



## Maximum Deflection Level of Different Orthodontic Fixed Lingual Retainers at Failure Occurrence

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### Keywords:

retention, fixed retainer, maximum deflection, debonding failure.

### Article Info.:

#### Article History:

Received: 23/10/2023

Received in revised form:  
1/11/2023.

Accepted: 5/11/2023

Final Proofreading: 5/11/2023

Available Online: 1/12/2024

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**Citation:** Hussain NA, AL-Khatieeb MM. Maximum Deflection Level of Different Orthodontic Fixed Lingual Retainers at Failure Occurrence. (An in vitro Study). Tikrit Journal for Dental Sciences 2024; 12(2): 399-409.

<https://doi.org/10.25130/tjds.12.2.15>

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### Abstract

This in-vitro study aimed to evaluate the maximum deflection level of different orthodontic fixed lingual retainers at debonding failure occurrence. Four types of fixed-bonded lingual retainers: fiber-reinforced composite with spot and full techniques (SF,FF), braided chain wire (BCW), round metallic wire (RMW), and flat metallic wire (FMW) were used to be tested. A three-point bending test was done to measure the maximum deflection with an acrylic Frasco mandibular model. These values were measured using a Universal Instron testing machine. Mean deflection were statistically treated by ANOVA and post hoc Tukey's test. The FF showed the highest mean values of the maximum deflection at debonding failure than the other retainer types, followed by the RMW, BCW, and SF respectively, while the FMW showed the lowest value of the maximum deflection of the retainer type at debonding failure occurrence from acrylic teeth. There were highly significant differences ( $P \leq 0.01$ ) between FMW and RMW, BCW, and FF, and between RMW and SF, and between SF and FF types; on the other hand, there were significant differences ( $P \leq 0.05$ ) between SF and FMW and BCW, while there were non-significant differences ( $P > 0.05$ ) between RMW and BCW, and FF groups. The FF retainer type was less flexible, while the SF retainer had a strong bending resistance. The BCW wire had higher impact strength, which gives the retainer more power to absorb forces and resist breakage. The RMW retainer type showed high rigidity. The FMW retainer had the least rigidity, which can be attributed to its dead-soft nature.

## **Introduction:**

One of the most popular strategies to prevent relapse is retention. There have been many different retention methods deployed. According to (1), the fixed retainer design is aesthetically pleasing and can be manufactured from multistrand wire, may be bonded with resin to the six anterior teeth, the six anterior teeth and the second premolars, when the first premolars have been extracted, or just to two teeth: the right and left canines in the same arch (2); however, a variety of materials and patterns can be used to create them. The number of retention failures brought on by using the incorrect bonding technique, the kind of material used for this purpose, and/or because of the direct wear or stress of the retainer could be blamed for the rise in the rate of post-orthodontic irregularity (2-4).

There is a retention period of therapy after orthodontic treatment (5). The retention phase is the time after orthodontic treatment when the periodontium remodels as a result of the skeletal and dental alterations, this process is completed throughout time by the many components that make up the periodontium. Reorganization of the periodontal ligament, for example, takes three to four months. The supracrestal fibers stay deviated for more than 232 days, and the gingival collagen-fiber network takes 4 to 6 months to repair (6). The retention phase is often thought to be completed within a year of concluding therapy (7). Newly positioned teeth must be given enough time for the surrounding bone and tissue to identify them.

It has been demonstrated that when teeth are shifted, the alveolar bone and periodontal ligament (PDL) around them change, and a significant amount of time must pass before the entire reorganization takes place (6). Given the numerous variables, including patient compliance, the length of the retention period, the appliance design, and whether or not the patient was growing, it is challenging to conclude that stability would increase with prolonged retention (8).

Flexible wires minimize bond failures by reducing stress concentration inside the

bonding compound. Unwanted tooth movements can; however, result from elastic deformation included into the wire during its manipulation and mechanical deformation from masticatory forces. The clinical counterpart of the modulus of elasticity, the deflection value, is a property of the alloy used to make the wires and governs their flexibility. Extremely high deflection wires place enormous stresses on teeth, and as teeth move, their strength rapidly declines (9).

Previous research noted the variations in the deflection level for various types of retainers, but it did not examine or contrast the deflection level of braided chain wire (stainless steel chain retainer wire) with other types. Therefore, the current report's goal was to assess the maximum deflection value of several fixed lingual retainers for orthodontic use and the deformation characteristics of a chain-type stainless steel fixed retainer by contrasting it with the other types. The present study's null hypothesis stated that there were no significant differences between the various groups that were going to be investigated.

## **Materials and Methods:**

A- Retainer materials:

Four different retainer materials were used for comparison:

1- Fiber-reinforced composite Angelus Interlig types (Angelus Interlig, Rua Waldir Landgraf, Brasil) as shown in (figure 1) and (table 1).

Angelus Interlig, a braided glass fiber soaked with light-cured composite resin, is used to temporarily stabilize teeth for orthodontic or periodontal treatment, when teeth are lost owing to periodontitis, pre-surgical splinting, strengthening the construction of fixed prostheses, making intraradicular cores, and preserving space in primary or permanent teeth, for the support of acrylic structures (temporary, complete prostheses), as well as the support of substantial composite resin restorations.

The intertwining of the glass strands makes it easier for the dentist to use them, and they are more malleable than polyethylene threads. Interlig can be cut

with any cutting tool; special tools are not necessary (10).

Pre-impregnation makes materials easier to handle and strengthens the bond between the composite resin and the glass fibers. High aesthetic quality is made possible by the translucency of Interlig fibers and the resin matrix. Interlig fibers have a strong bending resistance due to their structural makeup and processing for dental use, making them suitable for a variety of clinical settings (11).

2- Braided chain wire BCW (Stainless Steel Retainer Wire "Braided") (International Orthodontic Services, Stafford, USA) as shown in (figure 2) and (table 1).

BCW is a type of a 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. The width of the wire is 0.90 mm, and the thickness is 0.40 mm (International Orthodontic Services, Stafford, USA) (Figure 2).

3- Round metallic wire (ORTHO TECHNOLOGY, Pet Lane Lutz "Florida", USA) as shown in (figure 3) and (table 1).

Six Strands Coaxial Wire is a bonded lingual retainer wire, made from six flattened coaxial stainless steel strands rectangular wire. Diameter of wire is 0.44 mm (ORTHO TECHNOLOGY, Pet Lane Lutz "Florida", USA).

4- Flat metallic retainer wire (ORTHO TECHNOLOGY®, West Columbia, USA) as shown in (figure 4) and (table 1).

The flat metallic retainer wire is a very thin braid rectangular wire that may be adjusted without interfering with the occlusal surface thus ensuring patient comfort. It is used to create permanent fixed lingual retainers after orthodontic treatment, this three-strand, stainless steel retainer wire is heated, or "dead soft," so it can be easily molded and maintains bends to create bondable lingual retainers.

It eliminates unintentional tooth movement associated with active force wires. Made in the USA. The diameter of wire is 0.010" (0.25mm) depth x 0.028" (0.71mm) width x 6" (152.4mm) length (Figure 4).

**B- Materials used in the bonding procedure:**

1- G-aenial™ Universal Flo light cured radiopaque flowable composite "(syringe 3.4g (2mL)" (GC CORPORATION, TOKYO, JAPAN).

G-aenial™ Universal Flo is the next development in the field of flowable composites. In the past, dentists had to forgo durability and aesthetics in order to enjoy the flowable's easy handling. It is devoid of bis-GMA.

2- G-Premio Bond (one component light-cured adhesive) (GC CORPORATION, TOKYO, JAPAN).

All etching modes are compatible with the one-bottle universal bonding agent G-Premio BOND. Direct adhesive as well as repair and oversensitivity treatment are both possible uses. Additionally, GC wishes to provide this variety and ease of usage without compromising the bond's integrity (GC CORPORATION, TOKYO, JAPAN).

3- Blue Etch (38% Phosphoric Acid) (International Orthodontic Services, Stafford, USA) .

## **Methods:**

The acrylic mandibular teeth were fixed into an acrylic Frasco mandibular model (12). The lingual surface of the six lower teeth was treated with a thin uniform coat of the bonding agent, it was applied by a brush (G-Premio Bond) (one component light-cured adhesive) and cured for 10 seconds (13). All four types of fixed lingual retainers (flat metallic retainer wire, round metallic wire "6 strands coaxial wire", braided chain wire "stainless steel wire", and FRC splints) were prepared to be fixed on the lingual surface of acrylic teeth with G-aenial universal light-cured radiopaque flowable

composite. The flowable composite covered the wire only where it came to contact with each tooth, except in the full-bonded FRC splints, where the composite covered the entire splint. Each tooth was given 40 seconds (20 seconds mesially and 20 seconds distally) to undergo light curing on all specimens (14,15) as shown in (figure 5).

The universal testing machine was used to carry out the test after the bonding procedures with a crosshead speed of 1 mm/min and a customized chisel rod (16,17,18). The specimen was held in the lower jaw of the testing machine using a special clamping device. The load was applied vertically on it in the occluso-gingival direction roughly at the interface by using a custom-made plunger with a round head of 1 mm in diameter (fixed inside the upper arm of the Universal testing machine) (19) until the retainer failed occurred. The maximum deflection at the failure occurred were registered in computer software that was electronically linked to the Universal testing machine as shown in (figure 6).

#### Statistical analysis:

Data were submitted to statistical analysis using computer software (Statistical Package of Social Sciences) (IBM company, Chicagos, USA). The following statistics were used for this study: Descriptive statistics including: Mean, Standard deviation, Minimum, Maximum, and tables and figures. Inferential statistics including:

- A. Shapiro-Wilk test: To determine whether the data are normally distributed.
- B. One-way ANOVA test: To determine whether there are any statistically significant differences between measured variables among all groups.
- C. Post hoc Tukey's HSD test: To assess the significance of differences between pairs.

In the statistical analyses, the following levels of significance are considered: Non-significant:  $P > 0.05$ . Significant:  $0.05 \geq P > 0.01$ . Highly significant:  $P \leq 0.01$ .

#### Results:

Descriptive statistics of the maximum deflection (mm) of the retainer materials at debonding failure occurrence from acrylic teeth which included mean, minimum, maximum, standard deviations, and standard errors, were carried out for the five different fixed retainer wire types at the maximum deflection where the occurrence of debonding failure from acrylic teeth. The FF showed highest mean values of the maximum deflection than the others retainer' types, then the RMW, BCW, and SF respectively, while the FMW showed the lowest value of the maximum deflection of the retainer type at debonding failure occurrence from acrylic teeth as shown in (table 2) and (figure 7).

The comparison of mean differences of maximum deflection within groups were determined using One-way analysis of variance (ANOVA), indicating that there were a highly significant difference ( $P < 0.01$ ) between the five types of fixed retainers as shown in (table 3).

The Post-hoc Tukey's HSD test revealed that there were highly significant differences between FMW and RMW, BCW, and FF, and between RMW and SF, and between SF and FF types; on the other hand, there were significant differences ( $P \leq 0.05$ ) between SF and FMW and BCW, while there were non-significant differences between RMW and BCW, and FF, and between BCW and FF groups as shown in (table 4).

#### Discussion:

The current study's null hypothesis was disproved since there were significant variations in the maximum deflection values of several fixed retainer types using F test analysis of variance.

The FF showed highest mean values of the maximum deflection at the debonding failure than the other retainer types, then the RMW, BCW, and SF respectively, while the FMW showed the lowest value of the maximum deflection of the retainer type at debonding failure occurrence from acrylic teeth as shown in (table 1) and (figure 7).

The result of the FF group showed highest mean values of the maximum deflection at

debonding failure occurrence from acrylic teeth than the other retainer types, this would be in agreement with Kadhum and Alhuwaizi (2021) (19) who reported that the larger the composite diameter, the less flexible the wire gets, and the smaller the generated stresses in the retainer. Furthermore, the SF retainer showed lower deflection value than FF group but higher than FMW group due to their structural makeup, that Pre-impregnation makes materials easier to handle and strengthens the bond between the composite resin and the glass fibers, therefore had a strong bending resistance making them suitable for a variety of clinical settings.

RMW had greatest maximum deflection before failure occurrence after FF group, which can be attributed to its high ductility resulting from its coaxial six-stranded design. The design of round cross-sectional wire with composite bonding spots would allow of good oral hygiene measures, especially with the use of floss threaders, thus result was in agreement with Milheiro *et al.*, (2015) (20) and Kadhum and Alhuwaizi (2020) (21).

The result of maximum deflection before failure occurrence of RMW (1.30 mm) was in agreement with the result of the study done by Cooke *et al.* (2010) (22) due to the use of the same type and diameters of wire; otherwise, the result of FMW was in disagreement with this study because they used the same type of wire but with different diameters (0.016 \* 0.022 inch, the result would be 1.51 mm in the Cooke *et al.* Study (22)), i.e., the maximum deflection of the same stainless steel wire increases with the incrementing the width of it as the loading force across was increasing.

BCW retainer showed intermediate maximum deflection of the retainer materials at debonding failure occurrence, despite having a similar design as the FMW, this was due to that the higher impact strength, that gives the retainer more power to absorb forces and resist breakage, this feature is considered as a merit for this type of retainer over other type of retainers that were used in the current study.

On the other hand, The FMW retainer had the least maximum deflection at

debonding failure occurrence from acrylic teeth, which can be attributed to many factors: first the dead-soft nature, secondly, the flat design, which would have enhanced rigidity when the bending force is across the wider aspect (23), and finally stress accumulation that occurs in the composite bonding spots due to the thin edge, this was in agreement with Samson *et al.*, (2018) (9).

### Clinical considerations:

The teeth have limited mobility in the clinical setting, which is presumably less than 0.6 mm (the lowest value of deflection at failure in this investigation), which can be different from the clinical situation.

Since the retainer should be able to keep the teeth while responding to physiological stress and accompanying biologic tooth movement, its deflection is the most important clinical attribute. This suggests that retainers fail owing to fatigue mechanisms rather than direct overload. Nonetheless, it is worth noting that the in vivo and in vitro results are consistent, i.e. the FMW retainers with the lowest deflection at debonding failure that would be 0.62 mm as shown in (table 1) which performed clinically much worse than the other wires that were used in the current study.

Clinical reliability of FRC splints has been established, with several clinical uses and acceptable failure rates as compared to traditional multistranded metallic wires. Retainers should be flexible enough to allow for natural tooth movement without failure or debonding.

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 (SF) showed lower value than FF in this research, so it seems promising for lowering FRC rigidity, which subsequently will decrease the incidence of ankylosis.

Clinically, the fact that the BCW fitted flat against the bonded teeth and had a highly polished surface to reduce plaque

development improved patient comfort. Since the BCW is flexible, it does not need to be bent or curved to accommodate the anatomy of the lingual surface, taking less time during the bonding process.

### Conclusion:

- 1- The FF retainer type was the less flexible wire, and the least generated stresses in the retainer so it dose not used as retainers to avoid the ankylosis of teeth.
- 2- The SF retainer had a strong bending resistance making them suitable for a variety of clinical settings over other retainers types.
- 3- The BCW wire had higher impact strength, which gives the retainer more power to absorb forces and resist breakage.
- 4- The RMW retainer type showed high rigidity resulting from its coaxial six-

stranded design so it be less useful as retainers to avoid the possibility of teeth ankylosis.

5- The FMW retainer had the least maximum deflection at debonding failure occurrence from acrylic teeth which can be attributed to the dead-soft nature this indicate the high flexibility of wire.

### Conflicts of interest:

There are no conflicts of interest.

### Funding statement:

Self-funding.

### Acknowledgement:

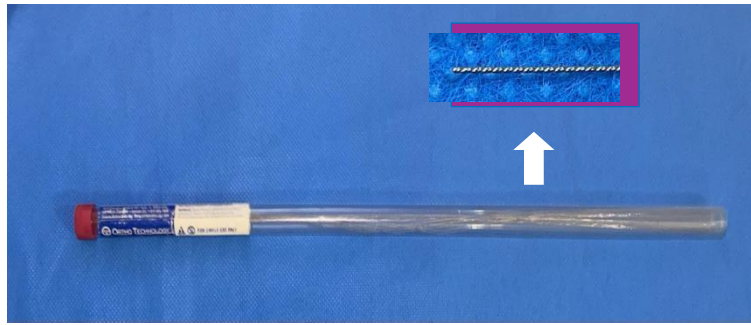
The authors thank the team in the laboratory at the College of Materials Engineering at the University of Babylon.



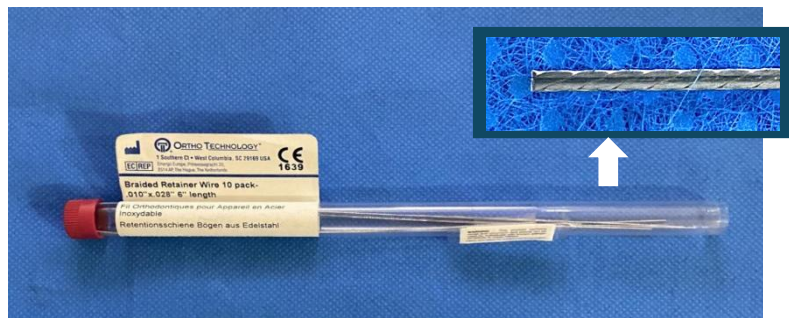
Figure 1: Fiber-reinforced composite angelus interlig types.



Figure 2: Stainless Steel Retainer Wire (Braided).



**Figure 3: Round metallic wire.**



**Figure 4: Flat metallic Wire.**



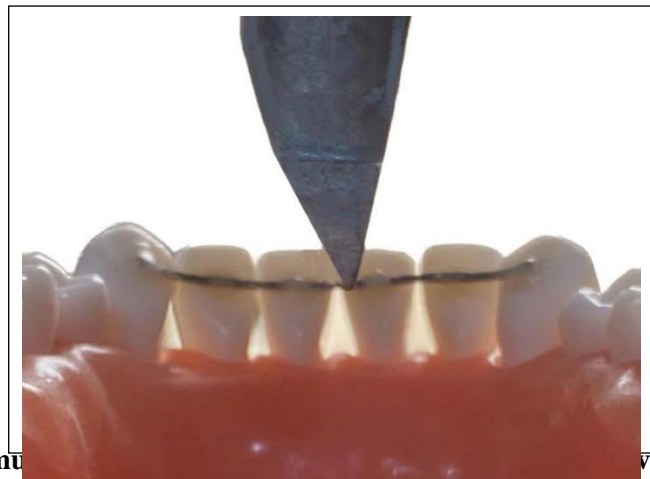
**A**

**B**

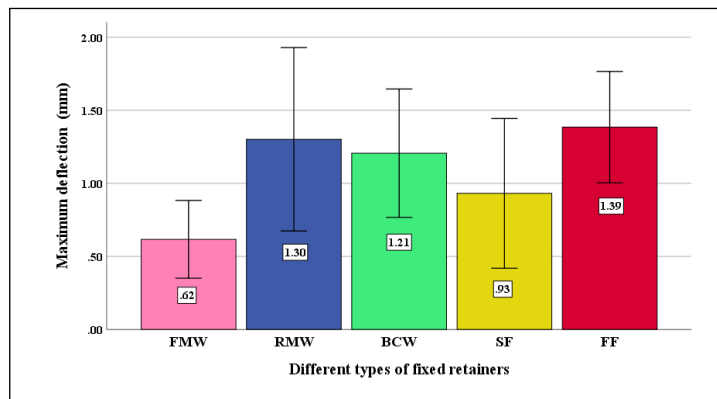




**Figure 5: Five bonding techniques of retainer wires: A: Spot-bonded fiber reinforced composite retainer, B: Full-bonded fiber reinforced composite retainer, C: Braided D: Round metallic retainer wire, E: Flat metallic retainer wire. chain retainer wire,**



**Figure 6: Maximum deflection testing machine.**



**Figure 7: Mean maximum deflection (mm) of retainer types at debonding failure occurrence from acrylic teeth.**

Table 1: Group of materials for different types of fixed retainers.

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

Table 2: Descriptive statistics of the mean maximum deflection (mm) of the retainer materials.

Materials	No.	M (mm)	SD	SE	Min.	Max.
SF	6	0.93	0.26	0.10	0.70	1.30
FF	6	1.39	0.19	0.08	1.24	1.73
BCW	6	1.21	0.22	0.09	0.90	1.50
RMW	6	1.30	0.31	0.13	1.00	1.90
FMW	6	0.62	0.13	0.05	0.50	0.80

Table 3: ANOVA test of the mean of the maximum deflection (mm) of the different retainers.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.367	4	0.592	11.109	0.001**
Within Groups	1.332	25	0.053		
Total	3.699	29			

0.01: Highly significance. \*\* P <

Table 4: Multiple comparison (Post-hoc Tukey’s test) of the mean maximum deflection value (mm) of the retainer materials.

0.01: Highly significance. \*\* P <

Materials	grouping	Mean Difference	P-value
FMW	RMW	-0.685	0.001**
	BCW	-0.590	0.001**
	SF	-0.315	0.026*
	FF	-0.768	0.001**
RMW	BCW	0.095	0.483
	SF	0.370	0.010**
	FF	-0.083	0.537
BCW	SF	0.275	0.050*
	FF	-0.178	0.193
SF	FF	-0.453	0.002**

\* 0.05 ≥ P > 0.01: Significance.

P > 0.05: Non-significance.

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