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Review Article

Clinical Applications of Cone-Beam Computed Tomography in Endodontics: A Systematic Review

Li Jingyi, Lim J Z Adrienne, Lum H B Song, Saion A M Muhamad and Mei Li*

Department of Oral Sciences, Faculty of Dentistry, University of Otago, Dunedin, New Zealand

***Corresponding author:** Li Mei, Department of Oral Sciences,Faculty of Dentistry, University of Otago.310 Great King Street, Dunedin, 9016, New Zealand, Tel: +64 3 479 7480; Email: li.mei@otago.ac.nz

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Abstract

Background: The application of cone-beam computed tomography (CBCT) in endodontics has been increased in popularity nowadays. The manufacturers of CBCT devices have advocated the benefits of using CBCT, but the scientific evidences supporting these claims are insufficient to date. The use of CBCT in endodontics is still poorly understood.

Methods: The following databases were searched: Pubmed, Embase, Web of Science, and Cochrane Library. The keywords used for electronic search included “CBCT”, “cone-beam computed tomography”, and “endodontics”. Only human studies were reviewed. The quality of the included studies was evaluated by assessing study design, outcome measurementsand statistical analysis.

Results: A total of 283 articles were identified and 42 met the inclusion criteria. Study topics included root canal morphology, periapical radiographs, apical periodontitis, procedural errors, root fractures, endodontic working length and root resorption. The average methodological quality of studies was not high, only about 65 percent of the maximum score on average.Studies on the identification of root canal morphology; periapical diseases as well as root fractures suggested some advantages that CBCT could offer. We could not prove CBCT was better than conventional 2-D imaging for aiding diagnosis, planning treatment and treatment outcome. High quality evidences supporting the use of CBCT as the first radiographic technique of choice are still insufficient.

Conclusion: CBCT has advantages on the identification of root canal morphology, periapical diseases and root fractures.The benefits of CBCT provided to each case should outweigh the extra radiation exposure it produces. Well-designedquantitative clinical studies are still needed to determine the value of CBCT on diagnosis, treatment and treatment outcome.

Introduction

The application of cone-beam computed tomography (CBCT) in dentistryhas causeda paradigm shift from two-dimensional (2-D) to three-dimensional (3-D) approach for imagingoral structures. An increasing number of studieson CBCT have recentlybeen published. The growing interest of the applications of CBCT in dental practices has resulted in a revolution in dentofacial imaging. The role of CBCT imaging techniqueshas also been expanded from diagnosis to image guidance of operative and surgical dental procedures [1, 2].

The mechanism of CBCT imaging is using a rotating gantry to which an x-ray source and detector are fixed. A cone-shaped source of ionizing radiation is directed through the middle of the area of interest, and then detected by x-ray detector on the opposite side. The x-ray source and detector rotate around a rotation fulcrum fixed within the center of the region of interest while multiple images are taken and subsequently reconstructed on a computer to form a 3-D data set [1].

The applications of CBCT in endodontitics have been investigated and discussed in various studies [3,4]. CBCT has been considered useful in endodontics as it can provide 3-D images for the detection of fractured endodontic file, strip root perforation, root fractures, and root resorption. In addition, CBCT can also aid visualization of the number and location of roots and canals, identification of unidentified canal, c-shaped canal systems and diagnosis of periapical lesions. The benefits of CBCT have been extensively advised, but there search evidences supporting the advantage of usage of CBCT imaging in dental applications are still insufficient to date [3].

The aim of this systematic review is to systematically review the studies of CBCT in endodontics and assess the quality of evidence supporting the benefits of CBCT application in endodontics.

Material and Methods

Electronic databases

The followingelectronic databases were searched in order to find the suitable publications. PubMed (1966 - 2013); MEDLINE (1966 - 2013), Web of Science (1980 - 2013), Embase (1980 - 2013), and Cochrane Library (1993 - 2013). Gray literatures were not searched and only English articles were included in this study.

Search strategy

The following search strategy was used for Pubmed search. “Endodontics” or “Endodontic” or “endo”, “Cone Beam CT” or “Cone Beam” or “Cone Beam computed tomography” or “CBCT” or “computed tomography” or “volume CT”. This search strategy

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Table 1: Methodological quality scores for studies regarding root canal morphology.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Huang CC, 2010	□	□	o	□	□	o	□	o	□	□	□	o	o	62
Zheng Q, 2011	□	□	o	□	□	o	□	o	□	□	□	o	o	62
Kim Y, 2012	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Scarfe WR, 2011	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Simek N, 2013	□	□	o	□	□	o	□	o	o	□	□	□	o	62
Plotino GI, 2013	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Silva EJ, 2013	□	□	o	□	□	o	□	□	□	□	□	□	o	77
Bauman R, 2011	□	□	o	□	□	o	□	o	□	□	□	□	□	77
Zhang R, 2010	□	□	o	□	□	o	□	o	□	□	o	o	o	54
Cheng L, 2011	□	□	o	□	□	o	□	o	□	□	□	o	o	62
Neelakantan P, 2010	□	□	o	o	□	o	□	o	□	□	□	o	o	54
Lee MH, 2013	□	□	o	□	□	o	□	o	□	□	□	o	o	62

□ methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.
NA: not applicable.

Table 2: Methodological quality scores for studies regarding apical periodontitis.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Paes da siva 2013	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Patel S, 2011	□	□	o	□	□	o	□	□	□	□	□	□	o	77
Lofthag-Hansens S, 2007	□	□	o	□	□	o	□	o	□	o	o	o	o	46
Estrela C, 2009	□	□	o	□	□	o	□	o	□	□	o	□	o	62
Patel S, 2012	□	□	o	□	□	o	□	□	□	□	□	□	o	77
Sadullah Kaya, 2012	□	□	o	□	□	o	□	o	□	□	o	□	o	62
Yoshioka T, 2011	□	□	o	□	o	o	□	o	□	□	□	□	o	62

□: methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.

was modified accordingly for the other electronic databases search mentioned above.

Study Selection

Databases were searched independently by three reviewers (reviewer L.S.H.B searched PubMed, reviewer L.J.Z. searched MEDLINE and Embase, reviewer M.A.S. searched Cochrane Library). Only human studies were included. Reviews, letters, and case reports were not included in this review. A mutual agreement was made by all thethree reviewersabove to resolve any differences regarding which articles to be included or excluded.

Table 3: Methodological quality scores for studies regarding periapical radiograph.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Cheung GSP, 2013	□	□	□	□	□	□	□	□	□	□	□	□	□	100
Abella F, 2012	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Lauber R, 2012	□	□	o	□	□	o	□	□	□	o	NA	o	o	58
Liang YH, 2011	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Low KMT, 2008	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Patel S, 2009	□	□	o	□	□	o	□	o	□	□	□	□	o	69

□: methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.
NA: not applicable.

Table 4: Methodological quality scores for studies regardingroot fracture.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Kajan ZD, 2012	□	□	o	□	□	o	□	□	□	o	o	o	o	54
Wang P, 2011	□	□	o	□	o	o	□	o	□	□	o	□	o	54
Metska ME, 2012	□	□	o	□	□	o	□	□	□	□	NA	o	o	67
Bernades RA, 2009	□	□	o	o	o	o	□	□	□	□	o	□	o	54
Kamburoglu, 2013	□	□	o	□	□	o	□	□	□	□	o	□	o	69
Hassan B, 2009	□	□	o	□	□	o	□	o	□	□	o	□	o	62

Quality assessment

All three reviewers (L.S.H.B, L.J.Z. and M.A.S.) evaluated the quality of the included studies based on a scoring system describedpreviously [2]. This scoring system used 15 criteria evaluating study design, outcome measurements and statistical analysis. The quality score of each study included in this review was assessedand calculated. The scores were averaged as percentages and the mean qualitywas rated (Q) as Q<60% = poor quality; 60%≤Q ≤75% = moderate quality; Q> 75% = good quality [2,5].

Results

After removal of duplicates, 205 articles were assessedfor eligibility. An additional 163 articles were excluded after reviewing full-text, mainly due to failing to meet inclusion criteria such as non-human studies. Finally, 42 articles were included for assessment.

The included 42 studies were further divided into seven categoriesbased on their topics (Table 1-7): root canal morphology (12 articles) [6-17], apical periodontitis (7 articles) [18-24], periapical radiograph (6 articles) [25-30], root fracture (6 articles) [31-36], root resorption (4 articles) [37-40], procedural errors (4 articles) [41-44], and working and obturation length (3 articles) [45-47].

The included12 studies on root canal morphology [6-17], CBCTwas used to identify and evaluate the number of roots and canals, c-shaped canal systems in molars and premolars. These studies

Table 5: Methodological quality scores for studies regarding rootresorption.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Estrela C, 2008	□	□	o	□	□	o	□	□	□	□	o	□	o	69
Patel S, 2009	□	□	o	□	□	o	□	o	□	□	o	□	o	62
Durack C, 2011	□	□	o	□	o	o	□	□	□	□	o	□	o	62
Kamburoglu, 2010	□	□	o	□	□	o	□	□	o	□	o	□	o	62

□: methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.

Table 6: Methodological quality scores for studies regarding procedural errors.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
Silva JA, 2012	□	□	o	□	□	o	□	o	□	□	□	□	o	69
Shemesh H, 2011	□	□	o	□	o	o	□	o	□	□	□	□	o	62
Dadazio PSS, 2011	□	□	o	o	□	o	□	o	o	□	□	□	o	54
Huybrechts B, 2009	□	o	o	o	□	o	□	o	□	□	□	□	o	54

□: methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.

Table 7: Methodological quality scores for studies regardingworking and obturation length.

First author, Year	Methodological Score													Average Score(%)
	Study Design						Study Measurements			Statistical Analysis				
	A	B	C	D	E	F	G	H	I	J	K	L	M	
JegerFb, 2012	□	□	o	□	□	o	□	□	□	□	□	□	□	85
Janner SFM, 2011	□	□	o	□	□	o	□	□	□	□	o	□	o	69
Liang YH, 2011	□	□	o	□	□	o	□	□	□	□	o	□	o	69

□: methodological criteria were satisfactory.
o: did not fulfill the methodological criteria.

assessed canal wall thickness, location of root canal orifices and apical foramina (Table 1).

The included seven studies onapical periodontitis [18-24], CBCT was used to investigate periapical lesions, its use in treatment planning, surrounding bone density and prevalence of apical periodontitis (Table 2).

The included six studies on periapical radiographs (PA) [25-30], investigators comparedthe difference between CBCT and conventional radiographs in terms of detection of periapical lesions, root canals, root fillings and other pathologies (Table 3).

The included six studies onroot fracture, investigators evaluated the use of CBCT in detecting root fractures [31-36], and compared CBCT with conventional radiographs for diagnosing root fractures (Table 4).

The included four studies on root resorption, investigators evaluated the diagnostic accuracy of CBCT in measuring root resorption (Table 5) [37-40].

The included four studies onprocedural errors, CBCT was used to detectfractured endodontic file, strip root perforation, cast postwith deviation, external root resorption and void in root fillings (Table 6) [41-44].

The included three studies on working and obturation length, investigators compared CBCT with standard working length measuring techniques (Table 7) [45-47].

Discussion

Cone beam computed tomography (CBCT) is a relatively new imaging technology in endodontic applications.Inthis systematic review; the recentstudies on clinical application of CBCT in endodontics was assessed and evaluated.

The use of CBCT in endodontics is a very new technology and most articles on this topic were publishedafter the year of 2007 [1-3]. All the included studies were divided into seven categories based on their research topics in this review. Some studied the benefits that CBCT imaging could bring to clinician in terms of diagnosis and treatment planning. And anumber of studiescompared CBCT with conventional 2-D imaging.Some papers also mentioned the current limitations of CBCT and expected future improvements to CBCT technology [9,10,15].

Based on the limited number of studies included, a routine use of CBCT imaging for endodontic patients in clinical practices could not be justified. CBCT should only be prescribed when traditional 2-D imaging is unable to provide the necessary information for diagnosis and treatments, especially in assessment and treatment of complex endodontic conditions [2]. According to the recommendations madeby the American Association of Endodontics and the American Academy of Oral and Maxillofacial Radiology, dental clinician must justify the need to use CBCT and select clinical cases carefully.

The quality of studies included in this review was not very high. And no large sample size studies on the risk or adverse event associated with CBCT scanning was found. All radiographic clinical examinations, including CBCT, must be justified for each patient by the risk-benefit analysis [2,16,25].

Conclusion

CBCT may have advantage on the identification of root canal morphology, periapical diseases and root fractures.High-quality evidence suggesting CBCT is better than conventional 2-D imaging technique is still lacking.Dental clinician should weight the extra radiation produced by CBCTagainst the possible benefits. Well-designed, large sample sized human studies are needed in the future to determine the value of CBCT on diagnosis, treatment and treatment outcome in endodontics.

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