When a Patient Asks About CBCT Radiation Risk

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INTRODUCTION

Dental CBCT units first became available in the United States in the early 2000s and have been growing steadily in popularity as CBCT capabilities increase and prices decrease. The capabilities of Dental CBCT have proved extremely useful in planning implants, endodontics, orthodontic treatment, and much more. There are many clear benefits of using CBCT, but many patients fear the increased exposure that these scans produce.

A common challenge we have heard from many dental professionals is how to weigh the tradeoffs that come with these advanced capabilities vs. the increased radiation exposure that comes with them. While the principles of ALARA (As Low As Reasonably Achievable) are of the highest concern, practicing it requires an understanding of the basics of radiation. Our goal with this paper is to provide an overview of some of the key variables that affect exposure that comes from a Dental CBCT and how these compare to some common imaging modalities. Specifically, we hope to arm the doctor with some concepts that may be useful in explaining the pros and cons to their patient in a way that instills confidence in the resulting treatment plan.

CBCT

Cone Beam Computed Tomography

ALARA

As Low As Reasonably Achievable

How is exposure measured?

Radiation is a very complex phenomenon, so it's important to recognize that all radiation is not created equal. The impact of radiation exposure on human health is affected not only by the type of radiation that is absorbed (high-energy vs. low-energy), but also by which organs absorb it. Because of this, dosage is most commonly measured and discussed in one of three ways:

Gy (Grays)

One Joule of radiation deposited in 1 kilogram of matter

Sv (Sievert)

Biological effect of 1 Gray

1. **Absorbed Dose** is more easily measured, but less directly correlated with health risk. It simply describes the average energy of ionizing radiation deposited into a unit of mass regardless of what type of radiation it consists of or what part of the body absorbs it. This is typically measured in grays (Gy), which represent one Joule of radiation deposited in 1 kilogram of tissue, (J/kg).

2. **Equivalent Dose** accounts for the type of radiation (e.g. Alpha particles vs. Gamma rays) that is absorbed. This is measured in sieverts (Sv), or more commonly in microsieverts (μSv), which are one millionth (1/1,000,000) of a sievert.

μSv (microsieverts) *One millionth of a Sievert*

3. Effective Dose is the most common way to express dosage in medical radiography because it correlates most closely with health risk. It is similar to equivalent dose except that it also accounts for the type of tissue being exposed. Various organs are assigned weighting factors by the ICRP, and the effective dose uses these factors to express the potential damage as if the radiation was being exposed to the entire body. Effective dose is also most commonly measured in microsieverts (μSv).

What variables affect radiation?

When evaluating the radiation exposure of a certain procedure or device, there are many variables that can affect the resulting dosage. Some of the key factors include: x-ray generator (sometimes informally called the "tube head") voltage, generator current, exposure time, distance from source, and beam size.

PEAK KILOVOLTS (kVp)

Determines how fast electrons travel from the cathode to the anode & therefore how much energy the x-ray photons possess when they travel out of the tubehead.

MILLIAMPS (mA)

Determines rate at which electrons are emitted from the tubehead.

$$Intensity \propto \frac{1}{Distance^2}$$

The generator voltage, expressed in peak kilovolts (kVp), determines how energetic the electrons are that travel from the cathode to the anode and therefore how much energy the x-ray photons possess when they travel out of the generator.

The generator current, expressed in milliamps (mA) determines the rate at which electrons are emitted from the generator.

Time is simply the duration of the exposure. Both time and mA are both directly correlated: doubling either time or mA and holding all else equal will result in double the dosage. A 10 second scan at 3 mA will produce the same amount of dosage as a 3 second scan at 10 mA (again holding all else equal).

Distance is simply how far the source is from the patient. The intensity of the x-ray is proportional to the inverse square of the distance, which means that if a source is moved to a distance that is twice as far from the patient, the dosage will be 75% less (one quarter of the original value).

Lastly, **beam shape** has a large effect on the dosage. Collimation is the use of a device to narrow the beam emitted from an x-ray source. Lead collimators absorb stray radiation to create precise beams that only hit the areas of interest and reduce unneeded radiation exposure to parts of the body that are not being imaged. If a collimater opening is larger, as it is in a dental CBCT as compared to a panoramic, the dosage increases. Similarly, if the beam is exposing a wider section of the anatomy, as it does with larger field of view CBCT's, this will also increase dosage absorbed.

How does CBCT compare to other tools?

For most panoramic units and Dental CBCT units, the range of kVp, mA, and exposure time is not dramatically different and for machines that have both capabilities, it can be exactly the same. A study comparing many Dental CBCTs was published in the European Journal of Radiology in 2010. According to this study, scans from most large field of view (FOV) machines ranged from 83 μSv to194 μSv. Scans from small FOV machines ranged from 19 μSv to 40 μSv.

According to the paper “Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation” published in The Journal of the American Dental Association in 2008, a typical panoramic x-ray can result in a effective dose of about 14 μSv. A typical full mouth series (FMX) that includes 18 intraoral radiographs results in about 171 μSv of effective dose.

ALARA Recommendations

As Low As Reasonably Achievable (ALARA) is the concept of minimizing the patient exposure while still being able to acquire useful images.   Doctors will make every effort to limit the beam to their area of interest only.

In 2010 The American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiologists released a joint position statement for selecting Endodontic patients for CBCT scans. Their position states that CBCT should not be used routinely and patients should only be selected if clear symptoms are present for conditions that traditional diagnostic imaging would not help identify.

For those endodontic cases that require a CBCT, they recommend a small Field of View CBCT as preferred over large-volume CBCT because a small FOV offers:

1. Increased spatial resolution to improve the accuracy of endodontic-specific tasks such as visualization of small features including accessory canals, root fractures, apical deltas, calcifications, etc.
2. The highest possible spatial resolution that provides a diagnostically acceptable signal-to-noise ratio for the task at hand,
3. Decreased radiation exposure to the patient,
4. Time savings due to smaller volume to be interpreted.

In 2012, The American Academy of Oral and Maxillofacial Radiology also issued a position on use of CBCT in dental implantology. The AAOMR recommends that cross-sectional imaging be used for the assessment of all dental implant sites and that CBCT is the imaging method of choice for gaining this information.

Finally, to help patients put the dosage numbers into perspective, is may be worth comparing these to some effective doses of common phenomenon from everyday life. According to the United Nations Scientific Committee on the Effects of Atomic Radiation, the average worldwide background radiation is about 2400μSv per year or approximately 6.7 μSv a day. A cross-country flight is about 30 μSv. Using these estimates, we can do a rough comparison with every day experiences (CBCT values are the median of the ranges above).

Study	Effective Dose (μSv)	Days of Background Radiation	Cross Country Flights
FMX (round cone)	171	25	6
Panoramic X-Ray	14	2	< 1
Small FOV Dental CBCT	29	4	1
Large FOV Dental CBCT	139	21	5

Overall, CBCT offers fantastic diagnostic capabilities when compared with traditional radiographic tools. Clearly, doctors will be practicing ALARA by carefully weighing whether the higher radiation risk outweighs the risk to the patient of a suboptimal treatment plan. However, it is also useful to consider how to best explain these tradeoffs to a patient so that the patient has confidence in the resulting plan.