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ORIGINAL RESEARCH

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Comparison of orthodontic adverse effects: braces versus clear aligners

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Abstract

Background: The aim of the study is to compare the potential side effects of fixed orthodontic treatment (FOT) and clear aligner therapy (CAT). **Methods**: 27 individuals who were treated with clear aligners (20 Female, 7 Male; mean age: 22.57 $\pm$ 7.37) and 22 patients treated with braces (14 Female, 8 Male; mean age: 17.05 $\pm$ 4.51) formed the study group. The periodontal statuses of the patients were evaluated before treatment (T0), 3 months (T1) after, and at 6th month (T2) following the beginning of the treatment. The amount of root resorption in maxillary & mandibular incisors was evaluated using the ImageJ software on periapical radiographies taken with the paralleling technique. Pain experience and chewing function were also recorded during treatment. **Results**: The root lengths showed a significant decrease from T0 to T2 in both groups. Compared to CAT, greater amount of root resorption was noted with FOT ($p < 0.05$). The highest degrees of pain and the highest chewing difficulty scores were recorded at the 24th hour for both groups. The pain scores after the 2nd week in CAT were similar to those before the orthodontic treatment, while this amelioration occurred after the 1st month in FOT. Chewing function improved after the 2nd week in CAT and after the 1stweek in FOT. Periodontal status evaluation showed that there was no significant difference in probing depth between the groups for the maxillary teeth. However, higher probing depth values were observed for all mandibular teeth in FOT. The change in the plaque index and the levels of bleeding were higher for FOT at all time points. **Conclusions**: CAT has some advantages in terms of protecting periodontal health and controlling root resorption during orthodontic treatment. In terms of the patients' treatment experience, while the pain levels felt by the patients in the CAT group decreased faster, chewing performance improved more rapidly in the FOT group. **Clinical Trial Registration**: The study was registered with ClinicalTrials.gov as NCT06709287.

Keywords

Clear aligners; Fixed orthodontic treatment; Adverse effects; Root resorption; Periodontal status

1. Introduction

The aim of the modern orthodontics has been summarized as achieving acceptable facial aesthetics and appropriate occlusal relationships. Since Dr. Andrews developed the straight-wire appliance system, the fixed orthodontic treatment technique (FOT) has been the most preferred method for orthodontic treatment [1]. Compared to-conventional braces used in conventional orthodontic treatments, the clear aligner therapy (CAT) was developed to find aesthetic solutions for orthodontic patients [2]. Orthodontic treatment with braces or clear aligners may have several adverse effects such as pain, root resorption and periodontal problems. Furthermore, the treatment may also affect the patient's chewing and speech functions, leading to changes in their quality of life [3].

Brandon *et al.* [4] and Jianru Yi *et al.* [5] reported less root resorption with clear aligners therapy. On the other hand, Al Zainal *et al.* [6] stated that clear aligners were not effective in preventing orthodontically-induced root resorption.

Issa *et al.* [7] and Jiang *et al.* [8] compared periodontal parameters between patients treated with braces and clear aligners and showed that patients treated with clear aligners presented better periodontal results. However, Pango *et al.* [9] found no significant difference in terms of periodontal health between these two orthodontic methods.

Although many studies have evaluated the potential side effects of FOT and CAT, there is no consensus on the superiority or certain advantages of these techniques in terms of their adverse effects in comparison to each other in the literature. Therefore, this study aimed to compare the effects of FOT and CAT on root resorption, periodontal status, pain experience and chewing performance. The null hypothesis states that there would be no difference between the two orthodontic treatment

methods in these parameters.

2. Materials and methods

The study was conducted at Bezmialem Vakif University between April 2020 and August 2022.

The inclusion and exclusion criteria are listed below:

Inclusion criteria: (1) patients treated with fixed braces or clear aligners, (2) patients with mild to moderate crowding, (3) patients without root canal treatment or resorption in anterior teeth, (4) patients with completed root development, (5) patients with good periodontal health at the beginning of the treatment, and (6) patients with no congenitally missing or impacted tooth.

Exclusion criteria: (1) history of orthodontic therapy, (2) poor patient compliance, (3) presence of any craniofacial syndrome or systemic disease, (4) presence of cleft lip and palate, (5) trauma history, (6) mental retardation, (7) use of oral antiseptic solutions during orthodontic treatment, (8) need for scaling and root planning during treatment, or (9) clear aligner patients with delayed movement of the anterior teeth.

The power analysis performed at the beginning of the study showed that at least 18 patients was necessary in each group to provide more than 85% power to detect significant differences with an effect size of 0.80 and a significance level of $\alpha = 0.05$.

A total of 58 patients were included in this study based on the inclusion criteria. The patients were randomly divided into two groups according to the method of orthodontic treatment using the coin toss technique: the fixed orthodontic treatment and the clear aligner therapy groups.

7 patients from the FOT group and 2 patients from the CAT group were excluded from the study due to bracket or attachment failure, poor oral hygiene, interruption of treatment, poor cooperation, or the patient's failure to keep orthodontic appointments. Finally, 22 patients (14 females, 8 males; mean age: 17.05 $\pm$ 4.51 years) who underwent fixed orthodontic therapy were included in the FOT group and 27 patients (20 females, 7 males; mean age: 22.57 $\pm$ 7.37 years) who underwent clear aligner therapy were included in the CAT group.

The patients were treated by senior assistants in the orthodontics department, and the analyses of the data were performed by the same researcher (I.E.M). All patients received the same oral hygiene instructions before and during the orthodontic treatment.

In both groups, leveling and alignment was performed without extractions and nor inter proximal reduction (IPR).

The patients in the CAT group had mean anterior crowding of 1.73 mm and 1.95 mm for the upper and lower arches, respectively. In the FOT group, the patients had mean anterior crowding of 1.54 mm and 2.03 mm for the upper and lower arches, respectively. There was no significant difference between the two groups in terms of the amount of crowding for the upper and lower arches ($p > 0.05$).

The patients in FOT were treated with 0.018-inch slot metal Roth brackets (Mini Master Series, American Orthodontics, USA). The arch wire sequence involved conventional 0.014-inch Ni-Ti, 0.016-inch Ni-Ti, and 0.016 $\times$ 0.022-inch Ni-Ti wires according to the patients' needs. The patients in CAT were treated with the Invisalign® system and anterior teeth movement started from the first pair of aligners. Microfill (Filtek A110 (AO), (3M-ESPE)), and brace paste primers were used for bonding the attachments. The patients changed their aligners every 2 weeks.

2.1 Radiographic evaluation

Pretreatment (T0) digital lateral cephalometric radiographs were taken from the patients to compare pretreatment characteristics between the groups. All cephalograms were traced by the same researcher using the NemoCeph software version 10.4.2 (Software Nemotec, SL, Madrid, Spain).

The digital periapical radiographs taken with the paralleling technique were obtained from the maxillary and mandibular incisors at the beginning of the treatment (T0) and after 6 months (T2) by the same dental radiologist for root resorption assessments. Linear measurements to evaluate root resorption were performed using the method which was reported by Lago *et al.* [10]. Digital periapical X-rays were imported into the ImageJ software (ImageJ software1.37, Maryland, USA). The calibration was performed using the Set Scale function on the ImageJ toolbar. When the setting procedure was completed, the program automatically calculated the distance based on the registered parameters. The closest linear distance from the center of the incisal edge to the root apex was used for tooth length measurements (Fig. 1).

2.2 Periodontal evaluation

Probing depth, plaque index, and bleeding on probing were recorded at T0, after 3 months of treatment (T1), and at 6 months (T2) to evaluate the periodontal status of the patients. Probing depth was measured in millimeters using a periodontal probe with William's markings. Ramfjord teeth (teeth numbers: 16, 21, 24, 36, 41 and 44) were selected for periodontal measurements. Each tooth was examined on six surfaces (mesio-buccal, buccal, distobuccal, mesio-lingual, lingual and distolingual), and the mean value of each tooth was recorded [11]. Bleeding on probing was recorded as the presence or absence of bleeding within 30 seconds [12]. Furthermore, the Silness-Loe plaque index was used for plaque measurements [13]. According to this index, 0 = Absence of microbial plaques, 1 = Thin film of microbial plaque along the free gingival margin, 2 = Moderate accumulation with plaque in the sulcus, and 3 = Large amount of plaque in the sulcus or pocket along the free gingival margin.

2.3 Subjective pain and chewing performance evaluation

Pain experience and chewing performance during treatment were assessed to quantify the quality of life of the patients. A 5-question survey introduced by Velez *et al.* [14] was used to evaluate pain levels, and a 9-question survey introduced by Stamm *et al.* [15] was used to evaluate chewing performance. The Visual Analog Scale (VAS) was used to quantify and statistically compare pain and chewing performance between the groups [16]. The data collection was performed before the orthodontic treatment and repeated at 7 time points, including the 4th hour, the 24th hour, the 1st week, the 2nd week, the 1st

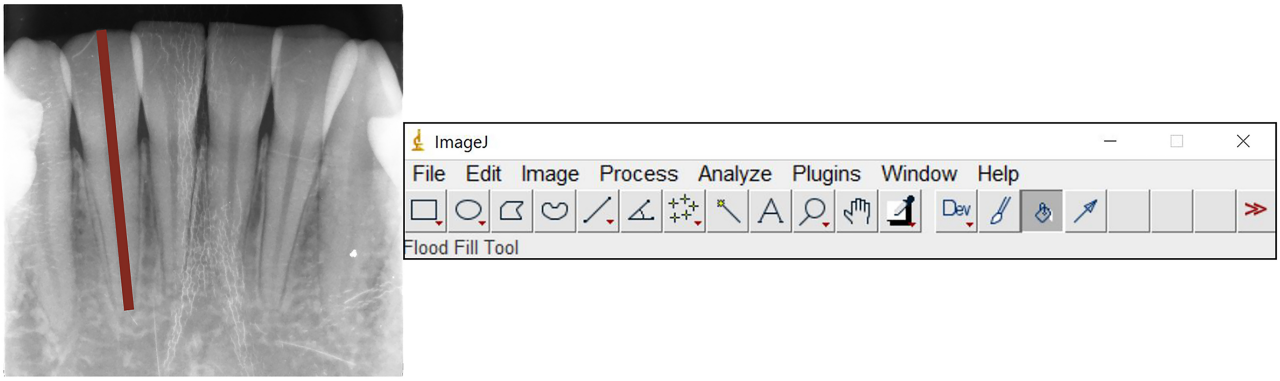

FIGURE 1. Root length measurement method.

month, the 3rd month, and the 6th month after the initiation of the treatment.

2.4 Statistical analysis

The SPSS package program (15.0; SPSS, Chicago, IL, USA) was used for the statistical analyses. Bland-Altman plots were used to evaluate intra-examiner agreement and determine the accuracy and reliability of the measurements. Intra-examiner error values showed good or excellent agreement in the root length and cephalometric measurements (intraclass correlation-ICC $>$ 0.90). The data were tested for normal distribution by using the Shapiro-Wilk test. Paired-samples *t*-test, Mann-Whitney U test, repeated-measures analysis of variance (ANOVA), and Chi-squared test were performed for the statistical comparisons. The level of statistical significance was set at $p < 0.05$.

3. Results

The comparison of the demographic characteristics of the groups at T0 are demonstrated in Table 1. The patients' cephalometric and occlusal characteristics were similar at the baseline. There was no difference in the amount of crowding for the maxilla and mandible between groups ($p > 0.05$). The mean age was found higher in CAT than FOT group.

3.1 Root resorption findings

The comparison of the tooth length measurements showed a statistically significant decrease from T0 to T2 in maxillary and mandibular incisors in both groups ($p < 0.05$) (Table 2). The intergroup comparison of changes in tooth length from T0 to T2 indicated a higher degree of root resorption in the patients in FOT than those in CAT ($p < 0.05$) (Table 2). The mean amount of root resorption was measured as 0.54 mm and 0.99 mm for CAT and FOT, respectively.

3.2 Pain and chewing performance findings

In the comparison of the pain scores within the groups, the highest pain scores were recorded at the 24th hour for both CAT and FOT. Furthermore, while the pain experienced by the patients after the 2nd week in CAT was similar to the pain scores recorded before treatment, this finding occurred 1 month later in FOT ($p < 0.05$) (Table 3).

The intragroup comparison of total chewing performance scores indicated that the highest level of chewing difficulty was recorded at the 24th hour in both groups. It was observed that chewing functions improved after the 2nd week in CAT and after the 1st week in FOT (Table 4).

3.3 Periodontal status findings

The comparison of changes in probing depth showed no significant difference between the groups for maxillary teeth, except for molars. However, a significantly greater probing depth was observed in all mandibular teeth in the FOT group unlike the CAT group ($p < 0.05$) (Table 5). The degree of change in the plaque index was significantly higher in FOT than in CAT in the measurements made at all time points ($p < 0.05$) (Table 5).

The comparison of the presence of bleeding on probing between the groups at T0, T1 and T2 indicated that the bleeding on probing rate was significantly greater in FOT for maxillary anterior teeth, maxillary premolars and mandibular premolars at all time points compared to CAT ($p < 0.05$) (Table 6). However, no significant difference was observed in terms of the bleeding on probing rates for maxillary or mandibular molar teeth ($p > 0.05$) (Table 6).

4. Discussion

The objective of this study was to assess and compare the potential adverse effects of FOT and CAT on root resorption, periodontal status, pain experience, and chewing performance.

Periapical radiographs taken using the paralleling cone technique were used to optimize magnification errors and eliminate false negative or false positive changes in measured root lengths. Gupta *et al.* [17] reported that periapical radiographs provide accurate data for actual tooth dimensions regardless of the patient's head position. Similarly to our study, Lago *et al.* [10] evaluated root resorption using cone-beam computed tomography (CBCT) and periapical X-rays after 6 months of orthodontic treatment on maxillary incisors. They revealed that both radiographic methods are suitable and reliable in the assessment of external root resorption. They concluded that the difference in magnitude between the measurements obtained using these radiographic methods does not justify requesting CBCT merely to assess external root resorption.

TABLE 1. Comparison of demographic data between the groups.

	CAT		FOT		
	Mean	sd	Mean	sd	*p*-value
Cephalometric parameters					
SNA°	80.43	3.74	79.34	3.40	NS
SNB°	78.40	3.91	77.54	4.15	NS
ANB°	2.08	1.67	1.82	2.54	NS
SN-GoMe°	31.60	7.50	32.87	5.96	NS
SN-PP°	8.47	3.24	9.06	3.03	NS
U1-SN°	102.06	7.25	101.12	8.21	NS
U1-PP	110.44	7.29	110.26	7.03	NS
IMPA°	97.19	6.45	95.13	6.76	NS
L1-NB°	24.29	8.20	24.46	2.14	NS
L1-NB (mm)	6.02	2.99	5.14	5.70	NS
Crowding					
Maxilla	−1.73	1.25	−1.54	1.18	NS
Mandibula	−1.95	1.12	−2.03	1.12	NS
Age	22.57	7.37	17.05	4.51	<0.001
	n	%	n	%	
Sex					
Male	7	25.90%	8	36.40%	NS
Female	20	74.10%	14	63.60%	
Smoking					
Yes	1	3.70%	3	13.60%	NS
No	26	96.30%	19	86.40%	

Independent t test was used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; Sd: standard deviation; n: number of samples; NS: non-significant ($p > 0.05$); SNA: the angle between the SN line passing through the sella and nasion points and the NA line passing through the nasion and A points; SNB: the angle between the SN line passing through the sella and nasion points and the NB line passing through the nasion and B points; ANB: the angle formed between lines NA and NB; SN-GoMe: the angle between the lines GoGn and SN; SN-PP: the angle formed between the SN line and the palatal plane; U1-SN: the long axis of upper incisor to the plane between Sella and Nasion; U1-PP: the long axis of upper incisor to the platal plane; IMPA: the angle formed between the axis of the lower most forward incisor and the mandibular plane; L1-NB: the long axis of lower incisor to the plane between Nasion and B points; L1-NB(mm): the distance of the incisal edge of the lower most forward incisor from the NB line.

TABLE 2. Intra-group comparison of the root lengths (mm) and Intergroup comparison of change of the root lengths between T0 and T2.

CAT	T0		T2		
Tooth N.	Mean	sd	Mean	sd	*p*-value
12	27.06	3.12	26.49	3.05	<0.001
11	28.84	2.80	28.11	2.77	<0.001
21	29.12	3.12	28.31	3.26	<0.001
22	27.21	2.93	26.47	3.04	<0.001
42	25.90	2.44	25.37	2.37	<0.001
41	24.71	1.88	24.23	1.88	0.02
31	24.59	1.96	23.99	1.93	<0.001
32	25.66	2.72	25.77	4.28	NS
FOT	T0		T1		
Tooth N.	Mean	sd	Mean	sd	*p*-value
12	25.95	3.14	24.87	3.11	<0.001
11	27.39	2.88	26.31	2.76	<0.001
21	27.02	3.12	25.88	3.23	<0.001
22	26.10	3.30	25.18	3.25	<0.001
42	25.84	2.15	24.93	2.17	<0.001
41	24.41	1.94	23.39	2.09	<0.001
31	24.47	2.17	23.50	2.21	<0.001
32	25.45	2.40	24.67	2.46	<0.001
Root length change	CAT		FOT		
ΔT2–T0	Mean	sd	Mean	sd	*p*-value
Δ12	−0.58	0.52	−1.07	0.59	<0.001
Δ11	−0.73	0.73	−1.08	0.77	NS
Δ21	−0.82	0.95	−1.14	0.72	0.02
Δ22	−0.73	0.72	−0.92	0.56	NS
Δ42	−0.52	0.72	−0.90	0.58	0.02
Δ41	−0.48	0.97	−1.02	0.54	0.01
Δ31	−0.60	0.83	−0.97	0.66	NS
Δ32	0.11	3.83	−0.79	0.45	0.04

Paired t test and Independent t test were used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; sd: standard deviation; NS: non-significant ($p > 0.05$); Δ: the change in the root lengths from T0 to T2.

TABLE 3. The intra-group comparison of total pain scores between different time points for CAT and FOT groups.

CAT											
	Mean	sd	*p*-value		*post-hoc p*-value						
BOT	1.63	3.54			4th h	24th h	1st w	2nd w	1st m	3rd m	6th m
4th h	9.94	11.78		BOT	0.01	<0.001	0.03	NS	NS	NS	NS
24th h	16.39	10.66		4th h		NS	NS	NS	NS	NS	NS
1st w	8.02	9.42	<0.001	24th h			<0.001	<0.001	<0.001	<0.001	<0.001
2nd w	6.43	9.12		1st w				NS	NS	NS	NS
1st m	4.26	7.23		2nd w					NS	NS	NS
3rd m	3.70	6.63		1st m						NS	NS
6th m	3.47	6.60		3rd m							NS
FOT											
	Mean	sd	*p*-value		*post-hoc p*-value						
BOT	1.35	2.44			4th h	24th h	1st w	2nd w	1st m	3rd m	6th m
4th h	17.70	9.32		BOT	<0.001	<0.001	<0.001	0.01	NS	NS	NS
24th h	20.09	9.45		4th h		NS	NS	<0.001	<0.001	<0.001	<0.001
1st w	12.17	8.85	<0.001	24th h			0.01	<0.001	<0.001	<0.001	<0.001
2nd w	7.19	6.85		1st w				<0.001	<0.001	<0.001	<0.001
1st m	4.60	5.45		2nd w					<0.001	0.03	<0.001
3rd m	2.13	3.74		1st m						NS	0.03
6th m	1.57	2.46		3rd m							NS

Repeated measures analysis of variance (ANOVA) was used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; BOT: before the orthodontic treatment; h: hour; w: week; m: month; sd: standard deviation; NS: non-significant (p > 0.05).

TABLE 4. The intra-group comparison of total chewing performance scores between different time points for CAT and FOT groups.

CAT											
	Mean	sd	*p*-value		*post-hoc p*-value						
BOT	10.93	2.02			4th h	24th h	1st w	2nd w	1st m	3rd m	6th m
4th h	18.07	3.89		BOT	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
24th h	19.56	4.63		4th h		NS	NS	NS	0.02	0.03	0.02
1st w	17.48	2.72	<0.001	24th h			NS	0.01	<0.001	<0.001	<0.001
2nd w	16.22	2.38		1st w				NS	<0.001	<0.001	<0.001
1st m	15.15	2.11		2nd w					NS	NS	NS
3rd m	14.78	2.75		1st m						NS	NS
6th m	14.59	2.75		3rd m							NS
FOT											
	Mean	sd	*p*-value		*post-hoc p*-value						
BOT	11.23	1.82			4th h	24th h	1st w	2nd w	1st m	3rd m	6th m
4th h	18.77	4.01		BOT	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
24th h	20.14	4.32		4th h		NS	NS	NS	NS	0.02	<0.001
1st w	17.18	3.42	<0.001	24th h			<0.001	0.02	<0.001	<0.001	<0.001
2nd w	16.68	3.40		1st w				NS	NS	NS	0.02
1st m	16.23	3.83		2nd w					NS	NS	NS
3rd m	15.73	2.66		1st m						NS	NS
6th m	15.00	2.41		3rd m							NS

Repeated measures analysis of variance (ANOVA) was used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; BOT: before the orthodontic treatment; h: hour; w: week; m: month; sd: standard deviation; NS: non-significant (p > 0.05).

TABLE 5. Comparison of the change in probing depth and plaque index parameters between CAT and FOT groups.

	ΔT1–T0					ΔT2–T1					ΔT2–T0				
	CAT		FOT			CAT		FOT			CAT		FOT		
	Median	Min/Max	Median	Min/Max	*p*-value	Median	Min/Max	Median	Min/Max	*p*-value	Median	Min/Max	Median	Min/Max	*p*-value
PD															
Δ16	0.07	−0.17/0.33	0.14	−0.50/0.67	NS	0.03	0.00/0.33	0.07	−0.33/0.50	NS	0.11	−0.17/0.33	0.21	−0.83/0.83	0.02
Δ21	0.08	−0.67/0.33	0.19	−0.17/0.83	NS	0.02	−0.17/0.50	0.03	0.00/0.67	NS	0.10	0.00/1.50	0.22	−0.67/0.67	NS
Δ24	0.10	−0.33/0.67	0.01	−2.83/0.67	NS	−0.02	−0.67/0.50	0.02	0.00/0.17	NS	0.09	−0.17/1.17	0.03	−0.33/0.67	NS
Δ36	0.02	−0.50/0.33	0.21	−1.33/2.17	<0.001	0.06	0.00/0.83	0.14	0.00/0.67	NS	0.07	−0.33/0.83	0.35	−0.67/2.17	<0.001
Δ41	0.04	−0.50/0.33	0.26	0.00/0.83	0.01	0.04	0.00/0.33	0.06	0.00/0.50	NS	0.08	−0.17/1.00	0.32	−0.17/0.50	0.01
Δ44	−0.02	−0.83/0.17	0.13	−0.83/1.50	<0.001	0.02	0.00/0.17	0.05	0.00/0.50	NS	−0.01	0.00/1.67	0.17	0.00/1.67	0.02
PI															
Δ16	0.13	0.00/0.67	0.42	0.00/0.83	<0.001	0.10	−0.17/0.50	0.25	0.00/1.00	0.04	0.23	0.00/0.83	0.67	0.00/1.17	<0.001
Δ21	0.03	0.00/0.17	0.20	−0.67/0.83	0.01	0.01	0.00/0.17	0.14	0.00/0.50	0.01	0.04	0.00/1.17	0.34	−0.67/1.00	0.02
Δ24	0.09	0.00/1.17	0.20	−0.17/0.83	NS	0.01	0.00/0.17	0.20	0.00/0.83	<0.001	0.09	0.00/1.17	0.40	−0.17/1.17	<0.001
Δ36	0.10	0.00/0.83	0.28	−0.50/0.83	0.02	0.04	0.00/0.50	0.32	0.00/1.00	<0.001	0.14	0.00/1.33	0.60	0.00/1.50	<0.001
Δ41	0.06	−0.17/0.67	0.18	−0.33/0.83	NS	0.10	0.00/0.67	0.27	0.00/1.00	0.04	0.16	0.00/0.67	0.45	−0.33/1.00	<0.001
Δ44	0.01	0.00/0.33	0.06	−0.50/0.83	NS	0.06	0.00/0.33	0.23	0.00/1.50	0.03	0.07	0.00/0.67	0.29	−0.17/1.50	0.03

Mann Whitney U test was used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; PD: Probing depth; PI: Plaque index; NS: non-significant ($p > 0.05$).

TABLE 6. The comparison of the bleeding on probing in buccal and lingual/palatal side of Ramfjord teeth at different time points.

		T0					T1					T2				
BOP		CAT		FOT			CAT		FOT			CAT		FOT		
		n	%	n	%	*p*-value	n	%	n	%	*p*-value	n	%	n	%	*p*-value
							Labial/Buccal Side									
16																
	yes	24	88.90%	15	68.20%	NS	25	92.60%	19	86.40%	NS	26	96.30%	22	100.00%	NS
	no	3	11.10%	7	31.80%		2	7.40%	3	13.60%		1	3.70%	0	0.00%	
21																
	yes	7	25.90%	12	54.50%	0.04	7	25.90%	14	63.60%	0.01	9	33.30%	15	68.20%	0.02
	no	20	74.10%	10	45.50%		20	74.10%	8	36.40%		18	66.70%	7	31.80%	
24																
	yes	7	25.90%	8	36.40%	NS	7	25.90%	13	59.10%	0.02	7	25.90%	15	68.20%	<0.001
	no	20	74.10%	14	63.60%		20	74.10%	9	40.90%		20	74.10%	7	31.80%	
36																
	yes	21	77.80%	18	85.70%	NS	22	81.50%	19	86.40%	NS	22	81.50%	21	95.50%	NS
	no	6	22.20%	3	14.30%		27	18.50%	22	13.60%		5	18.50%	1	4.50%	
41																
	yes	12	44.40%	9	40.90%	NS	12	44.40%	14	63.60%	NS	12	44.40%	14	63.60%	NS
	no	15	55.60%	13	59.10%		15	55.60%	8	36.40%		15	55.60%	8	36.40%	
44																
	yes	9	33.30%	11	50%	NS	9	33.30%	14	63.60%	0.03	9	33.30%	14	63.60%	0.03
	no	18	67.70%	11	50%		18	66.70%	8	36.40%		18	66.70%	8	36.40%	

TABLE 6. Continued.

		T0					T1					T2				
BOP		CAT		FOT			CAT		FOT			CAT		FOT		
		n	%	n	%	*p*-value	n	%	n	%	*p*-value	n	%	n	%	*p*-value
							Palatal/Lingual Side									
16																
	yes	21	77.80%	17	77.30%	NS	21	77.80%	20	90.90%	NS	22	81.50%	21	95.50%	NS
	no	6	22.20%	5	22.70%		6	22.20%	2	9.10%		5	18.50%	1	4.50%	
21																
	yes	10	37.00%	13	59.10%	NS	10	37.00%	15	68.20%	0.03	10	37.00%	16	72.70%	0.01
	no	17	63.00%	9	40.90%		17	63.00%	7	31.80%		17	63.00%	6	27.30%	
24																
	yes	10	37.00%	14	63.60%	NS	11	40.70%	16	72.70%	0.03	11	40.70%	16	72.70%	0.03
	no	17	63.00%	8	36.40%		16	59.30%	6	27.30%		16	59.30%	6	27.30%	
36																
	yes	24	88.90%	20	90.90%	NS	24	88.90%	22	100.00%	NS	26	96.30%	22	100.00%	NS
	no	3	11.10%	2	9.10%		3	11.10%	0	0.00%		1	3.70%	0	0.00%	
41																
	yes	14	51.90%	12	54.50%	NS	20	74.10%	21	95.50%	NS	21	77.80%	21	95.50%	NS
	no	13	48.10%	10	45.50%		7	25.90%	1	4.50%		6	22.20%	1	4.50%	
44																
	yes	9	33.30%	13	59.10%	NS	12	44.40%	15	68.20%	NS	11	40.70%	16	72.70%	0.03
	no	18	66.70%	9	40.90%		15	55.60%	7	31.80%		16	59.30%	6	27.30%	

Chi square test was used. CAT: Clear aligner therapy; FOT: Fixed orthodontic treatment; BOP: Bleeding on probing; n: number of samples; NS: non-significant ($p > 0.05$).

Among radiographic techniques, the accuracy of CBCT is higher than that of periapical radiography, and the accuracy of periapical radiography is higher than that of panoramic radiography in the detection of root resorption [18, 19]. On the other hand, Parrales-Bravo *et al.* [20] highlighted that both CBCT and periapical radiographs are good diagnostic methods for external root resorption. Furthermore, Zamani *et al*. [21] aimed to compare the absorbed dose and lifetime cancer risk between CBCT and panoramic X-rays on 332 patients and reported that CBCT had a significantly higher level of radiation risk.

The concept of "as low as reasonably achievable" (ALARA) should be adopted in dental imaging both for the patient and the clinician [22]. Therefore, to limit the harmful effects of ionizing radiation on patients, periapical X-ray imaging procedures using the paralleling cone technique were used to evaluate root resorption in this study.

Leveling and alignment generally constitute the first stage of orthodontic treatment. A previous study showed that the mean duration of the leveling and alignment of mild to moderate crowding without extraction was 6 months [23]. Therefore, in our study, the groups were compared following a 6-month observation period.

The root lengths of maxillary and mandibular anterior teeth were evaluated at the beginning of the treatment and at the end of the 6-month observation period. Accordingly, the degree of root resorption was markedly higher in FOT than in CAT ($p < 0.05$) (Table 2).

Clear aligners generate intermittent forces as they are occasionally removed during food consumption and hygiene maintenance [24]. Sawicka *et al*. [25] evaluated root resorption variations using continuous and discontinuous forces during orthodontic treatment and observed less resorption with intermittent forces because the intermittent force provided cementum the time to heal. If clear aligner treatment plans are designed well by orthodontists, they can help providing predictable tooth movement and avoid jiggling to reduce root resorption compared to fixed orthodontic treatments [26].

Brandon *et al*. [4] reported higher amounts of root resorption in the upper and lower incisors in the fixed treatment group than in the clear aligner group. Jianru *et al.* [5] also found that clear aligner therapy induced less risk for apical root resorption compared to fixed orthodontic treatment in the upper and lower incisors in non-extraction patients. Li *et al.* [27] reported that, the prevalence of apical root resorption in patients with clear aligners were lower than those in patients with fixed appliances.

The highest pain scores were recorded at the 24th hour of the treatment in both groups. Diddige *et al.* [28] also found the highest pain levels at 24th hours in both methods, and these pain levels gradually dropped to the baseline levels by the 7th day. It was reported that clear aligners apply lower forces on the 7th and 14th days compared to the initial levels [24].

The secretion of neuropeptides such as Calcitonin Gene-Related Peptide and Substance P, which stimulate the secretion of proinflammatory cytokines increases after the application of orthodontic forces during the first 2 days of treatment [29]. These biochemicals reduce the pain threshold by disrupting the mechanism in the nerve endings going into the periodontal ligament during the first two days after the initiation of orthodontic forces [30]. In this study, the decline in the perceived pain levels of the patients occurred in a shorter time in CAT compared to FOT (Table 3).

As stated in the literature, aligners can be removed by patients when they feel pain to relieve this pain, and the decrease in the perceived pain levels of patients was faster in CAT [31].

Almasoud *et al*. [32] and reported less pain in the clear aligner group in the first week of orthodontic treatment compared to the fixed orthodontic treatment group. Gao *et al.* [33] found that patients treated with clear aligners experienced lower pain levels in comparison to those receiving fixed orthodontic treatment. These findings were similar to those of our study.

The maximum discomfort scores in chewing performance in our study were also recorded at the 24th hour for both groups. This finding can be explained by the high pain levels at the 24th hour of treatment. Moreover, while the chewing function of the patients in the FOT group improved after the 1st week, it improved after the 2nd week in the CAT group.

Gameiro *et al.* [34] reported that a significant increase in pain was observed during chewing at 24 hours after the activation of the appliances, and this was significantly correlated with a decrease in their masticatory performance of the patients. The findings of their study were consistent with our findings.

Computerized analysis methods such as T-Scan® can provide accurate and repeatable occlusion recordings [35]. The number of contact points, occlusal force parameters during centric occlusion and lateral movements, occlusion and disocclusion times, and temporomandibular joint diseases can also be evaluated using various methods [36]. Moreover, a correlation was reported between surveys and VAS, which are more inexpensive, more practical, and objective methods [37]. The studies mentioned above suggested that subjective methods can be used to evaluate masticatory functions. In our study, the survey used in the study by Stamm *et al.* [15] was used to evaluate the chewing performance.

In support of our finding, Lou *et al*. [38] reported that CAT was associated with a transient increase in masticatory muscle activity, possibly because of an increase in wake-time parafunctional tooth clenching. They reported that patients without temporomandibular disorders adapted well to CAT as the masticatory muscle activity decreased toward the baseline levels after 2 weeks.

A current study also reported that the activation and/or installation of fixed labial appliances temporarily reduces masticatory performance and bite forces (for 24 to 48 hours) [39].

Ngan *et al.* [40] observed no significant difference on the 7th day, while discomfort reached its maximum levels at the 24th hour after fixed orthodontic treatment. Compared to fixed labial appliances, clear aligner wearers reported less chewing discomfort which might be related to the temporary removal of the aligners during meals [41].

Although clear aligners can be removed while eating and allow normal mastication function during orthodontic treatment, the doubled thickness of the aligner material increases the interocclusal distance, and their intrusive effect induced on

posterior teeth may prevent optimal mastication [42].

Ramfjord teeth were included in this study to make the outcomes related to data on periodontal parameters simpler and more comprehensible [43]. Probing depth was found higher in the FOT group than in the CAT group in this study. Plaque accumulation is the most significant etiological factor of gingival inflammation, and it causes gingival enlargement by increasing the flow of gingival groove fluids that feed plasma proteins required for the growth of proteolytic anaerobes [44]. Previous systematic review and meta-analysis studies reported similar findings to those in our study regarding probing depth [8, 45]. Moreover, the general biodiversity and salivary microbial community structure did not change significantly during the first six months of clear aligner treatment [46].

The plaque index scores, which is another parameter providing information about the periodontal status, were significantly lower in the CAT group at all time points in our study. Since clear aligners are removable, they allow flossing resulting in better oral hygiene [9, 47]. Furthermore, since this technique does not involve braces bonded on teeth that create retentive areas for dental plaque, a more effective mechanical cleaning occurs with masticatory function during clear aligner treatment. Moreover, braces can make toothbrushing more difficult and reduce natural self-cleansing by the saliva and the tongue [48]. Cantekin *et al*. [49] demonstrated high levels of dental plaque accumulation, gingival swelling, and gingival bleeding during orthodontic treatment with fixed appliances. In our study, the presence of bleeding on probing showed probably no significant difference between the groups for maxillary and mandibular molars and mandibular incisors due to their proximity to the salivary glands and the physical washing effect of saliva. On the other hand, FOT provoked significantly more bleeding than CAT for maxillary incisors and maxillary and mandibular premolars at T1 and T2. The factors leading to the accumulation of more dental plaque in the FOT group also increased bleeding on probing as a secondary outcome. Another explanation for this finding may be that patients treated with braces avoid brushing their teeth vigorously with the fear of damaging their appliances.

In contrast to our finding, Lanteri *et al*. [50] showed that clear aligner system did not demonstrate a significantly superior "periodontal performance" compared to traditional equipment, as opposed to what was expected. This was probably because the coverage, almost all day, of dental surfaces, can lead to the accumulation of various substances resulting in inflammation, especially in patients who consume snacks or drinks with high sugar content. According to Karkhanechi *et al*. [51], the CAT group had less bleeding on probing and less probing depth at 6 months of treatment compared to the FOT group. Our results were similar to those presented by Karkhanechi *et al*. [51] and Haili Lu *et al*. [45].

Our study had some limitations. The first limitation of our study was the short-term observation period. Additionally, we included patients with only mild to moderate crowding and the patients were monitored in terms of adverse effects for a limited time of 6 months, within the greatest amount of tooth movement occur. We recommend that further studies with longer observation periods to be performed on patients with more severe orthodontic malocclusions.

5. Conclusions

- Patients treated with clear aligners had better periodontal health during orthodontic treatment compared to patients treated with conventional fixed appliances.

- Although root resorption occurred in both groups, the FOT group developed more root resorption than the CAT group.

- Patients in both groups experienced the highest pain levels and chewing difficulty levels at the 24th hour. While pain decreased to the baseline levels earlier in the CAT group, chewing performance improved more rapidly in the FOT group.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

IEM and EDS—designed the research study and performed the literature search and data analysis. IEM—wrote the manuscripts. DS and EDS—help and advice on the write, drafted and/or critically revised the work. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This prospective study was approved by the Ethics Committee of Bezmialem Vakif University with 17/2 file number. Informed consent was received from the patients.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Papageorgiou SN, Tilen R, Vandevska-Radunovic V, Eliades T. Occlusal outcome after orthodontic treatment with preadjusted straight-wire and standard edgewise appliances. Journal of Orofacial Orthopedics. 2021; 82: 321–328.

[2] Pereira D, Machado V, Botelho J, Proença L. Comparison of pain perception between clear aligners and fixed appliances: a systematic review and meta-analysis. Applied Sciences. 2020; 10: 4276.

[3] Yassir YA, Nabbat SA, McIntyre GT, Bearn DR. Clinical effectiveness of clear aligner treatment compared to fixed appliance treatment: an

overview of systematic reviews. Clinical Oral Investigations. 2022; 26: 2353–2370.
[4] Fowler B. A comparison of root resorption between invisalign treatment and contemporary orthodontic treatment [master's thesis]. University of Southern California. 2010.
[5] Yi J, Xiao J, Li Y, Li X, Zhao Z. External apical root resorption in non-extraction cases after clear aligner therapy or fixed orthodontic treatment. Journal of Dental Sciences. 2018; 13: 48–53.
[6] Al-Zainal MH, Anvery S, Al-Jewair T. Clear aligner therapy may not prevent but may decrease the incidence of external root resorption compared to full fixed appliances. Journal of Evidence Based Dental Practice. 2020; 20: 101438.
[7] Hu L, Mulla Issa FK, Mulla Issa ZK, Rabah A. Periodontal parameters in adult patients with clear aligners orthodontics treatment versus three other types of brackets: a cross-sectional study. Journal of Orthodontic Science. 2020; 9: 4.
[8] Jiang Q, Li J, Mei L, Du J, Levrini L, Abbate GM, *et al*. Periodontal health during orthodontic treatment with clear aligners and fixed appliances. The Journal of the American Dental Association. 2018; 149: 712–720.e12.
[9] Pango Madariaga AC, Bucci R, Rongo R, Simeon V, D'anto V, Valletta R, *et al.* Impact of fixed orthodontic appliance and clear aligners on the periodontal health: a prospective clinical study. Dentistry Journal. 2020; 8: 4.
[10] Lago GV, Fernandes TMF, Oltramari NPVP, Almeida MR, Miranda LV, Conti ACDCF, *et al*. Reliability of CBCT and periapical radiography methods to evaluate external apical root resorption during early phase of orthodontic treatment. Journal of Health Sciences. 2018; 20: 2–7.
[11] Mumghamba EGS, Pitiphat W, Matee MIN, Simon E, Merchant AT. The usefulness of using Ramfjord teeth in predicting periodontal status of a Tanzanian adult population. Journal of Clinical Periodontology. 2004; 31: 16–18.
[12] Barnett ML, Ciancio SG, Mather ML. The modified papillary bleeding index-comparison with gingival index during the resolution of gingivitis. Journal of Preventive Dentistry. 1980; 6: 135–138.
[13] Fischman SL. Current status of indices of plaque. Journal of Clinical Periodontology. 1986; 13: 371–374.
[14] Velez JC, Friedman LE, Barbosa C, Castillo J, Juvinao QDL, Williams MA, Gelaye B, *et al.* Evaluating the performance of the pain interference index and the short form McGill pain questionnaire among Chilean injured working adults. PLOS ONE. 2022; 17: e0268672.
[15] Stamm T, Hohoff A, Ehmer U. A subjective comparison of two lingual bracket systems. European Journal of Orthodontics. 2005; 27: 420–426.
[16] Jones M, Chan C. The pain and discomfort experienced during orthodntic treatment: A randomized controlled clinical trial of two intial aligning arch wires. American Journal of Orthodontics and Dentofacial Orthopedics. 1992; 102: 373-338
[17] Gupta A, Devi P, Srivastava R, Jyoti B. Intra oral periapical radiography-basics yet intrigue: a review. Bangladesh Journal of Dental Research & Education. 2014; 4: 83–87.
[18] Bornstein MM, Lauber R, Sendi P, von Arx T. Comparison of periapical radiography and limited cone-beam computed tomography in mandibular molars for analysis of anatomical landmarks before apical surgery. Journal of Endodontics. 2011; 37: 151–157.
[19] Taravati S, Balak Z, Rakhshan V. Diagnostic accuracy of periapical radiography in detection and measurement of the external root resorption in primary molars: a single-blind prospective clinical study. International Journal of Dentistry. 2022; 2022: 1–10.
[20] Parrales-Bravo C, Friedrichsdorf SP, Costa C, Paiva JB, Iglesias-Linares A. Does endodontics influence radiological detection of external root resorption? An *in vitro* study. BMC Oral Health. 2023; 23: 221.
[21] Zamani H, Falahati F, Omidi R, Abedi-Firouzjah R, Zare M, Momeni F, *et al*. Estimating and comparing the radiation cancer risk from cone-beam computed tomography and panoramic radiography in pediatric and adult patients. International Journal of Radiation Research. 2020; 18: 885–893.
[22] Albin A, Goren A, Faber R, Anderson N, Dauer L, Quinn B, *et al*. Dosimetry comparison of CBCT versus digital 2D orthodontic imaging in a pediatric orthodontic patient [master's thesis]. State University of New York at Stony Brook. 2021.
[23] Genji L, Varghese RM, Subramaniyan AK. Comparison of duration of leveling and aligning in different types of crowding in lower anteriors. Journal of Pharmaceutical Negative Results. 2022; 13: 1255–1262.
[24] Remley ML. Force analysis of aligner materials in lingual bodily movement of a central incisor over time [master's thesis]. Saint Louis University. 2022.
[25] Sawicka M, Bedini R, Wierzbicki PM, Pameijer CH. Interrupted orthodontic force results in less root resorption than continuous force in human premolars as measured by microcomputed tomography. Folia Histochemica et Cytobiologica. 2014; 52: 289–296.
[26] Kalia S, Reginald M, Birte M. Clear aligners and their role in orthodontics. Adult Orthodontics. 2022; 31: 379–391.
[27] Li Y, Deng S, Mei L, Li Z, Zhang X, Yang C, *et al*. Prevalence and severity of apical root resorption during orthodontic treatment with clear aligners and fixed appliances: a cone beam computed tomography study. Progress in Orthodontics. 2020; 21: 1.
[28] Diddige R, Negi G, Kiran KVS, Chitra P. Comparison of pain levels in patients treated with 3 different orthodontic appliances—a randomized trial. Medicine and Pharmacy Reports. 2020; 93: 81.
[29] Scott P, DiBiase AT, Sherriff M, Cobourne MT. Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. American Journal of Orthodontics and Dentofacial Orthopedics. 2008; 134: 470.e1–470.e8.
[30] Batham P, Batham A, Kalia U, Nagar A, Jain S. Pathways of pain to pleasure in orthodontics: a review. Indian Journal of Orthodontics and Dentofacial Research. 2017; 3: 124–128.
[31] Cardoso PC, Espinosa DG, Mecenas P, Flores-Mir C, Normando D. Pain level between clear aligners and fixed appliances: a systematic review. Progress in Orthodontics. 2020; 21: 3.
[32] Almasoud NN. Pain perception among patients treated with passive self-ligating fixed appliances and Invisalign® aligners during the first week of orthodontic treatment. The Korean Journal of Orthodontics. 2018; 48: 326–332.
[33] Gao M, Yan X, Zhao R, Shan Y, Chen Y, Jian F, *et al*. Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving clear aligners and fixed appliances during the initial stage of orthodontic treatment. European Journal of Orthodontics. 2021; 43: 353–359.
[34] Gameiro GH, Schultz C, Trein MP, Mundstock KS, Weidlich P, Goularte JF. Association among pain, masticatory performance, and proinflammatory cytokines in crevicular fluid during orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics. 2015; 148: 967–973.
[35] Khamnuengsitthi N, Pipatphatsakorn M, Tansalarak R. Occlusal factors influencing non-carious cervical lesions in post-orthodontic patients: evaluation using T-Scan® III. Journal of International Dental and Medical Research. 2023; 16: 193–198.
[36] Sadry S, Giray B. Evaluation of occlusion parameters using T-scan III in patients receiving fixed orthodontic treatment. APOS Trends in Orthodontics. 2023; 13: 91–99.
[37] Kim BI, Jeong SH, Chung KH, Cho YK, Kwon HK, Choi CH. Subjective food intake ability in relation to maximal bite force among Korean adults. Journal of Oral Rehabilitation. 2009; 36: 168–175.
[38] Lou T, Tran J, Castroflorio T, Tassi A, Cioffi I. Evaluation of masticatory muscle response to clear aligner therapy using ambulatory electromyographic recording. American Journal of Orthodontics and Dentofacial Orthopedics. 2021; 159: e25–e33.
[39] Duarte L, Bezerra AP, Flores-Mir C, De Luca Canto G, Pereira LJ, Vega Gonçalves TMS. Activation and installation of orthodontic appliances temporarily impairs mastication. The Angle Orthodontist. 2022; 92: 275–286.
[40] Ngan P, Kess B, Wilson S. Perception of discomfort by patients undergoing orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics. 1989; 96: 47–53.
[41] Alajmi S, Shaban A, Al-Azemi R. Comparison of short-term oral impacts experienced by patients treated with invisalign or conventional fixed orthodontic appliances. Medical Principles and Practice. 2020; 29: 382–388.
[42] Boyd RL, Oh H, Fallah M, Vlaskalic V. An update on present and future considerations of aligners. Journal of the California Dental Association. 2006; 34: 793–805.
[43] Shi J, Zhou N, He B, Hong X, Guo W, Jiang L, Li H, *et al.* Diagnostic

accuracy of severe periodontitis for Ramfjord teeth based on different classifications. To be published in Oral Diseases. 2023. [Preprint].

[44] Marsh PD, Moter A, Devine DA. Dental plaque biofilms: communities, conflict and control. Periodontology 2000. 2011; 55: 16–35.

[45] Lu H, Tang H, Zhou T, Kang N. Assessment of the periodontal health status in patients undergoing orthodontic treatment with fixed appliances and Invisalign system. Medicine. 2018; 97: e0248.

[46] Zhao R, Huang R, Long H, Li Y, Gao M, Lai W. The dynamics of the oral microbiome and oral health among patients receiving clear aligner orthodontic treatment. Oral Diseases. 2020; 26: 473–483.

[47] Sharma R, Drummond R, Wiltshire W, Schroth R, Lekic M, Bertone M, *et al*. Quality of life in an adolescent orthodontic population. The Angle Orthodontist. 2021; 91: 718–724.

[48] Ren Y, Jongsma MA, Mei L, van der Mei HC, Busscher HJ. Orthodontic treatment with fixed appliances and biofilm formation—a potential public health threat? Clinical Oral Investigations. 2014; 18: 1711–1718.

[49] Cantekin K, Celikoglu M, Karadas M, Yildirim H, Erdem A. Effects of orthodontic treatment with fixed appliances on oral health status: a comprehensive study. Journal of Dental Sciences. 2011; 6: 235–238.

[50] Lanteri V, Poggi S, Blasi S, De Angelis D, Gangale S, Farronato M, *et al.* Periodontal aspects of orthodontic treatment with Invisalign® versus fixed appliances in the same patients: a pilot study. International Journal of Clinical Dentistry. 2020; 13: 419–447.

[51] Karkhanechi M, Chow D, Sipkin J, Sherman D, Boylan RJ, Norman RG, *et al*. Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy. The Angle Orthodontist. 2013; 83: 146–151.

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