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RESEARCH ARTICLE

IMPLICATIONS OF CBCT IN PEDIATRIC DENTISTRY-A REVIEW

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Abstract

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.

Introduction:-

Sir Wilhelm Conrad Roentgen brought the light on x-rays in 1895.Theintroductionofpanoramicradiographyinthe1960'sanditswidespreadadoption throughoutthe1970'sand80'ssignaledmajorprogressindentalradiologyproviding clinicians with asingle comprehensive imageof 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].Thetwomainrevolutionhavedrivendevelopmentoftheseimagingsystems.The firstistheswapfromanalogtodigitalimaging.Second,advancesinimagingtheoryand Volume-acquisition datawhich autherised for increasinglydetailed 3D imaging.

Conebeamtechnologyismedicalimageacquisitiontechniquethatusesacone shapedbeamofradiationcenteredona2Ddetector.Thesourcedetector system performs onerotation aroundthe object producing aseries of 2D images. Duringthe exposuresequence,hundredsofplanarprojectionimagesareobtainedofthefieldofview

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inanarcofatleast180°.Justasdigitalpictureissubdividedintopixelsthevolume acquiredbyaCBCTiscomposedofvoxel. Theimagesare recreatedina3Ddatasetusingamodificationoftheoriginalcone- beamalgorithmevolved by**Feldkampetal**.in1984.Inadditiontoincreasedaccuracyandhigher resolution,CBCTofferssignificantscan-timereduction,radiationdosereduction,and reducedcost forthe patient[4].

Withthe assistanceof viewer software,the clinicianisable toscrollthroughthe entire volumeandsimultaneouslyviewaxial,coronal,andsagittal2Dsectionsthatrangefrom 0.125–2.0mmthick. Theaxialandproximal(sagittalintheanterior,coronalinthe posterior)viewsareofparticularvalue,becausetheyaregenerallynotseenwith conventionalperiapicalradiography.Theabilitytoreduceoreliminatesuperimpositionof thesurroundingstructuresmakesCBVTsuperiortoconventionalperiapicalradiography.In additiontothe2Dslices,3-dreconstructionenablesfurtheranalysisofthe areaof 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.

CBCThasbeendescribedasthe-Goldstandardforimagingoralandmaxillofacial areaandwillnodoubtbecomeapartoftheeverydaylifeofmostpracticesinthecoming decades.Itisagreatresponsibilitytodeliverthistechnologytopatientsinaresponsible way,sothatdiagnosticvalueismaximizedandradiationdoseskeptaslowasreasonably 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

CBCTtechnologyinclinicalpracticehasmanyadvantageslike-

1. **Size and cost:**

CBCT equipment has agreatlyreduced sizeand cost($1/4^{th}$-$1/5^{th}$)compared with the conventionalCT. Boththesefeatures makeit available for the dental office.

2. **Rapid scan time:**

ComparedwithconventionalCT,thetimeforCBCTscanningis significantly lessen.This isbecausetheCBCTrequiresonlyasinglescantocapturethenecessarydatacomparedto conventionalscannerswhereseveralfanbeamrotationsarerequiredtocompletethe imagingofanobject.

3. Imageaccuracy:

CBCTconstructedimageswithsubmillimetervoxelresolutionrangingfrom0.4mmtoaslow as0.125mm.Becauseofthisproperty,coronalandsubsequentMPRofCBCTdatahas thesameresolutionasaxialdata[6].

CBCTprojectiongeometryresultsinalowlevelofmetalartifactinprimaryandsecondary reconstructions with reduced superimposition ofthe overlyingtissues.

4. **Low patient radiationdose:**

Patientradiationdosecanbeloweredbycollimatingthebeam,elevatingthe chinandusingthyroidandcervicalspineshieldingCBCTgivesarangeofdosedepletionofbetween51%and96%comparedwi th conventional head CT (1400-2100 μSv)[6].

Patientpositioningmodificationscan substantiallyreducethedose byup to 40%.

5. **Interactiveanalysis:**

Theavailabilityofcursor drivenmeasurementalgorithmsprovidethepractitionerwithaninteractivecapabilityof real-time dimensional assessment, annotation andmeasurements[7].

6. Beamlimitation:

CollimationoftheCBCTprimaryX-raybeamenableslimitationofradiationtotheareaof interestbasedondiseasepresentationandtheregiondesignatedtobeimaged.

Patient comfort:

Nointra-oralplacementoffilmorsensorisrequiredandthescanningcanbecarriedout with thepatient in seatedposition[8].

Disadvantages

CBCT has various disadvantages such as-

1. **Imagenoise:**

Alargeportionofphotonsinthecone-beamproduceComptonscatteringresultingin scatteredradiation.Inclinical applications,thescatter-to-primaryratiosareabout0.01forsingle-rayCTand0.05-0.15for fan-beam and spiral CT and maybe as large as 0.4-2 in CBCT[6].

2. Poor soft tissue contrast:

ContrastisthespatialvariationoftheX-rayphotonintensitiesthatarepass onthrough thepatient.TwoprincipalfactorswhichcontrolthecontrastresolutionofCBCTinclude:scattered radiationandFPDbasedartifacts[7].

Limitations Ofconventional Radiography

1. Compression of threedimensional anatomy-

Conventionalradiographycompressesthreedimensionalstructurestotwodimensional imageor shadowgraph which greatlyreduces thediagnostic performance[9,10]. Theradiographprovidesavisualizationoftheanatomyunderexamininginthe mesiodistalplane,whilstaffordingverylittleappreciationofstructuresinthethird (buccolingual) dimension.

2. **Geometricdistortion-**

Toreproduceapicalanatomy,parallelingtechniqueproducesmoregeometrically accurateimagesthanbisectingangletechnique[11].Thiscanbe placedcomfortablyinmandibularregionasfloorofthemouthcomfortably accommodatestheimagereceptor,althoughitmay becompromisedinpatientwithsmall mouth,gaggingorpoortolerancetothereceptor[12].Inthemaxilla,shallowpalatalvault alsopreventidealpositioningoftheoftheintraoralimagereceptor.Hencethislackof longaxisorientationresultsingeometricdistortionoftheradiographicimage[13].

3. **Anatomical Noise:**

Anatomyinorforcastedover,theareaofinterestduringconventional radiographicimagingmay h i n d e r visualizationoftheobjectunderinvestigation,and complicateinterpretationoftheradiograph.Theseanatomicalinterferencescanvaryin radio-densityand arereferred to as anatomical noise[14].

4. **Temporal perspective:**

Radiographicimagesrepresenta‘snapshot" intimeoftheareabeingassessed.To evaluatetheoutcomeofendodontictreatment,radiographsexposedatdifferentpointsin timeshouldbecompared.Pre-treatment,post-treatmentandfollow-upradiographs shouldbesystematizedwithrespecttotheirradiationgeometry,densityandcontrastto allowdependableinterpretationofanychangeswhichmayhaveoccurredintheperiapical tissuesasaresultoftreatment[15]. ThisisparticularlysalientintheassessmentofExternal RootResorption,whichcancommenceandprogressrapidly.Thishasbeenminimized usingcustomizedbiteblocksattachedtoparallelingdevices,butagaingettingidentical images of theobject for future assessment isneveridentical.

All these limitation of intra oral radiographyled to the development of alternative imagingtechniques of which CBCT is beingmostpromising

CBCT versus Multi detector computed tomography (MDCT)

These are various differences between CBCT and MDCT -

1. Costofthe CBCTequipmentisapproximately3-5timeslessthantraditionalMDCT. Thelowercostofthemachinemaybepassedontothepatientintheformoflower fees.
2. CBCT equipment is substantiallylighter and smaller; henceoccupies lesserspace.
3. Cone-beam CTs havebetterspatial resolution.
4. No special electricalrequirements needed.
5. No floor strengtheningrequired.
6. Theroom does not need to be cooled.
7. Veryeasyto operate andto maintain; little technician trainingis required.
8. Somecone-beammanufacturersand vendorsarededicatedtothedentalmarket.This makes foragreaterappreciation of thedentist‘s needs.

9. Inthemajorityofcone-beamCTs,thepatientis seatedascomparedwithlyingdown inaMDCTunit.This,togetherwiththeopendesignoftheconebeamCTs,virtually eliminatesclaustrophobiaandgreatlyenhancespatientcomfortandacceptance.The uprightpositionis alsothoughtbymanyto provideamorerealisticpictureof condylar positions during aTMJexamination.
10. Bothjawscanbeimagedatthesametime(dependingonthespecificcone-beam machine)
11. Radiation dose is considerablyless (3-20%) thanwith a medical CT.
12. Visual resolvingpowervaries upto 2 linepairs/mm, fourtimes that ofCT.
13. Todiagnoseadental arch,aCTcaptures1slice/secondat150kVpand200mA;for animplantsurgery40slicesarerequired.CBCTcancapturetheimageat80kVp and 5 mA within 12-24 seconds.
14. CTslicethicknessisusually1-2mm,whileaCBCTgives0.1mmslice thickness.
15. Plain-filmtomographyresultsinmagnification,thedegreeofwhichdiffersfrom manufacturer to manufacturer.
16. Plain-filmtomographyprovidesdirect(asopposedtoreconstructed)cross-sectional, sagittal andcoronal views.
17. Thedisadvantageofplain-filmtomographyisthatitrequiresmuchmorechairtime thanCT.Itcanthusbeespeciallydifficulttodoonpatientswhoareunabletositor holdstillfor aperiodoftime.CBCT,ontheotherhand,canbeperformedwithina 10-40secondrange,depending ontheregion beingimagedandonthedesired qualityof theimage.
18. Cone-beam CT also provides stronger indication of bonequality[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 evaluation 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 Computedtomography

Theprincipleofcone-beamcomputedtomography(CBCT)hasbeenasubjectof investigation sincethe proposition of**Feldkamp algorithm**[17].

TheoriginalclinicalCTscannerwasintroducedby**SirGodfreyN.Hounsfield**in**1967**. The dataacquisitioninconventionalCTimaginghasevolvedthrough4 generations ofacquisition geometries.

1. **First-generationdataacquisition**wasbasedonatranslate-rotateparallel-beamgeometry whereinpencilbeamsofx-raysweredirectedatadetectoroppositethesourceandthe transmittedintensityofphotonsincidentonthedetectorwasmeasured.Thegantrywould thenbothtranslateandrotatetocapture x-rayattenuationdatasystematicallyfrom multiple points and angles[18].
2. **Second-generationscanners**introducedfan-beam x-raygeometryandusedasingle- detector linear array.
3. **Inthird-generationscanners**,thesingle-detectorarcwasintroducedinconjunctionwith fan-beam x-ray geometry.
4. **Fourth-generation scanners**usedafan-beam of x-rays andacircular detector array.

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

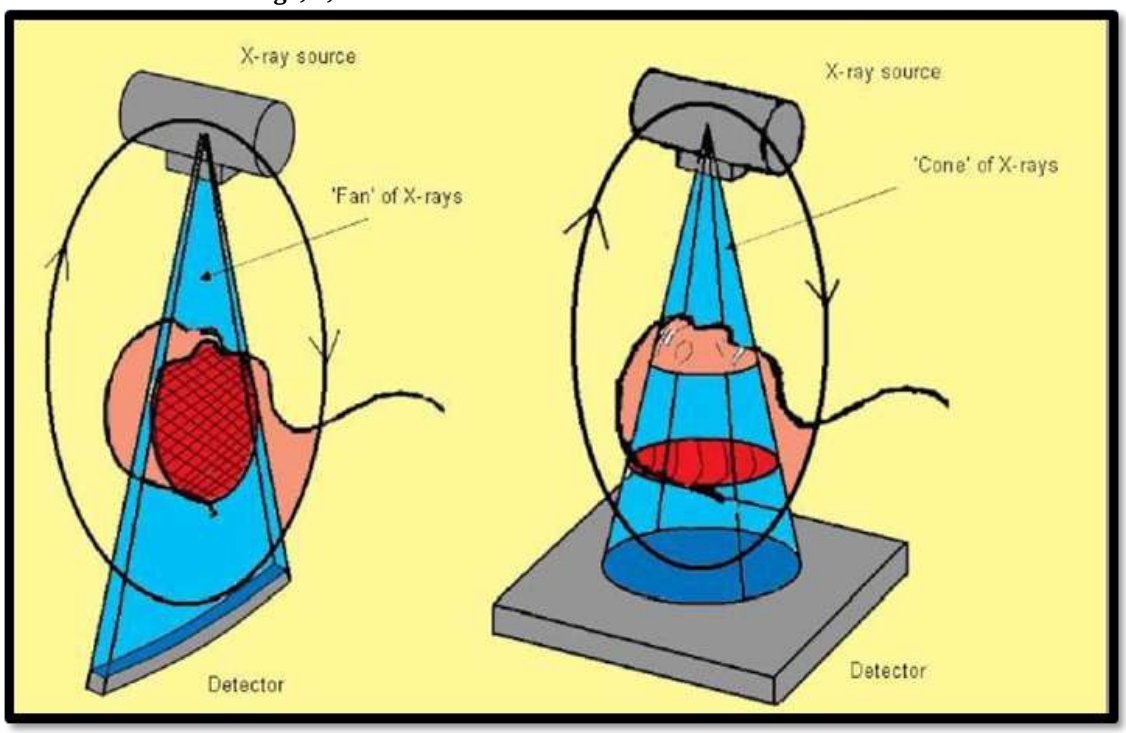

Fig 1:- Differencebetweenmultidetector CT(1)andCBCT(2).

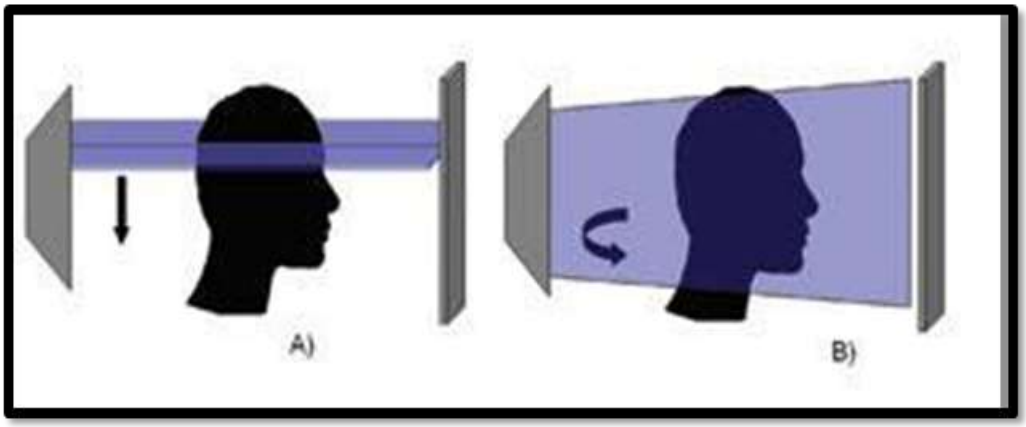

Figure2:- Illustration showing thedifferencebetween thedata captures systemof regular CT and CBCT. (A) A regular CTmachine captures thedata in a fan fashion; (B) theCBCT captures thedataina volumetricfashion.

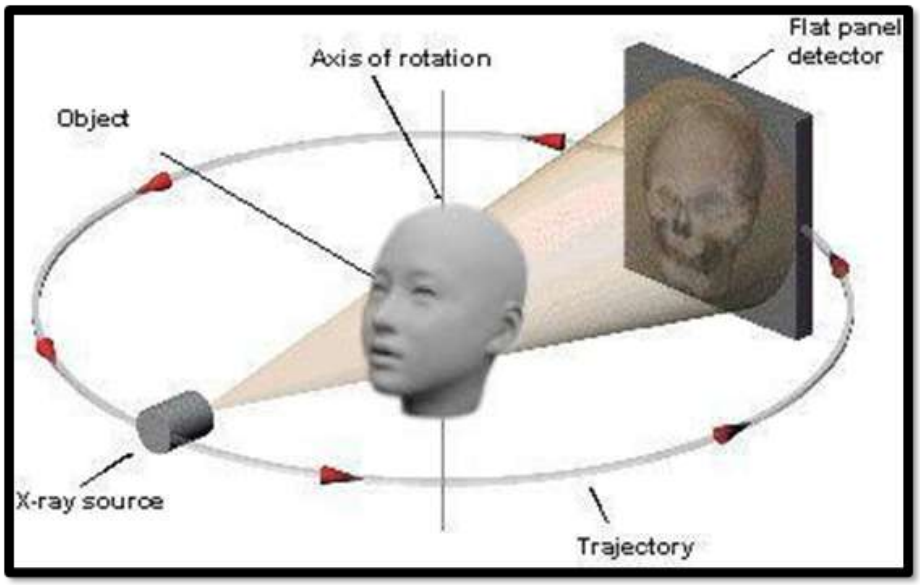

Figure3:- Principleof CBCT.

Two main parts of CBCT are-
1. X-raysourceand
2. Detector mounted ona rotating gantry.

Duringrotationofthegantry,thereceptordetectsX-raysattenuated bythepatient.CTcanbedividedintotwocategorieson the basis of acquisition X-raybeamgeometrynamely:
1. Fan beam and
2. Conebeam

ThetwoprincipaldifferencesthatdistinguishCBCTfromtraditionalCTarethetypeof imagingsource-detectorcomplexand the method of data acquisition.
TheX-raysourceforCTisahigh-outputrotatinganodegenerator,whilethatfor CBCTcanbealow-energyfixedanodetubesimilartothatusedindentalpanoramic machines.

CTemploysafan-shapedX-raybeamfromitssourceforimagingandrecordsthedata onsolid-stateimagedetectorsarrangedina360-degreearrayaroundthepatient.CBCT technologyusesacone-shapedX-raybeamwithaspecialII andasolid-statesensororan amorphous silicon platefor capturingthe image[19].

The principal feature of CBCT is that multiple planar projections are acquired by rotationalscantoproduceavolumetricdatasetfromwhichinterrelationimagescanbe generated[20].Cone-beamscannersuseatwo-dimensionaldigitalarrayprovidinganarea detectorratherthanalineardetectorasconventionalCTdoes.Thisiscombinedwitha three-dimensionalX-raybeamwithcircularcollimationsothattheresultantbeamisin the shapeofa cone, hencethe namecone-beam[6].

Conclusion:-

Conventionalintraoralradiographyprovidesclinicianswithanaccessible,costeffective, high-resolutionimagingmodalitythatcontinuestobeofvaluein pedodontic therapy.However, specificsituations,bothpre-andpostoperatively,wheretheunderstandingofspatial relationshipsisrequireditisbestprovidedbytheuseofCBCTwhichnotonlyfacilitates diagnosis but alsoinfluences treatmentplanning.

CBCTtechnologyaidsinthediagnosisofpathosis,canalmorphology, assessingrootandalveolarfractures,analysisofresorptivelesions,identificationofpathosisof non-endodonticorigin,and pre-surgicalassessmentbeforeroot-endsurgery. When differentiated withmedicalCT,CBCThasincreasedaccuracy,higherresolution,reducedscantime,a reductioninradiationdose,andreducedcostforthepatient.Whendifferentiatedwithconventional peri-apicalradiography,CBCTeliminatessuperimpositionofsurroundingstructures,providing additional clinicallyrelevant information.

However,despitesit'snumerousadvantagesoverconventionalradiographyandmedicalCT,it shouldnotbeusedforroutinediagnosisorforscreeningpurposesandaccordingto A A O M R (AmericanAcademyofOraland MaxillofacialRadiology),this3Dimagingmodalityshouldonlybeusedwhenthe questionforwhichimagingisrequiredcannotbeansweredadequatelybylower-dose conventional dental radiographyor alternate imagingmodalities.

Asthistechnologyisevolvingandisbeingembracedbymanyclinicians,theavailability ofCBCTwillbecomemorewidespreadinnearfutureasaccuratediagnosticinformationleads tobetterclinicaloutcomebutshouldbelimitedtotheassessmentandtreatmentofcomplex pedodontic conditions.

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