DRAFT GUIDELINES ON THE USE OF CONE BEAM COMPUTED TOMOGRAPHY IN DENTAL PRACTICE – A POSITION PAPER BY THE INDIAN ACADEMY OF ORAL MEDICINE AND RADIOLOGY *

TABLE OF CONTENTS

* This draft document was created by the Indian Academy of Oral Medicine and Radiology following a National Consensus building workshop held at New Delhi on the 14th of April 2019.

PREAMBLE

3 D imaging in general and CBCT in particular has captured the imagination of dental professionals across the globe and has rapidly gained importance in clinical practice. This is also true for India where presently more than 400 CBCT units are functional at teaching dental hospitals or at private hospitals, private clinics and general radiology clinics. The response to this new technique is quite enthusiastic though fraught with the danger that this imaging modality may be utilized indiscriminately without paying heed to the hazards associated with radiation.

The Indian Academy of Oral Medicine and Radiology (IAOMR) has taken cognizance of excessive and unjustifiable utilization of CBCT in dental practice (in India). The Academy notes with concern that injudicious use of CBCT technology may lead to radiation overdose to patients and the radiation workers. In view of the rapidly increasing number of CBCT installations across the country and the ever increasing number of CBCT prescriptions an urgent need was felt to formulate a position paper which would help to serve as a guide to dentists and all other end users of CBCT technology in addition to being a handy resource base for the regulators of dental education and radiation safety in the country.

The present 'guideline position paper' was created by the Academy through a consensus building workshop in collaboration with the IDA Defence Branch (which included specialists from all dental specialities, designated representative of the Atomic Energy Regulatory Board, a senior medical radiologist, technology partners from several leading CBCT companies in addition to several Academy members (from the specialty of Oral Medicine and Radiology). Where ever possible the guidelines are substantiated by published evidence and also include accepted 'good practices' from diagnostic radiology. An effort has also been made to 'tailor, the guidelines for India keeping in mind the man power and resources available. These guidelines provide research based consensus-derived clinical protocol for practitioners on the appropriate use of this imaging modality.

It is important to note that a large number of CBCT equipment brands/ models are available and are in use presently, each one with its own software capabilities. It is therefore difficult and not prudent to generalize the research findings. Many of the recommendations are therefore "good practices" rather than rigidly satisfying evidence grade and are based on informed judgement of expert members.

These guidelines will require regular amendments and alterations as the field of CBCT is continuously undergoing changes, improvement and advances.

INTRODUCTION AND GUIDELINE DEVELOPMENT

In the past X rays/radiographs were considered merely as an aid to diagnosis and the findings were even looked down upon by the practitioners and termed as imaginary. At present however due to fascinating advances in imaging modalities it is acknowledged by all concerned that the imaging has succeeded beyond imagination.

Radiography, basic and advanced is now essential to the dental practitioners for determining the nature and extent of the disease and has proved to be indispensable to the diagnostic process and is also mandatory for accurate and effective treatment planning.

With the benefit of radiographs in clinical practice there is an associated risk of radiation exposure to the patients/doctors/staff. Every effort must be made by the dental professional to minimize the radiation exposure (ALARA and ALADA) and ensure that the benefit from the imaging outweighs the risk associated with radiation.

CBCT is the most exciting advance in the dental imaging which has revolutionised the field of diagnostic radiology. Being a 3 D imaging modality it makes the radiographic image crystal clear and there is little scope for doubt, misjudgement of misinterpretation (associated with conventional radiographs).

However as it utilizes a cone shaped beam that revolves around the patient the radiographic exposure is bound to be greater than the Intra Oral Periapical Radiography/Panoramic Radiography. When compared to medical CT (which utilizes multiple rotations of the X ray tube around the patients), the CBCT exposure is considerably low.

The framing of these guidelines by the Indian Academy of Oral Medicine and Radiology is undertaken with the motive of establishing a protocol for safe and efficacious use of CBCT, designed to benefit the patients clinically, and simultaneously safe guarding the patient and the operator from the hazards of radiation.

The Indian Academy of Oral Medicine and Radiology, presents evidence based, consensus driven CBCT guidelines under the following headings:

A. Radiation Safety Aspects
B. Clinical applications of CBCT
C. Interpretation and Reporting of CBCT

A. RADIATION SAFETY ASPECTS

X rays are invisible electromagnetic radiations which travel at speed of light and have several important properties. X rays penetrate opaque substances, produce photochemical reactions in the films and exhibit the property of fluorescence. All these properties are of great significance in diagnostic radiography. However being ionizing radiations X-rays can have deleterious effects on the living tissues. The effect may be direct wherein the X ray photon directly or through secondary electron ionizes biological macromolecules. Indirect effect is due to radiolysis of water which is the most predominant biological molecule.

Radiation Injury can be

a. Deterministic wherein large number of cells are killed

b. Stochastic wherein sub-lethal damage to the genome of the individual cells can result in cancer formation or heritable mutation.

c. While dosage and risks of dental radiology are small, a number of epidemiological studies have provided limited evidence of an increased risk of radiation induced tumors.(SEDENTEX CT, Page 19)[1]

The use of CBCT imaging in the dental profession has rapidly gained popularity since its inception 15 years ago. As CBCT utilises a cone shaped beam which rotates around the patient, the radiation dose to the patient is substantially greater than the conventional imaging (IOPA, OPG etc.).

However when compared to conventional CT (Multi-slice CT) in which a fan shaped beam is used to scan the patient in multiple slices, the exposure in CBCT is much less.

A. 1.Tube Voltage, Current, Exposure Time

During CBCT scan each projection image set is made by sequential single image capture of the attenuated X-ray beam by the detector. X-ray generation may be continuous or pulsed to coincide with the detector activation. The pulsed X-ray beam is preferred to the continuous X-ray beam as the actual exposure time is upto 50% less than the scanning time. This technique reduces the patient radiation exposure considerably.[2, 3]

According to Pauwels et al [3] some X-ray tubes will provide pulsed exposure while the others provide continuous exposure. In case of pulsed exposures, the total scan time may be 20 s, but the actual exposure time would be much less. This point must be borne in mind to reduce the patient's exposure.

It is of utmost importance to adhere to ALARA principles of radiation protection. Consequently, due attention must be given to equipment related factors – Tube voltage, current, exposure time.

R Pauwels et al[4] measured the radiation dose as a function of kVp in a cylindrical polymethyl methacrylate (PMMA) phantom using small volume ion chambers. CNR was measured for PMMA phantom containing different materials (air, aluminium etc.). Optimal contrast at a fixed dose was found at the highest available kVp settings.

Adjustable kVp, mA and S is provided by most of the manufacturers and the common opinion amongst the researchers is that maximum kVp gives images with best contrast, and the radiation exposure can be kept to the minimum by reducing the mA.[4, 5]

Although both kVp and mA are fixed in certain CBCT equipments, they are automatically modulated in real time on some other units by feedback mechanism by detecting the intensity of the transmitted beam, a process known as Automatic exposure control. On other units, exposure settings are automatically determined by the initial scout exposure. This feature is highly desirable as it is operator independent. (White and Pharoah, pg 187)[2]

According to the systematic reviews by Goulston R, et al (2016), Margarete B McGuigan et al. (2018), most studies demonstrate that patient dose reduction is possible without a clinically relevant reduction in image quality. [6, 7]

Consensus :

- As adjustable tube voltage, current, and exposure time are provided by all the manufacturers, care must be taken to select adequate and minimum exposure parameters depending on case variables.

Recommendations :

A.1-1 : It is recommended that, for each clinical indication, maximum kVp should be used as it gives the best contrast, however, radiation exposure can be kept to the minimum by reducing mA upto 2-4mA.

A.1-2 : If feasible, equipment providing pulsed exposure (as against continuous exposure) may be used as it reduces the exposure by a considerable extent.

A. 1-3 : CBCT equipments provided with automatic exposure control are desirable.

A. 2 Field of View and Collimation

The dimensions of the FOV depend primarily on the detector size and shape, and the ability to collimate the beam. The shape of the FOV can be either cylindrical or spherical. Collimating the x-ray beam limits x-radiation to the ROI.[8] (White and Pharoah, pg 187) [2]

Depending upon the clinical need, smallest size FOV should be selected. For example, for implant study, CBCT of a single segment can be imaged on the smallest FOV (4x4 cm^2), whereas, (8 x 8 cm^2) is suitable for imaging the dentate areas of the maxilla and mandible. Large FOVs (> 15 cm in field height) are required for full craniofacial imaging (up to dimensions of 26 x 26 cm^2). Minimal dose of radiation was measured in the smallest FOV = 19 - 44 µSV, medium FOV: 28–265 µSv and large FOV: 68–368 µSv.[7] Each class of FOV shows a wide range of effective dose hence, there is a clear trend for smaller FOVs to offer smaller doses. [9]

Reducing the dimensions of the X-ray beam to the minimum size, is an obvious means of limiting the dose to the patients, as well as improving the image quality by increasing CNR (SEDENTEXCT pg 83)[1, 10, 11] A reduction in radiation dose can be achieved by using the lowest exposure settings and narrow collimation[12]

In case of protocol using stitched images, two or more segments are exposed separately, and the data obtained is stitched by using the software. In this process the margins of the constituent FOVs may be exposed twice, thereby adding to the radiation dose. Hence, it is recommended to avoid stitched images as far as possible. However, there is no compromise on the accuracy of the diagnostic quality of the images thus produced.[13, 14, 15,]

Consensus :

- Smallest FOV for a particular clinical application to be used to minimize patient dose.

Recommendations:

A. 2-1 : It is essential to select the smallest size FOV, depending upon the clinical need to minimize the radiation dose.

A. 2-2 : It is recommended to avoid stitched images as far as possible from the radiation protection view point.

A. <u>3. Collimation and Filtration</u>

The purpose of collimation is to control the shape and the size of the X-ray beam. Adequate collimation only exposes the area under study and also prevents unnecessary excessive scatter and increases signal to noise ratio. In CBCT the beam is cone shaped and depending upon the FOV under study, the radiation beam is adequately collimated to expose the region of interest. The use of FPD results in cylindrical FOV and use of IID results in spherical FOV. The cylindrical FOV gives adequate coverage to the anatomical structures under study whereas Spherical FOV has to cover greater area to obtain the same data. And hence, cylindrical FOV (FPD) is preferred over the spherical FOV. [16, 17]

Electronic collimation involves elimination of data recorded on the detector that are peripheral to the area of interest. Electronic collimation is undesirable because it results in greater exposure of the patient to radiation than is necessary for imaging task. (White and Pharoah, pg 193)[2] In the rare possibility of machines utilizing post-exposure electronic collimation, exposure to the patient is higher and hence, such equipments should be avoided.[18]

The purpose of filtration is to remove the soft x-rays, which are likely to be absorbed by the patient's tissues and cause radiation harm. Unwanted and excessive exposure of the patient's tissues is prevented by filtration which in turn reduces the scattered radiation and the resultant noise.

CBCT typically uses Al or Cu filtration with an Al equivalent thickness between 2.5mm and 10mm[7].

With added filtration, effective dose for medium FOV examinations for default settings were: small adult 76 mSv, medium adult 98 mSv, and large adult 166 mSv. Effective doses for large FOV examinations were: small adult 93 mSv, medium adult 163 mSv, and large adult 260 mSv [7]. Effective dose was reduced by an average of 43% in examinations made with increased filtration and adjusted kVp[19]

Consensus:

- CBCT equipment should permit choice of collimation. Electronic collimation should not be used .FOV should chosen as per indication.

Recommendations :

A. 3-1 : It is recommended to use adequately collimated beam to cover the region of interest and avoid unnecessary exposure of the adjacent areas.

A. 3-2 : It is recommended that total filtration used during CBCT exposure should be between 2.5-10 mm Al equivalent. Cu filters provided by some manufacturers also meet the purpose.

A. 4 Voxel Size

The spatial resolution and therefore the detail of a CBCT image is determined by individual volume element (Voxel) produced in formatting the volumetric data set. CBCT units provide voxel resolutions that are isotropic i.e equal in all three dimensions. (White and Pharoah – Pg 190)[2]

Voxel size can be selected on most dental CBCT systems according to the particular diagnostic task. Overall, voxel sizes of CBCT equipment range from 0.075 to 0.6 mm, although individual machines will not normally provide the full range. The smaller the voxel size, the higher the spatial resolution and therefore smaller voxel sizes are selected when a high level of detail is required e. g. for endodontic purposes (Liedke et al. 2009; Kamboroğlu & Kursun 2010; Melo et al. 2010; Maret et al. 2012)[7].

For selective clinical application such as endodontics, periodontics, minute details of the anatomic variations have to be studied and hence smaller voxel size is preferred. A voxel size of upto 0.150 mm^3 is found to be suitable for detection of periodontal defects.[20] For detection of external root resorption 300 µm voxel size can be used with adequate efficacy.[21] The optimal resolution CBCT imaging system used in endodontics is suggested to not exceed 200 μm [22] and a voxel size of 0.3 to 0.4 mm is considered adequate to provide CBCT images of acceptable diagnostic quality for implant treatment planning.[23]

However, smaller voxel size results in more image noise as detectors with smaller pixels capture fewer x-ray photons per voxel, thus, this may necessitate a compensatory increase in radiation dose to achieve a sufficient signal-to-noise ratio and improved diagnostic image quality (via increased mA or basis images).[7] (White and Pharoah, Pg 190)[2]

Consensus:

- Equipment should permit an adjustable voxel size (Optimal voxel size for a particular clinical application/diagnostic requirement to be preferred, thereby reducing radiation dose)
- For Endodontics and periodontal applications reduced voxel size will be useful.
- For others the voxel can be as large as 0.2 and 0.3mm.

Recommendations :

A. **4-1 :** For selective clinical applications such as endodontics and periodontics, smaller voxel size can be selected, however, it involves increased radiation exposure.

A. <u>5. Detector type: Flat panel vs image intensifiers</u>

Two types of image detectors are used in CBCT units :

1. A charge coupled device with a fibre optic image intensifier.
2. An amorphous silicon flat panel detector

The IIDs are larger and make the scanners overall dimensionally bulkier. They also demonstrate greater peripheral distortion, which ultimately reduces measurement accuracy of the reconstructed images. (DCNA 479 – 480)[24]

FPDs being smaller make the CBCT units less bulky. FPD also have minimal peripheral distortion of the image and generate better data set and the units have a smaller footprint. Use of FPD provides a cylindrical FOV which is preferred in dentomaxillofacial radiography as opposed to IID which gives rise to spherical FOVs. (DCNA 479 – 480)[24]

FPDs offer higher spatial and contrast resolution, greater dynamic range and reduced peripheral distortion compared with the earlier generation image intensifiers and charged coupled devices (CCD) technology, which have gradually been superseded (Baba et al. 2004; Nemtoi et al. 2013; Pauwels et al. 2015a)[7, 25.]

Recent advances in the IID technology using solid state x-ray image intensifiers, has improved quality over the previous IIDs. However, these IIDs are not known to be superior in comparison to FPD.[26]

FPD is preferred over Image Intensifiers because of more accurate volume rendering, higher spatial and contrast resolution, lesser peripheral distortion (superior geometric design)

Consensus:

- Flat panel detectors have an advantage over image intensifier detectors and hence are preferred.

Recommendations:

A. 5-1 : As flat panel detectors offer higher spatial and contrast resolution and reduced peripheral distortion, it is preferred over the earlier generation image intensifying devices.

A. 6. Rotation cycle 180^0 vs 360^0 and number of projections

CBCT units may provide 180^0 to 360^0 rotation. As basis images for 180 degree rotation is much less than 360 degree rotation there is increased reconstruction artefacts (Scarfe & Farman 2008; Bechara et al. 2013), increased noise and reduced image quality, though studies demonstrate that for particular diagnostic tasks image quality and diagnostic accuracy can be maintained (Lofthag-Hansen et al. 2011; Durack et al. 2011; Lennon et al. 2012)[7].

Shorter scan arc of 180^0 results in reduced scan time and reduced dose. Around approximately 50% dose reduction is achieved in comparison to 360º arc rotation. [27] Shorter scan time is desirable in patients finding it difficult to remain stable for prolonged periods of time for example patients with trauma, very old patients, mentally challenged patients, small children etc.

Even if 360º gantry rotation leads to improvement in contrast to noise ratio and spatial resolution and decrease in the artefacts compared to 180^0 gantry rotation (with the same voxel size and FOV), reduction in patient dose can be achieved by reducing the angular rotation to 180^0 without compromising on the image quality.

Consensus :

- Though, rotation cycle of 180^0 is found to be adequate for most diagnostic purposes, a rotation cycle of 360^0 is preferred in endodontic cases as it provides higher resolution, detail and clarity with minimal artefacts. Thus, rotation cycle should be chosen according to the diagnostic need.
- If the machine offers reduced dose protocol it would be an advantage.

Recommendation :

A. 6-1: 180^0 rotation cycle should be preferentially used as it reduces the radiation exposure substantially (compared to 360^0 rotation) without compromising on the image quality.

A. <u>7. Shielding Devices</u>

Necessary protocol for radiation protection of the patients and the operators must be scrupulously followed during CBCT exposure viz. Lead aprons and thyroid collars for the patients. Adequate lead partition with lead glass window.

Anyone who is in the X-ray room at the time of exposure must be behind a protective barrier. If someone must also be in the room to assist or maintain patient safety, then this individual must wear a protective apron. Lead-impregnated leather or vinyl aprons must be used to cover the reproductive organs of all patients, including pregnant patients, who undergo dental X-ray examinations. The apron should be preferably 0.5 mm of lead or lead-equivalent but not less than 0.25 mm of lead or lead-equivalent thickness.[28]

Although the thyroid doses associated with dental X-rays have not been shown to cause thyroid cancer. It is prudent to reduce thyroidal radiation exposure without compromising on the clinical goals of dental examination.

According to A Hidalgo (2013) [29], design 2 performed best regardless of its material and thickness. And the thyroid shield should be placed sufficiently high on the neck with good adjustment. It is recommended to tilt the mandible upwards during exposure, so that the exposure to the thyroid gland is reduced by the increased distance between the beam and the gland. Studies in the adult phantoms have shown that 0.35mm lead equivalence is most effective. Lead shielding is found to be as effective as non-lead equivalent material[29].

Radiation exposure of all the personnel involved with working of the CBCT machine should be monitored with the help of thermoluminescent dosimeter or equivalent measures and the records received from the radiation monitoring service must be maintained in the department. Care must be then not to exceed the maximum permissible dose for the radiation worker as per AERB guidelines.

<u>Consensus:</u>

- Shielding devices for protection of thyroid gland (when close to primary beam) and thorax/abdomen is recommended
- Lead Aprons providing protection to thorax, abdomen can be routinely used for all CBCT exposures; thereby providing protection from scattered / secondary radiation.
- Design of thyroid shielding devices should be optimum
- Lead aprons and thyroid collars should be used routinely.

Recommendations :

A. 7-1 : It is recommended to use lead aprons for thorax and abdomen regularly. Thyroid shields of 0.35 mm lead equivalence are considered to be most effective.

A. 8. Quality Standards and Quality Assurance

During installation of CBCT unit, all efforts must be made to ensure that the images produced by the equipment are of high quality and hence acceptable for diagnostic purpose. Care must be taken to ensure that the radiation exposure parameters are accurately displayed and adjustable and the radiation protection provided is of the highest standard. After continuous use of CBCT equipment over a period of time, the quality of the CBCT image might deteriorate and the machine might develop certain errors or artefacts which will require calibration and maintenance. If this is not done, there is always a chance of increased radiation hazard to the patient and a gradual decline in the quality of the radiograph. For these reasons it is desirable to carry out QA tests on a regular basis.

The DAP (Dose-Area-Product) indicates the radiation dose for 180 degrees and 360 degrees scan arc for different FOVs ranging from 50 X 50 mm to 130 X 150 mm (Ivana Kralik *et al* 2018)[29] .

QA tests should be routinely undertaken to assure the quality of the imaging and should be in compliance with the AERB protocol.

Assessment of clinical quality of images by comparing with reference images on regular basis.

Standard Protocol for equipment calibration using Reference Phantom to be proposed at various stages of equipment lifecycle:

a) Commissioning and Installation

b) Quarterly or half-yearly routine maintenance

c) Following any major breakdown repair e.g. Memory card / Electronic board / Tube head / Detector / Acquisition software crash

The design and implementation of such protocol should follow manufacturer/AERB guidelines and involve Oral Medicine and Radiology specialists designated by IAOMR and representative service engineers of major CBCT manufacturers / suppliers.

Recommendation to AERB to make it mandatory to involve an Oral Radiologist in all CBCT installation to adhere to all radiation norms especially for patient safety.

The purpose of Quality Assurance (QA) in dental radiology is to ensure consistently adequate diagnostic information, while radiation doses are controlled to be as low as reasonably achievable.

Those aspects of the programme that deal primarily with equipment performance and patient dose are commonly referred to as quality control (QC). A QC programme will include surveys and checks that are performed according to a regular timetable. A written record of this programme should be maintained by staff to ensure adherence to the programme and to raise its importance among staff. A specific person should be named as leader for the QC programme.(Sedentex CT)[1]

Commissioning tests

The main aim of the acceptance and commissioning tests is to ensure the imaging system is as specified and working at an acceptable performance level for the specific clinical indications in the local practice. These tests should usually be performed by a medical physics expert.

The essential content of these tests includes:

- testing of equipment performance parameters
- acquiring base line values for future routine tests
- verification of how the systems are pre-programmed for use in practice

All acceptance and commissioning testing protocols include tests of the X-ray tube output, voltage consistency and accuracy, filtration, exposure time and radiation field. These can be tested in the same way as for other modalities, like general radiology digital detector systems or MSCT scanners. Testing of the correct operation of any automatic exposure control device, if fitted, is also essential.(Sedentex Ct)[1]

Routine tests

Both medical physics experts and local personnel have a role in routine tests. A typical frequency for medical physics tests is annually (Health Protection Agency 2010a, 2010b; Statens strålevern, 2010). Local personnel should run a series of routine consistency tests more frequently in line with current national guidance, usually monthly (Qualitätssicherungs- Richtlinie, 2004; Health Protection Agency 2010a, 2010b; Statens strålevern, 2010). When introducing a new modality, its operation should be monitored more frequently, until the system is working reliably at its optimal point in terms of dose and image quality. Optimisation studies may be advisable at this stage. Routine testing may be helped with automatic procedures built into the system. These can include the evaluation of test objects against performance levels set by the company or by national or international protocols, the review of retakes (automatically stored into the system) and system self checks. Full documentation should be provided by the installers on these (automated) procedures. Exportable reports are preferable. (Sedentex Ct)[1]

Reject Analysis

All unacceptable scans (not meeting their clinical objective for any reason e.g. machine calibration error / artefacts / incomplete exposure of FOV) should be analysed and recorded

No more than 5% scans should fall in the category of "unacceptable" and this number should be decrease by 50% in every audit cycle as per European Guideline of 2012. (Sedentex ct)[1].

Consensus :

- Recommendation to AERB to make it mandatory to involve an Oral Radiologist in all CBCT installation to adhere to all radiation norms especially for patient safety.

Recommendations :

A. 8-1 : QA tests should be routinely undertaken to ensure the image quality and also to maintain the radiation exposure as per the ALARA principles.

A. 8-2: Commissioning tests and routine tests should be regularly carried out by designated authorities like AERB with the view to provide optimum image quality and also to reduce the radiation exposure.

A. 9. Installation of CBCT equipment

The protocol to be followed during installation regarding the space, walls, shielding, X-ray machine layout, entrance door, windows, ceiling and other features should strictly adhere to the guidelines provided by AERB. The radiation safety measures provided by the manufacturer and available during installation should be inspected and certified by the AERB for safe use.

Consensus :

- It is recommended that the design and designation of Controlled area for installation, and Personnel Monitoring be as per AERB regulations and guidelines.

Recommendations :

1. **9-1 :** The guidelines provided by the AERB regarding space, walls, shielding, X-ray machine layout, entrance door etc. should be scrupulously followed and the necessary certification should be obtained. The radiation protection guidelines should be regularly assessed and certified (3/5 yearly) by the AERB or designated authorities.

2. CLINICAL APPLICATIONS OF CBCT

B. 1. Basic Principles

Clinical guidelines are a means of providing a framework for the use of a new technology or technique. Guidelines should be systematically developed, with statements designed to assist the clinician and patient in making decisions regarding appropriate healthcare for certain specific clinical circumstances.

There are 3 fundamental methods to guideline development

1. To rely on the opinion of an expert panel's considered judgment
2. To employ some kind of consensus method
3. To use “evidence-based” guideline development methodology

In radiology, guidelines can provide assistance in choosing the suitable imaging conduit. Which are called “referral criteria”, “selection criteria” or “appropriateness criteria”. These are descriptions of clinical situations resultant of patient signs, symptoms or history that help identify patients who are likely to benefit from a particular radiographic procedure.

In the circumstance of CBCT in dentistry, where higher radiation doses are seen as compared to that in conventional dental radiography, it becomes most important to adhere to the radiation protection principle for justification. Guidelines, in the form of selection criteria, can provide the clinician with a supportive outline within which to work. There is reasonable agreement on the fundamental principle of rationalization and individual selection of patients for CBCT examinations.

Many times it was commented that CBCT should be reserved as a supplementary imaging technique where conventional radiography with lower dose or an alternate imaging modality has failed to answer the question for which imaging was required.

A CBCT scan should only be considered if the additional information from the reconstructed three-dimensional images will potentially aid in formulating a diagnosis and/or enhance the management. There are massive challenges in developing selection criteria for CBCT in dentistry.

The evidence base is still very limited for most clinical applications. While some studies of diagnostic accuracy are practicable, where a valid laboratory model can be used (e.g. dental fracture diagnosis); for other applications such as periapical inflammatory pathosis, it is impossible to achieve a study design entirely free of risk of bias or applicability difficulties.

There are many CBCT machines available in the market with different image quality and the diagnostic capability, each machine varies depending upon mode of operation. Thus could be understood that we will never be able to develop “definitive” guidelines with high grading of supporting evidence for CBCT. Whether to use CBCT or not is influenced by numerous factors.

Dentists are predictably influenced by many factors; one being teachers, both as undergraduates and during continuing education. Another factor is financial pressures, which may indulge the use of certain clinical techniques, such as CBCT, if they can increase profits.

Clinical applications of CBCT [30]

1. CBCT examinations must not be carried out unless a history and clinical examination have been performed.

2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.

3. CBCT examinations should potentially add new information to aid the patient’s management.

4. CBCT should not be repeated on a patient without a new risk/benefit assessment having been performed.

5. When referring a patient for a CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the justification process. Referring dentists should be aware of referring criteria.

6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography.

7. CBCT images must undergo a thorough clinical evaluation (‘radiological report’) of the entire image dataset. A copy of the clinical evaluation, including the selection criteria used and the patient dose factors, must be provided to the referring dentist.

8. Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT.

9. CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides a lower radiation dose to the patient.

10. Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used .

In the use of CBCT the roles in the delivery of ionizing radiation as a diagnostic tool are three fold:

1. The Holder : The person with legal responsibility, for a radiological facility
2. The Referrer (Prescriber) : An individual, who is entitled to prescribe/refer patients for a radiological investigation to a practitioner, and will be involved in the justification for that exposure
3. The practitioner: An individual, who should be entitled to take clinical responsibility for part or all of the radiographic exposure of a patient.[31]

THE HOLDER IN DENTAL PRACTICE IS COMMONLY ALSO A PRACTITIONER AND A PRESCRIBER

Full clinical information, along with information to allow patient identification, must be included in each referral. If essential information is missing, the referral should be returned or more details sought. A standard referral form providing the following information could facilitate this process [32]

1. Patient unique information
2. Clinical context for requesting the dental CBCT examination
3. Relevant results of history, clinical examination and other imaging
4. The question which the referrer would like the dental CBCT examination to answer
5. A clear indication of the areas for which dental CBCT imaging is requested

Justification

1. It must be justified by the practitioner, that the information sought on CBCT cannot be obtained on simple diagnostic imaging, thus substantiating the additional radiation exposure that the patient will be exposed to. A record of the Justification process must be maintained for each patient

2. CBCT should not be selected unless a history and clinical examination have been performed. “Routine” or “screening” imaging is unacceptable practice.

3. If the exposure is being done for medico legal reasons or if there is no direct health benefit to the patient, then the need for usefulness of such examinations should be critically examined when assessing whether the exposure is justified. Informed consent of the patient should be obtained in writing in such examinations.

Consensus:

- CBCT as a technology offers an advanced point-of-care imaging modality that clinicians should use cautiously as an adjunct to conventional dental radiography.
- The selection of CBCT for dental and maxillofacial imaging should be prescribed on professional judgment in accordance with the available scientific evidence, evaluating potential patient benefits against the risks associated with the radiation dose.
- Clinicians must relate to the ALARA principle in protecting patients and staff during the acquisition of CBCT images. This includes appropriate justification of CBCT use, optimizing technical factors, using the smallest FOV necessary for diagnostic purposes and using appropriate personal protective shielding[33]

Recommendation :

B 1.1 : Utilization of CBCT should be restricted to the patients who will stand to benefit with a better treatment outcome as compared to conventional radiography and where the imaging advantage will mitigate the associated risk

Table 1 - Basic principles to be followed in daily clinical practice before requesting cone-beam computed tomography[34]

Principle 1	CBCT should not be used routinely for all patients.
Principle 2	CBCT examinations must not be carried out unless a history and clinical examination have been performed.
Principle 3	CBCT examinations must be justified for each patient.
Principle 4	CBCT field of view (FOV) should be restricted as much as possible.
Principle 5	The lowest achievable resolution should be used without jeopardizing evaluation of the area of interest.

B. 2. CBCT IN ORTHODONTICS

From the time of introduction, CBCT has been widely used and many times overused in orthodontics. The probable adverse consequences of CBCT have become a concern, and stringent guidelines introduced. This brought into focus, ethical issues involved with the introduction of newer technology, which increases the exposure to radiation. Therefore, while prescribing CBCT along with the technical requirement, the ethical issues need to be assessed as misuse of CBCT may violate some of the existing accepted guidelines such as ALARA and ALADA.

Beauchamp and Childress proposed four principles of bioethics, namely autonomy, beneficence, non-maleficence, and justice. Autonomy has been described as a patient's ability to make treatment choices based on the sufficient information provided by the clinician [35-36].

Whenever radiographs are required, it is the duty of the orthodontists to provide their patients with justifiable diagnostic options. The risk– benefit analysis should be carried out before prescribing CBCT. Orthodontists should explain to the patients the need for CBCT in diagnosis and treatment planning and choice should be given to the patients for decision-making. Adequate information should be provided to the patients to make them understand the risks associated with radiation. Informed consent must be obtained from every patient before CBCT prescription. When patients are children and adolescents, their assent also be taken along with informed consent from parents/guardian.

The North-American guidelines for CBCT use in Orthodontics were published in 2013 with the coordination of the American Academy of Oral and Maxillofacial Radiology (AAOMR), Table 2 shows the orthodontic indications of CBCT according to the American guidelines.

Table 2 - CBCT recommendations for orthodontic purposes, according to the American Academy of Oral and Maxillofacial Radiology (AAOMR)[34].

Dental structural anomalies
Anomalies in dental position
Compromised dentoalveolar boundaries
Facial asymmetry
Sagittal skeletal discrepancies
Vertical skeletal discrepancies
Transverse skeletal discrepancies
TMJ signs and symptoms
Malformation and craniofacial anomalies
Localization of proper mini-implant placement sites
Airway assessment
Expansion procedures assessment

The European evidenced-based guidelines, known as SedentexCT Project, were issued in 2012 and were more conservative regarding the use of CBCT in Orthodontics. Table 3 summarizes the conclusion of these guidelines with regard to orthodontic cases.

Table 3 - CBCT recommendations in Orthodontics according to the European SedentexCT (2012) guidelines (*field of view should be as restricted as possible [34]

Localization of impacted teeth and identification of associated root resorption*	» CBCT should only be used when Multi-slice CT is necessary, in which case CBCT is preferred due to lower radiation dose; or » CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiograph;
Clef lip/palate*	» CBCT should only be used when Helicoidal CT is necessary, in which case CBCT is preferred due to lower radiation dose;
Mini-implants: Proper mini-implant placement site*	» CBCT are rarely necessary, except for cases with critical space left for mini-implant placement;
Severe cases of skeletal discrepancies	» CBCT of the face might be used to develop orthosurgical treatment planning; » Preference is given to patients older than 16 years of age;
Pre-surgical assessment of impacted teeth	» CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography;
Orthognathic surgery planning	» CBCT of the face might be used to develop orthosurgical treatment planning;
TMJ assessment	» CBCT should only be used when Helicoidal CT is necessary, in which case CBCT is preferred due to lower radiation dose;

Clinical Aspects:

1. **Impacted teeth**[37]:

After third molars, maxillary canines are the second most commonly impacted teeth and are probably the most common indications for CBCT imaging in orthodontics. Of the many types of clinical situations being presented to the orthodontist, impacted teeth are ones in which CBCT has been most shown to improve diagnosis and contribute to modifications in treatment planning. CBCT enhances the ability to localize impacted canines accurately, evaluate their proximity to other teeth and structures, determine the follicle size and the presence of pathology, estimate space conditions, assess resorption of adjacent teeth, assist in planning surgical access and bond placement, and aid in defining optimal direction for extrusion of these teeth into the oral cavity.

For root resorption associated with impacted teeth, CBCT scans provide substantially superior visualization of roots compared with conventional 2D radiographs by eliminating superimposition artefacts and capturing 3D root structures from all possible directions. Importantly, axial slices are the most appropriate CBCT scans used for diagnosis of root resorption associated with impacted teeth. Cross-sectional slices sometimes fail to show the entire cervico-apical portion of the roots, especially due to mesio-distal tooth angulation. Additionally, they might give a false impression of inexistent root resorption. The detection of abnormal anatomy of the root by CBCT, including dilacerated roots—(particularly, in the bucco-lingual direction not seen in 2D radiographs) may help determine the amount and direction that a dilacerated tooth can be moved or aid in the decision to extract it.

Besides aiding in tooth localization, CBCT is also valuable in determining the optimal site for surgical access to an impacted tooth and more importantly contributes to significantly higher confidence in a clinician's diagnosis and treatment planning than does the combination of panoramic, periapical and occlusal radiographs that traditionally have been used for this purpose.

Thus, the scientific evidence for the utility of CBCT both in refining diagnosis and modifying treatment plans for significant numbers of impacted teeth validate its use for most impacted teeth.

2. **Supernumerary teeth**[37]:

There are two imaging goals in these cases. The first goal is to precisely localize all supernumerary teeth, many of which are unerupted or may be impacted. The second goal is to study in detail the morphology of the supernumerary teeth. Information derived from CBCT images of unerupted supernumerary teeth could facilitate decisions on which of the teeth to retain, determination of the retrievability of those teeth and mapping the optimal surgical access to the teeth.

3. **Root angulation, morphology and resorption**[37]**:**

Since root parallelism is an important goal of orthodontic treatment, its accurate determination may provide valuable information in assessing the quality of treatment outcomes and, possibly, of post-treatment stability.

CBCT provides more accurate root angular measurements relative to those derived from 2D radiographs. CBCT has been shown as good as periapical radiography for determining tooth and root length. CBCT can generate precise images of small root defects, it provides more accurate insights into root resorption and has greater sensitivity and specificity than do panoramic or other 2D radiographs in detecting these lesions. 2D radiographs only provide visualization of the apex and the mesial and distal root surfaces, CBCT imaging enables the visualization of buccal and lingual root surfaces. This has led to the discovery that root loss is not only present at the root apex but often presents as a slanting root loss on surfaces adjacent to the direction of tooth movement. Identifying buccal or lingual root resorption, which is not visualized by 2D radiography but is detectable by CBCT, could contribute to differences in pre- or in-treatment decisions.

4. **Alveolar boundary conditions** [37]:

The effect of orthodontic treatment and various appliances on bone morphology and boundary conditions in three planes of space can be assessed relatively well with CBCT, although not perfectly owing to some of its technological limitations. Hence, though CBCT scans can accurately capture the dento-alveolar complex in 3D, it is best to be selective about what cases may benefit from CBCT scans for assessing boundary conditions.

5. **Quantity and quality of bone and anatomical considerations in temporary anchorage device placement [37]:**

While there is no evidence supporting the need for CBCT to treatment plan the placement of TADs, these images can prove helpful for macro-anatomical analyses through visualization of neighbouring structures such as tooth roots, sinuses and nerves that can be valuable for avoiding damage or complications. CBCT can also be useful for micro-anatomical evaluation of the quantity and quality of cortical bone and quality of the underlying trabecular bone that may determine primary stability of TADs, which in turn, is relevant to their secondary stability over the longer term. CBCT is not normally indicated for planning the placement of temporary anchorage devices in orthodontics.

6. **Quantifying cleft lip and palate defects and outcomes of alveolar bone grafts [37]:**

CBCT may provide more precise information on the numbers, quality and location of teeth in proximity of the cleft site, eruption status and path of canines in grafted cleft sites, and diagnosing for implant placement. CBCT images are valuable for determining the volume of the alveolar defect and, therefore, the amount of bone needed for grafting in patients with CL/P and for determining the success of bone fill following surgery. CBCT images enable the visualization of the 3D morphology of the bone bridge, the relationship between the bone bridge and roots of the neighboring teeth and their periodontal condition. CBCT can be useful for diagnosis and treatment of impacted canines that are common in patients with Cleft Lip/Palate and their paths of eruption through grafted bone sites.

7. **Temporomandibular joint morphology and pathology contributing to malocclusion [37]:**

CBCT has been shown to be more efficacious than conventional tomography and MRI in detecting osseous changes. CBCT images by allowing the concurrent visualization of the TMJs and assessment of the maxillo-mandibular-spatial relationships and occlusion provide the opportunity to visualize and quantify the local and regional effects associated with the TMJ abnormalities. Furthermore, CBCT proves a good method to assess TMJ after orthognathic surgery, particularly when there is considerable potential for resorption of the condyle.

8. **Airway morphology, vertical malocclusion and obstructive sleep apnoea [37]:**

There are no studies demonstrating that qualitative or quantitative assessments of CBCT images are capable of predicting OSA accurately. The method has its limitations. CBCT airway imaging might vary according to patient's swallowing movement and position during the exam. Whenever the patient swallows, the soft palate is lifted, which causes the nasopharynx to distort.

Furthermore, some CBCT scanners require the patient to be in supine position, while others require the patient to remain sited or standing. Different scanners register different images of upper airways due to soft palate mobility. Moreover, static analysis of patient's airways is another limitation posed by CBCT which differs from video-fluoroscopy, as the latter allows a dynamic pharyngeal analysis.

Additionally, the ideal method used to diagnose obstructive sleep apnea syndrome is polysomnography instead of CBCT. Previous studies found significant correlation between profile cephalogram and CBCT used to analyze patient's airways area and volume. Nasopharyngeal sagittal linear measurement is strongly correlated to volume of upper airways. Thus, despite building a 2D representation of a 3D structure such as patient's airways, profile cephalogram remains as a reliable method used to assess pharyngeal obstruction. Therefore, there is no point in requesting CBCT scans with a view to tri-dimensionally assess upper airways for orthodontic purposes.

9. **Maxillary transverse dimension and maxillary expansion [37]:**
   CBCT has enabled more in-depth dissection of responses of bone and teeth to maxillary expansion than was possible through 2D radiography or study models.

10. **Complex Cranio-Facial Deformity [37]:**
    Large volume CBCT should not be used routinely for orthodontic diagnosis. For complex cases of skeletal abnormality, particularly those requiring combined orthodontic/surgical management, large volume CBCT may be justified in planning the definitive procedure, particularly where MSCT is the current imaging method of choice.

Consensus:

- Cone-beam computed tomography is not a standard method of diagnosis in Orthodontics. CBCT should be indicated with criteria, when the potential benefits for diagnosis and treatment planning outweigh the potential risks of an increased radiation dose.
- Based on research evidence, orthodontists are advised to use their best clinical judgment when prescribing radiographs, including CBCT scans, to obtain the most relevant data using the least ionizing radiation possible.

- 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 [38]

Recommendation:

B2.1 : Avoid CBCT Scans solely to produce a lateral cephalogram and/or panoramic view if the CBCT would result in higher radiation exposure than would conventional imaging.

B2.2 : Avoid taking 2D radiographs if the clinical examination indicates that a CBCT study is indicated for proper diagnosis and/or treatment planning or if a recent CBCT is available

B. 3. CBCT IN PERIODONTAL ASSESSMENT

Based on a moderate level of evidence, CBCT could be useful for FI periodontal cases but it should only be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning [39]. CBCT measurements of the periodontal bone loss was found to be more accurate than intraoral radiographs and also surgical measurements[40].

CBCT provides accurate measurement of intrabony defects and allows clincians to assess dehiscence, fenestration defects, and periodontal cysts. Bone plates thinner than the imaging spatial resolution might not be revealed by CBCT, thereby reaching a false-positive diagnosis of bone dehiscence or achieving quantitative assessments that underestimate the level of bone crest. Images with reduced voxel size are more accurate in terms of thickness and height of buccal/ lingual bone plates.

Consensus :

- CBCT is not indicated as a routine method of imaging periodontal bone support. Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management.
- Large volume scans are contraindicated to assess bone levels.

Recommendation :

B 3.1 : CBCT is not indicated as routine methods of imaging periodontal bone support. Limited volume, high resolution CBCT may be indicated in selected cases of infra bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management

B.4. CBCT for Dental Caries Assessment

Although using of CBCT is not a routine method to detect primary caries, CBCT may be a valuable tool for detection of recurrent caries in certain clinical situations such as caries under FPD or buccal restorations. However, careful evaluation of each single case may be recommended in order to avoid unnecessary radiation specially, when other lower-dose radiographic methods may give similar diagnostic data [30,41].

Consensus:

- CBCT is not indicated for caries detection as better detection of caries can be achieved with lesser radiation with conventional radiographs like periapicals and bite wing.

Recommendation:

B4.1: CBCT is not indicated as routine methods of caries detection and diagnosis

B. 5. CBCT IN ENDODONTICS/PERI-APICAL PATHOLOGY

Limited volume, high resolution CBCT is indicated in the assessment of dental trauma (suspected root fracture) in selected cases, where conventional intraoral radiographs provide inadequate information for treatment planning. Most of the available studies on the diagnosis of VRFs had minor differences in study quality. Systematic review and metanalysis by Ma R. H. Ma, Z. P. Ge & G. Li confirms the detection accuracy of root fractures[42] in CBCT images. However, there were only a few in vivo studies available with a reliable reference standard and verification. According to the results of this meta-analysis, a trend for better performance was seen with CBCT imaging compared with PRs for unfilled teeth. However, the presence of filling material in the canals significantly reduced the specificity of CBCT imaging, which was attributed to the streaking artifacts.

With Periapical Radiographs, the overall sensitivity is reduced in filled teeth because of lesser visibility of fractures on radiographs. However, the overall diagnostic ability for PRs was marginally better than CBCT imaging in filled teeth. Hence, the chief reason for choosing CBCT imaging for certain cases may be purely the 3-dimensional image reconstruction of the area of interest, which may enable direct visualization of the fracture line. It may also overcome problems of magnification, distortion, and anatomic superimposition of structures. The diagnostic ability of CBCT imaging in cases of filled teeth may not be reliable[43]. CBCT could be reliable in detecting the presence of External Root Resorption in clinical practice, which has a higher diagnostic efficacy than Periapical Radiograph [44].

CBCT is not indicated as a standard method for identification of periapical pathosis. Limited volume, high resolution CBCT may be indicated for periapical assessment, in selected cases, when conventional radiographs give a negative finding when there are contradictory positive clinical signs and symptoms. Where CBCT images include the teeth, care should be taken to check for periapical disease when performing a clinical evaluation (report).

CBCT is not indicated as a standard method for demonstration of root canal anatomy. Limited volume, high resolution CBCT may be indicated, for selected cases where conventional intraoral radiographs provide information on root canal anatomy which is equivocal or inadequate for planning treatment such as dense in dente, palatal radicular groove, , taurodontism or as additional root canals(e.g. MB2 canal) and in multi-rooted teeth, radix entomolaris. Limited volume, high resolution CBCT may be indicated for selected cases when planning surgical endodontic procedures. The decision should be based upon potential complicating factors, such as the proximity of important anatomical structures[30].

Limited volume, high resolution CBCT may be indicated in selected cases of suspected, or established, inflammatory root resorption or internal resorption, where three dimensional information is likely to alter the management or prognosis of the tooth[30].

Limited volume, high resolution CBCT may be justifiable for selected cases, where endodontic treatment is complicated by concurrent factors, such as resorption lesions, combined periodontal/endodontic lesions, perforations and atypical pulp anatomy[30]

Consensus :

- CBCT is not indicated for routine Endodontic cases; however, is of great use in diagnosing difficult and complicated pathology and variations (such as, vertical root fractures, missed and accessory canals, and dens in dente, etc.) and in detecting procedural errors, not appreciated on conventional radiographs.

Recommendation :

B 5.1: CBCT is not indicated as a standard method for demonstration of root canal anatomy.

B 5.2: Limited volume, high resolution CBCT may be indicated, for selected cases such as dense in dente, palatal radicular groove, radix entomolaris, taurodontism or as additional root canals(e.g. MB2 canal) and in multi-rooted teeth where conventional intraoral radiographs provide information on root canal anatomy, which is equivalent or inadequate for planning treatment, most probably in multi-rooted teeth.

B 5.3 : Limited Volume, high resolution CBCT may be indicated, for selected cases when planning surgical endodontic procedures. The decision should be based on potential complicating factors, such as proximity to important anatomical structures.

B 5.5 : Limited volume, high resolution CBCT may be indicated, for selected cases of suspected or established, inflammatory root resorption or internal resorption, where 3 D information is likely to alter management or prognosis of the tooth.

B 5.6 : Limited volume, high resolution CBCT may be justifiable for selected cases, where endodontic treatment is complicated by concurrent factors, such as resorptions lesions, combined periodontal/endodontic lesions, perforations and atypical pulp anatomy.

B 5.7 : CBCT is not indicated as a standard method for identification of periapical pathosis.

B 5.8 : Limited volume, high resolution CBCT may be indicated for periapical assessment, in selected cases, when conventional radiographs give a negative finding when there are contradictory positive clinical signs and symptoms.

B.6. CBCT IN IMPLANT DENTISTRY

The decision to perform a CBCT examination must be clinically justified and based on professional judgment (that is, the judgment of the clinician is that the use of CBCT will potentially provide information needed for prosthetic treatment planning, implant selection, and/or surgical placement). The CBCT imaging protocol should include the smallest FOV necessary and available and optimize exposure parameters. For periodic, postoperative implant monitoring, periapical and, in some cases, panoramic images provide adequate imaging. Finally, all CBCT volumes, regardless of clinical application, should be systematically evaluated for signs of abnormalities[45].

1. **Initial examination**:

   Maxillofacial imaging interfaces with patient history, clinical examination, definitive diagnosis, treatment planning, and implant therapy. The purpose of the initial radiographic examination is to assess the overall status of the remaining dentition, to identify and characterize the location and nature of the edentulous regions, and to detect regional anatomic abnormalities and pathologies.

   Panoramic radiography should be used as the imaging modality of choice in the initial evaluation of the dental implant patient. Intraoral periapical radiography could supplement the preliminary information from panoramic radiography. Do not use cross-sectional imaging, including CBCT, as an initial diagnostic imaging examination [46].

2. **Preoperative site specific imaging** :

   Most studies indicate that data from panoramic and intraoral radiography alone are inadequate and provide insufficient information to determine treatment difficulty. The radiographic examination of any potential implant site should include cross sectional imaging orthogonal to the site of interest. Conventional tomography provides cross-sectional information but is technique sensitive and the images are more difficult to interpret than CBCT. CBCT usually results in lower patient exposures to ionizing radiation than does CT. CBCT should be considered as the imaging modality of choice for preoperative cross sectional imaging of potential implant sites.

There should be careful selection of exposure parameters and FOV. Although the FOV should be limited to the area of interest, the FOV may extend beyond the implant site to include the maxillary sinus or opposing dental arch.

The use of CBCT before bone grafting helps define both the donor and recipient sites, allows for improved planning for surgical procedures, and reduces patient morbidities. CBCT is best suited for the evaluation of volumetric and topographic changes of the restored residual alveolar ridge.

CBCT should be considered when clinical conditions indicate a need for augmentation procedures or site development before placement of dental implants:

(1) Sinus augmentation

(2) Block or particulate bone grafting

(3) Ramus or symphysis grafting

(4) Assessment of impacted teeth in the field of interest

(5) Evaluation of prior traumatic injury

CBCT imaging should be considered if bone reconstruction and augmentation procedures (e.g., ridge preservation or bone grafting) have been performed to treat bone volume deficiencies before implant placement.[46]

3. Postoperative imaging :

The purpose of postoperative imaging after dental implant placement is to confirm the location of the fixture at implant insertion. Imaging is used to assess the bone-implant interface and marginal peri-implant bone height. Titanium implant fixtures inherently produce artifacts such as beam-hardening and streak artifacts obscuring subtle changes in marginal and peri-implant bone.

In addition, the resolution of CBCT images for the detection of these findings is inferior to intraoral radiography. In the absence of clinical signs or symptoms, use intraoral periapical radiography for the postoperative assessment of implants. Panoramic radiographs may be indicated for more extensive implant therapy cases.[46]

Use cross-sectional imaging (particularly CBCT) immediately postoperatively only if the patient presents with implant mobility or altered sensation, especially if the fixture is in the posterior mandible. Do not use CBCT imaging for periodic review of clinically asymptomatic implants. Cases of implant failure, owing to either biological or mechanical causes, require a complete assessment to evaluate the associated defect and to plan for surgical removal and corrective procedures, such as ridge preservation or bone augmentation. CBCT will aid in identifying the effect of surgery on the defect and the adjacent structures. Cross-sectional imaging (optimally CBCT) should be considered if implant retrieval is anticipated.[46]

Consensus:

- The decision to prescribe a CBCT scan must be based on the patient's history and clinical examination and justified on an individual basis taking due consideration of diagnostic and pre-surgical treatment planning needs and benefits, radiation risk and cost.

- Effective assessment of proposed implant sites require that clinicians interpret implant sites for many factors related to successful implant restorations, including adequate bone volumes, distance away from teeth/implants, sufficient prosthetic space for restoration, and precise implant placement.

- A protocol is proposed on how to do a structured review and read a CBCT data volume to ensure that pathosis or critical anatomical structures are not missed that may impact on, or enhance diagnosis, treatment planning and treatment outcomes.

Recommendation

B 6.1 : CBCT is indicated for cross-sectional imaging prior to implant placement, due to its advantage of adjustable FOV as compared to MSCT.

B 6.2 : For pre surgical assessment it is indicated for; identification of critical anatomic boundaries, prevention of neurovascular trauma, assessment of bone morphology, volume and quality, bone augmentation procedures, grafting, distraction, zygoma implants, suspected trauma, prognosis of adjacent teeth, virtual implant.

B 6.3 : For post-surgical assessment it is indicated to evaluate any complication, check bone healing, mechanical implant failure, retrieval of osseo-integrated implant.

B. 7. CBCT IN ORAL &MAXILLO-FACIAL SURGERY

Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate initial imaging should be MSCT or MR, rather than CBCT. For maxillofacial fracture assessment, where cross-sectional imaging is judged to be necessary, CBCT may be indicated as an alternative imaging modality to MSCT where radiation dose is shown to be lower and soft tissue detail is not required. CBCT is indicated where bone information is required, in orthognathic surgery planning, for obtaining three-dimensional datasets of the craniofacial skeleton. Where the existing imaging modality for examination of the TMJ is MSCT, CBCT is indicated as an alternative where radiation dose is shown to be lower.

1. **Impacted Third Molars:**

   Periapical or PAN may be sufficient in most cases before removal of mandibular third molars, but CBCT may be suggested when one or more signs for a close contact between the tooth and the mandibular canal are present in the 2D conventional image - if it is believed that CBCT will change the treatment or the treatment outcome for the patient.[47]

   The presence of any of panoramic radiographic signs cannot definitely predict a true relationship; however, the presence of a close sign on panoramic radiography suggests the possibility of a true relationship to the canal. Hence, all patients with a close relationship on panoramic radiography should be referred for CBCT. Of all the sections in CBCT, the coronal, axial and mainly para-axial sections should be carefully examined as they are better at predicting true relationship.

   CBCT images provide a reliable insight in the bucco-lingual relationship between the third molar root and the mandibular canal, which cannot be achieved with panoramic radiography. On CBCT, the presence or absence of direct contact between the tooth root and the canal contents was three dimensionally evaluated. It was considered that direct contact was present when loss of bone tissue between the two structures was observed on all three sections, i.e., coronal, sagittal, and axial. CBCT is the best way of displaying the mandibular canal from different directions, coronal, axial, and sagittal.[19]

2. **Trauma:**

Trauma cases present with a wide range of diagnostic challenges. Not all of these are addressed by either medical CT or conventional dental radiography alone. By comparison, CBCT by itself can often deliver enough information for a diagnosis in one quick scan. It is useful in identification of fracture and defect morphology.

It is also useful for determining defect dimensions and the relative locations of pertinent anatomic structures. Such information is needed for planning restorations that involve alveolar bone augmentation and implant placement. Additionally, CBCT shows promise in airway identification, an application that can be developed to reduce operating room occupation times. CBCT in posttraumatic applications enables dentists to address many patient needs [49].

It is essential that the radiation exposure should be kept as low as possible. A single conventional plain film, compared with CT or CBCT, needs the lowest level of radiation, but when limited information is obtained by these films and further details are required for diagnosis and treatment planning or postoperative evaluation, CBCT should be considered instead of medical CT. CBCT suffers from image noise and lack of soft tissue differentiation. Compared the imaging findings of CT and CBCT in airgun injuries, and these author’s preferred CBCT images as a result of less metallic artifacts providing superior information and diagnosis.

Currently, CBCT is able to provide important information for all dental specialties not only contributing to the diagnostic accuracy of the maxillofacial complex but also decreasing cost and radiation exposure to the patient considerably [50]

3. **Paranasal Sinuses :**

Paranasal sinus pathoses were common incidental findings in CBCT of the maxillofacial area required for different dental diagnostic purposes. Because of the high incidence of collateral pathologies and incidental findings, dentomaxillofacial radiologists should examine the whole volume of CBCT images to avoid under- or overestimation of a potential pathology and ensure a comprehensive evaluation of the possibility of underlying diseases.

Clinically, when paranasal sinus pathoses are discovered on CBCT images, patient should be referred to an otolaryngologist. In addition, dentists should not overlook sinus diseases as the cause of dental and facial pain.[51] Paranasal sinus variations are very common. Before the sinus surgery, CBCT is the best imaging method with lower radiation dose for the determination of sinonasal anatomy.

Consensus:

- From a radiation protection point of view, conventional films still deliver the lowest doses to patients, however, it is of great clinical significance that the operating surgeon has a fair idea about the pathology under question and its relation to the adjacent vital structures, and this being so, CBCT may be imaging modality of choice in certain selected cases.

Recommendation:

B 7.1: Limited volume, high resolution CBCT is indicated in the assessment of dental trauma (suspected root fracture) in selected cases, where conventional intra oral radiographs provide inadequate information for treatment planning

B 7.2: Where conventional radiographs suggest a direct inter-relationship between a mandibular third molar and mandibular canal when surgery is planned.

B 7.3: CBCT may be indicated for pre-surgical assessment of an un-erupted tooth where conventional radiographs do not provide adequate information

B 7.4: For maxillofacial fracture assessment, where cross-sectional imaging is necessary.

B 7.5: In cases of orthognathic surgery planning, for obtaining 3-D data sets of the craniofacial skeleton

B.8. CBCT IN ASSESSMENT OF BONY PATHOSES

CBCT provides 3D imaging of bony pathosis in multiple thin slices and hence it is easy to determine the exact extent of the lesion & its relationship to the important anatomical structure. It also gives fair idea about the content of the lesion (whether cystic, soft tissue or bony), and the borders of the lesion. These features of the interpretation makes CBCT valuable in the radiographic diagnosis and subsequent treatment planning.

If extent of pathology needs to assesed to aid in patient management without need for soft tissue evaluation, CBCT of appropriate FOV may be advised. If bony pathology under study also requires soft tissue evaluation, then post contrast CT or MRI would be the imaging modality of choice.

Consensus :

- As CBCT gives 3D images of bony pathologies in multiple thin slices with a clear indication of the content and the margins of the lesion and it's proximity to the adjacent anatomical landmarks, CBCT may be utilised in cases which are likely to show ambiguous findings on conventional radiographic modalities.

Recommendation:

B 8.1: CBCT in case of large bony pathosis is recommended as it can cover the entire region, adjacent structure and also give an estimate of the volume of the pathosis.

B.9. CBCT IN ORAL CANCER

Detecting bone invasion in oral cancer is crucial for therapy planning and the prognosis. The sensitivity, specificity, and accuracy of CBCT were compared with panoramic radiography (PR), multi-slice computed tomography (CT) or magnetic resonance imaging (MRI), and bone scintigraphy (BS) using McNemar's test.

Histopathology and clinical follow-up served as references for the presence of bone invasion. CBCT and BS (84.8% and 89.3%, respectively), as well as CBCT and CT/MRI (83.2%), showed comparable accuracy (P = 0.188 and P = 0.771). CBCT was significantly superior to PR, which was reconstructed based on a CBCT dataset (74.1%, P = 0.002). In detecting bone invasion, CBCT was significantly more accurate than PR and was comparable to BS and CT/MRI.[52]

Limited volume, high resolution CBCT may be indicated for evaluation of bony invasion of the jaws CBCT by oral carcinoma when the initial imaging modality used for diagnosis and staging (MR or MSCT) does not provide satisfactory information. For assessing soft tissue & adjacent lymph node involvement MR or MSCT with contrast is the accepted imaging modality.

Consensus:

- Considering the high-resolution images delivered by CBCT along with minimized artefacts in the mandible, it provides an alternative imaging technique, which could be combined and accomplished with another soft-tissue imaging modality like MRI to obtain optimal hard and soft-tissue visualisation in patients with squamous cell carcinoma of the oral cavity.[53]
- However, in case where it may not be possible to conduct MRI imaging due to certain contraindications it is recommended to subject the patient to contrast CT so that both soft tissue, including lymph nodes as well as bony involvement can be studied.

Recommendation :

B 9.1: Limited volume, high resolution, CBCT may be indicated for evaluation of bony invasion of the jaws by oral carcinoma when the initial imaging modality used for diagnosis and staging does not provide satisfactory information.

B.10. CBCT IN ASSESSMENT OF TMJ'S

In a relatively short period of time, CBCT has emerged as a cost- and dose-effective alternative to CT for examination of the TMJs, although it may be more sensitive to motion artefacts. The imaging modality is superior to conventional radiographic methods, as well as MRI, in the assessment of osseous TMJ abnormalities. However, it should be emphasized that the diagnostic information obtained is limited to the morphology of the osseous joint components, cortical bone integrity and subcortical osseous abnormalities. For the assessment of inflammatory activity and soft-tissue abnormalities such as internal derangement in patients with TMD, MRI is the method of choice[54].

Consensus:

- Several radiographic methods are used to assess the TMJ, an area that is difficult to be imaged due to factors like superimposition of adjacent structures and morphological variations.

- The complexity of the TMD however, demands a clear and precise image of the region for effective management of the patient. CBCT provides a definite advantage over other techniques due to its low radiation dose to patient, smaller equipment size and ability to provide multiplanar reformation and 3D images.

- There is promising research in the field of CBCT in TMJ imaging. However more systematic clinical studies, adequate training of the personnel and complete understanding of the anatomical and functional dynamics of the TMJ are required to harness the true potential of this breakthrough technology[55].

Recommendation:

B 10.1: CBCT may be indicated for evaluation of bony component of the TMJ.
If soft tissue and disc has to be evaluated then MRI and Contrast Imaging are recommended.

B.11. CBCT IN ASSESSMENT OF AIRWAY SPACE

Refer to CBCT in Orthodontics- Airway Morphology The airway space includes the nasal cavity, nasopharynx, velopharynx, oropharynx and hypopharynx. Large FOV CBCT studies, such as those acquired to assess the craniofacial skeleton for orthodontics and orthognathic surgery, will typically include the airway spaces. In MDCT units where the patient is in a supine (lying with face up) position, gravitational forces on the tongue and soft palate will result in narrowing of the airway space.[50]

With most CBCT units the patient is in a seating position which does not replicate the sleeping position. The visualized airway is not only influenced by the position of the soft tissue of the neck, it is also influenced by the position of the tongue during acquisition, which can cause the airway to appear narrower.[51] CBCT can help identify patients with a high predisposition for obstructive sleep apnea (OSA), although the final diagnosis is typically made through a medical sleep study (polysomnography)[56].

CBCT studies provide only a static image of the airway space, and can be helpful in the detection of anatomical or pathological changes. The program automatically provides the area and total volume of any predefined region[57]. The airway space should be evaluated systematically for patency and symmetry, with the capability to measure airway dimensions or provide 3D modeling. Although CBCT imaging provides excellent visualization of static airway morphology, it does not provide any direct information on airflow or airway resistance.[56]

Consensus :

- Even if airway space can be appreciated and evaluated on CBCT, lateral cephalogram is reportedly sufficient for orthodontic analysis.

- For clinical assessment of cases with obstructive sleep apnoea, polysomnography is the preferred diagnostic method.

Recommendation:

B 11.1: CBCT images give only static information that is given also on a lateral cephalogram, hence it is not recommended. However using specialised software, the airway volume can be measured on CBCT which is an advantage over cephalometry wherein the 3D volume cannot be measured.

B.12. CBCT IN FORENSIC ODONTOLOGY

CBCT is useful in forensic contexts, offering several advantages for post-mortem forensic imaging including good resolution for skeletal imaging, relatively low cost, portability, and simplicity. 3D reconstruction, bite-mark analysis, age estimation, person identification and anthropological assessment using CBCT have shown promising results. CBCT imaging can provide the much-needed 3D perspective in certain cases that require more information that is beyond the scope of the traditional methods. There is a need for forensic odontologists to understand the role and scope of this imaging modality in the forensic practice. In future, CBCT will be a great tool and asset to the practice of forensic odontology.[58]

Consensus:

- As CBCT provides multi-slice 3D data, age and gender assessment, individual identification, will be more accurate when compared to conventional radiography, and may be considered favourably.

Recommendation:

CBCT is emerging as the modality of choice in forensic odontology.

B.13. CBCT IN PEDIATRICS

An important aspect in considering the use of CBCT in children is the radiation exposure. This is due to two factors: Rapid tissue growth and chances of subsequent deoxyribonucleic acid damage and secondly, as the child is expected to live longer than a 50-year-old adult, the chances of damaging effects of radiation manifesting in a tumor are higher. This means that the three basic principles of protection from radiation, i.e., "justification principle," "limitation principle" and "optimization principle" should be followed.

The justification principle means that if relevant information cannot be obtained without radiographs, only then we must consider their use. This principle also states that also suggests that if the patient cannot cope with the procedure, no radiographs should be taken. The limitation principle states that the radiation dose should always be kept as low as reasonably achievable for all patients.

Thirdly, there is the "optimization principle," which states that best diagnostic images should be obtained keeping in mind the aforesaid principles. The major advantages of CBCT in pediatric patients arise from lesser scan time and less complicated apparatus, which reduces anxiety in children. Images obtained with CBCT are highly magnified, with less distortion. A major advantage of CBCT as compared to conventional CT is the reduced dosage.[59] Though, CBCT has higher dose as compared with intra-oral radiography, the range of dose reduction is between 96% and 51% compared with conventional head CT

Clinical Applications –

1. **Development of teeth-**

Conventional imaging techniques make it difficult to visualize the complex phenomenon of tooth development. CBCT can help evaluate eruption pattern of teeth along with any anomalies in number or shape[59].

2. **Caries diagnosis-**

CBCT is not indicated for caries diagnosis - Diagnosis of impacted/supernumerary teeth Maxillary canines 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 seem to be present with supernumerary teeth such as mesiodens. CBCT is thought to be of great utility in such cases[59].

3. **Diagnosis of temporomandibular (TMJ) disorders**-

The application of CBCT in imaging the TMJ has been most significant in the evaluation of hard tissue or bony changes of the joint. Pathologic changes, such as fractures, ankylosis, dislocation and growth abnormalities such as condylar hyperplasia, are optimally viewed[59].

4. **Diagnosis of root resorption and root fractures –**

CBCT allows determining the exact site of resorption and this is particularly useful in cases where resorption is occurring on the lingual or facial side of the tooth. In multirooted teeth, the root in which resorption is present can be easily visualized. A very commonly observed root resorption phenomena is present with lateral and central incisors in case of canine eruption. Thus, with CBCT, this problem could be diagnosed and the extraction of deciduous canine can be planned well in time. In case of oblique fractures, which are not viewed properly on a 2D radiograph, CBCT provides an enhanced view with finer details. Another advantage of CBCT is that it can be acquired easily post-trauma also when periapical radiographs cannot be easily done due to swelling, bleeding and discomfort experienced by patients. The ability to view the section of a single tooth of interest in the three planes of space makes determining if the involved tooth displays fracture much easier.[59]

5. **Craniofacial morphology-**

Lateral cephalograms have been most commonly used for this purpose. However, these come with their own set of limitations such as superimposition of structures, distortion of images, magnification and head positioning. CBCT offers better image clarity as extraneous superimposing structures can be removed and it is also possible to reorient the head position after the initial scan if the head was not properly positioned at the time of scanning. In addition, the unilateral nature of posterior crossbites can be diagnosed more specifically. A determination of an asymmetric maxilla or mandible can be accomplished more easily by viewing and measuring the bones in 3D. [59]

6. **Cleft lip and palate-**

CBCT can provide the exact anatomic relationships 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. This provides more accuracy and ease in graft placement and other surgical procedures [59]

7. **Airway analysis-**

Conventionally, lateral cephalograms were used to analyze the airway of a patient. [59]

8. **Endodontic applications-**

It becomes difficult to analyze the extent of periapical pathologies, canal morphology, root fractures, exact location of broken instruments in root canal etc., with conventional 2D imaging modalities. CBCT provides an enhanced view in locating missed canals, calcified canals and curvature of roots. Measurements in relation to roots such as root length, type of canals present, angle of curvature etc., are simply available with CBCT, making it an effective diagnostic aid. In vivo and in vitro investigations demonstrate the superiority of CBCT to conventional imaging for almost all endodontic applications, except for assessing the quality of root canal fills. It has also been proved to be an effective tool in planning periapical microsurgery even in difficult accessible areas such as palatal roots of maxillary first molars[59]

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. The latter is also useful in determining the limitation to tooth movement in case orthodontic treatment is required.[59]

Consensus :

- In Paediatric patients due care must be taken to avoid indiscriminate and unnecessary radiation exposure and hence CBCT is indicated only in cases which are likely to clinically benefit the patient when compared to conventional radiography.

Recommendation :

B 13.1: Avoid using CBCT on patients to obtain data that can be provided by alternate non-ionizing imaging modatities
B 13.2: Use all patient protective shielding.

APPLICATIONS OF CBCT IN FIELDS OTHER THAN DENTAL

It is interesting to note that historically CBCT was utilized for Angiography in 1982 and later on it was used in the medical field for mammography.[60] CBCT scanners mounted on C – arm fluoroscopy unit, offer real time imaging with a stationary patient in the interventional radiology suite. Such units are of great use for treatment planning and intra-procedural localization during angiography. Other medical applications of CBCT are stent placement, middle ear pathologies, CBCT guided biopsies, mammography and many others.[61]

CBCT SCAN – RADIOLOGICAL INTERPRETATION AND REPORTING

Interpretation of the images obtained after CBCT scan & formulating a detailed report is the most important responsibility of the oral and maxillofacial radiologist. In order to achieve proficiency in accurate interpretation and reporting, the oral and maxillofacial radiologist must posses

1. Adequate knowledge of the working of the CBCT machine and expertise in using the software provided

2. Thorough knowledge of the sectional anatomy and anatomical variations of the maxillofacial complex

3. Excellent knowledge about the pathologies manifested in the region under study and also, proper understanding of the way these pathologies affect the normal structures and give rise to radiographic changes in the image

4. Understanding of various artefacts encountered occasionally in the CBCT images

In order to achieve the desired expertise in the CBCT interpretation it is expected that both the beginners as well as established radiologists undergo specialized training. Similarly, the dental surgeons who prescribe the CBCT examination must also have basic understanding about the CBCT functions and images and they also must undergo CDE programs.

Consensus-

- Dental specialist interpreting a CBCT scan should undertake theoretical and practical training in the sectional study of normal radiological anatomy, identification of common dento-alveolar/ jaw bone pathology, assessment of quantity and quality of bone and be familiar with the use of installed imaging software. Such training should be designed and conducted by the IAOMR through qualified personnel.

- The services of a qualified Oral Medicine and Radiology specialist (MDS) must be availed for the interpretation of CBCT data for both restricted FOV scans as well as large volume FOV scans (e.g. multi-purpose variable FOV CBCT units in institutions and imaging centre's).

Recommendations:

C 1.1: A basic curriculum on CBCT must be integrated in the Radiology subject of the BDS course for introducing the young under-graduates to the science of 3D dental digital imaging technology (CBCT).

C 1.2: The existing curriculum for the Masters program (MDS) in Oral Medicine & Radiology in India must also be modified to include a Detailed theoretical & practical training on CBCT technology.

C 1.3: Adequate theoretical & practical training (Annexure 1) should be validated by IAOMR or an academic institution (University or equivalent) where specialists in Dento-maxillofacial Radiology (DMFR) exist. The design and delivery of the basic CBCT training program should be done by a Dento-maxillofacial Radiologist.

C 1.4: A National academy could preferably be framed by the IAOMR for detailed practical & theoretical training of the young aspiring Dento-maxillofacial Radiologist in the field of CBCT.

C 1.5: Alternatively, those students, who are studying in institutes where CBCT facility is not available, four to five Dental Institutions having CBCT facility and fulfilling the basic requirements of conducting the Theoretical & Practical training in CBCT could be identified by IAOMR for conducting the CBCT courses annually for convenience of post graduate students residing in different regions of India.

C 1.6: There should be different level of training program for training for prescriber [Non OMR- general dentist] and practitioner [OMR specialist]. The outline for such training for the prescribers is outlined in Annexure I

C 1.7: For prescriber, training in CBCT should be limited to understanding the clinical indications, applications, and basic software training program with particular reference to Endodontic & Implant planning applications (Annexure I)

C 1.8: For practitioner [OMR specialist only] should be trained for comprehensive assessment and interpretation of entire CBCT volume. (Annexure II)

C 1.9: Those OMR post graduate students & /or faculty members who are presently studying and/or training in institutes where CBCT facility is available should be certified as trained for CBCT practices in future by the institutes.

C 1.10: Considering the progress in Digital technology, the delegates also welcomed the idea to initiate online courses in CBCT by IAOMR for distant students in remote areas.

Annexure I

LEVEL OF EDUCATION FOR GENERAL DENTISTS IN CBCT [62,63]

At least two levels of continuous education are necessary for general dentists:

Level 1 : A basic level, directed at Prescribers with limited knowledge of CBCT as an imaging modality and radiology in general (i.e. education in selection criteria, technology, radiation protection, outcome, interpretation of the examinations and influence on patient treatment).

Level 2: An advanced level directed at Practitioners who would be advising a CBCT imaging. It would include hands-on use of software so that the dentist can access and assess the scan three dimensionally.

To attend Level 2, the learning outcomes formulated for Level 1 must be fulfilled. It should be mandatory that the course (at least at Level 2) is carried out in a venue where sessions of hands-on training can be provided.

Because techniques and knowledge develop overtime, it is recommended that refresher courses are attended regularly.

The following learning outcomes should be achieved, and on completion of the course, the learner should have demonstrated:

KNOWLEDGE & UNDERSTANDING:

Level 1:

• Knowledge of the concept of the imaging "chain" from initiating the X-ray exposure to display of the image
• Knowledge of how X-rays interact with matter
• Knowledge of biological effects of radiation
• Knowledge of background radiation and its origin
• Knowledge of the principles of image detectors and their influence on image quality
• Knowledge of the selection criteria for intraoral and panoramic radiography and its influence on radiation protection
• Understanding of the difference between two-dimensional and 3D imaging
• Knowledge of the regulations that direct the use of CBCT in India.
• Understanding of the importance of gaining new knowledge by following scientific developments and improvements in diagnostic imaging and technology.

Level 2:

• Knowledge of the factors controlling X-ray quantity, quality and geometry and its influence on image quality

• Knowledge of the construction and function of CBCT equipment

• Understanding of the principles of CBCT radio-graphical techniques

• Knowledge of selection criteria for examination with CBCT

SKILLS AND ABILITY

Level 1:

• Ability to analyse normal anatomical structures of the teeth, jaws and facial skeleton in CBCT images

• Ability to recognize anatomy and disease of the teeth and their supporting structures in CBCT images

Level 2:

• Skills in practical use of software and other measures for radiation protection.

• Ability to differentiate between findings indicative of normal anatomical structures from those of diseased teeth, jaws and the facial skeleton

• Ability to identify and critically review adequate scientific literature.

PRACTICAL TIME REQUIREMENT FOR THE ENTIRE TRAINING

For Level 1, this cannot be delivered in less than 12 hours of theoretical and practical training.

• *To attend Level 2, the learner should have passed Level 1 course successfully.*

• *For Level 2, this cannot be delivered in less than 12 hours of theoretical training and an additional 12 h of training in practical aspects of CBCT.*

Annexure II

CBCT TRAINING PROGRAMME FOR IAOMR GRADUATES [62, 63]

Level 1 : A basic level, directed at OMR specialists:

1. *Understanding the working principal of CBCT.*
2. *Radiation physics, Radiation Biology & safety measures using CBCT.*
3. *Difference between 2D & 3D imaging.*
4. *Sectional anatomy of maxilla, mandible & surrounding structures.*

Level 2 : Advanced training aimed at rendering detailed information in understanding the diagnosis & interpretation & Reporting various pathologies three dimensionally using CBCT.

5. *Clinical applications of CBCT in (present & future scope)*
   a. *implant imaging, guided surgery*
   b. *Endodontic*
   c. *Oral surgery*
   d. *Orthodontics*
   e. *Periodontics.*

6. *Drawbacks of CBCT technology in Radio diagnosis.*

7. *Interpretation of a CBCT volume set & Report formatting*

8. *Demonstration & Hands-on training of various proprietary &/or third party CBCT Software demonstration.*

9. *Hands-on experience on the software using various clinical cases.*

10. *Various factors involved in setting up a CBCT centre.*

To attend Level 2, the learning outcomes formulated for Level 1 must be fulfilled. It should be mandatory that the course (at least at Level 2) is carried out in a venue where sessions of hands-on training can be provided.

Because techniques and knowledge develop overtime, it is recommended that refresher courses are attended regularly.

The following learning outcomes should be achieved, and on completion of the course, the learner should have demonstrated:

KNOWLEDGE & UNDERSTANDING:

Level 1:

• *Knowledge of the concept of the imaging "chain" from initiating the X-ray exposure to display of the image*
• *Knowledge of how X-rays interact with matter*
• *Knowledge of biological effects of radiation*

• *Knowledge of background radiation and its origin*
• *Knowledge of the principles of image detectors and their influence on image quality*
• *Knowledge of the selection criteria for intraoral and panoramic radiography and its influence on radiation protection*
• *Understanding of the difference between two-dimensional and 3D imaging*
• *Knowledge of the regulations that direct the use of CBCT in India.*
• *Understanding of the importance of gaining new knowledge by following scientific developments and improvements in diagnostic imaging and technology.*

Level 2:

• *Knowledge of the factors controlling X-ray quantity, quality and geometry and its influence on image quality*

• *Knowledge of the construction and function of CBCT equipment*

• *Understanding of the principles of CBCT radio-graphical techniques*

• *Knowledge of selection criteria for examination with CBCT.*

• *Understanding the various clinical applications, drawbacks of CBCT.*

• *Understanding the interpretation & reporting method of a CBCT data set.*

SKILLS AND ABILITY

Level 1:

• *Ability to analyse normal anatomical structures of the teeth, jaws and facial skeleton in CBCT images*

• *Ability to recognize anatomy and disease of the teeth and their supporting structures in CBCT images*

Level 2:

• *Skills in practical use of software and measures for radiation protection.*

• *Ability to differentiate between findings indicative of normal anatomical structures from pathological changes involving teeth, jaws and the facial skeleton*

• *Ability to identify and critically review adequate scientific literature.*

PRACTICAL TIME REQUIREMENT FOR THE ENTIRE TRAINING

For Level 1, this cannot be delivered in less than 12 hours of theoretical and practical training.

• *To attend Level 2, the learner should have passed Level 1 course successfully.*

• *For Level 2, this cannot be delivered in less than 2-3 days of theoretical training and an additional 1 day of training in practical aspects of CBCT.*

• *For Levels 1 and 2, interpretation would be included at an appropriate level (the theory and principles of interpretation). For Level 2, it is recommended that, additionally, further case reports are undertaken as case discussions.*

• *The learning outcomes should be adequately assessed to ensure that these have been achieved. For Level 2, this should include presentation of case reports.*

C.2 CBCT Data Set- Assessment Methodology [64]

Radiologic interpretation is predicated on a thorough knowledge of CT anatomy for the entire acquired image volume, anatomic variations and observation of abnormalities. It is imperative that all image data be systematically reviewed for disease.[65]

Consensus :

- The entire data set captured in the CBCT scan (based on clearly defined justification criteria and clinical objectives) is to be sequentially evaluated with focus on the region of interest. This evaluation based on the principles and practice of interpretation should include identification of normal anatomical landmarks and a detailed assessment of any pathology.

- Artefacts, if any in the ROI should also be documented. Evaluation of reconstructed volumetric data set should not be limited to any specific reformatted sectional plane. And assessment methodology should always involve study of two dimensional sectional image data.

Recommendations:

C 2.1 : The CBCT practitioner [OMR specialist] should analyse complete volume of CBCT captured data and not limit his/her examination only to the area of interest.

C.3 CBCT SCAN- REPORTING [66]

Consensus:

- It is the professional duty of a qualified Oral Medicine and Radiology specialist to report and document positive, incidental findings in all CBCT scans keeping in view of the multi-planar sectional image datasets obtained from such 3D Volumetric examinations.
- No CBCT scan should be dispatched without a Report written and authenticated by a qualified Oral Medicine & Radiology specialist. Such a report should be

mandatory for institutions (hospitals/colleges/training centres) and other imaging centres.

- Any such CBCT report should be accompanied by hard /soft copies of processed selective images relevant to primary indication and those containing information related to any other positive or incidental findings in the study volume.
- The CBCT report must include description of teeth, periodontal bone assessment, TMJ's, maxillary sinuses, jaw bones and adjoining soft tissues (when indicated), when these regions are included in the study volume. Group participants may propose a format for writing a CBCT report.

Recommendations:

C 3.1: The purpose of structured reporting is to communicate to colleagues in a clear way and to make that reported information accessible to the software applications that are meant to improve communication. All the factors to be considered for formulating a systematically structured CBCT reports are proposed in Annexure III A & III B

1. A ready format for reporting has been proposed for:

   A. General pathology Report (Annexure IV)
   B. Implant Report (Annexure V)
   C.TMJ Report (Annexure VI).
   D. Endodontic report (Annexure VII)

2. There should be a clear mention of DATE of SCAN and DATE of REPORT in case the two differ.

3. Scan parameter should completely evaluate the area of interest with minimum FOV possible to achieve maximum resolution and should be mentioned in the report.

Additional recommendations for implant, TMJ & endodontic reporting: [67,68]

a. There were different views that mention about bone density. It is unanimously agreed that, CBCT does not show reliable HU (grey scale) and does not measure the bone density accurately when compared to CT and hence there should not be volumetric quantification of bone on CBCT, however descriptive assessment of bone quality based upon the cortical & medullary bone morphological patterns should be mentioned in the report [e.g. classifications described by Carl Misch, Zarb & Lackholm etc.]

b. Length measurement of available bone to receive an endosseous implant should be marked from crest of alveolar bone up to the nearest vital structure like mandibular canal & floor of maxillary sinus.

c. The complete width of the bone should be mentioned from outer cortical margin, buccally to outer cortical margin lingually/ palatally at the crest of the bone.

d. Maintaining safety margin (eg: 2mm above the mandibular canal while selecting the length of implant & sparing 1mm of bone on all sides from Buccal & lingual cortex while selecting the width of the implant) is completely at the discretion of the operator.

e. Angulation of bone should be followed while measuring & marking length and width of bone for implant purpose.

f. A descriptive detailing of any Periapical pathologies pertaining to its size, shape, margins, internal structure & effect on surrounding structures should be mentioned in the report.

g. A TMJ report should be systematically structured to include comments about the bony components of the joint like structure of condylar head, its shape, articulating surface, joint space, glenoid fossa, articular eminence, condylar neck region and subcortical areas.

h. For Endodontic report, a structured format should be followed.

i. In cases, where prescriber dentist insists on carrying out CBCT for TMJ in open and close mouth positions which is otherwise not indicated, then an informed consent should be obtained from the patient before proceeding for the scan, to avoid legal issues regarding unnecessary radiation exposure

j. It is unanimously agreed that CBCT is not an effective modality for assessment of articular disk, joint tendons and ligaments (soft tissue components of the joint) for which MRI is accepted as gold standard.

k. Root Canal numbers, configuration and curvatures should be clearly mentioned with assessment of possibility of vertical crack, if any.

4. If there is a demand of reporting of surrounding regions not familiar to Dento-maxillofacial radiologist like the mastoid area, middle ear canal or cervical spine region, help must be sought from general radiologist in structuring the final CBCT report.

5. ntology: There should be a structured format for reporting forensic cases.

6. There was a discussion on the duration for which the CBCT volume data be preserved by the centre or institution for further reference, if any.
    a. Here one view reported was that, there should a system where all data be handed over to patient and an acknowledgement should be signed by the patient for receipt of data.
    b. The other view was that any data should be held for a period of two years as is followed for medical records.

7. Artefact and limitation of scan like metal artefacts, etc which are beyond the control of the CBCT operator should be mentioned in the final report.

Annexure III A

RADIOLOGY REPORTS

Neill Serman

Steven R. Singer

I. Purpose of Radiology Reports.
    a. Written record of diagnostic information
    b. Ethical imperative
    c. Medicolegal imperative ie: it is the standard of care
    d. Integration of radiographic findings with clinical exam data and other diagnostic modalities
    e. Communication with other practitioners
    f. Communication with the patient

II. Basic requirements of a Radiology Report
    a. Use the correct pre-printed Radiology Report form – Dentate or Edentulous
    b. Complete demographics
        - Patient's full name
        - Chart #
        - Date radiographs exposed
        - Student's name
        - Patient's age
    c. The report must be written and dated on the day that the radiographs are exposed and processed.
    d. Signature of the (student) radiologist and date of report must appear on report.
    e. Radiographs must be of diagnostic quality

III. Contents of a Radiology Report
    a. Missing teeth and caries

- Mark X in the appropriate box for each missing tooth - bright color
- Mark caries in the correct area(s)
- Do not indicate existing restorations
- Write “see above” on the first line of your report

b. Periodontal Bone Height
- MUST be included in ALL radiology reports where teeth are present; even if it is WNL
- It is only determined by the amount of interdental bone loss from the CEJ of the tooth
- If the generalized bone height is within 3 mm of the CEJ, mark “Periodontal bone height WNL” on the correct line
- If there is radiographic evidence of bone loss, three factors must be considered and noted:
    1. Generalized or Localized
    2. Horizontal or Vertical
    3. Mild, Moderate, or Severe
- General periodontal bone height should be noted first. eq: Generalized mild horizontal bone loss.
- Localized defects should then be noted on the correct line with the area specified first. e.g. #3M moderate vertical defect
- N.B. It is possible for the general periodontal bone height to be within normal limits and have localized defects
- If there are no localized defects, write ‘WNL’

c. Abnormalities
- List by quadrant, starting with the maxillary right quadrant and concluding in the mandibular right quadrant
- Describe exact area. e.g.: Left angle of mandible, #18 apex of distal root, etc.
- Describe in appropriate terminology, such as well demarcated, poorly demarcated, radiopaque, radiolucent, mixed, etc. Don’t forget to describe borders.
- Measure, with a ruler, all lucencies, opacities, and other abnormalities in two dimensions.
- Describe only in terms of what is visible on the radiograph. Do not make a diagnosis, but offer a differential diagnosis where appropriate.
- Draw all abnormalities on the diagram on the right- hand side of the form only. Use a contrasting color and superimpose your drawing over the normal structure

- Do not mention normal anatomy such as the submandibular gland fossa or the mental foramina in this section of the report unless you have been specifically requested to comment. For example, as a radiologist, you may be requested to examine the tempromandibular joint area on a High Panoramic view. It is then appropriate to remark that the joint structure appears to be within normal limits if no abnormalities are seen on the film

- Consider normal versus abnormal development and eruption patterns when assessing films of primary and transitional dentition. Indicate whether eruption sequence is WNL.

- Impactions are considered to be abnormalities. Impacted teeth should be distinguished from unerupted teeth, which may be perfectly normal. Draw and describe impacted teeth.
- Note discrepancies in dental treatment such as overhanging restorations or incomplete or overextended endodontic fill. Use only objective terms in your description. eg: #7 root fill is 3mm short of the radiographic apex.
- Significant anatomic variations such as dilacerated roots, extra roots, supernumerary teeth, widened periodontal ligament space, etc. should be included in your report
- For edentulous patients, abnormalities such as atrophic ridges, Conversion of the mandibular canal to a groove, root remnants, and pneumatized sinuses should be noted. Do not forget to use the edentulous report form.

d. Suggest additional views and tests

e. Treatment is never recommended in a radiology report. However, in order to write a more complete report, it may be necessary to visualize areas other than those visible on the prescribed films. Common additional recommended views are: bitewings; pans; periapicals; high pans; occlusal views. It is also appropriate to suggest vitality tests for teeth where deep caries, restorations, bases, large carious areas and questionable periapical lucencies or opacities are present and the vitality of a tooth is questionable.

Keeping all the above in mind, it is important that the report is brief but covers all relevant points.

IV. When looking at a lesion / structure radiographically the following point must be considered -

1. Normal or variation of normal anatomy
2. Abnormal

Acquired	Congenital
Infection	missing teeth / cusps / nerve canals
Traumatic	additional teeth / cusps / nerve canals

Cystic	size of teeth
Metabolic	dens in dente / dens evaginatus
fibro osseous	fusion / gemination
Benign	enamel pearl
giant cell lesion	taurodontia
Malignant	amelogenesis / dentinogenesis

Annexure III B

GUIDELINES ON DIAGNOSTIC CBCT REPORT

An official interpretation of CBCT (final report) shall be generated and archived following any examination, procedure, of officially requested consultation regardless of the site of performance (Dental institute, imaging center, etc.).

COMPONENTS OF THE CBCT REPORT

The following is a suggested format for CBCT reporting:

1. Demographics

a. The facility or location where the study was performed.

b. Name of patient, age, gender .

c. Name(s) of referring dentist or other healthcare provider(s). If the patient is self referred, that should be stated.

d. Name or type of examination.

e. Date of the examination.

2. Relevant clinical information as provided by the prescribing dentist

3. Body of the Report

a. Procedures and materials. The report should include a description of the studies and/or procedures.

4. Findings

The report should use appropriate anatomic, pathologic, and radiologic terminology to describe the findings.

5. Clinical issues

The report should address or answer any specific clinical questions. If there are factors that prevent answering of the clinical question, this should be stated explicitly.

5. Impression (conclusion or diagnosis)

a. Unless the report is brief, each CBCT report should contain an "impression" section.

b. A precise diagnosis should be given when possible.

c. A differential diagnosis should be rendered when appropriate.
d. Follow-up or additional diagnostic studies to clarify or confirm the impression should be suggested when appropriate.

Principles of Reporting (Final Report)
1. The final report is considered to be the definitive means of communicating to the referring Dentist or other relevant healthcare provider the results of a CBCT imaging examination or procedure. Additional methods for communication of results (eg: telephonically) are encouraged in certain situations.

2. The final CBCT report should be proof-read to minimize typographical errors, accidentally deleted words, and confusing or conflicting statements. Use of abbreviations or acronyms should be limited to avoid ambiguity.

3. The final report should be completed in accordance with appropriate state and standard requirements. Electronic or rubber- stamp signature devices, instead of a written signature, are acceptable.

4. The final report should be transmitted to the Dentist or healthcare provider. The Dentist also shares in the responsibility of obtaining results of CBCT imaging studies he or she has ordered.

5. When feasible, a copy of the final report should accompany the relevant images to other healthcare professionals.

6. *A copy of the final report should be archived by the imaging facility as part of the patient's Dental record (paper or electronic) and be retrievable for future reference.*

Annexure IV

GENERAL CBCT REPORT FORMAT:

Date of Scan: -

PATIENT PERSONAL INFORMATION:

Name - *Age/Sex-*

Tel No- *CBCT S.No.-*

REFERRING DOCTOR/ DEPATRMENT:

PURPOSE OF INVESTIGATION -

Clinical findings -

Provisional Diagnosis-

Standard volume protocol: (Field of view)

FINDINGS:

Pertaining to the area of interest

Other Findings: (Pertaining to the entire Field of View)

IMPRESSION

DIFFERENTIAL DIAGNOSIS

RECOMMENDATIONS

SIGNING AUTHORITY (Oral and Maxillofacial Radiologist)

Annexure V

(Implant Report Format)

Patient Data:

Images provided:

Clinical Information:

Diagnostic Objectives:

Findings

:

The details for the implant sites can be seen in the cross-sectional cuts .

Cross sectional Details
Image Width:
Image Interval:

DETAILS OF THE ALVEOLAR/ BASAL BONE

1. *MAXILLA:*

2. *MANDIBLE:*

BONE DENSITY CLASSIFICATION

1. *MISCH:*
2. *LEKHOLM AND ZARB*

.SURROUNDING STRUCTURES:

1. *MAXILLARY SINUS*
2. *FLOOR OF NASAL FOSSA*
3. *MENTAL FORAMEN, LINGUAL FORAMEN*
4. *INFERIOR ALVEOLAR CANAL*

OTHER FINDINGS:

MAXILLA

TOOTH NO.						
SLICE NO.						
RIDGE HEIGHT						
RIDGE WIDTH AT CREST						
RIDGE WIDTH 2MM BELOW CREST						

MANDIBLE

TOOTH NO.						
SLICE NO.						
RIDGE HEIGHT						

RIDGE WIDTH AT CREST						
RIDGE WIDTH 2MM BELOW CREST						

RADIOGRAPHIC IMPRESSION

RECOMMENDATIONS:

Signature of authority.

Annexure VI

TMJ EVALUATION REPORT FORMAT

Images Provided

Clinical Information :

TMJ EVALUATION (RT. SIDE & / or LT SIDE) :

- *Evaluation of the cortication over the Condylar Head:*
- *Articulating surface: (Normal/ Flattened/ Pencil head/ Ely's cyst/Osteophyte/DJD/Subcortical hyperostosis)*

- *Joint space: Normal/ Reduced/ Increased/Disappearance(ankylosis)/ Calcific bodies*
- *Glenoid Fossa : Unaffected/ shallow*
- *Articular Eminence: Normal/ flattened.*
- *Sigmoid Notch, coronoid process: Any pathology noted.*
- *Condylar Neck : fracture/ thinned*

OTHER FINDINGS:

Radiographic Impression

Recommendations:

SIGNATURE:

Annexure VII

ENDODONTIC REPORT FORMAT:

Date of Scan: -

PATIENT PERSONAL INFORMATION:

Name -	*Age/Sex-*
Tel No-	*CBCT S.No.-*

REFERRING DOCTOR/ DEPARTMENT:

PURPOSE OF INVESTIGATION –

Clinical findings -

Provisional Diagnosis-

Standard volume protocol: (Field of view)

Findings

Maxilla &/ or mandible:

Description of the Area Of Interest;

- *Findings in Coronal Region: Hypodense, Hyperdense regions,Altered morphology, Internal resorption ,pulp stones, Dens en Dente, Palato-radicular groove, Tooth Crack*
- *Findings in Radicular region: (Developing/developed root, Additional roots e.g. Radix Entomolaris, Number of root canals, additional root canals eg. MB2, length, shape, configuration, Dens en Dente, Palato radicular groove, VRF ,Internal and/or external resorption)*
- *Evaluation of Periapex: Open apex, blunderbuss apex, Lamina Dura, PDL space,*
- *Detailed Evaluation of Periapical Pathology pertaining to its Size in mm or cms, site, shape, margins, borders, surrounding area & effect on surrounding structures.*

OTHER FINDINGS: (Pertaining to the entire Field of View)

IMPRESSION

DIFFERENTIAL DIAGNOSIS

ARTIFACTS

RECOMMENDATIONS

SIGNING AUTHORITY (Oral and Maxillofacial Radiologist)

C.4 CBCT- FUTURE DIRECTIONS

Reuben Pauwels et al. have summarised the future prospects of CBCT as mentioned below. (box 1)[69]

BOX 1

Overview of future perspectives in dental cone beam CT

X-ray tube

- Reduction of focal spot size
- Optimal kVp and filtration
- Dual energy scanning

Adapted exposure

- AEC based on scout image
- Real-time dynamic AEC
- Continuous beam collimation

Beam shape and rotation

- Triangular FOV shape
- Small FOV option
- 180^0 rotation option

Detector

- Detector efficiency
- Temporal resolution
- Energy resolution

Reconstruction

- Iterative reconstruction
- Metal artefact reduction
- Motion detection and correction
- Grey value calibration

• Morphometric and structural bone analysis
Optical imaging • Intra-oral scanning merged with CBCT • Facial scanning merged with CBCT
Non-dental applications • Head and neck • Orthopedic • Extremities • Animal imaging
Phase-contrast tomography • Clinical application
AEC : Automatic exposure control; CBCT: Cone beam CT; FOV: Field of view; kVp: Peak voltage

The CBCT technology is rapidly undergoing advances in the hardware as well as in the software. The CBCT applications in different fields of dentistry are making full utilisation of these advances. To name a few examples [70]

- 3D Printing for implant stents (using CAD/CAM), surgical template, for planning prosthetic appliances
- CBCT use for orthodontic analysis i.e skeletal analysis with cephalometric projections, dental analysis (anatomodels), facial soft tissue analysis
- Virtual patient – combination of surface acquisition technology and CBCT technology allowing almost humanistic chair side approach
- CBCT use in surgical simulation and sleep apnea management
- Advanced software allowing the doctor to visually define the desired outcome to carry out comprehensive orthodontic treatment planning
- CBCT can be utilised for facial reconstruction employed for personal identification in forensic medicine

Artifical intelligence

Artificial Intelligence (AI) represents the capacity of machines to mimic the cognitive functions of humans (in this context, learning and problem solving). AI can be subdivided into artificial narrow intelligence, where computer can perform a very specific task as well as or better than humans (e.g., IBM's Watson computer which Beat two Jeopardy champions in 2011), and artificial general intelligence, where a computer goes beyond specific tasks to perform higher-order syntheses, emulating human thought processes .[71]

Radiomics:

Extraction of features from diagnostic images, the final product of which is a quantitative feature/parameter, measurable and mineable from images. A R radiomics analysis can extract over 400 features from a region of interest in a CT, MRI, or PET study, and correlate these features with each other and other data, far beyond the capability of the human eye or brain to appreciate. Such features may be used to predict prognosis and response to treatment[71]

Imaging bio banks:

The constantly enlarging memory capacity of computers permits storage of large amounts of data. In radiology, the need to store native images and big data derived from quantitative imaging represents the main cause of PACS Overload. Quantitative imaging can produce imaging biomarkers that can be stored and organised in large imaging biobanks (potentially using data from many institutions and locations), available to be processed, analysed, and used to predict the risk of disease in large population studies and treatment response.

Structured reporting:

AI can aid the reporting workflow and help the linking between words, images, and quantitative data, and finally suggest the most probable diagnosis

Machine learning :

This enables the computer to analyse the data provided to correctly generalise a setting of parameters within the algorithm to optimize the goodness of fit between the input (text or image which is fed into the algorithm) and the output (classification)[72]

Deep Learning :

This algorithm uses multiple layers to detect simple features such as line, edge and texture to complex shapes and lesions. Deep learning can potentially excel by learning the hierarchical normal representation of a specific type of image from a large number of normal exams.[72]

To put it simply there are two ways in which AI can help the Maxillofacial radiologist. The computer software will present number of questions to the radiologist after the image is fed to the software and depending upon the answers given by the radiologist, diagnosis will be given by the computer.

In the second possibility, the computer software which has an exhaustive data of different images involving various pathologies, will compare the image in question with the data available and arrive at a probable diagnosis.

By both these methods the task of the radiologist will be simplified to a great extent. However, the only disadvantage will be that the human brain will not be put to sufficient exercise and practice and over the passage of time will develop dependence on the computer software.

REFERENCES

1. SEDENTEX CT 2011, Radiation Protection : Cone Beam CT for Dental and Maxillofacial Radiology. Evidence Based Guidelines.
2. Oral radiology principles and interpretation, 1st South Asia Edition. Stuart C. White. Michael J. Pharoah.
3. Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspect of dental CBCT: state of the art. *Dentomaxillofac Radiol* 2014; 44: 20140224.
4. R Pauwels, Silkosessak, Jacobs,Bogaert, Bosmans et al. A pragmatic approach to determine the optimal kVp in cone beam CT: balancing contrast-to-noise ratio and radiation dose. *Dentomaxillofac Radiol.* 2014;43(5):20140059. doi: 10.1259/dmfr.20140059. Epub 2014 Apr 8
5. Jaideep Sur, Kenji Seki, , Hiroshi Koizumi, , Koh Nakajima, Tomohiro Okano. Effects of tube current on cone-beam computerized tomography image quality for presurgical implant planning in vitro. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;110:e29-e33)
6. Goulston R, Davies J, Horner K, Murphy F. Dose optimization by altering the operating potential and tube current exposure time product in dental cone beam CT: a systematic review. *Dentomaxillofac Radiol* 2016; 45: 20150254.
7. Margarete B McGuigan, Henry F Duncan, Keith Horner. An analysis of effective dose optimization and its impact on image quality and diagnostic efficacy relating to dental cone beam computed tomography (CBCT). *Swiss Dental Journal* SSO 128: 297–316 (2018).
8. Abramovitch K, Rice DD. Basic principles of cone beam computed tomography. DentClin NorthAm. 2014 Jul;58(3):463-84. doi: 10.1016/j.cden.2014.03.002.
9. Pauwels R, Beinsberger J, Collaert B, Theodoraku C, Rogers J, Walker A, Cockmartin L, Bosmans H, Jacobs R, Bogaerts R, Horner K, SEDENTEXCT Project Consortium: Effective dose range for dental cone beam computed tomography scanners. Eur J Radiol 81: 267–271 (2012).

10. Boulos Bechara, C. Alex McMahan, et al. Contrast-to-noise ratio with different large volumes in a cone-beam computerized tomography machine: An in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012 Nov;114(5):658-65. doi: 10.1016/j.oooo.2012.08.436.

11. Lofthag-Hansen S , Thilander-Klang A, Gröndahl K. Evaluation of subjective image quality in relation to diagnostic task for cone beam computed tomography with different fields of view. Eur J Radiol. 2011 Nov;80(2):483-8. doi: 10.1016/j.ejrad.2010.09.018. Epub 2010 Oct 20.

12. Palomo, J. Martin et al. Influence of CBCT exposure conditions on radiation dose Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, Volume 105, Issue 6, 773 - 782

13. WC Scarfe, Z Li, W Aboelmaaty, à SA Scott, et al. Maxillofacial cone beam computed tomography: essence,elements and steps to interpretation. Australian Dental Journal 2012; 57:(1 Suppl): 46–60doi: 10.1111/j.1834-7819.2011.01657.

14. M.R, Soares, W.O.G Batista et al. (2014). Effective dose comparison between protocols stitched and usual protocols in dental cone beam CT for complete arcade. 14 International Symposium on Solid State Dosimetry, Mexico: Sociedad Mexicana de Irradiacion y Dosimetria.

15. Egbert N, Cagna DR, Ahuja S, Wicks RA. Accuracy and reliability of stitched cone-beam computed tomography images. *Imaging Sci Dent*. 2015;45(1):41–47. doi:10.5624/isd.2015.45.1.41

16. J B Ludlow, R Timothy, et al. Effective dose of dental CBCT—a meta analysis of published data and additional data for nine CBCT units. Dentomaxillofac Radiol. 2015 Jan; 44(1): 20140197. doi: 10.1259/dmfr.20140197

17. Tianfang Li, Xiang Li, Yong Yang, Yongqian Zhang, Dwight E. Heron. Simultaneous reduction of radiation dose and scatter for CBCT by using collimators. Medical Physics 40, 121913 (2013); doi: 10.1118/1.4831970.

18. Ioannis A Tsalafoutas. Electronic collimation of radiographic images: does itcomprise an overexposure risk? *Br J Radiol* 2018; 91: 20170958 https:// doi. org/ 10. 1259/ bjr. 20170958

19. JB Ludlow. A manufacturer's role in reducing the dose of cone beam computed tomography examinations: effect of beam filtration. Dentomaxillofacial Radiology (2011) 40, 115–122, 2011 The British Institute of Radiology. http://dmfr.birjournals.org

20. Kolsuz ME, Bagis N, Orhan K, Avsever H, Demiralp KÖ. Comparison of the influence of FOV sizes and different voxel resolutions for the assessment of periodontal defects. *Dentomaxillofac Radiol*. 2015;44(7):20150070. doi:10.1259/dmfr.20150070

21. Nikneshan S, Valizadeh S, Javanmard A, Alibakhshi L. Effect of Voxel Size on Detection of External Root Resorption Defects Using Cone Beam Computed Tomography. *Iran J Radiol*. 2016;13(3):e34985. Published 2016 Jul 5. doi:10.5812/iranjradiol.34985

22. Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. *Int J Dent*. 2009;2009:634567. doi:10.1155/2009/634567

23. George Fokas. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: A systematic review. Clinical Oral Implants Research, Wiley. Accepted: 17 February 2018 DOI: 10.1111/clr.13142

24. Scarfe WC, Farman AG. What is cone–beam CT and how does it work? Dental Clin North Am 2008; 52(4): 707-30

25. Rika Baba, Yasutaka Kono, Ken Ueda. Comparison of flat-panel detector and image intensifier detector for cone-beam CT. Computerised medical imaging and Graphics 26 (2002) 153-158

26. Kuhls-Gilcrist A, Yadava G, Patel V, Jain A, Bednarek DR, Rudin S. The Solid-State X-Ray Image Intensifier (SSXII): An EMCCD-Based X-Ray Detector. *Proc SPIE Int Soc Opt Eng*. 2008;6913:69130K. doi:10.1117/12.772724

27. Güldner, C., Ningo, A., Voigt, J. et al. Eur Arch Otorhinolaryngol (2013) 270: 1307. https://doi.org/10.1007/s00405-012-2177-2

28. Radiation Safety In Dental Practice. A study guide and excerpts from The California Radiation Control Regulations pertaining to dental practice. Radiation Safety Protection Program template

29. Ivana Kralik, Dario Faj. Paper. Dose area product in estimation of effective dose of the patients undergoing dental cone beam computed tomography examinations. Journal of Radiological Protection, Volume 38, Number 4.

30. European Commission. Cone Beam CT for dental and maxillofacial radiology: evidence-based guidelines. Luxembourg: SEDENTEXCT; 2012. (Radiation Protection; n. 172).

31. Guidance: Cone beam computed tomography (CBCT). Dental Council; An Comhairle Fiacloireachta

32. Guidance on the safe use of Dental CBCT, Prepared by HPA working party on CBCT equipment, Ch3 IRMER Requirements for dental CT administrative aspects – page 17 -26

33. The use of cone-beam computed tomography in dentistry. An advisory statement from the American Dental Association Council on Scientific Affairs, JADA 2012;143(8):899-902

34. Garib DG, Calil LR, Leal CR, Janson G. Is there a consensus for CBCT use in Orthodontics? Dental Press J Orthod. 2014 SeptOct;19(5):136-49. DOI : http://dx.doi.org/10.1590/2176-9451.19.5.136-149.sar

35. Beauchamp TL, Childress JF. Principles of biomedical ethics. Oxford University Press, USA; 2001..

36. Parveen S, Kulkarni U, Mascarenhas R, Shetty R. Awareness and practice of ethics and guidelines with cone-beam computed tomography prescription in orthodontics. Journal of Indian Orthodontic Society. 2019 Jan 1;53(1):49.

37. Kapila SD, Nervina JM. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015; 44: 20140282.

38. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, Volume 116, Issue 2, 238 - 257

39. Haas LF, Zimmermann GS, De Luca Canto G, Flores-Mir C, Corrêa M. Precision of cone beam CT to assess periodontal bone defects: a systematic review and meta-analysis. Dentomaxillofac Radiol 2018; 47: 20170084.

40. Grimard BA, Hoidal MJ, Mills MP, Mellonig JT, Nummikoski PV, Mealey BL. Comparison of clinical, periapical radiograph, and cone-beam volume tomography measurement techniques for assessing bone level changes following regenerative periodontal therapy. J Periodontol 2009; 80: 48–55. doi: https:// doi. org/ 10. 1902/ jop. 2009. 080289 3.

41. Wenzel A (1998) Digital radiography and caries diagnosis. DentomaxillofacRadiol 27:3–11. 2. Salem, Walid. (2017). Role of CBCT in dental caries detection; a systematic review.. Oral Researc& Reviews. 1.

42. Ma, RH, Ge, ZP, Li, G. Detection accuracy of root fractures in cone-beam computed tomography images: a systematic review and meta-analysis. *International Endodontic Journal*, 49, 646– 654, 2016.

43. Talwar S, Utneja S, Nawal RR, Kaushik A, Srivastava D, Oberoy SS. Role of cone-beam computed tomography in diagnosis of vertical root fractures: a systematic review and meta-analysis. Journal of Endodontics. 2016 Jan 1;42(1):12-24.

44. Yi J, Sun Y, Yu L, Li C, Li X, Zhao Z. Cone-beam computed tomography versus periapical radiograph for diagnosing external rootresorption: a systematic review and meta-analysis. Angle Orthod. 2017;2:328 –37

45. Johan Hartshorne; Essential guidelines for using cone beam computed tomography (CBCT) in implant dentistry. Part 2: Clinical considerations, INTERNATIONAL DENTISTRY – AFRICAN EDITION VOL. 8, NO. 4

46. Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral surgery, oral medicine, oral pathology and oral radiology. 2012 Jun 1;113(6):817-26.

47. Matzen LH, Wenzel A. Efficacy of CBCT for assessment of impacted mandibular third molars: a review–based on a hierarchical model of evidence. Dentomaxillofacial Radiology. 2014 Oct 7;44(1):20140189.

48. Nayak DS, Raghavan SA, Birur P, Gurudath S, Keerthi G. Determination of Proximity of Mandibular Third Molar to Mandibular Canal Using Panoramic Radiography and Cone-beam Computed Tomography. J Indian Acad Oral Med Radiol 2017;29:273-7.

49. Palomo L, Palomo JM. Cone beam CT for diagnosis and treatment planning in trauma cases. Dental Clinics. 2009 Oct 1;53(4):717-27.

50. Shintaku WH, Venturin JS, Azevedo B, Noujeim M. Applications of cone-beam computed tomography in fractures of the maxillofacial complex. Dental traumatology. 2009 Aug;25(4):358-66.

51. Bozdemir E, Gormez O, Yıldırım D, Erik AA. Paranasal sinus pathoses on cone beam computed tomography. Journal of Istanbul University Faculty of Dentistry. 2016;50(1):27.

52. Linz, C. et al. Performance of cone beam computed tomography in comparison to conventional imaging techniques for the detection of bone invasion in oral cancer International Journal of Oral and Maxillofacial Surgery, Volume 44, Issue 1, 8 - 15

53. Hakim SG, Wieker H, Trenkle T, Sieg P, Konitzer J, Holl-Ulrich K, Jacobsen HC. Imaging of mandible invasion by oral squamous cell carcinoma using computed tomography, cone-beam computed tomography and bone scintigraphy with SPECT. Clinical oral investigations. 2014 Apr 1;18(3):961-7.

54. Larheim TA, Abrahamsson AK, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. Dentomaxillofacial Radiology. 2014 Dec 10;44(1):20140235.

55. Krishnamoorthy B, Mamatha NS, Kumar VA. TMJ imaging by CBCT: Current scenario. Annals of maxillofacial surgery. 2013 Jan;3(1):80.

56. Diane J. Flint, Regina Cassian Ruiz Velasco. Cone-Beam Computed Tomography (CBCT) Applications in Dentistry Airway Analyses. Dental care.com

57. Zinsly SD, Moraes LC, Moura PD, Ursi W. Assessment of pharyngeal airway space using cone-beam computed tomography. Dental Press Journal of Orthodontics. 2010 Oct;15(5):150-8.

58. Sujatha S, Rizwana Azmi S, Yashodha Devi BK, Shwetha V, Pavan Kumar T. CBCT-The Newfangled in Forensic Radiology. Journal of Dental and Orofacial Research. 2017;13(2):47-55.

59. Dhillon JK, Kalra G. Cone beam computed tomography: An innovative tool in pediatric dentistry. Journal of Pediatric Dentistry. 2013 May 1;1(2):27.

60. Wallace MJ, Kuo MD, Glaiberman C, Binkert CA, Orth RC, Soulez G (June 2008). "Threedimensional C-arm cone-beam CT: applications in the interventional suite". Journal of Vascular and Interventional Radiology. 19 (6): 799–813. doi:10.1016/j.jvir.2008.02.018. PMID 18503893.

61. Rehani, Madan & Gupta, Rajiv & Bartling, Soenke & C Sharp, G & Pauwels, Ruben & Berris, Theocharis & M Boone, J. (2015). ICRP Publication 129: Radiological Protection in Cone Beam Computed Tomography (CBCT). Annals of the ICRP. 44. 7-127. 10.1177/0146645315575485.

62. Brown J, Jacobs R, Levring Jäghagen E, Lindh C, Baksi G, Schulze D, Schulze R. Basic training requirements for the use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology. Dentomaxillofacial Radiology. 2013 Nov 22;43(1):20130291.

63. Carter L, Farman AG, Geist J, Scarfe WC, Angelopoulos C, Nair MK, Hildebolt CF, Tyndall D, Shrout M. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2008 Oct 1;106(4):561-2.

64. Scarfe WC. Incidental findings on cone beam computed tomographic images: a Pandora's box?. Oral surgery, oral medicine, oral pathology and oral radiology. 2014 May 1;117(5):537-40

65. WC Scarfe, Z Li, W Aboelmaaty,SA Scott, AG Farman, Maxillofacial cone beam computed tomography: essence elements and steps to interpretation, Australian Dental Journal 2012; 57:(1 Suppl): 46–60.

66. Miles DA, Danforth RA. A clinician's guide to understanding cone beam volumetric imaging. Special Issue. Academy of Dental Therapeutics and Stomatology, PennWell Publications; 2007. p. 1–13. Available at: www.ineedce.com.

67. Mah P, Reeves TE, McDavid WD. Deriving Hounsfield units using grey levels in cone beam computed tomography. Dento-maxillofac Radiol 2010;39:323–335.

68. Use of cone-beam computed tomography in endodontics Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics, Volume 111, Issue 2, 234 - 237

69. Pauwels R, Jacobs R, Bosmans H, Schulze R. Future prospects for dental cone beam CT imaging. *Imaging Med* 2012; 4: 551–63. doi: 10.2217/IIM.12.45

70. Miles DA. Cone Beam Computed Tomography: From Capture to Reporting, An Issue of Dental Clinics of North America, E-book. Elsevier Health Sciences; 2014 Sep 8.

71. European Society of Radiology (ESR. What the radiologist should know about artificial intelligence–an ESR white paper. Insights into imaging. 2019 Dec 1;10(1):44.

72. Yaji A. Artificial Intelligence in Dento-Maxillofacial Radiology. Acta Scientific Dental Sciences. 2019;3:116-21.