

Updating Health Technology Assessment Report; CBCT Technology: A Review Study

Morteza Arab-Zozani ¹, Somayeh Kakehbaraei ², Ali Akbari-Sari ^{3, *}

¹Social Determinants of Health Research Center, Birjand University of Medical Sciences, Birjand, Iran

²Department of Biomedical Engineering, Faculty of Advanced Medical Sciences, Tabriz University of Medical Sciences, Tabriz, Iran

³Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

* Corresponding author: Ali Akbari-Sari, Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran. Tel: +98-9127251294, Email: akbarisari@tums.ac.ir

Received 2019 January 30; Accepted 2019 March 05.

Abstract

Context: Cone-beam computed tomography (CBCT) is a medical imaging technology with various dental applications and diagnosis of oral and maxillofacial lesions. The current study mainly aimed at updating the safety and efficacy of CBCT technology.

Materials and Methods: This is a systematic review study of available evidence of CBCT technology. Since the time searching in the previous report was up to December 2010, electronic databases including Cochrane Library and Scopus were searched from January 2011 to June 2014. In the first step, based on inclusion and exclusion criteria, title, abstract, and full-text of articles were reviewed by two independent reviewers. In some cases, the full-texts of articles were not available; therefore, the authors of the articles were contacted and the full-texts were obtained. Also, non-English language articles were excluded from the study. The same design of the previous report was employed to extract data and information of the included articles. Due to the heterogeneity in studies, the qualitative and quantitative methods were employed to report the results.

Results: After removing duplicates, a total of 876 articles were included in the study. Finally, 23 studies reached the final analysis stage. In terms of quality, 13 articles were of average quality and 10 articles had good quality. Most of the studies were related to Iran (n = 5), Brazil (n = 4), Germany (n = 3), Britain, USA, Netherlands (n = 2), and Turkey, China, India, and Switzerland (n = 1). The included studies were conducted in 2011 (n = 8), 2012 (n = 6), 2013 (n = 5), and 2014 (n = 4). Totally, 1806 samples were reviewed in all the included studies. The most important reported results included sensitivity, specificity, accuracy, positive and negative predictive values, and area under the curve; 86.3% of the studies reported sensitivity and specificity (n = 19), accuracy (n = 8), and area under the curve (n = 8). Positive and negative predictive values were 36.3% and 27.2%, respectively.

Conclusions: CBCT is a highly sensitive imaging tool for the diagnosis of various oral lesions. However, due to the limited number of clinical trials and the lack of evidence, further studies are needed to obtain more conclusive results.

Keywords: CBCT; Oral Diseases; Dental Diseases

1. Context

In recent years, a tremendous growth is observed in the use of medical technology for the diagnosis and treatment of diseases (1). Employment of proper technologies helps to effectively diagnose and treat diseases. On the other hand, uncontrolled and unrestricted access to these technologies may lead to indiscriminate and unreasonable demand from service providers (2). This problem also occurred in many developed and developing countries and led to a high increase in costs. Hence, in some countries, precision and sensitivity to the licensing of new technologies, and how to use them are systematically assessed before technology introduction using a systematic method of health technology assessment to make the best use of available resources as much as possible.

Cone-beam computed tomography (CBCT) technology

was first introduced in dentistry in the 1990s, and recently, it is used in radiotherapy and ENT (3). Compared to conventional CT scanners, CBCT scanners made the application of flat panel technology possible to provide three-dimensional (3D) volumetric scanning of the head and neck. This technology does not take images in a single slice, instead of displaying a full volume instantly by a cone-beam (4). By rotating the beam around the target and shooting at multiple angles, the desired area is observed from different angles (5). Advanced image reconstruction algorithms create high-resolution 3D images with high visual contrast that can be observed in jawbone images (6). In recent decades, CBCT technology is employed in several clinical areas including oral, maxillofacial, and orthodontic surgeries. The technology is known for its low cost, easy access, and fewer radioactivi-

ties compared to other conventional computer imaging devices (7).

The current study aimed at updating the health technology assessment report (CBCT technology) conducted in 2010 (8). The project was commissioned by the Health Technology Assessment Office of the Ministry of Health and Medical Education to assess the safety and economic evaluation of the technology, according to the situation of the country, and introduce and implement the technology in Iran.

2. Method

2.1. Information Sources and Search

Since the time of searching in the previous report was up to December 2010, and based on the approved proposal by National Institute for Health Research, electronic databases including the Cochrane Library and Scopus were searched from January 2011 to June 2014 to assess the safety and efficacy of the technology. Keywords used in the search included cone-beam, cone-beam computed tomography, diagnostic accuracy study, sensitivity and specificity, and were restricted to the dental and dental fields within the mentioned interval.

2.2. Eligibility Criteria

Predefined inclusion and exclusion criteria were used in all screening stages of the studies. Inclusion and exclusion criteria were outlined based on PICOT: Population: patients with dental and maxillofacial diseases; indicator (index) test: studies that somehow used CBCT to diagnose and treat the disease; outcome: articles in which information related to technology application, technology safety, accuracy, positive and negative predictive values, change in treatment process, change in patient status were reported, and type of studies: diagnostic accuracy studies, randomized controlled trials, and comparative critical trials.

2.3. Study Selection

After completion of the search, articles were transferred into EndNote version X7 software and duplicates were removed. Then, the titles and abstracts of the articles were reviewed by two independent reviewers. Controversies were resolved by referring to the third party and irrelevant articles were excluded. The next step was to search for the full-text of the articles. If full-text was inaccessible, it was requested from the corresponding author. Articles that their full-texts were not retrieved and those with non-English language full-texts were excluded from the study.

2.4. Data Collection Process and Data Items

All the final articles were thoroughly evaluated by two reviewers and the appropriate data were extracted. Eli-

gible articles were independently evaluated based on the Cochrane indices by the reviewers. Controversies were resolved by census. To extract the data, a technology report form was employed and the information of the selected articles was transferred into this form (Appendix 1 in Supplementary File).

2.5. Synthesis of Results

The results were reported based on each outcome and categorized in the tables. To evaluate the quality, the results of articles were transferred into RevMan 5.3 software and their outputs were reported.

3. Results

3.1. Study Selection

Based on the PICOTas well as inclusion and exclusion criteria, the total number of included studies after excluding duplicates was 876, and after initial evaluation in title and abstract was 59. The 59 articles were reviewed manually for duplicate references and four duplicates were retrieved. After deletion of the duplicates, the search was done to find the full-text of the included articles. In three of the studies, full-text was available, but the text was non-English. The full-texts of four articles were not available (9). Finally, 23 studies reached the final analysis stage. The study flow-chart is shown in Figure 1.

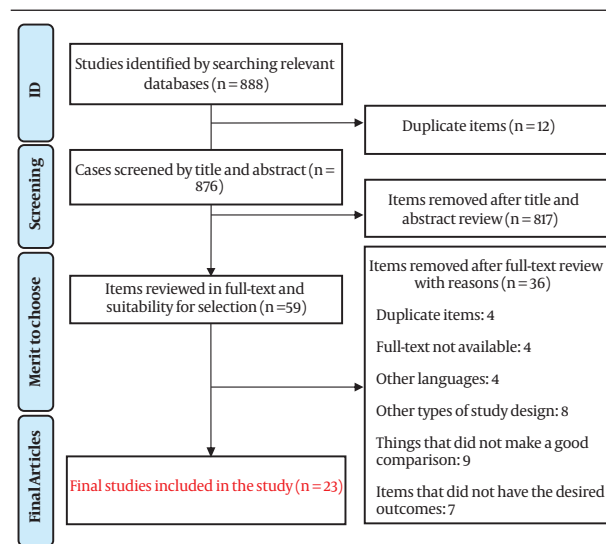


Figure 1. The study flow-chart

3.2. Study Characteristics

All final studies were in English. Most of the studies since 2010 were related to Iran (n = 5), Brazil (n = 4), Germany (n = 3), Britain, USA and Netherlands (n = 2), and Turkey, China, India, and Switzerland (n = 1). In terms of publication year, most articles belonged to 2011 (n = 8), 2012 (n = 6), 2013 (n = 5), and 2014 (n = 4).

3.3. Results of Individual Studies

The employed tests were similar to those of CBCT in different studies and the target sites of diagnosis varied widely. The type of studies according to the diagnostic test and the site of the diagnosis are shown in Table 1. Summary of all articles included in the current study is provided in Table 2. In these studies, CBCT was compared with a wide range of different diagnostic equipment, including IOR, bitewing, PR, film, CCD, SPECT, PSP, CI, MDCT, DR, X-ray, CR, MSCT, and PA. Most comparisons were made with a variety of radiographic methods; 1806 samples were checked in all of the studies. Various studies reported different effect sizes depending on the study type. The most frequent reported results were sensitivity, specificity, accuracy, positive and negative predictive values, and the area under the curve; 86.3% of studies reported sensitivity and specificity (n = 19), 36.3% accuracy (n = 8), 36.3% area under curve (n

= 8), and 27.2% and 27.2% positive and negative predictive values, respectively (n = 6). Summary results for sensitivity, specificity, accuracy, and other relevant items are shown in Table 3. Overall, studies were conducted on a wide range of oral, dental, and maxillary problems. The most important studies that used this technology included: diagnosis of vertical root fracture (n = 6), diagnosis of ruptured lesions and bone erosion (n = 2), detection of proximal surface cavities (n = 2), hole detection in canals after root filling (n = 2), hole detection in canals before root filling (n = 1), cortical bone invasion diagnosis (n = 1), apical cavity diagnosis (n = 1), external root resorption diagnosis (n = 1), occlusal caries diagnosis (n = 2), buccal surfaces and bite indentation diagnosis (n = 1), superficial tooth bone changes (n = 1), latent tooth detection (n = 1), oral and teeth malignancy (n = 1), and diagnosis of pre-apical lesions (n = 1).

Table 1. Type of Tests Used in the Studies Along with Site of Diagnosis

Author's Name	Detection Test	To Detect
Durack et al. (10)	CBCT and digital intraoral radiography	External inflammatory root resorption lesions
Sansare et al. (11)	CBCT and bitewing radiography	Proximal cavitated carious lesions
Haghanifar et al. (12)	CBCT and periapical radiography (PR)	Mesial root perforations of mandibular molars
Jakobson et al. (13)	CBCT (NewTom3G, I-CAT), film, and DR	VRFs
Hakim et al. (14)	CBCT, CT, and bone scintigraphy with SPECT	Preoperative tumor bone invasion of the mandible
Shokri et al. (15)	CBCT, CCD, and PSP	Detection of external root resorption
Wenzel et al. (16)	CBCT, DigoraOptime phosphor plate system, and Digora Toto CMOS sensor	Cavitated approximal surfaces
Shokri et al. (17)	CBCT, CI, PSP, and MDCT	Strip and root perforations in endodontically treated teeth
Khedmat et al. (18)	CBCT, DR, and MDCT	VRF in the absence and presence of gutta-percha root filling
Rathore et al. (19)	CBCT and IOR	Occlusal caries
Liang et al. (20)	CBCT and PR	Simulated tissue-occupied recesses in root canals
Zain-Alabdeen et al. (21)	CBCT and MDCT	Surface osseous changes in TMJs
Bechara et al. (22)	CBCT and PSP	RFs in endodontically treated teeth
Wriedt et al. (23)	CBCT and panoramic X-ray	Impacted upper canines
Kayipmaz et al. (24)	CBCT, CR, and storage phosphor plate	Occlusal and approximal caries
Dreiseidler et al. (25)	CBCT, MSCT, and SPECT	Bone invasion from oral malignancies
Valizadeh et al. (26)	CBCT, CR, and DR	VRF detection
Wang et al. (27)	CBCT and CR	Root fractures
Gaia et al. (28)	CBCT and MSCT	Identification of simulated bone lesions
Shemesh et al. (29)	CBCT and PR	Strip and root perforations after root canal treatment in mandibular molars
Bornstein et al. (3)	CBCT and CPR	Periapical lesions, the mandibular canal to the roots of the respective teeth, buccal bone
da Silveira et al. (30)	CBCT and CR	VRF in teeth with or without root canal treatment and metallic posts
Vizzotto et al. (31)	CBCT and CR	Second mesiobuccal canals in maxillary molar teeth

Table 2. Summary of Final Articles Information

Author's Name	Study Quality	Detection Test	Sample	Study Design Type	Country	Summary of Results
Duracket al. (10)	Moderate	CBCT and IOR	10 mandibular incisor teeth from three human mandibles	Ex-vivo comparative	Great Britain	CBCT is a reliable and valid method to detect simulated EIR and performs significantly better than intraoral periapical radiography.
Sansare et al. (11)	Moderate	CBCT and Bitewing	79 adjacent proximal surfaces without restorations in permanent teeth	Clinical trial	India	CBCT was more accurate in detecting cavitation in proximal surfaces than bitewing radiographs.
Haghani-far et al. (12)	Good	CBCT and PR	48 mandibular molars	In-vitro	Iran	For detection of perforation in filled-root canals, periapical radiography with three different horizontal angulations would be trustworthy, but it is recommended that CBCT be used for perforation detection before obturating root canals.
Jakobson et al. (13)	Good	CBCT1, CBCT2, film, and DR	100 human single-rooted	diagnostic	Brazil	The presence of metallic posts did not influence the sensitivity of most of the examinations, excluding the CBCT1 system. The fracture line orientation may influence VRF detection.
Hakim et al. (14)	Moderate	CT, CBCT, and SPECT	198 patients who undergo the test	Comparative	Germany	CT scan provides, by its high specificity and positive predictive value, a precise imaging technique for clinical routine. However, CBCT shows a much higher sensitivity for cortical bone invasion and a better negative predictive value.
Shokri et al. (15)	Good	CCD, PSP, and CBCT	54 maxillary first premolars	Comparative	Iran	CBCT was only useful for detection of cavities located in the apical one-third of the root, compared to other digital or conventional methods.
Wenzel et al. (16)	Moderate	CBCT, DigoraOptime phosphor plate system, and the Digora Toto CMOS sensor	257 Non-filled approximal surfaces	Comparative	Denmark	CBCT was much more accurate in the detection of surface cavitation in approximal surfaces than intraoral receptors.
Shokri et al. (17)	Moderate	CI, CBCT, PSP, and MDCT	72 recently extracted molar	Comparative	Iran	CBCT is the best radiographic technique, while MDCT is not recommended.
Khedmat et al. (18)	Good	DR, MDCT, and CBCT	100 extracted human single-rooted teeth	Comparative, ex-vivo	Iran	CBCT was the most sensitive imaging technique in detecting vertical root fracture. The presence of gutta-percha reduced the accuracy, sensitivity, and specificity of CBCT, but not MDCT.
Rathore et al. (19)	Moderate	CBCT and IOR	60 extracted teeth	Ex-vivo comparison	USA	Based on the results, it was concluded that the Sirona CBCT unit cannot be used for the sole purpose of looking at occlusal caries.
Liang et al. (20)	Good	CBCT and PR	30 extracted mandibular premolar roots	RCT	The Netherlands	Cone-beam computed tomography accurately detected tissue-occupied buccal and lingual recesses.
Zain-Alabdeen et al. (21)	Good	CBCT and MDCT	The sample consisted of 10 TMJs from 5 dried human skulls.	Comparative	Great Britain	CBCT and MDCT accuracy was similar in detecting surface osseous changes with comparable intra-observer reliabilities. However, since CBCT requires less radiation exposure, it should be the first choice for imaging the TMJ suspected of surface osseous changes.

Bechara et al. (22)	Moderate	CBCT and PSP	66 roots	Comparative	USA	CBCT small FOVs should be acquired for depicting RFs of endodontically treated teeth. Images obtained using PSP plates had the lowest rate of false-positive results and their use can save the patient a radiation dose.
Wriedt et al. (23)	Moderate	CBCT and panoramic X-ray (OPG)	21 patients with a total of 29 impacted maxillary canines	Diagnostic cross-over	Germany	Small volume CBCT may be justified as a supplement to a routine panoramic X-ray in the following cases: when canine inclination in the panoramic X-ray exceeds 30°, when root resorption of adjacent teeth is suspected, and/or when the canine apex is not clearly discernible in the panoramic X-ray, implying dilaceration of the canine root. The results of their study can be validated in a clinical trial.
Kayipmaz et al. (24)	Moderate	CBCT, CR, and storage phosphor plate	72 extracted human premolar and molar teeth	In-vitro comparison	Turkey	The CBCT system may be used as an auxiliary method for the detection of caries.
Dreiseidler et al. (25)	Good	CBCT, MSCT, and SPECT	77 patients with histologically proven malignancy	Prospective investigation	Germany	CBCT is accurate in predicting malignancies and bone involvement, and can compete with MSCT and SPECT in detecting bone invasion in patients with oral malignancies.
Valizadeh et al. (26)	Moderate	CBCT, CR, and DR	120 extracted single-rooted teeth	Diagnostic accuracy	Iran	CBCT seems better than conventional and digital radiography in detecting VRF and providing the most reliable data in comparison with the two other modalities.
Wang et al. (27)	Good	CBCT and CR	128 patients with clinically suspected root fractures in 135 teeth	Diagnostic accuracy	China	CBCT seems more accurate than conventional dental radiography in the detection of root fractures.
Gaia et al. (28)	Moderate	CBCT and MSCT	15 dry mandibles	Diagnostic accuracy	Brazil	CBCT results were similar to those of MSCT for the identification of the number of simulated bone lesions.
Shemesh et al. (29)	Moderate	CBCT and PR	45 curved mesial roots	Diagnostic accuracy	The Netherlands	The risk of misdiagnosed strip perforation was higher with both methods, but CBCT scans showed a significant higher sensitivity than PR. There was no significant difference between the methods for the detection of root perforations.
Bornstein et al. (3)	Moderate	CBCT and PA	38 molars with 75 roots	Diagnostic accuracy	Swiss	The present study highlights the advantages of using limited CBCT for treatment planning in mandibular molars before apical surgery.
da Silveira et al. (30)	Moderate	CBCT and CR	60 single-rooted human teeth	RCT	Brazil	The radiographic examination with horizontal angle variation should be encouraged as the first complementary approach to assess the presence of VRFs. If conventional imaging is not capable to provide adequate information, CBCT can be indicated if a root fracture is strongly suspected.
Vizzotto et al. (31)	Good	CBCT and CR	89 extracted human maxillary first molars	Diagnostic accuracy	Brazil	CBCT was associated with higher mean values of specificity and sensibility than radiographic examination for the detection of MB2 canals. When endodontic retreatment is necessary, removal of the root filling prior to the CBCT examination eliminates artefacts, thereby permitting the use of the 0.3-mmvoxel protocol that has good diagnostic performance and lower radiation dose.

Table 3. Summary of Study Results on Sensitivity, Specificity, Accuracy, Sub-Regional Area, and Positive and Negative Predictive Values

Author's Name	Machine	Sensitivity	Specificity	AUC	PPV	NPV	Accuracy
Bechara et al. (22)	Master 3D	61%	61%	0.66	-	-	-
	Promax	81%	78%	0.84	-	-	-
	PSP plates	51%	82%	0.70	-	-	-
Bornstein et al. (3)	CBCT	-	-	-	-	-	-
	PA	-	-	-	-	-	-
Dreiseidler et al. (25)	CBCT	0.92	0.965	0.931	0.98	0.875	-
	MSCT	0.8	1.0	0.894	1.0	0.75	-
	ASPECT	0.91	0.4	0.716	0.7	0.75	-
Durack et al. (10)	CBCT 1800	100	43.1 (4.6)	0.984	43.1 (13.3)	85 (12)	-
	CBCT 3600	100	92.3 (5.5)	0.990	95.6 (3.2)	100	-
	IOR	86.9 (9.3)	95.5 (4.8)	0.665	97.5 (2.7)	100	-
da Silveira et al. (30)	CBCT 0.2 mm voxel	0.97	1	0.967	-	-	0.98
	CBCT 0.3 mm voxel	0.87	0.97	0.867	-	-	0.92
	CBCT 0.4 mm voxel	0.76	0.80	0.683	-	-	0.77
	CR	0.93	0.83	0.800	-	-	0.88
Gaia et al. (28)	CBCT	98%	96.2%	-	-	-	-
	MSCT	95%	97.4%	-	-	-	-
Haghanifar et al. (12)	CBCT	85%	98%	-	98%	87%	-
	PA	71%	98%	-	97%	77%	-
Hakim et al. (14)	CBCT	94%	59%	0.772	73%	89%	-
	CT	63%	84%	0.720	76%	73%	-
	SPECT	97%	50%	0.720	64%	94%	-
Jakobson et al. (13)	CBCT 1	96.87%	57.5%	-	-	-	-
	CBCT 2	95%	92.5	-	-	-	-
	DR	56.25%	80%	-	-	-	-
	Film	63.75%	82.5%	-	-	-	-
Kayipmaz et al. (24)	CBCT	-	-	0.849	-	-	-
	Periapical	-	-	0.666	-	-	-
	Phosphor Plate	-	-	0.649	-	-	-
Khedmat et al. (18)	CBCT	86%	76%	-	-	-	81%
	DR	40%	88%	-	-	-	75%
	MDCT	62%	96%	-	-	-	68%
Liang et al. (20)	CBCT	0.95	0.75	-	-	-	0.88
	PR	0.0	0.96	-	-	-	0.32
Rathore et al. (19)	CBCT	70.37	65.16	0.720	-	-	-
	Bitewing	62.35	62.58	0.649	-	-	-
Sansare et al. (11)	CBCT	77%	77%	-	-	-	77%
	Bitewing	44%	85.5%	-	-	-	60%

Shemesh et al. (29)	CBCT	0.5	0.97	-	-	-	0.80
	2 angle PR	0.13	0.97	-	-	-	0.69
Shokri et al. (15)	CBCT	93.3%	94%	-	-	-	94%
	Film	84.6%	96%	-	-	-	92%
	CCD	58%	86.3%	-	-	-	85.6%
	PSP	82.6%	92%	-	-	-	88.6%
Shokri et al. (17)	CBCT	97.92%	85.42%	-	-	-	0.86
	CI	84.38%	93.75%	-	-	-	0.74
	PSP	87.50%	91.76%	-	-	-	0.76
	MDCT	77.08%	87.50%	-	-	-	0.60
Valizadeh et al. (26)	CBCT	94.6%	98.2%	0.989	98.1	94.6	-
	CR	66.7%	76.9%	0.742	76.0	67.8	-
	DR	74.1%	76.3%	0.796	75.4	75.0	-
Wang et al. (27)	CBCT	89.5%	97.5%	-	98.8%	79.6%	91.9%
	CR	26.3%	100%	-	100%	36.4%	48.1%
Wenzel et al. (16)	CBCT (Accuitomo)	40%	99%	-	-	-	-
	IOR (Optime)	17%	100%	-	-	-	-
	IOR (Toto)	19%	99%	-	-	-	-
Wriedt et al. (23)	CBCT	-	-	-	-	-	-
	Panoramic X-ray	-	-	-	-	-	-
Zain-Alabdeen et. Al. (21)	CBCT	32.64%	88.17%	-	-	-	-
	MDCT	34.02%	87.09%	-	-	-	-
Vizzotto et al. (31)	CBCT 0.2 mm voxel	0.92	0.68	0.84	-	-	-
	CBCT 0.25 mm voxel	0.69	0.74	0.71	-	-	-
	CBCT 0.3 mm voxel	0.83	0.53	0.74	-	-	-
	CR	34.3	0.80	0.49	-	-	-

Due to the variety of studies, the meta-analysis was not possible in terms of the devices used, outcome evaluated, and the area; therefore, the results of each study were reported separately.

3.4. Quality Appraisal

The quality of the reviewed articles was appraised by the Cochran quality appraisal tool. In terms of quality, 13 had moderate and 10 good quality (Figures 2 and 3).

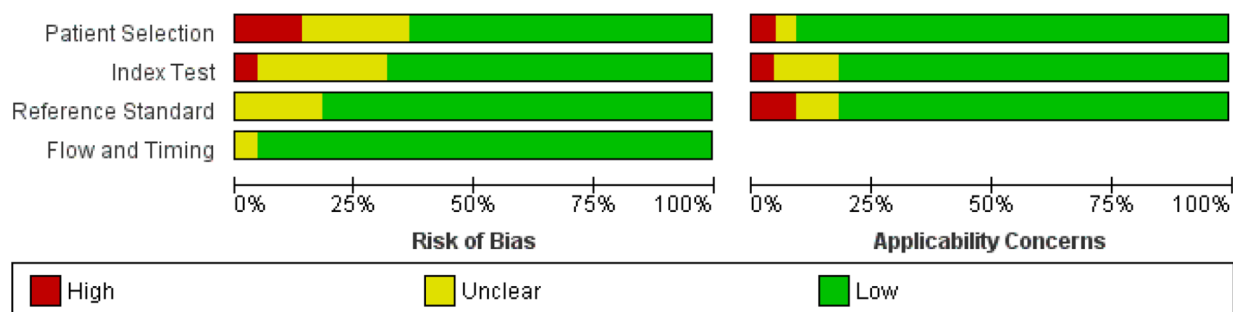


Figure 2. Risk of bias using the Cochrane criteria

	<u>Risk of Bias</u>				<u>Applicability Concerns</u>		
	Patient Selection	Index Test	Reference Standard	Flow and Timing	Patient Selection	Index Test	Reference Standard
Bechara et. al. 2013	+	+	?	+	+	+	?
Bornstein et. al. 2011	+	+	+	?	?	-	+
Da Silveira et. al 2012	+	?	?	+	+	+	+
Dreiseidler et. al. 2011	+	?	?	+	+	+	-
Durack et. al. 2011	?	+	+	+	-	+	+
Gaia et. al 2011	+	-	+	+	+	?	+
Haghanifar et. al. 2014	+	+	+	+	+	+	+
Hakim et. al. 2013	?	+	?	+	+	+	+
Jakobson et. al. 2014	+	+	+	+	+	+	+
Kayipmaz et. al. 2011	-	+	+	+	+	+	?
Khedmat et. al. 2012	+	+	+	+	+	+	+
Liang et. al. 2012	+	+	+	+	+	+	+
Rathore et. al. 2012	-	+	+	+	+	+	+
Sansare et. al. 2014	+	?	+	+	+	?	-
Shemesh et. al. 2011	+	?	+	+	+	?	+
Shokri et. al. 2013	+	+	+	+	+	+	+
Shokri et. al. 2014	?	?	+	+	+	+	+
Valizadeh et. al. 2011	?	+	+	+	+	+	+
Wang et. al. 2011	+	+	+	+	+	+	+
Wenzel et. al. 2013	-	+	+	+	+	+	+
Wriedt et. al. 2012	?	?	+	+	+	+	+
Zain-Alabdeen et. al 2012	+	+	+	+	+	+	+

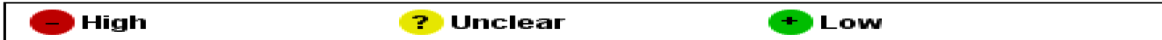


Figure 3. Summary of bias risk profile

4. Discussion

4.1. Detection of Vertical Root Fracture

The most studied categories included six studies (27.2% of total studies): comparing two types of CBCT with PSP (n = 1), comparing CBCT with CR (n = 2), comparing CBCT with film and DR (n = 1), comparing CBCT with CR and DR (n = 1), and comparing CBCT with MDCT and DR (n = 1). All studies reported sensitivity and specificity. The accuracy (n = 2), area under the curve (n = 2), and positive and negative predictive values (n = 2) were reported.

The study by Bechara et al. (22), was performed on 66 roots, and two large and small field-of-view (FOV) CBCTs were compared with PSP. The obtained results showed that devices with smaller FOV had significantly higher accuracy in detecting vertical root fracture. Specificity of PSP images was higher than those of the devices with larger FOVs, but this difference was not statistically significant. However, the difference was statistically significant with those of the smaller FOVs.

In the study by da Silveira et al. (30), performed on CBCT

with three different voxel types compared to those of CR in both pre- and post-tooth fillings, chi-square test results showed no statistically significant difference between the two tests and the results of diagnostic tests showed similar ability to detect vertical root fracture. The study suggested that radiographic tests should be used as the first approach for diagnosis, and if radiography fails to provide useful information, then CBCT should be used in case of a high suspicion of fracture. In terms of voxel, the state of 0.3 is suggested for the case of non-filled teeth and the state of 0.2 for filled teeth.

The study by Jakobson et al. (13), also evaluated metallic posts for diagnosis of vertical root fracture and compared two different CBCT systems (CBCT 1: NewTom 3G; CBCT 2: i-CAT next generation) with radiographic and DR films on 100 single rooted teeth in five groups. The results showed that the presence of metallic posts reduced sensitivity of CBCT 1 ($P = 0.0244$). Both CBCT devices and DR had a higher sensitivity to detect fractures in the post, while film and DR had a higher sensitivity in the absence of the post ($P < 0.05$). CBCT 1 showed the least specificity compared to other devices ($P < 0.05$). In general, results of the study showed that the presence of metallic posts did not affect sensitivity of devices (except CBCT 1).

In the study by Khedmat et al. (18), conducted on 100 root canals of extracted teeth, the results showed that in the absence of gutta-percha, the specificity of all three diagnostic devices (CBCT, DR, and MDCT) was similar. CBCT had the highest accuracy and sensitivity ($P < 0.05$). In the presence of gutta-percha, MDCT was more accurate than the other techniques ($P < 0.05$). Overall, results of their study showed that gutta-percha decreased sensitivity, specificity, and accuracy of CBCT, but did not affect MDCT, and on the other hand, decreased sensitivity of DR in the presence of gutta-percha.

In the study by Valizadeh et al. (26), on 120 single-rooted teeth, the results showed that CBCT had the highest sensitivity and specificity, and both DR and CR devices were less accurate than CBCT. According to their study, CBCT seemed better at diagnosing vertical tooth fracture and gave more reliable data than the other two instruments.

In the study by Wang et al. (27), on 128 patients with 135 teeth suspected of VRF, the results showed that CBCT accuracy was significantly higher than that of the CR ($P < 0.001$). Results also showed that sensitivity of CBCT decreased when the channels were filled, but specificity did not change. Filled channels had no effect on CR sensitivity and specificity. According to the results of their study, CBCT seemed more accurate than CR in detecting root fractures.

4.2. Detection of Ruptured Lesions and Bone Erosion

Of the 22 studies, two examined ruptured lesions and bone erosion (10, 28). The study by Durack et al. (10), was performed in ex-vivo and compared radiography with CBCT in two rotational modes of 1800 and 3600. The area under the curve was lower for IOR than CBCT ($P < 0.001$). The sensitivity and specificity of the two types

of CBCT were significantly better than those of the IOR ($P < 0.001$). The exact location of the lesions was significantly better defined by CBCT. According to the results of their study, CBCT seemed a reliable and valid method to diagnose degenerated bone lesions and was significantly better than IOR.

In another study, Gaia et al. (28), examined bone erosion in maxillofacial area and compared the results of CBCT and MSCT; the obtained results showed no statistically significant differences between the two methods and they were similar in the number of lesions. Finally, both methods had similar accuracy and were reliable in this regard.

4.3. Diagnosis of Lesions in Cavities of Proximal Surfaces

Two studies were performed in this regard. A study by Sansare et al. (11), conducted on 79 adjacent surfaces without permanent restoration and compared the results of CBCT and bitewing. Results of their study showed that the sensitivity was significantly higher in CBCT than bitewing, but the difference was not statistically significant. However, the accuracy of CBCT was significantly higher. The study by Wenzel et al. (16), on 257 proximal surfaces of premolar and molar permanent teeth, compared two different devices with CBCT. They showed that the sensitivity of CBCT was significantly higher according to all observers resulting in a higher total agreement for CBCT. There were no significant differences between the two devices (PSP and CMOS) in terms of the studied parameters.

4.4. Detection of the Hole in Root Canals

There were two studies on the detection of the hole in root canals; the study by Haghanifar et al. (12), on detection of the root canal before and after filling, and the study by Shemesh et al. (29), on detection of the hole in filled root canals. The study by Haghanifar et al. (12), was conducted on 48 mandibular molar teeth and the results showed that sensitivity and specificity of CBCT in root canals were lower than those of PR. Results of the study by Shemesh et al. (29), on 45 roots showed that CBCT sensitivity was higher, but there was no significant difference in specificity between CBCT and PR. Sensitivity of CBCT was also higher in the diagnosis of root inflammation, while its specificity was lower, and these differences were statistically significant. Overall, their study indicated no statistically significant difference between the methods to detect root lesions and CBCT was also more sensitive to detect the hole.

4.5. Diagnosis of Cortical Bone Invasion

There was only one study performed by Hakim et al. (14), which diagnosed bone tumor in squamous cell carcinoma using three devices (CT, CBCT, and SPECT). This study was conducted on 84 patients using one of the devices for preoperative examination and on 48 patients using all three devices. Results showed that CBCT and SPECT had

approximately equal sensitivity, which was significantly higher than that of CT. In addition, CBCT exhibited higher specificity than SPECT, while CT showed the highest specificity among all the three devices. Their study suggested that due to its high specificity and positive predictive value, CT is suitable for routine investigations in this field. In general, conclusions in this area need further clinical studies and decision-making based on one study should be made with caution.

4.6. Detection of External Root Resorption

There was a study by Shokri et al. (17), which examined ERR by four different devices (PSP, CBCT, CCD, and IOR). The sample included 54 maxillary premolar teeth. Results of the study showed that the differences between the four devices were not statistically significant. But detection of the location of the CBCT root resorption was significantly different from those of other devices. According to the results of their study, CBCT was useful to detect the apical cavity in one-third of the root area, but further evidence is needed to make a definitive decision.

4.7. Detection of Occlusal Caries

In this regard, two studies were conducted by Kayipmaz et al. (24), and Rathore et al. (19), that compared CBCT with other devices. The results showed that CBCT significantly outperformed PSP and CR in detecting occlusal caries, but was not different from IOR. According to the results of these two studies, it seems that the use of CBCT is not only appropriate to detect occlusal caries, but it can be used as an adjunctive technique.

4.8. Detection of Buccal Surfaces and Indentation of the Bite

Liang et al. (20), investigated this topic and compared CBCT and PR capabilities in the diagnosis of buccal surfaces and bite indentations. Results of their study showed that agreement between observers was greater in CBCT and accuracy of this device in detecting filled grooves was significantly higher than that of PR. Based on the results of this study, CBCT could detect this outcome with greater accuracy. To make more conclusive decisions, further clinical studies are required.

4.9. Detection of Superficial Tooth Bone Changes

Only one study by Zain-Alabdeen et al. (21), comparing CBCT and MDCT devices investigated this issue. Results of the study showed that sensitivity of both devices was low and almost equal, while specificity of both devices was high and almost equal. Overall, accuracy of both devices was almost identical in detecting superficial tooth bone changes. Since CBCT requires less exposure to radiation, it may be a better technique, but to make more conclusive decisions, further clinical studies are required.

4.10. Diagnosis of Impacted Bite Tooth

A study was performed by Wriedt et al. (23), to detect impacted bite tooth and compared CBCT and 2D panoramic X-ray machines. The results of their study indicated that CBCT had a higher ability to detect impacted teeth. More than a quarter of the impacted bite teeth were not identified by 2D and could be identified by 3D. The employment of CBCT as a supplement is appropriate for routine, but definitive decision-making needs further studies.

4.11. Diagnosis of Oral Malignancies

A prospective study examining oral malignancies was conducted by Dreiseidler et al. (25), which compared three devices (CBCT, SPCT, and MSCT) on 77 patients. Their results showed that CBCT was more accurate in predicting and diagnosing malignancies and could be used as a competitor for the other devices. To make more conclusive decisions, further clinical studies are required.

4.12. Diagnosis of Periapical Lesions

A study was conducted on the diagnosis of periapical lesions. Bronstein et al. (3), compared 38 molar teeth with 75 roots using both CBCT and PA. Results of their study showed that of the 58 lesions identified, 25.9% (15 cases) of the ones diagnosed with CBCT were missed by PA. Overall, the present study demonstrated the beneficial effects of limited use of CBCT in the design of treatment for preoperative periapical lesions, but definitive decision needs further studies.

4.13. Conclusions

According to all the studies included in the current study, CBCT seemed highly sensitive in detecting different types of lesion in oral area. However, due to the small number of clinical trials, it is definitely not possible to consider the results and the need for further clinical trials is increasingly felt. On the other hand, due to the different applications of this device in the oral area, it is difficult to make a general decision about this device. Articles reviewed in the current study showed that in some cases this device was less capable than the other ones, while in other variables it had higher capabilities. But the important point that can be definitely drawn from the results of these studies is that the ability of this device to detect different outcomes in the oral and dental area is comparable to that of other devices, but further studies are also required in this regard. CBCT appears to be less effective when teeth are filled or foreign bodies are present in the tooth, indicating that the presence of foreign bodies reduces the sensitivity and specificity of this device. In general, CBCT should be used prior to tooth filling or when foreign bodies are not used for tooth restoration, since the studies show that in almost all outcomes and in different areas of the mouth, external objects, plaques, gutta-percha, and other things reduce accuracy of this device.

References

- Hansen DC, Bassler N, Sorensen TS, Seco J. The image quality of ion computed tomography at clinical imaging dose levels. *Med Phys*. 2014;**41**(11):11908. doi:10.1118/1.4897614. [PubMed:25370641].
- Greenall CJ, Thomas B, Drage NA, Brown J. An audit of image quality of three dental cone beam computed tomography units. *Radiography*. 2016;**22**(1):56-9. doi:10.1016/j.radi.2015.05.008.
- Bornstein MM, Lauber R, Sendi P, von Arx T. Comparison of periapical radiography and limited cone-beam computed tomography in mandibular molars for analysis of anatomical landmarks before apical surgery. *J Endod*. 2011;**37**(2):151-7. doi:10.1016/j.joen.2010.11.014. [PubMed:21238794].
- Edlund R, Skorpil M, Lapidus G, Backlund J. Cone-Beam CT in diagnosis of scaphoid fractures. *Skeletal Radiol*. 2016;**45**(2):197-204. doi:10.1007/s00256-015-2290-6. [PubMed:26563560].
- Aboul-Hosn Centenero S, Hernandez-Alfaro F. 3D planning in orthognathic surgery: CAD/CAM surgical splints and prediction of the soft and hard tissues results - our experience in 16 cases. *J Craniomaxillofac Surg*. 2012;**40**(2):162-8. doi:10.1016/j.jcms.2011.03.014. [PubMed:21458285].
- Signorelli L, Patcas R, Peltomaki T, Schatzle M. Radiation dose of cone-beam computed tomography compared to conventional radiographs in orthodontics. *J Orofac Orthop*. 2016;**77**(1):9-15. doi:10.1007/s00056-015-0002-4. [PubMed:26747662].
- Perenyi A, Bella Z, Barath Z, Magyar P, Nagy K, Rovo L. Role of cone-beam computed tomography in diagnostic otolaryngological imaging. *Orv Hetil*. 2016;**157**(2):52-8. doi:10.1556/650.2016.30334. [PubMed:26726139]. Hungarian
- Shaabaninejad H, Akbari Sari A, Rafiei S, Mehrabi Sari A, Safi Y. The efficacy of CBCT for diagnosis and treatment of oral and maxillofacial disorders: A systematic review. *J Islam Dent Assoc Iran*. 2014;**26**(1):64-74.
- Xie XY, Zhang ZY. Diagnostic accuracy of cone beam computed tomography and eight-slice computed tomography for evaluation of external root resorption. *Beijing Da Xue Xue Bao Yi Xue Ban*. 2012;**44**(4):628-32. [PubMed:22898861]. Chinese
- Durack C, Patel S, Davies J, Wilson R, Mannocci F. Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. *Int Endod J*. 2011;**44**(2):136-47. doi:10.1111/j.1365-2591.2010.01819.x. [PubMed:21083575].
- Sansare K, Singh D, Sontakke S, Karjodkar F, Saxena V, Frydenberg M, et al. Should cavitation in proximal surfaces be reported in cone beam computed tomography examination? *Caries Res*. 2014;**48**(3):208-13. doi:10.1159/000354838. [PubMed:24481006].
- Haghanifar S, Moudi E, Mesgarani A, Bijani A, Abbaszadeh N. A comparative study of cone-beam computed tomography and digital periapical radiography in detecting mandibular molars root perforations. *Imaging Sci Dent*. 2014;**44**(2):115-9. doi:10.5624/isd.2014.44.2.115. [PubMed:24944960]. [PMC4061294:PMC4061294].
- Jakobson SJ, Westphalen VP, Silva Neto UX, Fariniuk LF, Schroeder AG, Carneiro E. The influence of metallic posts in the detection of vertical root fractures using different imaging examinations. *Dentomaxillofac Radiol*. 2014;**43**(1):20130287. doi:10.1259/dmfr.20130287. [PubMed:24191261]. [PMC3887484:PMC3887484].
- Hakim SG, Wieker H, Trenkle T, Sieg P, Konitzer J, Holl-Ulrich K, et al. Imaging of mandible invasion by oral squamous cell carcinoma using computed tomography, cone-beam computed tomography and bone scintigraphy with SPECT. *Clin Oral Investig*. 2014;**18**(3):961-7. doi:10.1007/s00784-013-1042-z. [PubMed:23873323].
- Shokri A, Mortazavi H, Salemi F, Javadian A, Bakhtiari H, Matlabi H. Diagnosis of simulated external root resorption using conventional intraoral film radiography, CCD, PSP, and CBCT: A comparison study. *Biomed J*. 2013;**36**(1):18-22. doi:10.4103/2319-4170.107156. [PubMed:23515150].
- Wenzel A, Hirsch E, Christensen J, Matzen LH, Scaf G, Frydenberg M. Detection of cavitated approximal surfaces using cone beam CT and intraoral receptors. *Dentomaxillofac Radiol*. 2013;**42**(1):39458105. doi:10.1259/dmfr/39458105. [PubMed:22842638]. [PMC3729187:PMC3729187].
- Shokri A, Falah-Kooshki S, Poorolajal J, Karimi A, Ostovarrad F. Evaluation of the location of mandibular foramen as an anatomic landmark using CBCT images: A pioneering study in an Iranian population. *Braz Dent Sci*. 2014;**17**(4):74. doi:10.14295/bds.2014.v17i4.1006.
- Khedmat S, Rouhi N, Drage N, Shokouhinejad N, Nekoofar MH. Evaluation of three imaging techniques for the detection of vertical root fractures in the absence and presence of gutta-percha root fillings. *Int Endod J*. 2012;**45**(11):1004-9. doi:10.1111/j.1365-2591.2012.02062.x. [PubMed:22551491].
- Rathore S, Tyndall D, Wright J, Everett E. Ex vivo comparison of Galileos cone beam CT and intraoral radiographs in detecting occlusal caries. *Dentomaxillofac Radiol*. 2012;**41**(6):489-93. doi:10.1259/dmfr/57329547. [PubMed:22184471]. [PMC3520394:PMC3520394].
- Liang YH, Yuan M, Li G, Shemesh H, Wesselink PR, Wu MK. The ability of cone-beam computed tomography to detect simulated buccal and lingual recesses in root canals. *Int Endod J*. 2012;**45**(8):724-9. doi:10.1111/j.1365-2591.2012.02025.x. [PubMed:22372870].
- Zain-Alabdeen EH, Alsadhan RI. A comparative study of accuracy of detection of surface osseous changes in the temporomandibular joint using multidetector CT and cone beam CT. *Dentomaxillofac Radiol*. 2012;**41**(3):185-91. doi:10.1259/dmfr/2498598110.1259/dmfr/24985971. [PubMed:22378752]. [PMC3520284:PMC3520284].
- Bechara B, McMahan CA, Noujeim M, Faddoul T, Moore WS, Teixeira FB, et al. Comparison of cone beam CT scans with enhanced photostimulated phosphor plate images in the detection of root fracture of endodontically treated teeth. *Dentomaxillofac Radiol*. 2013;**42**(7):20120404. doi:10.1259/dmfr.20120404. [PubMed:23625067]. [PMC3699972:PMC3699972].
- Wriedt S, Jaklin J, Al-Nawas B, Wehrbein H. Impacted upper canines: Examination and treatment proposal based on 3D versus 2D diagnosis. *J Orofac Orthop*. 2012;**73**(1):28-40. doi:10.1007/s00056-011-0058-8. [PubMed:22246048].
- Kayipmaz S, Sezgin OS, Saricaoglu ST, Can G. An in vitro comparison of diagnostic abilities of conventional radiography, storage phosphor, and cone beam computed tomography to determine occlusal and approximal caries. *Eur J Radiol*. 2011;**80**(2):478-82. doi:10.1016/j.ejrad.2010.09.011. [PubMed:20934291].
- Dreiseidler T, Alarabi N, Ritter L, Rothamel D, Scheer M, Zoller JE, et al. A comparison of multislice computerized tomography, cone-beam computerized tomography, and single photon emission computerized tomography for the assessment of bone invasion by oral malignancies. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011;**112**(3):367-74. doi:10.1016/j.tripleo.2011.04.001. [PubMed:21778080].
- Valizadeh S, Khosravi M, Azizi Z. Diagnostic accuracy of conventional, digital and Cone Beam CT in vertical root fracture detection. *Iran Endod J*. 2011;**6**(1):15-20.
- Wang P, Yan XB, Lui DG, Zhang WL, Zhang Y, Ma XC. Detection of dental root fractures by using cone-beam computed tomography. *Dentomaxillofac Radiol*. 2011;**40**(5):290-8. doi:10.1259/dmfr/84907460. [PubMed:21697154]. [PMC3520261:PMC3520261].
- Gaia BF, Sales MA, Perrella A, Fenyó-Pereira M, Cavalcanti MG. Comparison between cone-beam and multislice computed tomography for identification of simulated bone lesions. *Braz Oral Res*. 2011;**25**(4):362-8. doi:10.1590/s1806-83242011000400014. [PubMed:21860924].
- Shemesh H, Cristescu RC, Wesselink PR, Wu MK. The use of cone-beam computed tomography and digital periapical radiographs to diagnose root perforations. *J Endod*. 2011;**37**(4):513-6. doi:10.1016/j.joen.2010.12.003. [PubMed:21419300].
- da Silveira PF, Vizzotto MB, Liedke GS, da Silveira HL, Montagner F, da Silveira HE. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography - an in vitro analysis. *Dent Traumatol*. 2013;**29**(1):41-6. doi:10.1111/j.1600-9657.2012.01126.x. [PubMed:22413921].
- Vizzotto MB, Silveira PF, Arus NA, Montagner F, Gomes BP, da Silveira HE. CBCT for the assessment of second mesiobuccal (MB2) canals in maxillary molar teeth: effect of voxel size and presence of root filling. *Int Endod J*. 2013;**46**(9):870-6. doi:10.1111/iej.12075. [PubMed:23442087].