Computerised Tomography in Endodontics

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***Abstract*: This review provides an overview of digital radiography as it exists, including advanced imaging such as computed tomography (CT), cone beam-CT and micro-CT as relevant to the practice of Endodontics. New image reconstruction techniques have been introduced that provide information three-dimensionally to the clinician for routine endodontic and surgical treatment planning. Limitations and advantages of newly introduced imaging modalities are discussed briefly.In addition to using CT images, a 3-dimensional analysis was conducted for further visualization. The anatomical configurations of the teeth were clearly observed in the CT scans, as was the relation of the teeth to the periodontal tissues. Further, using CT scans made it possible to determine buccolingual and mesiodistal widths of teeth, and the presence or absence of root canal filling materials and metal posts. In addition, carious lesions of a certain size and expansions of the maxillary sinus and proximity to the roots were observed. The 3-dimensional image analysis was interesting, but detailed observations could not be made with this technique.**

***Keywords*: CT scan, CBCT, Root canal treatment, Advantages in dentistry.**

Introduction:-
Successful management of endodontic problems is reliant on diagnostic imaging techniques to provide critical information about the teeth under investigation, and their surrounding anatomy.(1,2)Since its inception, conventional radiography has remained the mainstay of imaging in Endodontics.(3)In recent decades, however, advances in medical imaging have been applied, with varying success, to the various dental disciplines(4).Among the specific imaging techniques, which have been researched as potential diagnostic and treatment planning tools in Endodontics, are digital subtraction radiology (DSR), tuned aperture computed tomography (TACT), ultrasound (US), magnetic resonance imaging (MRI) and computed tomography (CT) (5). These imaging techniques have been slow to gain acceptance in Endodontics, for an array of different reasons. As such, conventional radiography, despite its inherent limitations, remains the default imaging system in the field(6).However, the development of cone beam computed tomography (CT) has highlighted the inadequacies of conventional radiography when assessing the unique anatomy of the maxillofacial skeleton (7).

Conventional computed tomography (CT) scan:-
Computed tomography (CT) of the body uses special x-ray equipment to help detect a variety of diseases and conditions (8).CT scanning is fast, painless, noninvasive and accurate. In emergency cases, it can reveal internal injuries and bleeding quickly enough to help save lives.Computed tomography, more commonly known as a CT or CAT scan, is a diagnostic medical test that, like traditional x-rays, produces multiple images or pictures of the inside of the body. The cross-sectional images generated during a CT scan can be reformatted in multiple planes, and can even generate three-dimensional images(9).These images can be viewed on a computer monitor, printed on film.CT images of internal organs, bones, soft tissue and blood vessels typically provide greater detail than traditional x-rays, particularly of soft tissues and blood vessels.

Working mechanism of CT:-
X-ray slice data is generated using an X-ray source that rotates around the object; X-ray sensors are positioned on the opposite side of the circle from the X-ray source. The earliest sensors were scintillation detectors, with photomultiplier tubes excited by cesium iodide crystals (10). Cesium iodide was replaced by ion chambers containing high-pressure xenon gas. Initial machines would rotate the X-ray source and detectors around a stationary object. Following a complete rotation, the object would be moved along its axis, and the next rotation started(10). Newer machines permitted continuous rotation with the object to be imaged slowly and smoothly slid through the X-ray ring. These are called helical or spiral CT machines. Instead of a single row of detectors, multiple rows of detectors are used to effectively capture multiple cross-sections simultaneously. (11)

In conventional CT machines, an X-ray tube and detector are physically rotated behind a circular shroud (see the image above right). An alternative, short lived design, known as electron beam tomography (EBT), used electromagnetic deflection of an electron beam within a very large conical X-ray tube and a stationary array of detectors to achieve very high temporal resolution, for imaging of rapidly moving structures, for example the coronary arteries. Cone-beam CT functionality is also an increasingly common function found in medical fluoroscopy equipment; by rotating the fluoroscope around the patient, a geometry similar to CT can be obtained, and by treating the 2D X-ray detector.(11)

Cone beam computed tomography (CBCT):-

Cone beam computed tomography (CBCT) is a relatively new method to visualize an individual tooth or dentition in relation to surrounding skeletal tissues and to create three-dimensional images of the area to be examined. The use of CBCT in Endodontics is rapidly increasing worldwide.(13) Compared with traditional radiographic methods, which reproduce the three-dimensional anatomy as a two-dimensional image, CBCT is a three-dimensional imaging method that offers the possibility to view an individual tooth or teeth in any view, rather than predetermined 'default' views. (13)Therefore, CBCT can be a powerful tool in endodontic diagnosis, treatment planning and follow-up.Currently, CBCT is used most commonly in the assessment of bony and dental pathologic conditions, including fracture; structural maxillofacial deformity and fracture recognition; preoperative assessment of impacted teeth; and temporomandibular joint imaging; and in the analysis of available bone for implant placement. (12)In orthodontics, CBCT imaging is now being directed toward 3D cephalometry. CBCT diagnosis and 3D simulations with virtual surgery and computer-assisted design and manufacture. Image guidance is an exciting advance that will undoubtedly have a substantial impact on dentistry().Radiation dose of CBCT is minimal when compared to conventional CT scan.

Working mechanism of CBCT:-

CBCT is a recent technology. Imaging is accomplished by using a rotating gantry to which an x-ray source and detector are fixed. A divergent pyramidal-or cone-shaped source of ionizing radiation is directed through the middle of the area of interest onto an area x-ray detector on the opposite side.(14) The x-ray source and detector rotate around a rotation fulcrum fixed within the center of the region of interest. During the rotation, multiple sequential planar projection images of the field of view (FOV) are acquired in a complete, or sometimes partial, arc. This procedure varies from a traditional medical CT, which uses a fan-shaped x-ray beam in a helical progression to acquire individual image slices of the FOV and then stacks the slices to obtain a 3D representation. (15)Each slice requires a separate scan and separate 2D reconstruction.

Advantage of cone beam ct over conventional CT:-

CBCT is well suited for imaging the craniofacial area. It provides clear images of highly contrasted structures and is extremely useful for evaluating bone. (16)The use of CBCT technology in clinical practice provides a number of potential advantages for maxillofacial imaging compared with conventional CT:

1.X-ray beam limitation:

Reducing the size of the irradiated area by collimation of the primary x-ray beam to the area of interest minimises the radiation dose. (16)Most Cone Beam CT units can be adjusted to scan small regions for specific diagnostic tasks. In dentistry CBCT contains short and long film,short film used for particular area which reduces the radiation dose for the patients whereas long film capable of scanning the entire craniofacial complex when necessary.

2.Image accuracy:

The volumetric data set comprises a 3D block of smaller cuboid structures, known as voxels, each representing a specific degree of x-ray absorption. The size of these voxels determines the resolution of the image. (17)In conventional CT, the voxels are anisotropic rectangular cubes where the longest dimension of the voxel is the axial slice thickness and is determined by slice pitch.

3.Rapid scan time:

Because Cone Beam CT acquires all basis images in a single rotation, scan time is rapid (10–70 seconds) and comparable with that of medical spiral CT systems. (17)Although faster scanning time usually means fewer basis images from which to reconstruct the volumetric data set, motion artifacts due to subject movement are reduced.

4.Display modes unique to maxillofacial imaging:

Access and interaction with conventional CT data are not possible as workstations are required. Although such data can be converted and imported into proprietary programs for use on personal computers , this process is expensive and requires an intermediary stage that can extend the diagnostic phase. Reconstruction of CBCT data is performed natively by a personal computer.(18) Because the CBCT volumetric data set is isotropic, the entire volume can be reoriented so that the patient's anatomic features are realigned(19). In addition, cursor-driven measurement algorithms allow the clinician to do real-time dimensional assessment.

5.Reduced image artifact:

With manufacturers' artifact suppression algorithms and increasing number of projections, our clinical experience has shown that Cone Beam CT images can result in a low level of metal artifact, particularly in secondary reconstructions designed for viewing the teeth and jaws.

Use of CT Scan in dentistry:

1.A computed tomography scan is a noninvasive medical test that uses special X-ray equipment to produce multiple images or pictures of the inside of the body and a computer to join them together in cross-sectional views of the area being studied.(20)

2. Traditional panoramic X-rays performed by dentists provide only a limited two-dimensional view. While they can show the height and contour of the jaw bone, they give no indication of the bone width and density and may distort the location of the alveolar nerve.

3. Three-dimensional dental CT imaging takes the guesswork out of implants. This quick and safe diagnostic imaging exam produces life-like spatial views of the mouth that let the surgeon determine pre-surgically if a patient is an implant candidate(20). With 3D imaging, a surgeon can proceed with confidence, knowing the amount of bone a patient has, the distance to the alveolar nerve and the exact angles to situate the implant. Dental CT imaging is used when patients are being fitted for implants(21).

4. The more information a surgeon has about the anatomy of the patient's mouth before a dental implant, the better the outcome. Important measurements for the surgeon to know include the width and density of the jawbone ridge in order to assess implant feasibility and the exact placement of the alveolar nerve in order to prevent painful nerve damage.

5. Dental CT imaging can also help visualize nerve location prior to wisdom tooth extraction.(22)

6. In endodontics used to detect apical periodontitis,root canal anatomy and complex morphology.

Uses of ct in Endodontics:-

Assessment of periapical periodontitis :-

Apical periodontitis (AP) is the principal disease associated with infection of the root canal system. Currently, the accepted reference standard for the radiological detection of AP is periapical radiography(23) .However, in the early stages of AP, periapical bone destruction may be minimal or be masked by adjacent anatomy, such that its presence is not manifested on conventional radiographs. Periapical radiographs identified the presence of periapical lesions in 3% of the roots whilst CBCT could demonstrate the presence of AP in 14% of the paired roots. The current evidence suggests that CBCT does have a higher sensitivity compared with periapical radiography for the detection of periapical lesions. The specificity of both types of imaging systems is similar;CBCT should not be used for routine assessment of periapical disease prior to Endodontic treatment. However, it may be indicated to aid the diagnosis of (non)odontogenic pain when clinical examination and conventional radiographic assessment is not clear;CBCT should not be used for the routine assessment of the outcome of root canal treatment(24).

Assessment of root canal anatomy:-

Investigated to compare charged-couple device and photostimulable phosphor plate digital radiography systems with CBCT to detect the number of root canals in 72 extracted mandibular incisors, first premolars and maxillary first molar teeth. They found that with digital radiographs, regardless of the system used, Endodontists despite taking parallax radiographs failed to identify at least one root canal in 40% of teeth when compared with CBCT(25).assessed the prevalence of disto-lingual roots in mandibular first molar teeth assessed with conventional radiographs and CBCT; they found that the prevalence of disto-lingual canals was 21% and 33%, respectively, with radiographs and CBCT respectively. Cone beam computed tomography is a useful addition to the endodontist’s armamentarium for identifying root canals however, it should only be reserved for cases where root canal anatomy cannot be fully appreciated with existing aids, such as parallax radiographs and the dental operating microscope(25).

Pre surgical assessment:-

In addition to revealing radiographic signs of periapical pathosis and root canal anatomy, CBCT scans accurately determine the relationship of adjacent anatomical structures to teeth with endodontic problems(26). This clinically relevant information may be useful for treatment planning and the subsequent management of the tooth in question. Cone beam computed tomography should only be considered when existing radiographic techniques do not yield adequate diagnostic information, such as the proximity of the root apices (and associated periapical pathosis) to neighbouring anatomical structures (e.g. the maxillary sinus and inferior dental canal)(27).

Applications of dental trauma assessment:-

Radiographic assessment is essential for establishing a differential diagnosis of my traumatic dental injuries.Intra-oral views can help to identify the location, type and severity of the traumatic dental injuries(28) .In addition, periapical radiographs can help to assess: stage of root development in young permanent teeth, periapical pathosis and the correlation of displaced primary teeth with developing successors and proximity of pulp tissue with tooth fractures(28).

Diagnosis and management of root resorption :-

Due to its often quiescent onset, varying clinical presentation and potential to affect any part of the root’s external surface or canal wall, the detection of root resorption is often challenging. The definitive diagnosis of root resorption is ultimately dependent on the radiographic demonstration of the disease process, which in turn is limited by the diagnostic potential of the imaging device used to determine its presence(29).

Advantages of CT

1.There are several advantages that CT has over traditional 2D medical radiography. First, CT completely eliminates the superimposition of images of structures outside the area of interest. Second, because of the inherent high-contrast resolution of CT, differences between tissues that differ in physical density by less than 1% can be distinguished(30).
2.Finally, data from a single CT imaging procedure consisting of either multiple contiguous or one helical scan can be viewed as images in the axial, coronal, or sagittal planes, depending on the diagnostic task. This is referred to as multiplanar reformatted imagin(30).CT is used in medicine as a diagnostic tool and as a guide for interventional procedures.
3.Sometimes contrast materials such as intravenous iodinated contrast are used. This is useful to highlight structures such as blood vessels that otherwise would be difficult to delineate from their surroundings. Using contrast material can also help to obtain functional information about tissues(31).
4.The software necessary for CT data reconstruction can be run on personal computers, potentiating its use as a chairside diagnostic and treatment planning tool. In addition, multiple slices can be scrolled through in real time producing dynamic images. Cursor driven measurements allow dimensional assessments to be made, again in real-time.
5. In addition, basic image manipulations are possible(32).Window levels can be adjusted, specific areas can be magnified and annotations can be added(32).Surface rendering software is also available.
6.The scan times achievable with CT are short and comparable with panoramic radiography. This is beneficial in that the likelihood of patient movement during the scan is less. In addition, the CT hardware is much large and more expensive than CBCT machines. Therefore, CT is well suited to use in dental practice(33).

Limitations of CT

1. Computed tomography imaging is sometimes affected by radiographic artifacts related to the X-ray beam.
2. When the CT X-ray beam encounters an object of very high density, such as enamel or metallic restorations, lower energy photons in the beam are absorbed by the structure, in preference to higher energy photons.
3. The result is that the mean energy of the X-ray beam increases(34).This is called 'beam hardening' and the phenomenon produces two types of artifact: distortion of metallic structures, called 'cupping artifact', and the appearance of streaks and dark bands between two dense structures.
4. These artifacts can reduce the diagnostic yield of the images.Furthermore, patient movement during the scan can adversely affect the sharpness of the final image (34).

Technical consideration:-

CT radiation dose and digital image quality:-
The effective dose of CT scans is higher than periapical and panoramic radiography. The effective dose varies between scanners(34). It is also dependent on the region of the jaw being scanned, exposure settings of the CT scanner, the size of the field of view (FOV), exposure time (s), tube current (mA) and the energy/potential (kV)(28). An image always contains a degree of 'noise', that is, false grey scale level of a single pixel, which may influence the quality of the image generate (35).Too low mA causes noise in the image, conversely a higher mA decreases the amount of noise; however this comes at an increased radiation dose to the patient. Endodontic CT imaging should offer not only 3D assessment of the region of interest, but also generate the images with an adequate spatial resolution to allow detailed assessment of the tooth and the surrounding alveolar anatomy(36).CT systems have significantly lower spatial resolution than intra-oral radiographs(29).

Dose reduction and optimisation:-
To ensure patient safety, personnel who use a CT scanner must have appropriate training and knowledge of patient radiation doses related to the specific CT scanner they are using. For endodontic purposes, the FOV should be limited to the region of interest, that is, the FOV should encompass the tooth (or teeth) under investigation and its surrounding structures. This is an effective way to reduce the patient dose (37).The tube current (mA) selected should be as low as possible, so that the image produced is of sufficient diagnostic yield even though there may be a degree of noise(38) .The effective dose is also dependent on the region of the oral cavity being scanned(39).

Conclusion
The decision to expose a patient to a CT investigation must be carried out on a case-by-case selection; The potential benefits of the CT scan should outweigh the potential risks; Radiology is constantly evolving(40) .clinicians must regularly update their core knowledge in CT; Postgraduate endodontic programmes should incorporate the use of CT into their curriculum to ensure graduates are competent(41).The impact of CT on decision-making in endodontic treatment planning requires further investigation(42).

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