CBCT IN ORTHODONTICS: CURRENT TRENDS AND CAVEATS

Dr. P.G. Makhija*

ABSTRACT

Aim : of this article is to evaluate explicit and potential uses of CBCT in orthodontics, discuss some of the caveats, & summarize published evidence on CBCT in orthodontics.

Background: CBCT is well established diagnostic aid in the field of orthodontics, but there is lack of consensus on the clinical use of CBCT in orthodontics. With the increasing popularity of CBCT, evidence for various uses has to be documented for common consensus

Methods: Search for key words 'CBCT' 'CBCT Review' was done in PubMed [Ref] and top ranking orthodontic journals based on SCIMago journal Ranking index [Rference].

Results: Literature search did not yield evidence to justify the routine use of CBCT as essential diagnostic aid to be used for each and every patient of orthodontics.

Conclusion: There is lack of consensus at present on use of CBCT as routine procedure in orthodontics. This may change in future with more evidence on benefits v/s risks of CBCT accumulates

INTRODUCTION:

2D Radiography is established diagnostic tool in the field of Dentistry and orthodontics since its first use for intra oral radiography in 1896.[1]

2D images were the only imaging option available to orthodontists till CBCT (Cone Beam Computed Tomography), essentially a 3D radiographic technique was introduced to dentistry in 1998 in Europe and approved for use in the USA in 2001.[2] This shows that Radiographic imaging took about 100 years to travel from 2D to 3D reach dentistry. 2D x-ray images have been helping the orthodontist in diagnosis, treatment planning, evaluation, with inherent caveats like magnification, distortion or superimposition of overlapping structures till date. 3D imaging is essential for evaluation of 3D anatomy, enhancing diagnosis and orthodontic treatment mechanics, with gathering evidence and reduction of radiation dose, CBCT might become imaging method of choice in orthodontics in near future.

History and development of CBCT, technical terms and procedures, radiation safety guidelines, various machines, software have already been discussed in detail in literature.[3,4]

CBCT is basically an x-ray imaging technology where the series of 2D x-ray images are recorded on detector and stored as digital images called basis images. The computer with the native software algorithm reads all basis images and converts the data into DICOM (digital imaging & communication in medicine) files. DICOM files are then used by various software for secondary reconstruction. From here the real magic of 3D computer graphic starts.

Any digital 2D picture is made up of tiny elements known as Pixels ('Picture elements') pixel is a tiny dot with colour information in digital format. The CBCT volume however is made up of voxel ('volumetric element'). These voxels have same size in three dimensions which may be 0.3 X 0.3 X 0.3 mm, hence called isometric or isotropic, compared to medical CT voxel which is anisotropic. In a stack of 2D DICOM files, the number of 2D slices will depend upon the voxel size or resolution at which scan was taken and the FOV (Field of view). For orthodontic purposes, a voxel size of .3mm is enough, which has less radiation than .2mm or .125 mm used for other purposes. Scan height of 13 cm FOV thus may have 435 to 440 slices as follows (13 X 10 = 130 mm divided by .3mm). Ordinary computer laptops may not be in position to process such large data in real time, particularly 3D rendering. Also, Good graphic card with dedicated memory may be required by some software to manipulate images into volume.

CBCT Scanned volume is cylindrical in shape. Diameter of cylinder is fixed as per machine specifications, hence sometimes the patient's soft tissue nose tip is seen partially missing. If we accommodate nose tissue, then posteriorly skull part may be cut. Height of cylinder decides the largest FOV. Fig.1 is an example showing the area to accommodate that circular tissue for viewing purpose is square of 546 X 546 pixels which comes out to be 10.92 cm print area at127 Dpi (dots per inch by printer).

[a-] Professor & Head, Department of Orthodontics & Dentofacial Orthopedics, Modern Dental College & Research Centre,

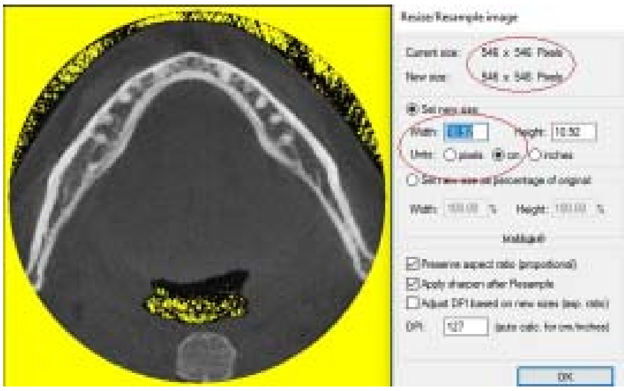


Fig. 1 Showing DICOM image composing of 546 X 546 Pixels. Print size of picture is 10.92 cm with 127 DPI. Note also that the main DICOM image grey in colour is circular in shape.

Role of computer and digital technology including software in use of CBCT

When the beam of X-rays passes through body tissues, it may be partially absorbed and reflected towards detector, based on such attenuation values body tissues can be detected by detector and transferred to computer as digital data of shades of grey colour values represented as Hounsfield units.[3] various body tissues thus can be isolated, segregated, given transparency effect, apply widow level effects, colour, hue, saturation, cutting, segmentation, paste, merging and mixing with other digital data and applications, measurements, converting to CAD files, working on CAD files with the help of computer technology. This opens the plethora of potential uses of dental CBCT. Most of the uses and applications of CBCT [3,4] are possible because of digital technology, faster computers, Graphic cards, software capability and high resolution digital image recording devices. It is the software that gives meaning to CBCT. Without software, it has practically no meaning.

By counting the number of voxels in given ROI (region of interest), computer can tell us the volume of particular group of selected voxels, For example, air volume, sinus volume, muscle volume or tooth volume.

Computer can assign artificial colours to group of voxels to differentiate one tissue from other or totally remove voxels belonging to one group of tissues thus we can visualize skin tissue, fat, muscles, bone, teeth, etc. computer can also increase or decrease the transparency of one group of voxels over other group, hence we can see hard tissue through the skin or teeth through the bone. Thus, it is important to have good DICOM editing software and its knowledge and skill for us to get maximum benefit for diagnosis and treatment planning.

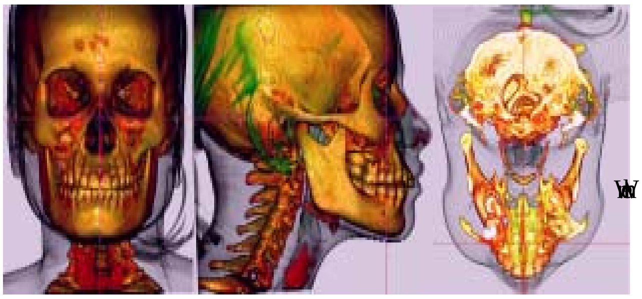
Here one thing should be born in mind that although, the linear measurements are one is to one in grey images, in order to render high definition brilliant 3D volumes, there may be some loss of some voxel to fill in cracks or remove the noise. Similarly, when we create a stl file for orthognathic surgery, there may be few voxel difference in linear measurements, as the stl files might remove few voxels for showing shining smooth models. This point is particularly important, when we want to evaluate growth or treatment changes involving very thin bony areas like glenoid fossa, where two stl models are to be superimposed over each other to find out difference in voxels.

For the same reason, it may be difficult to detect hairline fractures in cortical bone from 3D rendered computer model, hence, in such cases of doubt and otherwise also, the orthodontist or radiologist, should scroll through all computer generated orthogonal slices. (very difficult and time consuming indeed)]

The overenthusiasm and fascination to CBCT might have been so much so that In November, 2010, a publication in "The New York Times" reported the abuse by dental profession-als in prescribing CBCT to children and adolescents. It was found that by 2011, 83% of postgraduate programs in Or-thodontics in the US and Canada reported to use CBCT. CBCT started gaining more popularity in years to follow, seen by special issues of journals, influx of articles, presentation at conferences. The recommendation of CBCT in Orthodontics raised so much controversy that the American Journal of Orthodontics and Dentofacial Orthopedics pub-lished a Point-Counterpoint session on the subject in 2012.[5]

Uses of CBCT in orthodontics is well documented.[2,3,4,6,7,8,9,10,11,12]

Before summarising the evidence on current use of CBCT in orthodontics, let us see how the software and computer help us produce desired application.



we first load the DICOM CD of T1 (Time 1) ourselves in DICOM viewer, ideally, we should orient the head in 3D space to control pitch roll and yaw parameters. see Fig.2 The position of skull in X,Y&Z direction is considered zero to start with. Before treatment skull is oriented in particular fashion and then subsequent scan (T2) of same patient is oriented in that fashion only so as to standardise the comparison protocol. Ideally for evaluating growth or treatment changes, both the scans should be taken by same machine with controlled parameters. When we superimpose T2 over T1, the second scan T2, might have to change X,Y,Z location in space in relation to T1 also the pitch roll and yaw. This is called six degree of freedom

Fig. 2 showing Orientation of head. The Orbital plane (Roll), Frankfort horizontal plane (pith) and pane passing through crista Galli and centre of Basion (Yaw). The orientation is particularly important for generating

lateral cephalograms and PA views for analysis. Also, the orthogonal slices depend on the orientation of head, hence measurements may be affected if orthogonal slices are mad from wrong head position.

Once the head has been oriented, we can generate orthogonal slices and also volume view for further study. Fig. 3 shows 4-part screen window showing Coronal, Sagittal, axial slices and Volume view.

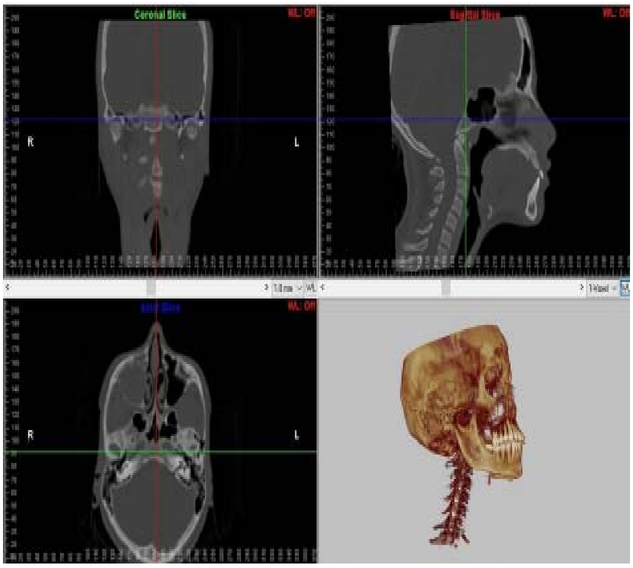


Fig. 3 Showing Orthogonal slices (coronal, Sagittal, Axial) and volume view.

Here, we can scroll through various slices with slider in coronal, axial, sagittal direction. Also we can rotate, zoom, pan the volume view like 3D movie. We can also view each quadrant separately as single set of coronal slice screen, axial screen or sagittal screen or volume screen to work in that area. In orthogonal views, we can measure distances, HU values of particular area, (bone density) (TAD sites), visualize tooth morphology, position, roots, dilacerations, fractures, nerve, foramen, paranasal air sinuses, TMJ, maxilla, mandible and all anatomical pathological structures. The window can show as grey images, x-ray like appearance or Maximum intensity projection to locate foreign bodies or missing teeth. We can also see various cephalometric landmarks in different views.

In the orthogonal view, we can change the window level brightness contracts to visualize soft or hard tissue.

Fig. 4 Shows that we can artificially assign arbitrary rainbow colours to these grey scale images to demarcate one tissue from another, to confirm the doubtful tissue's origin.

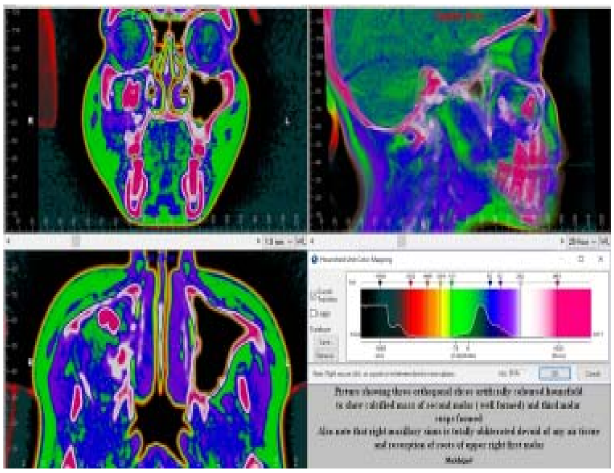


Fig. 4 It is possible to colour code the various tissues like air, soft tissue, muscle, cartilage, calcified structures, to detect abnormalities in development and associated pathologies. This picture has four quadrants. Three showing orthogonal slices, fourth one showing histogram. Colour can be applied through histogram over range of Hounsfield units. Note the difference between right and left maxillary sinus.

Coming to the volume view, as stated earlier, it is possible to isolate any type of tissue like skin and airway. We can do visualization and quantification. Change the colour and transparency of tissue. Fig. 5 shows transparent skin and airway tissue. Here the volume has been given threshold value of HU which fall in the range of air to soft tissue skin. All other HU values are hidden.so volume displayed is that of skin and airway.

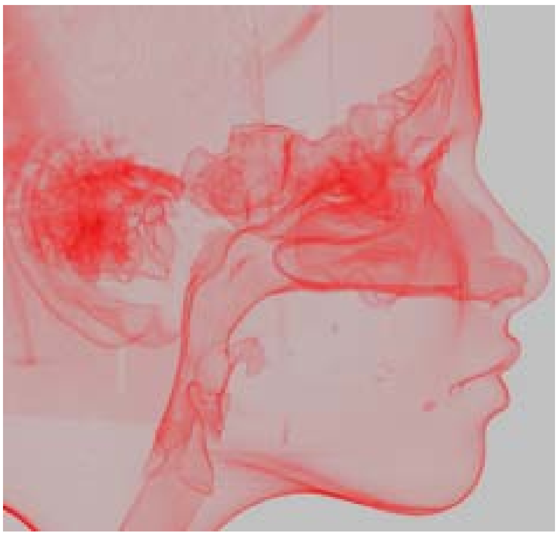


Fig. 5 Showing transparent skin and air tissue. Note the finely demarcated soft tissue outline

Fig. 6A shows that For the purpose of facial examination, soft tissue face can be generated by calling all HU values in the range of skin and increasing opacity value so that face looks solid. We can apply colour of our choice to face for viewing purpose. All the diagnostic parameters we apply to static facial examination and recording can be applied here like, facial type, profile, morphological examination of Lips, lip prominence, Morphological exam of nose, nostrils, chin, naso labial angle, mento labial sulcus, dimensions, midline symmetry, eye width, nose width, mouth width, soft tissue landmarks, linear measurements. Fig 6 shows only front view, but as this is 3D data, we can view face form sides, ¾ views, perspectives, top and bottom views to evaluate symmetry etc.

Fig 6B. It is also possible to isolate muscle tissue and volume of tongue, teeth, Muscles, nose and their relation to malocclusion can be studied. [15,16]

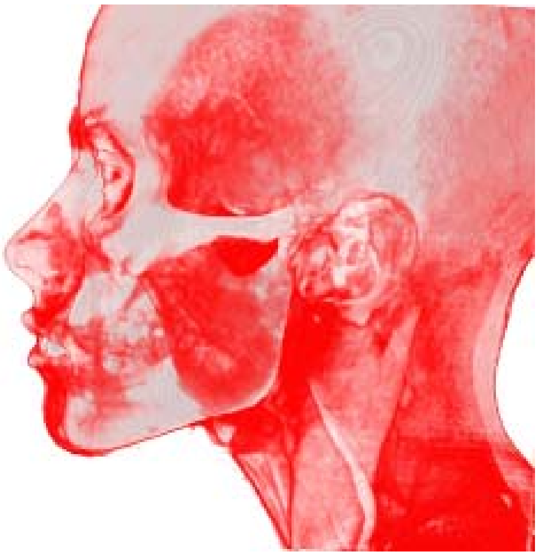


Fig. 6B showing isolation of masseter muscle.

Fig.6. Showing soft tissue solid view. This is like extraoral facial front photograph. The type of face, vertical & transverse dimensions, midline, symmetry, lip fullness, lip length, facial thirds, facial fifths can be checked. So also, morphological examination of eyes, nose, lips, chin can be done

Hard tissue can be visualised, as solid, translucent as black & white colour, default bony view or we may introduce colour for bone, cartilage, enamel, dentin etc. to make skeletal tissue look vivid. Fig. 7 show one such translucent view wherein teeth can be visualized, documented nicely. These skull models are used to isolate teeth and convert them to digital models and work on them, or we can segment maxilla, mandible for osteotomy cuts.

Fig.7 Translucent Bony view front. This like postero anterior cephalogram and actual vertical transverse anteroposterior dimensions can be measured. Various sutures may be visualized, 3D analysis can be made, osteotomy cuts planned, teeth also seen for number, size,

shape, root formation, root angulations, root parallelism, root resorption.

As we can see in fig. 8, It is possible to visualize two or more tissues together by varying the degree of transparency of each tissue. Also, we can apply standard cuts in vertical, sagittal, axial direction and to varying depths. We can also make free hand sculpting to view tissue isolate, mirror for craniofacial reconstruction, distractor planning, 3D analysis etc. we can carry out cephalometric analysis on such cuts. We can see occlusion from lingual side, relation to airway, cervical vertebrae, sinus can be seen

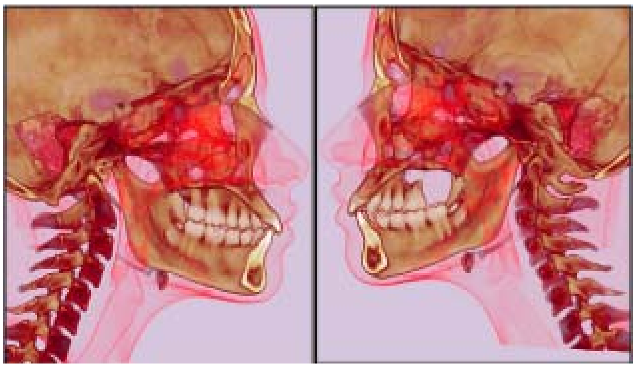


Fig.8 Figcombined view of Transparent skin and airway along with translucent hard tissue. All craniofacial relations can be seen and measured. The face is divide in two halves showing left and right side of face. Note that upper 2^{nd} and 3^{rd} molars are not seen on right side.

From the fig. 9, it will be clear that detailed information about dentaition in all possible ways is possible like, type of dentition, number of teeth present and erupted, unerupted, supernumerary, impacted, over retained, status odf tooth development, roort resorption, eruption path, location, morphometrics, stl formation, digital models and so on.

Fig.9 Visualization of teeth. Type of dentition, Number of teeth present, erupted, unerupted, size, shape, eruption status, development status, root resorption, direction of eruption, arch length tooth size discrepancy, space available for erupting premolars etc. can be visualized and quantified for better diagnosis & treatment planning.

CBCT is quite helpful in case of impacted canines and impacted teeth for diagnosis, treatment planning, treatment evaluation tooth position, space analysis, biomechanics as can be seen in fig. 10, and fig. 11

Fig.10 Small FOV picture of Dentition. This patient had mixed dentition with dilacerated upper incisors looking like cobra fang. Biomechanical treatment planning and feasibility of treatment is required in Such unerupted teeth with deviated path of eruption and dilaceration. This case was successfully resolved subsequently.

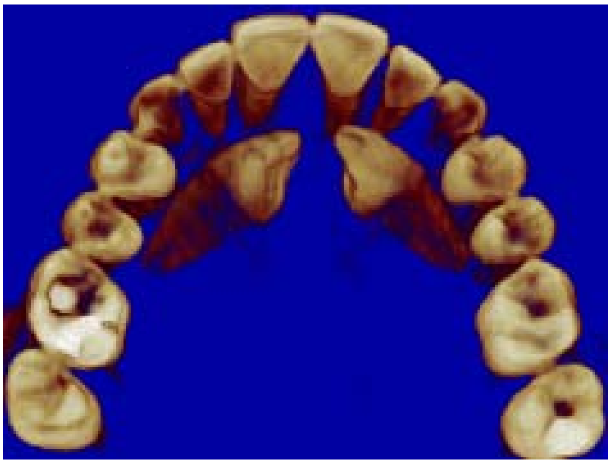


Fig.11 Another case with unerupted deviated kissing incisors. The 2D picture here is not sufficient for treatment planning. video should be made while viewing unerupted teeth from various angles for record purpose and planning treatment.

Symmetry evaluations and quantification is possible when we do mirroring. See fig. 12. When we superimpose half of face over the other half, dimensional asymmetry can be highlighted. Similarly, when one volume is superimposed over other, will show treatment changes or growth changes. We can do craniofacial prosthesis planning by mirroring.

Fig.12 Showing evaluation of asymmetry. This can be done with help of mirroring half side of structures over another half. The difference can be visualized and measured for recording and planning surgery.

It is possible to generate variety of x-rays form CBCT scan. There is no need to send the patient for lateral cephalogram or OPG if we have CBCT scan available. Variety of x-rays can be Lat Ceph, OPG, cross sectional view, Denta scan view, nerve tracing, PA, submento vertex view, etc. Fig. 13. shows Lat Ceph and PA view on which ceph analysis can be done, Fig. 14. TMJ and Fig. 15 shows routine OPG along with Bony view of OPG to give realistic appearance

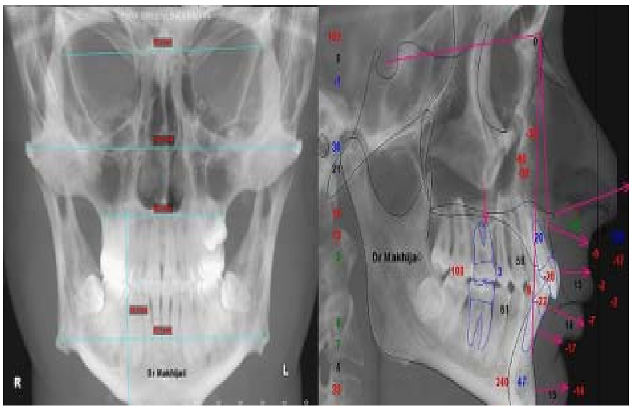


Fig.13 Series of X-rays can be generated and subjected to routine orthodontic analysis.

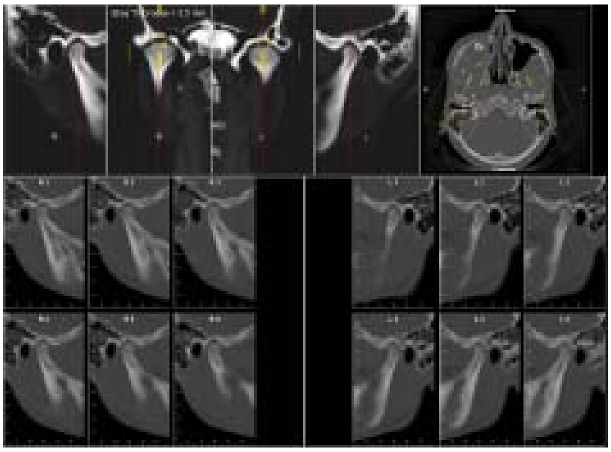


Fig.14 showing X-ray of TMJ (Temporo mandibular joint) CBCT generated TMJ radiographs are devoid of any shadows and superimposition of other structures and give excellent view of Condyles and glenoid fossa. Any hard tissue abnormality can be detected easily, also right and left joints can be compared at different angles of projection

Fig.15 Apart from routine OPG, some software give option of generating realistic bony OPG just for viewing purpose and better visualization of teeth.

Analysis of airway was sometimes part of cephalometric analysis. With 3D tools and computer, it is possible to count number of voxels, hence the volume of tissue. It is very important to dissect the tissue properly with semiautomatic method, otherwise results may not be appropriate. If the CBCT volume is converted to stl file, there may be minor difference in volume due to smoothing effect which removes few voxels. Fig. 16 shows airway analysis for sleep apnoea cases, changes due to RME, open close mouth, Myo functional appliances can be studied.

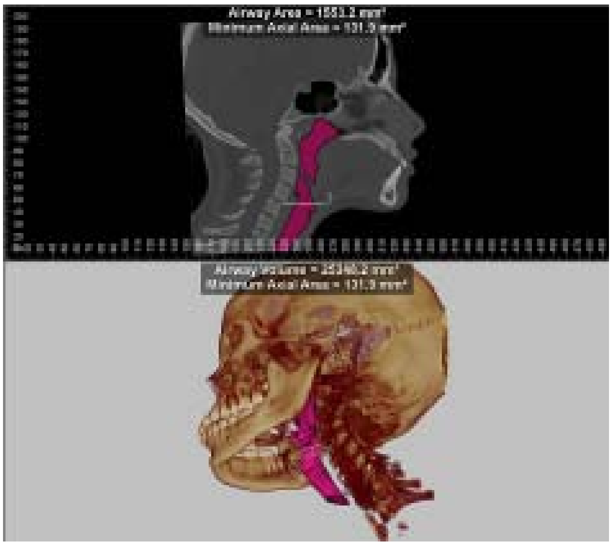


Fig.16 Showing how airway can be viewed in relation to head and neck, narrow area demarcated, airway volume be found out. The volume can be limited to superior and inferior limits for standardisation of results in sleep apnoea cases.

Being digital technology , integration of data with other digital data equipment etc is quite possible. Thus the segmented tissue can be converted into stl fiels for rapid prototypin, cad cam appliances, customized brackets, retainers, educational models, Fem analysis, ditractor planning, mockups, simulations, Fig 17. Shows one such compound stl model. It is good to use these anatomical models for Fem than the mathematical non anatomy models.

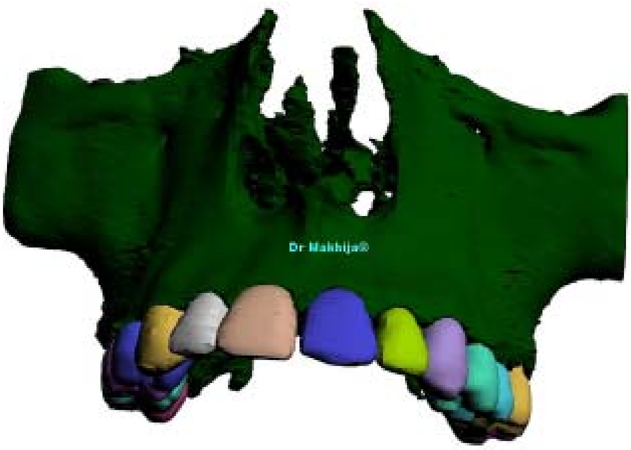


Fig.17 showing composite stl (stereolithographic) model. This complex model comprising of various parts is made up from CBCT scan by thresholding individual teeth and maxilla. These models can be used for rapid prototyping and various cad cam applications, orthodontic as well as surgical treatment planning simulations, superimpositions. Also, we can remove single part from complex model for patient education, treatment planning, and fabricate customized appliances and brackets.

It is ethical responsibility of radiologist/ orthodontist to go through the all DICOM files and report any pathology or incidental finding to patient which was not included in investigation while prescribing such scan. Fused vertebrae, ectopic teeth, metal objects and other things might be detected as incidental findings. See fig18.

Fig.18 Showing incidental findings. Cervical vertebrae fusion at C2, C3 and C6, C7.

Summary of above illustrated uses is summarised in table no 1.

Table 1. showing Summary of uses & research areas of CBCT in Orthodontics [1-12]

Area	Uses & Research areas
Soft tissue examination	Routine facial examination like Type of face, convexity, divergence, Lip seal, Incisor exposure, vertical & transverse dimensions, soft tissue analysis, facial proportions, facial symmetry, **craniofacial anomalies**. Examination of face from various angles for symmetry evaluation. Soft tissue thickness at various places, lip thickness, lip length, muscle volume, cross sectional area. soft tissue thickness in various areas, muscle thickness and volume,
Sinuses and airway and other tissues	Visualize, measure airways, constricted area, airway volume, sinuses pathology and anatomy, anatomical limits, polyps, nasal floor in relation to incisor roots, nerves, relation of nerves to teeth and implants, **sleep apnoea cases**, effect of Myofunctional appliances, RME on airway, tongue size shape, volume, posture,
Craniofacial Assessment	Craniofacial anatomy, Growth, syndromic patients, Cleft palate craniofacial Symmetry, asymmetry, TMJ
Maxillo mandibular assessment	Assessment of Jaws in relation to cranium, Symmetry, asymmetry, Individual Dental arches, arch dimensions Arch size, arch shape, symmetry, maxillo mandibular relationship & coordination, effects of RME, slow expansion, effect of self-ligating appliances on alveolar bone. quality and quantity of bone, periodontal problems, Bone density,
Dentition	Type of dentition present, number, size of teeth, tooth size arch length discrepancy, Bolton ratio, tooth morphology, root morphology, fractures and cavities of teeth, Unerupted, **impacted canines & multiple unerupted teeth**, supernumerary teeth, impacted third molars, their relation to mandibular nerve, relation of teeth to each other and jaws, root development, Root resorption, root fracture, Tip, Torque, collum angle, root parallelism, Dimensions of teeth, accuracy of linear measurements
Computer generated X-rays	Lat Ceph, OPG, Cross sectional views, Denta scan, PA view, submento-vertex view, various customized views, Bony view, TMJ view, leading to various cephalometric analyses. Landmark identification, verification, superimpositions, 3D cephalometric analysis.
Treatment planning	Impacted canines, Dilacerated teeth, TAD sites, bone density, fenestrations, cortical bone thickness, Biomechanics, Anchorage planning, collum angle, tip torque, customized appliances, trajectories of forces and tooth position, virtual patient, orthodontic and orthognathic surgery simulation. estimation of space requirement for unerupted impacted teeth,
CAD CAM	FEM analysis on anatomical models, Educational models, customized design and fabrication of appliance & retainers, Digital dental models, craniofacial reconstruction, customized screws, 3D distractor, TMJ Prosthesis, Lingual appliances, clear aligners
Evaluation of growth treatment changes	Superimpositions, shape correspondence, Craniofacial growth, spheno occipiatl synchondrosis, orthodontically induced root resorption, RME effect on buccal alveolar bone, condyle and glenoid fossa changes with Myofunctional appliances, buccal bone changes with Self ligating appliances, airway changes with RME and Myofunctional appliances, post orthodontic dental & skeletal changes, surgical outcome
Other areas	Orientation of head, pitch role, yaw calibration. Dosimetry.
Incidental findings	Ectopic eruption, fused vertebrae, hypo plastic condyle, broken instruments, screws, separators, Maxillary sinus pathology.

Evidence on consensus, guidelines, Risk, limitations, evidence, on current use of CBCT in orthodontics

In order to find out evidence on consensus for current uses of CBCT in orthodontics and clinical guidelines a systematic review of literature using PubMed [13] and some top ranking orthodontic journals based on SCImago index [14] (The SCImago Journal & Country Rank is a publicly available portal that includes the journals and country scientific indicators developed from the information contained in the Scopus® database (Elsevier B.V.)) was done shown in table 2.

Table2. showing Top ranking 10 journal listed by SCImago based on their impact factor and prestige.

SCIRank	Title	SJR	H index
1	Angle Orthodontist (AO)	1.254	62
2	American Journal of Orthodontics and Dentofacial Orthopedics (AJODO)	1.249	88
3	European Journal of Orthodontics (EJO)	1.09	60
4	Korean Journal of Orthodontics (KJO)	0.914	8
5	Orthodontics and Craniofacial Research (OCR)	0.881	42
6	Journal of Orofacial Orthopedics (JOO)	0.574	33
7	Progress in Orthodontics (Progress)	0.555	16
8	Journal of Orthodontics (J Orth)	0.501	37
9	Australian orthodontic journal (AOJ)	0.317	16
10	Seminars in Orthodontics (Seminars)	0.252	34

Also the Position statement by panel of American academy of oral and maxillofacial radiology (AAOMR) and board certified orthodontists on clinical recommendations regarding use of cone beam computed tomography in orthodontics [12], was used to find out uses, issues, guidelines and steps to performing and using CBCT scan.

"cbct orthodontics" for last 10 years was serched in PubMed search details were as follows: (cbct[All Fields] AND ("orthodontics"[MeSH Terms] OR "orthodontics"[All Fields])) AND (Review[ptyp] AND "2007/03/06"[PDat] : "2017/03/02"[PDat])

PubMed Search resulted in 730 items. filter "Review "was applied to get 39 review items. Individual journals were searched for word CBCT and review to find the relevant research. Lists were manually searched for review articles on evidence.

The search was further narrowed down by manual selection and only articles which dealt with the subject in general were studied in detail. The review articles that dealt with only one specific area of uses Like reliability of Pharyngeal airway assessment, diagnosis of root resorption, transverse deficiencies, cleft lip palate, supernumerary teeth, few case reports, landmark reliability reproducibility, and other general uses were excluded were omitted so as to find out common consensus and guidelines for use in orthodontics in general and the result was further narrowed down to 10 articles [Reference] which could put light on general consensus on use of CBCT were studied in detail. Table 3. Shows the result of searches

Table 3. showing list of databases searched and resulted articles.

Sr	Domain name	CBCT articles	Review articles
	PubMed	730 items	39
	AO	157 articles	4
	AJODO	310 articles	7
	EJO	63 articles	11
	KJO	43 articles	1
	OCR	41 articles	3
	JOO	7 articles	nil
	Progress	28 articles	3
	JOrth	46 articles	2
	Seminars	62articles	30

Discussion on results.

In their review article published in 2015, S D Kapila and J M Nervina [2] remarked that 'scientific evidence that the utilization of CBCT alters diagnosis & improves treatment planning or outcome has only recently begun to emerge for some of its suggested uses' They concluded that 'although CBCT continues to gain popularity its use currently is recommended in cases in which clinical examination supplemented with conventional radiography cannot supply satisfactory diagnostic information. To date this applies to impacted teeth, CLP and orthognathic or craniofacial surgery patients'. For other cases, each case has to be evaluated for merits and demerits.

Genevive L Machado,[6] stated that 'Accumulating evidence continues to demonstrate that CBCT is a valuable tool, and it is particularly important in cases where conventional radiography cannot provide adequate diagnostic information. The latter includes cases of cleft palate, craniofacial syndromes, supernumerary teeth, assessment of multiple impacted teeth, identification of root resorption caused by impacted teeth, and planning for orthognathic surgery'.

K Horner [7] concluded 'Reporting of guidelines development is often poorly represented'

Daniela G. Garib1, Louise Resti Calil, Claudia Resende Leal & Guilherme Janson,[5] In their article 'Is there a consensus for CBCT use in orthodontics' discussing current evidence and recommendations for CBCT in orthodontics, concluded that 'Cone-beam computed tomography is not a stan-dard diagnosis method in Orthodontics. It should be indicated with criteria, when the potential benefits for diagnosis and treatment planning out-weigh the potential risks of an increased radiation dose. The recommendations are time-dependent. In the future, new evidence as well as technological evolution and innovation of CBCT scanners could change the current indications of CBCT in Orthodontics'.

Several studies have accumulated valuable data on technology assessment, craniofacial morphology in health and disease, treatment outcomes and efficacy of CBCT images in diagnosis and treatment planning. [9]

Anne MarieKuijpers-Jagtman, MetteA.R.Kuijpers, JanG.J.H.Schols, Thomas J.J.Maal, KarelH. Breuning, and OlivierJ.C.vanVlijmen.[8] also discussed the same topic and recommended to use 10 basic guidelines given by SEDENTEXCT related to orthodontics and hoped that radiation dose, which is the biggest limitation against use of CBCT will decrease in the future.

Hadi Mohammed Alamri,, Mitra Sadrameli,, Mazen Abdullah Alshalhoob, Mahtab Sadrameli[1,] in their article affirmed various clinical applications of CBCT in various areas of dentistry and stated that CBCT examinations must not be performed unless they are necessary and the benefits clearly outweigh the risks. When utilizing CBCT, the entire image dataset (that is, a radiological report generated by an oral surgeon, neurologist, or general radiologist familiar with the head and neck region) must be evaluated thoroughly to maximize the clinical data obtained and ensure that medically serious incidental findings are reported'.

In 2011 review by Kapila, Conley and Harrell Jr,[9] on current understanding and evidence on clinical use of CBCT in orthodontics, accumulated uses of CBCT in areas like technology assessment, Craniofacial morphology, treatment outcomes, diagnosis & treatment planning, recommended use of CBCT in selectively in all cases including cases like cleft lip palate, where there is want of additional information not received from routine methods.

JM Nervina [11] in his article cone beam computed tomography use in orthodontics, tracked the uses in validation as accurate and reliable tool, diagnosis & treatment planning, and assessment of treatment outcomes to widespread agreement that CBCT images are better than conventional 2D radiography. He was of the opinion that with continued advancements in software development to manipulate CBCT images, the diagnostic and treatment planning value of these images will rise considerably in the near future and significant trend towards improved treatment planning & outcome prediction incorporating CBCT images into 3D modelling and FEM.

American academy of oral and maxillofacial radiology [12] on clinical recommendations regarding use of CBCT in orthodontics through consensus by their panel presented a position statement valid through 2013 till 2018, A must read article by all, concluded that the use of CBCT in orthodontic treatment should be justified on an individual basis, based on clinical presentation. This statement provides general recommendations, specific use selection recommendations, optimization protocols, and radiation-dose, risk-assessment strategies for CBCT imaging in orthodontic diagnosis, treatment and outcomes

They also have summarised evidence based current diagnostic uses in orthodontics in following areas: Dental structure anomalies, Anomalies in dental position, compromised dento alveolar boundaries, Asymmetry, Anteroposterior discrepancies, Transverse discrepancies, TMJ signs symptoms, Dentofacial deformities & craniofacial anomalies, conditions that affect airway morphology, specific surgical procedures, orthodontic mini implants as TADs, Maxillary expanders.

Limitations and Caveats: Currently, the main limiting factor for widespread use of CBCT in orthodontics is the **radiation dose especially in children**.

Other limiting factors are time required to go through scan ourselves, knowledge and skill of operator, Artefacts, Noise, high cost, cost of software, radiation poor soft tissue contrast are some of limitations of CBCT.[4]

There is limitation to use and understand 3 D data and 3D anatomy due to lack of familiarity. 3D norms for patients not available. Data regression and underutilization is another problem as only 2D snapshots of study, radiographic plates, photos are given by radiologist.

Mandibular condyles may seem to be eroded due to thresholding at one HU range. They have to be manually segmented. Stl files give only surface mesh and not volumetric mesh (CAD file), hence internal architecture of bone is not fully represented for FEM analysis HU numbers are not calibrated like in CT machines. Hence CBCT HU differ from CT HU numbers. All machines show some variations.

Discussion:

CBCT is a supplementary diagnostic aid with lot of radiation risk. It is not an essential diagnostic aid so it is unwise at present to make it mandatory for all patients. It is suggested that routine radiographs as well as 3D radiographs should not be prescribed routinely

CBCT examinations must not be carried out unless a history and clinical examination have been performed. CBCT examinations must be justified for each patient. CBCT field of view (FOV) should be restricted as much as possible. The lowest achievable resolution should be used without jeopardizing evaluation of the area of interest.

Conclusion: The indications to use of CBCT are very specific limited to syndromic case, orthognathic surgery cases, difficult cases as per the difficulty index, impacted teeth having been evaluated requiring further investigation for location and biomechanics. All other cases have to be evaluated on individual merits. There is no consensus on Routine use of CBCT in orthodontic practice.

Future: There will be increasing effort by companies to reduce Radiation dose, make machines and scans cheaper and easily available. **4D CBCT will be single standard and only one single diagnostic and medical record** for Diagnosis and treatment planning, smart appliance fabrication with intelligent robots. Based on the assumption that every patient is different individual needing different tooth positions in jaws and skull, requiring customised diagnosis, treatment planning, appliance fabrication with unique tip torque control and biomechanics, 4D **CBCT may be prescribed routinely for all orthodontic patients,** where a scan will be sent to laboratory with computer intervention to diagnose, design, fabricate appliance for the use of expert orthodontist. The custom labial/lingual bracket design, aligners, retainers. To handle such big data, Orthodontist will be compelled to employ fully trained assistant who can do big data analysis to save the clinical time for treating more patients.

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