Original Article

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A Radiographic Comparison of the Root Length and Area After Class II Treatment with Two Different Functional Appliances

Sınıf II Malokluzyonun Tedavisinde Kullanılan İki Farklı Fonksiyonel Aygıtın Kök Uzunluğu ve Alanına Etkisinin Radyografik Olarak Karşılaştırılması

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ABSTRACT

Objective: The purpose of this study was to compare the changes in root lengths and root surface areas that occur after treatment with two functional appliances the Twin Block (TWB) and Crown Herbst appliances.

Methods: Forty patients (12 boys, 28 girls) were included in this study. Half of them were treated with the stainless steel Crown Herbst appliance (with crowns placed on the first molars and the first and second premolars), and the other half were treated with the TWB appliance. Panoramic and cephalometric films were obtained before treatment (T1) and after the functional treatment (T2). All upper and lower teeth except second and third molars were analysed with the ImageJ software (version 1.37, National Institutes of Health, Bethesda) on panoramic films. Root length and area values were compared using t-tests.

Results: The intragroup comparison showed that root length values were significantly decreased in right and left mandibular incisors and canines in the Crown Herbst group (12 years 7 months ± 9 months). However, significantly increased root length was observed in right and left maxillary second premolars and right maxillary first premolar in the TWB group (11 years 1 month ± 4 months). The intergroup comparison indicated that root length values were

ÖZ

Amaç: Bu çalışmanın amacı, Twin Block (TWB) ve Kron Herbst apareyleri ile yapılan fonksiyonel tedavilerin dişlerin kök uzunlukları ve kök yüzey alanlarına etkisini karşılaştırmaktır.

Yöntemler: Bu çalışmaya kırk hasta (12 erkek, 28 kız) dahil edilmiş olup, bunların yarısı paslanmaz çelik Kron Herbst apareyi ile (birinci molar, birinci ve ikinci premolarlara yerleştirilen kronlar ile) ve diğer yarısı ise TWB apareyi ile tedavi edilmiştir. Çalışmaya dahil edilen hastalardan panoramik ve sefalometrik filmler tedaviden önce (T1) ve fonksiyonel tedaviden sonra (T2) elde edilmiştir. İkinci ve üçüncü molar dişler dışındaki tüm üst ve alt dişler, panoramik filmler üzerinde ImageJ yazılımı (version 1,37, National Institutes of Health, Bethesda) kullanılarak analiz edilmiştir. Kök uzunluğu ve alan değerleri t-testi kullanılarak karşılaştırılmıştır.

Bulgular: Grup içi karşılaştırmada, Kron Herbst grubundaki (12 yaş 7 ay ± 9 ay) sağ ve sol mandibular kesici dişler ve kaninlerde kök uzunluk değerlerinin anlamlı derecede azaldığı gözlendi. Bununla birlikte, TWB grubunda (11 yaş 1 ay ± 4 ay) sağ ve sol maksiller ikinci premolar ve sağ maksiller birinci premolarda kök uzunluğunda anlamlı bir artış gözlendi. Gruplar arası karşılaştırma, Kron Herbst grubunda TWB grubuna göre sağ maksiller premolar,

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significantly decreased in right maxillary premolars, right and left mandibular laterals and left mandibular canine in the Crown Herbst group when compared with those in the TWB group.

Conclusion: It was concluded that the Crown Herbst group showed a greater tendency for decreased root length than the TWB group. In orthopaedic correction of Class II malocclusions, in the absence of any contraindications, TWB appliance may be preferred for the promotion of root development.

Keywords: Orthodontics, malocclusion, root resorption, radiography

sağ sol mandibular lateraller ve sol mandibular kaninlerde kök uzunluk değerlerinin anlamlı olarak azaldığını göstermiştir.

Sonuç: Kron Herbst grubunda bulunan dişlerin kök rezorpsiyonu riski TWB grubundan daha fazlaydı. Sınıf II maloklüzyonlarının ortopedik düzeltmesinde, kontrendikasyon yoksa, kök gelişiminin desteklenmesi bakımından TWB cihazı tercih edilebilir.

Anahtar Sözcükler: Ortodonti, maloklüzyon, kök rezorpsiyonu, radyografi

Introduction

A large variety of functional appliances are utilised for the correction of Class II skeletal malocclusions (1). Two of the most frequently used functional appliances for treating Class II dento-skeletal malocclusion are the Herbst and the Twin-block (TWB) appliance, developed by Emil Herbst (2) and William Clark (3), respectively. It has been shown that both the appliances can result in considerable favourable effects in growing patients with Class II malocclusions (4). Numerous studies have compared the treatment efficacy of Herbst and TWB appliances (4-7) and shown that both appliances are equally effective at the dento-skeletal level in the correction of Class II malocclusion (4,5). Although, these appliances are commonly used for functional treatment; literature regarding the effects of their use is limited (4,8).

Few studies in literature have assessed the apical root resorption caused by Herbst appliance (8). To our knowledge, root resorption induced by TWB has not been evaluated thus far. Further we did not find any analysis comparing the effects of Herbst versus TWB treatment on root resorption.

The muscle forces used in the functional treatment tend to retract the lower jaw, and these are especially transmitted to the anchorage teeth (the upper first molars and the lower first premolars) (9). Heavy forces or prolonged treatment can induce resorption in the apical area or negatively affect the root development in teeth that have incompletely formed roots (10,11). Although, root resorption seen with functional appliances is mild (12), it is pertinent to question if the inhibition of root growth or the development of apical root resorption in the anchorage teeth results specifically from the treatment (13). Since, the biologic factors are specific to a patient and cannot be altered (14), it is necessary to define how the functional treatment affects root resorption or root development to reduce their risks and harms.

Radiography can be used for the evaluation of root resorption or development (8,9). Panoramic radiography is used extensively in orthodontics. Panoramic films have some advantages such as less radiation exposure, visualisation of the entire lower half of the face and simplicity (15).

The purpose of this study was to compare the root lengths and root surface area of teeth after functional treatment with Herbst and TWB appliances. We also aimed to assess whether root development in the premolars and canines is substantially restrained by functional treatment.

Method

This retrospective study was designed to evaluate the effect of Class II treatment on the root dimensions with two different functional appliances. The experimental protocol of the study was approved by the Erciyes University Local Ethics Committee (2018/602).

Forty patients were included in this study; half of them were treated with the stainless steel Crown Herbst appliance (with bands placed on the first molars and the first and second premolars), and the other half was treated with the TWB appliance. The appliance designs are demonstrated in Figure 1. The pre- (T1) and post-treatment (T2) records were collected. All patients were treated at the Erciyes University, Faculty of Dentistry, Department of Orthodontics.

Among the patients treated with the Crown Herbst appliance and TWB appliance there were 15 girls and 5 boys (12 years 7 months ± 9 months) and 13 girls and 7 boys (11 years 1 month ± 4 months) with an average treatment time of 9.2±2 months and 11.1±4 months, respectively. Demographic characteristics of the patients are shown in Table 1.

All patients had the following properties: (1) Class II malocclusion (2) treated with standardised Crown Herbst or TWB appliances,

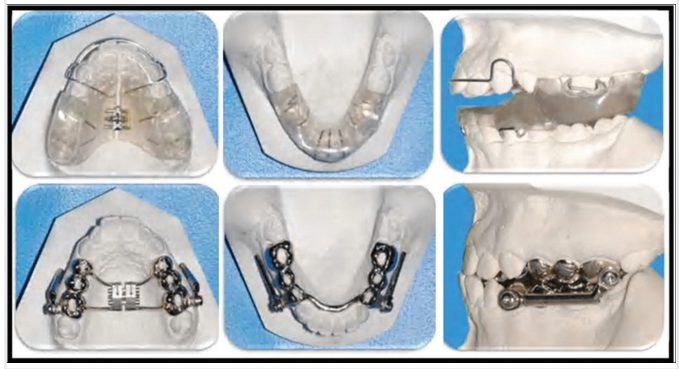

Figure 1. Crown Herbst and TWB appliance design used in this study

Table 1. Demographic characteristics of patients

	TWB	Crown herbst	Total
Boys (n %)	7 (35%)	5 (25%)	12
Girls (n %)	13 (65%)	15 (75%)	28
Mean age ± SD	11.08±0.3	12.58±0.5	

SD: Standard deviation

(3) non-extraction patients (before or during treatment) and (4) pre- and post-treatment radiographic records present.

Radiographic Analysis

Proclined or retroclined anterior teeth may change magnification and influence the root dimensions measured on radiographs (16). Therefore, in the present study, pre- and post-treatment lateral cephalometric films that were taken with the same method and the same radiography device were evaluated by the same investigator. On the digitised cephalometric images, using Dolphin Imaging Software (Version 8.0, Dolphin Imaging Cephalometric and Tracing Software, Chatsworth, Calif), sagittal variances in upper and lower incisors inclination that are seen with TWB and Crown Herbst treatment, were measured. To determine the inclination of the maxillary and mandibular incisors, U1-PP (inclination of the upper central incisor relative to the palatal plane) and IMPA (inclination of the lower central incisor relative to the mandibular plane) were measured, respectively. These measurements were obtained from Steiner and Rickets Analysis.

To determine the root length and area values, digitised panoramic films that they are routinely taken during orthodontic treatment were used.

The analysis of the digitised panoramic films was conducted by using the ImageJ software (version 1.37, National Institutes of Health, Bethesda) to detect root length changes from T1 to T2 (Figure 2). A total of 960 teeth (all upper and lower teeth, except second and third molars) were analysed before and after the functional treatment. The disto-buccal and palatal roots of the maxillary teeth were not measured as tracing these from the panoramic radiograph is difficult. Also distal roots of lower molar teeth were used for the length and area measurement.

Borders of root surfaces were drawn from cemento-enamel junction up to root apex with this programme on the radiograph and the root area was measured. For the linear root length measurement, reference points were the centre of the incisal edges or cusp tips and the root apices of the teeth (Figure 2) (17). To detect the changes in root length and area, the difference between the radiographic tooth lengths at T1 and T2 were calculated.

Since, the difference of magnification between pre- and post-treatment radiographs may affect the measurements, the differences of the root length and area values were calculated on panoramic films as follows (18);

Change of Root Length Value (T2-T1):

= C1 ÷ C2 x R2-R1

Change of Root Area Value (T2-T1):

= C1 ÷ C2 x A2-A1

(C1, radiographic incisor crown length at T1; C2, radiographic incisor crown length at T2; R1, radiographic root length at T1; R2, radiographic root length at T2; A1, radiographic root area at T1; A2, radiographic root area at T2).

Positive and negative values indicated an increase or decrease in the root length and area, respectively (19). All measurements were performed at the Erciyes University, Faculty of Dentistry, Department of Orthodontics.

Statistical Analysis

Fifteen cephalometric and panoramic radiographs were randomly selected for the assessment of measurement reliability. Each radiograph was re-assessed after 1 month to determine the method errors. Dahlberg's formula was used for method error (ME) analysis ($ME = \sqrt{\Sigma (x_1 - x_2)^2/2n}$; n = number of sample). ME was found to be clinically insignificant ($p<0.05$). Statistical analysis was performed with SPSS (version 15.0; SPSS, Chicago, III). The normality of data distribution was assessed using the Shapiro-Wilk normality test. For the intergroup differences, Student's t-Test and Wilcoxon t-test were performed to compare data following normal and non-normal distributions,

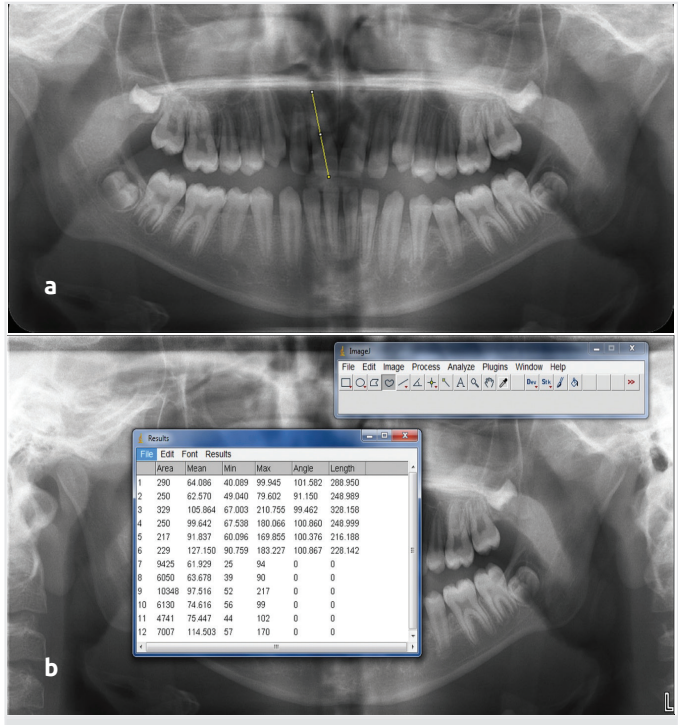

Figure 2. a. Measurement of the maxillary central incisor root length (the perpendicular distance from the centre of the incisal edge to the root apex). **b.** Analysis of the root dimensions on the digitised panoramic film with ImageJ software

respectively. For the intragroup comparison, Paired t-test and Wilcoxon t-Test were performed for normally and non-normally distributed data, respectively. The level of statistical significance was set at $p<0.05$.

Results

Comparison of cephalometric values associated with maxillary and mandibular incisor inclination was performed, since inclination changes of anterior teeth may affect the root lengths measured on panoramic films. Table 2 shows the results of the cephalometric analysis associated with maxillary and mandibular incisor inclination. We observed a significant increase in mandibular incisors proclination in both TWB and Crown Herbst group as was expected. However, no statistical difference was observed for T2-T1 values ($p>0.05$) between the groups. From the 40 patients in the TWB and Crown Herbst groups, a total of 960 root lengths and areas were evaluated on pre-treatment (T1) and post-treatment (T2) panoramic films. During the orthodontic treatment (T1-T2), differences in root length and area were detected for each of the maxillary and mandibular teeth. Table 3 demonstrates the comparison of the

Table 2. Mean U1-PP and IMPA (°) values of the patients studied at T1 and T2 and differences between T2 and T1

	TWB			HERBST			TWB-HERBST		
	T1	**T2**	**p**	**T1**	**T2**	**p**	**T2–T1**	**T2–T1**	**p**
U1-PP	116.9±3.7	116.3±7.3	0.85	106.2±9.1	108.2±6.8	0.34	-0.56±8.1	2.05±7.5	0.46
IMPA	95.4±6.3	102.4±7	0.008**	93.9±7.5	102.4±7.7	0.001***	7.02±6.8	8.44±5.1	0.29

**p<0.001, ***p=0.001
U1-PP: Maxillary incisor and palatal plane angle, IMPA: Lower incisor mandibular plane angle

Table 3. Comparison of root length and root area values between TWB and Crown Herbst groups at T1

	TWB	Herbst		TWB	Herbst	
	Root length			Root area		
	Mean SD	**Mean SD**	**p**	**Mean SD**	**Mean SD**	**p**
16	224.8±53.7	221.3±54.2	0.55	9122±1768.6	8907.8±2837.4	0.72
15	242±60	230.9±57.3	0.18	7457.5±1874.5	7269±1824.7	0.73
14	244.5±63.4	236.4±58.9	0.26	8595.7±2478.5	8602.4±2376.2	0.99
13	313.1±78.3	313.2±80	0.98	10517.5±3856.1	10150.4±2834.1	0.65
12	257.7±62.8	264.7±68.9	0.45	7074.3±3856.1	6752.5±1806.4	0.61
11	281±68.2	276±70.7	0.55	8512.6±2246.2	8089.2±2373.7	0.58
21	282.7±66.6	281±69.8	0.84	8607.4±2033.9	8128.7±2285	0.52
22	266.9±60.7	267.6±68.3	0.92	7132.3±1678.7	6724.5±1468.2	0.42
23	315.2±76.9	317.3±79.9	0.81	11079.3±3725.9	10449.8±3060.8	0.42
24	252.1±60.1	244.2±59.4	0.22	8867.8±2723.4	8960.6±2546.1	0.89
25	250.3±57.6	234.9±58.4	0.09	8130.4±2630.8	8033.4±2644.4	0.88
26	229.8±52.6	219.9±50.5	0.07	9112.7±2152	8464.5±1886.8	0.27
36	258.4±54	261.5±60.2	0.64	14289.9±1976.2	14459.5±3362.6	0.82
35	252.3±54.1	251.2±61.5	0.86	8409.6±1410.7	8563.6±2356	0.8
34	246.3±53.4	254.8±59.5	0.25	7955.1±1274.7	7822.7±2150.8	0.78
33	264.5±59.8	283.2±70.1	0.06	9520.3±2212.7	10284.1±3529.1	0.22
32	228±51.4	228.5±54.9	0.94	5774.3±1311.3	5531±1431.9	0.51
31	211.6±47.1	208.9±55.5	0.74	4598.9±862.9	4707.4±1308.8	0.74
41	217.7±45.5	207.8±52.8	0.214	4857.5±1044.5	4842.8±1248.9	0.97
42	229.3±49.3	226.5±58.6	0.75	5629.2±1347.1	5910.7±2098.8	0.52
43	263.8±58.1	277.2±70.6	0.11	10553.8±2549.3	11379.9±3983.4	0.38
44	248.6±53.3	249.4±56.9	0.89	8296.9±1314.2	7984.2±1859.2	0.55
45	252±49.9	252.7±60.8	0.93	9357.4±1693.9	8826.2±2011.4	0.4
46	256.6±52.8	263.6±59.6	0.26	13985.9±2369.1	14443.5±3125.8	0.47

SD: Standard deviation, T1:Pre-treatment

mean root length and area values between groups at T1. There were no significant differences in the root lengths and areas at T1 between the TWB and Crown Herbst groups (p>0.05).

Table 4 shows the comparison of the mean root length and area values between T1 and T2 in the Crown Herbst group. The results showed that root length values were significantly decreased for the right and left mandibular incisors and canines in the Crown Herbst group (p<0.05).

Significantly increased root lengths were observed in the right and left maxillary second premolars and right maxillary first premolar in the TWB group (Table 5, p<0.05). However, no statistical difference in the root area values between T1 and T2 was observed in both groups (p>0.05).

The statistical comparison of the differences in the root values between T1 and T2 between the TWB and Crown Herbst groups is shown in Table 6. The results indicated that root length values were significantly decreased in right maxillary premolars, right and left mandibular laterals and left mandibular canine in the Crown Herbst group (p<0.05). However, no statistical difference in the root area values was observed in the teeth studied (p>0.05).

Discussion

Numerous studies have indicated that TWB and Herbst appliances can induce major positive modifications in growing patients with Class II malocclusions (4,20,21). However, a similar effect in their functional treatment of Class II malocclusion has been reported (4,5). For this reason, the potential side effects of these appliances that are used frequently in orthodontic practice should be examined in detail.

The present retrospective study assessed the effects of the Crown Herbst and TWB appliances on root resorption and root formation. To the best of our knowledge, this is the first study that compared the root length changes of the maxillary and mandibular teeth associated with the Crown Herbst and TWB treatments.

Table 4. Comparison of root lengthand are a values between T1 and T2 in the Crown Herbst group

	Root length			Root area		
	T1	T2		T1	T2	
	Mean SD	**Mean SD**	**p**	**Mean SD**	**Mean SD**	**p**
16	221.3±54.3	221.8±61.9	0.98	8907.9±2837.5	8340.7±2278.4	0.49
15	230.9±57.4	234.1±62.8	0.87	7269.1±1824.7	7103±2226.1	0.8
14	236.4±58.9	240.8±62.8	0.82	8602.5±2376.3	8546.6±3686.6	0.96
13	313.3±80.1	308.2±79.9	0.84	10150.5±2834.1	9806.9±3130.8	0.72
12	264.8±69	264±68.8	0.97	6752.5±1806.4	7066.3±2000.1	0.61
11	276±70.7	272.8±70.4	0.89	8089.2±2373.8	8590.6±2431.1	0.51
21	281±69.8	279.8±70.2	0.96	8128.7±2285	8577.2±2011.5	0.51
22	267.6±68.4	263.4±66.6	0.84	6724.5±1468.3	6846.1±1829.4	0.82
23	317.4±79.9	318.6±81.8	0.96	10449.9±3060.9	9948.8±2497.6	0.57
24	244.3±59.5	247.6±63.4	0.86	8960.7±2546.1	8676.1±3319.4	0.76
25	234.9±58.4	241.2±63.8	0.74	8033.5±2644.5	7994.1±2592.2	0.96
26	220±50.6	216.4±55	0.83	8464.6±1886.8	8163.4±1923.4	0.62
36	261.6±60.2	260.6±62.8	0.96	14459.6±3362.6	14626.3±3776.6	0.88
35	251.2±61.6	253.9±65.5	0.89	8563.6±2356	8504.9±2387.9	0.94
34	254.9±59.5	247.7±58.9	0.7	7822.7±2150.8	7889±2033.8	0.92
33	283.2±70.2	264.9±74.7	0.01**	10284.1±3529.1	9668±3369.6	0.18
32	228.5±54.9	213.4±57.6	0.02*	5531±1432	5616.1±1909.9	0.87
31	209±55.5	192.1±55.6	0.01**	4707.4±1308.9	4466.5±1657.8	0.37
41	207.9±52.8	192.1±55.3	0.01**	4842.9±1248.9	4478.1±1247.7	0.22
42	226.5±58.6	212.2±56.7	0.01**	5910.8±2098.8	5700.9±2014.8	0.49
43	277.3±70.6	264.4±75.3	0.03*	11379.9±3983.5	11055.8±4459.1	0.62
44	249.5±57	242±59.1	0.22	7984.3±1859.2	8623.8±3319.7	0.26
45	252.8±60.8	252.9±61.2	0.98	8826.3±2011.4	8948.6±2595.9	0.8
46	263.7±59.7	261.4±64	0.76	14443.6±3125.9	14056.5±3892.4	0.56

SD: Standard deviation, *p<0.05,**p=0.01, T1: Pre-treatment, T2: Post-treatment

Table 5. Comparison of root lengthand are a values between T1 and T2 in the TWB group

	Root length			Root area		
	T1	T2		T1	T2	
	Mean SD	**Mean SD**	**p**	**Mean SD**	**Mean SD**	**p**
16	224.8±53.7	229.8±54.8	0.77	9122±1768.6	9393±1993.8	0.65
15	242.1±60.1	253.4±61.6	0.01**	7457.6±1874.5	7747.9±1550	0.25
14	244.5±63.5	258.6±60.3	0.01**	8595.7±2478.5	9307.9±2030.9	0.12
13	313.2±78.4	324.5±78.1	0.07	10517.6±3856.1	10866±2124	0.61
12	257.8±62.9	260.2±64.2	0.69	7074.4±2065.1	7382.7±1562.5	0.41
11	281±68.3	281.9±74.1	0.92	8412.7±2246.3	8481.7±2328.1	0.97
21	282.8±66.6	285.4±64.5	0.69	8607.5±2033.9	9278.8±1887.8	0.18
22	266.9±60.7	269±60.1	0.68	7132.4±1678.7	7945.6±1954.4	0.17
23	315.2±77	321.1±74.7	0.39	11079.4±3725.9	10744.5±2862.3	0.63
24	252.2±60.2	257.1±59.5	0.4	8867.9±2723.4	9996.6±2840.5	0.21
25	250.3±57.7	258.7±59.1	0.02*	8130.5±2630.9	8033.5±2644.5	0.91
26	229.9±52.6	234.4±52.9	0.21	9112.7±2152	14422.8±21492.8	0.29
36	258.4±54.1	261.6±60.2	0.36	14289.9±1976.2	14459.6±3362.6	0.85
35	252.3±54.1	253.9±54.2	0.64	8409.6±1410.7	8563.6±2356	0.8
34	246.4±53.5	250.6±56.4	0.2	7955.1±1274.7	7822.7±2150.8	0.81
33	264.5±59.8	266.6±61.1	0.69	9520.3±2212.7	10284.1±3529.1	0.42
32	228±51.4	229.1±48.6	0.77	5684.7±1282.7	6062.5±1486	0.31
31	211.7±47.1	207.6±46.2	0.41	4598.9±862.9	5078.2±1185.3	0.12
41	217.7±45.5	212±46.6	0.22	4857.6±1044.6	4898.1±907.5	0.87
42	229.4±49.3	231.2±48.9	0.71	5629.3±1347.2	6142±818.4	0.1
43	263.8±58.2	268.1±58.9	0.45	10553.8±2549.3	10741.7±2110.4	0.75
44	248.7±53.3	253.1±53	0.32	8297±1314.3	8333.5±1248.6	0.91
45	252±50	253.5±49.5	0.62	9357.5±1693.9	9479.7±1267.6	0.71
46	256.6±52.9	259±52.3	0.55	13985.9±2369.2	14356.5±2714.4	0.55

SD: Standard deviation, *p<0.05, **p=0.01, T1: Pre-treatment, T2: Post-treatment

Herbst and TWB appliances may influence the inclinations of the upper and lower incisors during the treatment (4,22). Overly proclined or retroclined anterior teeth can remain outside the focal trough of the X-ray machine. Magnification of roots that are outside the focal trough may change and this can influence the root dimensions measured on radiographs (16). In this study, we evaluated the inclinations of the upper and lower incisors on cephalometric radiographs. The differences in the inclination changes between T1 and T2 of the upper and lower incisors in the TWB and Crown Herbst groups were reported to be non-significant in a previous study (4). Therefore, it is reasonable to accept that the incisor inclination has no effect on the root length changes in TWB and Crown Herbst groups.

Root length may be measured by various methods. Measurements with any software program on a digitised radiographic image generally practical (23). We used panoramic films that are routine recorded for orthodontic treatment and ImageJ software to assess the root length and area. The results of root resorption related to orthodontic treatment on panoramic films may be exaggerated by 20% or more when compared with that on periapical films (15). This difference is mostly observed in the lower incisors, unlike the uppers (24). In this study, we did not aim to determine the root resorption quantitatively. We compared the effects of two different functional appliances on the root length. Stramatos et al. (25) reported that when the occlusal plane is retained in an equal position at different times at which the panoramic radiographs are taken, and not inclined more than 10°, the linear root length measurements are reliable on these radiographs.

A previous study reported that while the length measurements of the upper first molar's buccal roots were reproducible, those of the palatal root of the maxillary first molar were unreliable (9).

However, the disto-buccal roots of the maxillary molars were not measured as their tracing on the panoramic film was difficult and unreproducible. A retrospective study to assess the risk of apical root resorption in orthodontic treatment reported that the distal

root of the mandibular first molar showed significantly decreased length compared to the right root (26). Hence, we also included the measurements of the distal roots of the mandibular molars. In total we analysed 960 teeth roots including the maxillary incisors, canines, buccal roots of first premolars, second premolars, mesiobuccal roots of first molars and mandibular incisors, canines, premolars and the distal roots of first molars in the present study.

In the Crown Herbst group the root length values from T1 to T2 were significantly decreased in right and left mandibular incisors and canines (Table 4).

Right and left maxillary second premolars and right maxillary first premolar had significantly increased root length in the TWB group (Table 5). However, despite incomplete root development, no significantly increase in root length of premolars was observed between T1 and T2 in the Crown Herbst group, unlike the TWB group.

Nasiopoulos et al. (27) reported that the root lengths of the mandibular first premolars significantly decreased following the Herbst appliance treatment. Our results showed a tendency for root length reduction in mandibular first premolars in the Crown Herbst group similar to the findings of Kinzinger et al. (13). As mentioned before, we did not find any reports that evaluated the root resorption induced by TWB appliance on panoramic films.

The interesting result in intergroup comparison was significantly decreased root length of right maxillary premolars, mandibular laterals and left mandibular canine in Crown Herbst group compared with that in the TWB group (Table 6). It can be deduced that the Crown Herbst inhibits root development in upper premolars and induces root resorption in the lower laterals and canines greater than that by the TWB. In this study, similar to a previous report, lesser root resorption was observed for the removable appliance TWB when compared with the fixed appliance Crown Herbst (28). It can be expected that the anchor teeth may be more susceptible to the side effects of the force applied by these appliances. However, in this study, not only the anchor teeth but also the mandibular teeth (incisors and canines), to which the force was indirectly delivered with occlusal and proximal contacts, were affected by the Crown Herbst appliance. However, no significant differences in the root area values between T1 and T2 were observed in inter and intragroup comparisons.

Results of the root area measurement did not reflect the root length values. It can be explained that the resorption changed the morphology and shape of the apical region and the margins of the apex were ragged and irregular, as previously defined in literature (29). Hence, it is considered that the actual root area measurements were limited and dependent on the increased surface area in the apical region.

Study Limitations

The present study had some limitations such as the absence of an untreated control group. Another limitation of our study design was the use of two-dimensional panoramic radiographs to quantify root resorption. Recent studies have revealed that periapical radiographs or CBCT offer many advantages to detect the amount of apical root resorption induced by orthodontic forces. Conversely, high costs, high ionising radiation doses and ethical issues restrict the usage of CBCT imaging (30-32). Epidemiological studies have showed that higher radiation doses during adolescence are associated with cancer development (33). Risk of future malignancy may increase in preadolescents and adolescents who are exposed to cumulative ionising radiation. Adolescents have higher breast and thyroid gland radiosensitivity than adults. ALARA principles (the concept of 'as low as reasonably achievable') should be applied in clinical dentistry. Since, the exact relationship between radiation dose and its biological harm is poorly understood, and even very low doses may cause the development of cancer in children and adolescents (34); therefore, diagnostic imaging using ionising radiation such as CBCT should not be performed routinely to examine the effects of orthodontic treatment in adolescent patients.

Conclusion

According to the present study, radiographic assessment indicated a tendency for decrease in root lengths with the Crown Herbst appliance in both the anchoring teeth and mandibular teeth which were indirectly exposed to force. However, the TWB appliance promoted the root development of teeth during the functional treatment.

Therefore, the unfavourable effects on root development when using the Crown Herbst appliance for functional treatment should be taken into consideration. In orthopaedic correction of Class II malocclusions, if there is no contraindication, the TWB appliance can be preferred.

Further studies with larger sample sizes (involving control groups) are needed to approve our results.

Ethics

Ethics Committee Approval: The experimental protocol of the study was approved by the Erciyes University Local Ethics Committee (2018/602).

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: E.D.Ş., A.Y., K.K.D., Design: E.D.Ş., A.Y., K.K.D., E.N.Y., Data Collection or Processing: E.D.Ş., Analysis or Interpretation: E.D.Ş., A.Y., K.K.D., E.N.Y., Literature Search: E.D.Ş., A.Y., K.K.D., E.N.Y., Writing: E.D.Ş.

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References

1. Pangrazio-Kulbersh V, Berger JL. Treatment of identical twins with Frankel and Herbst 0 appliances: A comparison of results. Am J Orthod Dentofacial Orthop 1993;103:131-7.
2. Herbst E. Atlas und Grundriß der zahnärztlichen Orthopädie. München: JF Lelunenn Verlag; 1910.p.371-5.
3. Clark WJ. The twin block traction technique. Eur J Orthod 1982;4:129-38.
4. Schaefer AT, McNamara JA Jr, Franchi L, Baccetti T. A cephalometric comparison of treatment with the Twin-block and stainless steel crown Herbst appliances followed by fixed appliance therapy. Am J Orthod Dentofacial Orthop 2004;126:7-15.
5. O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S, et al. Effectiveness of treatment for Class II malocclusion with the Herbst or Twin-block appliances: a randomized, controlled trial. Am J Orthod Dentofacial Orthop 2003;124:128-37.
6. Baysal A, Uysal T. Soft tissue effects of Twin Block and Herbst appliances in patients with Class II division 1 mandibular retrognathy. Eur J Orthod 2013;35:71-81.
7. Rodi G, Fantasia E, Lombardelli E, Padalino G, D'emidio MM. Comparison Of Twin Block And Herbst Appliances In Treatment Of Class II Malocclusion: A Systematic Review. WebmedCentral Orthodontics 2016;7:WMC005201.
8. Schwartz JP, Raveli TB, Almeida KCM, Schwartz-Filho HO, Raveli DB. Cone Beam Tomography study of apical root resorption induced by Hebst Appliance. J Appl Oral Sci 2015;23:479-85.
9. Thanyakarn C, Hansen K, Rohlin M, Akesson L. Measurements of tooth length in panoramic radiographs. 1. The use of indicators. Dentomaxillofac Radiol 1992;21:26-30.
10. Casa MA, Faltin RM, Faltin K, Sander FG, Arana-Chavez VE. Root resorptions in upper first premolars after application of continuous torque moment. Intra-individual study. J Orofac Orthop 2001;62:285-95.
11. Faltin RM, Faltin K, Sander FG, Arana-Chavez VE. Ultrastructure of cementum and periodontal ligament after continuous intrusion in humans: a transmission electron microscopy study. Eur J Orthod 2001;23:35-49.
12. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 2. Literature review. Am J Orthod Dentofacial Orthop 1993;103:138-46.
13. Kinzinger GS, Savvaidis S, Gross U, Gülden N, Ludwig B, Lisson J. Effects of Class II treatment with a banded Herbst appliance on root lengths in the posterior dentition. Am J Orthod Dentofacial Orthop 2011;139:465-9.
14. Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: the basic science aspects. Angle Orthod 2002;72:175-9.
15. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: periapical vs panoramic films. Angle Orthod 2001;71:185-9.
16. Leach HA, Ireland AJ, Whaites EJ. Radiographic diagnosis of root resorption in relation to orthodontics. Br Dent J 2001;190:16-22.
17. Castro I, Valladares-Neto J, Estrela C. Contribution of cone beam computed tomography to the detection of apical root resorption after orthodontic treatment in root-filled and vital teeth. Angle Orthod 2015;85:771-6.
18. Liou EJW, Chang PMH. Apical root resorption in orthodontic patients with en-masse maxillary anterior retraction and intrusion with miniscrews. Am J Orthod Dentofacial Orthop 2010;137:207-12.
19. Kinzinger GS, Savvaidis S, Gross U, Gülden N, Ludwig B, Lisson J. Effects of Class II treatment with a banded Herbst appliance on root lengths in the posterior dentition. Am J Orthod Dentofacial Orthop 2011;139:465-9.
20. Jena AK, Duggal R, Parkash H. Skeletal and dentoalveolar effects of Twin-block and bionator appliances in the treatment of Class II malocclusion: a comparative study. Am J Orthod Dentofacial Orthop 2006;130:594-602.
21. Bollen AM. Herbst appliance more effective than twin-block appliance in treating adolescent Class II division I malocclusions. J Evid Based Dent Pract 2004;4:216-7.
22. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a cephalometric study. Am J Orthod Dentofacial Orthop 1998;114:15-24.
23. Harris EF. Root resorption during orthodontic therapy. Semin Orthod 2000;6:183-94.
24. Brin I, Tulloch JFC, Koroluk L, Philips C. External apical root resorption in Class II malocclusion: a retrospective review of 1-versus 2-phase treatment. Am J Orthod Dentofacial Orthop 2003;124:151-6.
25. Stramotas S, Geenty JP, Petocz P, Darendeliler MA. Accuracy of linear and angular measurements on panoramic radiographs taken at various positions in vitro. Eur J Orthod 2002;24:43-52.
26. Beck BW, Harris EF. Apical root resorption in orthodontically treated subjects: analysis of edgewise and light wire mechanics. Am J Orthod Dentofacial Orthop 1994;105:350-61.
27. Nasiopoulos AT, Athanasiou AE, Papadopoulos MA, Kolokithas G, Ioannidou I. Premolar root changes following treatment with the banded herbst appliance. J Orofac Orthop 2006;67:261-71.
28. Linge BO, Linge L. Apical root resorption in upper anterior teeth. Eur J Orthod 1983;5:173-83.
29. Sreeja R, Minal C, Madhuri T, Swati P, Vijay W. A scanning electron microscopic study of the patterns of external root resorption under different conditions. J Appl Oral Sci 2009;17:481-6.
30. Schröder ÂGD, Westphalen FH, Schröder JC, Fernandes Â, Westphalen VPD. Accuracy of Digital Periapical Radiography and Cone-beam Computed Tomography for Diagnosis of Natural and Simulated External Root Resorption. J Endod 2018;44:1151-8.
31. Krishnan V. Root Resorption with Orthodontic Mechanics: Pertinent Areas Revisited. Aust Dent J 2017;62(Suppl 1):71-7.
32. Kim SH, Son WS, Yamaguchi T, Maki K, Kim SS, Park SB, et al. Assessment of the root apex position of impacted maxillary canines on panoramic films. Am J Orthod Dentofacial Orthop 2017;152:489-93.

33. Ronckers CM, Land CE, Miller JS, Stovall M, Lonstein JE, Doody MM. Cancer mortality among women frequently exposed to radiographic examinations for spinal disorders. Radiat Res 2010;174:83-90.

34. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133:640.e1-5.