2D Vs 3D Imaging In Endodontics-A Review

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Abstract
Radiographic imaging is a preliminary and necessary phase in the diagnosis, treatment preparation, and follow-up in all endodontic patients. Several confounding considerations affect the perception, including the morphology and superimposition of the teeth, as well as the surrounding dentoalveolar structures. Because of the size of the maxillofacial skeleton, traditional two-dimensional (2-D) radiographic photographs tend to provide detailed detail about the area of interest. The superimposition of images in planar periapical radiography reveals only a small amount of detail about a three-dimensional (3-D) object. Geometric distortion affects the forms visualized in this manner. As a result, recent research has emphasized the importance of 3-D imaging in overcoming the possible shortcomings of traditional radiography. Health-related One of the first three-dimensional imaging devices was computed tomography (CT). It has had modest success in the area of endodontics over the last decade. With the introduction of cone beam computed tomography, imaging modalities entered a new age (CBCT). Contemporary endodontics emphasizes the importance of CBCT because it reduces radiation sensitivity and quickly produces 3D restored photographs that have been shown to be reliable. This paper examines the advantages of three-dimensional radiographic technology over traditional two-dimensional imaging systems, as well as their possible disadvantages.

Keywords
Dental radiography,Diagnosis, Oral radiology,Three dimensional imaging, Cone beam computed tomography

Introduction
Persistent periapical lesions in root canal treated teeth and related complications may present a significant diagnostic and recovery preparation problem. The precise issue is always difficult to determine, and a patient can appear to experience symptoms despite no radiographic evidence of more periapical illness. It is critical to properly define the issue and prepare accordingly to avoid discomfort on both the clinician's and the patient's part. According to research, periapical lesions confined inside the cancellous bone are normally undetected before they begin to erode the cortical plate.(Scarfe et al. 2009) (Schwarz et al. 1987; Bandy 1989)Two-dimensional radiographs have many drawbacks, including the superimposition of three-dimensional anatomy and the possibility of exposure or geometric errors. This is a field where three-dimensional imaging can be useful in accurately representing the true essence of the patient's dilemma(Mozzo et al. 1998; Ruprecht 2009; "Cone-Beam Volumetric Tomography" 2014).Cone beam CT (CBCT) has remodeled the face of medical specialty in many ways that, and it's established to be helpful in identification periapical lesions that periapical radiographs didn't discover.Ionizing radiation is used in CBCTs, and the lowest dose associated with the diagnostic mission can often be used. CBCT has opened newer avenues in diagnosis and treatment planning. Any new diagnostic or treatment modality should have enough evidence which is in favour of improving the health and the healthcare sector(Mozzo et al. 1998; Ruprecht 2009).There has been some research comparing 2-D vs 3D radiologic diagnostic methods, but studies indicating its application in the field of endodontics is limited. Previously our team has a rich experience in working on various research projects across multiple disciplines (Govindaraju and Gurunathan 2017; A. Christabel et al. 2016; Soh and Narayanan 2013; Mehta et al.

2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019a; Campeau et al. 2014; Kumar and S 2016; S. L. Christabel 2015; Kumar and Rahman 2017; Sridharan, Ramani, and Patankar 2017; Ramesh et al. 2016; Thamaraiselvan et al. 2015; Thangaraj et al. 2016; Ponnulakshmi et al. 2019; "Fluoride, Fluoridated Toothpaste Efficacy and Its Safety in Children - Review" 2018) (Jayaseelan Vijayashree Priyadharsini 2019; Pc, Marimuthu, and Devadoss 2018; Ramesh et al. 2018; Ramadurai et al. 2019; Sridharan et al. 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019b; Mathew et al. 2020; Samuel 2021; R et al. 2020; Chandrasekar et al. 2020; J. Vijayashree Priyadharsini, Smiline Girija, and Paramasivam 2018)

Now the growing trend in this area motivated us to pursue this project. More research is needed in this field to know more about the possible uses of this new diagnostic aid in the field of endodontics.

Why Three Dimensional Visualisation
Intraoral x-rays are used as a basis for the processing and attenuation of x-rays on a movie or a digital receiver.(Mozzo et al. 1998)To have precise projection it needs optimised geometry of the X-ray unit, sensor and object. If any of the components is affected, geometry or distortion errors can occur in the resulting image.The images produced by a periapical radiograph are a 2-D representation of 3-dimensional structures, which causes distortion,superimposition and difficulty in magnification.These constraints showed the way for three Dimensional imaging, this has revolutionised diagnosis and treatment planning, and the overall treatment outcome and the prognosis.(Mozzo et al. 1998)(Farman et al. 2008)

Evolution of CBCT
Previous publishers have brought attention to the revolution-Cone Beam Computerized Tomography (CBCT).A CT scan uses a thin fan-shaped X-ray beam and various exhibits to show 3D images as image slices around an object.A CT scan uses a thin X-ray beam (fan shaped) and various exhibits to show 3D images as slices around an object. It was a groundbreaking development in diagnosing and therapy, as it helped the clinician evaluate all 3D viewpoints on morphological characteristics, anatomy and effect.While precision pictures are provided compared to radiographic 2D, their popularity is limited by the high radiation exposure, cheap scanner units and long scanning time. Data recorded in the medical CT were also anisotropic voxels, which inaccurately measured on several planes.(Scarfe and Farman 2008; Tyndall and Rathore 2008; Nasseh and Al-Rawi 2018; Angelopoulos 2008; McClammy 2014) Therefore new 3-D machines were created, taking into account the diktat 'as low as realistically available' (ALARA).Mozzo et al; in 1998. developed a new CT volumetric machine using the current principle of CBCT and it is currently used for maxillofacial imaging.It was a groundbreaking development in diagnosing and therapy, as it helped the clinician evaluate all 3D viewpoints on morphological characteristics, anatomy and effect.In 1967 Sir Godfrey N.Hounsfield in 1967, an inventor, invented the first generation C.T. (Scarfe and Farman 2008; Tyndall and Rathore 2008)This instrument used to collect an X-ray beam with one detector. The source and detector rotated in one degree and were thus often referred to as a "pencil" beam scanner or translaterotate. It was meant to scan just the head.In1975, the 2nd generation of CT systems, also known as hybrids, was launched.They used a small fan beam and over one detector, but the image quality was weaker because of patient movement due to the length of time needed to take the scan.In 1976, the CT Scanner 3rd generation was developed using fluoroscopic devices,TV camera and light intensifier. They were capturing an X-ray beam with one sensor element.(Scarfe and Farman 2008)(Hashimoto et al. 2006)

Resolution
There are two kinds of image resolution:contrast resolution and spatial resolution.
Display of fine details such as the narrow root canal space or periodontal spaces
can be visualised using spatial resolution.(Palomo et al. 2008) This setting is possible for most CBCT systems. Lower resolution, resulting in a decreased patient radiation exposure may be selected according to the form of CBCT device. In contrast, the ability to distinguish between tissue types with very small absorption variations is the capacity and the differences are seen in the gray stage(Kwong et al. 2008). Many factors restrict CBCT contrast resolution that include noise, flat-panel detector solving capability, refined projection geometry, monitor display features and intrinsic discriminatory human eye constraints. (Qu et al. 2010)A heavy dose of radiation, which is undoubtedly dangerous for a patient, produces a higher image resolution. In order to ensure that the patient and clinician are not exposed to the toxic radiation, it is also critical to reduce the exposure parameters. The CBCT clinicians must therefore be well aware of the working environment and its impact on the image quality and radiation protection.(John B. Ludlow 2008)(Tsiklakis et al. 2005)

Exposure
CBCT units come with a preset exposure settings,but the peak kilovoltage (kvp) or/and milliamperage can also be changed manually. Before using the adjustable settings one should be aware of the impact these settings

would have on the radiation dose of the patient and the image characteristics and quality. Due to this selection of the values should match the values of as low as realistically achievable (ALARA) or as low as practicable (ALAP).(Scarfe et al. 2012) As discussed above both mA and kvp can be changed according to the patient requirements in conformity with the instructions provided by the manufacturer.(Kwong et al. 2008; "Cone-Beam CT Image Quality" 2014) Any adjustments made in kVp has a much stronger impact than any adjustments made in mA, radiation dose is reduced by 40% by decreasing the kVp by 20%, when all the other parameters are kept constant.

Radiation Dosage

The calculation of effective dose (E) or radiation is expressed in Sieverts as exposures to x-rays are measured (Sv). The relative tissue compositions determine the E values in the field of vision and their radiation sensitivity. In 2007, during the calculation of efficient dose of radiation, the International Commission for Radiologic Protection (ICRP) released new factor values for particular organs and tissues. For head area imagery, successful dosage measurement involves the bone,skin, oesophagus,thyroid,brain, salivary glands and "other" tissue. CBCT unit effectiveness is equivalent to panoramic X-rays and some intraoral X-rays but much less than the CT multi-slice(Hughes 2014). In CBCT,effective dose is determined by the FOV size, digital detector sensitivity, type of exposure light beam,x-ray tube electrical power, beam geometry and the number of rotations around the image object(John B. Ludlow and Ivanovic 2008). However, it is important to note that the fundamental rules of ALARA (as low as realistically achievable) must still be implemented successfully to prevent excessive exposure to radiation.(Hughes 2014; J. B. Ludlow et al. 2006)

Types of CBCT

Patient positioning, field of vision, therapeutic functionality, and detector style are all factors to consider when purchasing a CBCT device. Clinicians should weigh all of these factors when buying a unit. The first CBCT unit was designed similarly to MDCT, with the patient lying supine (reclined) during the scan. The patient is either sitting or standing in most CBCT units; this form of unit takes up less room in the dental office and may be more accessible to wheelchair users.Another way to classify these units is by their field of view (FOV). The field of view (FOV) refers to the physiological region that will be used in the data volume or the area of the patient that will be irradiated. The FOV can be categorised as small or limited, medium, or wide depending on the form of machine/detector and the geometry of the x-ray beam.(Scarfe et al. 2012; Jaju 2015)The units that scan small or small spaces cover approx. 5 teeth (5 cm in diameter) and anatomical components around them, which result in less volume to be interpreted by the practitioner Because of their high spatial resolution and capacity to image modifications to the periodontal ligament spaces (PDL) or lamina dura, root fractures, periapical lesions, the interaction of an affected tooth with the underlying anatomical structures, and root canal morphology, small FOV scans are typically used for endodontic purposes. T(Scarfe et al. 2012; Jaju 2015; Gonzalez 2017)he power of the narrow field of view modules to build a greater volume of the entire arch rather than only a few teeth is one of their capabilities.Medium field of view is usually referred to in the scans of about 6-11 cm high and which picture an arch or all dental arches. A median FOV is recommended where an assessment is required of the extent of an injury or the condition of the temporomandibular joints. A pseudo panoramic rendering can be obtained from the data collection when the two dental arches are scanned. In cases of implant preparation, a medium field of view is also provided.For special instances where an orthodontic/orthognathic operation is planned, the large field of vision is preferred. The area scanned can be between 11 and 24 cm high and occupies much of the craniofacial skeleton.
(Scarfe et al. 2012)

Recent Advancements

Tx STUDIO 5.4 software is the newest advancement in CBCT. It uses this technology and has a built in i-CAT CBCTtechnology(Weber et al. 2015)

Uses of CBCT

1. Assessment of Root Canal Preparations and Intra-Operative Procedures Periapical

Being a 3 dimensional imaging technique CBCT helps in assessing the canal surface, volume,taper and ,issues canal during the root canal procedure. Any iatrogenic procedures such as instrument separation, separated instruments, perforations, and calcifications are detected easily using CBCT as it is a 3-D representation of a 2-D structure.(Scarfe and Angelopoulos 2018; Ball, Barbizam, and Cohenca 2013; Liang et al. 2014; Estrela et al. 2008; Jain 2017)(Sekerci et al. 2013)

2. Diagnosis of Traumatic Injuries Facial fractures are usually diagnosed using clinical features, sensitivity tests and lastly radiographic examination. For the detection of horizontal fractures multiple periapical radiographs are required to come to a possible diagnosis. CBCT provides images of high resolution without any geometrical errors. Vertical root fractures on the other hand provide non specific signs and symptoms. (P. Wang et al. 2011; Ping Wang et al. 2012)CBCT helps in the visualisation of the fracture lines in all three planes (sagittal,axial and

coronal) in a single exposure. When compared to medical CT it requires a lesser radiation dose.(Bernardes et al. 2009) In a study by Edlund et al; which compared the efficacy of vertical root fractures in endodontically treated teeth it showed a 91% positive predictive value, therefore can be used as an adequate diagnostic tool in assessment of vertical root fractures.(Kamburoğlu, Ilker Cebeci, and Gröndahl 2009; Rothom and Chuveera 2017; Cuéllar, n.d.; Tang et al. 2011)

3. Analysis of Root Canal Morphology CBCT is a very non invasive and reliable method to explore the root canal anatomy in all the planes. Neelkantan et al; evaluated the canal morphology using dyes and different staining techniques. It showed 99.7% accuracy(Michetti et al. 2010; Neelakantan, Subbarao, and Subbarao 2010). When it came to caries detection; the rates increased from 60% to 93.3% suggesting that CBCT is superior in diagnosing caries than other two dimensional radiography methods.(Bauman et al. 2011) It is also used as an adjunct along with microscopes to detect different usual morphologies that are missed out usually such as MB2 canals, C shaped canals, dens invaginatus or teeth having abnormal root curvatures.(Baratto Filho et al. 2009; Vasundhara and Lashkari 2017)(Kapila 2014)

4. Diagnosis of Root Resorption and Perforations Exact location, extent and nature of a resorptive defect cannot be visualised properly using conventional imaging techniques.THis is due to the superimposition of the anatomical structures.(Cohenca et al. 2007)(D'Addazio et al. 2011)Images using CBCT provide less distortion and superimposition and the images are more geometrically accurate, this feature is useful in the differential diagnosis of cervical resorption from internal resorption. Less image distortion is due to the isotropic voxel size.(Cohenca et al. 2007)(Cohenca et al. 2007; Patel et al. 2009)(Estevez et al. 2010)

5. Assessment of the Quality of Root Canal Treatment and Outcome Assessment CBCT

CBCT can be used in measuring the working length of the root canals. A study by Liang et al; compared the use of CBCT and electronic apex locators in measuring the root canals. This can be particularly useful in patients where the use of apex locators are contraindicated (patients with cardiac pacemakers). CBCT also accurately detected non symptomatic lesions which cannot be visualised using two dimensional radiographic methods.(Martins and Versiani 2019; Spångberg and Haapasalo 2002)

6. Pre-surgical Assessment Conventional radiography gives limited information in the buccal-lingual plane and the presence of the buccal plate interferes while estimating the defects in osseous structures such as periapical lesions.(Behneke, Burwinkel, and Behneke 2012) Distortion of images in panoramic radiographs has also been well documented. CBCT is used for the planning surgical guide fabrication during implant placement and before endodontic surgeries. CBCT helps in the proper visualisation of the anatomic structures like nasal cavity sinuses etc.(Guerrero et al. 2006; Lofthag-Hansen, Gröndahl, and Ekestubbe 2009)

7. Detection of Periradicular Lesions If a periapical lesion is to be detected using 2-D radiology techniques there has to be a minimum of 40-50% of bone loss. Only extensive lesions can be detected , where there is erosion of the cortex of the bone. The early stages of the lesion which are usually within the cancellous bone cannot be detected using periapical radiographs.But with the use of CBCT earliest signs of the lesion can also be detected as there is no anatomic noise present while using CBCT. According to Estrella et al; apical periodontitis could be detected better using CBCT than conventional radiographic methods, this is also true for asymptomatic cases which are missed during routine diagnosis. CBCt can also be used in the diagnosis of When radiographs alone are used to diagnose periapical lesions, benign and malignant lesions such as carcinoma and odontogenic cyst may appear to be periapical lesions. As a result, it gives the clinician a lot of insight and proves the existence of some previously undiagnosed pathosis or odontogenic pain aetiology. This would help the clinician provide accurate diagnosis and treatment planning which would in turn improve the prognosis and the treatment outcome for the patient.(Martins and Versiani 2019; Spångberg and Haapasalo 2002; Dutta, Smith-Jack, and Saunders 2014; Garg and Garg 2014)

Advantages of CBCT

A better understanding of the disease process **-** Let's equate CBCT to traditional approaches to see what the benefits are. CBCT contains 3D information compared to the 2D information produced by periapical radiographs is perhaps the most important advantage of cone-beam CT. As a result, this advancement has transformed the dental industry, enabling dentists to make quicker and more precise diagnosis, treatment plans, and evaluations. Standard fan-beam CT, for example, can only image one jaw at a time. CBCT, on the other hand, can see both jaws at the same time.(Garg and Garg 2014; Garg and Khurana 2015)

Lower radiation exposure to the patient-Researchers also showed that CBCT emits much less radiation when compared to fan-beam CT. Radiation sensitivity from a CBCT machine with a normal full field of view is between 36 and 130 microsieverts. The typical medical CBCT scan of the oral and maxillofacial region, on the other hand, can exceed 1,200 – 3,300 microsieverts. As a result, CBCT will decrease radiation levels by up to 98 percent.

Many fields of application-For dentists to use different imaging modes for any therapeutic indication, CBCT devices often have several FOV sizes. The PreXion 3D Excelsior CBCT, for example, comes in five different FOV sizes: 50x50mm, 100x50mm, 100x81mm, 150x81mm, and 150x130mm, enabling dentists to use it for orthodontics, braces, oral surgery, periodontics, endodontics, TMJ, airway analysis, and ENT.Dental practitioners can achieve excellent image quality and minimise the chance of radiation for patients by varying the imaging mode and selecting the volume size according to the condition.

Faster scan time-CBCT creates, in a single scan rotation, a full volume image, when compared to fan beam CT which produces only a single slice per scan. This would reduce the time required for scanning drastically.

Cheaper-The newer CBCT machines are 5-6 times cheaper than fan based CT.

Easy to use-Since a cone beam scan is almost identical to a panoramic x-ray, there is no learning curve when it comes to understanding how to use cone-beam CT. Furthermore, most CBCT systems enable dentists to translate the CBCT image into other dental-specific formats, such as panoramic or cephalometric.

Improve patient satisfaction-One advantage of using CBCT that is always overlooked is that patients can have a much healthier experience when they visit the clinic. Dentists also use 2D images to visualise 3D images. Patients, on the other hand, are unable to read 2D scans. Patients, on the other hand, can clearly see and appreciate their problems thanks to CBCT.

Disadvantages of CBCT

Poor contrast resolution- This is because of the scattering of the images during the process of image acquisition. This makes the visualisation of the soft tissues difficult and it's one of the most significant disadvantage of CBCT.

Artifacts- Any distortions in the image that is not related to the area or subject of interest. There are two types of artefacts that are seen with CBCT; that being motion artefacts and streaking artefacts. The causes for these could be minor movement of the patient during the procedure of scanning.More studies are needed to prevent the formation of these artefacts during the scanning process.

Poor soft tissue contrast- This is caused due to many factors, the x ray beam that is directed on the patient is not uniform, as it is divergent in nature due to which the absorption alsi not uniform as there is an increased signal to noise ratio on the cathode side when compared to the anode side. So, the visualisation of any soft tissue lesions is difficult and its accuracy would be unknown.

Conclusion

With the introduction of three-dimensional CBCT imaging systems, clinicians now have a strong instrument for interactive image processing and improvement, greatly expanding the amount of data gleaned from a volume. This comparatively new state-of-the-art imaging technology has given dental radiography a new dimension, and it is rapidly becoming the gold standard for radiographic imaging in dentistry. Maxillofacial CBCT imaging offers highly accurate, submillimetre resolution images with excellent diagnostic accuracy, allowing for 3D visualisation of complex osseous structures.

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