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Diagnostic accuracy of conventional orthodontic radiographic modalities and cone-beam computed tomography for localization of impacted maxillary canine teeth

Behzad Salari[1], Maryam Tofangchiha[2,3], Parviz Padisar[4], Rodolfo Reda[5], Alessio Zanza[5] and Luca Testarelli[5]

[1]Department of Orthodontics, School of Dentistry, Tehran Medical Sciences Islamic Azad University, Tehran, Iran
[2]Dental Caries Prevention Research Center, Qazvin University of Medical Sciences, Qazvin, Iran
[3]Department of Oral and Maxillofacial Radiology, School of Dentistry, Qazvin University of Medical Sciences, Qazvin, Iran
[4]Department of Orthodontics, School of Dentistry, Qazvin University of Medical Sciences, Qazvin, Iran
[5]Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, Rome, Italy

Abstract

Background: Orthodontic treatment planning for an impacted canine tooth requires accurate information about its position. The aim of this study was to compare the diagnostic accuracy of two conventional orthodontic radiographic modalities with cone-beam computed tomography (CBCT) for localization of impacted maxillary canine teeth.

Materials and Methods: Panoramic radiographs, lateral cephalograms, and CBCT scans of 30 patients with unilaterally impacted maxillary canine teeth were retrieved from the archives.

Corresponding authors:
Rodolfo Reda, Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, Via Caserta 6, 00161, Rome, Italy.
Email: rodolforeda17@gmail.com

Maryam Tofangchiha, Dental Caries Prevention Research Center, Qazvin University of Medical Sciences, Qazvin, Iran.
Email: mt_tofangchiha@yahoo.com

Eight expert orthodontists evaluated the parameters related to the location of impacted canine teeth by using panoramic radiographs and lateral cephalograms of patients. After 4 weeks, the same parameters were evaluated on CBCT scans of patients. The diagnostic accuracy of conventional modalities and CBCT was compared with each other and also with the gold standard.
Results: The conventional radiographic modalities and CBCT had similar accuracy for assessment of the overall inclination ($p = 0.11$), apex morphology ($p = 0.18$), and mesiodistal position of the apex ($p = 0.12$). CBCT had significantly higher accuracy for determination of incisal tip location ($p = 0.001$), labiopalatal ($p = 0.001$) and vertical ($p = 0.01$) position of the crown tip, minimum bone thickness covering the crown ($p = 0.001$), and root resorption of the adjacent tooth ($p = 0.001$).
Conclusion: The combination of panoramic radiographs and lateral cephalograms was sufficiently accurate to assess some diagnostic parameters such as overall inclination, apex morphology, and mesiodistal apex location of impacted canine teeth.

Keywords
Impacted canine, cone-beam computed tomography, radiography, panoramic, cephalometry

Introduction

Eruption of a permanent tooth is expected upon formation of more than three-quarters of its root.[1] Impaction is defined as the failure of a tooth to erupt during or after its chronological age of eruption. Impaction of maxillary canine teeth is encountered in approximately 5% of patients seeking orthodontic treatment.[2] Maxillary canine teeth are the second most commonly impacted teeth after third molars.[3] Genetics and tooth size-arch length discrepancy have been reported as the main etiological factors for canine impaction.[4] Orthodontic treatment planning for an impacted canine is complicated and depends on its inclination, angulation, position, impaction depth, and bone density, among other factors.[5,6] It has been reported that 9 to 10 years of age is the proper time to anticipate canine impaction. At this time, the canine tooth begins its long intra-alveolar path to erupt into the oral cavity, and the primary canine root starts to resorb.[7]

The success of treatment of impacted canine teeth is influenced by the patient's age and degree of impaction.[8] Early extraction of the primary canine may correct the ectopic eruption path of permanent canine and prevent its impaction.[9] The prognosis of treatment is less favorable in case of horizontal angulation or a high degree of overlap between the impacted canine and lateral incisor.[10] If prevention or early interception is not possible, the clinician should surgically expose the impacted canine and apply orthodontic force to bring it into occlusion.[6] The accurate position of the crown and apex of the impacted tooth relative to the adjacent structures should be taken into account in treatment planning for impacted teeth.

Conventional two-dimensional (2D) radiographic modalities such as panoramic radiography, periapical radiography, occlusal radiography, and lateral cephalometry have been used for localization of impacted teeth, and assessment of the adjacent structures and barriers against their eruption in orthodontic practice. The accuracy of these radiographic modalities for the localization of impacted canine teeth is affected by the inherent limitations of 2D radiographic modalities such as superimposition, distortion, and magnification.[11] Three-dimensional (3D) imaging modalities such as cone-beam computed tomography (CBCT) do not have most of the limitations of conventional radiographic

modalities. Although CBCT has a high-resolution, short image acquisition time, and relatively low radiation dose (compared to medical computed tomography), it has a higher radiation dose and cost than the conventional 2D radiographic modalities.[12] CBCT is increasingly used for accurate localization of impacted canine teeth and estimation of the risk of root resorption in adjacent incisors.[13–15]

For long, conventional radiographic modalities have been applied for diagnosis and orthodontic treatment planning of impacted canine teeth. However; they are gradually replaced with CBCT.

Previous studies compared the accuracy of different combinations of convectional radiographic modalities (panoramic and occlusal, vertical and horizontal parallax, or panoramic, periapical and occlusal radiographs) with CBCT.[16–19] However, only a few studies compared the combination of panoramic radiographs and lateral cephalograms (as commonly requested orthodontic radiographs) with CBCT. Currently, it is unclear whether this combination is accurate enough for diagnosis and treatment planning of impacted maxillary canine teeth when CBCT is not available.

Thus, the aim of this study was to compare the diagnostic accuracy of conventional orthodontic radiographic modalities (combination of panoramic radiographs and lateral cephalograms) and CBCT for evaluation of parameters related to the location of impacted maxillary canine teeth.

Materials and methods

In this cross-sectional study, CBCT images of 30 patients with unilaterally impacted maxillary canine teeth (19 females and 11 males, with a mean age of 16.4 years) were retrieved from the archives (16 teeth with palatal and 14 teeth with buccal impaction). The CBCT scans had been taken with a small field of view and similar voxel size. The enrolled patients had also digital panoramic radiographs and lateral cephalograms in their medical records. The 2D and 3D records had to be taken within 12 weeks or less.

The study was designed according to the concept and methodology of previous studies.[15,20,21] A valid questionnaire was designed to assess the parameters related to the location of impacted canine teeth (Table 1). Eight expert orthodontists were asked to fill out the questionnaire according to the 2D records (panoramic radiographs and lateral cephalograms) of patients. A PowerPoint presentation of the radiographs of each patient was prepared in the "show only" mode of Microsoft PowerPoint software and presented to the observers on a single monitor to minimize visual errors (Figures 1 and 2). After 1 month, the observers were asked to fill out the previous questionnaire according to the CBCT scans of the same patients. For this purpose, the sagittal, coronal, and axial CBCT sections of impacted canine teeth were presented to all observers in the same manner in a slideshow. The correct answers were determined by an expert oral radiologist according to CBCT records of impacted teeth. All the records and answers were coded for the examiners, analyzers, and observers for blinding purposes. Data obtained from the primary and second assessments (2D and 3D image assessments) were compared with each other and also with the answers of an expert oral radiologist as the gold standard. Data were analyzed by the McNemar and Chi-square tests and kappa statistics at $p < 0.05$ level of statistical significance.

Table 1. The factors related to the impacted canine in the questionnaire.

Parameter	Choice A	Choice B	Choice C	Choice D	Choice E
Apex location	Between the incisor teeth and first bicuspid	Above the first bicuspid	Above the second bicuspid	Undetectable	-
Incisal tip location (vertical)	Between the incisal edge and CEJ of the adjacent tooth	Between the CEJ and the middle of adjacent root	Between middle of adjacent incisor root and its apex	Undetectable	-
Overall inclination	0°-15° relative to the dental midline	16°-30° relative to the midline	31°-60° relative to the midline	>61° relative to the midline	Undetectable
Mesiodistal overlap of incisal tip with adjacent incisor	No overlap	Less than the mesiodistal width	More than the mesiodistal width without covering the entire root	Complete overlap or more	Undetectable
Labiopalatal crown location	Palatal	Labial	Undetectable	-	-
Root resorption of the adjacent incisor	No resorption	Slight resorption of dentin	Less than half of the dentin width	More than half of the dentin width	Undetectable
Minimum covering bone	Less than 3mm	3 to 6mm	more than 6mm	Undetectable	-
Apex morphology	Open apex	Normal anatomy	Blunted	Dilacerated	Undetectable

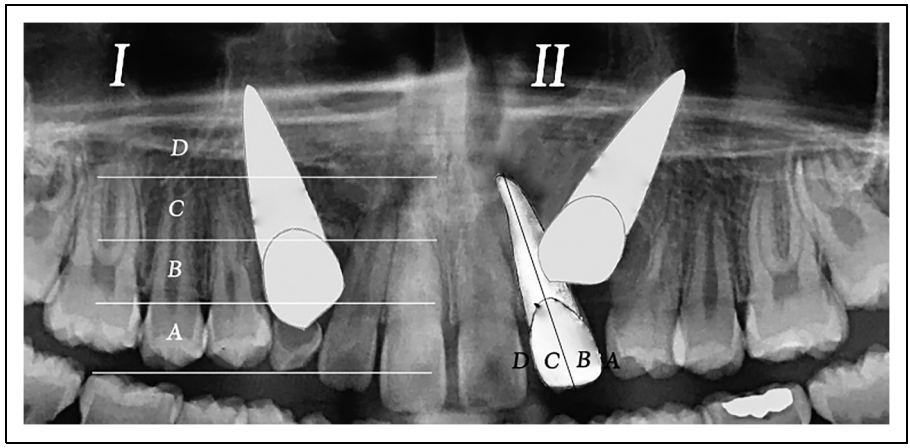

Figure 1. (a) Vertical location of incisal tip on a panoramic radiograph based on the sectors. (b) Mesiodistal overlap of the incisal tip with the adjacent incisor on a panoramic radiograph based on the sectors.

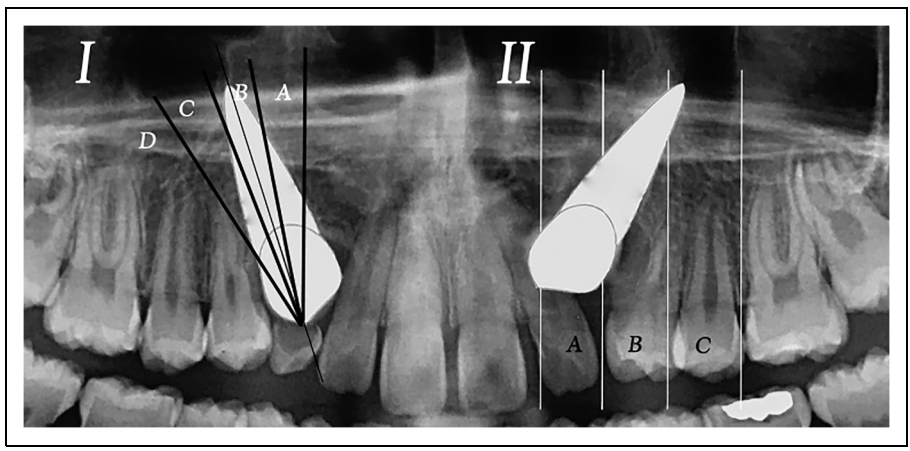

Figure 2. (a) Overall inclination of an impacted tooth relative to the line drawn parallel to the dental midline on a panoramic radiograph. (b) Apex location of an impacted canine based on the sectors.

Results

Overall inclination of impacted canine teeth

No significant difference was found between the two groups of images in the estimation of the overall inclination of impacted canine teeth relative to the dental midline ($p = 0.11$). The kappa coefficient of agreement of the observers for 2D and 3D images was

70% for this parameter. As compared with the gold standard, 2D and 3D radiographic modalities had the same number of correct answers (Table 1).

Apex location (mesiodistally)

No significant difference was noted in the determination of the mesiodistal apex location ($p = 0.12$). The kappa coefficient of agreement of the observers for 2D and 3D radiographic modalities was 72% for this parameter.

Incisal tip location (mesiodistally)

A significant difference was found between the application of 2D and 3D modalities for the assessment of the incisal tip location relative to the adjacent tooth ($p = 0.001$). The kappa coefficient of agreement of the observers was 70% for this parameter. The total number of correct answers was higher for CBCT images.

Palatal or labial position

There was a significant difference between the two groups in the assessment of this parameter ($p = 0.00$). The kappa coefficient of agreement was 78% for this parameter. The answers based on CBCT images were more accurate than 2D images.

Root resorption

There was a significant difference between the application of 2D images and CBCT scans for detection of root resorption in the adjacent incisors ($p = 0.001$). The kappa coefficient of agreement of the observers was 79% for this parameter. As compared with the gold standard, CBCT was more accurate than the combination of panoramic radiographs and lateral cephalograms (Table 2).

Covering bone thickness

A significant difference was observed between the two groups of radiographic modalities in measuring the minimum bone thickness covering the impacted tooth ($p = 0.001$). The kappa coefficient of agreement of the observers was 46% for this parameter. CBCT was more accurate than the combination of panoramic and lateral cephalometric radiographs.

Vertical incisal tip location

A significant difference was observed between the two groups in the localization of the vertical position of impacted teeth ($p = 0.01$). The kappa coefficient of agreement of the observer was 68% for this parameter.

Table 2. Summary of the results: level of agreement, *p*-value calculated with the McNemar–Bowker test and description of the diagnosis based on the combination of 2D radiographies.

Parameter	*p*-value	Percentage of Agreement	Description of the diagnosis based on 2D modalities
Incisal tip location (vertical)	0.01	68	Tendency to locate the crown apically
Apex morphology	0.18	56	Indicated similar variation with CBCT
Apex location (mesiodistal)	0.12	72	Indicated similar variation with CBCT
Minimum covering bone	0.001	46	Indicated more variation than CBCT
Root resorption	0.001	79	Tendency to underestimate the root resorption
Overall inclination	0.11	70	Indicated similar variation with CBCT
Incisal tip location (mesiodistal)	0.001	70	Tendency to underestimate the overlap
Palatal or labiol location of crown	0.001	78	Tendency to locate crown palatally

Apex morphology

No significant difference was seen between the two groups regarding this parameter ($p = 0.18$). The kappa coefficient of agreement of the observers was 56% for this parameter. As compared with the gold standard, the two groups of radiographic modalities had the same percentage of correct answers (Table 2).

Discussion

The current results regarding the accuracy of identification of tip location were in agreement with previous studies.[17,22] In the present study, the conventional radiographs overestimated the tip location. In other words, the observers reported greater incisor overlap when using a combination of panoramic radiographs and lateral cephalograms for assessment of impacted canine teeth. Similarly, another study advised the clinicians not to assess this parameter solely based on 2D images.[21] The lower accuracy of these 2D radiographic modalities for the assessment of this parameter could be attributed to projective displacement and geometric distortion.[23]

The interobserver agreement for canine inclination in the current study was similar to the results of a previous study.[24] Some others reported the same findings for a different combination of 2D radiographic modalities (panoramic radiographs, lateral cephalograms, and periapical radiographs). This finding implies that the lack of a periapical image in the current combination of imaging modalities did not significantly affect the diagnosis.[25] Padisar et al.[21] reported a lower interobserver agreement for this parameter in patients with alveolar cleft. This finding could be attributed to the parameters that complicate a correct diagnosis in such patients such as impaired anatomy and superimposition of structures over the cleft site. Haney et al.,[26] also reported similar results for this

parameter by comparing conventional imaging modalities and CBCT. In contrast, some others reported lower accuracy of panoramic radiography when used as the sole 2D imaging modality.[27]

Botticelli et al.[25] showed a significant difference between 2D and 3D radiographic modalities applied for the detection of the vertical position of the apex. This finding was in line with the current results that revealed superior accuracy of CBCT for this purpose. Some authors reported smaller differences between 2D and 3D radiographic modalities,[21] which may be attributed to the malposition of permanent teeth and supernumeraries in the cleft site that cause radiographic superimposition and complicate the assessments based on 2D images.[11] Accurate determination of this parameter is critical for a favorable prognosis.

Accurate determination of the labiopalatal position of the impacted tooth crown is important for both surgeons and orthodontists. The present results showed that CBCT was more accurate for the determination of this parameter both clinically and statistically. Haney et al.[26] reported significantly higher interobserver agreements compared with the rates reported in the current study, which might be attributed to using a different combination of 2D images in their study (occlusal and panoramic radiographs and lateral cephalograms). The observers in the current study tended to report the position of impacted canines palatally when using the conventional radiographic modalities. Botticelli et al.[25] mentioned that the labiopalatal location of the apex is more important than the labiopalatal location of the crown for orthodontic treatment planning of impacted canine teeth. Replacement of 2D conventional radiographic modalities with 3D images could considerably increase the accuracy of assessment of this parameter.[28,29]

In line with the current results, another study reported that a combination of 2D radiographic modalities should not be used for detection of root resorption.[30] The observers tended to underestimate root resorption as they used a combination of panoramic radiographs and lateral cephalograms for this purpose. Another study showed that expert clinicians could not detect resorptions smaller than 0.5 mm on 2D images.[31] Kalavritinos et al. found lateral root resorption in 18.5% of the cases with maxillary canine impaction by using CBCT.[32]

Consistent with previous reports, the present study indicated that CBCT had higher accuracy for the determination of the vertical position of the incisal tip.[25,33] The observers tended to report the position of impacted canines more apically when using the conventional radiographic modalities. Although a combination of panoramic radiographs and lateral cephalograms was presented to the observers in the present study, the interobserver agreement was close to the rate reported in a study that used a combination of periapical, panoramic, and occlusal radiographs.[26] A similar result but with a lower interobserver agreement was reported in patients with alveolar cleft21.

Relatively high variability was found regarding the apex morphology. Kapila and Nervina[34] proposed that the 3D sections could directly affect the assessment of apex morphology. The exposure settings and receptor quality could affect the assessment of apex morphology as well.

The present data showed that CBCT was more accurate for the determination of bone thickness covering the impacted canine teeth. Vera et al.[35] stated that CBCT may be applied as a reliable modality for the determination of alveolar bone width. The low

coefficient of agreement for this parameter could be attributed to the inherent weakness of 2D radiographs in visualizing the bone thickness over the impacted teeth. In contrast, Rosenstein et al.[36] reported no significant difference between 2D and 3D modalities in patients with alveolar graft, which could be attributed to the different study design since they used periapical and occlusal radiographs instead of panoramic radiographs and lateral cephalograms for their assessment.

Conclusion

The conventional orthodontic radiographic modalities may serve as an accurate diagnostic tool for the determination of apex morphology, apex location, and overall inclination of impacted maxillary canine teeth. However, CBCT had higher accuracy for the determination of other parameters related to impacted maxillary canine teeth.

Declaration of conflicting interests

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ORCID iDs

Rodolfo Reda https://orcid.org/0000-0003-1532-6524
Luca Testarelli https://orcid.org/0000-0003-3904-3000

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Author biographies

Behzad Salari is an orthodontist and an assistant professor of Orthodontics in Islamic Azad University, Tehran Medical sciences. His area of research is acceleration of orthodontic tooth movement, and clear aligner therapy.

Maryam Tofangchiha is a professor in Oral and Maxillofacial Radiology. Her area of research is root canal therapy, oral radiology, and maxillofacial imaging.

Parviz Padisar is a professor in Orthodontics. His area of research is maxillary canine, and malocclusion.

Rodolfo Reda is a prosthodontist and a PhD at Sapienza University. He is also an affiliate associate professor, University of Medicine, Tirana and distinguished adjunct professor at Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS). He is

also a clinical collaborator of the Polyclinic Campus Biomedico in Rome. Private Practitioner in Rome. His research areas are Prosthesis, dental materials, resin, inflammatory factors, and implant-dentistry.

Alessio Zanza is an endodontist and a PhD at Sapienza University. He is also an affiliate associate professor at University of Medicine, Tirana, and a clinical collaborator of the Polyclinic Campus Biomedico in Rome. Private Practitioner in Rome. His research areas are Ni-Ti rotary instruments, endodontics, oral biology, and bioceramics.

Luca Testarelli is an associate professor of Dental Restorative and Endodontics at Sapienza University of Rome, and Oral Care in School of Dental Hygienist in Sapienza University of Rome since 2006. His research areas are cross-infection control in Dentistry, experimental in vitro and in vivo evaluation of dental materials used in endodontic practice, particularly related to nickel-titanium rotary instruments, sealers and irrigants, experimental in vitro and in vivo evaluation of dental materials for dental hygienists, implantology, and 3D dental radiology.