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Root resorption after orthodontic treatment

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Background: Orthodontic treatment can result in root resorption.

Objective: To determine if apical root resorption is related to the type of appliance used and/or the direction and amount of tooth movement.

Methods: The pre- and post-treatment tooth lengths of the maxillary and mandibular first molars and incisors were measured on panoramic radiographs of 114 subjects. Associations between changes in the lengths of the incisors and positional changes in the upper and lower central incisors were determined for 45 subjects with pre- and post-treatment cephalometric radiographs.

Results: Taking into account the gender and OPT machine seven statistically significant differences were found between the appliance groups for the lengths of teeth 31 and 41. Within the groups four teeth decreased significantly in length when the pre-adjusted appliance was used (teeth 12, 11, 21, 26) and four teeth when the Speed appliance was used (teeth 26, 31, 41, 42). Only tooth 31 was shorter when the Tip-Edge appliance was used. Lower incisors were significantly shorter post-treatment if the apices were moved close to the lingual cortex.

Conclusions: When panoramic radiographs are used to assess treatment-induced changes in the lengths of the incisors, apical resorption is only one factor that should be considered. The images of lower incisors proclined during treatment may be foreshortened and/or the apices may lie outside the focal plane: both may result in 'shorter' teeth post-treatment. Because of the confounding factors panoramic radiographs may not be a reliable method of determining apical root resorption.

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Introduction

Root resorption is a complex process with a multifactorial aetiology.[1] It has been postulated that the degree of root damage is a function of the appliance and treatment mechanics used.[2] Early workers reported more root resorption occurred when either pin and tube or ribbon arch appliances were used compared with treatment methods that used mainly tipping movements.[3,4] However, when the same level of force was used, less root resorption occurred during bodily movement than occurred during tipping movements.[5] More recently, less resorption was reported to occur during bioefficient therapy than when treatment was carried out with either a simplified standard edgewise appliance or a straight-wire edgewise appliance.[6] It has also been reported that more apical root resorption occurred when standard edgewise appliances were used to treat Class II division 1 malocclusions, following extraction of at least two maxillary first premolars, compared with straight-wire edgewise appliances.[7] No statistically significant difference in apical root resorption was found between the Speed appliance and a straight-wire edgewise system.[8] To date there have been no reports comparing the extent of apical root resorption during treatment with either the Tip-Edge appliance, a self-ligating bracket system or a pre-adjusted edgewise appliance.

The aims of this study were to determine if apical root resorption was related to the duration of treatment, the gender of the subjects, the type of appliance used, whether or not premolars had been extracted, and/or the direction and amount of incisor movement.

Materials and methods

This retrospective study utilised the orthodontic records of 114 patients selected from the Orthodontic Department at the University of Sydney, a solo private practice employing the

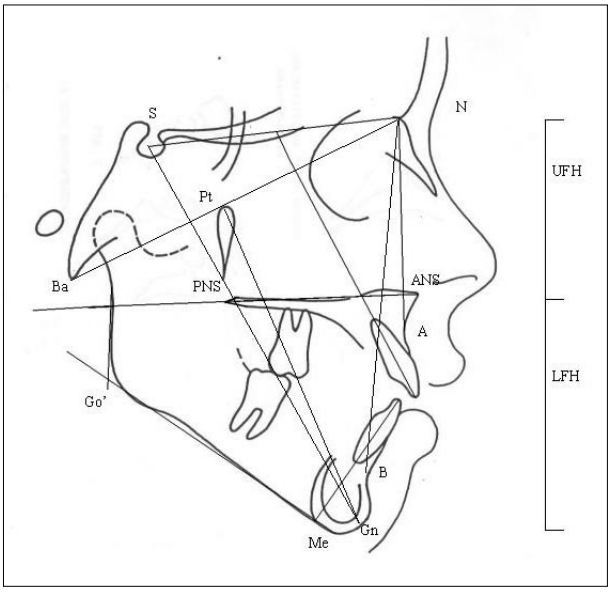


Figure 1. Cephalometric measurements. SNA, SNB, ANB, 1/SN, 1/Pal, 1/1, 1/MP, SN-Pal, SN-Md, Pal-Md, SN-OP, Y-axis, LFH, UFH, LFH:UFH, Jarabak, Overjet, Overbite, Wits, Gonial angle.

Tip-Edge appliance (TP Orthodontics, USA) exclusively and a solo private practice employing the Speed appliance (Strite Industries Ltd., Ontario, Canada) exclusively. Over 1000 panoramic radiographs were screened and only films with no visible magnification or distortion were selected. The selected cases also met the following criteria:

1. Details of the type of malocclusion at the start of treatment, and the duration of treatment were available.

2. Each subject had a single phase of either non-extraction or extraction treatment. In the latter treatment one premolar had been extracted from each quadrant.

3. All permanent teeth were present and there was no history of trauma, endodontic treatment or incisor reshaping.

4. No subjects had had maxillary expansion, orthognathic surgery or previous orthodontic/orthopaedic treatment.

5. Each subject had his/her pre- and post-treatment panoramic (OPT) radiographs taken on the same machine.

6. At the start of treatment all subjects were over 11 years of age. This criterion ensured that there would be minimal root growth of the teeth to be measured.[9]

The subjects were treated with either a pre-adjusted edgewise appliance (Nonextraction: N = 23; Extraction: N = 20), the Speed appliance (Non-extraction: N = 21; Extraction N = 12) or the Tip-Edge appliance (Non-extraction: N = 14; Extraction: N = 24). Of the 114 subjects 45 subjects had pre- and post-treatment lateral cephalometric films taken on the same machines, and 95 subjects had pre- and post-treatment study models.

To investigate changes in the lengths of the incisors and first molars on the pre- (T1) and post-treatment (T2) OPTs the outlines of the upper and lower first molars and upper and lower central and lateral incisors were traced and scanned at 300 dpi (AnalySIS Pro 3.1 imaging system, Munich, Germany). The resulting images were magnified 200 times and the lengths of the incisors (incisal edge – root apex through the midpoint of the CEJ) and first molars (mesiobuccal cusp tip – apex of the mesial root) were measured five times. The means of these measurements were used in all subsequent calculations. Changes in the lengths of each tooth (T2 minus T1) were calculated.

Pre- and post-treatment lateral cephalometric radiographs were available and traced for 45 (13 males, 32 females) subjects (Figure 1). Twenty parameters were measured directly on the tracings. In this group there were 10 pre-adjusted edgewise nonextraction subjects, 10 pre-adjusted edgewise extraction subjects, 11 Speed nonextraction subjects, 7 Speed extraction subjects and 7 Tip-Edge extraction subjects. The lengths of the upper incisors on the OPTs were correlated with changes in the positions of the central incisors on the cephalometric films. The cephalometric films were traced and the T1 and T2 tracings superimposed on the palatal plane (registered at ANS and the region between ANS and A point),[10,11] transferred to plain white paper, scanned, digitised and measured five times. Templates of the upper and lower central incisors were transferred from the pretreatment to the post-treatment radiographs so that any root resorption that occurred during treatment would not affect the measurements. The angular and linear measurements shown in Figures 2 and 3 were made on the tracings.

To provide an objective measurement of the quality of treatment the pre- and post-treatment study

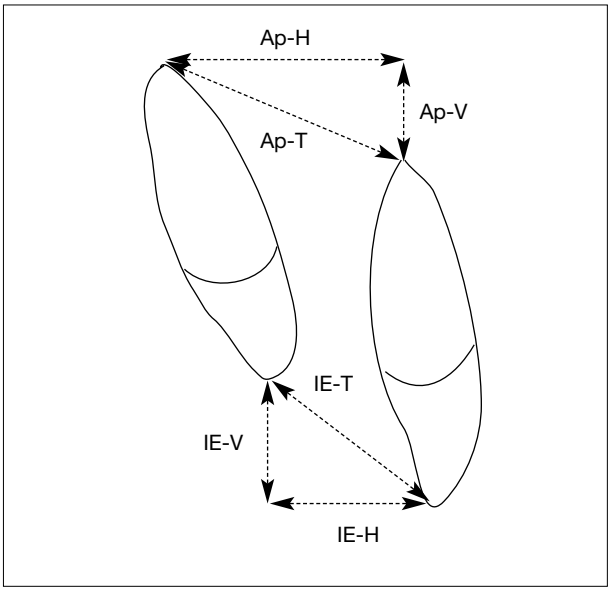


Figure 2. Pre- and post-treatment maxillary measurements. Linear: Ap-H, Ap-V, Ap-T, IE-H, IE-V, IE-T, IE-Ap. Angular: UI/Pal Plane (not shown).

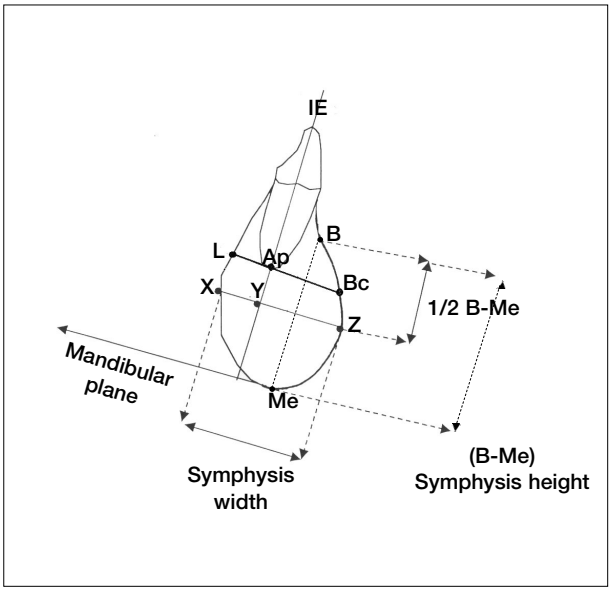


Figure 3. Pre- and post-treatment symphysis measurements. Symphysis width (X-Z), p-distance (X-Y), L-Ap, L-Bc, Ap-Bc, IE-Ap (measured parallel to OP), 1/Md, 1/OP.

models of 95 subjects were scored using the Peer Assessment Rating (PAR).[12,13] The models were scored to ensure that the appliances (pre-adjusted edgewise, Speed and Tip-Edge) and treatment plans (extraction, nonextraction) were performed to the same standard. If the end points were not equivalent treatment duration could not be considered as a factor in the analysis.

All data were analysed with the Statistical package for the Social Sciences (SPSS for Windows, release 10.0.0, SPSS Inc, Chicago, Illinois). A general linear model, univariate analysis was used with OPT machine, gender and group assessed as factors in treatment duration. 'Group' was the appliance type divided into extraction and nonextraction groups. In view of the number of variables statistical significance was set at $p = 0.01$. A bivariate correlation, with a two-tailed test of significance was also performed to correlate the variables measured on the lateral cephalometric radiographs, with changes in the lengths of the incisors on the OPTs.

Results

The distribution of the subjects with respect to appliance, gender, age at the start of treatment, treatment duration and malocclusion are given in Table I. The average age of the subjects was 14.54 years (SD: 2.70 years) and the mean duration of treatment was 25.10 months (SD: 6.26 months). The duration of treatment was significantly shorter ($p = 0.01$) in the nonextraction group (Mean duration: 23.29 months; SD: 5.85 months) than in the extraction group (Mean duration: 27.09 months; SD: 6.13 months). There were statistically significant differences in the durations of treatment of the subjects in the Tip-Edge extraction and the pre-adjusted nonextraction groups ($p = 0.000$); the Tip-Edge extraction and pre-adjusted extraction groups ($p = 0.003$); Tip-Edge extraction and Speed extraction ($p = 0.048$) groups. The pre-adjusted group had a small, but significantly greater PAR reduction (91.3 per cent) than the Speed (84.9 per cent) and Tip-Edge groups (85.1 per cent). All subjects were treated to a high standard.

Panoramic radiographs

On the 228 OPTs the outlines of 47 teeth (1.7 per cent) were indistinct and as a result changes in the lengths of 3.1 per cent teeth could not be established. In the remainder a total of 819 teeth (61.8 per cent) demonstrated tooth shortening, and 506 teeth (38.2 per cent) demonstrated an increase in tooth length. We have assumed that the teeth measured were fully formed and that increases in tooth length were due to different image magnifications of the teeth on the T1 and T2 OPTs. If we further assume that at T1 and T2 each radiographer is equally likely to place patients in

Table I. Distribution of the subjects by appliance group, gender, age at the start of treatment, treatment duration and malocclusion.

Appliance	N	Males	Females	Mean age (years) T1	Age range (years)	Mean duration of treatment ± SD (months)	Malocclusion I	II	III
Pre-adjusted nonextraction	23	9	14	15.58 ± 4.52	15.25–22.42	21.3 ± 3.66	12	6	5
Pre-adjusted extraction	20	6	14	15.05 ± 2.64	12.25–31.75	24.2 ± 1.745	8	8	4
Speed nonextraction	21	8	13	13.11 ± 1.16	11.50–16.33	23.6 ± 3.32	12	7	2
Speed extraction	12	5	7	14.18 ± 1.76	12.67–18.08	22.9 ± 2.74	6	6	0
Tip-Edge nonextraction	14	2	12	14.17 ± 1.19	13.25–16.00	27.1 ± 2.69	3	9	2
Tip-Edge extraction	24	4	20	14.74 ± 1.79	11.25–17.33	30.9 ± 1.75	8	12	4
Total	114	34	80	14.54 ± 2.70	11.25–17.33	25.1 ± 6.26	49	48	17

Table II. Statistically significant differences in the lengths of teeth 31 and 41 taking into account gender and OPT machine.

Tooth	Appliance groups	*p*	Group with shorter roots	Mean diff. (mm)
31	PE:TE	**0.012**	TE	2.92
31	Sp:P	**0.049**	Sp	1.80
31	Sp:PE	**0.000**	Sp	3.56
41	Sp:TE	**0.039**	Sp	1.88
41	PE:P	**0.029**	P	2.17
41	PE:Sp	**0.002**	Sp	2.75
41	PE:TE	**0.047**	TE	2.35

P, pre-adjusted edgewise; Sp, Speed; T, Tip-Edge; E, extraction
Univariate analysis
Significant values are in bold

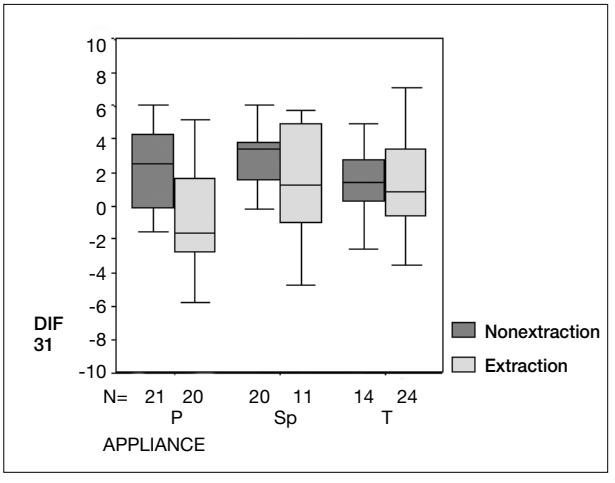


Figure 4a. Box plots demonstrating changes in the length of tooth 31.

positions that would result in either an increase or a decrease in the lengths of the teeth being measured, the differences would be evenly distributed between positive and negative values. That is to say, a normal distribution with a mean of zero would result. However, when the mean changes in tooth lengths were analysed they did not equal zero: the teeth were shorter at T2 than at T1. There was a different pattern of shortening for each appliance. From the statistical model, taking into account gender and the OPT machine used, there were statistically significant differences between the groups for the lengths of teeth 31 and 41 (Table II, Figure 4). The mean differences (T1-T2) in the lengths of the teeth in each appliance group are shown in Figure 5. Within the groups four teeth decreased significantly in length when the pre-adjusted appliance was used (teeth 12, 11, 21, 26) and four teeth when the Speed appliance was used (teeth 26, 31, 41, 42). Only tooth 31 was

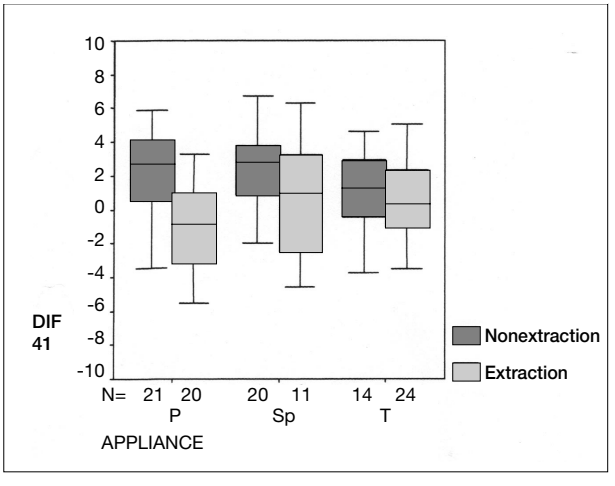


Figure 4b. Box plots demonstrating changes in the length of tooth 41.

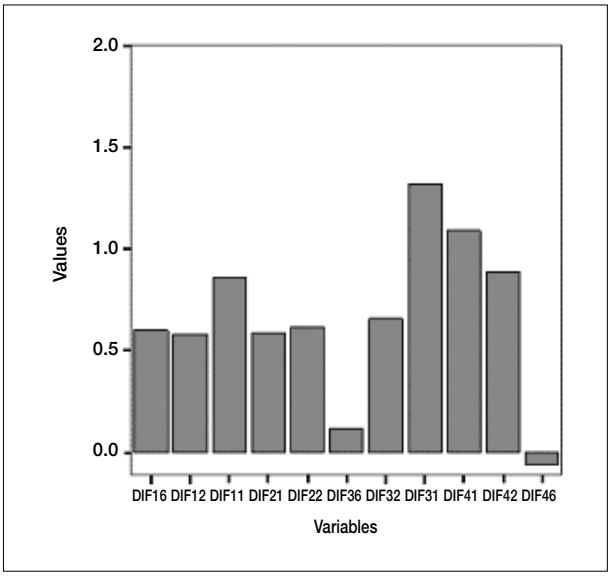


Figure 5a. Mean changes in tooth length (all appliances combined).

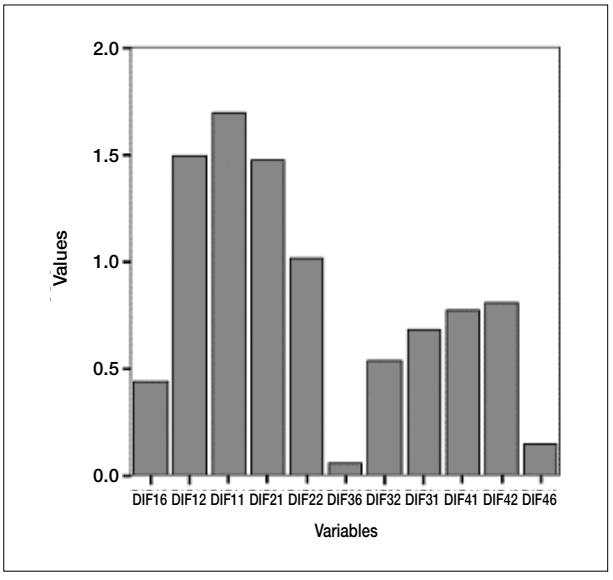


Figure 5b. Mean changes in tooth length (pre-adjusted appliance).

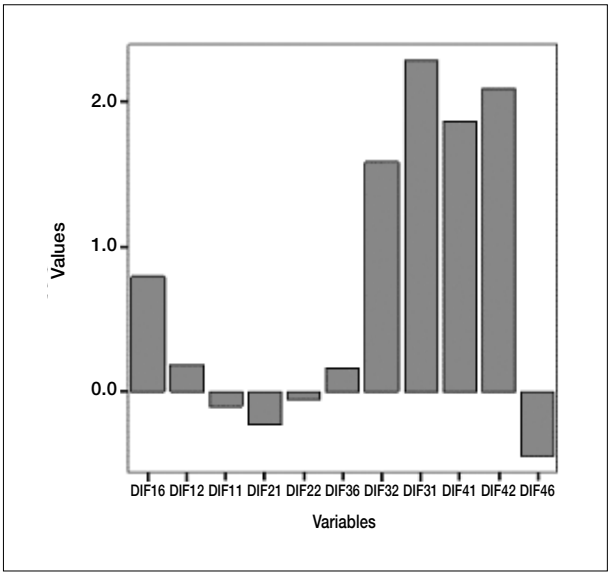


Figure 5c. Mean changes in tooth length (Speed appliance).

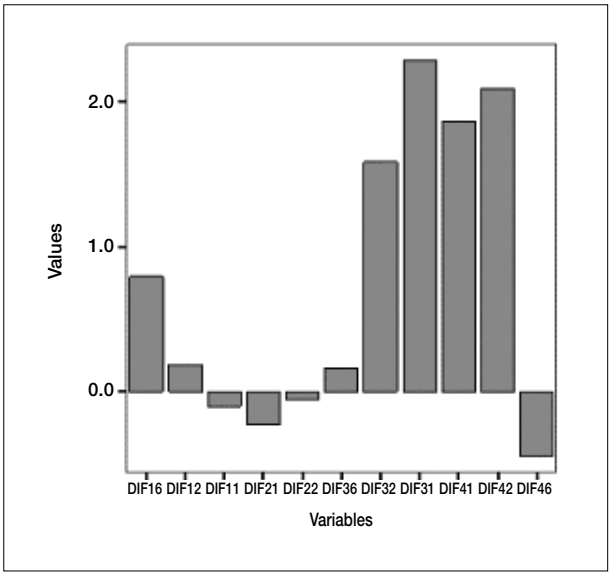


Figure 5d. Mean changes in tooth length (Tip-Edge appliance).

shorter when the Tip-Edge appliance was used (Table III).

Cephalometric radiographs

There were no significant associations between the cephalometric changes describing the upper central incisors and the lengths of the upper incisors on the OPTs. There were, however, several statistically significant associations between the positional changes in the lower central incisors and the lengths of the lower incisors. We have assumed that all incisors moved the same distance. For example, significant associations were found between proclination of the lower central incisors and shorter teeth at T2 for teeth: 31 ($p < 0.001$), 41 ($p = 0.001$), 42 ($p = 0.005$)

Table III. Mean differences (T1-T2) in the lengths of selected teeth. Extraction and nonextraction combined.

Tooth	Combined		Pre-adjusted		Speed		Tip-Edge	
	Mean difference (mm)	p	Mean difference (mm)	p	Mean difference (mm)	p	Mean difference (mm)	p
16	0.60	**.002**	0.46	.096	0.85	.016	0.57	.122
12	0.58	.015	1.54	**.000**	0.08	.806	0.07	.875
11	0.86	**.000**	1.68	**.000**	-0.14	.731	0.75	.064
21	0.58	.022	1.45	**.001**	-0.32	.446	0.44	.328
22	0.62	.023	1.03	.013	-0.06	.904	0.69	.166
26	0.66	**.000**	0.76	**.001**	1.11	**.000**	0.17	.423
36	0.12	.329	0.09	.624	0.17	.382	0.13	.627
32	0.66	**.004**	0.52	.054	1.61	.016	0.06	.787
31	1.32	**.000**	0.60	.176	2.35	**.000**	1.12	**.007**
41	1.09	**.000**	0.72	.102	1.85	**.001**	0.84	.052
42	0.88	**.002**	0.78	.089	2.08	**.000**	-0.08	.866
46	-0.06	.649	0.19	.314	-0.51	.020	0.14	.535

Significant values ($p < 0.01$) are in bold

and a weak correlation between proclination and shorter teeth at T2 for tooth 32 ($p = 0.010$). There was also a significant correlation between shorter teeth and the proximity of the apex of tooth 41 to the lingual cortex at T2 (L-Ap/L-Bc, $p = 0.009$). Other weaker correlations were found between tooth length and p-1/2 sym width at T2: tooth 32, ($p = 0.043$); tooth 41 ($p = 0.013$) and tooth 42 ($p = 0.018$). Tooth length and p-distance at T2: tooth 41 ($p = 0.043$) and tooth 42 ($p = 0.046$). Tooth length and L-AP/L-Bc at T2: tooth 42 ($p = 0.044$). Tooth length and L-Ap at T2: tooth 41 ($p = 0.036$) and tooth length and Ap-Bc at T2: tooth 31 ($p = 0.017$).

Discussion

We used the tooth lengths on serial panoramic radiographs to determine if apical root resorption was related to the appliance used and/or the direction and amount of tooth movement. Panoramic radiographs were chosen for several reasons: they are widely available and recent studies have reported that tooth lengths, crown-root ratios and tooth angulations can be reliably measured providing patients are consistently positioned in the machines and a constant vertical magnification setting is used.[14,15] Other investigators have measured treatment-induced root resorption with OPTs.[16–23]

From the outset we encountered a number of methodological problems. Despite the fact that we screened over 1000 radiographs and selected radiographs that appeared to have patients correctly positioned with no image distortions, almost 40 per cent of the teeth on the post-treatment radiographs increased in length. The increase in length is more likely due to magnification of the post-treatment images rather than root growth occurring during treatment. This finding underlines the importance of consistent positioning when taking these radiographs and using a machine with constant vertical magnification.[24,25]

The panoramic films we used were taken on several different machines with different operators and different focal troughs. A constant magnification setting was either not available or not used. As the same machine was used by the same operators for the T1 and T2 films, measurements of tooth lengths should not have been affected. However, lateral and/or anteroposterior variations in positioning the subjects will result in loss of image sharpness and affect image magnification. Because the different machines had different magnifications that could bias our measurements of tooth length we included the different OPT machines as a factor in the statistical analysis and found they did not contribute to the amount of change in tooth length. The method we used to measure tooth lengths on the OPTs involved carefully tracing the teeth, scanning the tracings and measuring magnified images of the teeth. Few clinicians

would have the time and resources to use this method, which we designed to answer a research question.

When the appliances were compared using the multivariate analysis, teeth 31 and 41 were shorter. We also found that lower incisors proclined during treatment were more likely to appear shorter at the end of treatment. It is generally believed that if teeth or their apices are moved into cortical bone, root resorption will result.[26,27] But there are other explanations when panoramic radiographs are used to determine changes in tooth length. If the lower incisors are proclined their apices may move outside the focal trough of a panoramic machine; in which case the apical area would not be imaged and the tooth would appear shorter at the end of treatment. Furthermore, a proclined incisor might appear shorter if the image is foreshortened. In both cases one might conclude that the teeth had been shortened by resorption when in fact no resorption had taken place. Taking these factors into account we consider that studies using panoramic radiographs to measure changes in tooth lengths and draw conclusions about apical root resorption should be treated with scepticism.

We found that the duration of treatment was approximately four months shorter in the nonextraction than in the extraction group. Many clinicians would agree with this finding, but may not be aware that the difference is relatively small. The variation in each group was similar. We also found statistically significant differences in the durations of treatment of the subjects in the various groups, but again we urge caution in interpreting our results. The subjects in the Tip-Edge and Speed groups were drawn from single clinician practices whereas the subjects in the pre-adjusted edgewise group were drawn from a large university teaching department. Bias could affect both the subjects and the clinicians carrying out treatment. The two clinicians who participated in our study may not represent the majority of clinicians using the Tip-Edge and Speed appliances, and the student clinicians using the pre-adjusted appliance may have used it differently on similar malocclusions.

Conclusions

On serial panoramic radiographs the majority of lower central incisors were shorter post-treatment.

The lower incisors appeared to be shorter post-treatment if the apices were close to the lingual cortex.

When panoramic radiographs are used to assess treatment-induced changes in the lengths of the incisors apical resorption is only one factor that should be considered: the images of lower incisors proclined during treatment may be foreshortened and/or the apices may lie outside the focal plane: both may result in 'shorter' teeth post-treatment.

Because of the confounding factors panoramic radiographs may not be a reliable method of measuring changes in tooth length thought to be due to apical resorption.

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