The effectiveness of Hawley and vacuum-formed retainer usage protocols on the stability of fixed orthodontic treatment results

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Objectives: To compare the effectiveness of Hawley and vacuum-formed retainer (VFR) usage protocols on post-treatment stability.
Methods: The inclusion criteria included patients who initially presented with mild or moderate pretreatment crowding and a Class I or Class II malocclusion. The retention protocols were defined as Group 1: Hawley retainers, 12 months full-time wear; Group 2: Hawley retainers, six months full-time, six months night-only wear; Group 3: VFR, 12 months full-time wear; Group 4: VFR, six months full-time, six months night-only wear. Study models were taken prior to treatment (T0), after debonding (T1), six months after debonding (T2), and 12 months after debonding (T3). Little's irregularity index, intercanine and intermolar widths, arch length, overjet and overbite were measured. Repeated measure ANOVA with one-fixed factor, one-way ANOVA, Kruskal Wallis or Welch's heteroscedastic F-test, were applied.
Results: Fifty-eight patients were analysed at T2, and 52 patients at T3. There was no significant difference between the effectiveness of a Hawley appliance or VFRs on arch stability after six months. The intercanine width changes from the sixth to 12th month of retention showed a significant difference (*p* = 0.016) between Group 2 (-0.38 ± 0.58 mm) and Group 3 (0.39 ± 0.94 mm).
Conclusions: Different wearing regimens of a Hawley appliance or VFR retainers did not reveal any difference determined by Little's irregularity index. Full-time usage of VFRs provided better intercanine width retention than night-only Hawley retainer wear in the maxillary arch.
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Introduction

An orthodontic challenge, beyond establishing an ideal occlusion and aesthetics through treatment, is the maintenance of achieved corrections. A broad range of different protocols has been recommended for retention and, in a recent systematic review,[1] it was concluded that there is not enough high-quality evidence to recommend a single specific retention approach.

Either fixed or removable appliances are possible alternatives during the post-treatment retention phase. The advantages of removable retainers can be listed as the easier maintenance of oral hygiene by removing the appliance during tooth cleaning, and the possibility of night-time only wear.[2] The two removable retainers most commonly used in orthodontic practice are the Hawley appliance and vacuum-formed retainers (VFRs).[3] Several studies have previously compared the provision of a Hawley retainer or VFR, related to stability,[4,5] acceptability,[6] speech performance,[7] changes in occlusal contacts,[8] survival time,[9] and retainer wear and compliance.[10]

A significant patient issue is the duration of the retention period. Joondeph et al.[11] described retention as a 12-month healing phase, in which the newly completed tooth movements are stabilised. However, the usage protocol of retention appliances during this 'healing period' is a matter for debate. Proffit[12]

reported that teeth require essentially full-time retention for three to four months after orthodontic treatment and, later, night-time retention. Jäderberg et al., in a six-month follow-up study,[13] stated that night-time wear of an Essix retainer was sufficient to maintain the results after orthodontic treatment. Similarly, Shawesh et al.[14] concluded that night-only wear of a Hawley retainer for one year was as effective as six months full-time followed by six months night-only wear. When a Hawley retainer was used for six months full-time and six months night-only, a mean standard deviation of 1.8 ± 0.7 mm and 2.0 ± 0.8 mm increases in Little's irregularity index were reported. It is therefore questionable whether this is the best protocol.

One reason for retention is to allow the gingival and periodontal tissues time to reorganise, and adapt to the soft tissue pressures that influence post-treatment change. It is known that, although the reorganisation of collagenous fibres can be completed in four to six months, the supracrestal fibres remodel more slowly, and can still exert forces that displace a tooth 12 months after the removal of orthodontic appliances.[12] Several studies have previously been performed to compare different usage protocols for removable retainers;[5,13-16] however, none of the studies evaluated if full-time usage (except for meals) for removable retainers provided better retention than alternative time periods. If the protocol to achieve a stable orthodontic treatment is to wear a removable appliance for 12 months full-time, patients should be encouraged to follow instructions. Therefore, the aim of this study was to evaluate and compare the clinical effectiveness of different usage protocols between Hawley and VFR appliances on post-treatment stability according to Little's irregularity index, intercanine and intermolar widths, arch length, overjet and overbite measurements.

The null hypotheses of the study were: (1) that there is no difference in the effectiveness of Hawley and VFR appliances on stability following full-time usage for the first six-month period after debonding, (2) that there is no difference in the effectiveness of different usage protocols applied to Hawley and VFR appliances.

Materials and methods

This single-centre prospective clinical trial was approved by Hacettepe University Interventional Clinical Research Ethics Committee (2017/02-53(KA17006)), and conducted in Hacettepe University, Faculty of Dentistry, Department of Orthodontics from May 2017 to May 2018.

All subjects were treated by two authors (H.G-C. or E.A.) and were invited to participate close to the removal of the fixed appliances. The inclusion criteria for the subjects were: (1) mild or moderate initial crowding, (2) a Class I or Class II malocclusion according to the ANB angle and molar relationship, (3) treated only with fixed appliances, (4) non-extraction treatment, (5) no missing teeth, (6) no syndromes, (7) older than 14 years of age, (8) compliance with the retention protocol prescribed by the orthodontist.

Interventions

On the same day following debonding of the fixed orthodontic appliances, either a VFR or a Hawley retainer was provided to the patients, who were informed about the retention protocols. None of the patients had fixed bonded lingual retainers.

Upper and lower Hawley retainers were comprised of a vestibular arch, two Adams' clasps and an acrylic plate. Upper and lower vacuum-formed retainers were prepared from thermoplastic blanks of 1 mm thickness (Duran, Scheu Dental, Iserlohn, Germany) by using an Essix Vacuum Thermoforming Machine (Dentsply Raintree Essix, FL, USA). The VFRs covered the occlusal surfaces up to and including the most distal molars and so presented a full-arch design.

Determined by the retainer type and wear protocol, the following study groups were created:

Group 1 (for six months N = 14, median age 15.5 years; for 12 months N = 12, median age 16.15 years): Wore Hawley retainers full-time, except during meals, for 12 months.

Group 2 (N = 12, median age 16.1 years): Wore Hawley retainers full-time, except during meals, for six months, then night-only for the following six months.

Group 3 (for six months N = 16, median age 16.95 years; for 12 months N = 13, median age 17 years): Wore VFRs full-time, except during meals, for 12 months.

Group 4 (for six months N = 16, median age 17.4 years, for 12 months N = 15, median age 17.25 years): Wore VFRs six months full-time, except during meals, and then six months night-only.

Patients were instructed regarding the use of the appliances, the wearing regimen, and the oral hygiene and cleaning requirements. In addition, they were encouraged to contact the providers if questions or problems arose. The patients were advised to attend review appointments at six and 12 months.

The primary outcome was to evaluate the effectiveness of the retainer wear protocols of either 12 months full-time usage or six months full-time and six months night-only usage, on arch stability during the first year after debonding. A secondary outcome was to evaluate the effectiveness of full-time retainer usage on arch stability during the first six months after debonding. Comparative measurements were performed on dental casts taken before fixed orthodontic treatment (T0), at debonding (T1), six months after debonding (T2), and 12 months after debonding (T3). The following measurements were performed from the dental casts:

1. Little's Irregularity Index:[17] The linear displacement of the adjacent anatomic contact points between six maxillary or mandibular anterior teeth was determined, and the sum of the five interproximal measurements represented the irregularity index of the case.

2. Intercanine width: The distance between the crown tips of the right and left canines.

3. Intermolar width: The distance between the mesiobuccal cusp tips of the right and left molars.

4. Arch length: The distance from the interincisal midline to the mesial contacts of the first molars were straight–line measured for the right and left segments, and then summed for the dental arches.

5. Overjet: The distance parallel to the occlusal plane from the incisal edge of the most labial maxillary central incisor to the most labial mandibular central incisor.

6. Overbite: The vertical overlap of the maxillary to the mandibular central incisors.

An ID number was assigned to the models by one author, and the measurements were performed by the second author. To determine the intra-examiner reliability, 50 models (25 upper, 25 lower) were re-measured by the same investigator two weeks later. A digital calliper was used for precision measurement of the dental casts to the nearest 0.01 mm.

The sample size calculation was based on a published study[15] that compared the effectiveness of two different removable retainers on stability. A statistically significant difference was found at the change of Little's irregularity index scores in the Begg (0.37 ± 0.29 mm) and Essix (0.12 ± 0.12 mm) retainer groups. G-Power Analysis (G*Power 3.1) was applied, and when the alpha significance level was set at 0.05, to achieve 80% statistical power, a sample size of 14 patients was required for each group. It was decided to enrol 18 patients per group to compensate for subject dropout.

The patients who fulfilled the inclusion criteria were informed about the study, invited to participate, and their informed consent was provided. As the retention protocols were known by the patients and the dentists, blinding was not possible. However, for the blinding of the measurements, one author (E.A.) coded the patients and models, and the measurements were performed by the second author (H.G-C.).

Statistical analysis

Data were analysed by using IBM SPSS Statistics for Windows Version 22.0 (2013, NY, USA: IBM Corporation). The intra-class correlation coefficients (ICC) were used to assess the intra-observer reliability of the measurements. The results were between 0.704 and 0.994, and within acceptable limits. The normality of the data and homogeneity of the variance was assessed with the Shapiro-Wilk and Levene's tests, respectively.

For the intergroup comparisons of continuous demographic variables, a one-way analysis of variance (ANOVA) was used for the parametric analyses, and the Kruskal Wallis test for non-parametric analyses. The chi-square test was used for comparison of categorical variables. The Wilcoxon signed rank test and paired samples t-test were used to assess the intragroup changes that occurred in six months. The independent samples t-test and Mann Whitney U test were used for intergroup comparisons at the sixth month period.

Repeated measures ANOVA with one fixed factor was used with a Bonferroni correction to assess the significance of time-dependent changes in the groups at six and 12 months. To compare the intergroup changes, one-way ANOVA with a Bonferroni correction was used when the assumptions were met, the Kruskal Wallis with Dunn's correction was used when the data did not distribute normally, and the Welch heteroscedastic F-test[18] was used when the homogeneity assumption was not met.

Results

Of the 72 patients, 14 failed to complete the first six months of the trial, and six failed after the following six months. The patients with lost or broken appliances were excluded from the study. None of the patients who required replacement appliances were analysed in the study. A second exclusion reason was discontinued intervention. Finally, 58 patients were evaluated for six-month changes, and 52 patients were evaluated for 12-month changes.

The demographic variables, the changes in arch dimensions with active orthodontic treatment, and the comparisons between the groups are shown in Table I. None of the variables showed significant differences between the groups, except for gender ($p = 0.009$).

Sixth month changes

To evaluate and compare the effects of six-month full-time wear of Hawley and VFR retainers, groups 1 and 2

Table I. Comparisons of gender and age at debonding, molar relationships and ANB° before orthodontic treatment, and changes in arch dimensions with active orthodontic treatment between the groups.

		Group 1 N (%), median (min, max) or mean ± SD)	Group 2 N (%), median (min, max) or mean ± SD)	Group 3 N (%), median (min, max) or mean ± SD)	Group 4 N (%), median (min, max) or mean ± SD)	p-value
Gender	Female	12 (100%)	5 (41.7%)	11 (84.6%)	10 (66.7%)	0.009*,a
	Male	0 (0%)	7 (58.3%)	2 (15.4%)	5 (33.3%)	
Molar relationship	Class I	9 (75%)	9 (75%)	8 (61.5%)	7 (46.7%)	0.198a
	End-to-end	3 (25%)	2 (16.7%)	3 (23.1%)	8 (53.3%)	
	Class II	0 (0%)	1 (8.3%)	2 (15.4%)	0 (0%)	
Age (years)		16.15 (14.1, 19.9)	16.1 (14.1, 18)	17 (15.3, 19.1)	17.25 (14, 23)	0.162b
ANB°		3.15° (0.7°, 4.2°)	4.9° (1.6, 5.7)	3.8 (1, 5.1)	3 (0.9, 7)	0.113b
Little (mm) (T1-T0)	Maxilla	-7.86 (-14.98,-4.62)	-8.97 (-14.6,-2.9)	-8.05 (-13.14,-3.09)	-8.21 (-16.8, -6.13)	0.885 b
	Mandible	-6.58±2.43	-6.81±3.08	-8.25±3.40	-7.40±3.08	0.521 c
Intercanine width (mm) (T1-T0)	Maxilla	0.52 (-4.13, 5.33)	0.51 (-4.42,6.98)	1.54 (-1.75, 2.74)	0.78 (-2.45, 4.27)	0.957 b
	Mandible	0.44±1.20	1.07±1.67	1.11±1.66	0.97±1.21	0.640 c
Intermolar width (mm) (T1-T0)	Maxilla	0.18 (-2.73, 4.6)	1.73 (-1.5, 4.6)	0.99 (-0.71, 6.32)	0.12 (-1.01, 5.4)	0.175 b
	Mandible	-0.01±1.60	1.96±1.65	0.24±1.83	1.32±2.44	0.051 c
Arch length (mm) (T1-T0)	Maxilla	2.08±2.10	1.90±2.65	2.12±3.16	2.31±2.96	0.986c
	Mandible	2.64±1.89	2.81±4.71	2.14±3.64	3.61±3.26	0.732 c
Overjet (mm) (T1-T0)		-0.73±1.24	-0.63±1.24	-0.27±1.35	-1.03±1.12	0.456c
Overbite (mm) (T1-T0)		-0.66±1.13	-1.53±1.27	-1.00±1.38	-1.29±1.27	0.372c

[a]chi-square test was applied.
[b]Kruskal-Wallis test was applied.
[c]One Way Analysis of Variance (ANOVA) was applied.
*$p < 0.05$ was accepted as statistically significant.

were pooled as the Hawley group, and groups 3 and 4 were pooled as the VFR group (Table II).

Hawley Group (N = 26)

Post-treatment Little's irregularity scores increased significantly in the maxilla and mandible ($p < 0.001$). Additionally, a significant change was seen in intermolar width in the maxilla ($p < 0.001$) as well as in overbite ($p = 0.047$).

VFR Group (N = 32)

Little's irregularity scores were significantly increased in the maxilla and mandible ($p < 0.001$). In addition, a significant overbite change of 0.31 ± 0.49 mm was recorded ($p = 0.001$).

Intergroup Comparison

The only significant difference was observed in intermolar width changes in the Hawley and VFR groups ($p < 0.001$).

Twelfth month changes (Table III)

Group 1 (N = 12, 12 months full-time usage of Hawley retainers)

Little's irregularity scores increased significantly following debonding to the 12th month of retention ($p < 0.001$). Additionally, maxillary intermolar width changed significantly ($p = 0.001$).

Group 2 (N = 12, six months full-time, six months part-time wear of Hawley retainers)

Along with the significant increase in Little's irregularity scores from T1 to T3 as in Group 1, increases were also statistically significant from T2 to T3.

Group 3 (N = 13, 12 months full-time wear of VFRs)

From T2 to T3, significant changes were seen in intermolar width ($p = 0.010$) and arch length ($p = 0.024$) in the maxilla, intermolar width in the mandible ($p = 0.027$), and overjet ($p = 0.048$). At the 12-month retention period, significant changes were observed for Little's irregularity scores in the maxilla ($p = 0.010$) and mandible ($p < 0.001$), and the intermolar width in the mandible ($p = 0.011$).

Group 4 (N = 15, six months full-time, six months part-time usage of VFRs)

The Little irregularity scores significantly increased in the maxilla and mandible from T2 to T3, and T1 to T3.

Intergroup comparison

Although the irregularity scores of the six-month part-time wear protocol groups showed statistically significant increases from the sixth to the 12th month, unlike the 12 month's full-time usage protocol groups, no significant intergroup differences were noted related to irregularity score increases, for any time period. The only significant difference between the groups was observed associated with intercanine width changes ($p = 0.016$) from the sixth to the 12th month of retention, which resulted from the differences between Group 2 (-0.38 ± 0.58 mm) and Group 3 (0.39 ± 0.94 mm).

Discussion

The present study aimed to compare the effectiveness of different wear protocols between Hawley and VFR retainers on arch stability during the first 12 months of retention. There are few studies that have evaluated the effects of different wear regimens on stability.[5,13,14,16,19,20] One study[21] compared the full-time usage of Hawley and VFR retainers for 12 months, and found no significant difference between the effectiveness of the appliances with regard to arch widths, arch length or Little's irregularity scores. However, there is no study that has evaluated if 12 months full-time wear of removable retainers provides better retention than six months full-time followed by six months night-only usage. Therefore, the wear regimens of the groups were created as 12 months full-time Hawley, six months full-time followed by six months night-only Hawley wear, 12 months full-time VFR, and six months full-time followed by six months night-only VFR wear. In addition, it was aimed to compare the effectiveness of full-time wear of Hawley and VFR retainers during the first six months of retention.

The analysed sample consisted of four groups with comparable pretreatment properties related to the ANB angle and molar relationships. In addition, the age of the patients and the changes that occurred in Little's Irregularity scores, intercanine and intermolar widths, arch lengths, overbite and overjet during active orthodontic treatment did not show any significant difference between the groups. To achieve better homogeneity, patients who had been treated by extractions were excluded, and only patients with mild and moderate crowding and Class I or Class II malocclusions were included in the study sample. With

Table II. Arch measurements at debonding (T1), after six month full-time retention (T2), measurement changes from T1 to T2, comparisons of the changes between Hawley and vacuum-formed retainer groups.

		HAWLEY (N=26)				VACUUM-FORMED RETAINER (N=32)				Intergroup comparison
		T1 Mean ± SD or median (min, max)	T2 Mean ± SD or median (min, max)	T2-T1 Mean ± SD or median (min, max)	P	T1 Mean ± SD or median (min, max)	T2 Mean ± SD or median (min, max)	T2-T1 Mean ± SD or median (min, max)	P	P
Maxilla	Little (mm)	0 (0,0)	0.44 (0, 2.08)	0.44 (0, 2.08)	<0.001****,a	0 (0,0)	0.05 (0, 2.3)	0.05 (0, 2.3)	<0.001****,a	0.225c
	Intercanine width (mm)	36±2.17	36.16±2.14	0.17±0.72	0.253b	35.07 (31.9, 38.08)	34.94 (31.56, 38.86)	0 (-2.78, 0.78)	0.414a	0.081c
	Intermolar width (mm)	51.29 (43.69, 59.20)	51.83 (45.10, 59.28)	0.32 (-0.57, 1.82)	<0.001****,a	51.12 (45.75, 58.06)	51.31 (44.82, 58.06)	0 (-1.65, 1.25)	0.679a	<0.001****,c
	Arch length (mm)	71.83±4.00	71.91±3.96	0.77±0.90	0.663b	70.00 (62.76, 78.30)	70.18 (62.8, 77.8)	0.01 (-1.8, 3.26)	0.940a	0.969c
Mandible	Little (mm)	0 (0,0)	0.46 (0, 2.64)	0.46 (0, 2.64)	<0.001****,a	0 (0, 1.36)	0.39 (0, 1.79)	0.37 (0, 1.61)	<0.001****,a	0.703c
	Intercanine width (mm)	27.53±1.76	27.52±1.72	-0.02±0.52	0.884b	26.85±1.41	27.02±1.42	0.16±0.43	0.039*,b	0.156d
	Intermolar width (mm)	44.64±2.69	44.88±2.62	0.24±0.61	0.057b	44.76 (38.45, 52.05)	44.62 (38.88, 52.05)	0.04 (-1.11, 1.90)	0.204a	0.334c
	Arch length (mm)	61.93±3.61	61.70±3.83	-0.23±0.90	0.204b	61.29 (52.88, 66.74)	60.77 (52.88, 66.17)	0.10 (-1.74, 5.79)	0.926a	0.260c
Inter-arch	Overjet (mm)	2.27±0.88	2.30±0.73	0.04±0.63	0.776b	2.16±0.72	2.18±0.72	0.02±0.48	0.825b	0.910d
	Overbite (mm)	2.36±0.73	2.59±0.76	0.23±0.56	0.047*,b	2.48±0.71	2.79±0.65	0.31±0.49	0.001***,b	0.571d

a Wilcoxon Signed Rank test was applied.
b Paired t-test was applied.
c Mann Whitney-U test was applied.
d Independent samples t-test was applied.
* p < 0.05 was accepted as statistically significant.
*** p = 0.001
**** p < 0.001

the aid of the strict inclusion criteria, it was aimed to create study groups with comparable characteristics, and to minimalise confounding factors.

Except for maxillary intermolar width stability associated with the six-month changes, the first null hypothesis was accepted. The intermolar width changes of the maxillary arch showed significant differences between the Hawley and VFR retainers. However, a difference of 0.32 mm in intermolar width may not be considered clinically significant. Except for this result, no significant differences were found related to other changes during the first six months of the retention period. Little's irregularity scores increased significantly in both the Hawley and VFR groups, but the changes were not significantly different between the groups. Rowland et al.[4] assessed the effectiveness of Hawley and VFRs for six months and found greater increases in Little's irregularity scores in the Hawley retainer group. The difference in the results may arise from different wear regimens, as the present study encouraged full-time wear for six months whereas in the study by Rowland et al.[4] Hawley retainers were worn for three months full-time, three months half-time, and the VFRs were worn one week full-time and then half-time. Barlin et al.[21] compared the effectiveness of full-time wear of Hawley and VFRs, and found no significant differences between arch widths, arch length or Little's irregularity scores, in support of the present findings. According to the results of the present study, after six months of a full-time wear protocol, either a Hawley retainer or VFRs may be chosen for clinical effectiveness.

In a consideration of the 12-month changes, the null hypothesis was partially rejected, as the changes in maxillary intercanine width showed a statistically significant difference between night-only Hawley and full-time VFR usage from the sixth to 12th month. The difference likely originated from a slight decrease in the Hawley group and a slight increase in the VFR group. This finding is in contrast to those of a systematic review,[3] which indicated that no difference existed to distinguish the value of Hawley retainers and VFRs with respect to changes in intercanine and intermolar widths after orthodontic retention. Nevertheless, it is recommended that additional high quality, randomised, controlled trials concerning these retainers are necessary to determine which retainer is better. The conflicting results between the studies may arise from different wear protocols. As an

intercanine width decrease is one factor that affects relapse in anterior irregularity, better retention in the VFR group could be considered as an advantage when deciding between the removable retainers.

Little's irregularity scores showed statistically significant increases in all groups from debonding to 12 months; however, from the sixth to the 12th month, the significant increases were only present in the night-only wear protocol groups for both retainers, in both arches. From the sixth to the 12th month, the mean changes in Little's irregularity scores were in a non-significant decreasing pattern, from night-only wear of Hawley, night only wear of VFR, full-time wear of Hawley and full-time wear of VFR in both arches. The highest mean irregularity increase was in night-only wear of a Hawley retainer, with 0.80 ± 0.58 mm, and the least was in full-time wear of VFR, with a 0.27 ± 0.37 mm change in the mandible. However, the Little's irregularity score changes did not reveal a statistically significant difference between the groups. Ramazanzadeh et al.[5] compared Hawley and VFRs and different retention protocols. The retention protocols were four months full-time followed by four months night-time Hawley wear, four months full-time followed by four months night-time VFR wear, and one-week full-time followed by night-only VFR wear. It was concluded that VFRs were more effective than Hawley retainers for stable incisor alignment, after eight months of wear.

Although some intragroup changes were observed related to intermolar width, arch length and overjet during the retention period, no significant differences were observed between the groups. These findings were in accordance with the findings of Barlin et al.[21] and Demir et al.[22] When taking the results of the present study into consideration, it may be noted that six months full-time followed by six months part-time wear of Hawley retainers or VFRs can be retention alternatives rather than 12 months full-time wear. However, if better retention is needed, especially in the maxillary anterior region, 12 months full-time wear of VFRs may be encouraged, if retention is only provided by removable appliances.

Limitations

The allocation of the retainers to the groups was based on a consecutive basis rather than a clinical decision. This can be considered as a limitation of the study

Table III. Intragroup and intergroup arch measurement changes occurred from debonding (T1) to 12th month (T3), and from sixth (T2) to 12th month (T3 of retention, and their significances.

| | | Maxilla | | | | Mandible | | | | Inter-arch | |
		Little (mm) (mean±SD)	Intercanine width (mm) (mean±SD)	Intermolar width (mm) (mean±SD)	Arch length (mm) (mean±SD)	Little (mm) (mean±SD)	Intercanine width (mm) (mean±SD)	Intermolar width (mm) (mean±SD)	Arch Length (mm) (mean±SD)	Overjet (mm) (mean±SD)	Overbite (mm) (mean±SD)
Group 1 (N=12)	T3-T2	0.30±0.27	0.03±0.30	0.01±0.18	0.03±0.43	0.31±0.45	-0.05±0.20	0.04±0.11	0.17±0.84	-0.18±0.49	0.02±0.41
	P	0.172 a	1.000 a	1.000 a	1.000 a	0.212 a	1.000 a	1.000 a	1.000 a	0.482 a	1.000 a
	T3-T1	1.02±0.84	0.91±0.64	0.71±0.61	0.15±0.69	1.10±0.92	-0.14±0.51	0.45±0.58	-0.18±0.95	0.08±0.63	0.35±0.47
	P	<0.001 ****,a	1.000 a	0.001 ***,a	1.000 a	<0.001 ****,a	1.000 a	0.347 a	1.000 a	1.000 a	0.121 a
Group 2 (N=12)	T3-T2	0.41±0.43	-0.38±0.58	0.03±0.46	-0.12±0.5	0.80±0.58	-0.08±0.31	0.08±0.40	-0.25±0.62	-0.10±0.42	0.14±0.39
	P	0.028 *,a	0.178 a	1.000 a	1.000 a	<0.001 ****,a	1.000 a	1.000 a	0.890 a	1.000 a	0.884 a
	T3-T1	0.81±0.76	-0.17±0.84	0.25±0.73	-0.11±1.05	1.17±0.79	-0.11±0.61	0.09±0.79	-0.30±0.82	-0.36±0.90	0.23±0.58
	P	0.001 ***,a	1.000 a	0.569 a	1.000 a	<0.001 ****,a	1.000 a	1.000 a	1.000 a	0.213 a	0.557 a
Group 3 (N=13)	T3-T2	0.23±0.66	0.39±0.94	0.51±1.00	0.44±0.88	0.27±0.37	-0.17±0.59	0.46±0.95	0.11±0.95	-0.30±0.54	-0.24±0.50
	P	0.371 a	0.134 a	0.010 **,a	0.024 *,a	0.287 a	0.409 a	0.027 *,a	1.000 a	0.048 *,a	0.172 a
	T3-T1	0.62±0.55	0.21±0.60	0.36±0.71	0.44±1.69	0.91±0.66	0.19±0.76	0.82±1.42	0.60±2.45	-0.32±0.53	0.15±0.60
	P	0.010 **,a	0.919 a	0.165	0.579	0.001 ***,a	0.805 a	0.011 *,a	0.519 a	0.289	1.000 a
Group 4 (N=15)	T3-T2	0.34±0.62	0.36±0.71	0.14±0.42	0.00±0.37	0.59±0.77	0.06±0.42	0.34±0.62	-0.05±0.83	0.12±0.29	-0.04±0.45
	P	0.048 *,a	1.000 a	1.000 a	1.000 a	0.001 ***,a	1.000 a	0.120 a	1.000 a	0.936 a	1.000 a
	T3-T1	0.76±0.73	-0.03±0.80	0.18±0.55	0.20±1.09	1.10±0.91	0.07±0.50	0.25±0.86	-0.25±1.38	0.19±0.59	0.22±0.64
	P	0.001 ***,a	1.000 a	0.890 a	1.000 a	<0.001 ****,a	1.000 a	0.945 a	1.000 a	0.852 a	0.453 a
Intergroup comparison (p value)	T3-T2	0.897 b	0.016 *,b (2-3; p=0.008 **)	0.286 b	0.306 d	0.119 b	0.651 b	0.298 b	0.494 b	0.092 c	0.206 c
	T3-T1	0.604 c	0.599 c	0.196 c	0.399 b	0.875 c	0.481 c	0.575 b	0.727 b	0.076 b	0.527 b

a Repeated measure ANOVA with one fixed factor was used to detect significant differences. Bonferroni adjustment was done for multiple comparisons.
b Kruskal Wallis test was applied. Dunn's correction was performed for subgroup analysis, when significant difference was found.
c One-way ANOVA was used to detect significant differences, with Bonferroni correction.
d Welch heteroscedastic F-test was applied.
* p < 0.05 was accepted statistically significant.
*: p = 0.01
***: p = 0.001
****: p < 0.001

because of the possibility of introduced bias.

Because of the nature of the study, it was not possible to blind the orthodontists and the patients to the treatment allocations. However, as all the models were coded the orthodontist who performed the measurements was blinded, and unable to identify the treatment groups.

The minimum sample size was not achieved because of the drop-outs. However, the sample size calculation was done to detect a 0.25 mm difference between two groups, and this level of difference might not be clinically significant. In addition, as the sample size calculation was based on the primary outcome, and the secondary outcome measure pooled two groups (Group 1 and 2 formed Hawley group, and Group 3 and 4 formed vacuum-formed retainer group), the study was overpowered when comparing the six-month results.

As it was aimed to compare the effectiveness of different wear protocols of two different removable appliances, the results were possibly affected by patient compliance. Additional studies might be conducted with adjunctive sensors to document the real wear time of removable retainers.

Conclusions

1. There was no statistically significant difference between full-time wear of Hawley retainers and VFRs after fixed appliance debonding until the sixth month, with regard to Little's irregularity index, intercanine and intermolar widths, arch length, overjet and overbite.

2. Considering intercanine widths, using full-time VFR provides better stability than using night-only Hawley retainers from the sixth to the 12th month of retention in the maxillary arch. Therefore, if better intercanine width retention is needed, full-time usage of VFRs for 12 months is recommended.

3. Considering the irregularity scores, intermolar width, arch length, overjet and overbite, no statistically significant difference was found between 12 months full-time and six months full-time followed by six months night-only wear protocols between a Hawley retainer and VFRs.

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