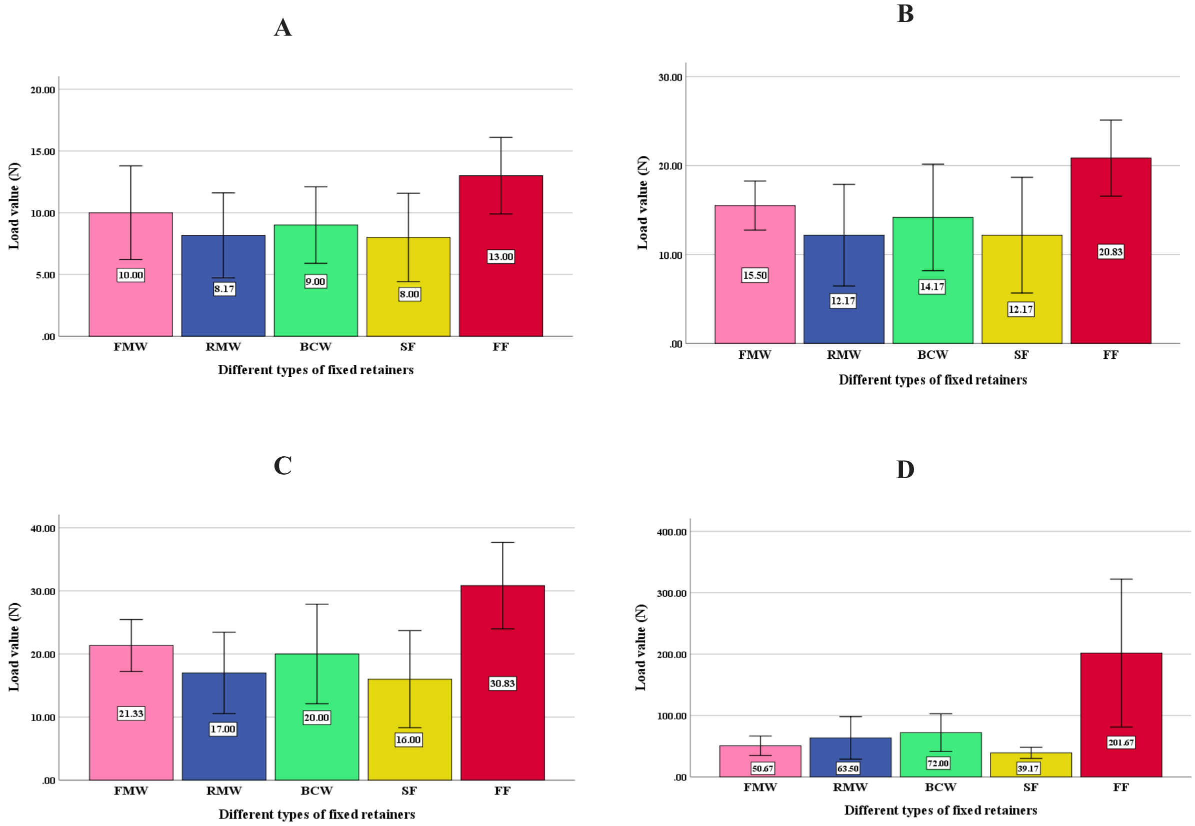

Figure 3. The mean load value (N) at: A- 0.1 mm,B- 0.2 mm, C- 0.3 mm, D- Maximum load deflection for different types of fixed retainers (**Prepared by Authors, 2025**).

4. Discussions

The null hypothesis of the present study has been rejected, there were significant differences between the deflection load values of different types of fixed retainers.

The results of the present study of the load values of stainless steel retainers (FMW, RMW) at 0.1, 0.2, and 0.3 mm can come in agreement with (31) who stated that the load values between metal retainers were near each other, this was also expected and consistent with the findings of (20) who discovered very slight changes between metal wires in this regard.

According to the maker of the flat braided wire (FMW), using it for intra-arch splinting reduces torque control issues that could occur when round braided wires are utilized. They also claimed that the flattened wire was more comfortable for the patient. Multistranded retainer wires (FMW, RMW) had been characterized as very elastic and very resilient (32), enabling natural movement of the teeth as well as a design that provided excellent mechanical retention of the material (33).

A braided chain wire is a type of permanent lingual retainer made of a braided wire that does not need to be bent or shaped. It was the first research that studied the load deflection of such a retainer; therefore, it was selected in the current study to compare its mechanical properties with those of another stainless steel wire and fiber-reinforced composite with both spot and full techniques.

However, International orthodontic services (IOS) had designed retainer with three unique features its that characterized it from other stainless steel retainers; higher flexibility; note how the wire edge is more rounded, allowing more flexibility; and on the other hand, the higher flexibility will help for better adaptability to the Higher impact teeth. anterior lingual surface of most forces absorb strength gives the retainer more power to and resist breakage, and a higher polished surface to minimizesplaque buildup.

The results of the current study of the load values of BCW were close to the results of FMW at 0.1, 0.2, and 0.3 mm load deflections; nevertheless, the result at the maximum load deflection before debonding failure occurrence had a higher value that that with the BCW, which had a higher impact strength, whichg avethe forces and resist breakage absorb retainer more power to. These results came back for a reason of deferred nature of materials and the large diameters of the BCW.

On the other hand, the BCW retainer showed lower mean values of load at different load deflections (0.1, 0.2, and 0.3 mm, and at the maximum load deflection) than that of FF due to the higher rigidity of FF acquired from full coverage of composite. BCW showed higher results than that of RMW and SF, which went back to the excellent strength of BCW as it was made from a special grade stainless wire-medical, i.e., BCW had higher rigidity and strength than that of the RMW and SF retainer types. The cross section of BCW would reduce the torque control issues that can occur when round braided wires are utilized, i.e., resampling the FMW in this feature.

The FF retainer showed significantly higher load deflection values than other retainer types at 0.1, 0.2, and 0.3 mm and at the maximum load deflection, therefore, the full-bonded technique (FF) significantly increased FRC rigidity. On the other hand, there were no significant differences between the remaining types of fixed retainers, except for the significant differences between FMW and RMW and the SF groups at 0.2 and 0.3 mm.

FRCs were thought to be the final major frontier in orthodontic materials. Because of their aesthetics and strength, as well as their ability to adapt their properties to the needs of the orthodontist, FRCs were predicted to replace metals in orthodontics. FRCs, without a doubt, present significant abilities in biomechanics and have the potential to transform orthodontic practice (34).

Earlier studies that assessed the strength properties of FRCs found substantial load values even at low deflections; these were corroborated in the current investigation for FF when evaluating the values obtained at low deflections and at maximum load (18, 20). The present investigation's report of high load values for FF is a confirmation of earlier studies that revealed the high rigidity of FRC splints when compared with metallic splints (18), and the spot technique of FRC (34). As a result, FF demonstrated strong stiffness even at low deflections, but SF (as FMW, RMW, and BCW) demonstrated high load values only at maximum load, this could be regarded as a promising result in terms of enhancing FRC splints, letting them behave more like metallic retainers than standard FF retainers, this is in agreement with (20). In fact, physicians dislike excessive rigidity when splinting a set of teeth because it reduces physiologic tooth movement, which increases the incidence of ankylosis (35). The spot-bonded technique's (SF) low bend values observed in this research seem promising for lowering FRC rigidity.

The SF retainer had lower load deflection values than the FF retainer, as previously reported (20, 36). The current findings are consistent with prior research, indicating that the maximum load of SF displayed intermediate values between the typical FF technique and metal splints. Lastly, the functional safety of FRC splints has been demonstrated in numerous clinical applications (37). FRC materials, on the other hand, demonstrated enhanced fatigue tolerance as compared to metals and may provide a solution to the problem of metal fatigue (38).

A canine to canine fixed retainer inhibits lingual movement of the incisors and is also reasonably successful in preserving incisor rotation correction, this retainer is made of thick wire to withstand distortion caused by a long inter-canine distance. Retainers should be flexible enough to allow for natural tooth movement without failure or debonding. Reynolds believed that orthodontic attachments could withstand 5-8 MPa in strength.

The deflection of the retainer is the most significant clinical characteristic because it should be able to maintain the teeth while responding to functional stress and associated physiologic tooth movement, this implies that retainers fail due to fatigue mechanisms rather than direct overload.

The BCW retainer was an excellent choice for retaining tooth positionas it had excellent torsional strength as well as tensile strength when compared with other retainer types, i.e., it would not rust or break if applied correctly. Moreover, the BCW does not need to be bent or shaped to accommodate the anatomy of the lingual surface as it is flexible, i.e., it take less time in the bonding procedure. Clinically, it improved patient comfort as it layflat against the bonded teeth and had a highly polished surface to minimize plaque buildup.

Clinical relevance of stiffness measurement to properly interpret the measured stiffness values, it is essential to compare them with the physiological tooth mobility range, which is approximately 0.1 mm under normal functional loading. This comparison provides a meaningful clinical context for understanding whether a tested retainer system behaves within the limits of natural tooth movement. If the deflection observed in the in-vitro model substantially exceeds 0.1 mm, the retainer may be considered insufficiently rigid and could permit unwanted tooth movement in vivo. Conversely, an overly stiff retainer that restricts movement below the physiological limit may impair the natural periodontal ligament function or increase stress concentrations at the adhesive interfaces. Therefore, aligning laboratory stiffness data with physiological tooth mobility helps clarify the practical implications of material rigidity and ensures that the tested design maintains an appropriate balance between flexibility and stability. When compared FRC splints to conventional multistranded metallic wires, clinical reliability of it had been reported, with many clinical applications and acceptable failure rates.

The SF showed close results to the RMW, so the SF retainer type can be used as an alternative to stainless steel retainer wire in cases of hypersensitivity to nickel and other metals and provide excellent aesthetic results. Furthermore, the spot-bonded technique's (SF) showed low bend values in this research, so it seems promising for lowering FRC rigidity, which subsequently will decrease the incidence of ankylosis.

Suggestions for future studies

1. Conducting the same study but using acyclic loading test instead of the bending test.

2. Performing other studies on the mechanical properties of the same retainer wire in wet conditions (such as using artificial saliva to assess the effect of the oral environment).

3. Investigation of the effect of various commercially available fluoride-containing products (toothpaste, mouthwashes, etc.) on the bending properties of different lingual wire retainers.

4. It is important to study the alterations in the mechanical properties of aged retainers, since the incisors are more susceptible to retainer bonding failure and relapse after orthodontic treatment.

5. Conclusion

The FMW retainer showed the lowest rigidity compared to other retainer types in the current study. The RMW retainer showed intermediate rigidity, which was enabledfor natural movement of the teeth ,as well as a design that provided excellent mechanical load deflection of the material. The BCW retainer would be an excellent choice for retaining tooth positionas it has an intermediate load deflection values compared with other retainer types. BCW does not need to be bent or shaped to accommodate the anatomy of the lingual surface as it has high flexibility, i.e., it takes less time in bonding procedures. BCW may offer intermediate rigidity beneficial for clinical applications, but further in-vivo testing is required. The SF showed close results to the RMW, so the SF retainer type can be used as an alternative to stainless steel retainer wire. The FF had the largest values of load deflection and maximum deflection at debonding failure occurrence from acrylic teeth; therefore, it should be used with caution due to its high rigidity, which could have a negative effect on the periodontal tissues.

6. Declarations

6.1 Acknowledgments

The authors thank the team in the laboratory at the College of Materials Engineering at the University of Babylon.

6.2 Ethical Considerations

Not applicable.

6.3 Authors' Contributions

Al-Khatieeb designed the study, performed the statistical analysis. Hussein collected the data, drafted the manuscript. All authors reviewed and approved the final version of the manuscript.

6.4 Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this study.

6.5 Fund or Financial Support

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6.6 Using Artificial Intelligence Tools (AI Tools)

The authors were not utilized AI Tools.

7. Publisher's Note

This article is part of the Special Issue arising from the Second International Conference for Pharmaceutical Sciences (SICPS 2025), College of Pharmacy, University of Misan, Iraq (29 Nov – 1 Dec 2025, see https://uomisan.edu.iq/pharmacy/conference/). All manuscripts in this issue were peer-reviewed and accepted for publication in *Journal of Advances in Medical and Biomedical Research (J Adv Med Biomed Res)*.

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