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Radiation Dose, Risks and Protection in CBCT – A Literature Review

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Abstract **Review Article**

Cone beam computed tomography imaging in orthodontics has its advantages and disadvantages. The choice to use cone beam computed tomography imaging is made after weighing the risks and the necessity of this choice of imaging for the patient. Quantifying the radiation dose and evaluating its side effects continues to be reevaluated over the time. Reducing the radiation dose to as low as possible to get the required results has been of utmost importance. Protection to both the clinicians and technicians on basis of regular exposure has guidelines issued. Protection to patients is also given equal importance.
Keywords: Radiation Dose Cone beam tomography.

INTRODUCTION

Accurate diagnosis is the key factor for deciding treatment strategies and managing the treatment goals. In orthodontics a variety of imaging modalities are used as supplements and adjuncts for accurate diagnosis. Also, it is only through these imaging techniques, a clinically not so evident pathology or a variance in dentition or bone structure makes its self pronounced. Imaging modalities available are of both the categories- those which use ionising radiation and those which don't. The techniques that primarily use ionising radiation of what everdoses, carry a definite risk of health hazards for both the patient and the clinician or staff who conducts the procedure of imaging. Imaging techniques with no risk are those thatdo not using ionizing radiation, namely, magneticresonance imaging (MRI) and ultrasonography. Among the ones that carry the risk of use of radiation, falls one of the most advanced imaging modalities of today, CBCT. Of particular use in orthodontics, maxillofacial CBCT has revolutionised imaging and hence the diagnosis and sequentially the treatment planning. Though popular, CBCT is not extensively used as the protols for safety call for judicious and limited usage, owing to the risks that comes along with the radiation. This review article tries to put forth a varitety of risks involved, radiation doses and the protection needed when maxillofacial CBCT is used.

RADIATION DOSE IN CBCT

Exposure is the simplest measure of radiation dose. Avariety of radiation detection devices, including ionizationchambers, radiosensitive films, thermo or opticallight-stimulated luminescent dosemeters, and metal oxidesemiconductorfield-effect transistor devices may be usedto measure ionization caused by radiation [1].

The effective exposure dose for a patient from a CBCT machine has been reported to range from 45 microsievert (lSv) to 650 lSv. The reported doses for an analog full mouth series and an analog panoramic radiograph are 150 lSv [1] and 54 lSv [2], respectively.

In 2003, Mah *et al*. reported only a 20% reduction in the total radiation dose associated with cone beam CT compared with conventional CT [3]. However, Schulze *et al*. subsequently reported that 3D volumetric imagesobtained with cone beam technology involved up to four timesless radiation than conventional CT.

The radiation dose in CBCT has been extensivelyreported, using a variety of CBCT models, dosequantities, and measurement methodologies. Acommon conclusion from these studies is thatthere is a wide range in patient dose in CBCT, correspondingto the range of exposure parametersused in clinical practice. In terms of FOV size, - small (~2 teeth), intermediate.

(e.g., single or both jaws), and large (maxillofacial) FOVs are used in CBCT [5]. In addition, tubevoltage for clinical scans ranges between 70 and120 kV, whereas mAs usually range between 20and 150 mAs. As a result, while CBCT doses arehigher than those of intraoral and cephalometricradiography, the low end of the CBCT dose rangeoverlaps with the range found in panoramic radiography,while the high end of the range overlapswith that of CT [6-9].

While many studies have been conducted on the risks involved in CBCT imaging and have controversial results, the use of any radiographic imaging technique, including CBCT, demands that [10, 11] :

- Any healthcare worker prescribing and/or operating radiographic equipment is aware of the effects of ionizing radiation and knowledgeable of potential radiation risks for specific procedures.
- Justification. Each radiographic examination is justified clinically, based principally on the
- Individual patient's presentation including considerations of the chief complaint, medical and dental history, and assessment of the physical status as determined with a thorough clinical examination and an evaluation of treatment goals.
- An appropriate imaging modality is chosen based on selection criteria.
- Optimization. Principles and evidence-based procedures are incorporated into clinical practice that minimizes patient radiation exposure while optimizing maximal diagnostic benefit.
- Healthcare workers are aware of their legal responsibilities when operating CBCT equipment and interpreting images and complies with all government and third party payer regulations.

The extension of the principles of "justification" and "dose optimization" such that total exposure is "as low as reasonably/diagnostically achievable" (ALARA/ALADA) (NCRP [12] 1990, 2003, 2017; ICRP 2007 [13]) to CBCT imaging is supported by the various national and international authoritative agencies. (American Dental Association Council on Scientific Affairs 2012; European Commission 2012).

Risks involved in the use of cbct

All forms of ionizing radiation, including X-rays, have the potential to cause cellular and tissuedamage. The type and extent of damage dependon many factors, including [15]:

1. The type of radiation
2. The amount or dose of radiation
3. The size of the beam
4. The radio-sensitivity of the tissues irradiated
5. How the radiation is delivered (dose rate, fractionation)
6. Sex and age of the patient
7. The adequacy of the repair mechanisms of the organism.

Some consequences of radiation, such as carcinogenesis, are thought to require the interaction ofradiation with other initiators and/or promotersfor cancer to occur. There may be a long latentperiod between the time the radiation injury occursand the time the signs or symptoms are observable.For many cancers, the latent period may be 20–30years, making it difficult to determine the cause forany specific case of cancer. This latency also maymake it easier to dismiss the idea that radiationexposure to the head during a childhood orthodonticexamination might be the cause of the cancer. Much of the radiation damage to cells and tissuesis a direct effect of X-ray energy on the cells, leadingto ionization of molecules, along with the disruptionof molecular bonds and the reformation ofthose bonds that often does not occur correctly.Radiation also may cause effects indirectly by ionizingother molecules in the tissue (e.g., water), leading to the production of free radicals, whichthen can interact with adjacent molecules toproduce damage. Most of the radiation effectsoccur as a result of damage to the DNA that, depending on the specific injury, may lead to celldeath, heritable mutations, or carcinogenesis.

Despite its limitations and uncertainties, the linear no threshold (LNT) model applies to the estimation of cancer risk from CBCT and predict that risk increases linearly with dose. This risk can vary considerably between CBCT units and high- and low dose exposure protocols. Furthermore, smaller patients (e.g., females and children) will receive a higher radiation dose at a given tube output [16]. Risk also varies with age and gender. Combining all factors, there canbe a 35-fold difference between the highest and lowest risk for a particular patient sample [17]. The average risk for a CBCT scan can be almost 4 times lower for patients over 60 years than for children younger than 12, with the risk for females 40%, on average, higher than for males [17]. Therefore, low-dose protocols should be used when scanning children in particular, adapting the tube output to the size of the patient.

Protection

Protection of workers and public is covered by the principle of application of Dose Limits of the ICRP, which states that:

"… The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission [18]".

Dose limits to workers have been proposed by the ICRP, and are usually implemented in national and regional legislation unaltered. Current limits adhere to ICRP Publication 103 (ICRP 2007), except for the eye lens for which a lower dose limit for occupational exposure was proposed in 2012

TYPE OF LIMIT	OCCUPATIONAL	PUBLIC
Annual effective dose	20 mSv	1 mSv
Annual equivalent dose to :		
Eye lens	20 mSv	15 mSv
Skin	500 mSv	50 mSv
Hands & feet	500 mSv	

Dose limits for occupational and public exposure, according to ICRP Publication 103 (ICRP 2007) and ICRP's statement on tissue reactions (ICRP 2012).

According to Sedentex CT guidelines, the prescriber, the clinics where the exam is taken and the medical physics expert share the responsibility over a radiographic exam. All professionals involved with CBCT, including the prescriber, should receive theoretical and practical training that includes the technical procedure of image acquisition, radiation dose, radiation protection and tomographic reading [19].

The reduction of radiation dose to workersand public can be achieved by adhering to the followinggeneral principles:

- Distance: According to the inverse square law, the intensity of X-rays decreases proportionallyto the square of the distance to the source.
- Shielding: The use of shielding inside wallsand windows can absorb a large amount of scattered and leaked radiation. High-densitymetals (typically lead and leaded glass) areoften used, although equivalent thickness of concrete or other materials can be considered, especially in low-dose environments. Inspecial circumstances in which a worker orother individual (e.g., parent) is required to bein the room with the patient during the exposure, personal shielding such as lead apronsand collars should be used.
- Time: The time in which a worker is exposedshould be limited as much as possible usingrotation schedules. For example, if a clinicinvolves radiographic equipment with a highand low amount of scattered radiation, workers should is shifted between equipment rather than having the same worker operate inthe high-scatter environment at all times.

There are numerous methods to reduce the radiationexposure to patients when CBCT imaging is used.The simplest is to reduce the field of view (FOV) ofthe CBCT unit to cover a specific region of interest bycollimating the x-ray beam and therefore limiting thearea of exposure. Exposure can also be minimised bythe adjustment of exposure settings (kVp and mA), and a reduction in the number of basis projectionimages. Avoiding regions of high relative radiationrisk (e.g. eyes and thyroid gland) can also reduce therisk to patients. The use of patient protective shieldingsuch as lead torso aprons and thyroid shields.is recommended, when possible, to minimize exposure to radiosensitive organs outside the field of view [20].

CONCLUSION

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. Overall, irrespective of the patient's age, it isimportant to weigh the risks of radiation exposureagainst the expected clinical benefits of imaging, given the possible sequelae of exposure to radiation. Knowledgeof radiation exposure and risks should be usedto make informed decisions on when CBCT couldprove to be beneficial for extracting additionaldiagnostic information and/or providing optimaltreatment to the patient.Once a decision is made that a CBCT scanwill be beneficial for a specific patient, the clinicianthen should select the imaging parameters thatwill provide the needed diagnostic information for the lowest possible dose compatible with theimaging task. When installing a CBCT unit in a hospital and clinic, proper consideration should be given to the layout of the room and the need for shielding to protect workers and public

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