Original Article

Comparison of treatment stability among maxillary round multi-strand wire, chairside rectangular chain and vacuum formed retainers: a randomized clinical trial

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ABSTRACT

Objectives: To compare the effect of three different maxillary retainers: round multi-strand stainless steel (SS), rectangular white gold-plated SS, and vacuum-formed (VF) retainers on treatment stability, retainer integrity, and gingival health over 12 months.

Materials and Methods: Seventy subjects who finished fixed orthodontic treatment and required orthodontic retainers in the upper arch were randomly divided into three groups. The first group (mean age: 21.0 years) received bonded three multi-strand round (0.0175-inch) SS retainer, the second group (mean age: 20.4 years) received bonded rectangular (0.038 $\times$ 0.016-inch) white gold-plated SS retainer, the third group (mean age: 20.0 years) received removable VF retainer. Bonded retainers were extended from lateral to lateral incisor while VF retainer was extended to the most distal molar. After 1 year, all subjects were recalled. The primary outcome was to assess relapse in upper labial segment alignment. The secondary outcome was to evaluate the plaque index (PI) and gingival index (GI) of the upper labial segment teeth and retainer failure rate.

Results: There was no statistical difference in the average irregularity index (IRI), PI, and GI among the three groups ($P = .667$, $P = .781$, $P = .487$, respectively). Retainer failure rate was significantly higher in Group III (60.9%) compared to Group I (20.8%) and Group II (34.8%, $P = .017$).

Conclusions: After 1 year, anterior tooth alignment stability and gingival health parameters were not different between bonded and VF retainers. However, the VF retainer exhibited a higher failure rate compared to bonded retainers. (*Angle Orthod*. 0000;00:000–000.)

KEY WORDS: Upper orthodontic retainers; Fixed retainer; Removable retainer; Relapse; Gingival health; Failure rate

INTRODUCTION

Keeping teeth in their properly aligned position after orthodontic treatment can be difficult, as teeth naturally tend to move back to their initial alignment.[1] To avoid relapse, use of orthodontic retainers for long-term stability is suggested.[2] These retainers can be either removable or fixed.

Removable retainers have been employed for several decades,[3] with the most prevalent variants being Hawley and vacuum-formed (VF) retainers. In 1973, fixed retainers were pioneered to mitigate relapse in the anterior dentition.[4] These fixed retainers are highly regarded by orthodontists for their esthetic discretion and the ease with which patients can maintain them over prolonged periods.[5]

Different types of fixed orthodontic retainers have been described.[2,6,7] The most commonly used are multi-stranded stainless steel (SS) wires. The Ortho-FlexTech retainer, a recently introduced fixed retainer, is made of flexible SS or white gold-plated alloy. Orthodontists favor this retainer because it can be placed directly without laboratory work. However, no previous studies have addressed the effectiveness of

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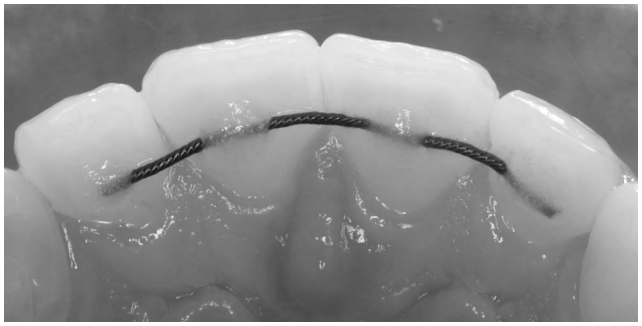

Figure 1. multi-strand wire retainer bonded to the palatal surfaces of maxillary incisors.

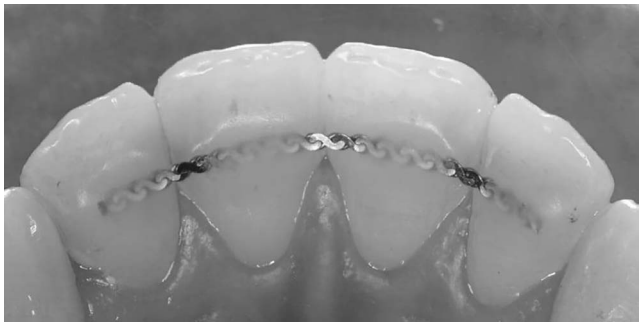

Figure 2. Ortho-FlexTech wire retainer bonded to the palatal surfaces of maxillary incisors.

Ortho-FlexTech retainer in maintaining the alignment of maxillary anterior teeth, its effect on gingival health, and failure rate.

The primary objective of this study was to evaluate and compare the efficacy of round multi-strand SS, rectangular Ortho-FlexTech gold-plated SS and VF retainers, in preserving tooth alignment. The secondary objective included assessing plaque accumulation, gingival health, and the rate of retainer failure.

The null hypothesis was that there would be no significant difference in anterior tooth alignment stability, plaque accumulation, gingival health or retainer durability when fixed round multi-strand, rectangular white gold-plated SS, or VF retainers were used to retain maxillary anterior teeth.

MATERIALS AND METHODS

Trial Design and Any Changes After Trial Commencement

This single-center study was a three-arm parallel randomized clinical trial with a 1:1:1 allocation. The methods were not changed after trial commencement.

Participants, Eligibility Criteria and Settings

This trial was conducted at the Private Orthodontic Clinics at Jordan University of Science and Technology. The study was approved by the Institutional Review Board Committee, King Abdullah University Hospital (#101/116/2022).

Eligibility Criteria

The inclusion criteria were: (1) Medically fit patients; (2) Patients requiring fixed or VF retainers for the upper anterior segment; (3) Caucasian patients with pretreatment crowding in the maxillary anterior region; (4) The presence of the four maxillary incisors and two canines; (5) Well-aligned anterior teeth and a Class I incisor relationship after completion of orthodontic treatment (IRI $=$ 0 mm); (6) Adequate oral hygiene and healthy periodontal status (full mouth plaque score $<$ 20% using the O'Leary index[8]).

Exclusion criteria were: (1) Patients who had scaling and polishing during the study; (2) Relevant medical history affecting the gingival condition or tooth brushing capability; (3) Craniofacial anomalies or syndromes affecting bone or stability of the teeth.

Informed consent was signed by patients (or parents, if the patient was under 18 years) who agreed to participate.

Interventions

All patients were treated by the same experienced orthodontist (KA) with 0.022 $\times$ 0.028-inch slot brackets (Victory series, MBT prescription; 3M Unitek, Monrovia, CA, USA). At the end of orthodontic treatment, patients who met the inclusion criteria were randomly distributed into three groups:

- Group I received a 0.0175-inch three multi-strand SS wire retainer (n $=$ 28) (Figure 1).
- Group II received a 0.038 $\times$ 0.016-inch white gold-plated SS alloy Ortho-FlexTech wire retainer (n $=$ 28) (Figure 2).
- Group III received a VF retainer (n $=$ 28).

At the completion of orthodontic treatment, the fixed orthodontic appliances were debonded. After this, all teeth were thoroughly scaled by the same orthodontist (KA), and alginate (Hydrogum, Zhermack, Badia Polesine, Italy) impressions were taken for patients in Groups I and III to fabricate the retainers.

For fixed retainers, the upper incisors (from lateral to lateral) were etched with 37% phosphoric acid gel (Super Etch, SDI, Victoria, Australia) for 30 seconds. The etchant was then removed using water spray for 10 seconds, and the enamel was dried with oil-free compressed air for 5 seconds. multi-strand wire retainers were shaped by a dental technician using the dental casts and were indirectly bonded using a localizing template and Transbond LR light-cure adhesive (3M Unitek, Peck Rd, MN, CA, USA).

Table 1. Description of Plaque Index Scores

Score	Criteria
0	No plaque.
1	A film of plaque adhering to the free gingival margin and adjacent area of the tooth. The plaque may be seen in situ only after application of disclosing solution or by using the probe on the tooth surface.
2	Moderate accumulation of soft deposits within the gingival pocket, or on the tooth and gingival margin, which can be seen with the naked eye.
3	Abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin.

Ortho-FlexTech retainers were directly bonded to the upper incisors using the same materials. Articulating paper was used to identify the contact points between the retainer and the lower incisors, ensuring that the upper retainer was bonded away from these contacts. The VF retainers were made from a 1mm polyethylene sheet fabricated within 1 hour after debonding. All retainers were manufactured by a single technician to ensure consistency. The bonding of all retainers was performed in the clinic by the same author (KA). Patients were advised to return to the clinic within 48 hours in the event of retainer fracture or debonding from any tooth, for either rebonding or replacement. Retainer failures were documented as they occurred.

After retainer placement, comprehensive written and verbal oral hygiene instructions were provided, including guidance on interdental cleaning around the bonded retainers. The modified Stillman brushing technique was recommended for effective brushing. Participants were advised to wear their VF retainers only at night.

Subjects were monitored every 2 months over 12 months to assess retainer stability and to reinforce oral hygiene practices. Upon completion of the follow-up period, all subjects were recalled and examined by the same author (KA). The following variables were recorded:

1. Oral hygiene, assessed by the Simplified Oral Hygiene Index[9] (OHI-S).
2. Upper anterior teeth Irregularity Index[10] (IRI).
3. Upper anterior teeth Plaque Index[11] (PI).
4. Upper anterior teeth Gingival Index[12] (GI).
5. Number of breakages or detachments of the retainers.

Oral hygiene was compared using the OHI-S.[9] The OHI-S is measured by scoring the surfaces of two anterior and four posterior teeth for the deposition of debris and calculus. The six surfaces evaluated were the labial surface of the maxillary right and mandibular left central incisors, the buccal surface of the maxillary first permanent molars, and the lingual surface of the mandibular first permanent molars. In the present study, the maxillary right central incisor was not included because the retainer may have had an impact on the amount of debris and calculus.

Sample Size Calculation

Based on the findings of Al-Maaitah et al.,[13] documenting a mean IRI of 0.096 $\pm$ 0.085 for round multistrand wire and 0.01 $\pm$ 0.1 for rectangular Ortho-FlexTech wire, the sample size was determined using the G*Power 3.1.9.7 software. The analysis revealed that 24 participants per group were required at alpha level of 0.05 and desired power (1 - β) of 0.90. Five individuals were added to each group to account for dropout (Attrition rate = 20%). A dropout was classified as either missing scheduled follow-up appointments or failing to address a retainer breakage within 48 hours.

Outcomes (Primary and Secondary)

Primary outcomes. The primary outcomes were to assess the IRI of the upper anterior teeth using Little's irregularity index. Contact point displacements were measured on digital casts generated from plaster models using a 3Shape TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark). Tooth displacement was measured in mm using computer-aided design OrthoAnalyze software (3Shape, Copenhagen, Denmark). The IRI for each subject was the sum of the measurements of the five contact points from the canine to canine.

Secondary outcomes. The secondary outcomes were to assess the PI and the GI of the upper incisors as well as the retainer failure rate. One year after debonding, all subjects were recalled and the PI and the GI were recorded. To obtain the PI score, the buccal, lingual, mesial and distal surfaces of the upper incisors were scored from zero to three (Table 1). The score for each tooth was the sum of the four surfaces divided by four. To calculate PI for the entire labial segment, the PI scores for the upper anterior teeth were averaged. The same method was used to obtain the GI (Table 2).

Table 2. Description of Gingival Index Scores

Score	Criteria
0	Absence of inflammation.
1	Mild inflammation with slight change in color and little change in texture.
2	Moderate inflammation with moderate glazing, redness, edema, and hypertrophy. Bleeding on probing.
3	Severe inflammation with marked redness and hypertrophy. Tendency to spontaneous bleeding.

Failure patterns were considered as follows: fixed retainers failed at the wire–composite interface, the enamel–composite interface, or wire fracture. VF retainer failures were classified as lost, fractured retainer, or full-thickness breach in the retainer necessitating replacement.

Measurement Error

To calculate the measurement error, 15 subjects (5/group) were randomly selected and re-examined by the same clinical examiner seven days after the initial examination for OHI-S, PI, and GI. Additionally, 15 models (5/group) were measured for anterior teeth irregularity by the same examiner, for the IRI measurement error. The differences between the first and second measurements were tested using the intraclass correlation coefficient.

Randomization

The three groups were randomly selected from among the participants. To keep the investigator (K.A), who oversaw group assignments, from influencing the allocation procedure, the randomization sequence was concealed using sequentially numbered, opaque and sealed envelopes. Each participant's assigned leveling method was determined by the sealed envelope they selected.

Blinding

Blinding was not possible during intervention and data collection and was only applied during data analysis by coding the participants.

Statistical Analysis

Statistical Package for the Social Sciences software, version 25.0 (Chicago, Ill), was used to obtain descriptive and analytical statistics. The Shapiro-Wilk test was used to determine the normality of all measurements.

The three groups were compared using analysis of variance (ANOVA) for age, OHI-S, IRI, PI and GI. The three groups were compared for gender and retainer failure rate using the Chi-square test, and the significance of age by gender and group was examined using two-way ANOVA. At $P \leq .05$, significance was established.

RESULTS

Subjects

The study involved recruitment of 84 patients and 14 were excluded during follow-up. Final analysis was performed for 70 subjects. Ten patients were dropped because they failed to attend for their scheduled appointments, four patients were excluded because they underwent scaling during the study period (Figure 3).

Demographic Characteristics

There were no significant differences among the three groups regarding gender ($P = .998$) and age ($P = .770$). The mean ages were 21.0 years, 20.4 years, and 20.0 years for Groups I, II, and III, respectively. There was no significant difference among the three groups in gender regarding age ($P = .250$).

Baseline Data

The three groups were matched in pretreatment crowding and IRI and preretention PI and GI (Table 3).

Simplified Oral Hygiene Index

The OHI-S index was similar across the three groups (Table 4), with no statistically significant difference ($P = .192$).

Outcomes (Primary and Secondary)

Primary outcome. The average IRI for Group I (0.483 mm) was not significantly different from that for Groups II and III (0.417 mm, 0.413 mm, respectively, $P = .667$) (Table 4).

Secondary outcomes. There was no significant difference among the three groups in the PI ($P = .781$) and GI ($P = .487$) (Table 4).

Timing, frequency, and pattern of fractured retainers are shown in Table 5. In Group III (one incident in eight subjects and two incidents in three subjects) was greater than that in Group II (one incident in six subjects and two incidents in one subject) and Group I (one incident in three subjects and two incidents in one subject); this difference was statistically significant ($P = .017$).

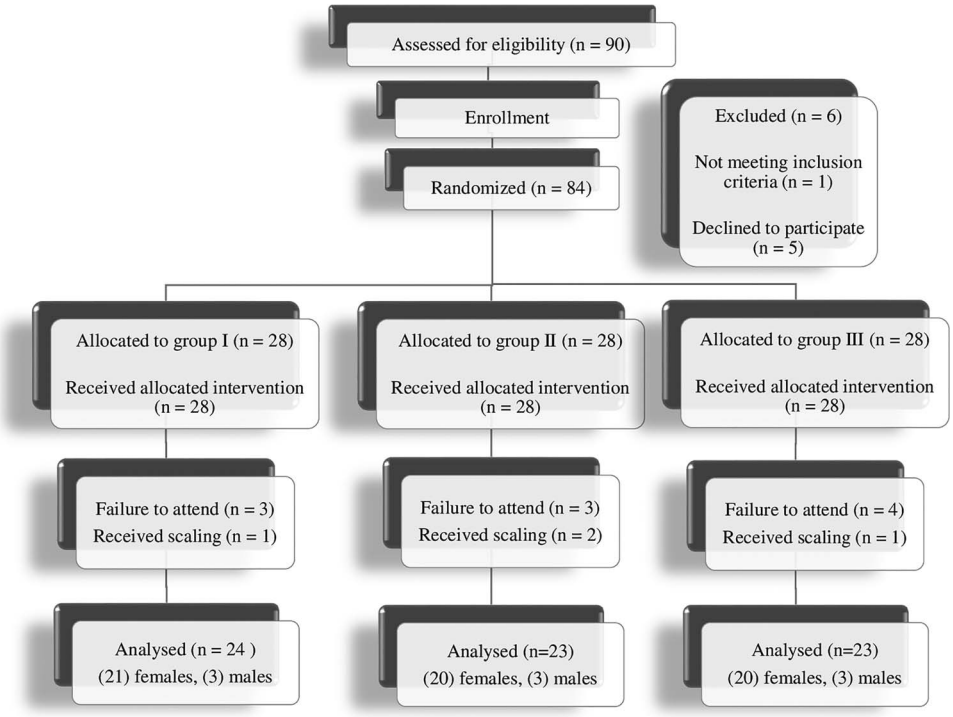

Figure 3. CONSORT flowchart illustrating patient flow during the trial.

DISCUSSION

The primary objective of this study was to compare round multi-strand wire, rectangular Ortho-FlexTech wire and VF retainers in terms of effectiveness of these retainers in maintaining tooth alignment. The secondary objectives were to assess gingival condition and retainer failure rate.

To facilitate a meaningful comparison of treatment outcomes, essential demographic variables such as age and gender and oral hygiene status, were analyzed to confirm compatibility across all groups. This approach aimed to minimize potential confounding influences stemming from these variables.

Given that gingival health and plaque accumulation could be affected by oral hygiene status, it was critical to ensure that all groups were well-matched in terms of oral hygiene. Consequently, only individuals demonstrating good oral hygiene were enrolled in the study from the beginning. In addition, randomization was implemented to mitigate the risk of uneven group distribution.

Primary Outcome

In the current study, no significant differences were detected among the three groups regarding IRI. The results were in agreement with previous research by Naraghi et al.[14] and Forde et al.,[15] which concluded that bonded and VF retainers were equally effective in retention capacity, and both could be recommended as retention methods for the maxillary incisors. In contrast, Bellini-Pereira et al.,[16] which followed patients for 12 months, found that fixed retainers were more effective in maintaining alignment of maxillary incisors compared to VF retainers. Nonetheless, Bellini-Pereira et al.[16] noted that, even though VF retainers were less effective, no patient had an IRI greater than 2 mm after 12 months.

Table 3. Comparison of Baseline Preorthodontic Treatment Crowding and IRI, Preretention PI and GI Measurements, and Age Among Three Groups[a]

	Group I		Group II		Group III		
Variable	Mean	SD	Mean	SD	Mean	SD	*P* Value
Age (y)	21.01	4.38	20.41	6.39	19.96	3.88	.770
Pretreatment crowding	3.928	0.280	4.062	0.319	3.971	0.288	.235
Pretreatment irregularity index	3.203	0.254	3.250	0.267	3.156	0.202	.349
Preretention plaque index	1.291	0.763	1.543	0.962	1.502	0.745	.478
Preretention gingival index	1.614	0.786	1.966	0.881	2.075	0.766	.088

[a] GI indicates gingival index; IRI, irregularity index; PI, plaque index.

Table 4. Means, Standard Deviations, and *P* Values of OHI-S, IRI, PI and GI, and Fracture Rate Percentages Among Maxillary Retainer Groups[a]

	Group I		Group II		Group III		
Variable	Mean	SD	Mean	SD	Mean	SD	*P* Value
Simplified oral hygiene index	1.308	0.541	1.296	0.4666	1.070	0.481	.192
Irregularity index	0.483	0.303	0.417	0.345	0.413	0.244	.667
Plaque index	0.867	0.509	0.809	0.314	0.894	0.391	.781
Gingival index	1.268	0.293	1.356	0.338	1.369	0.309	.487
Fracture rate	20.8%	–	34.8%	–	60.9%	–	.017

[a] GI indicates gingival index; IRI, irregularity index; OHI-S, simplified oral hygiene index; PI, plaque index.

As shown in Table 6, the IRI results for Group I in the current study were comparable to those reported by Bellini-Pereira et al.,[16] but lower than those reported by Naraghi et al.[14] and Forde et al.[15] Similarly, the IRI for Group III was lower than values reported by other studies[14–16]. No previous studies evaluated the Ortho-FlexTech wire retainer in maintaining tooth alignment.

Secondary Outcome

GI and PI scores were assessed 1 year after debonding, as a follow-up period of at least 6 months is needed to distinguish gingival inflammation caused by fixed orthodontic treatment from that caused by orthodontic retainers[17] and to minimize the Hawthorne effect.[18] Few studies in the literature studied the impact of fixed and removable retainers in the upper arch regarding oral health. Storey et al.[19] evaluated the effect of multi-strand and VF retainers on periodontal health. They found significantly less plaque accumulation and better gingival health with VF retainers than with fixed retainers over a 12-month evaluation period. This was in contrast to the current results, which showed no difference between fixed multi-strand and VF retainers.

As shown in Table 6, the average PI and GI in Groups I and III were higher than the values reported by Storey et al.[19] This difference may have been related to patient attitude and general oral hygiene. No previous studies have assessed the impact of the Ortho-FlexTech retainer on the gingival condition of the maxillary anterior segment.

Only two published studies[15,16] directly compared VF retainers to bonded retainers in retainer fracture rates. Forde et al.[15] and Bellini-Pereira et al.[16] compared round SS and VF retainers. After 1 year, they found no significant differences between the two groups. This finding was in contrast with the current study, which found a significant difference among the studied groups.

Based on the data in Table 6, the failure rate for Group I in the current study was lower than that reported by Forde et al.,[15] who attributed their higher failure rate to lack of experience by the operator. A general increase in failure rate has been associated with less experienced operators.[20] Another reason for the difference may have been that, in the current study, care was taken to bond the upper retainer away from the contact between the upper and lower incisors. The retainer failure rate of Group III in the current study was higher than that reported by Forde et al.[15] and Bellini-Pereira et al.[16] This difference may be attributed to the different methods used for calculating the failure rate. The previous studies[15,16] considered only the number of patients with retainer failures, while the current study used the number of failed retainers. This approach captured multiple failures per patient, providing a more detailed and accurate assessment of retainer durability.

The high failure rate of VF compared to fixed retainers in the upper arch may be explained by two factors. First, VF retainers are designed to be removable. This characteristic makes them prone to being lost easily, and the loss of a retainer was considered a failure in this study. Second, the extension of VF retainers to cover the posterior teeth made them more susceptible to wear due to parafunctional habits. Retainer perforation or wear that breached the full thickness of the retainer was also considered a failure, as this requires replacement, increases cost, and was time consuming

Table 5. Timing, Frequency, and Pattern of Failures Among Maxillary Retainer Groups Over 12-month Follow-up Period[a]

Time (mo)	Group I (n = 5) Frequency (Pattern of Failures)	Group II (n = 8) Frequency (Pattern of Failures)	Group III (n = 14) Frequency (Pattern of Failures)
1–2	—	—	4 (2 L, 2 F)
3–4	—	2 (ECID)	2 (L, FTB)
5–6	—	—	1 (L)
7–8	—	2 (WCID)	2 (F, FTB)
9–10	1 (WF)	1 (WCID)	1 (L)
11–12	4 (2 ECID, 2 WCID)	3 (WF, 2 WCID)	4 (L, 3 F)

[a] ECID indicates enamel-composite interface detachment; F, fractured; FTB, full-thickness breach; L, lost; n, number of incidents; WCID, wire-composite interface detachment; WF, wire fracture.

Table 6. Comparison Between Previous Studies and Present Study in IRI, PI, GI, and Failure Rate of Maxillary Retainers[a]

Study (y)	Group	Retainer	IRI (mm)	PI	GI	Failure Rate
Forde et al. (2018)	G I	Round 0.0195" Multi-strand SS	1.10	—	—	36.7%
	G II	VF	0.76	—	—	26.7%
Storey et al. (2018)	G I	Round 0.0195" Multi-strand SS	—	0.5	0.75	—
	G II	VF	—	0.33	0.42	—
Naraghi et al. (2021)	G I	Round 0.0195" Multi-strand SS	0.8	—	—	—
	G II	VF	1.6	—	—	—
Bellini-Pereira et al. (2024)	G I	Round 0.024" V-bend SS	0.34	—	—	8%
	G II	VF	0.68	—	—	8%
Present study	G I	Round 0.0175" Multi-strand SS	0.48	0.87	1.27	20.8%
	G II	Rectangular Ortho-FlexTech	0.42	0.81	1.36	34.8%
	G III	VF	0.41	0.89	1.37	60.9%

[a] GI indicates gingival index; IRI, irregularity index; PI, plaque index.

for the patient. No previous studies have evaluated the Ortho-FlexTech wire retainer bonded to maxillary teeth in terms of failure rate.

An incidental finding, though it was not the study's focus, showed that rectangular wires require about 10 minutes for cementation, whereas multi-strand wires take an hour due to the need for an impression and lab work. The shorter chairside time may improve efficiency and patient convenience, warranting further research.

CONCLUSIONS

- No significant differences were found in the alignment of maxillary incisors, gingival health or plaque accumulation among Ortho-FlexTech, multi-strand SS or VF retainers.
- The VF retainer had a higher failure rate than the multi-strand SS or Ortho-FlexTech retainers.

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