American Journal of Advances in Medical Science
www.arnaca.com
eISSN: 2347 -2766

Review Article

# Cone-Beam Computed Tomography (CBCT) in endodontics: A Review

**Varsha H Tambe***

Department of Conservative Dentistry & Endodontics, SMBT Dental College, Amrutnagar-414 101, Ahmednagar, Maharashtra, India

**Abstract**

Canal location, morphology and its structure has always raised curiosity among practioners and patients. Various techniques are developed by scientists to capture and study the internal structures. Recently imaging hard tissues of the maxillofacial region has been made easy by the use of a novel technique called cone-beam computed tomography (CBCT). CBCT also referred to as C-arm CT, cone beam volume CT, or flat panel CT) is a medical imaging technique that provides high-quality, accurate three-dimensional (3D) replica of the osseous elements of the maxillofacial skeleton. It can be used in various specialties of the dentistry like oral medicine, periodontics, orthodontics, implantology, endodontics and oral surgery. This article provides a review of the specific application of various CBCT display modes to clinical endodontic practice, its importance and the advantages.

**Keywords:** Cone Beam Computed Tomography, assessment, dose, limitations

**Cite this article as :**
Varsha H Tambe. Cone-Beam Computed Tomography (CBCT) in endodontics: A Review. American Journal of Advances in Medical Science. 2014; 2(2): 64-74.

**Source of Support**: Nil, **Conflict of Interest** : None declared.

## Introduction

The sound diagnosis, proper treatment planning, as well as the follow-up of an endodontic patient, relies heavily upon the efficiency of the radiographic imaging technique used. Ever since 1899, when Kells first proposed the thought of viewing a lead wire placed inside a root canal, in order to determine the canal length by viewing it on a "radiogram". Radiographic aids have become indispensible to the practice of endodontics [1,2]. While conventional radiography continues to uphold the mainstay even today, the advent of "PANORAMIC RADIOGRAPHY" revolutionized dental radiography, by providing single comprehensive images of the jaws and the related maxillofacial structures. However, the conventional intraoral,as well as the extraoral procedures used hitherto, all suffer from a basic drawback,in that, they provide only a two-dimensional picture of the three-dimensional tissue, and as such, any compromise in the configuration of geometry, can result in errors and misrepresentation of structures[3]. Additionally, the radiographic limitations of magnification, distortion, and superimposition of images, continue to persist. These flaws can be overcome by using limited-volume Cone bean computed tomography (CBCT) technique, to produce accurate three-dimensional images of the teeth, and the supporting tissues under consideration [4-6] , thereby heralding the transformation of dental diagnosis and treatment planningfrom two-dimensional images to three-dimensional data acquisition. Cone-beam computed tomography, with its origins in conventional CT, was also initially developed for use in angiography [7], but has been used in the dental field since 1981. Apart from its extensive use in the periodontal field, particularly in the detection of bony aspects of the disease, and widespread applications in the surgical field, cone-beam computed tomography has been gaining popularity in endodontics, covering the broad spectrum of diagnosis of pulpal inflammation leading to periapicalpathoses, visualization of canals, vertical and horizontal root fractures, as well as internal and external tooth resorption. Alongside, the CBCT technology has gone a long way in occlusal and proximal caries detection and depth characterization [8].

## What is CBCT and how does it works ?

Cone-beam computed tomography is a recent, three-dimensional system that has been dedicated specifically for imaging the maxillofacial skeleton [9,10]. The hardware consists of an x-ray source and a detector (or a sensor) mounted on a rotating gantry. A divergent, pyramidal or cone-shaped source of ionizing radiation is directed through the area of interest into the patient's maxillofacial skeleton, and onto an x-ray detector on the opposite side. The source and the detector rotate simultaneously around a rotation fulcrum, or the patients head, in a single sweep. Depending upon the exposure parameters and the type of equipment used, scan time varies between 10 to 40 seconds, during which hundreds of sequential basis images of the area of interest are acquired in a partial or a complete arc.

Specialized software then reconstructs the basis images to produce a cylindrical volume of data, called the “FIELD OF VIEW” or FOV. The dimensions of the field of view are directly proportional to the shape and size of the detector, projection geometry, and collimation of the primary X-ray beam. Collimation ensures limited radiation exposure to the area under consideration. As a smaller field of view results in better resolution of the image, and efficiently reduced radiation exposure to the patient, the FOV can be optimized for each patient depending on the region of interest and the disease presentation. The image that has been reconstructed from the basis image is then displayed synchronously in the sagittal, coronal, and the axial planes, thus offering a thorough three-dimensional view of the object/region of interest, to the clinician. In this way, the reconstructed image displays the object of interest from all aspects, while eliminating the unimportant or unwanted region from view. An accurate, true to dimension representation of the object of interest is thus obtained by using CBCT.

**Types of CBCT equipments**

Cone-beam computed tomography systems have been classified in a number of ways. The most widely accepted and commonly used classification is based on the dimensions of the FOV, or the scan volume being irradiated. On the basis of the scan volume height, the following categorization has been made-

**Localised/focused/small field CBCT equiptments**

These employ a maximum scan volume height of 5 cm.

**Single arch CBCT equipments**

These employ a scan volume height of 5 cm to 7 cm.

**Inter-arch CBCT equipments**

The scan volume height is between 7 cm to 10 cm.

**Maxillofacial CBCT equipments**

These have a scan volume height between 10 cm to 15 cm.

**Cranofacial CBCT equipments**

Scan volume height is greater than 15 cm.

CBCT systems have also been classified based on the patient positioning during the scan. Maxillofacial cone-beam computed tomography can be performed with the patient in

- Sitting position
- Standing position
- Supine position

**Dose considerations and patient selection criteria**

Every effort possible is made to reduce the effective radiation exposure to the patient for endodontic-specific tasks**.** Radiation exposures are converted to effective dose (E) measured in Sieverts (Sv), for rational comparison of radiation risks. Radiation exposure to the specific tissues is calculated, adjusted for the volume of that specific tissue in the field of view,and weighted based on radiation sensitivity of that tissue. The weighted tissue doses are summed to assess the effective dose (E), and compared with respect to natural background radiation.

According to the INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP), the organs included in the calculation of effective dose of the maxillofacial region include the salivary glands, skin, brain, bone marrow, bone surface, esophagus, thyroid, and the remainder tissues [11].A large number of factors influence the radiation dose produced by a CBCT system. These include the imaging parameters, nature of the X-ray beam i.e. whether continuous or pulsatile, size of the FOV, and amount and type of beam filtration. Ideally, the radiation dose applies decreases with a decrease in the size of the FOV [12,13]. Reduction in effective dose radiation can be achieved by using a short exposure time, low mA setting, the smallest possible FOV and a small voxel size, alongwith a pulsed exposure mode rather than the continuous. As the effective dose is a weighted summation of the respective doses to various organs, the effective dose can be reduced by removing some organs from the path of the X-ray beam. For example,restricting the primary beam to the maxilla only rather than the whole head, greatly reduced the effective dose as the radiation received by the thyroid gland is eliminated.

**Patient selection criteria**

The use of CBCT in endodontics is warranted by the benefits of CBCT outnumbering the hazards and risks. CBCT should not be used for routine screening purposes, or in the absence of positive clinical signs and symptoms.

Applications of CBCT in endodontic practice

Radiographic imaging plays a role at all the stages in endodontics, whether pre-operative or post-operative.

**Pre-operative assessment**

Pre-operative assessment of the case at hand establishes the true cause and nature of the problem or disorder, points to the need for endodontic treatment, and ensures that the patient is well-informed regarding the planned procedure, and consents to go ahead with it. Proper and careful pre-operative assessment minimizes post-treatment complications, and as such, the need for accurate pre-operative assessment cannot be over-estimated. Radiographic visualization provides indispensible information regarding the morphology of the tooth ad root, size, location, and number of canals, fractures, caries extent, pathologic calcifications and periapical lesions. Although conventional radiography, CT and magnetic resonance imaging have been used, due to its advantages of high resolution and low-dose radiation to the skin [9], cone-beam computed tomography is gaining wider acceptance.

**Tooth and root morphology**

The key to effective and efficient endodontic treatment lies in the thorough identification of all root canals, so that they can be accordingly accessed, successfully cleaned, shaped, and obturated. [15] conventional radiographic techniques often fail to disclose the exact number of canals in teeth undergoing root-canal treatment [16,17], especially in the cases of the prevalence of MB2 (second mesiobuccal canal) in first maxillary molars, where the superimposition of structuresin the buccolingual plane, makes visualization of small structural density changes difficult [18,19], which can thereby affect the success rate of the treatment. In the ex-vivo experiment conducted by Matherne et al [20] it was seen that conventional radiography failed to disclose atleast one root canal, in 40% of the teeth examined. CBCT results in these terms proved much superior, thus instilling the application of CBCT technology in the detection of accessory canals.

Besides identifying the “number” of canals, the curvature of the canals, the degree of their convergence or divergence can also be reliable noted by visualizing them in the three spatial planes. Also, the degree of root curvature, or “dilaceration” can be detected.

A rare, but not unimportant application of CBCT in the identification of tooth morphology, is in the assessment and treatment planning of teeth with developmental anomalies, such as the ‘DENS INVAGINATUS’ “CONCRESCENCE” “FUSION” or ‘DILACERATION’ which require endodontic treatment [21,22].

**Detection of periapical pathogenesis**

Pathologies commonlyinvolving the teeth are those due to inflammatory lesions of the pulp and periapical areas. In the study by Bender and Seltzer [23,24] in an attempt to demonstrate the limitations of intraoral radiography in the detection of periapical lesions, they showed that a lesion becomes radiographically evident only after the cortical plate of the bone has been involved. Such limitations can be overcome by the CBCT technology, because, conventional radiographs being two-dimensional in nature, fail to reflect the clinical and biological features, which are accurately evidenced in a CBCT view.

The prevalence of apical periodontitiswas seen to be significantly higher when CBCT was used in its diagnosis, as compared to when conventional radiographs were used [25]. Conventional radiography cannot demonstrate periapical pathologies in cancellous bone [26]. On the other hand, CBCT can reveal bone defects of the cortical and cancellous bone separately. Thus CBCT has been found to be a more sensitive diagnostic method in the detection of apical periodontitis. The success rate of endodontic treatment is seen to be improved when treatment is started before the appearance of apical periodontitis on conventional radiographs [27].

In addition to the detection of periapical pathologies, CBCT can also be used to differentiate the nature of the lesions. Using grayscale values in the lesions, Simon and co-workers differentiated the solid from the fluid-filled lesions [28] i.e the periapicalgranulomas from the cysts. Theirs was one of the few studies, which, being clinical in nature, was verified by histologic analysis.13 of the 17 lesions in this study were identified correctly by CBCT. The remaining lesions were infact found to be more accurately identified by CBCT rather than by microscopic analysis, owing to poor biopsy sampling. Thus CBCT has proved to be an effective pre-operative aid in the detection of the presence as well as the nature of periapical lesions.

**Assessment of root fractures**

Root fractures, although a relatively rare occurrence compared to crown fractures, are difficult to diagnose using conventional radiography. Identification of root fractures poses a challenge to the endodontist, as clinical and radiographic features of the condition do not present themselves for a long period after the fracture has occurred. Ex vivo studies by Hassan et al [29] and Kamburoglu et al [30] have demonstrated CBCT to be more sensitive in the detection of root fractures, compared to conventional radiography [29].

**Assessment of root resorption**

The detection of external root resorption by conventional radiographs can only be done after a significant amount of hard tissue damage has already taken place. In this regard, the use of cross-sectional CT to diagnose the location and extent of external root resorption has been well documented [31-33]. Patel et al [34] made a clinical comparison of CBCT versus conventional intraoral radiography in the diagnosis and management of external and internal resorption lesions. They reported CBCT to be 100% accuratein diagnosing the presence of root resorption. CBCT was shown to be an effective tool in diagnosing the presence of the resorption, determining the extent, and also differentiating between external and internal resorption. Determination of the prognosis of the lesion as also the assessment of post-orthodontic apical root resorption [35] can be positively determined by CBCT.

**Assessment of dental trauma**

CBCT provides valuable information regarding the type, severity and the exact nature of the injuries to dentoalveolar structures, thereby facilitating prompt and appropriate treatment. The diagnosis of alveolar fractures, invasive resorptive defects, and the degree f displacement caused by luxation injuries can be well-elucidated by using CBCT. Furthermore, CBCT being an extraoral imaging modality, patient comfort is greatly enhanced in the dental trauma patients, where intraoral radiographic procedures are complicated by painful tissues and mobile teeth.

**Assessment of potential surgical sites**

CBCT has been found to be the gold standard in the determination of the approximation of structures while planning surgical endodontic treatment. The spatial relation of the specific root planned for the procedure with important anatomical structures such as the maxillary sinus, the inferior alveolar nerve canal, and the mental foramen, can be clearly identified by the clinician in any of the planes that he wishes to view [36-38], from this, the space available for surgical manipulation can be gauged. Alongside, the inclination of the tooth roots under consideration for surgery, pattern of cancellous bone and cortical plate thickness can also be determined pre-surgically from a CBCT scan [39].

**Post-operative assessment**

Post-operative assessment of an endodontic patient warrants imaging required to evaluate delayed healing responses, the results of prior therapy, potential obstacles for retreatment considerations, as well as surgical considerations [40]. CBCT technology has come at par in being used for post-operative evaluation with conventional radiography.

An important aspect of the post-operative assessment of endodontic patients, is the careful and periodic monitoring of the healing progress of apical lesions. In the study of Paula-Silva et al [41] the comparative outcomes of endodontic treatment in dogs six months after the treatment, the success rates of the treatment were found to be 79%

when conventional radiography was used, and 35% when CBCT was used. In a similar clinical study by Liang et al [42] to compare the outcome of endodontic treatment in humans, success rates of endodontic treatment were found to be 87% when assessed by conventional intraoral radiographs, and 74% when assessed by CBCT. These findings suggest that CBCT is indeed a more sensitive marker for the success of endodontic treatment, as compared to conventional radiography.

**Limitation of CBCT**

While the applications of CBCT are expanding day by day, gaining wider acceptance, the current CBCT technology suffers from limitations with regard to detector sensitivity, lack of clarity and contrast resolution, and artifacts related to the X-ray beam and patient positioning. Despite the provision of geometrically accurate images in three dimensions, the spatial resolution of CBCT images is inferior to conventional intraoral radiographs [43]. Image artifacts result from the phenomenon of “beam hardening” I,e, increase in the mean energy of the beam due to preferential absorption of low-energy photons. This can result in the ‘CUPPING ARTIFACT’ i.e. distortion of metallic structures, and streaks and dark bands between two radiodense objects. In the cases where large FOVs are used, additional recorded X-ray non-linear attenuation results in graininess of the image.

Due to the lack of contrast resolution, maxillofacial CBCT images are unable to record subtle changes in attenuation, which may be of important diagnostic value to differentiate the nature of sinus, or periapical soft tissue contents. Movement of the patient during the scan can cause misrepresentation of data. CBCT images, also suffer from ‘scanner-related artifacts’ which actually present as circular or ring-shaped artifacts. These occur either due to improper scanner detection, or due to poor calibration

The projection geometry of the CBCT beam, and the method used in the reconstruction of image, also pose as sources of certain artifacts. When a reduced data sample due to too few basis images occur, it results in fine striations in the image, an artifact called as “undersampling”. The divergence of the CBCT beam is also a potential source of artifacts in the peripheral portions. This leads to greater peripheral noise. It also results in streaking artifacts and image distortion. The effective dose of CBCT, although greatly reduced when compared to conventional CT, is higher than that of conventional intraoral radiography, resulting in greater patient exposure. This difference, however, is narrowing rapidly.

**Summary**

The revolution brought in by CBCT technology in the field of maxillofacial imaging cannot be underestimated. It has proved to be a useful adjunctive tool especially in endodontics, where CBCT images have yielded more promising results as compared to the normal two-dimensional images. However, CBCT technology cannot be appropriated as the imaging modality of first choice. It should only be used when the lower dose conventional radiographic modalities prove insufficient for the problem at hand. CBCT apparatus is a sophisticated tool that requires special operator skills for equipment handling and image manipulation. The protocol for patients requiring a CBCT scan must be justified on the basis of the benefits outweighing the potential hazards. In general, the use of CBCT in the field of endodontics should be restricted to the assessment of complicated endodontic problems, which include-

1] Suspected accessory canals to be identified in teeth with complex morphology.

2] To diagnose or confirm the presence of a periapical pathology, in patients with non-specific clinical symptoms.

3] Diagnosis and management of dental trauma.

4] Evaluation of complex root canal anatomy and dilacerated roots.

5] Post-operative endodontic treatment assessment for healing progress of apical lesions, or the complications such as perforations

6]Pre-surgical evaluation for the proximity of vital structures to the root apices under consideration.

7] Planning dental implants.

Thus the utility value of CBCT is undisputed. It is a task-specific imaging modality in comprehensive endodontic evaluation. With ever-increasing populariy, like any other equipment of the modern era, further evolution and refinement in the technology can be expected. For now, like its medical counterpart, CBCT technology can be viewed as a largely useful and indispensible part of the dental imaging armamentarium.

**Reference**

1. Langland OE, Langlais RP. Early pioneers of oral and maxillofacial radiology. Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontol. 1995;80(5):496–511.
2. Jacobsohn PH, Fedran RJ. Making darkness visible: the discovery of X-ray and its introduction to dentistry. J Am Den Ass. 1995;126(10):1359–1367.
3. Grondahl HG, Huumonen S. Radiographic manifestations of periapical inflammatory lesions. Endodon Top. 2004;8:55–67.
4. Patel S, Dawood A, Pitt Ford T, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. Int Endod J. 2007;40:818-30.
5. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone beam volumetric tomography. J Endod. 2007;33:1121-32.
6. Scarfe WC, Levin MD, Gane D, Farman AG. Use of conebeam computed tomography in endodontics. Int J Dent. 2009;2009:634-637
7. Robb RA. Dynamic spatial reconstruction: an x-ray video fluoroscopic CT scanner fordynamic volume imaging of moving organs. IEEE Trans Med Imag. 982;M1:22–3.
8. Kalathingal SM, Mol A, Tyndall DA et al. In vitro assessment of cone beam local computedtomography for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:699–704.

9. Arai Y, Tammisalo E, Iwai K, Hashimoto K, ShinodaK. Development of a compact computed tomographic apparatus fordental use. Dentomax Radiol. 1999;28:245-248.
10. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A newvolumetric CT machine for dental imaging based on the conebeamtechnique: preliminary results. Eur Radiol. 1999;8:1558-1564.
11. Valentin J. The 2007 Recommendations of the International Commission on Radiological Protection. 2009. (Publication 103, Annals of the ICRP, vol. 37).
12. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. Brit J Radiol. 2009;82(973):35–40.
13. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofacial Radiol. 2006;35(4):219–226.
14. Walton RE. Diagnostic imaging A. endodontic radiography. In: Ingle JI, Bakland LK, Baumgartner JC, editors. Ingles' Endodontics. 6th edition. Hamilton, Canada: BC Decker; 2008. 554.
15. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Sur Oral Med Oral Pathol. 1984;58(5):589–599.
16. Tu MG, Tsai CC, Jou MJ, Chen WL, Chang YF, Chen SY. Prevalence of three-rooted mandibular first molars amongTaiwanese individuals. J Endod. 2007;33:1163-1166.
17. Zheng Q, Xue-dong Z, Jiang Y, Sun T, Liu C, Xue H. Radiographic investigation of frequency and degree of canalcurvatures in Chinese mandibular permanent incisors. J Endod. 2009;35:175-178.
18. Pineda F. Roentgenographic investigation of the mesiobuccal root of the maxillary first molar. Oral Sur Oral Med Oral Pathol. 1973;36(2):253–260.
19. Nance R, Tyndall D, Levin LG, Trope M. Identification of root canals in molars by tuned-aperture computed tomography. Int Endodon J. 2000;33(4):392–396.
20. Matherne RP, Angelopoulos C, Kulild JC, Tira D. Use of cone-beam computed tomography to identify root canal systems in vitro. J Endodon. 2008;34(1):87–89.
21. Patel S. The use of cone beam computed tomography in theconservative management of dens invaginatus: a case report. Int Endod J. 2010;43:707-713.
22. Durack C, Patel S. The use of cone beam computed tomographyin the management of dens invaginatusaffecting a strategic toothin a patient affected by hypodontia: a case report. Int Endod J. 2011;44:474-483
23. Bender B, Seltzer S. Roentgenographic and direct observation of experimental lesions inbone I. J Am Dent Assoc. 1961;62:152–160.
24. Bender B, Seltzer S. Roentgenographic and direct observation of experimental lesions inbone II. J Am Dent Ass. 1961; 62:708–716.
25. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic radiography for the detection of apical periodontitis. J Endod. 2008;34:273-9.
26. Bender IB, Seltzer S. Roentgenographic and direct observation of experimental lesions in bone: I. J Endod. 2003; 29:702-6.

27. Friedman S. Prognosis of initial endodontic therapy. Endod Topics. 2002;2:59-98
28. Simon JSH, Enciso R, Malfaz JM. Differential diagnosis of large periapical lesions using cone-beam computed tomographymeasurements and biopsy J Endodon. 2006; 32(9):833-837.
29. Hassan B, Metska ME, Ozok AR, Van der Stelt P, Wesselink PR. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endodon. 2009;35(5):719–722.
30. Kamburoglu K, Ilker Cebeci AR, Grondahl HG. Effectiveness of limited cone-beam computed tomography in the detection of horizontal root fracture. Den Traumatol. 2009;25(3):256–261.
31. Kim E, Kim KD, Roh BD, Cho YS, Lee SJ. Computed tomography as a diagnostic aid for extracanal invasive resorption. J Endodon. 2003; 29(7):463–465.
32. Gulsahi A, Gulsahi K, Ungor M. Invasive cervical resorption: clinical and radiological diagnosis and treatment of 3 cases. Oral Sur Oral Med Oral Pathol Oral Radiol Endodontol. 2007; 103(3):e65–e72.
33. daSilveira HLD, Silveira HED, Liedke GS, Lermen CA, Dos Santos RB, Figueiredo JAP. Diagnostic ability of computed tomography to evaluate external root resorption in vitro. Dentomaxillofacial Radiol. 2007;36(7):393–396.
34. Patel S, Dawood A, Wilson R, Horner K, Mannocci F. The detection and management of root resorption lesions usingintraoral radiography and cone beam computed tomography – anin vivo investigation. Int Endod J. 2009; 42:831-838.
35. Dudic A, Giannopoulou C, Leuzinger M, Kiliaridis S. Detection of apical root resorption after orthodontic treatment by using panoramic radiography and cone-beam computed tomography of super-high resolution. Am J Orthodon Dentofacial Orthoped.2009; 135(4):434–437.
36. Lofthag-Hansen S, Huumonen S, Gröndahl K, Grondahl HG. Limited cone beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007; 103:114-119.
37. Patel S. New dimensions in endodontic imaging: Part 2. Conebeam computed tomography. IntEndod J 2009; 42:463-475.
38. Rigolone M, Pasqualini D, Bianchi L, Berutti E, Bianchi SD. Vestibular surgical access to the palatine root of the superior first molar: “low-dose cone-beam” CT analysis of the pathway and its anatomic variations. J Endodon. 2003;29(11):773–775.
39. Nakata K, Naitoh M, Izumi M, Inamoto K, Ariji E, Nakamura H. Effectiveness of dental computed tomography in diagnostic imaging of periradicular lesion of each root of a multirooted tooth: a case report. J Endodon. 2006;32(6):583–587.
40. Rushton VE, Horner K, Worthington HV. Screening panoramic radiology of adults in general dental practice: radiological findings. Brit Den J. 2001;190(9):495–501.
41. Paula Silva FWG, Hassam B, Da Silva LAD, Leonardo MR, Wu MK. Outcome of root canal treatment in dogs determined byperiapical

radiography and cone-beam computed tomographyscans. J Endod. 2009;35:723-726.
42. Liang Y-H, Li G, Wesselink PR, Wu M-K. Endodontic outcome predictors identified with periapical radiographs and cone-beam computed tomography scans. J Endod. 2011;37:326-331.
43. Farman AG, Farman TT. A comparison of 18 different x-raydetectors currently used in dentistry Oral Surg Oral Med OralPathol Oral Radiol Endodontol. 2005;99(4):485-489.