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Cone beam computed tomography study of apical root resorption induced by Herbst appliance

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ABSTRACT

Objective: This study evaluated the frequency of root resorption during the orthodontic treatment with Herbst appliance by Cone Beam Computed Tomography (CBCT). Material and Methods: The sample comprised 23 patients (11 men, 12 women; mean ages 15.76±1.75 years) with Class II division 1 malocclusion, treated with Herbst appliance. CBCT was obtained before treatment (T0) and after Herbst treatment (T1). All the dental roots, except third molars, were evaluated, and apical root resorption was determined using the axial guided navigation method. Paired t-tests and Wilcoxon T Test were used to compare the dependent samples in parametric and nonparametric cases, respectively. Chi-Square Test with Yates' correction was used to evaluate the relationship between apical root resorption and gender. Results were considered at a significance level of 5%. Results: Apical resorption was detected by CBCT in 57.96% of 980 roots that underwent Herbst appliance treatment. All patients had minimal resorption and there was no statistical significance between the genders. Conclusion: CBCT three-dimensional evaluation showed association between Herbst appliance and minimal apical root resorption, mostly in the anchoring teeth, without clinical significance.

Keywords: Root resorption. Activator appliances. Cone-beam computed tomography.

INTRODUCTION

Inflammatory root resorption orthodontically induced is a side effect of tooth movement related to the biological tissue response, and this correlation was reported in literature for the first time in 1914[13]. It is a pathological or physiological localized condition, characterized by loss of the cells layer surface that protects the tooth roots, associated with a structure loss caused by clastic cells[10].

Apical root resorption is usually classified as minor, moderate or severe[4]. Minor root resorption can be repaired with secondary cementum once orthodontic movement ceases. However, when root resorption is sufficiently severe to exceed the reparative capacity of the root, a cementum island may separate from the root surface, resulting in an irreversible root resorption mostly in the apical part of the root[10,20].

Orthodontic treatment has some risk factors for root resorption such as treatment duration, tooth movement direction, amount of apical displacement, and type and magnitude of the force applied[28]. Herbst is a fixed functional appliance with a bilateral telescopic mechanism that keeps the mandible in an anterior position and induces skeletal and dentoalveolar changes such as upper molars distalization[8,15,17-19,21], mesial movement of the lower molars[8,18,19,21,26], and protrusion of lower incisors[2,9,17-19,21,26,27,29]. Emil Herbst, in 1934, published his experience with the device in Zahnärztliche Rundschau, and, in the same journal, Martin Schwarz criticized the Herbst appliance, stating that the device could result in overloading the anchorage teeth with periodontal damage as a consequence[20].

There are only two studies in literature that evaluated the apical root resorption induced by Herbst appliance. In the first, statistical difference was not found in upper and lower premolars. However, regarding lower premolars, the first premolars showed more resorption than the second premolars[16]. The second study supports that the teeth more affected by the apical root resorption was the upper first molars and the lower first premolars[11].

These orthodontic studies have evaluated apical root resorption by conventional radiography, i.e., two dimension radiographies, periapical and panoramic, respectively. However, conventional radiographs may underestimate or overestimate the amount of root structure loss[5]. Panoramic radiography underestimates apical root resorption when compared with microtomography, and overestimates it when compared with periapical radiography[24]. Periapical radiographs were considered less accurate than the cone beam computed tomography (CBCT) to evaluate the root length[25]. The apical root resorption is a three-dimensional change which can affect the root surface as a whole. The ability of CBCT to obtain distortion-free and reproducible images of single roots provides excellent possibilities to evaluate apical root resorption[13]. Different voxel sizes are frequently found in the literature to evaluate the apical root resorption induced by orthodontic tooth movement by CBCT[6,7,12,14,30].

Despite the common use of the Herbst appliance, there is still a lack of literature about the consequences of its use. To our knowledge, there are no studies assessing root resorption through the evaluation by CBCT. This research aimed to evaluate the apical root resorption induced by the Herbst device with CBCT.

MATERIAL AND METHODS

This retrospective study was reviewed and approved by the Ethics Committee of Araraquara Dental School, Univ. Estadual Paulista (FOAr-UNESP). The subjects consisted of 23 patients, sequentially treated (11 men, 12 women; mean age 15.76±1.75 years), who had skeletal Class II division 1 malocclusion.

The inclusion criteria were bilateral Class II molar relationship, overjet bigger than 5 mm and complete permanent dentition, except third molars. The exclusion criteria were syndrome patients, extreme vertical grow pattern and prior orthodontics treatment. Face and occlusion were clinically analyzed to determine skeletal Class II division 1 malocclusion. Facial analysis observed the convex profile, straight nasolabial angle, and short mentocervical line, and occlusion analysis observed the molar and canines in Class II, equal to or higher than the half of a cusp, and overjet equal to or greater than 5 mm.

Patients used banded Herbst appliance until they complete eight months of treatment (mean 8.50±0.70 months) with one step mandibular advancement until the incisor edge to edge relationship[19]. The telescopic mechanism used was Flip-Lock Herbst® (Tp Orthodontics, Inc.) model, which was constituted by connectors, tubes and pistons.

To upper anchorage, transpalatal fixed bar at the first molars was used, made with 1.2 mm steel wire, distant 2 mm from the palate and with an extension of 1.2 mm steel wire to second molar. In the lower arch, the Nance lingual arch modified for Herbst was used in the first molars, made with 1.2 mm steel wire and distant 3 mm from lingual face incisors. Anchor appliances were constructed only by one prosthetic.

To evaluate the apical root resorption induced by Herbst appliance, CBCT images were obtained before treatment (T0) and after treatment (T1) with Herbst appliance. Patients were scanned in an upright position with maximum intercuspation using tomography i-CAT® Classic (Imaging Sciences International, Hatfield, PA, USA) with a 17x13.3 cm of field of vision, 120 kVp tube voltage, 18.45 mA tube current and 0.4 mm isometric voxel. CBCT images were examined using Dolphin® Imaging software (Dolphin Imaging and Management Solutions, Chatsworth, Calif., USA) by multiplanar reconstruction (axial, sagittal and coronal).

All upper and lower teeth, except third molars, were evaluated by tooth length (apical root resorption). The coronal and sagittal cursors were adjusted in the tooth long axis (incisal edge center or cusp to root apex) according to the tooth root of interest[6,7]. The length measurement was linear between two points, one at the root apex and other at the incisal edge or tooth cusp. To precise the localization of root apex and incisal edge or cusp, the axial guided navigation (AGN) method was used. This method used the axial cursor movement at the sagittal and coronal multiplanar reconstruction[6,7]. The reference point to determine the root apex, incisal or cusp tooth is the intersection between axial and sagittal or coronal cursors (Figure 1).

Reference points to the measurements of each tooth were: incisal edge to root apex of the central and lateral incisors (sagittal section); cusp tip to root apex of canines (sagittal section); buccal cusp tip to apex of single-rooted premolar (sagittal section); buccal cusp tip to apex of buccal root of two-rooted premolar (sagittal section); lingual cusp tip to apex of lingual root of two-rooted premolar (coronal section); mesiobuccal cusp tip to apex of mesiobuccal root of upper molar (sagittal section); distobuccal cusp tip to apex of distobuccal root of upper molar (sagittal section); mesiolingual cusp tip to apex of lingual root of upper molar (coronal section); mesiobuccal cusp tip to apex of mesial root of lower molar (sagittal section); distobuccal cusp tip to apex of distal root of lower molar (sagittal section) (Figure 2).

Measurements were randomly reevaluated after two weeks by the same examiner. The error of the method was evaluated by Intraclass Correlation Coefficient (ICC). Shapiro-Wilk Test was used to assess normal distribution, and Student's t-Test and Wilcoxon t-Test were used to compare dependent samples in parametric and non-parametric cases, respectively. Chi-Square Test with Yates' correction was used to evaluate the relationship between apical root resorption and gender. Results were considered at a significance level of 5%. Statistical analysis was performed using SPSS® (SPSS Inc, Chicago, III) and GraphPad Prism® (GraphPad Prism Inc, San Diego).

RESULTS

Systematic intra-examiner error indicated excellent reliability (ICC=0.91). There was statistical difference for mesiobuccal root of right upper first molar, distobuccal root of left upper first molar, distobuccal root of left upper second molar, root of left lower second premolar, distal root of left lower first molar, mesial root of right lower first molar, mesial root of right lower second molar and distal root right lower second molar (Table 1). However, the apical root resorption detected was minimal, with mean smaller than 0.5 mm (Table 1).

All subjects and 57.96% of 980 roots showed apical resorption. The root resorption frequency for each tooth can be observed in Table 2. Apical root resorption analyses between genders do not show statistical difference (Table 3).

DISCUSSION

This CBCT study evaluated the apical root resorption induced by Herbst appliance. Patients with mean age of 15.76 years composed the group to simulate the post pubertal period, stage in which Class II treatment with Herbst appliance shows more dentoalveolar than skeletal response[23].

CBCT images were used to analyze 980 tooth roots, and 568 (57.96%) presented resorption after the Herbst appliance treatment. Previous studies showed a high frequency of apical root resorption after the orthodontic treatment by two-dimensional radiographs analisys[1,24]. As already mentioned, there are no literature reports assessing apical root resorption induced by Herbst appliance by CBCT, therefore, there are no parameters for comparison of our results. It is noteworthy that a more accurate assessment can be obtained by the use of CBCT, which allows a more accurate analysis of the treatment results[12].

In T1 the roots were longer than at T0 for tooth 21, 22, buccal root of 15 and palatal root of 14, 15, 25, and 27 (Table 1). This occurs probably by the accuracy of CBCT with voxel resolutions 0.4 mm to linear measurement of apical root resorption used in this study. However, in a previous similar study with voxel resolutions 0.25 mm the same problem was observed[7], and this may be attributed to the incomplete development of the tooth apices, except for teeth 21 and 22, or by the CBCT issues of methods sensitivity and specificity for apical root resorption assessment.

There was no statistical difference in apical root resorption between genders, which is a data similar to those related in literature[1,3]. There was significant statistical difference for mesiobuccal root of right upper first molar, distobuccal root of left upper first molar, distobuccal root of left upper second molar, root of left lower second premolar, distal root of left lower first molar, mesial root of right lower first molar, mesial root of right lower second molar and distal root right lower second molar. The Nance lingual arch modified to Herbst distant from lingual face of lower incisors, and the transpalatal fix bar in the upper arch may further the apical root resorption in the anchorage teeth.

Such resorption can be justified by the fact that banded Herbst appliance might deliver unphysiologic forces to immediate anchor teeth, thereby exposing these to a higher risk of root resorption than the other teeth incorporated into the anchorage either directly via bands or indirectly via occlusal and proximal contacts[11]. Another study showed no significant statistical difference in the roots morphology after the Herbst appliance treatment, however, in relation to lower premolars, the first showed more root resorption than the second[16]. Apical root resorption associated to Herbst appliance showed a mean of teeth length reduction smaller than 0.5 mm (Table 1). This root shortening is classified as minor root resorption, and is repaired with secondary cementum once orthodontic movement ceases[10,20]. Despite the apical root reduction, this minimal resorption has no clinical significance.

This CBCT study evaluated the amount of apical root resorption and showed that the forces delivered by the propulsion mechanism have no clinical significance to anchor teeth. Our results are in accordance with Nasiopoulos, et al.[16] (2006) and in disagreement with Kinzinger, et al.[11] (2011), however, these studies evaluated root resorption associated to Herbst appliance by two dimension radiographies, periapical and panoramic, respectively.

Table 1- Mean (x̄), standard deviation (SD) and level of significance (P) of the initial (T0) and final (T1) measurements obtained by teeth (in millimeters)[a]

Tooth	Root	T0, x̄ ± SD	T1, x̄ ± SD	T1-T0, x̄ ± SD	P Value
11	SR	23.92 ± 2.18	23.86 ± 2.24	-0.06 ± 0.04	0.518
12	SR	22.80 ± 2.15	22.68 ± 2.40	-0.12 ± 0.08	0.355
13	SR	26.94 ± 2.44	26.90 ± 2.51	-0.04 ± 0.02	0.725
14	BR	21.24 ± 1.62	21.15 ± 1.54	-0.09 ± 0.06	0.586
14	PR	19.68 ± 1.54	19.95 ± 1.64	0.27 ± 0.19	0.308
15	BR	20.96 ± 1.40	20.97 ± 1.53	0.01 ± 0.00	0.968
15	PR	19.82 ± 1.82	20.20 ± 1.77	0.38 ± 0.26	0.068
16	MBR	19.35 ± 1.55	19.09 ± 1.45	-0.26 ± 0.18	0.009**
16	DBR	19.02 ± 1.53	18.87 ± 1.47	-0.15 ± 0.10	0.066
16	PR	20.99 ± 1.34	20.91 ± 1.44	-0.08 ± 0.05	0.446
17	MBR	19.02 ± 1.66	18.86 ± 1.72	-0.16 ± 0.11	0.195
17	DBR	18.65 ± 1.38	18.41 ± 1.35	-0.34 ± 0.16	0.117
17	PR	20.39 ± 1.22	20.38 ± 1.24	-0.01 ± 0.00	0.948
21	SR	23.93 ± 1.92	24.19 ± 1.92	0.26 ± 0.18	0.019
22	SR	22.55 ± 2.32	22.67 ± 2.33	0.12 ± 0.08	0.278
23	SR	26.80 ± 2.41	26.73 ± 2.32	-0.07 ± 0.04	0.727
24	BR	21.29 ± 1.73	21.19 ± 1.83	-0.10 ± 0.07	0.591
24	PR	19.83 ± 1.82	19.81 ± 1.73	-0.02 ± 0.01	0.924
25	BR	21.46 ± 2.00	21.33 ± 1.63	-0.13 ± 0.09	0.472
25	PR	20.80 ± 1.52	20.81 ± 0.79	0.01 ± 0.00	0.974
26	MBR	19.37 ± 1.67	19.25 ± 1.86	-0.12 ± 0.08	0.174
26	DBR	18.87 ± 1.60	18.67 ± 1.68	-0.20 ± 0.14	0.043*
26	PR	21.22 ± 1.60	20.99 ± 1.58	-0.23 ± 0.16	0.125
27	MBR	19.17 ± 1.54	18.95 ± 1.32	-0.22 ± 0.15	0.152
27	DBR	18.81 ± 1.51	18.47 ± 1.37	-0.34 ± 0.24	0.002**
27	PR	20.30 ± 1.20	20.38 ± 1.32	0.08 ± 0.05	0.585
31	SR	21.19 ± 1.33	20.94 ± 1.28	-0.25 ± 0.17	0.107
32	SR	22.48 ± 1.53	22.24 ± 1.61	-0.24 ± 0.16	0.174
33	SR	25.48 ± 1.86	25.08 ± 1.92	-0.40 ± 0.28	0.064
34	SR	21.88 ± 1.81	21.78 ± 1.65	-0.10 ± 0.07	0.526
35	SR	22.20 ± 2.08	21.86 ± 2.12	-0.34 ± 0.24	0.017*
36	MR	20.65 ± 1.14	20.52 ± 1.57	-0.13 ± 0.09	0.467
36	DR	19.95 ± 1.31	19.66 ± 1.36	-0.29 ± 0.20	0.028*
37	MR	20.28 ± 1.43	20.12 ± 1.74	-0.16 ± 0.11	0.337
37	DR	19.46 ± 1.18	19.41 ± 1.56	-0.05 ± 0.03	0.718
41	SR	20.98 ± 1.52	20.88 ± 1.42	-0.10 ± 0.07	0.518
42	SR	22.31 ± 1.49	22.14 ± 1.48	-0.17 ± 0.12	0.153
43	SR	25.26 ± 2.05	25.25 ± 2.20	-0.01 ± 0.00	0.929
44	SR	21.97 ± 1.72	21.89 ± 1.87	-0.08 ± 0.05	0.593
45	SR	22.08 ± 1.94	21.84 ± 1.93	-0.24 ± 0.16	0.079
46	MR	20.94 ± 1.46	20.44 ± 1.39	-0.50 ± 0.35	0.012*
46	DR	19.92 ± 1.20	19.74 ± 1.30	-0.18 ± 0.12	0.078
47	MR	20.45 ± 1.18	20.05 ± 1.49	-0.40 ± 0.28	0.011*
47	DR	19.81 ± 1.31	19.47 ± 1.07	-0.34 ± 0.24	0.013*

[a] SR, single root; BR, buccal root; PR, palatal root; MBR, mesiobuccal root; DBR, distobuccal root; MR, mesial root; DR, distal root. *P <0.05; ** P <0.01

Table 2- Absolute frequency and percentage frequency (%) of apical root resorption[a]

Tooth	Root	n	Absolute frequency	Frequency %
11	SR	23	14	60.87
12	SR	23	14	60.87
13	SR	23	9	39.13
14	BR	23	12	52.17
14	PR	23	10	43.48
15	BR	23	13	56.52
15	PR	7	1	14.28
16	MBR	23	14	60.87
16	DBR	23	15	65.22
16	PR	23	14	60.87
17	MBR	23	13	56.52
17	DBR	23	12	52.17
17	PR	23	14	60.87
21	SR	23	4	17.39
22	SR	23	11	47.83
23	SR	23	15	65.22
24	BR	23	11	47.83
24	PR	23	12	52.17
25	BR	23	14	60.87
25	PR	7	2	28.57
26	MBR	23	16	69.57
26	DBR	23	16	69.57
26	PR	23	15	65.22
27	MBR	23	13	56.52
27	DBR	23	19	82.61
27	PR	23	11	47.83
31	SR	23	9	39.13
32	SR	23	13	56.52
33	SR	23	15	65.22
34	SR	23	14	60.87
35	SR	23	18	78.26
36	MR	23	12	52.17
36	DR	23	16	69.57
37	MR	23	14	60.87
37	DR	23	13	56.52
41	SR	23	11	47.83
42	SR	23	14	60.87
43	SR	23	9	39.13
44	SR	23	14	60.87
45	SR	23	13	56.52
46	MR	23	19	82.61
46	DR	23	15	65.22
47	MR	23	16	69.57
47	DR	23	19	82.61
-	Total	980	568	57.96

[a] SR, single root; BR, buccal root; PR, palatal root; MBR, mesiobuccal root; DBR, distobuccal root; MR, mesial root; DR, distal root. *P <0.05; ** P <0.01

Table 3- Absolute frequency and percentage frequency (%) of apical root resorption by gender

Gender	Number of roots with resorption		Number of roots without resorption		P Value
	Absolute Frequency	Frequency, %	Absolute Frequency	Frequency, %	
Female	274	57.93	199	42.07	0.963
Male	294	57.99	213	42.01	-
Total	568	57.96	412	42.04	-

Regarding the acquisition of tomographic image, the accuracy of CBCT with different voxel resolutions (0.2 and 0.4 mm) to linear measurement of apical root resorption was evaluated. There was no significant statistical difference between these voxel protocols, and both are more accurate than the periapical radiograph to quantify the resorption[22]. More studies must be performed with a larger sample size, including control group, with others protocols of tomography images acquisitions (smaller voxel size and field of vision to increase spatial resolution and decrease scatter noise) and with changes in the Herbst appliance anchorage, a fact that may influence the force distribution on anchorage teeth.

CONCLUSION

According to this study, three-dimensional evaluation of dental roots by CBCT showed an association between Herbst appliance and orthodontically induced inflammatory root resorption mostly in the anchoring teeth, however, root structure loss was minimal and clinically insignificant.

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