Palatally displaced maxillary canines: factors influencing duration and cost of treatment

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SUMMARY The purpose of this retrospective study was to assess the relationship between the initial position of palatally displaced canines (PDCs) on panoramic radiographs and the duration of the orthodontic treatment and further to estimate the costs of the treatment. Data from panoramic radiographs and patient records of 66 consecutive patients (mean age 14.9 ± 1.7 years) with PDC were analysed. The initial position of the canine, the distance between the canine cusp tip and the occlusal plane, and the inclination of the canine were significantly associated with treatment duration both unadjusted and adjusted for background characteristics. The average estimated cost of the treatment of PDC was €3200 per case. The total annual cost for treatment of PDC in Sweden may therefore be estimated at €600 000. In this study, duration of treatment averaged 17 months for canines displaced in impaction zone 1 or 2, 2.6 [95% confidence interval (CI) −1.0 to 6.2] months longer for those in impaction zone 3, and 7.6 (95% CI 4.1–11.1) months longer for canines displaced in impaction zone 4 or 5. This information makes it easier, through study of the panoramic radiograph, to estimate the duration of treatment and to give patients more precise information about the expected length of their treatment.

Introduction

Predicting treatment duration and number of office visits needed to treat palatally displaced canines (PDCs) and providing this information to adolescent patients may encourage these patients to be more cooperative and less likely to become ‘treatment tired’ near the end of the intervention. Estimation of treatment duration for these patients is often based only on subjective clinical experience. More knowledge of factors that may affect the duration of orthodontic treatment in patients with displaced maxillary canines would be beneficial to both orthodontists and their patients (Stewart et al., 2001).

The prevalence of maxillary displaced canines is reported to be about 2–3 per cent in a Caucasian population (Thilander and Jakobsson, 1968; Ericson and Kurol, 1986) and the incidence in Sweden is estimated at 1900 cases/year. Palatal displacement is more common than labial displacement and the ratio varies from 2:1 to 9:1 for canine displacements (Wolf and Mattila, 1979; Jacoby, 1983; Ericson and Kurol, 1987). The most frequent consequence of PDC is impaction of the canine. While a genetic aetiology has been postulated for palatal displacement of upper canines, the pathogenesis of the displacement involves both the long duration and the anatomical complexity of the eruption path of this tooth (Baccetti et al., 2008).

A displaced canine requires complex therapeutic management, which can be considered successful only if the forced eruption and the subsequent alignment lead the tooth to the correct position in the dental arch without serious damage to other teeth. Patients with displaced canines are perceived to be more difficult and time consuming to treat than the average orthodontic patient (Stewart et al., 2001).

The therapeutic approach to displaced canines should be interdisciplinary, considering the many factors that can account for the final treatment outcome. Pre-treatment radiographic features, such as angle, distance, and sector or zone of impaction according to Ericson and Kurol (1988), may be used as predictive factors for the duration of orthodontic traction and comprehensive orthodontic treatment to reposition the displaced tooth (Nieri et al., 2010). Greater angulation of impacted canines is associated with more severe tooth displacement and with greater distance of the impacted canine from the occlusal plane.

The purpose of this retrospective study was to assess the relationship between the initial position and the duration of the orthodontic treatment of PDCs. In addition, this study aimed to estimate the costs of this treatment at the Department of Orthodontics in Orebro County and to extrapolate those costs to an annual total cost of this type of treatment in Sweden.

Subjects and methods

The study protocol was approved by the Central Ethical Review Board in Stockholm, Sweden.
In this observational study, we analysed patient records and panoramic radiographs from patients with the diagnosis ‘displaced canine’ treated at the Postgraduate Dental Education Centre, Department of Orthodontics, Orebro County Council, Sweden, over a 9 years period (2001–09).

An earlier study with similar study design conducted by Stewart et al. (2001) had included 47 consecutive cases and we agreed to include over 60 cases to increase the power in this study compared to the study conducted by Stewart et al. further more. A database of 515 records of patients with a diagnosis displaced canines, under the observation period, was retrieved. This database was a blended list of records with both labially or PDCs. Hence, the first sample selection aimed at identifying cases with solely PDCs and to exclude the labially displaced canines. Records were then consecutively selected from the database until 70 cases with PDCs were identified. Of these 70 cases, 66 patients with 81 displaced canines (Table 1) were found to be eligible for inclusion in the study according to the predetermined selection criteria below.

The selection criteria for inclusion in the study were 1. age younger than 20 years, with at least 1 PDC treated by forced eruption; 2. regular attendance at orthodontic appointments with fewer than 10 missed appointments during the entire treatment period; and 3. patient records that included complete diagnostic and treatment notes, pre-treatment panoramic radiographs, and a surgical referral stating the presence and surgical exposure date of at least one PDC. Subjects with craniofacial syndromes, odontomas, cysts, or cleft lip or palate were not considered eligible for the study.

All surgical exposures were performed at the Postgraduate Dental Education Centre, Department of Paediatric Dentistry, Orebro County Council, with closed surgical exposure technique. All the clinicians in the Department of Paediatric Dentistry were specialists and had the same level of qualifications. Most of the clinicians in the Department of Orthodontics were specialists and also had the same level of qualifications. Eight patients were treated by residents in Orthodontics, during the observations period, under supervision. The majority of the cases (n = 54) had then been treated with forced eruption using a transpalatal arch with spring arm (Figure 1) and the orthodontic traction started within 2 weeks of the surgery. Because of the favourable position of the PDCs (in zone 1 or 2), 12 cases were treated with orthodontic traction using elastics attached directly to the fixed appliances; no transpalatal arches were necessary or used in these patients. In both groups, the traction force was reactivated once every 4 weeks. When the displaced canines were visible in the oral cavity, orthodontic traction was followed by the use of fixed orthodontic appliances to bring the displaced canine into the dental arch with full alignment.

### Table 1  Patient characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Palatally displaced canine (patients n = 66)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at diagnosis, mean (SD), range</td>
<td>14.9 (1.7), 12–19</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Boys, n (%)</td>
<td>23 (35)</td>
</tr>
<tr>
<td>Girls, n (%)</td>
<td>43 (65)</td>
</tr>
<tr>
<td>Impactions</td>
<td></td>
</tr>
<tr>
<td>Unilateral, n (%)</td>
<td>51 (77)</td>
</tr>
<tr>
<td>Bilateral, n (%)</td>
<td>15 (23)</td>
</tr>
<tr>
<td>Side of impaction</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>39 (59)</td>
</tr>
<tr>
<td>Left</td>
<td>27 (41)</td>
</tr>
<tr>
<td>Orthodontic traction technique</td>
<td></td>
</tr>
<tr>
<td>Fixed appliance</td>
<td>12 (18)</td>
</tr>
<tr>
<td>Transpalatal arch with spring arm</td>
<td>54 (82)</td>
</tr>
<tr>
<td>Clinical qualification</td>
<td></td>
</tr>
<tr>
<td>Residents in orthodontics</td>
<td>8 (12)</td>
</tr>
<tr>
<td>Orthodontist</td>
<td>58 (88)</td>
</tr>
<tr>
<td>Number of debonds</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>59 (89)</td>
</tr>
<tr>
<td>1–4</td>
<td>7 (11)</td>
</tr>
<tr>
<td>Missed appointments</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>59 (89)</td>
</tr>
<tr>
<td>1–3</td>
<td>7 (11)</td>
</tr>
<tr>
<td>Zone</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2 (3)</td>
</tr>
<tr>
<td>2</td>
<td>17 (26)</td>
</tr>
<tr>
<td>3</td>
<td>19 (29)</td>
</tr>
<tr>
<td>4</td>
<td>21 (32)</td>
</tr>
<tr>
<td>5</td>
<td>7 (11)</td>
</tr>
<tr>
<td>Distance (d), mean (SD)</td>
<td>10.3 (2.6)</td>
</tr>
<tr>
<td>Inclination ((\theta)), mean (SD)</td>
<td>27.4 (13.9)</td>
</tr>
</tbody>
</table>

### Data gathering

Of the 66 patients investigated, 37 had analogue panoramic radiographs. These radiographs were digitalized by Depona AB, Stockholm, Sweden, into the Digital Imaging and Communications in Medicine format. The distortion of these panoramic radiographs after digitalization was so small (less than 1 per cent) that it was considered negligible. All the panoramic radiographs were taken at the Postgraduate Dental Education Centre, Department of Oral Radiology, Orebro County Council, using a standardized technique.

The main outcome variable was treatment time. The main independent variables were distance from the occlusal plane to the canine crown (\(d\)), canine inclination to the midline (\(\alpha\)), and sector of the canine crown position according to Ericson and Kurol (1988) (Figure 2), in association with potential effect on treatment duration. Other independent variables, which could influence the associations in focus were sex, age (at time of diagnosis), unilateral or bilateral impaction, side of impaction, number of debonds (emergency visits), missed appointments, the traction technique, and the clinical qualifications of the clinicians involved (Table 1). For bilateral displaced canines (15 patients), only one of the canines was included in the analysis to avoid bias due to the patient effect in the statistical analysis. In these cases, the
canine that took the longest time to arrive in the arch was chosen.

Treatment time was defined as the time between the start of orthodontic traction to the completion of the fixed appliance treatment when the displaced canine was brought into correct position and occlusion.

All the panoramic radiographs were calibrated before tracing in FACAD software (version 3.0, Ilexis AB, Linköping, Sweden). Reference lines that consisted of a horizontal occlusal line, the midline, and the zones occlusal plane line, and zones 1 – 5 of the displaced canine crown (adapted from horizontal occlusal line, the midline, and the zones 1 – 5).

Additional dental lab fee: €86 (calculated for transpalatal arches with spring arm for forced eruption used in 57 patients).

Figure 1  Transpalatal arch with spring arm.

Figure 2  (A and B) Reference lines and linear and angular measurements. Canine inclination (α) to the midline, perpendicular distance (d) from the occlusal plane line, and zones 1 – 5 of the displaced canine crown (adapted with permission from Ericson and Kurol).

Figure 3  Reference lines and linear and angular measurements derived using FACAD software.

According to Ericson and Kurol were drawn in the FACAD software to calculate ‘d’ and ‘α’. The ‘zones’ were registered at the same time (Figure 3).

Costs of treatment

Treatment costs were estimated from the following codes bases on the severity and duration of procedures. Depending on the duration of the orthodontic treatment, three different treatment codes are used for orthodontic treatments with fixed appliances by the Public Dental Service organisation in Sweden. The first treatment code corresponds to a treatment duration ranging from 1 to 1.5 years, the second and the third code correspond to treatments ranging from 1.5 to 2 years and more than 2 years, respectively. These codes correspond to single jaw treatments.

A treatment code is selected based on the treatment duration, which in turn is correlated to the severity of the malocclusion and the degree of difficulty of the treatment. The cost for single jaw orthodontic treatment in Orebro County averages from €1880 to €2752 (adjusted for year 2011) which covers all costs of orthodontic visits and even includes braces, arch wires, and retention apparatus. Because the treatment codes are based on the treatment duration, an appropriate code is selected at the start of the retention phase. The only indication for orthodontic treatment was canine impaction in the selected cases in this study.

The length of treatment in months was extracted from each patient’s records. The proper treatment code for the fixed appliance treatment was selected individually for each patient.

All surgeries were carried out under conscious sedation at the Department of Paediatric Dentistry and the total treatment cost for each was calculated on the following data:

1. orthodontic consultation fee (examination fee): €162
2. panoramic x-ray fee: €50
3. nitrous oxide–oxygen sedation: €97
4. surgery to access the displaced canine: €414
5. additional dental lab fee: €86 (calculated for transpalatal arches with spring arm for forced eruption used in 57 patients).
These costs were added to the treatment costs for fixed appliances, which ranged from €1880 to €2752 for each patient.

Statistical analysis

One operator (AD) performed all the measurements. Each tracing was measured twice on 10 randomly selected panoramic radiographs, with 3 months between the measurement sessions. Examiner reliability was assessed through intra-class correlation coefficient (ICC) and standard deviation (SD) in patients of replicated measurements calculated from one-way analysis of variance. Within-subject coefficient of variation (COV) defined as the ratio between SD within patient and mean of the measurements were also calculated.

Linear regression was used to evaluate differences in length of treatment between different zones for displaced canines. Stepwise linear regression was used for the adjusted model with stepwise selection of background variables in Table 1, all modelled as categorical variables, with significance level at 0.20. The same way of analysis was done to evaluate the association between length of treatment and distance of the PDC from the occlusal plane (d) as well as the inclination of the PDC to the midline (α). Spearman correlation coefficient (r) was used to measure correlation between zones, distance (d), and angle of inclination. Statistical software SPSS (version 17.0; SPSS, Chicago, Illinois, USA) was used for all calculations. A P-value lower than 0.05 was considered statistically significant.

Results

Intra-examiner reliability for the panoramic measurements showed high agreement for linear measurements [ICC 0.997, 95% confidence interval (CI) 0.987–0.999 and COV 2.1 per cent] as well as for angular measurements [ICC 0.990 (95% CI 0.963–0.998) and COV 3.6 per cent]. There were no differences in category placement for ‘zone’ in the repeated tracings.

The 66 patients in the study had a mean treatment time of 22 months (range 10–45). The mean age at the time of diagnosis was 14.9 (SD 1.7) years (Table 1). PDC occurred more often in girls than in boys, more often unilaterally, and more often on the right side of the palate. Transpalatal arch with spring arm was the orthodontic apparatus mainly used and the majority of the treatments were done by specialists in orthodontics with the same level of qualification. Seven patients had few emergency visits or debonds. Seven of 66 included had missed appointments during their entire treatment period: 3 had one missed appointment each, 2 patients had two missed appointments, and 2 had three missed appointments. These patients were called to the next visit within 1–3 weeks after their failed appointment. The other 59 patients had no missed appointments registered.

The treatment duration averaged 17 months for canines displaced in zone 1 or 2, 20 months for those in zone 3, and 27 months for canines displaced in zone 4 or 5 (Figure 4, Table 2). Linear regression showed a trend of increasing duration of treatment of PDCs by their position in less favourable zones. Unadjusted treatment times were 2.9 months longer (95% CI 1.4–7.3) in zone 3 and 9.8 months longer (95% CI 5.8–13.8) in zones 4 and 5 than in zones 1 and 2. Following adjustment for background variables, there was still a statistically significant difference of 7.6 months (95% CI 4.1–11.1) longer treatment time in zones 4 and 5 than in zones 1 and 2.

Furthermore, treatment time increased with increasing distance (d) of the PDC from the occlusal plane (Figure 5, Table 2), on average (unadjusted) by 1.7 months (95% CI 1.0–2.3) per millimetre increased distance and adjusted on average by 1.2 months (95% CI 0.7–1.8) per millimetre increased distance. In the unadjusted model, distance (d) alone explains about 29 per cent ($R^2 = 0.29$) of the variation in treatment time.

There was also a statistically significant association between treatment time and inclination (α) of PDC to the midline (Figure 6 and Table 2). Unadjusted treatment time was on average 0.30 months (95% CI 0.17–0.42) longer treatment per increased α and adjusted was 0.19 months (95% CI 0.08–0.31) longer. Inclination (α) alone explains around 27 per cent ($R^2 = 0.27$) of the variation in treatment time.

Zone, distance (d), and inclination (α) do correlate fairly high with each other, from $r = 0.62$ to $r = 0.83$, with the highest correlation coefficient between zone and inclination (α). This suggests that all three measurements mainly are measuring the same phenomenon, impaction severity.
The average cost of the treatment of PDC was €3200 per case. The total annual cost for treatment of PDC in Sweden could thereby be estimated as €6000000 for approximately 1900 cases/year.

Discussion

This observational study shows that length of the treatment is associated to different zones for displaced canines, distance of the PDC from the occlusal plane, and inclination of the PDC to the midline. These associations were not explained by difference in other background characteristics but are strongly correlated to each other, which suggest mainly three measurements of the same phenomenon. Treatment of PDC is relatively expensive.

Treatment of PDC is a clinical challenge in dentistry because it requires an interdisciplinary therapeutic approach that involves both orthodontic and pedodontic operators. The outcome of treatment of an impacted canine is successful when the tooth emerges and is in a stable position in the dental arch with full alignment.

Our study population consisted of 66 patients with PDCs. The distribution of characteristics like sex and type of impaction in this sample of patients was very similar to earlier published studies (Ericson and Kurol, 1988; Nieri et al., 2010).

The average age of the patients at time of the diagnosis in this study was 14.9 years. Frequently, PDCs are not noticed until the patient is somewhat older because the rest of the dentition often displays only mild malocclusion or crowding problems (Stewart et al., 2001). The displaced canine is often not noticed by the patient or diagnosed by the general dentist until after the age of 11–14 years, when it would normally erupt.
The initial position of the displaced canines did significantly influence the duration of treatment. The pre-treatment α angle on panoramic radiographs appeared as a determinant for the severity of displacement and, consequently, of the duration of treatment. Greater angulation of the displaced canine with respect to the midline was related to greater distance of the tooth cusp from the occlusal plane and also indicated the higher zone of impaction. This was too has been described in previous studies (Stewart et al., 2001; Olive, 2005; Zuccati et al., 2006; Nieri et al., 2010). The effect of distance (d) on treatment duration showed a similar pattern to that of the α angle and indicated on average 1.2 months longer treatment time per millimetre increased distance to the occlusal plane.

The larger zone number indicated a more medially positioned canine, generally, in combination with a higher position in the alveolus bone and a larger α angle. Our study showed that it took, on average, 7.6 months longer to treat a canine displaced in zones 4 and 5 than in those displaced in zones 1 and 2. Logically, this could be explained by the larger distance that canines in higher numbered zones would need to ‘travel’ to erupt.

The pre-treatment α angle, distance, and the zone affiliation of the PDCs showed a fairly high correlation with each other. This indicates that they all measure the same phenomenon but in different ways. The question is which of these independent factors are more reliable for predicting the treatment duration on panoramic radiographs.

Stewart et al. (2001) suggested that the PDC’s distance from the occlusal plane on panoramic radiographs might be used to estimate the length of treatment. In the study conducted by Stewart et al., PDCs less than 14 mm from the occlusal plane showed an average treatment time around 24 months and those more than 14 mm were treated for around 31 months. The distance measurements (millimetre) on panoramic films are very dependent on the magnification factor of the radiographs taken, which varies between the different panoramic machines and even with the patients’ age. We suggest using zones as a technique to avoid some of the technical problems associated with distance measurements on radiographs. We acknowledge, however, that zone affiliation relies on a standardized radiographic technique, with the patient accurately positioned in the panoramic machine, because the head posture could affect and influence the inclination of the PDC in relation to the selected reference lines. In general, angular measurements are found to be more reliable than vertical and even horizontal measurements on panoramic films (Wyatt et al., 1995). All the radiographs in the current study were taken using the standardized technique at the Department for Oral and Maxillofacial Radiology and may therefore be considered reliable.

The treatment duration averaged 17 months for canines displaced in zone 1 or 2, 20 months for those in zone 3, and 27 months for canines displaced in zone 4 or 5. This information makes it easier to estimate the duration of treatment by studying the panoramic radiograph and to give patients more precise information about the expected length of their treatment.

The cost calculations in this study reveal relatively high expenses for the general treatment of PDCs. Orthodontic treatments in Sweden are free of charge for children and adolescents (up to 19 years of age). The cost calculation was done to estimate the cost of treatment for PDCs for the Orebro County Council. If all counties in Sweden were to follow the same procedure for management of PDCs as Orebro County Council, the national annual treatment costs could be as high as €600,000. This shows the importance of early diagnosis of maleruptions and may support the institution of interceptive measures first advocated by Ericson and Kurol (1988) to possibly change the path of ectopic erupting PDCs by extracting the primary canines in children aged 10–13 years.

This study has some limitations. The retrospective nature of the current study limits the control of the confounding variables. However, the study conducted by Stewart et al. (2001) showed that the effect of impacted canines was significantly greater than the error associated with confounding variables such as missed appointments, the number of replaced brackets and bands, etc. in a case–control study. Zuccati et al. (2006) did not consider such potential confounders in their study due to the results indicated by Stewart et al. (2001). In this study, we included these potential confounding factors in our stepwise regression analysis, which was expected to adjust for the most correlated factors.

Further studies with prospective RCT design are required to accurately restrict the effect of the confounding factors and to improve the accuracy of the pre-treatment estimates and hopefully be conductive to confirm or question the results of this study.

Conclusions

Estimation of treatment duration based on the location of the PDC on the panoramic radiograph can roughly be predicted. The predictions might be helpful in providing information to the patients and this information could give the patient information about the expected length of their treatment. This retrospective study indicates the following.

1. If the PDC were located in zones 4 and 5, it took approximately 7.6 months longer to bring the PDC into the arch in compared with those in zones 1 and 2.
2. Treatment duration increased on average 1.2 months per millimetre increased distance of the PDC from the occlusal line.
3. Treatment of PDC is a relatively expensive treatment.
References


