*European Journal of Orthodontics* 25 (2003) 49–56 

# The effect of changes in tooth position of unerupted canines on cephalograms

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SUMMARY Although many radiographic procedures have been described to localize an impacted canine, they all submit the patient to extra radiation. The purpose of the entire study was to evaluate if the combined interpretation of cephalograms and dental panoramic tomograms (DPTs), which are used in orthodontic practice, can provide adequate information as to the position of impacted canines. In a previous study the radiographic image of impacted canines on DPTs was evaluated. In this investigation, the effect of changes in position and inclination of an impacted canine on cephalograms was studied in an experimental set-up.

An upper canine was removed from a human skull and placed in a positioning device to imitate various positions of impaction. Starting from a buccally impacted position, three different displacements were simulated: 10 mm frontally, 10 mm sagittally, and 5 mm vertically. In each of these positions nine different changes in inclination (in the sagittal and the frontal plane) were registered, resulting in 36 different cephalographic exposures.

Analysis revealed the following: the degree of vertical and sagittal displacement of the incisal point of the impacted canine, the angulation of the tooth as well as the tooth length, measured on a cephalogram, appeared to give an accurate representation of the experimental set-up. Combining these findings and those from the previous study, it became possible to define a series of points to enable an adequate three-dimensional (3D) estimation of the canine's position. A clinical case of an impacted canine is used as an illustration of this experimental set-up.

## Introduction

Impaction of maxillary canines occurs infrequently, 0.92 per cent (Dachi and Howell, 1961) and 1–2 per cent (Rayne, 1969; Brin *et al.*, 1986).

In orthodontic treatment planning, the exact localization of the position of impacted canines is of importance. The decision as to whether the canine should be extracted or retained may considerably influence the treatment plan. Early intervention, such as extraction of the primary canine, or exposing the canine, with or without orthodontic guidance, can only be performed after careful evaluation of the tooth's position.

Moreover, accurate knowledge of the position of the impacted canine may contribute to a less invasive surgical procedure if exposure of the canine is required. A periapical repositioning flap might be the choice of treatment in buccally retained canines, whereas extensive removal of bone may be necessary in the case of palatal impaction.

Clinical investigation is the first and most important aid in the diagnosis of impacted canines (Rayne, 1969; Williams, 1981; Leivesley, 1984). However, impaction must be confirmed by imaging techniques, such as radiography (Langlais *et al.*, 1979).

According to Seward (1963), a number of radiographs used to diagnose impaction, are based on two main principles:

1. The degree of magnification of the imaged object in comparison with the surrounding teeth, may give an indication of the malposition of the impacted tooth.
2. The cone-shift or parallax technique aims to register the relative displacement of an object in relation to its environment.

Both principles enable the interpretation of displaced teeth on radiograph. The interpretation of impaction is usually based on additional radiographic views, which are taken especially for this purpose. The total amount of unnecessary radiation could be reduced if radiographs, which are used in a routine orthodontic practice provide adequate information.

It was the aim of this experimental study to evaluate critically the information stored on dental pantomograms (DPTs) and cephalograms in an attempt to localize accurately the position of impacted canines. The hypothesis tested was that the DPT and cephalogram could be compared with the two radiographs used in the cone-shift technique where the change in inclination of the cone between the two exposures approximates 90 degrees. Before combining the information provided by both radiographic images, the values of the DPT and cephalogram in locating impacted canines were investigated. In a previous study (Gavel and Dermaut, 1999) the effect of changes in position and inclination of impacted canines on the DPT was investigated, resembling the frontal registration of the cone-shift technique. In this research the reliability of a cephalogram in locating impacted canines was investigated (sagittal registration of the cone-shift technique). In addition the combination of information of the two radiographic views could contribute to an improved assessment of the location of impacted canines.

## Materials and methods

The material consisted of a series (36 exposures) of cephalograms in which the distance between the focus of the X-ray tube and the midsagittal plane of the patient's head was 250 cm. The machine used for this purpose was a Trophy Omnix® (Vincennes, France). A dry skull with well-aligned teeth was positioned in the cephalostat by means of an adjustable system, which enabled reproducible repositioning. The teeth were then removed and transferred to an acrylic spoon device on the skull, which enabled maintenance of the dentition in its original position in the cephalostat (Figure 1).

Tooth 13 was then removed from the acrylic device and a positioning system was developed (Figure 2) to simulate changes in the position of the impacted canine within well-defined biological and realistic limits.

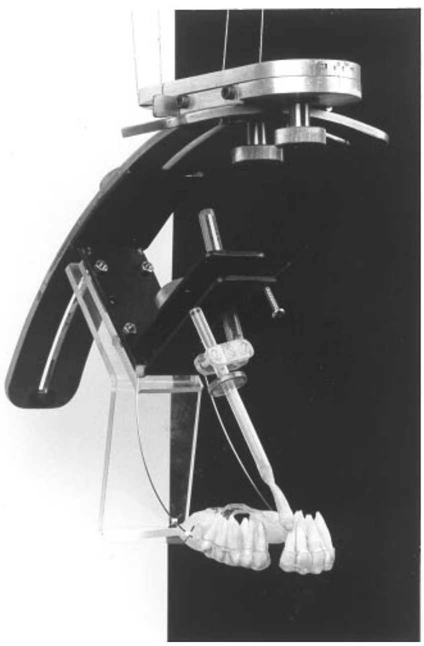

**Figure 1** Fixation system of the upper dentition.

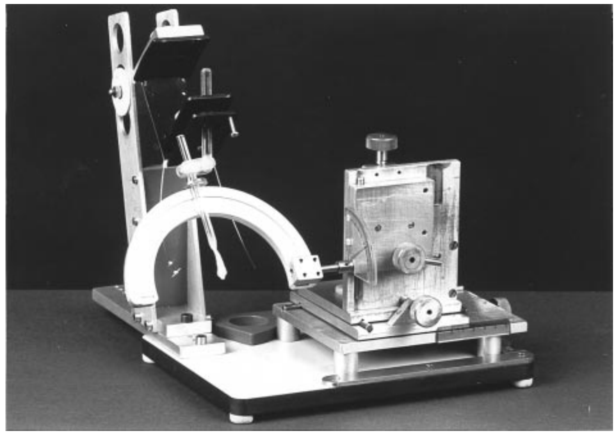

**Figure 2** Positioning system for the isolated canine.

The device was constructed to avoid bony obstacles in the skull and the dentition while varying the position of the canine for the different exposures.

All variations in positioning of the canine (Figure 3) could be accurately recorded three-dimensionally (3D) on the positioning device. The parameters and the method of measuring are illustrated in Figure 4. In some parameters the relative position of the occlusal plane was involved. It was defined as the incisal edge of the 11 and the mesiobuccal cusp of the 16.

The positioning system for tooth 13 was isolated and separate cephalograms of this tooth in different positions were taken (Figure 5). Metallic tentacles (T) were used for superimposition of the different cephalograms. All measurements (linear measurements were carried out with callipers whereas angulations were measured by means of a protractor) were undertaken twice in a darkened room with all light blocked out. Some measurements were carried out directly on the radiograph whereas for other measurements tracing on acetate paper were undertaken. A pencil, 0.2 mm diameter, was used for this purpose.

The above procedure was similar to the set-up used in the study of Gavel and Dermaut (1999) concerning DPTs.

Combinations of displacements and inclinations were evaluated in the present investigation. Initially the canine was moved into a buccally impacted position and the crown was defined as being in the most buccal position at a vertical level located close to the middle of the root of the lateral incisor (Figure 3).

Starting from the buccally impacted position, three different displacements were simulated: 10 mm towards the midsagittal plane, 10 mm posteriorly in the sagittal plane, and 5 mm in a vertical direction. In each of these positions the changes in inclination were registered. In the sagittal direction the three inclinations varied between 30, 50, and 70 degrees, respectively, whereas the frontal tilting varied between 60, 80, and 100 degrees, respectively.

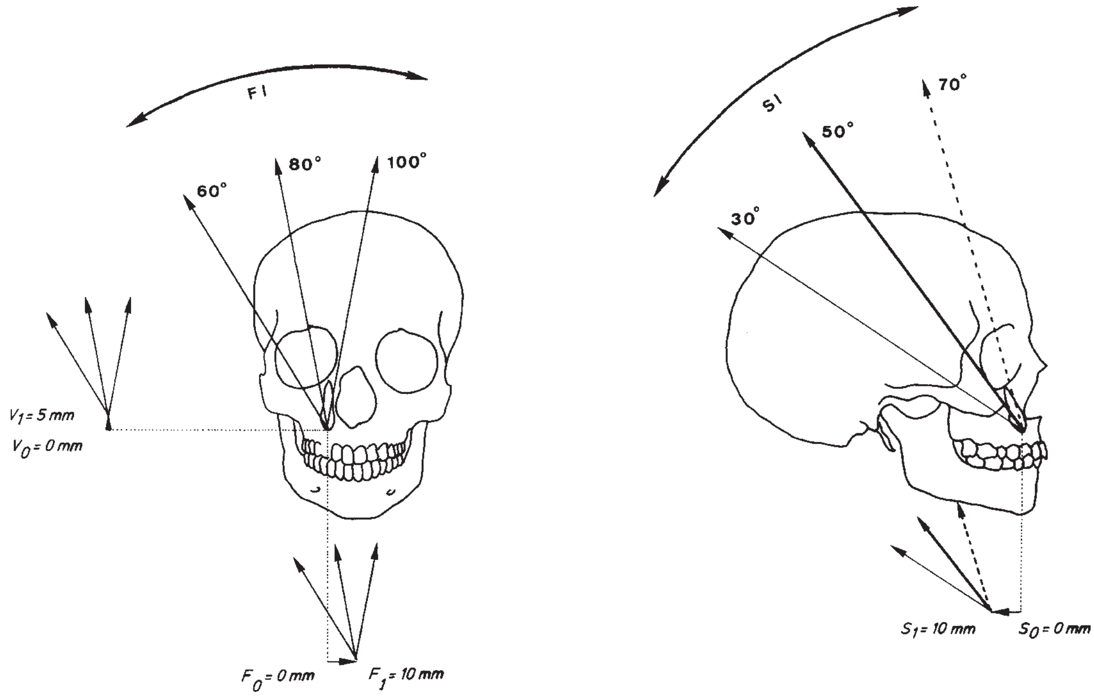


**Figure 3** Different studied combinations of displacements and inclinations. $S_0$, buccally impacted position in the sagittal plane; $S_1$, posterior displacement (10 mm) in the sagittal plane; $F_0$, buccally impacted position in the frontal plane; $F_1$, displacement towards the midsagittal plane; $V_0$–$V_1$, vertical displacement (0–5 mm); FI, inclinations in the frontal plane (60–100 degrees); SI, inclinations in the sagittal plane (30–70 degrees).

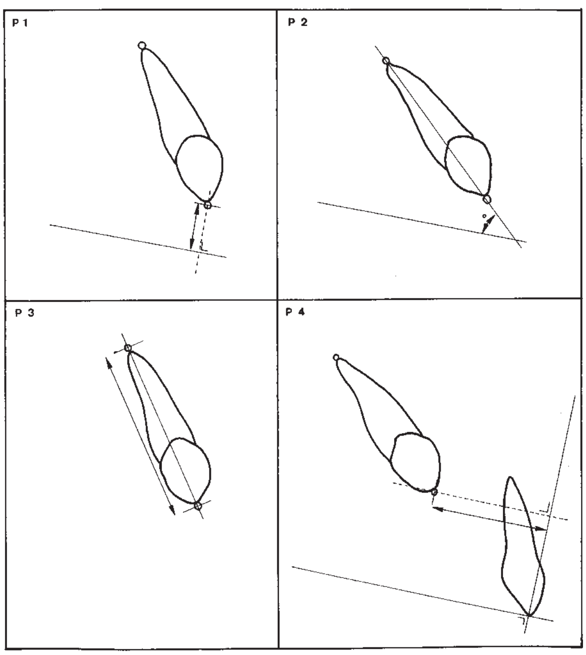


**Figure 4** Illustration of the different parameters investigated. $P_1$, vertical level related to occlusal plane; $P_2$, angulation related to occlusal plane; $P_3$, tooth length; $P_4$, sagittal shift to perpendicular on the occlusal plane through the incisal edge of the central incisor.

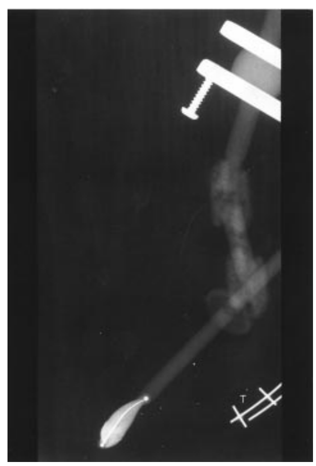

**Figure 5** Cephalogram of the isolated canine. Metallic tentacles (T) were used for superimposition of the different cephalograms.

All positional changes were illustrated in four series of diagrams. Each series represented the different changes for each parameter. Figure 6a–d shows a compilation of an example of each series of diagrams. No statistical analysis was carried out as this study was purely descriptive. The reliability of the method was tested by taking two radiographs for each canine position. To determine the overall error of the registration procedure between the two radiographs, the acrylic device was removed from the cephalostat and repositioned. An average value of 0.3 mm was found for linear and 0.2 degrees for angular measurements, indicating that the error of the method was minimal (Dahlberg, 1940).

## Results

All parameters shown in Figure 4 were measured for different displacements and angulations imaged on DPTs and cephalograms. In the frontal plane, three experimental inclinations were registered (60, 80, and 100 degrees) and in the sagittal plane angulations of 30, 50, and 70 degrees.

### *Cephalogram*

*Distance of the incisal point of the impacted canine to the occlusal plane (Figure 6a).* Only a vertical displacement of the canine caused a shift of the incisal point in a cranial direction. The distance of the displacement of the canine on the cephalogram was comparable with the real vertical displacement.

*Tooth angulation (Figure 6b).* The value of the angle between the tooth axis and the occlusal plane on the

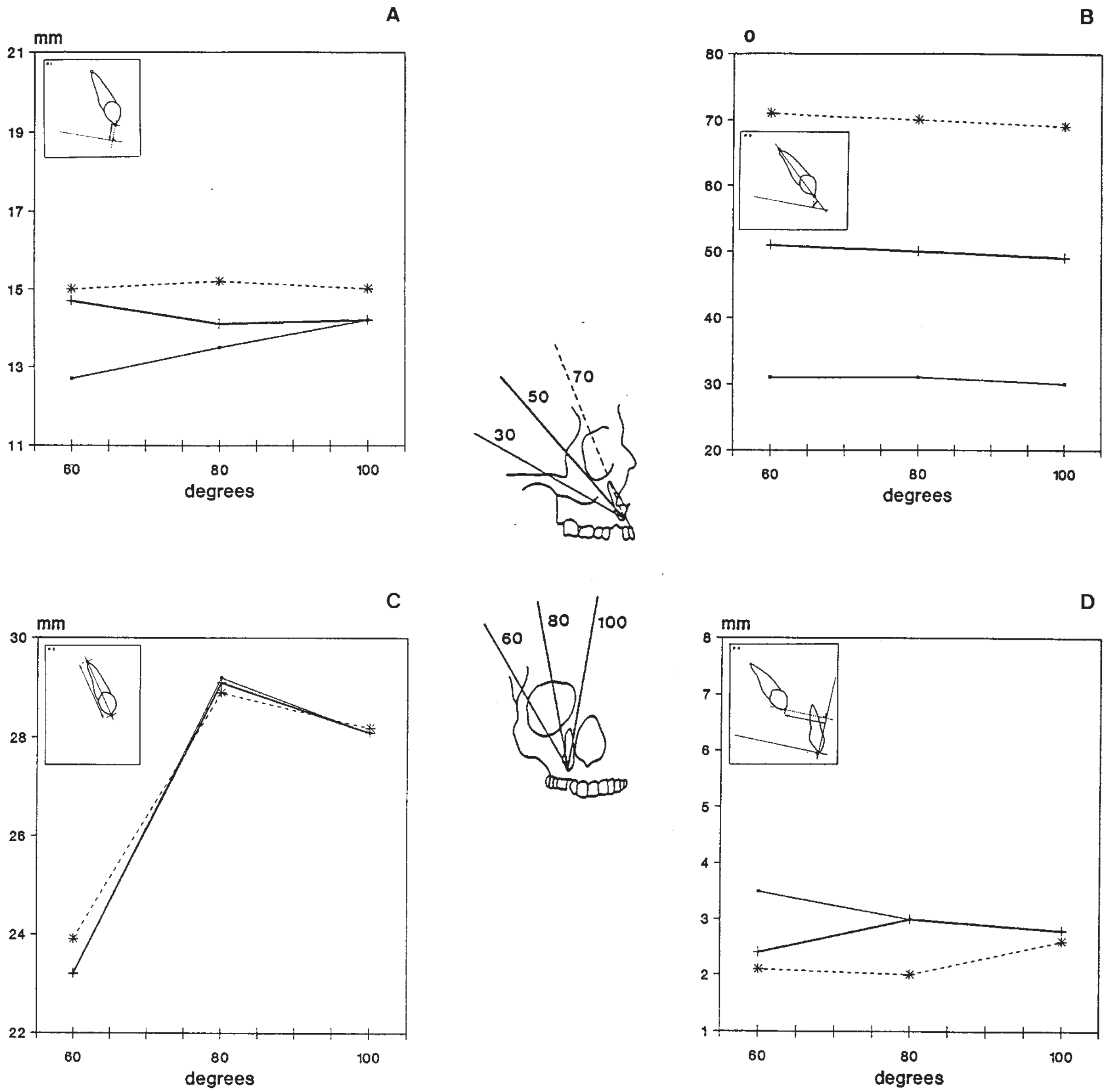


**Figure 6** Diagrams of investigated parameters on the cephalogram related to changes in inclination in the frontal plane (*X*-axis) for three different inclinations (30, 50, and 70 degrees) in the sagittal plane (thin, thick, and dashed line) in the buccally impacted position. Investigated parameters (*Y*-axis). (a) Vertical distance to the occlusal plane. (b) Tooth angulation. (c) Tooth length. (d) Sagittal shift to a perpendicular line from the occlusal plane through the incisal edge of the central incisor.

cephalogram was comparable with the real inclination of the canine in a sagittal direction. In all simulated impactions any sagittal inclination was exactly reproduced on the cephalogram.

*Changes in tooth length (Figure 6c).* The tooth length on the cephalogram was mainly influenced by inclinations in the frontal plane. The more the impacted canine was inclined in the frontal plane, the shorter the tooth length, and the more perpendicular to the horizontal plane the larger the imaging. Displacements in the sagittal, frontal, and vertical directions had no influence on imaging.

*Position of the incisal edge of the impacted canine in the sagittal plane in relation to a perpendicular from the occlusal plane drawn through the incisal edge of the central incisor are shown in Figure 6d.* Only a displacement in the sagittal direction was responsible for changing the distance between the incisal edge of the impacted canine and the perpendicular line from the occlusal plane. The size of the displacement was comparable with the distance the canine was displaced.

## Discussion

### *Cephalogram*

The reliability of measurements on cephalograms has been investigated previously (Baumrind and Frantz, 1971a,b; Bergersen, 1980; Stabrun and Danielsen, 1982; Tsao *et al.*, 1983; Ahlqvist *et al.*, 1986). All the above studies revealed different conclusions, which highlights that caution should be taken when measurements are transferred to reality. The reports can be summarized as follows: enlargement is a result of the inherent property of X-rays to proceed in straight lines diverging from the source or anode which is a very small area or 'point'. Obviously, if an object is placed between the anode and a film or screen, the image that results becomes enlarged. The closer the object (the patient) to the X-ray source (focus) or the further the film is from the object, the greater the enlargement. Therefore, to reduce enlargement in cephalometric radiography it is necessary to increase the anode-object distance and reduce the object-film distance as much as possible. The clinician should be aware of this phenomenon when interpreting a cephalometric view: compensation tables are available to deal with this phenomenon (Bergersen, 1980). Distortion is a further problem that can be distinguished from enlargement in that it is an inaccurate duplication of a structure or area, while enlargement is an accurate proportional expansion of a structure. Although distortion is of much greater importance when evaluating DPTs, cephalograms should also be interpreted correctly:

1. Objects not situated in the same sagittal plane, parallel to the film, experience different degrees of enlargement, for example both mandibular condyles are projected differently. The more projected objects are located in the same plane or the smaller the object (for example one single canine), the less this phenomenon has an influence. However, consideration must be given to this distortion in interpreting the comparison of the left and the right canine. This distortion is rather small but, nevertheless, still present.
2. Rotation of the head during exposure influences correct interpretation of the measured values. Adequate and careful fixation of the patient into the cephalostat should eliminate this problem.
3. Distortion also occurs when the divergent X-rays form tangents to rounded surfaces that fall on the target side of the midsagittal plane. The use of the apical and the incisal points of the impacted canine for interpretation should diminish the interpretation errors of this form of distortion.

Each of the above-mentioned sources of error was minimized in the set-up of this experimental study. This was reflected in the results: the enlargement was limited due to a large target-object distance and a small object-film distance. Errors induced by rotation of the head during exposure were controlled by rigid fixation of the spoon device. Distortion was also negligible, due to the reasons and precautions mentioned.

From the results it was concluded that after interpretion of the cephalogram the following are known:

1. The vertical position of the incisal edge of the impacted canine is located in relation to the occlusal plane.
2. The angle at which the impacted canine is inclined to the occlusal plane in a sagittal direction.
3. The degree the impacted canine is displaced in a sagittal direction. While interpreting these parameters the degree of magnification should be considered.

Even with a shorter film-focus distance, which mostly provides a 10 per cent magnification, this interpretation is valid.

### *After interpretion of the cephalogram the following can be evaluated*

Whether an impacted canine is excessively inclined or upright in the frontal plane. This can be evaluated by measuring its length and comparing it with the contralateral canine. This interpretation, however, can only be made if the outline of the incisal and apical points of the contralateral canine can be accurately observed.

After interpretion of the cephalogram it is difficult to say whether or not the impacted canine is displaced in relation to the midsagittal plane in a lateral or medial direction.

*Combination of the common parameters on the cephalogram and the DPT*

The findings indicate that measurements on cephalograms are more reliable and less subject to distortion. Therefore, it is preferable to consider first the information of this exposure. In this way the vertical position of the incisal edge as well as the inclination of the impacted canine in the sagittal plane can be established.

The DPT offers valuable information about the position of the impacted canine towards the midsagittal plane: the measurement of the distance of the incisal edge of the canine to the midsagittal plane on a DPT approximates the real position. Displacement in the sagittal plane has a minor influence on this distance (Gavel and Dermaut, 1999).

The inclination of the impacted tooth in the frontal plane can be assessed using a combination of both radiographs. Gavel and Dermaut (1999) have shown that the angle tooth-axis/occlusal plane on the DPT is determined by the sagittal inclination of the canine and affected linearly by its inclination in the frontal plane: for canines with the same sagittal inclination, the more upright they are in the frontal plane, the larger the angle tooth-axis/occlusal plane. The *Y*-axis represents the angle tooth-axis/occlusal plane on a DPT (Figure 7b) and the *X*-axis the simulated angulation of the impacted canine in the frontal plane. The dashed, thick and thin lines represent changes in the angle tooth-axis/occlusal plane on the DPT for varying angulations in the sagittal plane. For example, a canine, tilted in the frontal plane by 60 degrees can give a varying angle tooth-axis/occlusal plane on the DPT between 30 and 55 degrees, depending on its inclination in the sagittal plane. On the other hand, an angulation of 70 degrees (dashed line) in the sagittal plane can give a varying angle tooth-axis/occlusal plane on DPT between 55 and 85 degrees, depending on its inclination in the frontal plane. Thus, the measured angle on a DPT is a combination of the canine's inclination in the frontal and sagittal planes. Bodily displacement of the canine has a minor influence on this measurement. As Figure 7b is a compilation of a variety of inclinations in the frontal and sagittal planes, it can be used for assessing the canine's inclination in the frontal plane.

A clinical case of an impacted canine (Figure 8a,b) illustrates the use of this guidance. The method of measuring shown in Figures 8c–f and 9 and Table 1 clarifies how the inclination in the frontal plane was determined.

## Conclusions

In this study the radiographic image of an impacted canine on cephalograms were analysed. The radiographic behaviour of the impacted canine with the incisal edge displaced in three directions and inclined in the frontal and the sagittal planes was investigated. By analysis and evaluation of both DPTs and cephalograms the estimation of the real position of the canine could be accurately determined. The largest positional changes on the cephalograms approximate the real position whereas the information obtained from DPTs is not always as easy to understand and must be interpreted with caution. Some bodily displacements and inclinations of the impacted canine caused obvious changes in their imaging position, whilst some had no influence and still others were the cause of significant distortions. Table 1 attempts to indicate which information can be determined

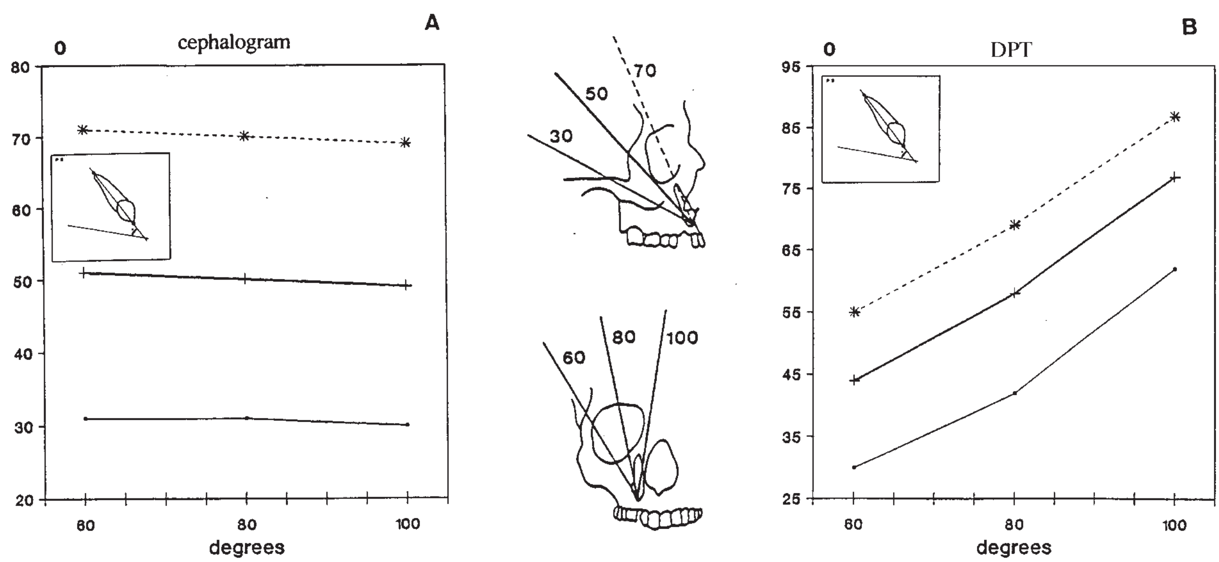


**Figure 7** Example of changes in tooth angulation (*Y*-axis) on the cephalogram (a) and on the DPT (b) related to changes in inclinations in the frontal plane (*X*-axis) for three different inclinations in the sagittal plane: thin (30 degrees), thick (50 degrees), and dashed (70 degrees) in the buccally impacted position.

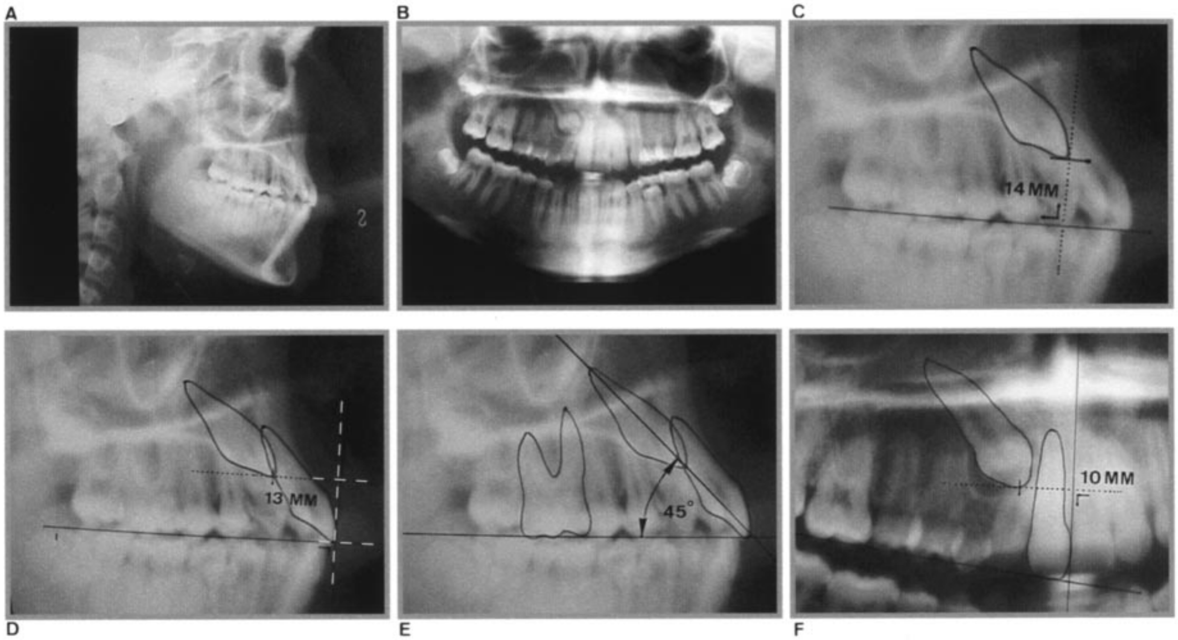


**Figure 8** (a) Impacted canine on cephalogram. (b) Impacted canine on DPT. (c) Vertical position (measured on cephalogram). (d) Sagittal position (measured on cephalogram). (e) Sagittal inclination (measured on cephalogram). (f) Frontal displacement (measured on DPT).

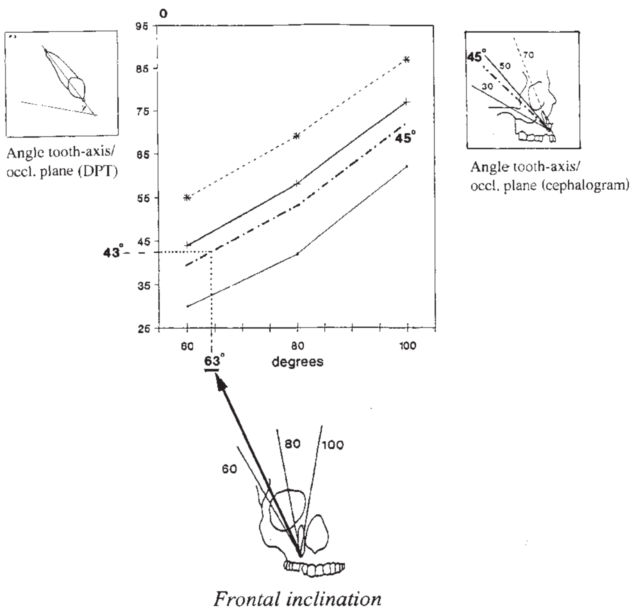


**Figure 9** Diagram for determining the frontal inclination of an impacted canine using the values of the angles measured on the DPT and cephalogram (tooth-axis/occlusal plane). The sagittal inclination of the canine measured on the cephalogram is 45 degrees (dashed line) and its angulation to the occlusal plane on the DPT is 43 degrees ($Y$-axis), thus the frontal inclination is 63 degrees (the $X$-value).

from both imaging procedures on a given example. When there are changes in frontal inclination both the cephalogram and the DPT provide additional information.

In a future study, the proposed procedure will be tested on a group of patients with impacted canines from which the exact position of the impacted canine was determined by computerized tomography. Moreover radiographic assessment of adjacent teeth and skeletal environment may provide additional valuable information.

**Table 1** An example of the analysing system for evaluating the location of an impacted canine (see Figure 9).

| | Cephalogram | DPT |
|---|---|---|
| Vertical position | 14 mm | |
| Sagittal displacement | 13 mm | |
| Sagittal inclination | 45° | |
| Frontal displacement | | 10 mm |
| Frontal inclination | 45° | 43° |
| | 63° | |

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