

# Occlusal contact area changes with different retention protocols: 1-year follow-up

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**Introduction:** The purpose of this study was to evaluate the occlusal contact area and cast-radiograph evaluation (CRE) score changes in patients with 3 different retention protocols after a 1-year retention period.

**Methods:** A total of 90 patients with acceptable final occlusion according to American Board of Orthodontics CRE were equally divided into 3 groups according to the retention protocol: upper bonded retainer and lower Essix or bonded retainer (Essix group); upper bonded retainer and Hawley or lower bonded retainer (Hawley group); and upper bonded retainer and lower bonded retainer (bonded retainer group). Digital models were used to assess occlusal contact area changes after a 1-year retention period. The follow-up occlusion models were assessed with the American Board of Orthodontics CRE. **Results:** Occlusal contact areas increased significantly in the Hawley and bonded retainer groups for all teeth except incisors. The bonded retainer group showed the greatest amount of settling, but differences with the Hawley group were not statistically significant. However, statistically significant decreases in occlusal contact areas were recorded for the Essix group except for incisors. A decrease of CRE scores was seen in the Hawley group, whereas a statistically significant increase was recorded in the Essix group. **Conclusions:** Both Hawley and bonded retainers allowed settling of the occlusion during the retention phase, whereas the Essix retainer did not allow relative vertical movement of the posterior teeth. The Hawley group showed improvement in the total CRE score, whereas the Essix group showed worsening. (Am J Orthod Dentofacial Orthop 2020;157:533-41)

Orthodontic treatment goals can be expressed as achieving ideal tooth alignment, esthetic, functional occlusion, and stability at the end of active treatment. One of the most important challenges in orthodontics is maintaining the occlusal stability achieved at the end of active treatment. Long-term studies have shown that various occlusal changes occur after the active phase of orthodontic treatment.<sup>1,2</sup> Some of these changes are unwanted changes and are considered as relapse. Others may be beneficial and desirable, such as the improvement of the interdigitation of the teeth.<sup>3</sup>

The retention appliances are used to maintain the arch dimensions and alignment of the teeth after

completion of the orthodontic treatment.<sup>3</sup> Settling is the natural vertical, and horizontal movement of the teeth after orthodontic treatment toward the functionally stable interocclusal contacts.<sup>4</sup> Occlusal stability affects the health of the stomatognathic system and may play a role in preventing relapse after active treatment.<sup>5,6</sup> Surveys have shown that the number of occlusal contacts may increase during retention period and the selection of retention appliance may affect settling.<sup>7-10</sup>

There are 2 types of retention appliances, fixed and removable. The use of both types of retention appliances is widely accepted to avoid possible posttreatment changes.<sup>11-15</sup> The removable retention appliances allow the teeth to perform their normal functions and are expected to provide settling.<sup>16</sup> However, this obliges clinicians to rely on patient cooperation for stability.<sup>17</sup> Essix retainer is a removable, thermoplastic retention appliance that is well tolerated by patients. It is often preferred because of its hardness, size, esthetic appearance, and low-cost characteristics.<sup>18</sup> However, Essix appliances are less effective in long-term stabilization than other retention appliances and may not allow for the settling of the occlusion.<sup>16,18-20</sup> Fixed retainers bonded to anterior teeth are esthetically more pleasing than

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removable retainers and are less problematic in a matter of patient cooperation. In contrast, accidental debonding occurs in 6%–20% of patients, depending on the bonding technique and retention duration; moreover, fixed retainers can affect oral hygiene negatively.<sup>21–23</sup>

The cast-radiograph evaluation (CRE), formerly called the objective grading system, created by the American Board of Orthodontics (ABO) and used for the evaluation of treatment results since 1999, is a detailed and reliable index.<sup>24</sup> A total of 8 criteria, including alignment and rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts, and root angulation, assess the quality of the final occlusion. The first 7 criteria are measured on the dental models with a special instrument, ABO measuring gauge, and the final criterion, which is the root angulation, is measured on panoramic radiographs. The lower CRE score indicates the better final occlusion. According to the rules set by ABO, 1 of the criteria that a case must meet in order to be successful in the board examination is that the total CRE score be 27 or below.

Most studies investigating the effect of retainers on the number of occlusal contacts during the retention period indicate that the number of contacts increases and the occlusion improves over time.<sup>3,25–29</sup> However, some studies reported no improvements or worsening of the occlusion.<sup>19,20,30,31</sup> There is no definite conclusion about the effects of various retention devices on settling, and it is still to be discussed as to which appliance is more successful.

Sauget et al<sup>8</sup> reported that at the end of the 3-month-retention period, more settling was seen with Hawley compared with clear overlay retainers, whereas Basciftci et al<sup>28</sup> found no statistically significant difference in the posterior occlusal contacts between Hawley and Jensen plate at the end of the 1-year retention period. Durbin and Sadowsky<sup>3</sup> reported significantly more settling with the active positioners than with passive Hawley retainers; in contrast, Haydar et al<sup>27</sup> found no significant difference in occlusal contacts using the same appliances. Method differences used to determine occlusal contacts and biased case selection may explain these conflicting results because most studies did not randomly assign their patients.

The purpose of this study is to compare the effects of Essix, Hawley, and fixed retainers on occlusal contact areas and CRE scores after a 1-year retention period, and to reveal, if possible, their superiority to each other.

## MATERIAL AND METHODS

Ninety patients treated by postgraduate students at the Department of Orthodontics, Faculty of Dentistry, Bezmialem Vakif University, Istanbul, Turkey, between 2014 and 2017 were included in the study. All patients received nonextraction fixed orthodontic treatment with a straight wire technique. Patients were selected based on the availability of the records such as dental models, bite records and panoramic radiographs taken after the treatment (T1) and 1-year posttreatment (T2).

The patient selection was based upon the following criteria: (1) treatment with fixed orthodontic appliances without extraction with or without auxiliary appliances; (2) optimum occlusion at the end of treatment with Class I molar and canine relationship (CRE score  $\leq 27$ ); (3) good compliance regarding retainer wear; (4) good oral hygiene and no periodontal disease; (5) normal growth pattern (SN/GoMe:  $32^\circ \pm 7^\circ$ ); (6) no missing teeth except third molars; and (7) no presence of prosthetically restored tooth.

The exclusion criteria for this study included patients with a dental and skeletal open bite or deep bite before treatment, patients with incomplete records, final occlusion scores more than 27 according to CRE, large restorations on posterior teeth, and symptoms related to temporomandibular joint disorder.

Thirty patients were provided for each retention groups: maxillary bonded retainer and Essix or mandibular bonded retainer (Essix group;  $n = 30$ ), maxillary bonded retainer and Hawley or mandibular bonded retainer (Hawley group;  $n = 30$ ), and maxillary and mandibular bonded retainer (bonded retainer group;  $n = 30$ ). Patients with removable appliances were instructed to wear their retainers full time, except during meals, for 6 months and only at nights for the next 6 months.

The sample included 58 females (64.4%) and 32 males (35.6%). The average age was  $18.2 \pm 7.3$  years, with a range of 10.41–41.0 years. The average length of the treatment time was  $15.8 \pm 3.4$  months and the average length of retention time was  $12.1 \pm 0.5$  months. Fifty-three patients had Class I malocclusion, 29 had Class II Division 1 malocclusion, and 8 had Class III malocclusion before treatment. The group characteristics of different retention protocol groups are described in Tables I and II.

All dental models and panoramic radiographs were measured according to ABO's CRE including all 8 criteria: alignment and rotation, marginal ridges, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, interproximal contacts, and root angulation as described by Casco et al.<sup>24</sup>

**Table I.** Posttreatment characteristics of sample groups

Characteristics	Essix		Hawley		Bonded retainer		P
	Mean	SD	Mean	SD	Mean	SD	
ANB	3.22	1.64	2.84	2.29	3.01	1.91	0.752
Age	18.43	7.57	15.90	6.80	20.30	6.99	0.002*
Treatment time	16.37	3.51	16.10	3.50	14.90	3.10	0.207

Note. One-way analysis of variance and Kruskal-Wallis test (\* $P < 0.01$ ).

SD, standard deviation.

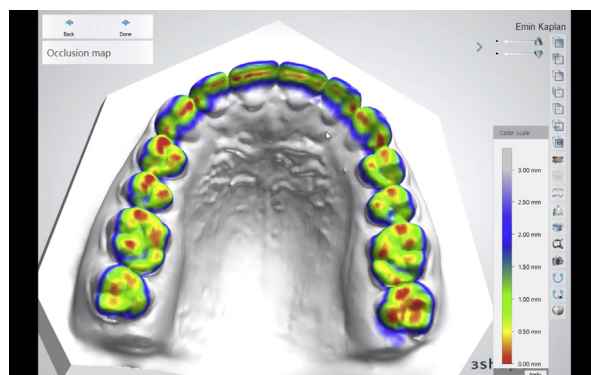
**Table II.** Gender distribution of groups

Sex	Essix		Hawley		Bonded retainer		Total		P
	n	%	n	%	n	%	n	%	
Female	15	50	20	66.7	23	76.7	58	64.4	0.093
Male	15	50	10	33.3	7	23.3	32	35.6	
Total	30	100	30	100	30	100	90	100	

Note. Chi-square test.

Dental casts and occlusal records were gathered from all patients at 2 time points: after the removal of orthodontic appliances (T1), and following the retention period 12 months later (T2). The dental casts were digitized separately and together with maximum intercuspation relationship by using 3Shape (Copenhagen, Denmark) R900 3-dimensional laser scanner (Fig 1). After obtaining a pair of digital occluded models, the Ortho Analyzer program was used to assess the occlusal contacts. This program includes the “occlusion map” tool, which reveals occlusion contacts with a color scale (Fig 2). In order to measure the occlusal contact areas which are defined as red areas on digital models, the image analysis software ImageJ (version 1.52a for Macintosh, National Institutes of Health, Bethesda, Md) was used to trace the red areas manually. The images were taken from 3Shape separately for all teeth and calibrated to ImageJ with the distance between 2 points in mm dimensions. The outlines of the occlusal contact areas were traced using the freehand preselection tool with the computer mouse, and the ImageJ program automatically calculated the traced area in mm<sup>2</sup> dimensions (Fig 3).

The contacts recorded on the maxillary and mandibular dental models at each of the 2 time points were divided into 2 to obtain the contact areas of molars, premolars, canines, and incisors. All measurements were made by a single examiner (BK) at each time point, repeated twice and averaged.

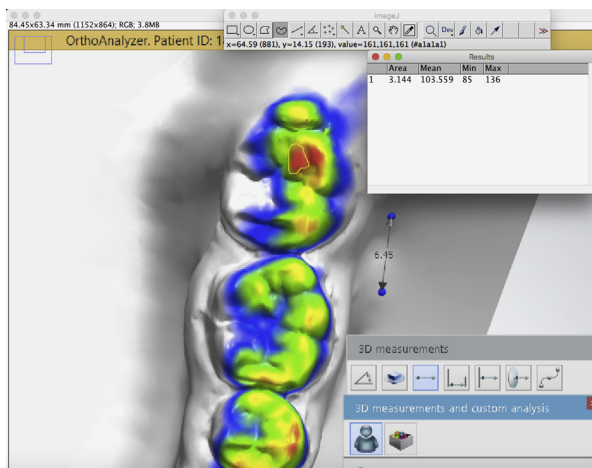
**Fig 1.** Three-dimensional scanning of dental casts with 3Shape R900 scanner.**Fig 2.** Assessment of occlusal contact areas with 3Shape OrthoAnalyzer software.

### Statistical analysis

All statistical analyses were performed using SPSS (version 21.0; Chicago, Ill) software package. Kolmogorov-Smirnov test was performed to assess the normal distribution of the studied samples. Paired sample *t* tests were used to assess differences between the mean at T1 and T2 for occlusal contacts, and the Wilcoxon test was used for CRE scores. One-way analysis of variance test was used to compare the intergroup means for occlusal contacts and the Kruskal-Wallis test was used for CRE scores.

### RESULTS

Comparisons of the posttreatment patient characteristics between groups showed significant differences for age ( $P = 0.002$ ; Table I).



**Fig 3.** Measurement of occlusal contact areas with ImageJ software.

Table III shows the changes of mean contact areas of the 3 groups on the anterior and posterior segments and total in  $\text{mm}^2$ . The contact area differences recorded during the retention period for different retention appliances were statistically significant. In the Essix group, the total occlusal contact areas decreased from  $34.41 \text{ mm}^2$  to  $32.21 \text{ mm}^2$ , which was statistically significant ( $P = 0.003$ ). The mean contact areas of anterior ( $P = 0.018$ ) and posterior ( $P = 0.007$ ) segments decreased from  $7.86 \text{ mm}^2$  to  $7.32 \text{ mm}^2$  and  $26.55 \text{ mm}^2$  to  $24.89 \text{ mm}^2$ , respectively.

There was a statistically significant increase in the anterior segment ( $P = 0.002$ ;  $P = 0.004$ ), posterior segment ( $P < 0.001$ ;  $P < 0.001$ ), and total contact areas ( $P < 0.001$ ;  $P < 0.001$ ) in Hawley and bonded retainer groups. The total occlusal contact areas increased from  $33.47 \text{ mm}^2$  to  $35.41 \text{ mm}^2$  in the Hawley group and increased from  $34.21 \text{ mm}^2$  to  $37.02 \text{ mm}^2$  in the bonded retainer group.

The mean occlusal contact areas recorded in canines, premolars, and molars decreased in the Essix group and increased in the Hawley and bonded retainer groups, with all changes being significant ( $P < 0.05$ ). The change of the contact area recorded in incisors was statistically insignificant in any group ( $P > 0.05$ ; Table III).

Table IV shows the comparison of occlusal contact area changes among three retention groups. The results of the analysis of variance demonstrated statistically significant differences in 3 groups for all investigated teeth ( $P < 0.05$ ). The Tukey test showed that occlusal contacts for all segments increased significantly in Hawley and bonded retainer groups compared with the Essix group ( $P < 0.05$ ). No statistically significant changes were

determined between the Hawley and bonded retainer groups ( $P > 0.05$ ).

Table V shows the variables of each retention group that were compared at posttreatment and postretention recalls. The total CRE scores were worsened significantly for the Essix group from 25.7 to 27.82 and improved significantly for the Hawley group from 26.33 to 23.87. The Hawley and bonded retainer groups showed the greatest improvement with 5 criteria that showed significant improvement, and only 2 criteria showed significant worsening, but overall, the bonded retainer group did not have a significant improvement in total CRE score. The Essix group demonstrated the least improvement among 3 retention groups with 3 criteria improved and 3 criteria worsened significantly.

The criteria that showed worsening were alignment or rotation ( $P < 0.001$ ) and buccolingual inclination ( $P < 0.05$ ) in all groups. The most improvements were measured for the marginal edges, overjet, and occlusal contact criteria ( $P < 0.05$ ).

The comparison of variables among the different retention groups (Table VI) showed statistically significant differences for alignment, buccolingual inclination, overjet, occlusal contacts, occlusal relationship, and interproximal contacts ( $P \leq 0.001$ ). Marginal ridges and root angulation differences between the retention groups were not statistically significant ( $P > 0.05$ ). There was a significant change from T1 to T2 for the total CRE score among the 3 retention groups with the Hawley group showing the biggest change with 2.47 ( $P < 0.001$ ) and the bonded group showing the least with 0.33 ( $P < 0.001$ ).

## DISCUSSION

Occlusal contact changes may take place after the removal of the active appliances during the period of posttreatment “settling.” An increase in the number of occlusal contacts represents an improved interdigitation which may have a role in the stability of the orthodontic results.<sup>3,32</sup> Various studies have evaluated occlusal contact changes with conventional retainers such as Hawley appliances and positioners, and there is limited research concerning occlusal contacts when Essix retainers and bonded retainers are used.<sup>3,8,19,20,27-29,32</sup> Although Hawley, Essix, and bonded retainers are the most frequently used retention appliances in orthodontic practice, there is no research comparing these 3 retention appliances’ effects on the occlusal contact area changes. This disparity is the reason why we aimed to evaluate the effects of 3 different retention protocols on occlusal contact areas following a 1-year retention period.

**Table III.** Average contact area changes with different retention appliances pre- and postretention

Variables	Essix					Hawley					Bonded retainer				
	T1		T2		P	T1		T2		P	T1		T2		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Incisor	4.64	2.45	4.29	2.42	0.055	3.99	2.03	4.27	2.08	0.051	4.66	2.13	5.01	2.06	0.092
Canine	3.22	1.15	3.03	1.04	0.021*	3.3	0.8	3.47	0.76	0.035*	3.19	0.94	3.38	0.88	0.04*
Premolar	11.04	2.99	10.21	2.97	0.045*	10.78	2.04	11.44	2.08	<0.001***	10.89	3.02	11.91	3.31	<0.001***
Molar	15.51	3.36	14.56	3.32	0.023*	15.4	2.23	16.23	2.44	0.008**	15.46	3.27	16.72	3.43	<0.001***
Anterior	7.86	4.49	7.32	4.09	0.018*	7.29	2.18	7.74	2.15	0.002**	7.85	3.92	8.39	3.6	0.004**
Posterior	26.55	5.78	24.89	5.85	0.007**	26.18	4.08	27.67	3.95	<0.001***	26.36	6.11	28.63	6.45	<0.001***
Total	34.41	9.3	32.21	8.96	0.003**	33.47	5.75	35.41	5.53	<0.001***	34.21	9.47	37.02	9.12	<0.001***

Note. Paired sample *t* test (\**P* < 0.05, \*\**P* < 0.01, \*\*\**P* < 0.001).  
SD, standard deviation.

**Table IV.** Intergroup comparison of occlusal contact area changes pre- and postretention

Variable	Essix		Hawley		Bonded retainer		P	Intergroup comparison
	Mean	SD	Mean	SD	Mean	SD		
Incisor	-0.35	0.97	0.27	0.7	0.35	1.11	0.008*	2 > 1; <i>P</i> = 0.003* 3 > 1; <i>P</i> = 0.013*
Canine	-0.19	0.87	0.17	0.62	0.19	0.59	<0.001**	2 > 1; <i>P</i> = 0.001** 3 > 1; <i>P</i> < 0.001**
Premolar	-0.82	2.14	0.66	0.82	1.01	0.94	<0.001**	2 > 1; <i>P</i> < 0.001** 3 > 1; <i>P</i> < 0.001**
Molar	-0.95	2.16	0.82	1.59	1.25	1	<0.001**	2 > 1; <i>P</i> < 0.001** 3 > 1; <i>P</i> < 0.001**
Anterior	-0.54	1.63	0.45	0.99	0.54	1.3	<0.001**	2 > 1; <i>P</i> = 0.001** 3 > 1; <i>P</i> = 0.001**
Posterior	-1.65	3.12	1.48	1.93	2.27	1.46	<0.001**	2 > 1; <i>P</i> < 0.001** 3 > 1; <i>P</i> < 0.001**
Total	-2.2	4.13	1.94	2.36	2.81	1.94	<0.001**	2 > 1; <i>P</i> < 0.001**

Note. One-way analysis of variance (\**P* < 0.01; \*\**P* < 0.001).  
SD, standard deviation.

Sauget et al<sup>8</sup> aimed to examine the occlusal contact changes caused by the Hawley and Essix appliances and used a silicone bite record to measure the number of occlusal contacts. Haydar et al<sup>27</sup> recorded occlusal contact changes following orthodontic treatment by exposing the interocclusal silicone registration to the light and scored the light transmittance. This method is the most frequently used method for examining occlusal contacts in the literature.<sup>19,20,28,29,32</sup> However measuring only occlusal contact numbers with silicone-based impression materials provides incomplete information about posterior contacts and the results obtained with translucent sections recorded as contacts may vary depending on the orientation of the interocclusal record to the light source. Modern systems such as T-Scan and the Dental Prescale System can be used to determine occlusal contacts, but they are more commonly used to measure bite forces. These systems

may interfere with and alter the occlusion because patients bite on a 0.004-inch-thick sensor plate that they cannot perforate. Moreover, the registered contacts are those projected on the sensor plate, and they are not directly related to the 3-dimensional occlusal anatomy of the teeth because the pressure sensor is not easily formable as bite registration wax or silicone and may not lay on the deep fossae.

In our study, pre- and postretention models were scanned with a 3-dimensional laser scanner (3Shape) separately and in an occluded manner. This method provides quantitative, 3-dimensional registration of the occlusal contacts with 3-dimensional models. However, it was not possible to perform area measurements while examining occlusal contacts within the software properties. For this reason, screenshots of each tooth were transferred to the ImageJ program and 2-dimensional area measurements were performed. Sousa et al<sup>33</sup>

**Table V.** Average CRE scores changes with different retention appliances pre- and postretention

Variables	Essix							Hawley							Bonded retainer									
	T1			T2				P	T1			T2				P	T1			T2				
	Mean	SD	Max	Min		Max	Mean		SD	Max	Mean	SD	Max	Mean	SD		Max	Mean	SD	Max	Mean	SD	Max	
				Min	Max																			Min
Alignment/rotation	5.37	0.86	3	6	7.43	0.74	6	<0.001***	5.47	0.97	3	7	6.20	0.92	4	<0.001***	5.60	0.72	4	7	7.50	0.77	6	<0.001***
Marginal ridges	4.27	0.58	3	5	3.23	0.67	2	0.021*	4.43	0.77	3	6	3.47	0.81	2	<0.001***	4.07	0.52	3	5	3.03	0.66	2	<0.001***
Buccolingual inclination	3.53	0.68	2	5	4.03	0.89	3	<0.001***	3.70	0.53	3	5	4.0	0.69	3	0.013*	3.60	0.85	2	5	5.10	0.80	4	<0.001***
Overjet	3.77	0.93	2	6	3.07	0.90	2	0.023*	4.10	0.75	3	6	2.97	0.80	2	<0.001***	3.97	0.76	3	6	2.40	0.72	1	<0.001***
Occlusal contact	3.27	0.64	2	4	2.83	0.79	1	0.002*	3.07	0.82	1	5	2.03	0.61	1	<0.001***	3.37	0.71	2	4	2.63	0.71	1	<0.001***
Occlusal relationship	2.87	0.62	2	4	4.70	0.91	3	<0.001***	2.93	0.64	2	4	3.20	0.88	2	0.087	2.87	0.62	2	4	2.40	0.49	2	<0.001***
Interproximal contacts	1.13	0.77	0	2	1.10	0.71	0	0.705	1.20	0.61	0	2	0.80	0.55	0	0.001***	1.03	0.61	0	2	1.23	0.50	0	0.109
Root angulation	1.50	0.50	1	2	1.43	0.62	0	0.414	1.43	0.50	1	2	1.20	0.40	1	0.008**	1.30	0.46	1	2	1.17	0.37	1	0.046*
Total	25.7	1.02	23	27	27.83	1.85	25	<0.001***	26.33	0.95	24	28	23.87	0.97	22	<0.001***	25.80	1.09	24	27	25.47	2.30	20	0.315

Wilcoxon test (\* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ ).  
SD, standard deviation.

**Table VI.** Intergroup comparison of CRE scores changes pre- and postretention

Variables	Essix			Hawley			Bonded retainer			P	Intergroup comparison
	Mean	SD	Min Max	Mean	SD	Min Max	Mean	SD	Min Max		
Alignment/rotation	2.07	0.58	1 3	0.73	0.69	0 2	1.9	0.66	0 3	<0.001**	1 > 2; P < 0.001** 3 > 2; P < 0.001**
Marginal ridges	-1.03	0.61	-3 0	-0.97	0.55	-2 0	-1.03	0.61	-2 0	0.901	
Buccolingual inclination	0.5	0.9	-1 2	0.3	0.59	-1 1	1.5	0.5	1 2	<0.001**	3 > 1; P < 0.001** 3 > 2; P < 0.001**
Overjet	-0.7	0.91	-2 1	-1.13	0.73	-3 1	-1.57	0.72	-3 0	0.001**	3 > 1; P = 0.001**
Occlusal contact	-0.43	0.62	-2 0	-1.03	0.61	-3 0	-0.73	0.69	-2 0	0.001**	2 > 1; P = 0.001**
Occlusal relationship	1.83	0.74	0 3	0.27	0.82	-1 2	-0.47	0.57	-1 1	<0.001**	1 > 2; P < 0.001** 1 > 3; P < 0.001** 3 > 2; P = 0.026*
Interproximal contacts	-0.03	0.49	-1 1	-0.4	0.56	-2 0	0.2	0.66	-1 1	0.001**	2 > 3; P = 0.001**
Root angulation	-0.07	0.45	-1 1	-0.23	0.43	-1 0	-0.13	0.34	-1 0	0.313	
Total	2.13	1.65	-1 6	-2.47	0.9	-5 -1	-0.33	1.91	-4 4	<0.001**	2 > 1; P < 0.001** 2 > 3; P = 0.001** 1 > 3; P < 0.001**

Kruskal-Wallis H test (\*P < 0.05; \*\*P < 0.001).  
SD, standard deviation.

reported the accuracy and reproducibility of measurements on digital models with the 3Shape scanner. ImageJ software has been tested and has been proven to be reliable and repeatable.<sup>34</sup>

The selection of retainer type to be used in each patient was determined according to the patient's post-treatment needs. Comparisons of the pretreatment patient characteristics between groups were insignificant regarding size, sex, Angle classification, and treatment time. In contrast, the fact that individuals in the Hawley group are younger compared with other groups may indicate that they are more susceptible to passive eruption because of continued vertical growth, which may have positively affected the results. The models of the patients in which extraction was performed according to the treatment plan were not included in the study in order to have comparable and standardized sample collection.

Durbin and Sadowsky<sup>3</sup> reported a statistically significant increase in the number of total contacts after 3 months of retention with the Hawley retainers. Sauget et al<sup>8</sup> found similar results with the Hawley appliance following 3 months, and both researchers reported that the increase in total contact numbers was due entirely to an increase in the posterior contacts. Rzdolsky et al<sup>26</sup> investigated contact number changes with the Hawley appliance following 21 months and reported a

statistically significant increase in the number of posterior and total contacts.<sup>2</sup> Similarly, Başıçiftçi et al<sup>28</sup> and Sari et al<sup>29</sup> found a statistically significant increase in total and posterior occlusal contacts following a 1-year retention period with the Hawley appliance. In our study, the changes in occlusal contact area measurements in all teeth, except for incisors, were statistically significant for all retention protocols following a 1-year retention period. The total contact area increased from 33.47 mm<sup>2</sup> to 35.41 mm<sup>2</sup>, and the posterior contact area increased from 26.18 mm<sup>2</sup> to 27.67 mm<sup>2</sup> in the Hawley group. These differences were due mostly to the changes in the premolar and molar regions because there were no significant changes in the incisor segment. According to the results from the previous studies compared with our findings, we can conclude that the Hawley appliance allows the vertical movement of posterior teeth, which is beneficial for the settling of the occlusion during the retention period.

Sauget et al<sup>8</sup> found no significant increase in posterior contacts at the end of 3 months of night-time wear of Essix retainers.<sup>8</sup> Similarly, Dinçer and Aslan<sup>20</sup> reported no significant increase was determined in the number of posterior contacts with Essix retainers at the end of 9 months of retention. In addition, Aslan et al<sup>19</sup> reported no significant increase in posterior contacts with Essix retainers following 9 months. In

contrast to these findings, we demonstrated that Essix retainers not only prevented settling but also decreased the contact areas significantly over a 1-year retention period with a mean decrease from 34.41 mm<sup>2</sup> to 32.21 mm<sup>2</sup>. Although the occlusal contact numbers did not seem to decrease with the use of Essix appliances, the occlusal contact areas might have diminished, and this reduction cannot be demonstrated by the method used in these studies. These studies registered the occlusal contact numbers, whereas we recorded the occlusal contact areas. The occlusal contact areas are more important than the number of occlusal contacts. The different results in our study might be explained with the occlusal contact areas taken into consideration. Furthermore, in these studies patients used both maxillary and mandibular Essix retainers and the studies consisted of mixed groups with extraction and nonextraction treatment plans.

Anterior occlusal contact findings in our study are similar to those of Durbin and Sadowsky,<sup>3</sup> Basciftci et al,<sup>28</sup> and Sari et al.<sup>29</sup> The development of contacts in the incisors were not statistically significant during the retention period. However, in our study, the changes canine in the region were significant. This finding may be explained by the increased contact of the upper canine region with lower canine over time. The increase in contact might be related to the reduction of the composite thickness over the retainer by function and perhaps by the fact that the lower canines tips have slightly eroded and contacted the upper canine with wider enamel surface.

In the literature, only Sari et al<sup>29</sup> investigated occlusal changes during retention with fixed retainers on both arches. Corresponding to the results of their study, we found a significant increase in occlusal contact areas for the posterior segment and total occlusion. Nevertheless, it is difficult to make direct comparisons of the occlusal contact areas with other studies because the methods are different, and the number of contacts and contact area values are different parameters.

Significant changes in total CRE scores were recorded at the end of the 1-year retention period with the Hawley group showing a significant decrease ( $P < 0.001$ ) and the Essix group showing a significant increase ( $P < 0.001$ ). The bonded retainer group did not have a significant improvement in total CRE scores ( $P > 0.05$ ). The Essix group was the only group to worsen among the 3 retention protocols. Meanwhile, the Essix group showed significant improvements in 3 criteria; marginal ridges, overjet, and occlusal contacts. Occlusal contact area measurements showed a decrease in the Essix group, but no decrease in "occlusal contacts" criterion-related to CRE scoring was observed. This finding may be

explained by the change in the occlusal areas, although the occlusal contact numbers remain the same.

A significant increase (worsening) was recorded in all groups for alignment and rotation and buccolingual inclination criteria. According to our results, marginal ridges, occlusal contacts, and overjet showed improvement after treatment for all retention protocols. The Hawley group showed the best posttreatment results with a statistically significant improvement in 5 criteria, as well as showing a significant decrease in total CRE score. Similarly, Hoybjerg et al<sup>4</sup> and Nett and Huang<sup>31</sup> agreed that alignment worsened over a 1-year retention period and marginal ridges, overjet, and occlusal contacts improved following retention.

In contrast, the results of the Essix group were different from the study of Hoybjerg et al.<sup>4</sup> They found that the total CRE scores decreased with the Essix appliance. This difference in findings may be related to total CRE scores at debonding. In this study, we only included patients with a total CRE score of 27 and less, and well-finished cases tend to have more deterioration than poorly finished ones.<sup>31</sup>

One of the limitations of this study is the patient's cooperation, as in all retention studies. We relied on verbal feedback of the patients concerning the duration of the use of the appliances. It was observed that patients were more reluctant to use the Hawley appliance and that the Essix appliance was better accepted most likely because they are less visible. Another limitation of our study is that contact areas were measured only after 1 year. In future studies, the records can be repeated more frequently to check whether the occlusal settling occurs in the early or late phase of the retention period. In addition, the duration of the follow-up period can be increased by considering that the retention period lasts more than 1 year.

Further studies are needed to investigate settling and tooth movement after orthodontic treatment. In future studies, better results can be obtained with software that provides 3-dimensional occlusal contact area measurement. The changes related to wraparound retainers could also be investigated in a future study.

## CONCLUSIONS

- (1) At the end of the 1-year retention period, a significant decrease in occlusal contact areas was found for all teeth in the Essix group, except for the incisors.
- (2) A statistically significant improvement was observed on occlusal contacts for all teeth except the incisors in both the Hawley and bonded retainer groups.

- (3) In the Essix group, CRE scores showed a significant increase, indicating a worsening of final occlusion, whereas in the Hawley group, a significant decrease was noted, indicating improvement of the occlusion. There was no statistically significant difference in the total CRE score in the bonded retainer group.
- (4) The Hawley group showed the greatest CRE improvement during a 1-year retention protocol.

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