Original Article

Evaluation of relapse with thermoplastic retainers equipped with microsensors

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ABSTRACT

Objectives: To examine relapse with thermoplastic retainers equipped with microsensors 1 year after treatment.

Materials and Methods: A total of 42 patients (29 females, 13 males) treated with four premolar extractions were included in this study. Thermoplastic appliances equipped with TheraMon microsensors (Handelsagentur Gschladt, Hargelsberg, Austria) were used to assess daily wear time (DWT), and the patients were monitored at 2-month intervals for a period of 12 months. At the end of the follow-up, the following two groups were formed based on the mean DWT: short wear time (SWT; $<$9 h/d) and long wear time (LWT; $\geq$9 h/d). Digital models were constructed before treatment (T0), at debonding (T1), and 6 months (T2) and 12 months (T3) after debonding. Little's Irregularity Index (LII) and the intercanine and intermolar widths, arch lengths, overjet, and overbite were calculated based on the digital models. Data were analyzed statistically.

Results: Irregularity and overjet increased, whereas transverse measurements and arch lengths decreased with time in both groups. During the retention period, overbite decreased in the SWT group but increased in the LWT group. There were significant differences between groups only in mandibular irregularity. The LII values of the SWT group were significantly higher than those of the LWT group for the T1–T2 and T1–T3 time intervals ($P < .05$).

Conclusions: A mean DWT less than 9 hours/day was inadequate for controlling irregularity within clinically acceptable limits. A wear time of at least 9 h/d is recommended for the maintenance of mandibular anterior alignment. (*Angle Orthod.* 2022;92:340–346.)

KEY WORDS: Microsensor; Relapse; Stability

INTRODUCTION

Relapse can occur in approximately 70% of cases after orthodontic treatment.[1] The only known way to maintain satisfactory alignment in the posttreatment period is with long-term use of fixed or removable retainers. Therefore, it is essential that clinicians fully understand the etiology of relapse and take into account the advantages and disadvantages of various retainers for prolonged stability.[2] Removable thermoplastic retainers have the advantages of esthetics, comfort, and cost-effectiveness.[3] However, wear time based on patient cooperation is the main drawback of removable retainers.

The success of retention with removable appliances depends on patient compliance with instructed wear time, and removable retainer wear can be evaluated with several approaches.[4] Currently, wear time can be objectively measured by thermosensitive microsensors incorporated into removable appliances.[5] For this purpose, the TheraMon microsensor (Handelsagentur Gschladt, Hargelsberg, Austria) is commonly used because of its accuracy and comfortable design.[6] Microsensors have demonstrated that patients wear their retention appliances for a shorter time per day than is recommended.[7–13]

The published data regarding stability are based on subjective wear-time measures such as patient and parent reports or estimates of orthodontists.[14–23] Although wear data are subjective, part-time retainer wear (8–12 h/d) is reported to be as beneficial as full-time wear in preserving treatment results.[16–18,20] Never-

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theless, these findings need to be verified because of the subjective measurements of full-time or part-time wear. In addition, a few studies including four-premolar extraction cases have emphasized the effects of removable retention appliances on stability.[15,17,22]

Only one previous study assessed stability outcomes with objectively measured retainer wear.[13] However, the question of whether short wear times (SWTs) or long wear times (LWTs) are effective for the maintenance of stability remains questionable. Therefore, the aim of this study was to determine how the amount of objectively measured retainer wear affects posttreatment stability. For this purpose, the null hypothesis tested was that there would be no difference in stability between retainer SWTs and LWTs.

MATERIALS AND METHODS

This prospective, single-center study was approved by the Ethics Committee of Pamukkale University (25. 09.2018/18). Informed consent was obtained from all participants. Power analysis (SPSS version 24.0; IBM, Armonk, N.Y.) showed that 34 patients would give more than 80% power at the 95% confidence level with a medium effect size ($r = 0.4$). More patients were included to increase the power of the study.

A total of 47 patients (31 females and 16 males) aged between 15 and 25 years were included based on the following criteria: (1) completion of fixed orthodontic treatment with four premolar extractions, (2) good final occlusion and oral hygiene, (3) no missing teeth, (4) no requirement for fixed lingual retainer (ie, midline diastema or severe rotations before treatment), and (5) same bracket system (0.022-inch MBT, American Orthodontics, Sheboygan, WI, USA). The exclusion criteria were (1) agenesis, (2) cleft lip or palate, (3) surgical treatment, and (4) need for restoration in the anterior segment.

All patients received upper and lower thermoplastic appliances made of 1.0-mm thick Essix A+ (Dentsply Raintree Essix, Sarasota, FL, USA) material. Each appliance was integrated with a TheraMon microsensor (Handelsagentur Gschladt) to assess the daily wear time (DWT). The microsensors were incorporated into the right palatal side of the upper right buccal side of the lower appliances (Figure 1).

The patients were instructed to wear the appliance for at least 20–22 h/d (except during meals) for a period of 1 year, as in previous studies.[19,21] During this study, every 8 weeks, the data collected by each sensor were read by a TheraMon reader connected to a personal computer. At the end of follow-up, the mean DWT was calculated in hours per day for each patient. The patients were not informed that their DWT was being monitored during this investigation.

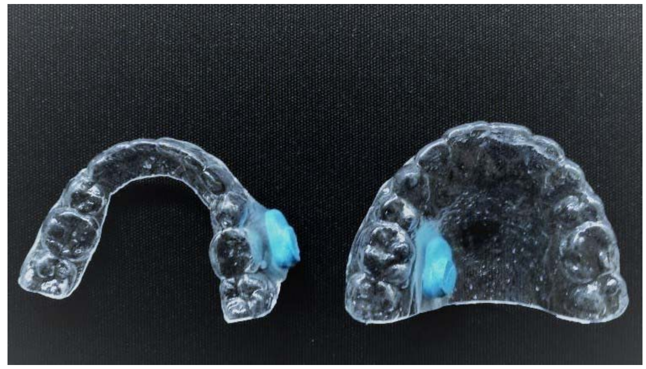

Figure 1. Retention appliances equipped with microsensors.

Stability measurements, including Little's Irregularity Index (LII),[24] and the intercanine and intermolar widths, arch length, overbite, and overjet were performed with OrthoAnalyzer (3Shape, Copenhagen, Denmark) software on three-dimensional digital models constructed before treatment (T0), at debonding (T1), 6 months after debonding (T2), and 12 months after debonding (T3). LII was measured as the sum of the distances between the anatomic contact points from the mesial aspect of the left canine through the mesial aspect of the right canine. The intercanine and intermolar widths, overjet, and overbite were measured as described by Gill et al.[16] Arch length was measured with the aid of a parabola that contoured from the mesial contact of the left first permanent molar to the corresponding point on the other side by passing through the incisal edges of incisors.[25] Stability measurements were repeated by the same researcher (Dr İshakoğlu) on 14 randomly selected patient records to determine intraobserver reliability 1 month later.

Statistical Analysis

The data were analyzed with SPSS (version 25; IBM Corp.). The independent-samples *t*-test was used to compare the mean DWT, age, and stability parameters between groups. The χ^2 test was used to compare the distribution of sex between groups. The changes over time were compared with repeated-measures analysis of variance. The reliability of the measurements was assessed by intraclass correlation coefficient (ICC). The level of significance was set at $P < .05$.

RESULTS

Actual Wear Time and Group Characteristics

The mean objectively measured wear time was 9.24 h/d for all patients. Thus, the participants were divided into the SWT group (DWT <9 h/d) and LWT group

Table 1. Baseline Data of the Sample[a]

	Group SWT (n = 20)	Group LWT (n = 22)	*P* Value
DWT, h	5.45 (1.73)	12.69 (3.38)	.001*
Age, y	17.83 (2.64)	18.15 (3.04)	.175
Sex, n			
Male	6 (30)	7 (32)	1.000
Female	14 (70)	15 (68)	
Changes, T0–T1			
Maxillary irregularity, mm	12.0 (3.68)	11.22 (2.98)	.430
Mandibular irregularity, mm	8.70 (2.93)	8.95 (2.86)	.781
Maxillary ICW, mm	−0.67 (1.55)	0.03 (1.51)	.147
Mandibular ICW, mm	0.13 (1.99)	−0.45 (1.96)	.349
Maxillary IMW, mm	0.45 (1.60)	1.29 (2.07)	.151
Mandibular IMW, mm	1.78 (1.50)	2.70 (1.56)	.060
Maxillary arch length, mm	6.11 (4.02)	8.64 (4.13)	.052
Mandibular arch length, mm	7.58 (2.55)	8.45 (3.13)	.334
Overbite, mm	−0.24 (1.26)	0.45 (1.62)	.132
Overjet, mm	1.22 (1.60)	1.86 (1.94)	.255

[a] SWT = DWT<9 h/d; LWT = DWT ≥9 h/d. ICW indicates intercanine width; IMW, intermolar width.
* $P < .05$.

(DWT ≥9 h/d), with mean DWTs of 5.45 ± 1.73 and 12.69 ± 3.38 h/d, respectively.

During the follow-up period, five patients dropped out of the study because of patient requests (2 females), loss of appliances (2 males), and unavailable wear-time data (1 female), leaving 20 patients in the SWT group and 22 in the LWT group. The changes at the T0–T1 time interval showed no significant differences between the groups in maxillary and mandibular LII, transverse measurements, arch length, overjet, or overbite parameters ($P > .05$; Table 1).

Table 2. Comparison of Maxillary Stability Measurements Between Groups and Times[a]

	Group[b]		
	SWT	LWT	*P* Value
LII, mm			
T1	0.21 ± 0.50[A]	0.00 ± 0.00	.06
T2	0.67 ± 0.85[B]	0.25 ± 0.47	.06
T3	0.93 ± 0.98[B]	0.49 ± 0.76	.11
P value	<.001*	.051	
ICW, mm			
T1	35.57 ± 1.34[A]	34.71 ± 1.82[A]	.09
T2	35.28 ± 1.40[B]	34.48 ± 1.94[B]	.13
T3	35.11 ± 1.39[C]	34.38 ± 1.95[C]	.17
P value	<.001*	<.001*	
IMW, mm			
T1	47.86 ± 1.51[A]	46.66 ± 2.64[A]	.08
T2	47.78 ± 1.50[B]	46.61 ± 2.63[B]	.09
T3	47.72 ± 1.51[B]	46.60 ± 2.61[AB]	.101
P value	.002*	.016*	
Arch length, mm			
T1	62.40 ± 2.50[A]	61.42 ± 3.30	.29
T2	61.95 ± 2.63[B]	60.49 ± 4.11	.18
T3	61.64 ± 2.79[B]	59.65 ± 4.99	.12
P value	<.001*	.051	

[a] Data are provided as mean ± standard deviation.
[b] A–C: no difference between times with the same letter in each group. SWT = DWT <9 h/d; LWT = DWT ≥9 h/d.
* $P < .05$.

Intraobserver Reliability

The stability measurements were repeated on four occasions and demonstrated excellent reliability, with ICCs ranging from 0.893 to 1.00 for both groups.

Maxillary Stability Measurements

Intragroup evaluation showed that, in the SWT group, a significant increase occurred in mean LII over time ($P < .001$; Table 2); however, no significant increase was found in the LWT group. Transverse widths significantly decreased in both groups over time. In the SWT group, arch length significantly decreased with time ($P < .001$; Table 2); however, nonsignificant decreases were observed in the LWT group.

Intergroup evaluation showed that there were no significant differences between the groups in maxillary stability measurements at any of the three time points ($P > .05$; Table 2).

Mandibular Stability Measurements

Intragroup evaluation showed that, in both groups, irregularity significantly increased and intercanine width significantly decreased with time ($P < .001$). In the LWT group, intermolar width significantly decreased with time ($P = .009$). Similar changes were observed in arch length ($P < .001$; Table 3). However, in the SWT group, nonsignificant decreases in these parameters were observed.

Intergroup evaluation showed that there were no significant differences between groups in mandibular

Table 3. Comparison of Mandibular Stability Measurements Between Groups and Times[a]

	Group[b]		
	SWT	LWT	*P* Value
LII, mm			
T1	0.38 ± 0.70[A]	0.21 ± 0.53[A]	.388
T2	1.84 ± 1.07[B]	0.82 ± 0.86[AB]	.001*
T3	2.37 ± 1.19[C]	1.06 ± 1.01[B]	.001*
P value	<.001*	<.001*	
ICW, mm			
T1	26.36 ± 1.15[A]	26.22 ± 1.48[A]	.74
T2	26.01 ± 1.23[B]	25.89 ± 1.51[B]	.78
T3	25.90 ± 1.25[C]	25.77 ± 1.53[C]	.78
P value	<.001*	<.001*	
IMW, mm			
T1	39.98 ± 1.12	39.40 ± 2.06[A]	.26
T2	39.83 ± 1.07	39.35 ± 2.06[AB]	.34
T3	39.81 ± 1.08	39.31 ± 2.04[B]	.32
P value	.135	.009*	
Arch length, mm			
T1	51.31 ± 1.64	50.63 ± 2.82[A]	.352
T2	50.97 ± 1.58	50.23 ± 2.88[B]	.305
T3	50.86 ± 1.59	50.05 ± 2.96[B]	.275
P value	.051	<.001*	

[a] Data are provided as mean ± standard deviation.
[b] A–C: no difference between times with the same letter in each group. SWT = DWT <9 h/d; LWT = DWT ≥9 h/d.
* $P < .05$.

stability measurements at three time points except for the mean LII values at T2 and T3 ($P < .001$; Table 3); there was greater irregularity in the SWT group than in the LWT group at T2 and T3.

Interarch Stability Measurements

Intragroup evaluation showed that overbite decreased with time in the SWT group, whereas overbite increased in the LWT group. Overjet significantly increased with time in the LWT group ($P < .001$; Table 4). However, the increase in overjet in the SWT was nonsignificant.

Intergroup evaluation showed that there were no significant differences between groups in interarch stability measurements at any of the three time points.

Changes in Stability Measurements for Different Time Intervals

There were increases in maxillary and mandibular irregularity and overjet in both groups. A slight increase was found in the overbite measurement of the LWT group in each time interval. No significant differences were found between groups in changes in stability measurements with two exceptions. There were statistically significant differences in the changes in mandibular irregularity between groups for the T1–T2 and T1–T3 time intervals. Significantly greater irregularity increases were observed in the SWT group ($P < .05$; Table 5).

Table 4. Comparison of Interarch Stability Measurements Between Groups and Times[a]

	Group[b]		
	SWT	LWT	*P* Value
Overbite, mm			
T1	2.11 ± 0.53	2.05 ± 0.62	.75
T2	2.02 ± 0.67	2.08 ± 0.59	.72
T3	2.01 ± 0.86	2.16 ± 0.61	.53
P value	.423	.364	
Overjet, mm			
T1	2.40 ± 0.63	2.57 ± 0.52[A]	.33
T2	2.58 ± 0.73	2.78 ± 0.60[B]	.32
T3	2.70 ± 0.87	2.90 ± 0.60[C]	.40
P value	.103	<.001*	

[a] Data are provided as mean ± standard deviation.
[b] A–C: no difference between times with the same letter in each group. SWT = DWT <9 h/d; LWT = DWT ≥9 h/d.
* $P < .05$.

DISCUSSION

Objective wear-time measurements demonstrated that patients wore their retention appliances for a shorter time than was recommended per day.[11,12] Therefore, in this study, the DWT of each participant was determined via microsensors to assess whether there was a threshold DWT required for retention to be effective in clinical practice. Patients treated with four premolar extractions were selected for the study population because of the different effects of extraction and nonextraction treatments on mandibular stability.[26] Because of the study design, the presence of microsensors was not explained to the patients. Because patients might alter their wear time after being aware of the use of microsensors in removable retention appliances, awareness of being monitored was previously shown to influence wear time in a positive way.[7,10]

Objective wear-time measures indicated that patients averaged 9.24 h/d of wear. This finding was supported by Moreno-Fernández et al.,[5] who recently reported that the mean DWT of removable appliances without informing patients of monitoring was 8.65 h/d. Patients were divided into wear-time groups considering the threshold mean DWT value. The wear-time groups matched favorably in baseline parameters so it was therefore likely that the distribution of patients in the study groups was homogeneous. Patients were followed for 12 months and monitored for wear time because the majority of relapse has been shown to occur in four-premolar extraction cases in the first year.[22] Because of the findings of previous stability studies with indirectly measured wear time based on patient reports,[15–23] the extent to which the objective

Table 5. Mean Differences of Stability Measurements Between Groups for Different Time Intervals[a]

	Time Interval	Group[b]		*P* Value
		SWT	LWT	
Maxillary LII, mm	T1–T2	−0.47 ± 0.62	−0.25 ± 0.47	.167
	T2–T3	−0.26 ± 0.44	−0.25 ± 0.49	.282
	T1–T3	−0.73 ± 0.77	−0.49 ± 0.76	.235
Maxillary ICW, mm	T1–T2	0.29 ± 0.30	0.23 ± 0.22	.442
	T2–T3	0.17 ± 0.18	0.1 ± 0.06	.217
	T1–T3	0.46 ± 0.38	0.32 ± 0.24	.174
Maxillary IMW, mm	T1–T2	0.08 ± 0.11	0.05 ± 0.09	.362
	T2–T3	0.05 ± 0.11	0.01 ± 0.04	.152
	T1–T3	0.14 ± 0.18	0.06 ± 0.11	.112
Maxillary arch length, mm	T1–T2	0.44 ± 0.47	0.93 ± 1.91	.870
	T2–T3	0.31 ± 0.54	0.84 ± 3.16	.641
	T1–T3	0.75 ± 0.84	1.77 ± 3.68	.687
Mandibular LII, mm	T1–T2	−1.47 ± 1.08	−0.62 ± 0.85	.008*
	T2–T3	−0.53 ± 0.56	−0.24 ± 0.43	.077
	T1–T3	−1.99 ± 1.25	−0.86 ± 1.06	.005*
Mandibular ICW, mm	T1–T2	0.35 ± 0.31	0.33 ± 0.54	.208
	T2–T3	0.12 ± 0.11	0.12 ± 0.12	.801
	T1–T3	0.46 ± 0.40	0.45 ± 0.64	.231
Mandibular IMW, mm	T1–T2	0.15 ± 0.35	0.05 ± 0.11	.464
	T2–T3	0.02 ± 0.21	0.04 ± 0.09	.810
	T1–T3	0.17 ± 0.50	0.09 ± 0.15	.588
Mandibular arch length, mm	T1–T2	0.34 ± 0.70	0.4 ± 0.48	.930
	T2–T3	0.11 ± 0.38	0.17 ± 0.35	.278
	T1–T3	0.45 ± 0.96	0.58 ± 0.73	.715
Overbite, mm	T1–T2	0.1 ± 0.37	−0.02 ± 0.35	.266
	T2–T3	0.01 ± 0.25	−0.08 ± 0.25	.246
	T1–T3	0.09 ± 0.59	−0.11 ± 0.51	.099
Overjet, mm	T1–T2	−0.18 ± 0.57	−0.21 ± 0.24	.247
	T2–T3	−0.13 ± 0.28	−0.12 ± 0.14	.916
	T1–T3	−0.31 ± 0.77	−0.33 ± 0.33	.537

[a] Data are provided as mean difference ± standard deviation.
[b] SWT = DWT <9 h/d; LWT = DWT ≥9 h/d.
* $P < .05$.

LWT or SWT of the removable retainer influenced posttreatment results was noteworthy.

According to the recorded LII changes, irregularity increases were found regardless of wear time. This increase was significant in the maxillary arch over time with SWTs, but not with LWTs. However, the increase in irregularity in the mandibular arch was significant in both groups over time. The mean changes in irregularity between debonding and 12 months after debonding in the maxillary arch were 0.73 mm and 0.49 mm for the SWT and LWT groups, respectively. In the mandibular arch, the mean changes were 1.99 mm and 0.86 mm for the SWT and LWT groups, respectively. Therefore, there were greater changes in mandibular and maxillary incisor irregularity with SWT than with LWT after 1 year of retention.

Contrary to previous studies based on subjectively evaluated wear times of thermoplastic retainers,[16,17,20] the current results demonstrated significant differences in mandibular incisor irregularity at 6 and 12 months after treatment between wear-time groups. On the other hand, the differences in the maxillary arch between the two groups were not statistically significant and also clinically negligible for the SWT group even when the irregularity change was restricted to a unique tooth position at 12 months after treatment. Ma et al.[27] concluded that misalignment was clinically significant when LII reached 1.5 mm for one maxillary central incisor.

Transverse widths were generally well maintained; decreases less than 0.5 mm are considered clinically acceptable. Decreases in intercanine widths were found to be associated with increases in maxillary and mandibular incisor irregularity. Similarly, small decreases in intermolar widths may be explained by decreases in arch length. However, the reason for the more pronounced decreases observed in mandibular arch length in the LWT group could not be solely attributed to decreases in intermolar width accompanied by increased irregularity. The inclination change of the lower incisors may have been responsible for arch length reductions in patients who had worn their appliances for a long time. When the lower incisors were inclined lingually during the retention follow-up, arch length decreased, overbite increased, and overjet significantly increased, as found in the LWT group. However, this relationship should have been confirmed by angular measurements in the present study.

The arch lengths decreased over time because of the multifactorial etiology of relapse.[28] Interestingly, at 12 months after treatment, more decreases (1.77 $\pm$ 3.68 mm) were observed in the maxillary arch of patients with LWTs, although the irregularity increase was lower than that in the mandibular arch. Nevertheless, this finding may have been related to the insufficiency of the irregularity index to account for posterior tooth rotations and axial inclinations.[24] Differences in the arch length changes between the wear-time groups were insignificant.

Insignificant decreases in overbite were observed in the SWT group, whereas an increase occurred in the LWT group. An increase over time could be explained by occlusal settling as a result of longer wear and changes in the inclination of the lower incisors. Contrary to the current findings, Thickett and Power[17] found an increase in overbite in subjects reporting part-time wear compared to those reporting full-time wear; however, wear times were not evaluated objectively. In the current study, the change in overjet between debonding and 12 months after debonding was a maximum increase of approximately 0.3 mm for both groups, which was unlikely to be clinically significant. However, regardless of whether thermoplastic appliances were used with SWTs or LWTs, there were no significant differences in interarch measurements between the different wear-time groups during this study.

The null hypothesis was partially rejected. Among the stability measurements, significant differences were only found between the wear-time groups for mandibular irregularity. The evidence indicated that the difference in changes of irregularity in the mandibular anterior teeth between SWTs and LWTs was clinically significant; the difference was more than 1 mm at 6 and 12 months after treatment. Accordingly, retainer SWT caused more deterioration in the alignment of mandibular anterior teeth. This study was novel in showing that an objectively measured wear time of thermoplastic retainers of at least 9 hours daily was more effective for maintaining the clinical stability of mandibular anterior tooth alignment during a 12-month retention period.

One limitation was the lack of patient randomization because of the study design. The actual threshold value of the mean DWT (9.24 h/d) required for retention to be effective was first calculated in this study. Although this study highlighted that there was a threshold value of DWT, the evidence was weak because of the relatively small sample size. Regular patient follow-up is necessary because wear data are only available when the patient comes for a control session during retention treatment. In addition, the results could not be compared in detail with previous stability studies based on subjective wear-time data. Future studies are needed to strengthen the findings with a larger study population and to evaluate posttreatment stability for more than 1 year with a randomized clinical study design based on the threshold wear time with different retention regimens.

CONCLUSIONS

- The mean DWT of thermoplastic retainers was objectively calculated as 9.24 h/d.
- Mandibular irregularity was significantly greater with SWT (DWT$<$9 h/d) than with LWT (DWT$\geq$ 9 h/d) at the end of the 12-month follow-up period.
- No significant differences were found between wear-time groups when maxillary irregularity, transverse measurements, overjet, overbite, and arch length were examined after 1 year of retention.

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