Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: A systematic review of comparative studies

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Introduction: We systematically reviewed observational, experimental, and diagnostic accuracy studies to assess the comparisons between cone-beam computed tomography (CBCT) and conventional radiography (CR) in the localization of maxillary impacted canines. **Methods:** An open-ended electronic search of PubMed, Web of Science, ProQuest, and other databases for both published and unpublished articles up to May 2016 was performed. The reference lists of the included studies were screened. Two authors performed the searches with no language restrictions. The research questions were outlined based on a hierarchical model. The primary outcomes were diagnostic accuracy, level of intermodalities agreement, effect of these images on treatment planning and treatment outcomes, and societal efficacy between the CBCT and CR in the localization of impacted canines. Two reviewers evaluated the risk of bias assessment by using the Quality Assessment of Diagnostic Accuracy Studies tool and the Newcastle Ottawa Scale. **Results:** Eight studies met the inclusion criteria. Two studies reported diagnostic accuracy, 6 reported intermodalities agreement in impacted canine localization, and 3 reported treatment planning agreement between the modalities. No therapeutic and societal efficacy study found. The accuracy of CBCT ranged from 50% to 95%, and the accuracy of CR ranged from 39% to 85%. A wide range of kappa intermodalities agreement from 0.20 to 0.82, with observed agreement of 64% to 84%, was reported in canine localization. Broad kappa treatment planning agreement values from 0.36 to 0.72 were reported. Most studies suffered from a high risk of bias in subject selection. **Conclusions:** The fair to moderate intermodalities agreement in maxillary canine localization might mean that the information obtained through these modalities is deviant and ultimately might affect treatment planning. Although there is still a lack of strong evidence, CBCT is more effective than CR in evaluating cases that are difficult to diagnose in the initial evaluation with CR. **Funding:** No funding was received for this study. (Am J Orthod Dentofacial Orthop 2017;151:248-58)

Maxillary canines are the second most common teeth (after the third molars) with a tendency for impaction and ectopic eruption. The prevalence ranges from 1% to 3%.[1-5] Aside from creating esthetic and functional issues, canine impaction may also create root resorption of neighboring teeth, which may then necessitate orthodontic and surgical intervention.[6] Determining the correct location of impacted canines and their relationship to the adjacent dentition and anatomic structures is essential for successful orthodontic treatment.

Various diagnostic methods are used to localize impacted teeth. The techniques allow for the practitioner to predict the difficulty of orthodontic treatment, the duration of treatment, and possible treatment options (including observation, interceptive treatment by extracting the deciduous canines,[7] simple surgical exposure or surgical exposure and placement of an

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orthodontic attachment,[8] auto transplantation,[9] and canine extraction). The diagnostic process begins with a clinical examination and palpation of alveolar bone followed by radiographic assessments.[4,5,10-12]

Despite the historical use of 2-dimensional (2D) conventional radiographs, 2 inherent drawbacks limit the information obtained: anatomic superimposition and geometric distortion. The resulting poor visibility and misrepresentation of structures may ultimately affect the localization and treatment planning of maxillary impacted canines. As a result, many practitioners have resorted to 3-dimensional (3D) imaging technology.[13-15]

Cone-beam computed tomography (CBCT) was specifically developed for 3D imaging of the head and neck.[16,17] Moreover, 2D multiplanar images reconstructed from CBCT volumetric data sets can navigate through submillimeter slices in the axial, coronal, and sagittal planes.[18] However, the benefit-to-risk assessment of CBCT imaging is still controversial. Although CBCT exposes the patient to higher levels of radiation compared with conventional modalities, the long-term effects of excessive ionizing radiation above background levels of ionizing radiation remain unknown.[19,20] Recent risk estimates have reported higher cancer rates based on current exposure levels.[21-23] As a result, evidence-supported criteria to ensure the responsible application of CBCT should be weighed against the biologic and financial costs to the patient.

Some studies have reported that CBCT imaging is clearly advantageous in the management of impacted canines.[3,24] Other studies have reported that CBCT allows orthodontists to improve diagnostic capabilities and that it is more accurate at localizing maxillary impacted canines.[25,26] However, we could not find any comparative systematic review that evaluated the difference in the information yielded between CBCT and conventional imaging in their localization of maxillary canine impaction, the efficacy of these approaches in treatment planning, and their treatment outcomes.

In this study, we aimed to systematically review whether there is any difference in the diagnostic accuracy, the level of intermodalities agreement in impacted canine localization, treatment planning, and therapeutic and societal efficacy between CBCT and conventional radiograph imaging.

MATERIAL AND METHODS

The research questions were outlined based on the 6-tiered hierarchical model by Fryback and Thornbury.[27] Therefore, according to clinical usefulness in the decision-making process, we investigated responses to the following questions.

Table I. Key words based on details in databases

Database	Key words
PubMed: up to May 28, 2016	((“Cone-Beam Computed Tomography”[Mesh] OR cone beam computed tomography OR CBCT) AND (“Radiography, Panoramic”[Mesh] OR “Cephalometry”[Mesh] OR conventional imaging OR traditional imaging OR panoramic OR periapical OR cephalogram OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal) AND (canine))
Web of Science: up to May 15, 2016	((“cone beam computed tomography” OR CBCT) AND (conventional OR traditional OR panoramic OR periapical OR cephalogram OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal) AND (canine))
CINHAL: up to May 13, 2016	((“cone beam computed tomography” OR CBCT) AND ((MM “Radiography, Panoramic”) OR (MM “Cephalometry”) OR conventional OR traditional OR panoramic OR periapical OR cephalogram OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal) AND canine))
Cochrane Library: up to May 15, 2016	((“cone beam computed tomography” OR CBCT) AND ((MM “Radiography, Panoramic”) OR (MM “Cephalometry”) OR conventional OR traditional \OR panoramic OR periapical OR cephalogram OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal)) AND canine))
Google Scholar: up to May 10, 2016	((“cone beam computed tomography” OR CBCT) AND (conventional OR traditional OR panoramic OR periapical OR cephalogram OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal) AND (canine)))
ProQuest: up to May 14, 2016	(“cone beam computed tomography” OR CBCT) AND (conventional OR traditional OR panoramic OR periapical OR cephalometry OR “2D image” OR “two dimensional” OR orthopantomogram OR occlusal) AND (canine)

1. What is the difference between the modalities in the accuracy of maxillary impacted canine localization?
2. What is the intermodalities agreement between information obtained by CBCT compared with conventional radiographs for the localization of maxillary impacted canines?
3. What is the level of agreement between the treatment decisions made from CBCT compared with conventional radiographs?
4. What is the difference between the treatment outcomes provided through these modalities?
5. What is the difference between the societal costs incurred with these modalities?

An open-ended electronic search was conducted through PubMed, CINHAL, Web of Science, and Cochrane Library databases up to May 2016 with a wide variety of key words. A search of unpublished literature was also conducted through the Pro-Quest Dissertation Abstracts and Thesis database and Google Scholar by limiting the search by the first 200 hits. Table I provides a detailed summary of the final search key words for each database. A manual search of the included studies' references was performed to supplement the literature search. There were no language restrictions. Also, to improve the reporting of this systematic review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines were followed.[28] No protocol registration was conducted.

The Population, Intervention, Comparison, Outcome and Study design (PICOS) framework was followed. The population was defined as the patients or models who had a maxillary impacted canine with or without neighboring lateral incisor root resorption. The intervention and comparison were respectively defined as the CBCT scan data and conventional (2D) radiographs (panoramic, periapical, occlusal, and cephalograms). The primary outcome was described as the diagnostic accuracy between the modalities, intermodalities agreement in impacted canine localization, treatment planning and outcome efficacy, and societal assessment. The secondary outcome included the intermodalities agreement in lateral root resorption detection and intraobserver and interobserver agreement values. All types of study designs such as observational (other than case reports), experimental, and diagnostic accuracy studies were included.

The included studies compared CBCT imaging with conventional 2D radiographs (panoramic, periapical, occlusal, and cephalograms) in maxillary impacted canine localization (with or without associated features: ie, lateral root resorption) that reported any of the following.

1. Accuracy, sensitivity, or specificity between the modalities while applying an appropriate reference test such as a simulated model (ex vivo) or surgical exploration (in vivo).
2. The level of intermodalities agreement in localization of the impacted canine.
3. The level of intermodalities agreement in treatment planning.
4. Treatment outcomes (the primary outcome was defined as the treatment outcomes or complications between the modalities that were compared based on prospective or retrospective studies).
5. Societal efficacy (the primary outcome was defined as direct or indirect costs: capital costs, accommodation costs, provider time costs, operational costs, radiologic costs, radiographic costs, overheads, time costs of patients and accompanying persons, and out-of-pocket costs for the examination fee and visit).

In addition, the excluded studieswere those that assessed conventional tomography scans; case reports, reviews, editorials, commentaries, or conference proceedings comparing CBCT scans with 2D radiographs generated from CBCT volumetric data; or reports by observers in the control group (conventional radiographs) who were exposed to the case group (CBCT) results.

The studies found by electronic and manual searches were selected for inclusion independently by 2 authors (E.E., H.B.). The definitive inclusion of a potentially relevant article was decided by consensus. Data extraction was independently performed by the same reviewers. The reviewers extracted data investigating the response to the research questions. The data extraction items were first author, publication year, imaging systems, sample size, scanning parameters for CBCT systems, number of examiners, study design, outcome variables, and corresponding results. Any discrepancies were resolved by discussion and consensus agreement between the 2 authors.

The quality of the studies was evaluated for a risk of bias independently by the same investigators (E.E., H.B.). The Newcastle-Ottawa Scale was used for the assessment of case-control and cohort studies. This scale assesses 3 domains: selection, comparability, and outcome.[29] The Newcastle-Ottawa Scale tool for the cohort studies was modified for the cross-sectional studies. Three of the 9 items, "demonstration that outcome of interest was not present at start of study," "was follow-up long enough for outcomes to occur?" and "adequacy of follow-up," were excluded, because they are not relevant to cross-sectional studies. A study could be awarded a maximum of 1 star for each item of the selection and outcome categories, and a maximum of 2 stars for comparability. The overall quality rating was the sum of the stars (maximum of 9 for case control and cohort studies and 6 for cross-sectional studies).

The Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool was applied to rate the methodologic quality of the diagnostic accuracy studies.[30] This tool consists of 4 key domains: patient selection, index test, reference standard, and flow and timing. The risk of bias was judged as low, high, or unclear.

For the diagnostic studies, accuracy, specificity, and sensitivity outcome variables were reported when available. For the observational studies, any type of agreement between the modalities (Fleiss kappa, Cohen's kappa, logistic regression model, observed agreement, and so on) in terms of localizing the impacted canine and treatment planning were disclosed. In addition, the intraobserver and interobserver agreements for each modality were reported when available. A meta-analysis was not appropriate because of the heterogeneity in the design, type of intervention, study population,

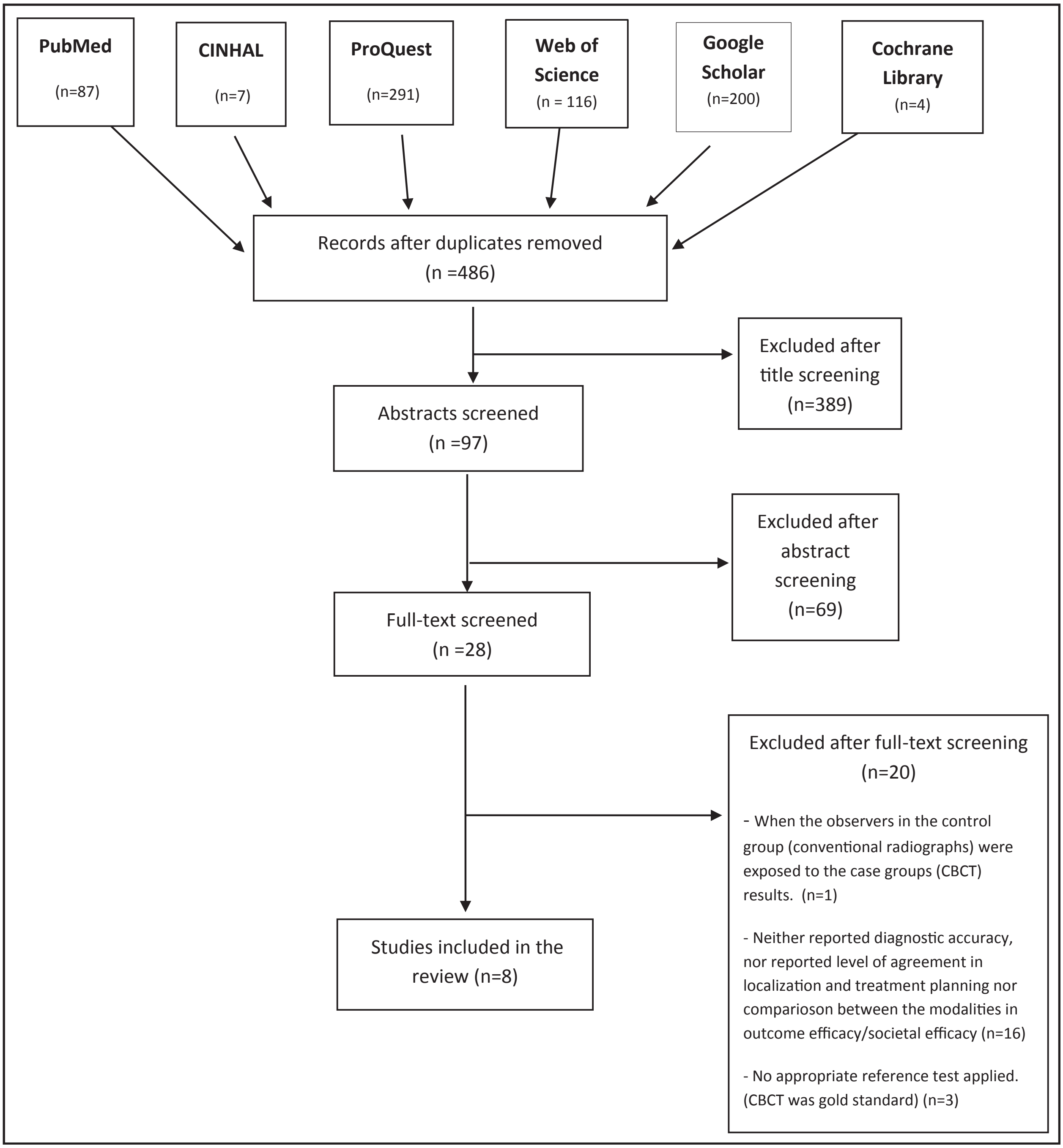

Fig. Flow diagram.

and outcome variables of the included studies. To synthesize and interpret the kappa level of agreement, the kappa classification of Landis and Koch[31] was applied (slight, 0.01-0.20; fair, 0.21-0.40; moderate, 0.41-0.60; substantial, 0.61-0.80; and almost perfect, 0.81-1.00).

RESULTS

The Figure shows the database search and the study inclusions. The initial review included 705 articles. When duplicate results were excluded, 486 review articles remained. No study was added after a manual review. A total of 28 articles were considered potentially eligible after screening of the title and abstract. Upon evaluation of the full texts, 8 of the 28 remaining studies met all inclusion and exclusion criteria.[26,32-38] These studies are listed in Table II.

Table III gives the risk of bias assessment of the observational studies. Most studies had a high risk of selection bias, with some difficult-to-diagnose cases to compare between modalities.[32,34,35,37] Table IV also demonstrates the risk of bias in studies with diagnostically accurate study designs.[26,38]

We looked at diagnostic accuracy between the modalities. Two studies reported the level of accuracy between the modalities. The accuracy of CBCT ranged from 50% to 95%, and the accuracy of conventional radiographs ranged from 39% to 85%. CBCT showed higher accuracy than conventional radiographs (Table V).[26,38]

For the intermodalities agreement in canine localization, 6 studies evaluating various outcome variables for canine localization were finally extracted.[32-37] The outcome variables of these studies were categorized as labiopalatal position, vertical position, mesiodistal position, angular measurements, and position of the impacted teeth in relation to surrounding structures. The studies demonstrated that the information gained from CBCT scans was different from that of conventional radiographs (Table V). There was a statistically significant difference with a wide range of kappa agreement from 0.20 to 0.82 and with observed agreement of 64% to 84% reported between the modalities in canine localization. In addition, in lateral root resorption detection, a broad range agreement was reported (k, 0.3 to 0.65; observed agreement, 63% to 82%). However, although the level of agreement ranged from fair to substantial, only 1 study that applied an inappropriate clinical method reported real agreement above 0.6.[36]

Three studies reported intraobserver agreement. The kappa ranges of intraobserver agreement for conventional radiographs and CBCT were 0.65 to 0.92 and 0.53 to 0.77, respectively (Table V).[26,32,36]

Interobserver agreement was reported in 3 studies. The kappa interobserver agreement was statistically higher for CBCT, 0.50 to 0.68, vs 0.31 to 0.48 for conventional radiographs (Table V).[26,32,33]

Three of the 6 included studies assessed the therapeutic efficacy of CBCT and conventional radiographs. The data demonstrated 70% to 83% agreement, with kappa agreement values of 0.36 and 0.72 (fair to substantial) between the imaging modalities (Table V).[34-36]

No study on patient outcome efficacy and societal efficacy was found.

DISCUSSION

This review provides a comparison of the efficacy between CBCT and conventional radiographs for the assessment of impacted canine localization using the 6-tiered hierarchical model of Fryback and Thornbury[27] (level 1, technical efficacy; level 2, diagnostic accuracy efficacy; level 3, diagnostic thinking efficacy; level 4, therapeutic efficacy; level 5, patient outcome efficacy; and level 6, societal efficacy). Therefore, in this systematic review, we aimed to evaluate accuracy and intermodalities agreement between CBCT and conventional radiographs when used to identify the position of maxillary impacted canines. We also aimed to identify the differences between the 2 imaging modalities with respect to treatment planning, treatment outcomes, and societal efficacy.

A limited number of diagnostic accuracy studies that applied an actual gold standard have been conducted. However, it has been reported that CBCT is more accurate when compared with horizontal, vertical parallax, or a combination of both. Specialty training also affects the amount of information obtained through CBCT and conventional radiographs: radiologists use conventional images more effectively than do orthodontists.[38] In addition, it has been shown that observers had greater complications in diagnosing buccal canines vs palatal ones. The included studies used equal numbers of buccal and palatal canine case simulations, although palatal canine impactions are far more common than buccal canine impactions in the real clinical situation. Therefore, the accuracy of traditional radiographs may be underestimated in these ex-vivo studies.[26,38]

In the assessment of intermodalities agreement, different conventional radiographs methods (panoramic; panoramic and study cast evaluation; panoramic, periapical, and lateral cephalometry; 2 periapicals with different angulations) were compared with CBCT imaging. The kappa agreement has been mainly reported in the included studies. Based on the Landis and Koch[31] kappa classification, almost perfect agreement ($k = 0.82$) was found in only 1 study, in which 2 periapical intraoral images with different angulations were used as the conventional radiograph modality.[36] However, the other investigators who studied conventional radiographs did not provide radiographs taken at multiple angulations. Two studies reported slight to fair agreement (kappa, <0.4) between CBCT and conventional radiographs in localizing the labiopalatal position.[32,34] Nevertheless, the outcomes were heterogeneous in reference to both vertical positions and angular measurements.

Table II. Demographic data of included studies

Author, year	*Imaging systems*	*Sample size*	*Imaging parameters for CBCT systems*	*Examiners*	*Study design*
Serrant et al,[26] 2014	CON: horizontal parallax (periapical), vertical parallax (panoramic and occlusal) CBCT: I-CAT	One extracted tooth mounted in 9 different positions	FOV: 6 cm Scan time: 8.9 sec VS: 0.3 mm	6 4 orthodontists 1 dentist 2 dental and maxillofacial specialists	Diagnostic accuracy
Pittayapat et al,[32] 2014	CON: digital OPG CBCT: 3D Accuitomo 170	38 patients	FOV: 14 × 10 cm kVp:90 mA; 5 Scan time:30.8 sec VS: 0.25 mm	8 3 radiologists 5 orthodontic residents	Observational-cross sectional
Lai et al,[37] 2014	CON: OPG CBCT: Accuitomo XYZ Slice View Tomograph	60 patients (72 impacted canines)	FOV: 4 × 4, 6 × 6 or 8 × 8 cm mA: 5 kV: 80	11 OPG 5 oral surgeons 5 orthodontists CBCT 1 orthodontist	Observational- cross sectional
Wriedt et al,[35] 2012	-CON: OPG -CBCT: Accuitomo	21 patients (29 impacted canines)	FOV: 4 × 4 cm NR	26 10 orthodontists 8 dental surgeons 8 general dentists	Observational -cross sectional
Alqerban et al,[33] 2011	-CON: OPG -CBCT: Accuitomo-XYZ Slice View Tomograph -CBCT: Scanora	-Group A (Accuitomo vs CON): 30 -Group B (Scanora vs CON): 30 Total of 60 patient (89 impacted canines)	Accuitomo-XYZ: VS: 0.125 mm FOV: 3 × 4 cm kV: 80 mA: 3 Scan time: 18 sec Detector type: IIT Scanora: VS: 0.2 mm FOV:75 × 100 mm kV:85 mA:15 Scan time: 3.7 sec	3 experienced dental practitioners	Observational- cross sectional
Botticelli et al,[34] 2011	-CON: OPG, LC, PA -CBCT: NewTom 3G	27 patients (39 impacted canines)	Volumetric rendering method	8 dentists 5 residents 3 specialists with >5 y experience	Observational-cross sectional
Haney et al,[36] 2010	-CON: OPG, occlusal, and 2 periapical -CBCT: MercuRay	18 patients (25 impacted canines)	Volumetric rendering method	7 4 orthodontists 3 oral surgeons	Observational- cross sectional
Herring,[38] 2006	-CON: panoramic, 2 periapical, 2 occlusal. -CBCT: NewTom 3G	10 simulated skulls	FOV: 12 in Slice thickness: 0.5 mm	17 specialists: 11 orthodontists 6 radiologists	Diagnostic accuracy

CON, Conventional; *FOV*, field of view; *OPG*, panoramic; *VS*, voxel size; *NR*, not reported; *LC*, lateral cephalometry; *PA*, periapical.

Table III. Risk of bias assessment according to Newcastle Ottawa Scale

Study	*Selection (of 3 stars)*	*Comparability (of 2 stars)*	*Outcome (of 1 star)*	*Total (of 6 stars)*
Alqerban et al[33]	***	**	*	******
Pittapayat et al[32]	**	**	*	*****
Haney et al[36]	**	**	*	*****
Wriedt et al[35]	**	*	*	****
Lai et al[37]	**	*	*	****
Botticelli et al[34]	*	*	*	***

A wide range of intermodalities agreement was also found in detecting the root resorption of neighboring incisors. The difference in agreement of root resorption detection between the modalities may be related to disparities in the sample populations. Discrepancies in the location, size, and direction of root resorptions may contribute to inconsistency. Ren et al[39] reported a highly significant difference between periapical radiography and CBCT in the detection of mild and moderate root resorption lesions ($P < 0.05$), although severe lesions are easily detectable in both modalities. Also, this search demonstrated that 2D radiographs show hard-to-detect root resorption along the buccolingual root surfaces.

One advantage of CBCT when compared with conventional methods appears to be its reliability, which may affect the intermodalities agreement. Dalessandri et al[10] reported that the intraobserver and interobserver agreement values for 3D CBCT indexes are higher than for 2D measurement indexes. Their results, which agree with the findings of previous studies, demonstrate that CBCT reconstruction provides superior reliability with improved visualization of the impacted maxillary canine.[26] Haney et al[36] reported that observers have greater intraconsistency for conventional radiographs compared with CBCT scans in both impacted canine localization and lateral root resorption detection, although no statistically significant difference was shown. Moreover, for CBCT interpretation, tooth-to-tooth variations might also significantly affect the observers' self-assurance with regard to their specialty training and discipline. However, some studies in our systematic review reported greater differences in statistical significance in CBCT scans than conventional radiographs when measuring interobserver agreement.[32,33] Nevertheless, in this review, the number of included studies that reported intraobserver and interobserver agreement was limited.

According to the 6-tiered hierarchical model of Fryback and Thornbury,[27] only 3 studies were designed with a high level of evidence (therapeutic efficacy, level 4), yet their data differed significantly. Wriedt et al[35] reported below-moderate agreement between CBCT scans and conventional radiographs in treatment planning ($k = 0.36$), whereas CBCT data led to the retraction of premature decisions to extract teeth. Haney et al[36] showed a substantial kappa agreement, although this inconsistency may be the result of the heterogeneity in the clinical methodology.

Although no treatment outcome efficacy study was found, the risk of bias assessment showed that all studies that recruited difficult cases to compare with conventional radiographs had a low level of agreement between the tested radiographic modalities.[32-34,37] One study that examined a sample of consecutive patients (more randomized) showed a superior level of agreement.[36] In agreement with our data, Alqerban et al[25] assessed the treatment outcomes between CBCT and conventional radiographs in maxillary impacted canines. However, since the authors did not directly assess the efficacy of CBCT because the observers in the CBCT group were exposed to conventional radiographs, the study was excluded from this systematic review. However, it was concluded that the use of CBCT improved the chances of success in more difficult cases. In agreement, Wriedt et al[35] reported that more than 25% of canine apices were not identifiable in 2 dimensions, whereas CBCT detected more lateral root resorptions and root dilacerations. Also, they showed that the dilemma of therapeutic decisions based on conventional radiographs arises when canine inclination exceeds 30° relative to the midline. Therefore, a hypothesis might be that CBCT shows better outcome efficacy in complex cases. Nevertheless, adequate evidence is still lacking to

Table IV. Risk of bias assessment according to QUADAS 2

	Risk of bias				*Applicability*		
Study	*Patient selection*	*Index test*	*Reference standard*	*Flow and timing*	*Patient selection*	*Index test*	*Reference standard*
Serrant et al[26]	☹	☺	☺	☺	☺	☺	☺
Herring[38]	☹	☹	☺	☺	☺	☺	☺

☺, Low risk; ☹, high risk.

Table V. Summary of results and quality assessment of studies assessing maxillary canine impaction

Authors	*Outcome variables*	*Results*
Serrant et al,[26] 2014	Intermodalities accuracy:	CBCT (94%), horizontal parallax (83%), vertical parallax (65%) (P <0.01)
	Interobserver agreement:	Cohen weighted kappa = 0.7528
	Intraobserver agreement:	Cohen weighted kappa = 0.8985
Pittayapat et al,[32] 2014	Intermodalities agreement:	CBCT vs OPG: (Fleiss kappa)
	-canine localization (palatal, buccal, middle)	-k = 0.2, 27.7% unidentified in OPG, P <0.0001
	-canine angulation to midline	-k = 0.3, P <0.0001
	-lateral root resorption	-k = 0.3, P <0.0001, unidentified 24% in OPG and 7% in CBCT
	Intraobserver agreement	-3D: k = 0.71, 2D: k = 0.65 P <0.0001. CBCT shows better intra-agreement.
	Interobserver agreement	-3D: k = 0.50, 2D: k = 0.40. P <0.0001
Lai et al,[37] 2014	Intermodalities agreement:	CBCT vs OPG: (Pr agreement)
	-labiopalatal canine localization	-Pr: 0.29, P = 0.04
	-lateral root resoprtion	-Pr: 0.93, P = 0.52 (NSD)
Wriedt et al,[35] 2012	Intermodalities agreement	Between OPG + study cast vs CBCT + study cast: (Cohens k)
	-canine localization (total agreement)	-observed agreement: 64%, k = 0.47 agreement with master findings: CBCT: 0.7, OPG: 0.37
	-therapy proposals (no statement, alignment, osteotomy)	-observed agreement: 82%, k = 0.36. CBCT led to retraction of premature decisions to extract teeth
Alqerban et al,[33] 2011	Angular distances:	2 CBCT vs OPG: (P value)
	-canine angle to lateral incisor	-NSD
	-canine angle to midline	-NSD for A and <0.0001 for B group
	-canine angle to occlusal plane	-0.0101 for A and 0.0010 for B group
	-canine location: palatal, buccal, arch line)	-0.0074 for group A and P = 0.0008 for B
	-root resorption detection	-group A: 53% vs 29%, P = 0.0201 -group B: 50% vs 30%, P <0.001
	Interobserver agreement	
	-canine location	3D: k = 0.63-0.68 2D: k = 0.31
	-lateral root resoprtion	3D: k = 0.63-0.65 2D: k = 0.48 Higher in CBCT
Botticelli et al,[34] 2011	Intermodalities agreement:	CON (PA, LC, OPG) vs CBCT: (observed agreement and Cohen kappa agreement)
	-inclination to midline	-NSD, 74% agreement
	-mesiodistal position of apex	-0.001 (P value): 64% agreement, less variation in apex position in 2D
	-vertical level of crown	-0.013: 66% agreement, higher vertical level in 2D
	-overlap with lateral incisor	-0.001: 70% agreement, less overlap in 2D
	-labiopalatal crown position	-0.001: 68% agreement, more palatal position of crown in 2D, k = 0.3
	-labiopalatal apex position	-0.001: 65%, agreement, more palatal position of crown in 2D, k = 0.2
	-root resorption of neighboring incisor	-0.0001, 82% agreement, k = 0.3, 2D indicated less root resorption
	-treatment choice (deciduous canine extraction, observation, permanent canine extraction, surgical extraction and orthodontics, surgical transplantation)	-0.0008, 70% agreement CBCT leads more orthodontic and surgical intervention; 2D leads observational intervention
Haney et al,[36] 2010	Intermodalities agreement:	Observed and kappa agreement:
	-mesiodistal cusp tip location	-CBCT vs occlusal: 79%, k = 0.76
	-labiopalatal location	-CBCT vs 2 periapical: 84%, k = 0.82, significant difference
	-vertical location	-CBCT vs OPG: k = 0.63
	-root resorption detection	-63%, k = 0.65, P <0.0001
	-treatment plan (extract, leave, recover)	-73% agreement. k = 0.72, <0.0001
	Intra observer agreement	

Table V. Continued

Authors	*Outcome variables*	*Results*
	-canine localization	-2D: k = 0.73-0.92, 3D: k = 0.53-0.77
	-lateral root resorption	-2D: k = 0.73, 3D: k = 0.55
	-treatment planning.	-2D: k = 0.77, 3D: k = 0.64 NSD between 2D and 3D
Herring,[38] 2006	Intermodalities accuracy:	CBCT vs CR: (%)
	Buccopalatal localization- relative to lateral incisor	orthodontists: 95 vs 65 (P <0.0001) radiologists: 90 vs 85 (P <0.4)
	relative to central incisor	orthodontists: 54.5 vs 54.5 radiologists: 50 vs 66.6
	Proximity relative to canine	orthodontists: 60 vs 39 (P = 0.0005) radiologists: 85 vs 40 (P <0.0001)
	Lateral root resorption	orthodontists: 70 vs 48 radiologists: 87 vs 55

OPG, Panoramic; *Pr*, Pearson agreement; *NSD*, nonsignificant difference; *LC*, lateral cephalometry; *PA*, periapical.

definitely argue that 3D imaging necessarily and consistently improves treatment outcomes. Future studies are encouraged to compare the efficacy of CBCT in comparison with conventional radiographs in patients with different levels of complexities.

Although the importance of the diagnostic and therapeutic efficacy for a given medical imaging is evident, it is also needed to develop an appreciation of the connection between costs and achieved benefits. A part of this priority is the quantification of cost-effectiveness, cost-utility, and cost-benefit analyses. Few studies in dentistry have assessed the societal and economic aspects of a new technology, and our review supports this claim. However, in agreement with the study of Hatcher,[40] this review shows that various diagnostic conventional modalities—ranging from panoramic radiographs and lateral cephalograms to occlusal and periapical radiographs used to locate impacted teeth—are available. Studies have reported that the exposure from CBCT is within the same range as traditional dental imaging,[41] because a combination of traditional dental radiographs is warranted for sufficient assessment,[42] and this advantage may justify the societal efficacy of CBCT scans.

This systematic review supports the SEDENTEX project,[43] the British Orthodontic Society recommendations,[44] and the American Association of Orthodontists recommendations[45] on using CBCT for localizing maxillary impacted canines. CBCT may be indicated for localizing the assessment of an impacted tooth when the information cannot be obtained adequately by lower-dose conventional radiography. Because of the lack of evidence on societal efficacy of CBCT, the smallest volume size compatible with the situation should be selected. Using a large volume of CBCT requires careful justification. Furthermore, in agreement with the previous guidelines, several important gaps based on quantification of the benefit to the patient's outcome became evident.[43-45]

Although randomization is considered a primary risk of bias assessment criteria, only a few of the included studies randomly selected their subjects. In some studies, the subjects were initially identified as undiagnosable by 2D radiographs before CBCT evaluation; thus, these included studies suffered from a high risk of bias in subject selection. These undiagnosed patients through conventional radiographs were basically considered those with a difficult diagnosis; this might have caused underestimation of CBCT efficacy. It is suggested that future studies could lower the risk of selection bias by recruiting consecutive participants from a clinic (ideally, several clinics) or by randomly selecting subjects.

Another limitation of the included studies was the study design. Levels 4 through 6 (therapeutic efficacy, patient outcome efficacy, and societal efficacy) in the model of Fryback and Thornbury[27] are considered to be strong evidence in the decision-making process. However, difficulty in conducting a randomized clinical trial in this domain is 1 burden for investigating CBCT outcome efficacy. Fryback and Thornbury suggested performing retrospective case-control studies with large samples to determine the independent contribution of imaging to patient outcomes in these circumstances.

CONCLUSIONS

1. CBCT is more accurate than conventional radiographs in localizing maxillary impacted canine.
2. Broad ranges of interobserver agreement and intermodalities agreement in impacted canine localization and treatment planning between the CBCT and conventional groups might result from possible

within-observer and between-observer consistencies, methodologic diversity, and possible different complexity levels of the subjects between the studies.

3. The fair to moderate agreement between modalities in maxillary canine localization with better interobserver agreement for CBCT means that the information obtained through these modalities can be deviant and that it is more reliable for CBCT. This degree of variation between the 2 modalities ultimately affects treatment planning.
4. There is no robust evidence to support using CBCT as a first-line imaging method for impacted maxillary canine evaluation, but it is indicated when conventional radiography does not provide sufficient information. However, there is still a lack of evidence in relation to patient outcome efficacy and societal efficacy in the decision-making process.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.ajodo.2016.07.018.

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