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Randomized controlled trial

The use of panoramic radiographs to decide when interceptive extraction is beneficial in children with palatally displaced canines based on a randomized clinical trial

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Summary

Objective: To evaluate which palatally displaced canines (PDCs) benefit from interceptive extraction of the deciduous canine, to assess possible side effects from the extraction, and to analyse other dental deviations in patients with PDCs.

Design, settings, participants, and intervention: A sample of 67 patients (40 girls, mean age: 11.3 ± 1.1; 27 boys, mean age ± SD: 11.4 ± 0.9) with unilateral (45) or bilateral (22) PDCs were consecutively recruited and randomly allocated to extraction or non-extraction using block randomization. No patients dropped out after randomization or during the study. The patients were given a clinical examination and panoramic radiographs were taken at baseline and after 6 (T1) and 12 months (T2). An individual therapy plan was made for the PDCs that had not erupted at T2. Measurements were performed blindly and the outcome measures were: canine position and angulation, root development, midline shift, rotation, or movement of adjacent teeth into the extraction site, and frequency of other dental deviations.

Results: Interceptive deciduous canine extraction is beneficial if the alpha angle is between 20 and 30 degrees. A PDC located in sector 4 with an alpha angle >30 degrees should have immediate surgical exposure, while canines angulated less than 20 degrees and located in sector 2 can be observed without prior interceptive extraction. Deciduous canine extraction was more beneficial in younger patients with less advanced root development. Minor side effects, such as rotation or migration of teeth into the extraction space, were observed in 15 out of 35 patients. A majority of the patients had other dental deviations than PDC in the dentition.

Limitations: The results are only valid for patients with no space deficiency in the maxilla and with PDCs located in sector 2–4.

Harms: No harms were detected.

Conclusions: The alpha angle and sector position are good diagnostic predictors of when interceptive extraction is beneficial. Minor side effects are seen after the extraction and the majority of the patients had other dental deviations too.

Registration: This trial was registered at http://www.fou.nu/is/sverige, registration number: 211141.

Introduction

It is well known that an early diagnosis of canine displacement and prediction of subsequent impaction is important to decrease the patient's need for surgical exposure and prolonged orthodontic treatment with additional costs and various complications.[1–3]

Different interceptive treatment alternatives for palatally displaced canines (PDCs) have been the focus of numerous prospective studies for the last 15 years,[4–9] despite systematic reviews reporting that the scientific evidence is too sparse to support an interceptive approach.[10,11] Since then, several randomized clinical trials have come to the same conclusion; namely, that extraction of the deciduous canine is an effective interceptive treatment in patients with PDC.[12,13] However, not all permanent canines erupt, as pointed out in the study by Naoumova *et al.*[14], where the authors tried to identify which cases benefit from extraction of the preceding deciduous canine. A small mesioangular angle, a long distance from the canine cusp tip to the midline and a short distance from the canine cusp tip to the maxillary dental arch plane, measured with cone beam computed tomography (CBCT), were suggested as predictors of a successful outcome, with the distance between the canine cusp tip to the midline being the best predictor. In the literature, there are many other suggestions of predictors of canine eruption. Ericson and Kurol[15] found that a more mesially located crown or a more horizontally positioned PDC, measured with angles and sectors, reduced the chance of eruption after deciduous canine extraction. These results were confirmed by Power and Short,[16] who found that an angulation of 31 degrees or more to the midline decreases the chance of successful eruption. Additional reported predictors are the vertical distance from the canine tip to the occlusal plane,[14,17–19] from the canine to the first premolar angle, and the distance from the canine cusp tip to the midline, measured with CBCT.[19,20]

Comparing sector location[21,22] and angulation[22] as predictors of possible impaction of the permanent canine indicates that the sector location is a better predictor, and that canines overlapping the adjacent lateral incisor will become impacted in 78–82% of cases. Predictors based on aetiology for early identification of patients who may later develop PDCs have also been widely investigated. The aetiology of PDCs appears to be multifactorial with a genetic complex that controls other concomitant dental anomalies.[23] The suggested associated dental anomalies seen in the literature are agenesis of the second premolars, small size of or agenesis of the lateral maxillary incisors, infraocclusion of the primary molars, enamel hypoplasia, ectopic eruption of the first permanent maxillary molars, distal angulation of the lower second premolars, morphological deviations of the maxillary incisors and the dentition in general. Since some of these tooth disturbances may occur before the maxillary canine becomes palatally displaced, they can be used as early risk indicators.[24–31]

Although eruption prediction based on the position of the permanent canine has been reported in several previous studies, none of the above-mentioned studies had a prospective randomized control design, except for part I of the present study[14] using CBCT images. Accordingly, it is important to identify cut-off points for a successful outcome of interceptive deciduous canine extraction on the panoramic radiograph (PAN), as this is more extensively used in daily practice than CBCT. It is also important to examine whether there are any side effects on the dentition from extracting the deciduous canine, especially with unilateral extraction, and to assess other dental deviations. None of the clinical studies referred to above,[4–9,15,16] evaluating the success of interceptive treatment in patients with PDC, has reported any side effects, except for one study, which noted that the maxillary midline was not affected by unilateral extraction.[12]

Aims

The primary aim of this trial was to:

- Analyse whether possible predictors and cut-off points can be found on the PAN, when considering whether interceptive extraction of the deciduous canine is beneficial or not during the mixed dentition in patients with a PDC.

The secondary aims were to:

- Report any side effects on the dentition by unilateral extraction of the deciduous canine.
- Describe the frequency of other dental deviations than PDC on the PANs of the present sample.

Hypothesis

The null hypothesis was that a successful outcome (emergence of the permanent maxillary canine through the gingiva) following interceptive extraction of the deciduous canine is not influenced by the position or the angulation of the PDC measured on a PAN. The second hypothesis was that unilateral extraction of the deciduous canine does not cause any side effects on the dentition.

Materials and methods

Ethical issue

The research ethics committee of the Sahlgrenska Academy at the University of Gothenburg, Sweden (Reg. no. 578-08) and the radiation protection committee, Sahlgrenska Academy at the University of Gothenburg, Sweden approved this study. Before participation, informed consent was provided by the child and the parent or by an adult with parental responsibilities and rights in accordance with the Declaration of Helsinki.

Registration

This trial was registered in the Research and Development database in 'FoU i Sverige', http://www.fou.nu/is/sverige, registration number 211141.

Subjects

Study setting and eligibility criteria

Dental general practitioners (DGPs) from 15 Public Dental Clinics in Gothenburg, Västra Götaland County Council, Sweden, identified patients during the period from September 2008 to January 2011, and the consulting orthodontist invited the potential patients to participate in the study. A more detailed explanation of the subjects and the study setting can be found in part I of this trial.[13]

The inclusion criteria were:

- Children aged 10–13 years with maxillary unilateral or bilateral PDCs;
- Persisting deciduous canines;
- No previous experience of orthodontic treatment.

Palatal displacement of the maxillary permanent canine was considered if there was an absence of a labial bulge and/or presence of a palatal bulge and when the canine crown was diagnosed on intraoral radiographs as being palatally positioned, using Clark's rule.[32] Intraoral radiographs were taken by the DGPs.

The exclusion criteria were:

- Crowding in the lateral part of the maxilla exceeding 2 mm;
- On-going orthodontic treatment;

- Resorption of the adjacent teeth, grade 3 and 4 according to Ericson and Kurol,[3] either at the start or during the trial and caused by the displaced canine;
- Craniofacial syndromes;
- Odontomas, cysts;
- Cleft lip and/or palate.

Trial design and randomization

This randomized clinical trial (RCT) was designed as a parallel trial with an allocation ratio of 1:1. Patients enrolled were randomly allocated to extraction of the deciduous canine (EG) or to a control group (CG). Patients with bilateral PDCs were randomized to have either the right or the left deciduous canine extracted. The permuted block randomization method was used. The allocations were concealed in sequentially numbered sealed opaque envelopes that were opened by a dental nurse after written consent was obtained. An intention-to-treat analysis (ITT) was performed in the study; thus, all participants were analysed according to the intervention to which they were allocated, regardless of what treatment they actually received and of subsequent withdrawal from treatment or deviation from the protocol. Dropouts were considered as unsuccessful outcomes.

Treatment protocol and process

All patients underwent a clinical examination, including intra- and extra-oral photography, at baseline (T0), after 6 (T1) and after 12 (T2) months, at the Orthodontic Specialist Clinic in Gothenburg, Sweden. Radiographic examination was performed at the Department of Oral and Maxillofacial Radiology, the Institute of Odontology at the Sahlgrenska Academy, Gothenburg, Sweden, consisting of CBCT (study I, II),[13,14] and PANs were taken in connection with the clinical examination. If the canine was clinically visible at the 6-month or 12-month control, no radiographs were taken. After 12 months, an individual treatment plan was decided on for the PDCs that had not erupted. Canines that had improved their position, judged from measurements made on the radiographs, were followed until they emerged through the gingiva. In the CG, the deciduous canine was extracted if there was no mobility of the tooth. However, if the canine was impaired or had not changed its position after 12 months, surgical exposure followed by orthodontic treatment was initiated (Figure 1).

Blinding

Data from the PAN at T0 were compiled as blinded data to the operator. Blinding was not possible at T2 since the extraction site was visible. However, all data were blinded to the statistician who made the analysis. One orthodontist made the measurements on the PAN and on the clinical images, while an oral radiologist performed the radiographic assessment of dental deviations.

Measures of treatment effect

The initial *canine position* was assessed on the PAN using the method first described by Ericson and Kurol.[15] The following linear and angular measurements were measured using the Facad Software (version 3.0, Ilexis AB, Linköping, Sweden) (Figure 2):

- Alpha angle: the angle formed by the long axis of the canine and the midline.
- D distance: the distance in mm from the canine cusp tip to the occlusal plane.
- Sector: mesiodistal crown position in sector 1–5.

The root development of each PDC was assessed with the method developed by Nolla.[33]

The *side effects* were assessed by clinical examination and by visual assessment on intra-oral and extra-oral images at T0 and at T2. The following parameters were recorded for patients in the EG:

- Midline change in the upper arch (measured clinically with a ruler in centric relation between the two central incisors

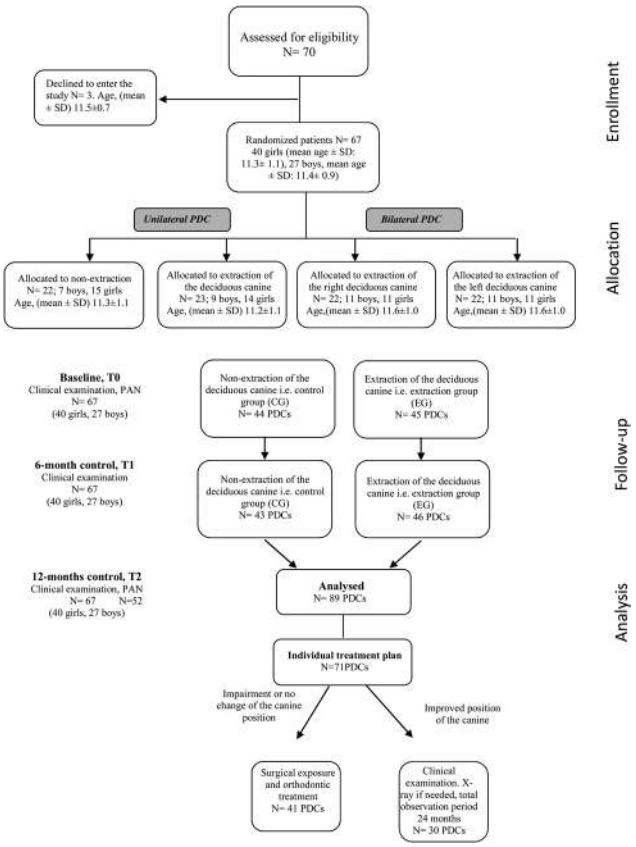

Figure 1. Flowchart describing the protocol and the patients included in the study. N, amount of patients of PDCs: palatal displaced canines; SD, standard deviation; PAN, panoramic radiograph; T0, baseline; T1, 6 months control; T2, 12 months control.

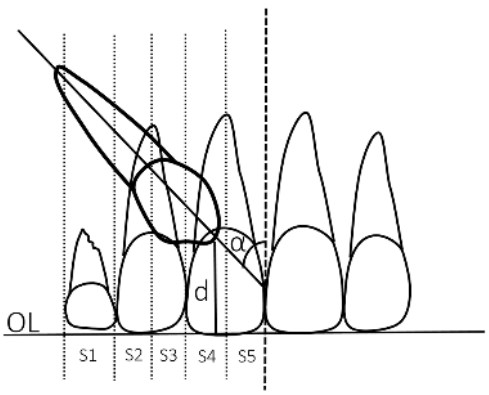

Figure 2. Measurements made on the panoramic radiograph according to the method first described by Ericson and Kurol[15]: a-angle, angle formed by the long axis of the canine and the midline; d-distance, distance in mm from the canine cusp tip to the occlusal plane (OP); and sector, mesiodistal crown position in sector 1–5.

using a reference line: vertical line through the Glabella and Subnasale in the natural head position).
- Rotation or movement of the adjacent teeth into the extraction site.

The following deviations inspired by Sørensen *et al.*[29] were registered on the PAN and supplemented with CBCT when needed:

- Morphology:
  - *Invaginations:* fillings at the normal locations of invaginations and in teeth with radiographically distinct enamel notching;
  - *Narrow-shaped incisor crowns:* narrower incisal width than the width at the column;
  - *Taurodontic molar roots:* mesotaurodontia and hypertaurodontia were recorded according to the criteria defined by Schulze[34];
  - *Malformed roots of the upper incisors:* equal length of the root or shorter than the height of the crown, slender/narrow root.
- Agenesis, except the third molars.
- Eruptional deviations beyond canine displacement.

The following outcome measures were assessed:

Primary outcomes

- To compare successful (defined as permanent maxillary canine emerged through the gingiva) and unsuccessful cases (PDCs that did not erupt, despite extraction of the deciduous canine), and to identify predictors with possible cut-off points regarding which cases would benefit from deciduous canine extraction.

Secondary outcomes

- To document whether extraction of the deciduous canine affects the upper midline and/or causes rotation or movement into the extraction site of the adjacent teeth.
- To describe the frequency of other dental deviations in the current sample.

Statistics

Sample size calculation

The sample size calculation has previously been described in part I of this study.[13]

The statistical analysis was performed using SAS, version 9.3 for Windows (SAS Institute Inc., Cary, North Carolina, USA). *P* values less than 0.05 were considered statistically significant. For numerical variables, arithmetic means and standard deviations were calculated. Dependent and independent *t*-tests were used for comparison of baseline variables between and within the groups. The bilateral PDC group was tested for independence with Fisher's exact test and McNemar's test.[13] Independent *t*-tests were used to test whether there were any significant differences in the numerical values between successful and non-successful outcomes. Fisher's exact test was used to calculate differences in categorical data. To detect possible predictors and to determine cut-off points for successful and unsuccessful outcomes, respectively, logistic regression analysis and receiver operating characteristic (ROC) curve analysis were performed. The accuracy of the clinical test was measured by the area under the curve (AUC). The following rough guideline was used for the interpretation of the AUC: 0.50 to 0.75 = fair; 0.75 to 0.92 = good; 0.92 to 0.97 = very good; 0.97 to 1.00 = excellent.

The method of error was calculated using the Dahlberg formula[35] on 20 randomly selected subjects, and measured on two separate occasions with 3 months in between.

Harm

No harm was detected during the study.

Results

The repeatability for angular measurements was 0.5 degree and for the distance measurements 0.2 mm. The assessment of canine displacement, root development and dental deviations showed a reproducibility of 100%. One operator performed all the measurements (JN).

Participant flow

Three patients declined to participate before the randomization procedure. Thus, in total, 67 patients were randomly allocated to the EG or the CG. Forty-five patients had a unilateral PDC (29 girls, mean age ± SD: 11.2 ± 1.1; 16 boys, mean age ± SD: 11.7 ± 0.8) and 22 patients had bilateral PDCs (11 girls, mean age ± SD: 11.5 ± 0.9; 11 boys, mean age ± SD: 11.6 ± 0.8) (Figure 1).

Baseline findings

The unilateral and bilateral groups did not show any statistically significant differences regarding right and left extraction side. There were no significant difference in gender and age between the EG and CG; however, there were more females than males and more 10- to 11-year-olds than individuals aged 12–13 years old, in total. No significant differences were seen either for the radiographic baseline measurements between the EG and the CG or between the unilateral and bilateral group (Table 1). All patients had PDCs with root development of Nolla stage[33] 8–10 (8: two thirds of root completed, 9: root almost completed, 10: root completed).

More detailed information about patient characteristics, success rate between the groups, mean eruption time, and the number of patients who had surgical exposure and orthodontic treatment or root resorption are presented in part I of this trial.

Primary outcomes

Predictors and cut-off points

In the present sample, there were no PDCs located in sector 1 or 5. The PDCs that showed spontaneous eruption in the non-extraction group had a significantly smaller alpha angle and were positioned in a 'lower sector'; i.e. showed less overlapping of the incisors in comparison with canines that erupted spontaneously after extraction of the deciduous canine. In the group that showed no eruption, either with or without extraction of the deciduous canine, the PDCs were positioned significantly more horizontally (i.e. larger alpha angle) in a higher sector, and root development was more advanced (Figure 3, Table 2). The children who showed no spontaneous eruption were also older than the children in the eruption group.

A logistic regression analysis was made on the significant baseline variables that affected the main outcome (Table 2). The analysis revealed that extraction of the deciduous canine was the variable most effecting eruption of the PDC followed by alpha angle, sector measurement, and the age of the patient (Table 3). ROC curve

Table 1. Baseline variables (T0) for the unilateral and bilateral groups with mean, standard deviations (SD), and *p* values.

Unilateral PDC (patients, *n* = 45)				Bilateral PDCs (patients, *n* = 22)			
Variable at T0	EG (*n* = 24 PDC), mean ± SD, 11.2 ± 0.9	CG (*n* = 21 PDC), mean ± SD, 11.4 ± 1.1	*P*-value*	EG (n = 22 PDC), mean ± SD, 11.6 ± 1.0	CG (*n* = 22 PDC), mean ± SD, 11.6 ± 1.0	*P*-value*	EG–CG, *P*-value*
Alpha angle (°)**	26.9 ± 5.2	25.9 ± 4.9	0.806	25.4 ± 5.0	26.6 ± 4.5	0.898	NS
d distance (mm)**	15.0 ± 2.6	15.9 ± 2.6	0.535	15.9 ± 2.8	15.4 ± 2.5	0.513	NS
Sector 1, *n* (%)**	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	NS
Sector 2, *n* (%)**	14 (31)	12 (27)	0.245	11 (25)	10 (23)	0.352	NS
Sector 3, *n* (%)**	7 (15.5)	7 (15.5)	1.000	8 (18)	8 (18)	1.000	NS
Sector 4, *n* (%)**	3 (7)	2 (4)	0.358	4 (9)	3 (7)	0.452	NS
Sector 5, *n* (%)**	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000	NS
Root development of PDC***	8.6 ± 1.0	8.1 ± 0.6	0.292	8.4 ± 0.8	8.45 ± 0.8	1.000	NS

CG, control group; EG, extraction group; PDC, palatally displaced canines; SD, standard deviation; NS, not significant.
*P value <0.05 is considered statistically significant.
**Described in Figure 1.
***According to Nolla study.[33]

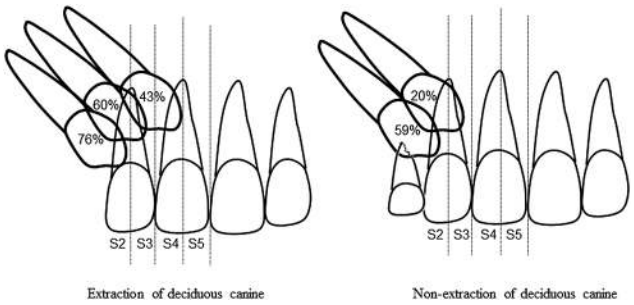

Figure 3. Percentage of spontaneous eruptions of palatal displaced canines after extraction of the deciduous canine (left drawing) or non-extraction (right drawing), by sector before extraction.

analyses were therefore made on two radiographic variables in patients with erupted PDCs; i.e. 'easy cases of PDCs', and in patients in the EG where no eruption was seen and who had to be treated with surgical exposure; i.e. 'severe cases of PDCs'.

The ROC analysis showed that both the alpha angle and the sector could be used to determine a cut-off point; thus, we can reject our null hypothesis.

'Easy cases of PDCs'; i.e. canines erupted in the CG, had a cut-off point of 20 degrees of alpha angle with a sensitivity of 0.931 and a specificity of 0.948 (P = 0.000), and an AUC of 0.980 (95% confidence interval [CI] 0.972 to 1.000). For spontaneous eruption without prior deciduous canine extraction it was essential that the PDCs were located initially in sector 2 (AUC; 0.932 (95% CI 0.841 to 0.990); sensitivity 0.912; specificity 0.856; P = 0.000) (Figures 4 and 5).

'Severe cases of PDCs'; i.e. canines that did not erupt in the CG, had a cut-off of 30 degrees alpha angle (sensitivity, 0.935; specificity, 0.898; P = 0.000). The AUC was 0.940 (95% CI 0.924 to 1.000), suggesting a very good discriminatory power. PDCs located in sector 4 did not erupt despite deciduous canine extraction (AUC; 0.990 (95% CI 0.990 to 1.000); specificity, 0.950; sensitivity, 0.913, P = 0.000) (Figures 4 and 6).

Secondary outcomes

Side effects

Fifteen out of 35 patients showed minor side effects 1 year after the extraction of the deciduous canine. Eight of these patients had surgical exposure of the canine. An increasing midline shift of 0.5–1.5 mm to the extraction side was noticed in 6 of the 35 patients after 1 year. In 37% of the patients, rotation (n = 6 premolars) or movement (n = 4 premolars, n = 4 laterals) into the extraction sites was seen. These side effects were seen already after 6 months and after that, no additional rotation/movement occurred (Supplementary Figures 7 and 8). The null hypothesis regarding the side effects can be rejected.

Dental deviations

Only 16% of the patients had no deviations in the dentition, all of them in the unilateral group (Table 4). All patients with bilateral PDCs had some malformations in the dentition and females had more malformations than males. Eruptional deviations of 36 teeth were found in 39% of the patients (n = 26 patients); most of them premolars (n = 12) in the maxilla in the unilateral group, while in the bilateral group, an almost equal number of upper (n = 8) and lower ectopic premolars (n = 7) was noted. Five teeth were ectopic canines in the lower arch (n = 3 in the unilateral group and n = 2 in the bilateral group). In the unilateral group, four teeth were buccally

Table 2. Differences in baseline measures (T0) between canines that erupted spontaneously after 1 year and non-erupting canines.

	Erupted (n = 40 patients, 48 PDC)				Non-erupted (n = 27 patients, 41 PDC)				
	EG	CG			EG	CG			
Variables at T0	Mean ± SD[a]	Mean ± SD[a]	Differences mean (95% CI)	*P*-value, EG–CG*	Mean ± SD	Mean ± SD	Differences mean (95% CI)	P-value, EG–CG	*P*-value, erupted versus non-erupted*
Alpha angle (°)**	24.8 ± 3.5	17.7 ± 2.5	8.1 (6.1, 8.1)	**0.000**	31.9 ± 4.2	31.6 ± 3.7	0.3 (−2.2, 2.9)	0.777	**0.000**
d distance (mm)**	15.7 ± 2.4	15.7 ± 1.9	−0.0 (−1.3, 1.3)	0.998	15.2 ± 2.8	15.7 ± 2.9	−0.5 (−2.4, 1.4)	0.597	0.550
Sector**	3.0 ± 0.4	2.0 ± 0.6	1.0 (0.2, 0.8)	**0.000**	3.6 ± 0.6	3.8 ± 0.5	−0.2 (0.1, 0,3)	0.890	**0.005**
Root development of PDC***	8.2 ± 0.7	8.1 ± 0.5	0.1 (−0.1, 0.3)	0.800	8.9 ± 1.0	8.7 ± 0.8	0.2 (0, 0.4)	0.638	**0.050**
Age, years	11.0 ± 0.9	10.7 ± 0.99	0.1 (0.6, 0.7)	0.676	12.0 ± 1.0	11.9 ± 1.0	1.0 (2.3, 0.8)	0.112	**0.000**

SD, standard deviation; CI, confidence interval; EG, extraction group; CG, control group. Bold indicates the values are significant.
*P value <0.05 is considered statistically significant.
**Described in Figure 1.
***According to Nolla study.[33]

displaced in the maxilla. Agenesis of premolars was observed in 15% of the patients (n = 10 patients), more in the bilateral group (n = 14) than in the unilateral group (n = 6), and 16 out of 20 cases of agenesis referred to premolars in the mandible. Only one patient had agenesis of laterals.

An equal number of invaginations (n = 58% of the patients, n = 39 patients), narrow-shaped crown of laterals (n = 43% of the patients, n = 29 patients), and malformed incisor roots (n = 15% of the patients, n = 10 patients) was seen in the unilateral and bilateral group. Sixteen taurodontic molars (n = 3 patients) were found only in the unilateral group. Suppementary Figure 9 shows two PANs exemplifying other dental deviations found in the current PDC patients.

Discussion

Interceptive extraction of the deciduous canines in patients with PDC during the mixed dentition has been shown to be an effective measure.[11–12] However, since not all canines erupt spontaneously, efforts have been made to develop guidelines for when interceptive extraction is beneficial,[11,15–22] which was also the focus of the present study. Our findings show that both the alpha angle and sector measurements made on PAN are good predictors of whether the canine will erupt spontaneously or not. This is in accordance with previous studies,[15–17] while other studies report that the pre-treatment alpha angle is not correlated with a successful outcome.[36,37]

The percentage of spontaneous eruption of PDCs decreased, the more mesially located the canine crown, which is similar to what Ericson and Kurol[15] found, although the numbers differ from the present study. This can be explained by the authors considering both canine eruption and improvement of the canine eruption path as successful outcomes, and by previous studies also including PDCs located in sector 1. It could be debated whether or not canines in sector 1 should be defined as PDCs instead of normally erupting canines. Looking at the literature there are no consensus about the precise definition of normally erupting canines or PDCs as highlighted by Hadler-Olsen *et al.*[38] The wide range of inclusion of canines with a certain alpha angle or sector measurements[6,9,22,38] makes it difficult to compare the studies.

Sector measurements have shown to be the single most important prognostic factor,[14,16] but according to our study, both the alpha angle and sectors are similarly good predictors. A cut-off point of an alpha angle of more than 30 degrees was found to be associated with a notably decreased chance of successful eruption, which has also been reported previously by Power and Short.[16] The novelty in the current study is a more detailed description on when interceptive extraction is beneficial; i.e. in cases with an alpha angle of 20–30 degrees, canines located in sector 2–3, and when the operator could wait and observe; for instance, for canines with an alpha angle of less than 20 degrees located in sector 2.

Additional predictors reported in the literature are the vertical distance from the canine tip to the occlusal plane measured on PAN[17,18]—a finding that is not in accordance with our study or with other earlier studies.[4,15,16]

In most of the previous studies,[4–9,12,15–20] as well as in the present study, the effect of extracting the deciduous canine was assessed on PAN using the measurement method developed by Ericson and Kurol.[15] However, lately, predictors retrieved from CBCT examinations have also been presented. A small mesioangular angle, a long distance from the canine cusp tip to the midline and a short distance

Table 3. Logistic regression calculated on the baseline means from Table 2 that affected successful eruption of the PDC.

Variables at T0	β	df	OR	95% CI	Sig.
Extraction versus non-extraction	2.833	1	288.877	8.846 to >999.999	**0.0014**
Alpha angle (°)	−2.120	1	8.333	1.988 to 34.488	**0.0037**
D-distance (mm)	−0.504	1	1.037	0.863 to 1.109	0.1617
Sector	−1.350	1	7.500	1.450 to 6.386	**0.0029**
Root development of PDC	−1.032	1	2.249	0.964 to 2.739	0.0620
Age, years	−1.732	1	5.649	1.464 to 21.739	**0.0120**

β, beta; df, degree of freedom; OR, odds ratio; CI, confidence interval; Sig., statistical significance. Bold indicates the values are significant.

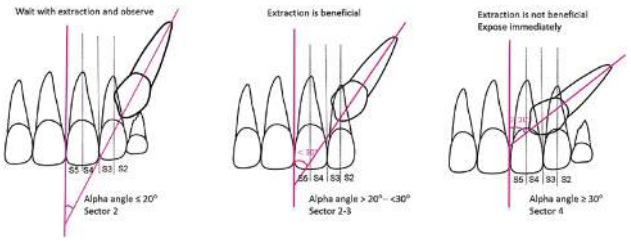

Figure 4. Schematic drawing with cut-off points for sector and alpha angle, showing when extraction of the deciduous canine in patients with palatal displaced canine is beneficial.

Figure 5. Eleven-year-old boy with bilateral palatal displaced canines. Sixty-three was randomized for extraction and at the 12-month control, 23 (baseline alpha angle: 23.5 degree, sector: 2) was under eruption as well as 13 (baseline alpha angle: 19.7 degree, sector: 2). Looking at the case retrospectively and applying the cut-off points, it was a good choice to extract the deciduous canine on the left side only.

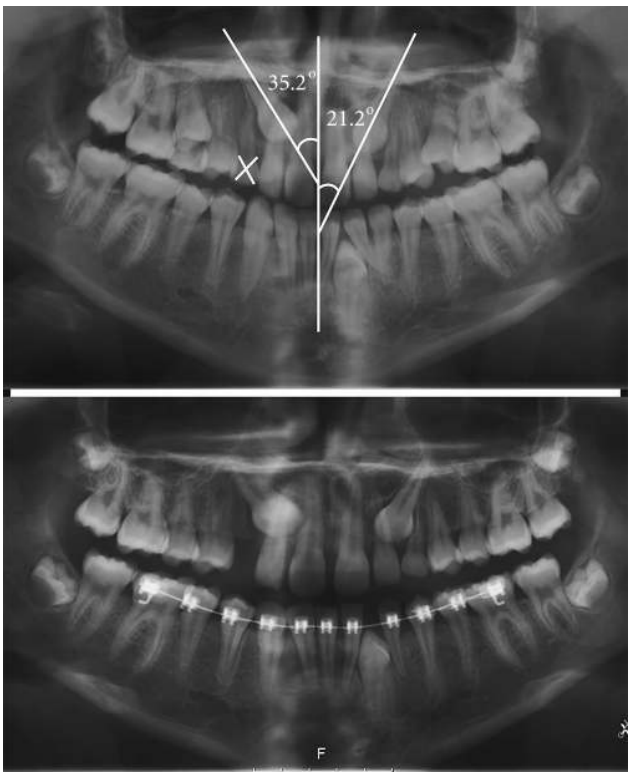

Figure 6. Twelve-year-old girl with bilateral palatal displaced canines. Fifty-three was randomized for extraction and at the 12-month control, 13 (baseline alpha angle: 35.2 degree, sector: 4) and 23 (baseline alpha angle: 21.2 degree, sector: 3) had become more ectopically positioned and were surgically exposed. Looking at the case retrospectively and applying the cut-off points, it would have been beneficial to extract the deciduous canine on the left side at baseline and to expose surgically the permanent canine on the right side.

Figure 7. Eleven-year-old girl with 23 palatal displaced canines. Note the distal movement of the lateral incisor and the mesial movement and the slight rotation of the first premolar into the extraction site at the 6-month control (T1). No further movement was seen at the 12-month control (T2). Patient had surgical exposure of 23.

from the canine cusp tip to the maxillary dental arch have been suggested as predictors of a successful outcome.[14,18]

In daily practice, PAN and intra-oral radiographs are more frequently used than CBCT, making cut-off points on 2D images of greater clinical value. However, since it is difficult to have a standardized projection with intra-oral radiographs, reliable predictors cannot be achieved and the use of PAN is therefore an acceptable substitute for CBCT for predicting the outcome.

The root development of the displaced canine was assessed according to the method developed by Nolla.[33] Canines that did not erupt, regardless of whether or not deciduous canine extraction had been performed, had significantly more advanced root development than the canines that did erupt. Similar results have been shown previously.[6,8]

Minor midline shifts in the maxilla were observed in 17% of the patients after one-sided deciduous canine extraction, which is contrast with the findings in a previous study.[12] The differences may depend on how the midline was measured. In our study, the midline was assessed clinically, while in the other study it was measured on study casts. Rotation or movement into the extraction site was noticed in 37% of the patients after 6 months, with no additional changes during the

Table 4. Prevalence of dental deviations in the unilateral and bilateral (palatally displaced canine) PDC group.

	Dental deviations						
PDC group	Invaginations, N = 58%	Narrow-shaped incisor crowns, N = 43%	Malformed roots, N = 15%	Agenesis, N = 15%	Taurodontic molars, N = 0.5%	Eruptional deviations, N = 39%	Other malformations
Unilateral PDC (n = 45 patients)	UJ: 31 incisors	UJ: 21 incisors	UJ: 9 incisors	UJ: 1 premolar; LJ: 5 premolars	UJ: 10 molars; LJ: 6 molars	UJ: 12 premolars, 4 BDC; LJ: 3 BDC	—
Bilateral PDCs (n = 22 patients)	UJ: 28 incisors	UJ: 25 incisors	UJ: 7 incisors	UJ: 3 premolars, 2 incisors; LJ: 11 premolars		UJ: 8 premolars; LJ: 7 premolars, 2 canines	—

The percentage expresses percentage of patients in the total PDC group. PDC, palatally displaced canine; BDC, bucally displaced canine; UJ, upper jaw; LJ, lower jaw.

rest of the observation period. This is slightly different from what Bazargani *et al.*[12] found; namely, that the space at the extraction site continued to decrease during their observation time of 18 months. Thus, the null hypothesis regarding the side effects can be rejected.

Even though no other dental deviations than PDCs were assessed in a larger population sample, the findings in the present study were largely similar to previous studies, including other eruptional deviations such as ectopic premolars or mandibular canines, agenesis of premolars, small size of lateral maxillary incisors, invaginations and taurodontia.[24–30,39] Almost 80% in the unilateral group and all patients in the bilateral group had some malformations and these were more often observed in females than in males, supporting the theory of the aetiology of PDCs being multifactorial with a genetic complex controlling other dental anomalies.[23] These dental deviations, especially those occurring before the maxillary canines become palatally displaced, may be used as early clinical predictors. Since only patients with no space deficiencies were included in the trial, this could explain why there were no ectopic eruptions of the first permanent maxillary molars or other dental anomalies associated with space deficiency.[39]

Clinical implications

Our recommendation is to use the cut-off points presented in this article as guidelines to decide whether an interceptive extraction should be performed or not. A prospective study assessing the effectiveness of using the guidelines would be a clinically relevant future study. Interceptive extraction is most likely to be beneficial in cases with an alpha angle of 20–30 degrees located in sector 2–3. Selecting cases that would benefit from interceptive extraction would be economically advantageous to both patients and clinicians.

Unnecessary extractions could most likely be avoided in PDC cases with alpha less than 20 degrees, located in sector 2, which would reduce the number of patients being exposed to the potential pain and discomfort after extraction.[40] However, it is the clinician's responsibility to follow and observe the permanent canine until it erupts in order not to miss a feasible change in the eruption path. A reasonable follow-up period with apical radiographs to monitor the eruption would be after approximately 10 months instead of 6 months, which has been the recommendation earlier.[15] This interval can also be used in cases where the deciduous canine is extracted, since part I of the present study showed that the majority of the permanent canines erupted after 12 months with the latest after 22 months.[13] In addition, the CBCT showed, both in the extracted and non-extracted cases, that the degree of resorption of the adjacent teeth was low (grade 2) at baseline and did not increase significantly during the 12-month observation period.[14] Future studies assessing the length of the control intervals may reveal whether our recommendations can be further extended.

In severe PDC cases; i.e. an alpha angle of more than 30 degrees, located in sector 4, where interceptive extraction most likely is not effective, treatments such as surgical exposure, with simultaneous extraction of the deciduous canine, followed by the treatment of aligning the retained canine, could begin earlier. This might decrease the risk of the canine becoming more impacted but also minimize the risk of root resorption of the adjacent teeth.

Limitations

Since the criterion for exclusion was crowding in the maxilla exceeding 2 mm, a conclusion cannot be drawn as to whether crowded cases would also benefit from deciduous canine extraction or which side effects might occur in such cases. Other dental

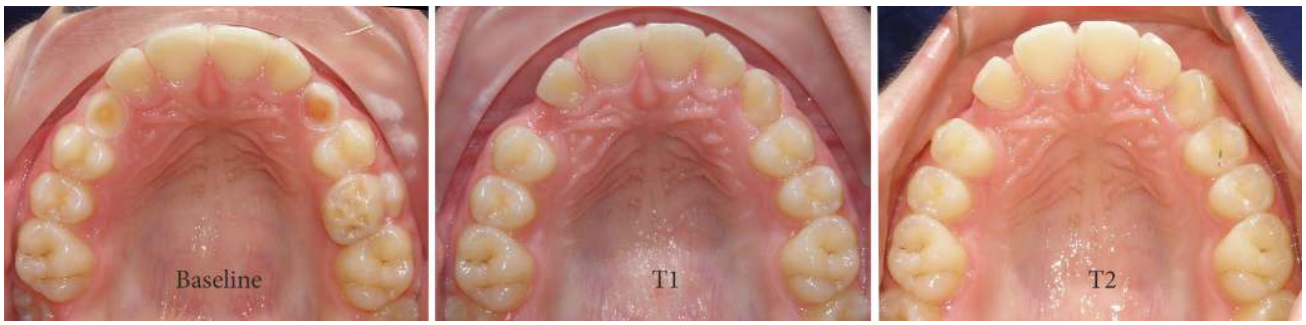

Figure 8. Twelve-year-old girl with 13 palatal displaced canines. Note the distal movement of the lateral incisor into the extraction site at the 6-month control (T1). No further movement was seen at the 12-month control (T2). Patient had surgical exposure of 13.

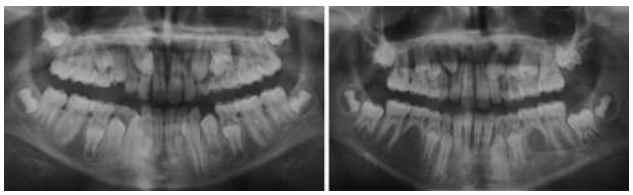

Figure 9. *Right PAN*: bilateral palatal displaced canines (PDCs) with additional dental deviations, such as agenesis of mandibular second premolars, narrow-shaped laterals dens invagination on the laterals. *Left PAN*: unilateral PDC with additional dental deviations such as ectopic maxillary second premolars, narrow-shaped laterals, taurodontic first and second maxillary and mandibular molars.

deviations might also have been noted if crowded cases had been included. However, including crowded cases would have meant the inclusion of a confounding factor. In our opinion, crowded cases with PDC will also need treatment of the crowding, in addition to extraction of the deciduous canine. Gaining space with rapid maxillary expansion[5,6] or with headgear[4,7,41] has shown to have a positive effect on PDCs. Resorption of adjacent teeth with grades 3 and 4 was also excluded, as these cases require another treatment strategy, such as surgical exposure of the impacted canine followed by orthodontic traction and, in some cases, extraction of the resorbed tooth.

Patients were included by their chronological age instead of their dental developmental stage, which is a limitation as there is poor correlation between the dental and chorological age. However, since most clinicians use the chronological in their daily practice when assessing dental development, we have kept this protocol. The majority of the permanent canines erupt between the ages of 10 and 13 years. However, in patients with PDCs, the dental development, according to several studies, is delayed and it is therefore important to consider the overall stage of dental development of the child when assessing PDCs.[31]

Side effects were assessed unblinded, as the extraction site was visible and could not be blocked. An alternative would have been to use an assessor who had no knowledge of the study.

Strict cut-off points were used in this trial to maximize the sensitivity and the specificity. The limitation of the ROC curve analysis is that the cut-off points may differ in different studies, depending on whether the operator finds it more important to have high sensitivity rather than high specificity and vice versa. Since no PDCs were located either in sector 1 or 5, no conclusion can be drawn as to how the canine would react in these sectors, but it is reasonable to believe that a PDC in a lower or higher sector would follow the same path as those in sector 2 or 4.

Generalizability

The results can be generalized on a Caucasian population aged 10–13 years with PDCs located in sector 2–4 and no space deficiency in the maxilla using the determined cut-off points. Even though one operator performed all the extractions, the treatment outcomes could be generalized for a larger number of operators, as several general practitioners and orthodontic specialists performed the screening of the patients.

Conclusions

- Alpha angles and sectors measured on a PAN are good predictors of which PDCs may benefit from an interceptive deciduous canine extraction.
- Minor side effects are seen after deciduous canine extraction.
- The majority of the patients had dental deviations other than PDC in the dentition.

Supplementary material

Supplementary data are available at *European Journal of Orthodontics* online.

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Conflict of Interest

None to declare.

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