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# Are panoramic radiographs good enough to render correct angle and sector position in palatally displaced canines?

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**Objectives:** The early interceptive treatment of palatally displaced canines (PDCs) has for decades been based on their position in panoramic radiographs. In the 1990s, cone-beam computed tomography (CBCT) started to become popular in cases with PDCs. The aims of this prospective study were to evaluate the agreement of PDC sector position and angle to midline between panoramic radiographs and CBCT scans. **Methods:** PDC sector and angle to midline were measured in panoramic radiographs and CBCT scans in 58 consecutive patients with 64 PDCs. Kappa with linear weighting was used to assess the agreement between the measurements of PDC sector position and Bland-Altman limits of agreement to assess the agreement between the PDC angular measurements in the 2 methods. **Results:** PDC sector position and angle to midline had systematically higher values in panoramic radiographs compared with those in the CBCT scans. The agreement of sector position between the methods was fair: weighted kappa 0.36 (95% CI 0.24-0.49). The mean difference in angle was almost 7° (95% CI 5.9°-7.9°) higher in panoramic radiographs compared with CBCT. **Conclusions:** Panoramic radiographs overestimate PDC sector and angle to midline position, compared with the use of CBCT scans, but clinically the differences are quite modest. Panoramic radiographs could be considered good enough for rendering PDC position when the need for 3D information is not crucial for treatment planning. (Am J Orthod Dentofacial Orthop 2019;155:380-7)

The prevalence of maxillary palatally displaced canines (PDCs) is reported to be about 2%.[1,2] The first step to localize a nonerupted canine when there is suspicion of displacement is palpation. If this does not confirm the buccopalatal position, 2 additional periapical radiographs, taken according to the Clark rule,[3] are recommended. If the patient needs orthodontic treatment, the next step is often a panoramic radiograph, which provides an overview of the teeth and jaws. The recommended treatment to prevent a PDC from impaction is then to extract the deciduous canine at the right time, to increase the possibility of the PDC improving its unfavorable position. Several clinical trials have demonstrated the effectiveness of this interceptive treatment.[4-8] To classify the degree of displacement of the PDC, correlated with the success rate of the interceptive treatment, Ericson and Kurol used panoramic radiographs to describe and sort the PDCs into sectors. Since then, panoramic sector position of the PDC has been by far the most-used criterion in early interceptive orthodontic treatment planning.[5,9] Ericson and Kurol measured panoramic PDC sector position, angle to midline, and distance to occlusal line, which became popular for correlating with outcomes such as impaction,[10] orthodontic treatment duration,[11-13] and risk of root resorption of neighboring teeth.[14,15]

The popularity of panoramic radiographs in clinical orthodontic practice is quite understandable, because they provide an easy accessible overview of teeth and jaws at low radiation dose. However, panoramic radiographs incorporate some error sources of importance, such as magnification variation, distortion,

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superimposed structures, imaging artefacts, projection errors, and sensitivity to head position.[16] The limitations of the panoramic technique have contributed to the popularity of computed tomographic techniques, such as cone-beam computed tomography (CBCT). CBCT offers high diagnostic value and is considered to be the most accurate method for the localization of impacted teeth.[17] Consequently, recent efforts have been made to find predictive CBCT measurements correlated with outcomes of interceptive treatment[18] and risk of impaction.[19] However, CBCT is associated with higher overall effective radiation dose than conventional 2D radiography.[17] The CBCT radiation dose, depending on the scan mode, is 3-6 times higher than that of panoramic radiographs.[20] Reports of routine use of CBCT are therefore alarming.[21] Hujoel et al[22] highlighted the hazardous lifetime radiation risk when they studied change in radiation dose in adolescents from 1992 to 1999. Advocates of routine CBCT may stress that 3D information is needed because of the root resorption risk in PDC cases, but information about root resorption is seldom crucial at the time for undertaking interceptive treatment, that is, when the PDC is found early. Radiography should always be justified and in agreement with the as-low-as-diagnostically-acceptable principle.

Because PDC sector position and angle to midline in panoramic radiographs are still used for decision making in interceptive treatment—keeping in mind the varying results of their importance in different studies[12,23,24] and the limitations of panoramic radiography—the question is what they are worth in a world of CBCT information possibilities.

The aim of the present study was not to evaluate the intra- or interreliability between evaluators that compare canine position, treatment, or root resorption between panoramic radiographs and CBCT scans. That task has already been undertaken,[15,25-27] even though the authors did not exclusively evaluate PDCs, but palatally and buccally canines together. Instead, we aimed to study agreement between the 2 methods, exclusively in PDC cases, because different buccopalatal positions also may affect the sector (ie, mesiodistal) position in panoramic radiographs. To our knowledge, there are no previous or ongoing studies evaluating agreement between the 2 common modalities—panoramic radiographs and CBCT scans—for PDC position. This would help us to clarify the need of additional radiographic examinations, especially in the initial decision making of interceptive treatment of PDCs with extraction of the deciduous canines, where prediction of treatment outcomes is based mainly on studies made on PDC position in panoramic radiographs.[7,9,28] The aims of this prospective study were therefore to compare measurements of the sector position and the angle to midline of PDCs in panoramic radiographs and CBCT scans.

## MATERIAL AND METHODS

The study participants were included consecutively from 2 orthodontic centers of the Public Dental Health Service in Örebro and Eskilstuna, Sweden, from January 16, 2014, to December 14, 2016, into an ongoing randomized controlled trial (Clinicaltrials.gov ID: NCT02186548; Researchweb.org ID: 127201). The regional Ethical Review Board in Uppsala, Sweden, which follows the guidelines of the Declaration of Helsinki, approved the study protocol.

The following inclusion criteria had to be fulfilled by the participants enrolled in the study: diagnosis of uni- or bilateral PDC planned for surgical exposure and orthodontic treatment, and panoramic radiographs and CBCT scans taken the same day. Patients with ongoing orthodontic treatment, aplasia of the adjacent upper lateral incisor, craniofacial syndromes, odontomas, cysts, cleft lip or palate, or older than 16 years of age were not eligible for the study.

After informed consent was obtained, every participant had panoramic radiographs and CBCT scans taken before surgical exposure of PDC. All panoramic radiographs and CBCT scans were acquired in standardized positions and performed by experienced radiographers at the 2 maxillofacial radiology departments: the Postgraduate Dental Education Center, Örebro, and the Public Dental Health Service, Eskilstuna. The evaluations on the CBCT images were made perpendicular to the dental arch to mimic the intended panoramic view.

The digital panoramic radiographs at the Postgraduate Dental Education Center in Örebro were taken with the use of Cranex Tome or Scanora equipment (both Soredex, Orion Corp, Helsinki, Finland). The exposure technique used phosphor plates, scanned in a Digora PCT scanner for both apparatuses. The exposure parameters for Cranex Tome were set at 66 kV, 10 mA, and 15 or 19 seconds adjusted to patient size; for Scanora the exposure parameters were set at 66 kV, 13 mA, and 13 seconds. The CBCT examinations were made with the use of a Morita Accuitomo 170 dental CBCT scanner (J Morita Mfg Corp, Kyoto, Japan), at a 360° rotation. The exposure parameters were 85 kV, 5-7 mA, and 17.5 seconds (6×6 cm field of view [FOV], 0.08 mm voxel size). The digital panoramic radiographs at the Public Dental Health Service in Eskilstuna were taken with the use of Orthophos XG5 equipment (Sirona, Bensheim, Germany) equipped with a charge-coupled device sensor or Scanora equipment with the exposure technique of phosphor plates, scanned in a

**Table I.** Angle and sector definitions in panoramic radiographs

| *Reference* | *Abbreviation* | *Definition* |
|---|---|---|
| Midline | Sp ant–Sut im | Line from spina nasalis anterior through the alveolar process at sutura intermaxillare |
| Long axis of PDC | C tip–C ap | Line through PDC's radiologic cusp tip and apex |
| Angle to midline | C angle | Angle between midline and long axis of PDC |
| Long axis of incisors | inc–ap | Line through radiologic center of incisor edge and apex |
| Sector II | SII | Distal to long axis of lateral incisor |
| Sector III | SIII | Long axis of lateral incisor to line bisecting the approximal area between the lateral and central incisor; mesial to sector II |
| Sector IV | SIV | The bisecting line between lateral and central incisor to long axis of central incisor; mesial to sector III |

**Table II.** Angle and sector definitions in CBCT scans

| *Reference* | *Abbreviation* | *Definition* |
|---|---|---|
| Sagittal line | SL | Line from spina nasalis anterior to spina nasalis posterior through sutura mediana |
| Frontal line | FL | Line from spina nasalis anterior through sutura intermaxillaris |
| Sagittal plane | SP | A vertical plane created by the lines of SL and FL |
| Axial plane | AP | Axial plane is perpendicular to SP and parallel to SL at the level where PDC cusp tip is identified |
| Long axis of PDC | C tip–C ap | Line through PDC cusp tip and apex |
| Angle to midline | C angle | Angle between FL and long axis of PDC |
| Long axis of incisor | inc–ap | Line through the radiologic center of incisor edge and apex |
| Sector I | SI | The area distal to a line at the distal aspect of lateral incisor crown and root, interpreted in the axial plane (AP) |
| Sector II | SII | The area mesial to a line at the distal aspect of lateral incisor crown and rot, ie, mesial to sector I, and distal to long axis of lateral incisor, interpreted in the axial plane (AP) |
| Sector III | SIII | The area from long axis of lateral incisor to a line bisecting the mesial aspect of the lateral incisor and the distal aspect of the central incisor, interpreted in the axial plane (AP) |
| Sector IV | SIV | The area from a line bisecting the central and lateral incisor, ie, the mesial aspect of the lateral incisor and the distal aspect of the central incisor, to long axis of central incisor, interpreted in the axial plane (AP) |

Digora PCT scanner. The exposure parameters for the Orthophos were set at 64 kV/8 mA or 69 kV/15 mA, depending on patient size, with an exposure time of 14.1 seconds; for the Scanora the exposure parameters were set at 66 kV, 13 mA, and 13 seconds. The CBCT examinations were made with the use of a i-CAT unit (Imaging Sciences International, Hatfield, Pennsylvania) equipped with a flat-panel detector, at a 360° rotation. The exposure parameters were 120 kV, 5 mA, and 8.9 seconds scan time (16×3.8 cm FOV, 0.3 mm voxel size).

Angle and sector definitions in panoramic radiographs and CBCT scans are listed in Tables I and II, respectively. Graphical representation of reference points and lines in panoramic radiographs are shown in Figs 1 and 2, and reference points and lines in CBCT scans are shown in Figures 3-5.

### Statistical analyses

Kappa with linear weighting was used to assess the agreement between the measurements of PDC sector position in the panoramic radiographs and the CBCT scans, and the website from Vassar College (www.vassarstats.net) was used for computation. The sign test was used to evaluate whether the panoramic radiographs classified the PDC sector position systematically differently from the CBCT scans. Weighted kappa was used to assess the repeatability in the measurements of PDC sector position in the panoramic radiographs and the CBCT scans. To assess the agreement between the PDC angular measurements in the panoramic radiographs and the CBCT scans, the Bland-Altman limits of agreement (LoA) method was used.[29] This method involves plotting the difference (d) of the paired measurements with d ± 1.96 times the standard deviation of d between the methods against their mean. The potential bias between the methods was estimated by the mean differences of d with 95% CIs estimated from a paired *t* test. Lin concordance correlation coefficient (CCC) was calculated to measure the correlation in angular measurements between the 2 methods, as well as the repeatability between the first and second measurements in PDC angle in both panoramic radiographs and CBCT scans. A $P$ value $<0.05$ was considered statistically significant, and the statistical analyses were done with the use of SPSS version 22 (IBM Corp, Armonk, New York) and Stata release 14 (Stata Corp, College Station, Texas).

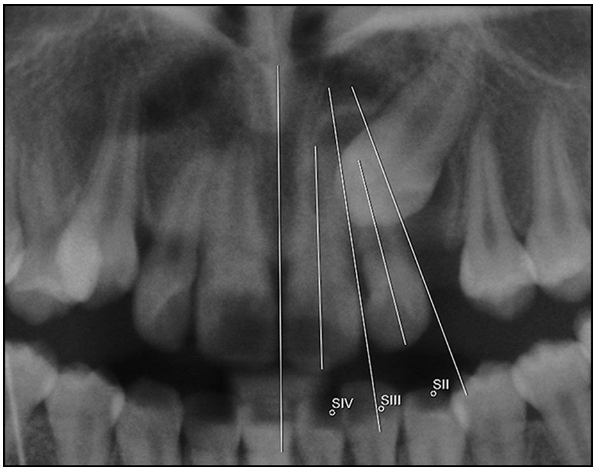


Fig 1. Canine cusp tip according to sector in a panoramic radiograph, here in sector III.

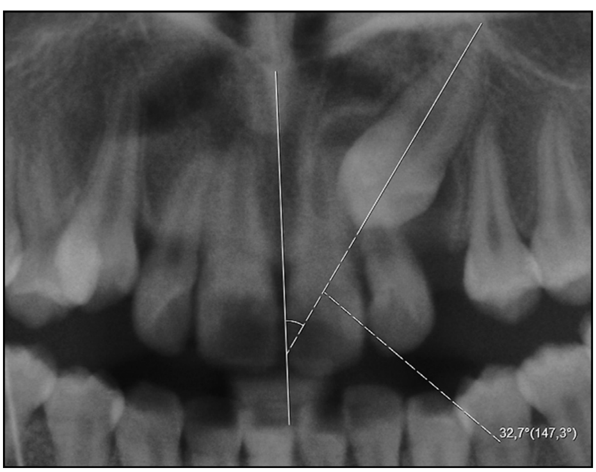


Fig 2. Canine long axis angle to midline in a panoramic radiograph.


Fig 3. Canine cusp tip according to sector in axial plane in a CBCT scan, here in sector III.

Fig 4. Canine long axis angle to midline in a CBCT scan.

## RESULTS

The mean age of the 58 study participants was 13.3 years (SD 1.5), with 21 boys with mean age 13.4 years (SD 1.2) and 37 girls with mean age 13.2 years (SD 1.7). Two boys and four girls had bilateral PDCs. This resulted in 64 studied palatally displaced canines.

For PDC sector position the agreement estimated by weighted kappa was 0.36 (95% CI 0.24-0.49) when the methods of panoramic radiographs and CBCT scans were compared (Tables III–V). The panoramic radiographs classified systematically with higher sector values compared with the CBCT scans ($P$ <0.01). Among the 64 PDCs, 33 had higher sector values, 2 had lower values, and 29 of the 64 had the same values in the panoramic radiographs compared with the CBCT scans. The mean angle in panoramic radiographs was 34.8° (SD 8.7°) and in CBCT scans 27.9° (SD 7.9°) in the 64 PDCs. The mean difference was 6.9° (95% CI 5.9°-7.9°) higher in panoramic radiographs compared with CBCT scans. The Bland-Altman plot (Fig 6) showed the mean difference between methods together with the 95% limits of agreement: −1.1° to 14.9°. The measured concordance correlation coefficient, Lin CCC, between the methods was 0.65 (95% CI 0.54-0.74). Method comparison of PDC angle to midline measurements is presented in Table IV, also with the 2 centers separated.

The panoramic and CBCT measurements were performed by the same radiologist, who after 2 weeks repeated classification of the PDC sector position in 49 randomly selected patients and measurement of

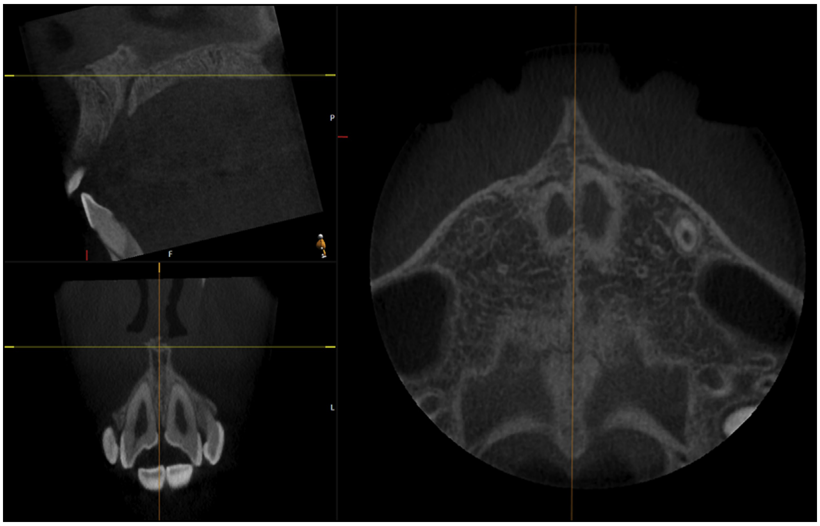

**Fig 5.** The section on the right illustrates the sagittal plane, the left top section illustrates the sagittal line, and the left bottom section illustrates the frontal line in CBCT scans.

**Table III.** Distribution of the PDCs in sector positions I-V, between panoramic radiographs and CBCT scans

| | | *CBCT* | | | | | |
|---|---|---|---|---|---|---|---|
| | *Sector* | *I* | *II* | *III* | *IV* | *V* | *Total* |
| Pano | I | | | | | | 0 |
| | II | | 4* | 1 | | | 5 |
| | III | 1 | 15 | 12* | | | 28 |
| | IV | | 1 | 14 | 13* | 1 | 29 |
| | V | | | | 2 | | 2 |
| Total | | 1 | 20 | 27 | 15 | 1 | 64 |

*Total agreement. The agreement for PDC sector position between the panoramic radiographs and CBCT scans was 0.36 (95% CI 0.24-0.49), as estimated by weighted kappa.

**Table IV.** Repeatability between first and second PDC sector position measurements in panoramic radiographs

| | | *Pano 2* | | | | | |
|---|---|---|---|---|---|---|---|
| | *Sector* | *I* | *II* | *III* | *IV* | *V* | *Total* |
| Pano 1 | I | | | | | | 0 |
| | II | | 5* | | | | 5 |
| | III | | | 19* | | | 19 |
| | IV | | | | 23* | | 23 |
| | V | | | | | 2* | 2 |
| Total | | 0 | 5 | 19 | 23 | 2 | 49 |

*Total agreement. The repeatability for PDC sector position in panoramic radiographs was estimated by weighted kappa to be 1.0.

**Table V.** Repeatability between first and second PDC sector position measurements in CBCT scans

| | | *CBCT 2* | | | | | |
|---|---|---|---|---|---|---|---|
| | *Sector* | *I* | *II* | *III* | *IV* | *V* | *Total* |
| CBCT 1 | I | | | | | | 0 |
| | II | | 11* | 3 | | | 14 |
| | III | | 1 | 19* | 1 | | 21 |
| | IV | | | 2 | 11* | | 13 |
| | V | | | | 1 | | 1 |
| Total | | 0 | 12 | 24 | 13 | 0 | 49 |

*Total agreement. Repeatability for PDC sector position in CBCT scans was estimated by weighted kappa to be 0.80 (95% CI 0.67-0.93).

the PDC angle in 29 randomly selected patients. The repeatability of PDC sector position was in total agreement: weighted kappas 1.0 in panoramic radiographs and 0.80 (95% CI 0.67-0.93) in CBCT scans (Table III). The repeatability of PDC angle measurements in panoramic radiographs and in CBCT scans, measured with the use of Lin CCC, was 0.98 (95% CI 0.97-0.99) in panoramic radiographs and 0.97 (95% CI 0.93-0.98) in CBCT scans (Table IV). To evaluate possible differences in repeatability between the measurements in the radiographs from the 2 different departments, Lin CCC was measured for angle to midline (Tables VI and VII). In the panoramic radiographs, CCC for the angle to midline was 0.99 (95% CI 0.96-1.0) in center I and 0.98 (95% CI 0.95-0.99) in center II. In the CBCT scans CCC for the angle to midline was 0.96 (95% CI 0 0.89-0.99) in center I and 0.97 (95% CI 0.92-0.99) in center II.

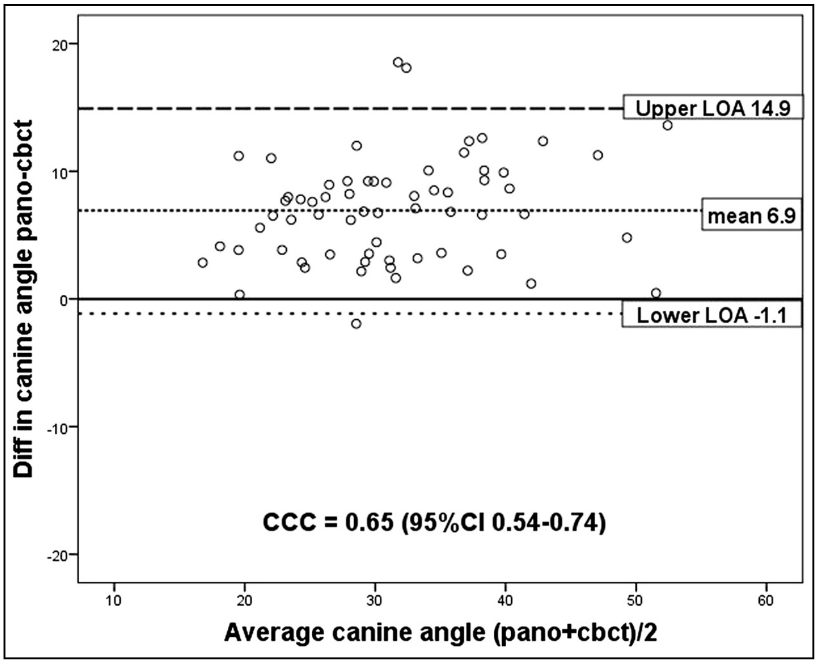


**Fig 6.** Bland-Altman plot with limits of agreement (LOAs), illustrating differences in PDC angular measurements between panoramic radiographs and CBCT scans. The solid line represents a difference of 0, the middle dashed line represents the mean of the differences, the upper dashed line represents the upper LOA (mean + 1.96 SD of the differences), and the lower dashed line represents the lower LoA (mean − 1.96 SD of the differences). The Lin concordance correlation coefficient (CCC) for correlation between the methods is 0.65 (95% CI 0.54-0.74).

**Table VI.** Method comparison in canine angulation to midline measurements between panoramic radiographs and CBCT scans, together and by center

| | | | | | | Pano–CBCT | |
|---|---|---|---|---|---|---|---|
| *Center* | *n* | *Pano* | *CBCT* | *Mean difference (95% CI)* | P *value* | *LOA* | *CCC (95% CI)* |
| All | 64 | 34.8 ± 8.7 | 27.9 ± 7.9 | 6.9 (5.9-7.9) | <0.01 | −1.1 to 14.9 | 0.65 (0.54-0.74) |
| Center I | 47 | 35.0 ± 9.3 | 27.5 ± 8.1 | 7.5 (6.2-8.8) | <0.01 | −1.0 to 16.0 | 0.64 (0.50-0.74) |
| Center II | 17 | 34.3 ± 6.6 | 29.0 ± 7.5 | 5.3 (3.9-6.7) | <0.01 | −0.1 to 10.7 | 0.71 (0.49-0.85) |

## DISCUSSION

The results of this study show that both PDC sector position and angle to midline had systematically higher values in panoramic radiographs compared with CBCT scans. The agreement of sector position between the panoramic radiographs and the CBCT scans was fair (weighted kappa 0.36). The majority of PDCs were in a more mesial sector position, and their angle to midline was on average 6.9° higher in panoramic radiographs compared with the CBCT scans. Also, the PDC angle has shown correlation with sector position in panoramic radiographs, which is why the higher angle per se could push the PDC into a higher sector.[11] The differences in the mesiodistal aspect (ie, sector) and angulation to midline between panoramic radiographs and CBCT scans in the present study somewhat aggravate the position of the PDC in panoramic radiographs in relation to the CBCT scans. An average difference in angle to midline of ~7° between the modalities is quite small, and the differences were from −1.1° to 14.9° in 95% of the cases. The disagreement in sector values, where agreement was found in only 45% of cases and a more severe sector position was found in 52% of cases in panoramic radiographs, confirms the slight difference.

Haney et al[26] and Botticelli et al,[25] among others,[15,27] studied agreement among evaluators who compared canine position in buccally and palatally displaced

**Table VII.** Repeatability in canine angulation to midline measurements, between panoramic radiographs and CBCT scans; all together and according to center

| *Method and center* | *n* | *Measure 1* | *Measure 2* | *Measure 1 vs 2, CCC (95% CI)* |
|---|---|---|---|---|
| Panoramic radiography | | | | |
| All | 29 | 34.7 ± 8.2 | 35.3 ± 7.9 | 0.98 (0.97-0.99) |
| Center I | 12 | 35.3 ± 10.2 | 35.7 ± 9.5 | 0.99 (0.96-1.00) |
| Center II | 17 | 34.3 ± 6.6 | 35.1 ± 6.9 | 0.98 (0.95-0.99) |
| CBCT | | | | |
| All | 29 | 28.7 ± 7.9 | 29.7 ± 8.5 | 0.97 (0.93-0.98) |
| Center I | 12 | 28.4 ± 8.8 | 29.7 ± 9.6 | 0.96 (0.89-0.99) |
| Center II | 17 | 29.0 ± 7.5 | 29.7 ± 7.9 | 0.97 (0.92-0.99) |

canines together between conventional radiographs and static CBCT images (no software provided). Haney et al did not find any statistically significant difference between conventional radiographs and CBCT scans, when evaluators judged mesiodistal canine cusp location (ie, sector) in 25 maxillary impacted canines. Botticelli et al found an agreement between evaluators of 70% in canine overlap with the lateral incisor (ie, sector) among the studied 39 canines, but the disagreement reflected a larger overlap in the CBCT scans. This is contradictory to the results in the present study, which showed a lower sector in the CBCT scans. In the studies conducted by Botticelli et al and Haney et al, numerous canines were localized buccally or centrally, respectively, which could explain the contradictory results.

Alqerban et al,[30] who studied agreement between evaluators in buccally and palatally displaced canines together and their angle to the midline in 2 CBCT systems and panoramic radiographs, found a statistical difference between the panoramic radiographs (mean angle 24°) and the Scanora scans (mean angle 14.5°), but not between the panoramic radiographs and the Accuitomo scans (mean angle 25°). The values of mean angle to midline were higher in our material, ∼35° in the panoramic radiographs and ∼28° in the CBCT scans, which might reflect the population differences and the fact that our sample consisted exclusively of PDCs. Alqerban et al suggested that the mean angle to midline value in the Accuitomo scans in their study might be the result of the smaller FOV in the Accuitomo system, because of difficulty in accurate determination of the midline. The CBCT volumes in the present study, though, were from an Accuitomo system or an i-CAT unit, and it was possible to determine the midline (Table II) in all cases. It is not likely that the radiographic machines in the 2 centers had any impact on the results in the present study. The average angulation to midline between panoramic radiographs and CBCT scans and between centers indicated a somewhat higher measurement error in center I for higher angulations values, but this difference may well be explained by chance (Tables VI and VII).

The findings in the present study of overestimations of both PDC sector and angle in panoramic radiographs may result in an illusion of a more severe case, with the PDC appearing to be closer to midline and farther from its correct position in the panoramic radiographs. When clinicians are aware of the quite modest degree of overestimation in PDC position in a panoramic radiograph compared with a CBCT scan, it may hopefully result in fewer routine CBCT scans. This would be in accordance with the recommendation by Soumalainen et al,[16] who sorted out advantages and disadvantages of the 2 modalities, and concluded that panoramic and intraoral radiographs are still the basic imaging methods in dentistry, and that CBCT scans should be used in more demanding cases. Also a recently conducted systematic review[31] found lack of evidence to support CBCT as the first imaging method in the decision-making process.

No sample size calculation was done before this study, but the sample enabled a detection of a 5° (SD 8°) difference with a power >90% at an alpha level of 5%.

This study had a prospective design, and all the radiographs were taken by radiographers under standardized conditions at radiology departments, with both panoramic radiographs and CBCT scans taken at the same time point, which made it possible for a more exact evaluation between the 2 methods. However, although this study had a larger sample than most of the studies evaluating both buccally and palatally displaced canines together,[15,25-27] an even larger sample with a larger spread in position of the PDC could possibly have strengthened our results.

## Clinical implications

3D images, such as those produced by CBCT, allow more precise localization of impacted canines.[17] Information on the exact position of the crown is often relevant when performing surgical exposure, if the orthodontist and the surgeon need to localize both crown and apex to define the vector of traction[32] or for removal of the impacted canine. When root resorptions are considered, CBCT scans are superior to conventional radiographs because of the ability to show buccopalatal and axial sections.[30] However, when it comes to early interceptive treatment of PDCs, it is often enough to use panoramic and intraoral radiographs.

## CONCLUSIONS

1. The results in this study showed a systematically more severe PDC position in panoramic radiographs compared with CBCT scans, but clinically the differences may be considered quite modest.
2. This knowledge should be used to minimize the use of routine additional CBCT scans.
3. Panoramic radiographs could be considered good enough for rendering PDC position when the need for 3D information is not crucial for treatment planning.

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