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Ectopic eruption of the maxillary canine quantified in three dimensions on cephalometric radiographs between the ages of 5 and 15 years

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SUMMARY The eruption paths of 20 ectopic maxillary canine teeth (10 right, 10 left) were measured in three dimensions on annual lateral and depressed postero-anterior cephalometric radiographs of 15 patients between the ages of 5 and 15 years and compared with the eruption of normal canines.

It was found that between the ages of 8 and 12 years ectopic canines on the left side moved more anteriorly than the normally erupting canines and the same was true of the right canines between the ages of 7 and 12 years. While the ectopic canines moved occlusally, their vertical movement was less than normal which accounts for the clinical finding that canines are impacted in the palate at a high level. The average palatally ectopic canine always moves palatally, and never shares in the buccal movement shown by normally erupting canines between the ages of 10 and 12 years. It was interesting to find that the differences between growth of normal and ectopic canines in the lateral plane of space are present as early as 5–6 years.

Introduction

The maxillary canine tooth (the canine) is second only to the mandibular third molar in its frequency of impaction. The reported prevalence varies from less than 0.8–2.8 per cent (Shah *et al.*, 1978; Grover and Lorton, 1985). The impacted canine is placed palatal to the dental arch in 85 per cent of cases and labial/buccal in 15 per cent of cases (Rayne, 1969; Ericson and Kurol, 1987). The aetiology of the impaction is obscure. Jacoby (1983) found that adequate space was present in the arch in 85 per cent of cases where the canine was palatally placed and suggested that excessive space in the canine area might be an aetiological factor.

Becker (1984) found absence of maxillary lateral incisors in 5.5 per cent of a large group of patients with palatal canines, which is 2.4 times the rate in the general population. A genetic or familial trend has been pointed out by some workers (Peck *et al.*, 1994). Pirinen *et al.* (1996) examined first and second degree relatives of 106 consecutive patients with displaced canines, and concluded that palatal displacement of the canine is both genetic and related to hereditary incisor or premolar abnormalities such as peg-shaped lateral incisors. Mossey *et al.* (1994) found a weak statistical relationship between the occurrence of a palatally displaced canine and the absence or reduced crown width of the adjacent lateral incisor, but Brenchley and Oliver (1997) were unable to confirm this finding in respect of crown size.

Coulter and Richardson (1997) quantified the movements of normally erupting maxillary canines in three dimensions using lateral and postero-anterior cephalometric radiographs from the Belfast Growth Study taken annually between 5 and 15 years of age. They showed that canines travel almost 22 mm on average during this period.

Between 5 and 9 years of age, canines tended to move palatally with substantial movement in a buccal direction between 10 and 12 years. Failure to make this buccal movement has been implicated in palatal canine impaction (Williams, 1981). The scarcity of longitudinal records has limited investigation of the path of eruption of ectopic canines which does not seem to have been quantified.

The objective of this study was to measure the eruption pathway of the palatally ectopic maxillary canine in three dimensions from age 5 to 15 years and to make comparisons with normally erupting canines.

Subjects and methods

Scrutiny of the casts at age 15 years in the Belfast Growth Study (Adams, 1972) revealed that one or both maxillary canines had failed to erupt in 15 subjects (nine female, six male). The presence of the canines in palatal positions was confirmed by examination of the corresponding lateral and depressed postero-anterior (PA) cephalometric radiographs taken annually between the ages of 5 and 15 years.

In the sample there were 20 impacted canines, 10 unilateral and five bilateral. There were 10 on the right side and 10 on the left. In each case all 10 sets of annual radiographs were available. None of the subjects had undergone orthodontic or surgical treatment.

To assist head orientation in taking the films, a lead spot was attached to the skin over the lowest point on the rim of the right orbit. The lead spot showed clearly on both films. In order to ensure that the lateral and PA films were precisely orientated to each other the following technique was used (Figure 1).The lateral and depressed postero-anterior (PA) radiographs at 5 years were placed on the tracing desk so that a horizontal line passed through the mid points of the images of the ear rods. A second horizontal line was defined through the upper margin of the lead spot on the PA view. The lateral view was then rotated round the image of the ear rod until the upper margin of the lead spot on the lateral view coincided with the second line. Thus, the views were orientated to each other in the three planes of space. The horizontal lines and the outline of the anterior surface of the zygomatic process on the films at 5 years were traced from both radiographs. In addition, the palatal outline was traced from the lateral view and the nasal septum from the PA view. The positions of the canine tips were marked on both tracings. The lateral tracings were placed individually over the lateral radiographs at 6 years with the anterior surface of the zygomatic process and palatal outlines in register, and the second positions of the canine tips added to the tracing. Similarly, the second positions of the canine tips were added to the PA tracing with the anterior surface of the zygomatic process and midline in register. This process was repeated with each pair of radiographs in turn up to the age of 15 years so that the successive location of each canine cusp was represented by a series of dots (Figure 2). All tracings were repeated after at least 2 weeks for reproducibility testing. Tracings were placed on the screen with the tracing horizontal, superimposed on a horizontal line generated by the digitizer and successive positions of the canine tip digitized. The x (horizontal) and y (vertical) co-ordinates were digitized on the lateral tracings and the z (lateral) co-ordinate on

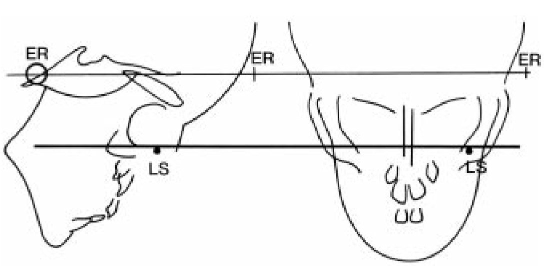

Figure 1 Orientation of lateral and depressed postero-anterior radiographs. ER = ear rod; LS = lead spot.

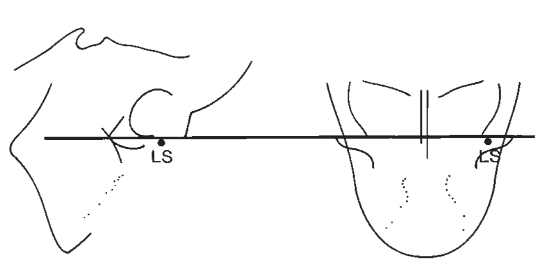

Figure 2 Composite tracing showing annual cusp tip movement of normal canines. LS = lead spot.

Table 1 Reproducibility data.

Co-ordinates	Mean (mm)	SD (mm)	SE (mm)	*t*	*P*	SE (Dahlberg)
Left A–P	0.05	0.53	0.05	0.96	NS	0.39
Left vertical	–0.08	0.59	0.06	–1.31	NS	0.44
Left lateral	0.04	0.81	0.08	0.48	NS	0.60
Right A–P	0.03	0.21	0.02	1.61	NS	0.34
Right vertical	–0.04	1.07	0.11	–0.34	NS	0.85
Right lateral	–0.08	0.77	0.07	–1.06	NS	0.57

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance.

the PA tracing. Positive changes indicated movement upwards and to the right. The data were imported into a spreadsheet for calculation of the annual changes using the initial position of the canine cusp as the origin and for application of correction factors to account for radiographic magnification and annualization of changes as described by Coulter and Richardson (1997). The two recordings of annual movements of each canine were averaged to give the best estimate of the annual changes.

The reproducibility of measurements between tracings was tested using paired *t*-tests and the standard error according to Dahlberg's method (1940).

The mean annual eruption increments were tested for statistical significance against a theoretical expectation of zero on the null hypothesis using paired *t*-tests. The annual changes were compared with those previously derived for normally erupting canines (Coulter and Richardson, 1997) using the independent samples *t*-test.

Results

The outcomes of the reproducibility tests are shown in Table 1. The largest mean discrepancy was 0.08 mm, none of the *t*-tests gave a significant result and the largest standard error was 0.85 mm. The annual movements of the normal and ectopic canines in the three planes of space and the differences between them are shown in Tables 2–7. The differences are shown graphically in Figures 3–5.

Antero-posteriorly, the left and right normal canines showed significant movements in a posterior direction between 7 and 13 years as did the left ectopic canines in some of these years,

Table 2 Differences between left normal and ectopic canines antero-posteriorly.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	*P*
	Mean (mm)	SD (mm)	*P*	Mean (mm)	SD (mm)	*P*			
5–6	–0.16	0.98	NS	–0.41	0.56	NS	0.26	0.25	NS
6–7	–0.33	1.20	NS	–0.55	0.49	**	0.23	0.27	NS
7–8	–1.01	1.30	***	–0.60	0.65	*	–0.42	0.32	NS
8–9	–2.04	1.60	***	–0.25	0.34	NS	–1.79	0.31	***
9–10	–2.45	1.51	***	–0.47	0.36	**	–1.98	0.30	***
10–11	–2.10	1.54	***	–0.48	0.52	*	–1.62	0.33	***
11–12	–2.03	1.97	***	–0.11	0.64	NS	–1.93	0.41	***
12–13	–0.95	1.71	**	–0.20	0.27	*	–0.75	0.32	*
13–14	–0.08	0.92	NS	–0.23	0.34	NS	0.15	0.20	NS
14–15	–0.21	1.01	NS	–0.16	0.34	NS	–0.05	0.21	NS

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

Table 3 Differences between left normal and ectopic canines vertically.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	P
	Mean (mm)	SD (mm)	P	Mean (mm)	SD (mm)	P			
5–6	–1.15	0.52	***	–1.35	0.61	***	0.20	0.21	NS
6–7	–1.41	0.68	***	–1.17	0.78	**	–0.24	0.28	NS
7–8	–1.87	1.12	***	–0.94	0.69	**	–0.93	0.30	**
8–9	–2.66	1.79	***	–1.35	0.36	***	–1.31	0.35	***
9–10	–3.39	1.85	***	–1.27	0.57	***	–2.12	0.38	***
10–11	–3.16	2.07	***	–1.06	0.42	***	–2.10	0.40	***
11–12	–2.86	2.26	***	–1.21	0.59	***	–1.65	0.45	***
12–13	–1.43	2.23	**	–1.39	0.42	***	–0.04	0.43	NS
13–14	–0.68	1.86	NS	–0.97	0.39	***	0.29	0.36	NS
14–15	–0.14	0.46	NS	–0.50	0.41	**	0.35	0.15	*

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

Table 4 Differences between left normal and ectopic canines laterally.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	P
	Mean (mm)	SD (mm)	P	Mean (mm)	SD (mm)	P			
5–6	–0.28	0.88	NS	–1.65	0.74	***	1.38	0.28	***
6–7	–0.16	1.06	NS	–1.27	0.68	***	1.11	0.29	***
7–8	0.03	0.94	NS	–1.58	0.73	***	1.61	0.29	***
8–9	–0.06	1.82	NS	–1.83	0.73	***	1.77	0.41	***
9–10	0.36	2.00	NS	–1.84	0.78	***	2.20	0.44	***
10–11	0.40	1.66	NS	–1.71	0.62	***	2.12	0.36	***
11–12	1.30	0.26	***	–1.61	0.67	***	2.91	0.22	***
12–13	0.66	1.73	*	–1.63	0.66	***	2.29	0.38	***
13–14	0.09	0.74	NS	–1.17	0.55	***	1.25	0.22	***
14–15	0.07	0.89	NS	–0.59	0.46	**	0.66	0.22	**

SD, standard deviation; SE, standard error; *P*, probability. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

but the majority of annual changes for ectopic canines were not statistically significant. Some of the levels of significance for ectopic canines were low and these may be ignored in avoidance of type 1 errors as multiple *t*-tests were used. None of the changes in the right canines were significant. There were significant differences between normal and ectopic canines between the ages of 8 and 12 years, with the normal canines moving in a more posterior direction.

Vertically, both normal and ectopic canines showed significant changes throughout the age range. These were negative, indicating that the teeth were moving towards the occlusal plane. However, the vertical growth of the ectopic canines was significantly diminished between the ages of 7 and 12 years on the left side, and between 9 and 11 years on the right side.

Laterally, normally erupting canines showed significant movement in a buccal direction after

Table 5 Differences between right normal and ectopic canines antero-posteriorly.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	P
	Mean (mm)	SD (mm)	P	Mean (mm)	SD (mm)	P			
5–6	0.04	0.81	NS	–0.19	0.57	NS	0.23	0.23	NS
6–7	–0.05	1.00	NS	–0.42	0.46	NS	0.37	0.23	NS
7–8	–1.61	1.47	***	–0.62	0.47	NS	–0.99	0.30	**
8–9	–1.98	1.85	***	–0.47	0.41	NS	–1.51	0.36	***
9–10	–1.83	2.23	***	–0.80	0.35	NS	–1.03	0.42	*
10–11	–2.06	1.63	***	–0.31	0.29	NS	–1.75	0.31	***
11–12	–2.17	1.62	***	–0.22	0.32	NS	–1.95	0.31	***
12–13	–1.02	1.49	***	–0.36	0.30	NS	–0.66	0.28	*
13–14	–0.65	1.41	NS	–0.43	0.51	NS	–0.22	0.30	NS
14–15	–0.16	0.52	NS	0.40	0.31	NS	–0.56	0.13	***

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

Table 6 Differences between right normal and ectopic canines antero-posteriorly.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	P
	Mean (mm)	SD (mm)	P	Mean (mm)	SD (mm)	P			
5–6	–1.00	0.77	***	–1.93	1.15	***	0.93	0.39	*
6–7	–1.34	0.68	***	–1.25	0.74	***	–0.09	0.27	NS
7–8	–1.83	1.42	***	–1.82	0.34	***	–0.00	0.28	NS
8–9	–2.48	1.61	***	–1.77	0.96	***	–0.71	0.42	NS
9–10	–2.74	1.27	***	–1.41	0.55	***	–1.32	0.29	***
10–11	–3.13	1.93	***	–1.38	0.35	***	–1.75	0.37	***
11–12	–3.10	2.80	***	–1.76	0.69	***	–1.34	0.56	*
12–13	–1.66	2.28	***	–1.30	1.08	**	–0.36	0.54	NS
13–14	–0.89	2.00	*	–1.37	0.57	***	0.48	0.41	NS
14–15	–0.07	0.28	NS	–1.37	0.88	***	1.30	0.28	***

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$.

10 years, whereas the ectopic canines moved significantly in a palatal direction in each of the years from 5 to 15. There were significant differences between normal and ectopic canines throughout the age range studied.

Discussion and conclusions

The anterior surface of the zygomatic process was chosen for superimposition as it has been shown to be stable in relation to metallic implants throughout the period in question (Björk and Skieller, 1977; Doppel *et al.*, 1994). The apparent posterior movement of normal canines compared with the generally non-significant antero-posterior movement of ectopic canines must be interpreted with regard to the orientation of the lateral films with the face tilted downwards. With more conventional orientation, the normal canines would be seen to erupt vertically

Table 7 Differences between right normal and ectopic canines laterally.

Age (years)	Normal			Ectopic			Difference between means	SE (diff)	P
	Mean (mm)	SD (mm)	*P*	Mean (mm)	SD (mm)	*P*			
5–6	0.35	0.67	**	1.51	0.39	***	–1.15	0.14	***
6–7	–0.21	1.09	NS	1.73	0.39	***	–1.94	0.21	***
7–8	0.56	1.73	NS	1.55	0.31	***	–1.00	0.32	**
8–9	–0.36	1.34	NS	1.82	0.76	***	–2.18	0.28	***
9–10	–0.10	1.28	NS	1.41	0.43	***	–1.51	0.26	***
10–11	–1.27	1.60	***	1.68	0.69	***	–2.95	0.32	***
11–12	–0.87	1.57	**	1.84	0.85	***	–2.71	0.33	***
12–13	–0.62	1.53	*	1.33	0.59	***	–1.95	0.30	***
13–14	–0.35	1.16	NS	1.54	1.00	***	–1.89	0.28	***
14–15	–0.03	0.50	NS	0.83	0.37	***	–0.86	0.11	***

SD, standard deviation; SE, standard error; *P*, probability; NS, non-significance. $^{***}P < 0.001$; $^{**}P < 0.01$; $^{*}P < 0.05$.

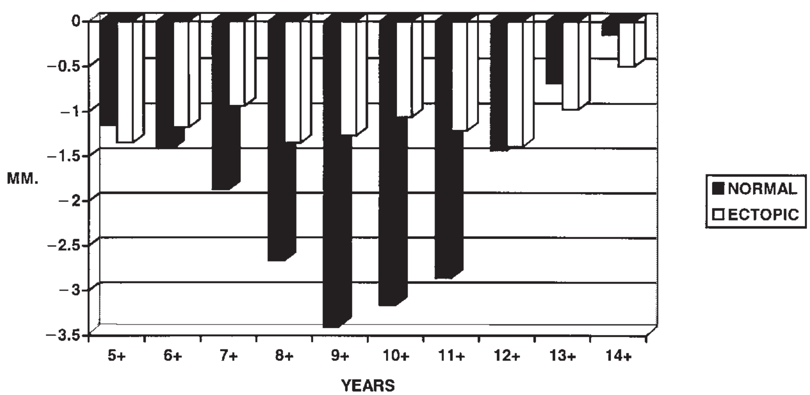

Figure 3 Antero-posterior movement of normal and ectopic canines.

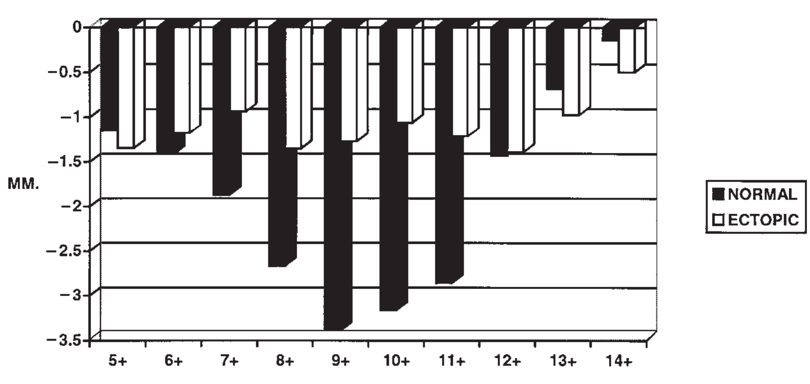

Figure 4 Vertical movement of normal and ectopic canines.

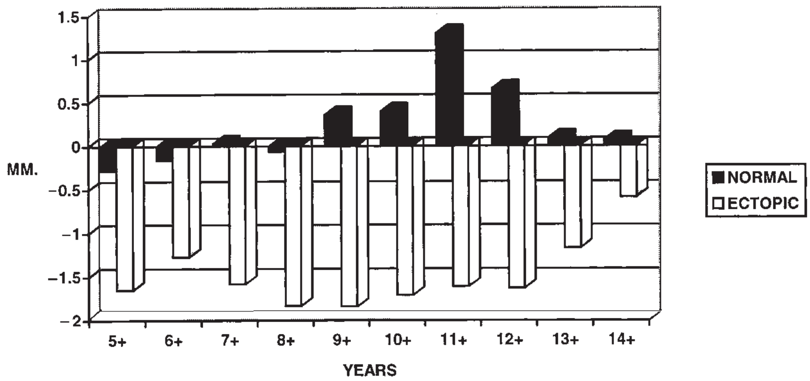

Figure 5 Lateral movement of normal and ectopic canines.

while the ectopic canines move mesially around the palatal surfaces of the lateral incisors. While the ectopic canines did move occlusally, their eruption in this direction was less than normal and accounts for the clinical finding that canines impacted in the palate are at a high level.

The most remarkable findings were that the average palatally ectopic canine never moves buccally, always moves palatally, and never shares in the buccal movement shown by normally erupting canines between the ages of 10 and 12 years. Thus, the suggestion that failure to make this buccal movement is the cause of palatal canine impaction is only partially correct. In fact, it is due more to continual and quite consistent movement of the ectopic canine in a palatal direction. It was of note to find that the differences between growth of normal and ectopic canines in the lateral plane of space are present as early as 5–6 years and continue throughout the growth period. This adds credibility to the term 'ectopic canine' because it seems that the abnormality of growth is present at a very early stage, it may be seen to favour a genetic rather than a faulty mechanical origin at a later stage of development and it may add to the known possibilities of intercepting palatal canine impaction.

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