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Evaluation Study

An evaluation of occlusal changes during orthodontic retention

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ABSTRACT

The problem of orthodontic relapse is of fundamental importance for clinicians. In the literature there are few studies concerning the change in position of the teeth after orthodontic treatment. This study analyzes the occlusal changes during the first six months of orthodontic retention and the effectiveness of the Hawley retainer at the upper arch and the canine-to-canine multi-stranded fixed retainer at the lower arch in maintaining the anterior tooth alignment. 48 patients were recruited. PAR index, ABO DI, ABO CRE, Irregularity Index, intercanine, interpremolar and intermolar widths were measured for each patient before (T0) and at the end (T1) of the fixed orthodontic treatment and after 1 (T2), 3 (T3) and 6 (T4) months of retention. Statistics used were paired samples t-test and Wilcoxon matched-pairs signed-ranks test. The p-value was considered statistically significant for $P<0.05$. During 6 months in retention there was a worsening of PAR index (mean: 1.13±1.08; $P<0.001$), dental alignment (median: 2.5; $P=0.0001$) and occlusal relationships (median: 2; $P=0.0101$); a statistically significant improvement of posterior occlusal contacts (median: 2.54; $P=0.0004$), marginal ridges (median: 0.5; $P=0.0250$) and interproximal contacts (median: 0.46; $P=0.0305$). The stability of the orthodontic results has proved to be similar for the two dental arches, as well as the effectiveness of the two retainers in maintaining the alignment of the anterior teeth. During 6 months in retention the occlusal changes were minimal and didn't affect the stability of the orthodontic treatment in a clinically significant manner. The effectiveness of the upper Hawley retainer and the lower multi-stranded fixed retainer in maintaining the alignment of the anterior teeth was similar.

INTRODUCTION

The stability of the orthodontic treatment is a problem that has always afflicted orthodontists. The focus of the problem had already been understood by Charles A. Hawley, who stated: "If anyone would take my cases when they are finished, retain them and be responsible for them afterward, I would gladly give them half the fee" (1). Numerous researches have been carried out on the stability and relapse of orthodontic treatment and many procedures and appliances have been introduced to improve orthodontic retention; however, despite the knowledge and techniques in this area have evolved, a definitive solution to the problem has not been found yet (2-4). Most of the studies in the literature that address this topic focus on the long-term occlusal changes that occur once the retention phase is over (5-8). Short-term teeth movements after fixed orthodontic treatment have been little studied, if not studied at all (9, 10). Precisely for this reason we decided to analyze the dental occlusion during the first six months of retention. The aim of this work was indeed to evaluate on study models and on radiographs: 1) Occlusal changes during the first six months of orthodontic retention by means of upper Hawley retainer and lower multi-stranded fixed retainer. 2) The differences in stability of the results obtained with the fixed orthodontic treatment between the upper and lower arch during the period of retention. 3) The differences in effectiveness between the Hawley retainer and the multi-stranded fixed retainer in maintaining the dental alignment respectively at the level of the upper and lower anterior sextant. The occlusal changes occurred between the beginning and the end of the orthodontic treatment were also analyzed to evaluate these three elements in an accurate and complete way and to understand if orthodontic relapse had occurred or not.

MATERIALS AND METHODS

Forty-eight subjects (24 males and 24 females; mean age at the beginning of the treatment: 16.64 ± 3.15 years; mean age at the end of the treatment: 18.94 ± 2.74 years) were enrolled in this study, that was approved by the Clinical Investigation Ethics Committee of Verona and Rovigo, Italy (protocol number 70252, 30 October 2018). The inclusion criteria were: two-arch multibracket fixed orthodontic treatment carried out by the same orthodontist; complete clinical documentation (clinical records, dental casts, radiographs, and intra-oral and extra-oral photographs); patient compliance to wear retention appliances; absence of periodontal problems. At the end of orthodontic treatment (T1) the following procedures were performed on each patient:

1) Debonding of the fixed orthodontic appliance and professional oral hygiene (11).

2) Application of the lower multi-stranded fixed retainer (TRI-FLEX ™ Twisted Wire 0175 inches, Rocky Mountain® Orthodontics, Denver, CO, USA) to the lower anterior sextant.

3) Taking alginate impressions (Kromopan®, LASCOD Spa, Sesto Fiorentino (FI), Italy) of the two arches and taking the bite registration wax (Small platewax for orthodontics, Zeta®, Industry Zingardi srl, Novi Ligure (AL), Italy) for the construction of the dental casts and of the superior Hawley retainer (12-14). After one week from debonding, each patient received Hawley retainer: it must be worn at night for at least one year. After 1 month from the debonding (T2), dental occlusion and the integrity of the retention appliances were evaluated, and alginate impressions and a bite registration wax were taken for the construction of the dental casts. The same procedure was performed at 3 (T3) and 6 months (T4) after the end of the orthodontic treatment. Subsequently, the initial (T0), final (T1) and post-treatment dental casts at 1 (T2), 3 (T3) and 6 months (T4), the T0 lateral teleradiographs and the orthopantomograms at T1 and T4 were analyzed. The analyses were performed using the Peer Assessment Rating index (PAR index) (15), the American Board of Orthodontics Discrepancy Index (ABO DI) (16), the American Board of Orthodontics Cast-Radiograph Evaluation (ABO CRE or ABO OGS) (17) and the Little Irregularity Index (II) (18). Intercanine, interpremolar and intermolar widths were also measured (19).

The PAR index, the ABO DI and the ABO CRE were analogously measured with the PAR ruler and the ABO Measuring Gauge respectively; the measurements of the II and of the dental arch widths were performed with the 3Shape OrthoViewer software (3Shape, Copenhagen, Denmark) after having transformed the dental models in plaster in digital format (.stl) with a dental scanner (Dental Smart scanner, Open Technologies, Rezzato, Brescia, Italy). The ANB, SN-MP and lower- incisors MP of ABO DI were calculated on the cephalometric traces of the initial lateral teleradiographs with the software Dolphin Imaging 11.7 (Dolphin, Imaging & Management Solutions, Chatsworth, CA, USA). Finally, the root angulation for the ABO CRE index was evaluated on orthopantomograms.

The statistical analysis was performed using STATA (version 13; StataCorp LP, College Station, Texas, USA). The median, maximum, minimum, 10th, 25th, 75th, and 90th percentile were calculated for all parameters; moreover, mean and standard deviation (SD) were reported for the normally distributed variables. Paired samples t-test and Wilcoxon matched-pairs signed-ranks test were performed for the evaluation of the occlusal changes that occurred during treatment and during the first six months of orthodontic retention. The same tests were used to compare the differences in stability of the results obtained with the orthodontic treatment between the two arches and the differences in effectiveness in maintaining the alignment of the anterior teeth between the upper Hawley retainer and the lower multi-stranded fixed retainer. The p-value was considered statistically significant when it was less than 0.05.

RESULTS

Regarding the occlusal changes that occurred between the beginning and the end of the orthodontic treatment, a statistically significant improvement was recorded in the PAR index and its variables (Table I).

Table I. *PAR Index and its variables at the beginning (T0) and the end (T1) of the treatment.*

	Median		Maxi-mum		Minimum		Mean ± SD		10th percentile		25th percentile		75th percentile		90th percentile		p-value
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	
PAR Index	18	9	39	15	11	3			11	5	13.5	7	23	10.5	29	13	P<0.001
Upper right segment	2	1	4	3	1	0	2.13 ± 0.9	1.25 ± 0.79	1	0	1.5	1	3	2	3	2	P=0.0002
Upper anterior segment	3	1	12	2	2	0			2	1	2.5	1	4	2	4	2	P<0.001
Upper left segment	2	1	5	2	0	0	1.92 ± 1.14	1.04 ± 0.75	1	0	1	0.5	2	2	3	2	P=0.0006
Lower right segment	2	1	3	2	0	0	1.67 ± 0.7	1.13 ± 0.61	1	0	1	1	2	1.5	2	2	P=0.0005
Lower anterior segment	3	1	4	2	1	1			2	1	2	1	3	1	4	2	P<0.001
Lower left segment	2	1	3	3	1	0	1.96 ± 0.75	1.33 ± 0.7	1	1	1	1	2.5	2	3	2	P=0.0030
Right buccal occlusion	1.5	0	5	1	0	0			0	0	0	0	2	1	4	1	P=0.0004
Overjet	1	0	4	1	0	0			0	0	1	0	1.5	1	3	1	P=0.0002
Overbite	1	0	2	1	0	0	0.83 ± 0.7	0.25 ± 0.44	0	0	0	0	1	0.5	2	1	P=0.0012
Centreline	0	0	2	1	0	0			0	0	0	0	1	0	1	1	P=0.0255
Left buccal occlusion	1	0	5	2	0	0	1.54 ± 1.67	0.46 ± 0.66	0	0	0	0	2	1	5	1	P=0.0036

Moreover, the alignment of the anterior sextants has improved with the orthodontic therapy: the maxillary II changed from 7.07 ± 4.22 mm to 1.98 ± 0.75 mm (P<0.001); also the mandibular II has been statistically improved (from 5.59 mm at T0 to 1.67 mm at T1, P<0.001). The orthodontic treatment then determined the expansion of both dental arches (Table II). Concerning the dental occlusion evaluated according to the ABO indices, it was not possible to compare the ABO DI at T0 with the ABO CRE at T1 because the two indices are based on different variables (Table III). Regarding the occlusal changes during the first 6 months of orthodontic retention (Table IV), a statistically significant worsening of the occlusion according to the PAR

index was recorded: the score increased from 8.75 ± 2.98 at T1 to 9.88 ± 3.04 at T4 (P<0.001). In particular, for the aforementioned index, the worsening of the upper anterior segment, the lower left segment and the left buccal occlusion was statistically significant.

Table II. *Dental arch widths at beginning (T0) and the end (T1) of the treatment.*

	Median		Maximum		Minimum		Mean ± SD		10th percentile		25th percentile		75th percentile		90th percentile		p-value
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	
Maxillary intercani-ne width	34.17	34.84	36.74	37.43	27.12	29.91	33.29 ± 2.61	34.42 ± 1.85	29.6	32.12	32.28	33.35	35.04	35.63	36.14	36.94	P=0.027
Maxillary interpre-molar width	39.84	42.49	44.35	50.05	29.15	38.33	39.55 ± 3.4	42.61 ± 2.66	35.87	39.27	37.62	40.85	41.97	44.27	43.02	45.66	P=0.0004
Maxillary intermo-lar width	49.61	50.58	54.84	58.04	41.12	45.66	48.94 ± 3.36	51.22 ± 3.34	44.32	46.71	46.94	48.39	51.33	53.5	53.05	55.39	P=0.0019
Mandibu-lar interca-nine width	25.81	25.82	28.72	29.3	19.42	23.24	25.36 ± 2.29	25.89 ± 1.5	21.48	23.9	24.35	24.97	26.76	26.58	28.21	28.16	P=0.2962
Mandibu-lar interpre-molar width	33.23	34.68	36.37	38.82	25.92	30.41			29.9	32.72	31.54	33.33	34.71	35.65	35.88	36.94	P=0.0152
Mandi-bular inter-molar width	43.87	44.11	52.8	50.33	38.43	39.21	44.26 ± 3.51	44.46 ± 3.09	39.89	40.56	41.34	42.51	46.63	46.92	49.27	49.37	P=0.6770

Table III. *ABO DI and its variables at the beginning of the treatment (T0) and ABO CRE and its variables at the end of treatment (T1).*

	Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile
ABO DI (T0)	21.5	47	7	23.29 ± 10.71	13	15	27.5	38
Overjet (T0)	2	11	0		0	1	3	5
Overbite (T0)	0	5	0		0	0	2	2
Anterior open bite (T0)	0	10	0		0	0	1	3
Lateral open bite (T0)	0	12	0		0	0	0	2
Crowding (T0)	7	7	4		7	7	7	7
Occlusal relationship (T0)	4	6	0	2.92 ± 1.95	0	2	4	6
Lingual posterior crossbite (T0)	0	6	0		0	0	1	4
Buccal posterior crossbite (T0)	0	0	0	0	0	0	0	0
Cephalometrics (T0)	4	20	0	5.58 ± 6.02	0	0	10	14
Other (T0)	0	8	0	1.83 ± 2.5	0	0	4	5
ABO CRE (T1)	50.5	78	21	51.38 ± 13.03	38	44	57.5	69
Alignment / rotations (T1)	14	26	5	15.63 ± 6.44	8	10	22.5	25
Marginal ridges (T1)	5.5	9	1	4.92 ± 2.19	1	4	6	7
Buccolingual inclination (T1)	7	17	1	7.5 ± 4.14	2	5	10.5	12
Overjet (T1)	7	16	1	7.17 ± 3.51	4	4.5	10	12
Occlusal contacts (T1)	9	17	2	9.17 ± 3.64	4	7	11.5	14
Occlusal relationship (T1)	4	15	0		2	2.5	7	10
Interproximal contacts (T1)	0	4	0		0	0	1.5	4
Root angulation (T1)	1	3	0	0.92 ± 0.97	0	0	1.5	2

Table IV. *PAR Index and its variables at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
PAR Index	T1	9	15	3	8.75 ± 2.98	5	7	10.5	13	
	T2	9	15	4	9.13 ± 2.89	6	7	11.5	13	P=0.0166
	T3	9.5	15	4	9.33 ± 3.07	6	7	12	13	P=0.0036
	T4	9.5	16	5	9.88 ± 3.04	6	7.5	13	14	P<0.001
Upper right segment	T1	1	3	0	1.25 ± 0.79	0	1	2	2	
	T2	1	3	0	1.38 ± 0.71	1	1	2	2	P=0.0830
	T3	1	3	0	1.33 ± 0.76	0	1	2	2	P=0.3277
	T4	1	3	0	1.33 ± 0.76	0	1	2	2	P=0.3277
Upper anterior segment	T1	1	2	0	1.33 ± 0.56	1	1	2	2	
	T2	1	2	0	1.38 ± 0.58	1	1	2	2	P=0.3277
	T3	1.5	2	0	1.46 ± 0.59	1	1	2	2	P=0.0830
	T4	2	3	1	1.67 ± 0.56	1	1	2	2	P=0.0025
Upper left segment	T1	1	2	0	1.04 ± 0.75	0	0.5	2	2	
	T2	1	2	0	1.04 ± 0.75	0	0.5	2	2	
	T3	1	2	0	1.08 ± 0.78	0	0.5	2	2	P=0.3277
	T4	1	2	0	1.08 ± 0.78	0	0.5	2	2	P=0.3277
Lower right segment	T1	1	2	0	1.13 ± 0.61	0	1	1.5	2	
	T2	1	2	0	1.25 ± 0.68	0	1	2	2	P=0.0830
	T3	1	2	0	1.21 ± 0.72	0	1	2	2	P=0.3277
	T4	1	2	0	1.25 ± 0.74	0	1	2	2	P=0.1853
Lower anterior segment	T1	1	2	1		1	1	1	2	
	T2	1	2	1		1	1	1.5	2	P=0.3173
	T3	1	2	1		1	1	1.5	2	P=0.3173
	T4	1	2	1		1	1	2	2	P=0.0833
Lower left segment	T1	1	3	0	1.33 ± 0.7	1	1	2	2	
	T2	1	3	0	1.42 ± 0.72	1	1	2	2	P=0.3277
	T3	1	3	0	1.5 ± 0.78	1	1	2	3	P=0.1035
	T4	1	3	0	1.58 ± 0.83	1	1	2	3	P=0.0109
Right buccal occlusion	T1	0	1	0		0	0	1	1	
	T2	0	1	0		0	0	1	1	
	T3	0	1	0		0	0	1	1	
	T4	0	1	0		0	0	1	1	P=0.6547
Overjet	T1	0	1	0		0	0	1	1	
	T2	0	1	0		0	0	0.5	1	P=0.1573
	T3	0	1	0		0	0	0	1	P=0.0833
	T4	0	1	0		0	0	0.5	1	P=0.3173
Overbite	T1	0	1	0		0	0	0.5	1	
	T2	0	1	0		0	0	0.5	1	
	T3	0	1	0		0	0	0.5	1	
	T4	0	1	0		0	0	1	1	P=0.3173
Centreline	T1	0	1	0		0	0	0	1	
	T2	0	1	0		0	0	0	1	
	T3	0	1	0		0	0	0	1	
	T4	0	1	0		0	0	0	1	
Left buccal occlusion	T1	0	2	0	0.46 ± 0.66	0	0	1	1	
	T2	0	2	0	0.5 ± 0.66	0	0	1	1	P=0.3277
	T3	1	2	0	0.63 ± 0.65	0	0	1	1	P=0.0428
	T4	1	2	0	0.63 ± 0.65	0	0	1	1	P=0.0428

The upper anterior and lower left segments remained stable in the first 3 months of retention: their worsening reached statistical significance at the sixth month of follow-up when the difference in the score between T1 and T4 became respectively 0.33 ± 0.48 points (P=0.0025) and 0.25 ± 0.44 points (P = 0.0109). The worsening of the left buccal occlusion was not statistically significant at T2 (P = 0.3277): in fact, the score increased from 0.46 ± 0.66 points at T1 to 0.5 ± 0.66 at T2. At T3, the difference between the scores was 0.17 ± 0.38, reaching statistical significance (P=0.0428); at T4, the same values were obtained. Some variables of the ABO CRE have changed during the follow-up (Table V).

Table V. *ABO CRE and its variables at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
ABO CRE	T1	50.5	78	21	51.38 ± 13.03	38	44	57.5	69	
	T2	48.5	76	26	49.79 ± 12.49	36	41	57	68	P=0.0805
	T3	47.5	75	33	50.71 ± 11.9	38	42	58.5	72	P=0.5578
	T4	49.5	78	28	51.54 ± 13.27	35	41	60.5	71	P=0.9139
Alignment / rotations	T1	14	26	5		8	10	22.5	25	
	T2	14	27	6		8	11	24	26	P=0.0195
	T3	14.5	30	7		9	11	24.5	28	P=0.0024
	T4	16.5	31	7		9	12	25	29	P=0.0001
Marginal ridges	T1	5.5	9	1	4.92 ± 2.19	1	4	6	7	
	T2	5	9	1	4.83 ± 2.14	2	3	6.5	7	P=0.5748
	T3	5	8	1	4.75 ± 2.21	2	3	6	8	P=0.4445
	T4	5	8	1	4.42 ± 2.32	1	2	6	7	P=0.0250
Buccolingual inclination	T1	7	17	1	7.5 ± 4.14	2	5	10.5	12	
	T2	7	17	2	7.63 ± 4.13	2	5	10.5	12	P=0.2656
	T3	6.5	17	2	7.42 ± 3.65	4	5	10	12	P=0.7233
	T4	6.5	17	2	7.33 ± 3.64	4	5	10	12	P=0.4770
Overjet	T1	7	16	1	7.17 ± 3.51	4	4.5	10	12	
	T2	6	13	1	6.75 ± 2.91	4	5	8.5	11	P=0.1703
	T3	7	13	2	7.13 ± 3.19	4	4.5	9.5	12	P=0.9326
	T4	6.5	13	1	7.25 ± 3.19	4	5	10	11	P=0.8984
Occlusal contacts	T1	9	17	2	9.17 ± 3.64	4	7	11.5	14	
	T2	7.5	13	2	7.71 ± 3.3	4	5	10.5	12	P=0.0042
	T3	7.5	12	3	7.04 ± 2.91	3	4.5	9	11	P=0.0002
	T4	6	13	2	6.63 ± 3.24	3	4	9	12	P=0.0004
Occlusal relationship	T1	4	15	0		2	2.5	7	10	
	T2	5	15	0		2	3	7.5	8	P=0.2514
	T3	6	15	2		2	3	8	9	P=0.0143
	T4	6	14	2		2	3	8	12	P=0.0101
Interproximal contacts	T1	0	4	0		0	0	1.5	4	
	T2	0	4	0		0	0	1	2	P=0.0256
	T3	0	4	0		0	0	1	1	P=0.0171
	T4	0	4	0		0	0	0.5	1	P=0.0305
Root angulation	T1	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T2	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T3	1	3	0	0.92 ± 0.97	0	0	1.5	2	
	T4	1	3	0	0.92 ± 0.97	0	0	1.5	2	

Among these, the "Alignment/rotations" showed a statistically significant difference between T1 and T2: the maximum and the minimum increased by 1 point (P=0.0195). At T3, the score increased to 14.5 points (P=0.0024), while at T4 it reached 16.5 points (P=0.0001). The "Marginal ridges" variable has improved instead. It started from a score of 4.92 ± 2.19 at T1 and reached 4.42 ± 2.32 points at T4: the difference between the scores proved to be statistically significant (P=0.0250). In addition to the marginal ridges, there was a reduction in the score of the "Occlusal contacts" variable: already one month from the end of the orthodontic treatment, the score decreased from 9.17 ± 3.64 to 7.71 ± 3.3 reaching statistical significance (P=0.0042). The score further decreased at T3 (7.04 ± 2.91; P=0.0002) and at T4 (6.63 ± 3.24; P=0.0004). On the other hand, the "Occlusal Relationship" variable has already worsened at T2 from 4 to 5 points (P=0.2514). Still, the statistical significance was reached at T3 (P=0.0143) when the variable was measured at 6 points. This score was maintained at T4, although the statistical significance increased (P=0.0101).

Interproximal contacts improved in the first six months of orthodontic retention. Already at T1 the 75th percentile changed from a value of 1.5 to a value of 1; this variation was statistically significant (P=0.0256). A further improvement occurred at T3: the 90th percentile went from 2 at T2 to 1 at T3 (P=0.3173 between T2 and T3). At T4, the scores were similar to those of the previous phase, although the 75th percentile changed

from a value of 1 (T3) to a value of 0.5 (T4; P=0.9760 between T3 and T4). The maxillary and mandibular II suffered a statistically significant worsening during the first six months of orthodontic retention (Table VI), while the dental arch widths did not change (Table VII). As regards the stability of the results obtained in the two arches, it is possible to state that no statistically significant differences were found at 6 months from the end of the orthodontic treatment (Table VIII).

Table VI. *Maxillary and mandibular Irregularity Index (II) at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Maxillary II	T1	1.86	3.55	0.95	1.98 ± 0.75	1.12	1.42	2.29	3.34	
	T2	1.94	3.81	0.98	2.07 ± 0.81	1.14	1.33	2.7	3.26	P=0.2500
	T3	2.06	3.87	1	2.19 ± 0.82	1.21	1.42	2.9	3.08	P=0.0258
	T4	2.2	4.13	1.15	2.43 ± 0.91	1.24	1.68	3.14	3.77	P=0.0005
Mandibular II	T1	1.67	3.28	1.11		1.16	1.34	1.94	2.72	
	T2	1.78	3.32	1.16		1.18	1.32	2.15	3.11	P=0.0053
	T3	1.8	3.54	1.16		1.22	1.41	2.15	3.17	P=0.0001
	T4	1.85	3.6	1.22		1.26	1.43	2.25	3.28	P<0.001

Table VII. *Dental arch widths at the end of the treatment (T1), after 1 (T2), 3 (T3) and 6 (T4) months of orthodontic retention.*

		Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Maxillary intercanine width	T1	34.84	37.43	29.91	34.42 ± 1.85	32.12	33.35	35.63	36.94	
	T2	34.44	37.5	29.62	34.45 ± 1.8	31.91	33.56	35.55	36.86	P=0.7683
	T3	34.32	37.69	28.86	34.37 ± 1.92	31.92	33.55	35.46	36.96	P=0.7216
	T4	34.17	37.9	28.55	34.27 ± 2.05	31.8	33.52	35.47	37.06	P=0.3639
Maxillary interpremolar width	T1	42.49	50.05	38.33	42.61 ± 2.66	39.27	40.85	44.27	45.66	
	T2	42	49.16	38.26	42.4 ± 2.55	38.97	40.86	43.6	45.77	P=0.1293
	T3	41.93	48.52	38.09	42.36 ± 2.48	38.8	41.13	43.5	45.82	P=0.16699
	T4	41.88	48.14	37.2	42.24 ± 2.47	38.96	41.2	43.36	45.08	P=0.0910
Maxillary intermolar width	T1	50.58	58.04	45.66	51.22 ± 3.34	46.71	48.39	53.5	55.39	
	T2	50.76	57.68	45.71	51.07 ± 3.29	47.41	47.92	53.26	55.61	P=0.0738
	T3	50.79	57.62	45.24	51.09 ± 3.37	47.07	48.09	53.44	55.76	P=0.2775
	T4	50.65	57.66	45.32	50.97 ± 3.34	46.83	48.05	53.38	55.92	P=0.0682
Mandibular intercanine width	T1	25.82	29.3	23.24	25.89 ± 1.5	23.9	24.97	26.58	28.16	
	T2	25.75	29.37	23.22	25.84 ± 1.51	24.16	24.65	26.29	28.29	P=0.4203
	T3	25.97	29.4	23.16	25.89 ± 1.54	24.41	24.62	26.27	28.66	P=0.9953
	T4	25.93	29.6	23.14	25.89 ± 1.55	24.41	24.63	26.27	28.66	P=1.000
Mandibular interpremolar width	T1	34.68	38.82	30.41	34.55 ± 1.81	32.72	33.33	35.65	36.94	
	T2	34.37	37.22	30.34	34.45 ± 1.59	32.9	33.25	35.55	36.21	P=0.4784
	T3	34.6	37.35	30.32	34.51 ± 1.67	32.86	33.13	35.62	36.66	P=0.8005
	T4	34.6	37.38	30.21	34.51 ± 1.66	32.82	33.33	35.66	36.63	P=0.8328
Mandibular intermolar width	T1	44.11	50.33	39.21	44.46 ± 3.09	40.56	42.51	46.92	49.37	
	T2	44.17	50.59	39.87	44.32 ± 2.86	40.36	42.23	46.28	48.47	P=0.2608
	T3	44.17	51.04	39.86	44.36 ± 2.91	40.64	42.33	46.28	48.3	P=0.5839
	T4	44.02	51.34	39.94	44.31 ± 3.06	40.19	41.93	46.25	48.56	P=0.4011

Table VIII. *Difference of the maxillary and mandibular Irregularity Index, the upper and lower segments (anterior, right and left) and the maxillary and mandibular dental arch widths (intercanine, interpremolar and intermolar) between the end of the treatment (T1) and the first six months of orthodontic retention (T4).*

	Median	Maximum	Minimum	Mean ± SD	10th percentile	25th percentile	75th percentile	90th percentile	p-value
Difference of the maxillary Irregularity Index between T1 and T4	0.47	1.67	- 0.49		-0.26	0.1	0.73	1.39	P=0.0613
Difference of the mandibular Irregularity Index between T1 and T4	0.16	0.84	0.02		0.04	0.07	0.37	0.46	
Difference of the upper anterior segment between T1 and T4	0	1	0		0	0	1	1	P=0.1317
Difference of the lower anterior segment between T1 and T4	0	1	0		0	0	0	1	
Difference of the upper right segment between T1 and T4	0	1	-1		0	0	0	1	P=0.9451
Difference of the lower right segment between T1 and T4	0	1	-1		0	0	0	1	
Difference of the upper left segment between T1 and T4	0	1	0		0	0	0	0	P=0.0588
Difference of the lower left segment between T1 and T4	0	1	0		0	0	0.5	1	
Difference of the maxillary intercanine width between T1 and T4	-0.11	1.23	-1.79	-0.15 ± 0.78	-1.26	-0.73	0.43	0.96	P=0.4151
Difference of the mandibular intercanine width between T1 and T4	-0.02	0.69	-0.67	0.00 ± 0.37	-0.57	-0.26	0.28	0.5	
Difference of the maxillary interpremolar width between T1 and T4	-0.32	1.55	-3.59		-1.17	-0.79	0.18	0.59	P=0.2713
Difference of the mandibular interpremolar width between T1 and T4	-0.12	1.41	-2.38		-0.7	-0.39	0.46	1.11	
Difference of the maxillary intermolar width between T1 and T4	-0.3	0.97	-1.62	-0.25 ± 0.64	-1.11	-0.7	0.27	0.53	P=0.6263
Difference of the mandibular intermolar width between T1 and T4	-0.3	1.85	-2	-0.16 ± 0.89	-1.07	-0.74	0.52	0.91	

Comparing the differences between the maxillary and mandibular II, the anterior superior and inferior segments, the superior and inferior right segments, the upper and lower left segments, and the maxillary and mandibular dental arch widths (intercanine, inter-premolar, intermolar) between T1 and T4, no statistically significant difference was found. Finally, regarding the efficacy between the Hawley retainer and the lower multi-stranded fixed retainer in maintaining the anterior teeth alignment, by comparing the differences of the

II, the anterior segments, and the maxillary and mandibular intercanine widths between T1 and T4, it can be stated that, although there were more variations in the upper arch, there was no statistically significant difference between the two orthodontic retainers.

DISCUSSION

The orthodontic treatment determined an overall improvement in the occlusion. Comparing our results (PAR index: from 18 points at T0 to 9 points at T1) with those of Onyeaso and Begole (PAR index: from 18.55 ± 9.34 points at T0 to 0.96 ± 1.80 points at T1) (20), they obtained an improvement in the occlusion greater than ours. The difference of the obtained values can be due to the following reasons: Onyeaso and Begole could have considered only the patients with the best orthodontic results; moreover, their measurements made with the caliper could be less accurate than ours, which were made through a dedicated software. Orthodontic treatment has led to an improvement in the alignment of the anterior sextants. The maxillary II, in fact, decreased from 5.49 mm (T0) to 1.86 mm (T1), while the mandibular from 5.59 mm (T0) to 1.67 mm (T1).

The two final scores are similar to those of Bjering et al. (21), who obtained a maxillary II of 2.0 ± 1.1 mm and a mandibular II of 1.5 ± 0.8 mm at the end of the treatment. The orthodontic treatment determined the expansion of the dental arches: the upper arch was expanded more than the inferior one. These results agree with what was reported by other Authors (22-24), who have shown that during the phase of dental alignment a certain degree of dentoalveolar expansion often occurs, necessary to correct the crowding and the occlusal relationship. Regarding the occlusal changes during the first 6 months of orthodontic retention, a statistically significant worsening of the occlusion was recorded according to the PAR index: from T1 to T4 the score rose from 8.75 ± 2.98 points to 9.88 ± 3.04 points. This difference was found to be greater than that obtained by Al Yami et al. (8) after a year of orthodontic retention (0.56 ± 6.4): however, it is difficult to compare these data with each other because the retention appliances that were used were not specified in that study.

In our work, the PAR index parameters that statistically significantly worsened were the anterior superior segment, the left inferior segment and the left buccal occlusion, while in the study of Al Yami et al. the worsening concerned all the parameters of the PAR index except the lateral occlusion, the anterior crossbite and the open bite. Regarding the trend of the ABO CRE, it did not present statistically significant changes during the follow-up. The parameters of the ABO CRE that were statistically improved during the period under review were: marginal ridges, occlusal contacts and interproximal contacts. These results are in agreement with what was reported by Hoybjerg et al. (9): the reduction of the score of the parameter "Occlusal Contacts" underlines how the posterior teeth seek stable contact with each other (settling) after the orthodontic treatment and how the upper Hawley retainer is an appliance that favors this phenomenon (10, 25). The improvement of the three aforementioned parameters also occurred in a study by Lyotard et al. (26) on occlusal changes after one month from the debonding in patients not subjected to orthodontic retentions. The parameters of the ABO CRE that have worsened in our work were "Alignment-rotations" and "Occlusal relation".

The worsening of the dental alignment, also present in the studies of Hoybjerg (9) and Lyotard (26), is mainly due to the instability of the upper anterior sextant: in fact, the maxillary II during the first six months of orthodontic retention increased from 1.98 ± 0.75 mm at T1 to 2.43 ± 0.91 mm at T4. Destang and Kerr (27) have shown that relapse may already occur during the retention period in a study that compared two protocols for the use of the upper Hawley retainer: the mean difference of the maxillary II over time reported by us (0.45 ± 0.55 mm) was found to be better than those reported by those two Authors (0.99 mm in the group who wore Hawley retainer for 6 months; 0.71 mm in the group that wore it for 1 year). On the other hand, the mandibular

II, although worsened, showed a more limited variation: its value at T1 was 1.67 mm, while at T4 it was 1.85 mm. From the comparison between the two variations of the II at T1 and T4 (0.47 mm for the maxilla and 0.16 mm for the mandible) a difference was found at the limits of the statistical significance (P=0.0613). However, it is possible to hypothesize that the major change in the upper anterior sextant depends on the type of retention appliance: in fact, the effectiveness of the Hawley retainer, being a removable appliance, depends on the patient's compliance; moreover, its application time is certainly lower than that of a fixed retainer.

At the level of the mandibular arch, on the other hand, the bonded retainer has led to a smaller variation in the alignment of the anterior teeth. However, even these teeth were not exempt from small movements. This is in line with what reported by other studies: in fact, Dahl and Zachrisson (28) described space reopening at the level of the inferior anterior sextant despite the presence of the fixed retainer in situ, while Katsaros et al. (29) reported cases of changes in torque and rotations of these teeth: these events did not occur in our work. The slight displacements of the teeth involved in the fixed retention were most likely caused by the deformation of the wire and the lack of passivity of the retainer as reported by Wolf et al. (30) and by Atack et al. (31). This latter, although her study was aimed at investigating the effectiveness of the fixed and of the Hawley retainer at the inferior arch, has reached conclusions similar to ours, that is, at one year of follow-up there are no statistically significant differences between the variations of the II in the two groups; however, this parameter changes more in the dental arch that is retained through the use of removable appliances.

From our investigations the increase in the score of the ABO CRE "Occlusal relationship" (4 points at T1 vs 6 points at T4), also occurred in the study of Hoybjerg (9), reflects the slight worsening of the occlusal relationship and alignment of the left emiarches: in fact, the median of the left vestibular occlusion of the PAR index passed from 0 to 1 and a difference in the average score of the lower left segment was recorded (0.25 ± 0.44 points between T1 and T4). This difference between the left and right sides of the mouth could be justified because the sample showed a greater number of variations in the interproximal contacts (diastema closure or reopening) at the level of the left emiarches. Overall, the upper and lower dental arch widths dunderwent nostatistically significant change. These results are in agreement with what was reported by Destang and Kerr (27) for the upper arch and by O'Rourke et al. (32) for the lower arch. In our work, the maxillary widths narrowed more than the mandibular ones: this is due to the greater expansion of the upper arch compared to the inferior one during the orthodontic treatment and therefore to its greater tendency to relapse (5). The intercanine mandibular width has proved to be more stable than the interpremolar and the intermolar ones: the reason lies in the fact that, since the multi-stranded fixed retainer extended up to the canines, the stability of the posterior mandibular teeth depends only on their settling with the antagonists (32).

CONCLUSIONS

A slight worsening of the dental occlusion was found according to the PAR index but not according to the ABO CRE index during the first six months of orthodontic retention, using the upper Hawley retainer and the lower multi-stranded fixed retainer. In particular, the dental alignment and the occlusal relationship worsened. However, there was also an improvement in posterior occlusal contacts, marginal ridges, and interproximal contacts. The worsening of the alignment of the anterior sextants was statistically significant for both arches. Although the maxillary II worsened slightly more than the mandibular one, the variation was similar. Upper and lower dental arch widths did not undergo any statistically significant changes during the follow-up; however, the maxillary widths narrowed more than the mandibular ones, most likely as a consequence of the greater expansion occurred during the orthodontic treatment.

In the coming years, better algorithms and new, fully automated methods of 3D comparison will probably be developed, making comparison even more precise and dependable (33). At the same time, less compliance will be required during retention and orthodontic treatment (34).

The stability of the results obtained with orthodontic therapy at the two arches was substantially similar, as was the effectiveness of the upper Hawley retainer and the lower multi-stranded fixed retainer in maintaining the alignment of the anterior teeth in the first six months of orthodontic retention. Overall, occlusal changes during the follow-up were minimal and the stability of the orthodontic treatment was not clinically compromised.

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