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RESEARCH ARTICLE

IMPLICATIONS OF CBCT IN PEDIATRIC DENTISTRY-A REVIEW

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Abstract

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The introduction of CBCT (Cone Beam Computed Tomography) devices, modified the way dentistry is practiced. CBCT was encircled into dentistry very expeditiously due to its low cost, compact size, low ionizing radiation exposure. CBCT with 3D (Three dimensional) technology is a replacement for conventional 2D (Two dimensional) imaging & has a wide application among child patients in pediatric dentistry. This article provides an overview of basics of CBCT technology & reviews the specific implications of CBCT technology to pediatric & preventive dentistry.

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Introduction:-

Sir Wilhelm Conrad Roentgen brought the light on x-rays in 1895.The introduction of panoramic radiography in the 1960's and its widespread adoption throughout the 1970's and80's signaled major progressing dental radiology providing clinicians with a single comprehensive image of both jaws and maxillofacial structures[1]. 3D advanced to meet the demands of current technologies in delivering the treatment and at the same time responsible for the advancement of new treatment strategies. The introduction of CBCT to dentistry has created an unprecedented revolution in oral and maxillofacial imaging, eclipsing the introduction of panoramic radiography in the 1960's. The radiographic imaging used to treat patients by recording images of internal structures of body to assess the presence or absence of disease, foreign objects and structural damage or anomaly.

CBCT signaled a new dental technology for the twenty- first century. The disclosure of cone-beam computed tomography has enlarged the field of oral and maxillofacial radiology. CBCT imaging constructed three-dimensional volumetric data construction of dental and associated maxillofacial structures with isotropic resolution and high dimensional[2,3].The two main revolution have driven development of these imaging systems.The first is the swap from analog to digital imaging. Second, advances in imaging theory and Volume-acquisition datawhich autherised for increasingly detailed 3D imaging.

Cone beam technology is medica limage acquisition technique that uses a cone shaped beam of radiation centered on a 2D detector.The source detector system performs one rotation around the object producing a series of 2D images.

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During the exposure sequence, hundreds of planar projection images are obtained of the field of view in an arc of at least 180°. Just as digital picture is sub divided into pixels the volume acquired by a CBCT is composed of voxel. The images are recreated in a 3D data set using a modification of the original cone- beam algorithm evolved by **Feldkampetal**. In1984.In addition to increased accuracy and higher resolution, CBCT offers significant scan-time reduction, radiation dose reduction, and reducedcost for the patient[4].

With the assistance of viewer software, the clinician is able to scroll through the entire volume and simultaneously view axial, coronal, and sagittal 2D sections that range from 0.125–2.0 mm thick. The axial and proximal (sagittal in the anterior, coronal in the posterior) views are of particular value, because they are generally not seen with conventional periapical radiography.The ability to reduce or eliminates upper imposition of the surrounding structures makes CBVT superior to conventional periapical radiography.In addition to the 2D slices, 3-d reconstruction enables further analysis of the area of interest[5].

Oral diagnosis and treatment planning is of paramount importance in pediatric dentistry. Since the advent of X-rays, dental radiology has played an important role in the diagnosis and treatment planning and prognosis of dental diseases in pediatric patients.

CBCT has been described as the – Gold standard for imaging oral and maxillofacial area and will no doubt become a part of the everyday life of most practices in the coming decades .It is a great responsibility to deliver this technology to patients in a responsible way, sso that diagnostic value is maximized and radiation doses kept as low as reasonably achievable**.**

Discussion:-

CBCT is a technology used to take 3D images of teeth, maxillary sinus, nerve pathways and bone in maxillofacial region with a single scan. It rotates around patients in approximately 30s, capturing data using a cone shaped x-ray beam.it is used when regular 2D dental x-rays are not sufficient. With CBCT, clinicians can get highly detailed 3D views of facial regions with lower radiation exposure than a conventional CT scan. This may helps with the diagnosis, treatment planning and evaluation of certain conditions.

Advantages

CBCT technology in clinical practice has many advantages like-

1. **Size and cost:**

CBCT equipment has a greatly reduced size and cost ($1/4^{th}$-$1/5^{th}$) compared with the conventionalCT. Both these features make it available for the dental office.

2. **Rapid scan time:**

Compared with conventional CT, the time for CBCT scanning is significantly lessen.This is because the CBCT requires only a single scan to capture the necessary data compared to conventional scanners where several fan beam rotations are required to complete the imaging of an object.

3. Image accuracy:

CBCT constructed images with submillimeter voxel resolution ranging from 0.4mm to a slow as 0.125mm. Because of this property, coronal and subsequent MPR of CBCT data has the same resolution as axial data[6].

CBCT projection geometry results in a low level of metal artifact in primary and secondary reconstructions with reduced superimposition of the overlying tissues.

4. **Low patient radiationdose:**

Patient radiation dose can be lowered by collimating the beam, elevating the chin and using thyroid and cervical spine shielding CBCT gives a range of dose depletion of between 51% and 96% compared with conventional head CT (1400-2100 μSv)[6].

Patient positioning modifications can substantially reduce the dose by up to 40%.

5. **Interactive analysis:**

The availability of cursor driven measurement algorithms provide the practitioner with an interactive capability of real-time dimensional assessment, annotation and measurements[7].

6. Beam limitation:

Collimation of the CBCT primary X-ray beam enables limitation of radiation to the area of interest based on disease presentation and the region designated to be imaged.

Patient comfort:

No intra-oral placement of film or sensor is required and the scanning can be carried out with the patient in seated position[8].

Disadvantages

CBCT has various disadvantages such as-

1. **Image noise:**

A large portion of photons in the cone-beam produce Compton scattering resulting in scattered radiation.Inclinical applications, the scatter-to-primary ratios are about 0.01 for single-ray CT and 0.05-0.15 for fan-beam and spiral CT and may be as large as 0.4-2 in CBCT[6].

2. Poor soft tissue contrast:

Contrast is the spatial variation of the X-ray photon intensities that are pass on through the patient. Two principal factors which control the contrast resolution of CBCT include: scattered radiation and FPD based artifacts[7].

Limitations Of conventional Radiography

1. **Compression of three dimensional anatomy** -

Conventional radiography compresses three dimensional structures to two dimensional image or shadow graph which greatly reduces the diagnostic performance[9,10]. The radiograph provides a visualization of the anatomy under examination in the mesio-distal plane, whils taffording very little appreciation of structures in the third (buccolingual) dimension.

2. **Geometric distortion-**

To reproduce apical anatomy, paralleling technique produces more geometrically accurate images than bisecting angle technique[11]. This can be placed comfortably in mandibular region as floor of the mouth comfortably accommodates the image receptor, although it may be compromised in patient with small mouth, gagging or poor tolerance to the receptor[12]. In the maxilla, shallow palatal vault also prevent ideal positioning of the intra oral image receptor. Hence this lack of long axis orientation results in geometric distortion of the radiographic image[13].

3. **Anatomical Noise:**

Anatomy in or forcasted over, the area of interest during conventional radiographic imaging may hinder visualization of the object under investigation, and complicate interpretation of the radiograph. These anatomical interferences can vary in radio-density and are referred to as anatomical noise[14].

4. **Temporal perspective:**

Radiographic images represent a ‘snapshot’’ in time of the area being assessed. To evaluate the outcome of endodontic treatment, radiographs exposed at different points in time should be compared. Pre-treatment, post-treatment and follow-up radiographs should be systematized with respect to the irradiation geometry, density and contrast to allow dependable interpretation of any changes which may have occurred in the periapical tissues as a result of treatment[15]. This is particularly salient in the assessment of External Root Resorption, which can commence and progress rapidly. This has been minimized using customized bite blocks attached to paralleling devices, but again getting identical images of the object for future assessment is never identical.

All these limitation of intra oral radiography lead to the development of alternative imaging techniques of which CBCT is being most promising

CBCT versus Multi detector computed tomography (MDCT)

These are various differences between CBCT and MDCT -

1. Cost of the CBCT equipment is approximately 3-5 times less than traditional MDCT. The lower cost of the machine may be passed onto the patient in the form of lower fees.
2. CBCT equipment is substantially lighter and smaller; hence occupies lesser space.
3. Cone-beam CTs have better spatial resolution.
4. No special electrical requirements needed.
5. No floor strengthening required.
6. The room does not need to be cooled.
7. Veryeasyto operate andto maintain; little technician training is required.
8. Some cone-beam manufacturers and vendors are dedicated to the dental market. This makes for a greater appreciation of the dentist‘s needs.
9. In the majority of cone-beam CTs, the patient is seated as compared with lying down in a MDCT unit. This, together with the open design of the cone beam CTs, virtually eliminates claustrophobia and greatly enhances patient comfort and acceptance. The upright position is also thought by many to provide a more realistic picture of condylar positions during a TMJ examination.
10. Both jaws can be imaged at the same time(depending on the specific cone-beam machine)
11. Radiation dose is considerablyless (3-20%) than with a medical CT.
12. Visual resolving power varies upto 2 line pairs/mm, four times that of CT.
13. To diagnose a dental arch, a CT captures 1 slice/second at 150kVp and 200mA; for an implant surgery 40 slices are required. CBCT can capture the image at 80kVp and 5 mA within 12-24 seconds.
14. CT slice thickness is usually 1-2mm, while a CBCT gives 0.1mm slice thickness.
15. Plain-film tomography results in magnification, the degree of which differs from manufacturer to manufacturer.
16. Plain-film tomography provides direct (as opposed to reconstructed) cross-sectional, sagittal andcoronal views.
17. The disadvantage of plain-film tomography is that it requires much more chair time than CT. It can thus be especially difficult to do on patients who are unable to sit or hold still for a period of time. CBCT, on the other hand, can be performed within a 10-40 second range, depending on the region being imaged and on the desired qualityof the image.
18. Cone-beam CT also provides stronger indication of bone quality[16].

Diagnostic Applications

1. **Development of teeth**
   Conventional imaging techniques make it difficult to visualize the complex phenomenon of tooth development. CBCT can help to evaluate eruption pattern of teeth along with any abnormality in number and shape. This can help clinicians plan eruption guidance and serial extraction customized to individual patient.
2. **Caries diagnosis**
   CBCT imaging appears to be the best proposer for improving the detection and depth assessment of caries in a proximal and occlusal lesions.
3. **Diagnosis of impacted/supernumerary teeth**
   CBCT modality can be used broadly for diagnosing impacted teeth in pediatric patients. Maxillary canine are the most common teeth to get impacted. Other than canines, permanent second molars may also get impacted due to malpositioning of third molars inside the alveolar bone. It is also observed that impacted teeth may often seen to be present with supernumerary teeth such as mesiodens.
4. **Diagnosis of temporomandibular (TMJ) disorders**
   Conventional tomography has been used extensively for the evaluation of TMJ hard tissues. However, technique sensitivity and the length of examinations have made it a less attractive diagnostic tool. The application of CBCT imaging the TMJ has been most significant in the e valuation of hard tissues and bony changes of the joint.
5. **Soft tissue analysis**
   Using the soft-tissue data gathered in the CBCT scan, it is possible to rotate and tilt the head in an infinite number of positions to evaluate symmetry of the soft-tissues. CBCT allows for the creation of separate images of the left and right sides for assessment of asymmetries.

6. **Cleft lip and palate**
   CBCT can provide the exact anatomic relationship of the osseous defect and bone thickness around the existing teeth in proximity to the cleft or clefts, which is not possible with 2D imaging modalities.
7. **Airway analysis**
   CBCT is a paramount value in this as there is a clear distinction between the soft-tissues of the pharynx and the airway space. This allows for clear segmentation of the airway while doing volumetric analysis.
8. **Orthodontic temporary anchorage device (mini implant) placement**
   CBCT data can be used to construct placement guides for positioning mini-implants between the roots of adjacent teeth in anatomically difficult sites, which has been difficult for 2D radiography.
9. **Diagnosis of hard tissue lesions of the oral cavity**
   It can provide valuable information regarding cystic lesions and their extent, various bony pathologies such as tumors, fracture lines in case of traumatic injuries, condensing osteitis and focal apical osteopetrosis. Also useful in determining the limitation to tooth movement in case orthodontic treatment is required.
10. **Assessment of root canal morphology**
    Second mesiobuccal canal (MB2) in maxillary first molar vary from 70-90%, this variability occur in buccolingual plane, where the superimposition of anatomical structure impedes the detection of small structural density changes.
11. **Dental periapical pathosis**
    Most common pathologic condition that involves teeth have inflammatory lesions of the pulp and periapical areas, lesions confined to cancellous bone with little or no cortical plate erosion is difficult to diagnose with intraoral modality.
12. **Root fractures**
    CBCT in diagnosis and management of specific aspects of dentoalveolar trauma, especially root fractures, luxation, displacement and alveolar fracture.
13. **Root resorption**
    Root resorption is the loss of dental hard tissues as a result of clastic activities (extrinsic & intrinsic).
14. **Postoperative assessment**
    Healing of apical lesions is an important aspect of postoperative assessment, adequately of root canal obturation is a important determinant of treatment success, integrity of root canal fillings, precise nature of perforation etc.
15. **Maxillofacial trauma**
    CBCT is useful in case of gun-shot injury. It provides 3D view of the site.

Principle Of Cone Beam Computed tomography

The principle of cone-beam computed tomography (CBCT) has been a subject of investigation since the proposition of **Feldkamp algorithm**[17].

The original clinical CT scanner was introduced by **Sir Godfrey N.Hounsfield** in **1967**. The data acquisition in conventional CT imaging has evolved through 4 generations of acquisition geometries.

1. **First-generation data acquisition** was based on a translate -rotate parallel-beam geometry where in pencil beams of x-rays were directed at a detector opposite the source and the transmitted intensity of photons incident on the detector was measured. The gantry would then both translate and rotate to capture x-ray attenuation data systematically from multiple points and angles[18].
2. **Second-generation scanners** introduced fan-beam x-ray geometry and used a single- detector linear array.
3. **Inthird-generation scanners** thesingle-detector arc was introduced in conjunction with fan-beam x-ray geometry.
4. **Fourth-generation scanners** used a fan-beam of x-rays and a circular detector array.

All CT scanners as shown in **Fig1, 2, 3**[6]

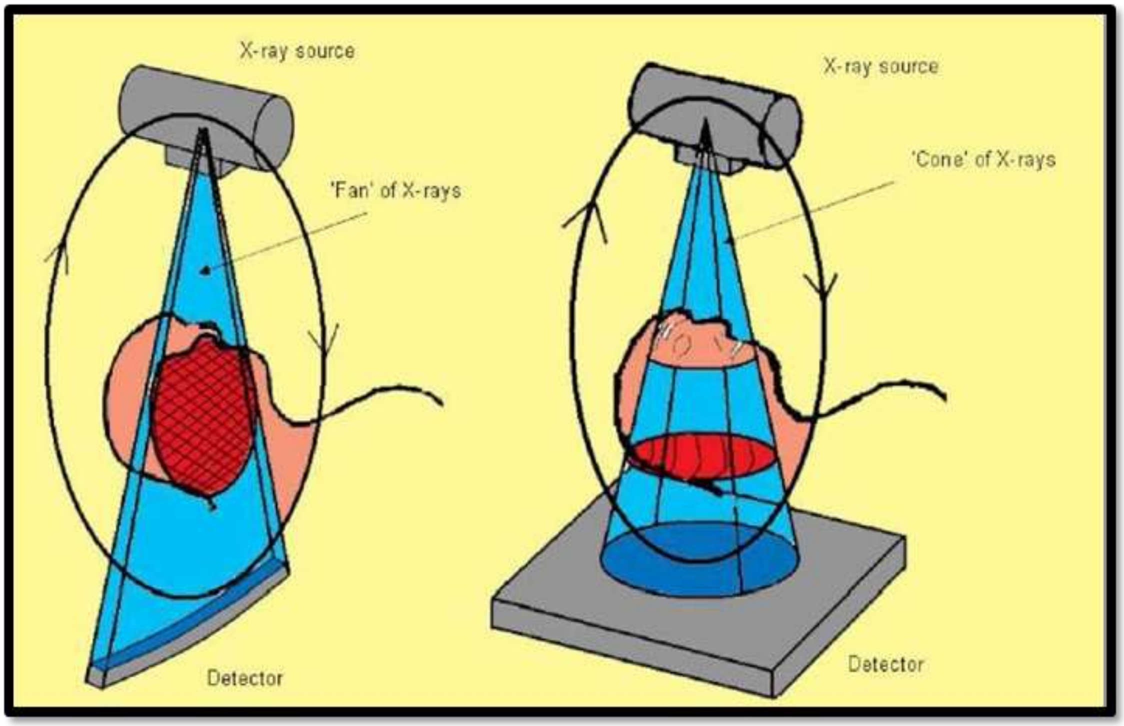

Fig 1:- Difference between multidetector CT(1)andCBCT(2).

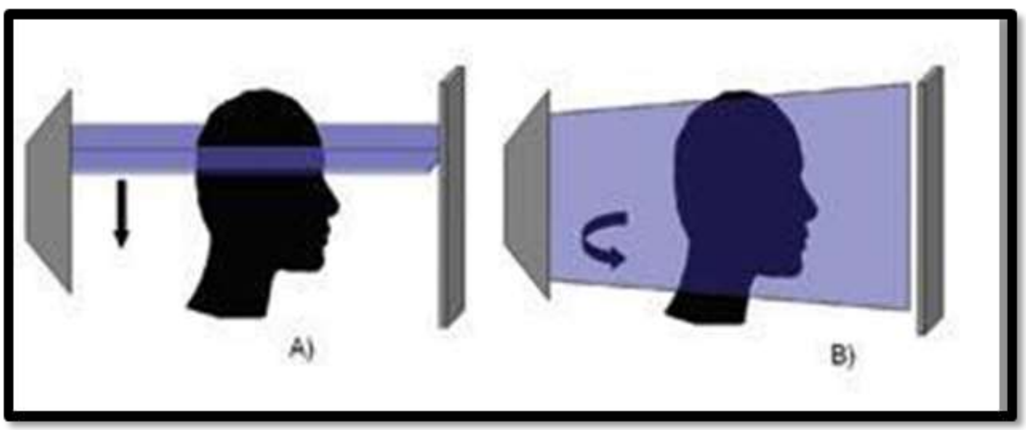

Figure2:- Illustration showing the difference between the data captures systemof regular CT and CBCT. (A) A regular CT machine captures the data in a fan fashion; (B) the CBCT captures the data in a volumetric fashion.

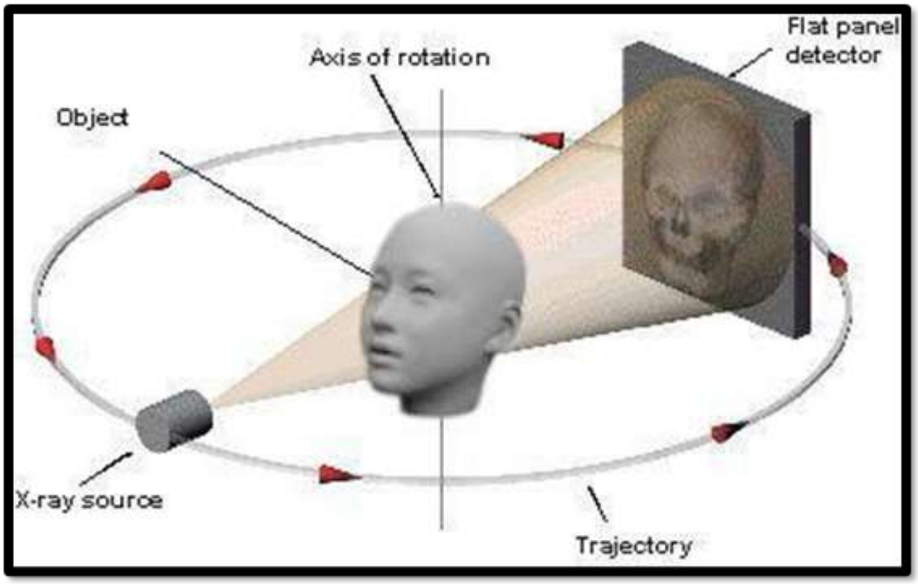

Figure3:- Principle of CBCT.

Two main parts of CBCT are-
1. X-ray source and
2. Detector mounted on a rotating gantry.

During rotation of the gantry, the receptor detects X-rays attenuated by the patient. CT can be divided into two categories on the basis of acquisition X-ray beam geometry namely:
1. Fan beam and
2. Conebeam

The two principal differences that distinguish CBCT from traditional CT are the type of imaging source-detector complex and the method of data acquisition.

The X-ray source for CT is a high-output rotating anode generator, while that for CBCT can be alow-energy fixed anode tube similar to that used in dental panoramic machines.

CT employs a fan-shaped X-ray beam from its source for imaging and records the data on solid-state image detectors arranged in a 360-degree array around the patient. CBCT technology uses a cone-shaped X-ray beam with a special II and a solid-state sensor or an amorphous silicon plate for capturing the image[19].

The principal feature of CBCT is that multiple planar projections are acquired by rotational scan to produce a volumetric data set from which interrelation images can be generated[20]. Cone-beam scanners use a two-dimensional digital array providing an area detector rather than a linear detector as conventional CT does. This is combined with a three-dimensional X-ray beam with circular collimations that the resultant beam is in the shape of a cone, hence the name cone-beam[6].

Conclusion:-

Conventional intraoral radiography provides clinicians with an accessible, cost effective, high-resolution imaging modality that continues to be of value in pedodontic therapy. However, specific situations, both pre-and postoperatively, where the understanding of spatial relationships is required it is best provided by the use of CBCT which not only facilitates diagnosis but also influences treatment planning.

CBCT technology aids in the diagnosis of pathosis, canal morphology, assessing root and alveolar fractures, analysis of resorptive lesions, identification of pathosis of non-endodontic origin, and pre-surgical assessment before root-end surgery. When differentiated with medical CT, CBCT has increased accuracy, higher resolution, reduced scantime, a reduction in radiation dose, and reduced cost for the patient. When differentiated with conventional peri-apical radiography, CBCT eliminates superimposition of surrounding structures, providing additional clinically relevant information.

However, despites it's numerous advantages over conventional radiography and medical CT, it should not be used for routine diagnosis or for screening purposes and according to AAOMR (American Academy of Oral and Maxillofacial Radiology), this 3D imaging modality should only be used when the question for which imaging is required cannot be answered adequately by lower-dose conventional dental radiography or alternate imaging modalities.

As this technology is evolving and is being embraced by many clinicians, the availability of CBCT will become more widespread in near future has accurate diagnostic information leads to better clinical outcome but should be limited to the assessment and treatment of complex pedodontic conditions.

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