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Review Article

Radiation safety standards during 3D CBCT imaging: A review in dentistry

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ABSTRACT

The development of cone-beam computed tomography (CBCT) technology altered the practise of oral and maxillofacial radiology. When compared to medical computed tomography, CBCT was quickly adopted in dentistry settings due to its small size, relatively reduced cost, and decreased ionising radiation exposure. CBCT referrals are still being made incorrectly due to a lack of sufficient education among dentists and specialists. Furthermore, in order to get high-quality pictures, operators may raise the radiation dose, exposing the patient to unnecessary hazards. The objective of this review is to give an insight into 3D imaging with CBCT technology and a prudent radiation monitoring during CBCT for the benefit of both patients and dentists.

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1. Introduction

Cone-beam computed tomography (CBCT) is typically prescribed for evaluating abnormalities particularly in maxillofacial region. CBCT exposes patients to less radiation than traditional CT. Three-dimensional imaging (3D) has emerged to satisfy the demands of improved technology in patient treatment while also being responsible for the emergence of novel treatment strategies, given the limits of 2D imaging (superimpositions, distortions etc.)

CBCT has a broad range of applications and implications in dentistry, making it an essential clairvoyance. But as every coin has two sides to it, CBCT too has its own drawbacks. From its very introduction in the early twentieth century, the number of CBCT equipment at dental institutes, private dental clinics, and radiology centres have increased dramatically. Several old CBCT machines utilized image intensifiers with a wide field of view (FOV). As a result, these machines exposed patients to a higher radiation dose than contemporary CBCT devices but still a lower dose than traditional multislice CT.[1] According to the data of a 2009 comprehensive study, the most prevalent uses of dental CBCT are for maxillofacial surgery (41%), dentoalveolar pathology (29%), and orthodontics (16%), and implantology (13%).[2]

2. Discussion

Because CBCT is a crucial component of dentistry, the question of whether the "as low as reasonably achievable" (ALARA) approach can still be used for CBCT prescription arises. ALARA has been revised throughout time to "as low as diagnostically acceptable" (ALADA) approach, which aids doctors in selecting the optimal field of view (FOV) based on the region of interest (ROI).[1] Although the risk of dento-maxillofacial imaging is minimal for an individual, when amplified by the vast number of patients who undergo diagnostic imaging, the radiation exposure becomes a

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substantial public health concern.[3]

CBCT was developed to substitute medical CT for the craniofacial region and to reduce the patient's overall radiation dose. Unfortunately, because of lack of stringent rules and general misconception of the role of CBCT in dentistry, it has become an alternative to conventional radiography, such as those for periapical, bitewing, and panoramic radiographs.[4] Over more than a century, radiographic imaging has been one of the most extensively used investigative procedures. While radiographs give useful information, the radiation dose poses long-term radiation concerns.[5]

Latest studies have proven that X-ray radiation from diagnostic imaging of the craniofacial region increases the risk of cancer. In a recent study on CBCT dosimetry by Ludlow et al, Qu et al, Hirsch et al using various CBCT machines from various manufacturers and different FOV settings, it was discovered that increasing the FOV height draws new and potentially radiosensitive tissues into the area of direct exposure, whereas increasing the width of the beam merely increases the dose to tissues already being exposed.[3]

Ludlow et al used a radiation analogue dosimeter (RANDO) phantom with commercially manufactured TLD 100 TLD chips to examine dose and risks in oral diagnostic imaging, with an increased emphasis on dosimetry of CBCT. The Chips were placed in 24 various positions to illustrate the location of weighted tissues in the maxillofacial and neck region that may be heavily exposed during maxillofacial imaging.[6] In panoramic charge-coupled devices, the effective dose observed was 16.1 μSv, 5.6 μSv in postero-anterior cephalometric photo-stimulable phosphor (PSP), 5.1 μSv in lateral cephalometric PSP, 68 μSv in New Tom 3G-Large FOV, and 569 μSv in CB Mercuray-"Facial" FOV.[7]

In a study by Qu et al., the mean tissue-absorbed dose was calculated for a New/Tom 9000 CBCT scanner using TLD chips in a phantom. Scans were performed in a dual manner i.e, with and without thyroid collars. The effective organ dose and total effective dose were derived using the 2007 ICRP recommendations.It was concluded that the effective organ doses to the thyroid and esophagus were 31.0 μSv and 2.4 μSv respectively, during the collarless CBCT scan. When the thyroid collars were worn loosely around the neck, no effective organ dose reduction was observed.The effective organ dosage for the thyroid gland and oesophagus were dropped to 15.9 Sv (48.7 percent reduction) and 1.4 Sv (41.7 percent reduction), respectively, when a single thyroid collar was worn snugly in front of the neck. When CBCT scanning was done with two collars, one firmly on the front and the other on the rear of the neck, comparable organ dose reduction (46.5 percent and 41.7 percent) was attained. Moreover, there were no significant changes in total effective doses when the scans with collars and without the collars around the neck were compared.[8]

Hirsch et al. calculated the doses taken up in 16 sensitive organ locations by using an anthropomorphic phantom packed with TLDs. The two CBCT units were utilized with distinct FOVs: three-dimensional Accuitomo with two protocols (anterior 464 cm scan and anterior 666 cm scan) and three-dimensional Veraviewepocs with three protocols (anterior 464 cm scan, anterior 864 cm scan, and panoramic + anterior 464 cm scan). The ICRP 2005 guidelines were used to compute equivalent and effective doses. He discovered that the three-dimensional Accuitomo 464 cm (20.02) had the lowest effective dose and the three-dimensional Accuitomo 666 cm (43.27μSv) had the highest. For Veraviewepocs three-dimensional, the effective dose was 39.92 μSvfor the 864 cm scan and 30.92 μSv for the 464 cm scan and 29.78 μSv for the panoramic + 464 cm scan protocol.[9]

The effective doses for E1990 and E2007 were as follows: full FOV of the head, 47 μSv and 78 μSv; 13 cm scan of the jaws, 44 μSv and 77 μSv; 6 cm standard mandible, 35 μSv and 58 μSv; 6 cm high-resolution mandible, 69 μSv and 113 μSv; 6 cm high-resolution maxilla, 35 μSv and 60 μSv. Conclusions: Using the ICRP 2007 tissue weighting factors, the effective dose of the new generation of CBCT scanner is lower than that of the original generation machine for an equivalent FOV.[5]

Given that CBCT examinations routinely utilize higher doses of radiation than traditional diagnostic radiography, it becomes even more critical that everyone using this technology knows the rational explanation of patient exposure, optimizing the patient dose, and radiation safety practises of staff. It is crucial for oral and maxillofacial radiologists to understand and explain to their patients and referring practitioners the dose and related risk of specific investigations.[10] Healthcare professionals must balance the potential usefulness of diagnostic information with the expense and hazard of the imaging system. The radiation exposures from full-field-of-view dental CBCT scans have been calculated to be 4-42 times that of a panoramic radiograph.[11]

Using the protocol described, measurements of effective dose have been made on a variety of x-ray units. When considering dose characteristics in CBCT examinations, the size of the field of view (FOV) is a significant factor. It is instructive to evaluate the effect of this factor as an ordinal variable by grouping FOVs into three sizes.[7] A somewhat arbitrary division of those sizes might be: small (less than 10 cm) detector-useful for dento-alveolar imaging, medium (10-15 cm) detector-adequate for mandibulo-maxillary imaging, and large (greater than 15 cm) detector-is desirable for maxillofacial diagnosis.

A comparison of effective doses calculated using 1990 and 2007 weights is seen. When comparing the magnitude of change by size of FOV it can be seen that, on average, an increase of 71% was seen with large FOV examinations, 124% with medium FOV examinations, and 181% with small FOV examinations. Looking at the effect of changes in effective dose calculation it is clear that the estimation of risk has increased for all FOVs following the ICRP 2007 recommendations.

We being responsible professionals should educate our colleagues about the risk differences between "diagnostically acceptable" and "absolutely magnificent" photos. This has led to the introduction of the ALADA concept, "as low as diagnostically acceptable," which is a revised version of ALARA, "as low as reasonably achievable." To get a diagnostically acceptable and interpretable image, the proper FOV, mAs, and kVp settings, as well as high definition/high-resolution parameters, should be determined based on the scan purpose.[12,13]

A growing number of CBCT scans are being managed to perform on children and adolescents, which is alarming because youngsters are more vulnerable to radiation, notably in the thyroid gland, gonads, and breast tissue, and the cancer risk per Sievert increases with age.[1]

3. Conclusion

The advantages of radiographic imaging should be balanced against their disadvantages. Lately, CBCT has taken the world by storm in a variety of dental specialties. It is obvious that radiation doses administered to patients are determined not only by exposure parameters but also by FOV in CT and CBCT.[14–20] It is fundamental to educate both dental practitioners and patients about the use of this progressive technology with its little consequence on general well being.

4. Source of Funding

None.

5. Conflict of Interest

None.

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