Technical Report

# Minimal radiation exposure with cone-beam computed tomography

## Radiation safety: state-of-the-art diagnostic radiology

**An important issue in diagnostic radiology is the intensity of the effective dose because, irrespective of the technology being used in individual cases, the benefits and risks of taking an X-ray need to be assessed. Whereas modern 3D imaging systems, such as computer tomography (CT) or cone-beam computed tomography (CBCT), undoubtedly have brought significant advantages to dental diagnostics, they are attended by a higher radiation dose compared to 2D X-ray technology. So, what options do users of 3D scans have when striving for maximum diagnostic safety and minimal radiation dose at one and the same time?**

Dentists can only treat their patients successfully if they have complete information. In addition to the communication with patients and clinical examinations, modern diagnostic radiology is frequently used to gain a full picture. Whenever 2D imaging reaches a limit, such modern 3D technologies as computer tomography (CT) or, compared to CT, low-radiation cone-beam computed tomography (CBCT) supplement the representation of anatomical structures in all three spatial levels. Currently, above all CBCT is gaining a foothold in more and more dental disciplines. The recommended indications primarily are defined by the guideline of the German Association of Dental, Oral and Maxillofacial Medicine (DGZMK) [1]. Contrary to CT, the radiation source in CBCT does not circle around the examination area several times but rotates around the area only once. Besides "pure" CBCT units, combination units are highly interesting options for dental practices because they can also make panoramic scans (e.g. 3D Veraviewepocs R100, Morita). Software applications are available for evaluating and processing the images: sliced views are displayed in all levels and can be processed (e.g. i-Dixel und i-Dixel Web, Morita). Nonetheless, the indication has to justify the taking of an X-ray, in other words, the benefit of the X-ray diagnostics has to outweigh the radiation risk.

**Natural vs. artificial sources of radiation**

According to information published by the German Federal Office for Radiation Protection (BfS), the average natural radiation exposure is about 2.1 mSv per year; in addition to this there is the average share of artificial radiation exposure of about 1.8 mSv. Most of artificial radiation can be traced back to medical diagnostic procedures and treatments. Although dental and maxillofacial diagnostics come to 37 % in this connection, the total effective dose that can be attributed to dental procedures comes to only 0.2 % [2]. As a rule, everyone is exposed to a certain radiation (dose), for example, the natural radiation in the soil (terrestrial radiation) or radiation from space (cosmic rays). The extent of natural radiation increases at high altitudes: According to figures compiled by the BfS a flight from Frankfurt to Rome adds up to <0.01 mSv (comparable X-ray examination: X-ray of a tooth) and from Frankfurt to San Francisco to about 0.05 – 0.11 mSv (comparable X-ray examination: limbs < 0.01 – 0.1 mSv) [3]. As far as artificial sources of radiation in medical procedures are concerned, radiation protection and dose minimization are the prime considerations, also in dentistry. This is true also with regard to three-dimensional imaging techniques such as CT and CBCT, which are more dose intensive than 2D imaging procedures.

**Minimizing the effective dose with digital X-rays**

The benefits and risks, e.g. radiation exposure, have to be considered carefully before deciding to carry out an X-ray examination. In the course of time, guidelines were drawn up, e.g. the German X-ray Ordinance (RoeV), recommendations of the German Association of Dental, Oral and Maxillofacial Medicine (DGZMK) or, on an international level, the guidelines of ICRP (International Commission on Radiological Protection). Pursuant to Section 23 of the German X-ray Ordinance, "each individual medical radiation exposure needs to be justified, i.e. the individual benefit must outweigh the associated radiation risk. This includes that the doctor shall also consider procedures associated with low or no radiation exposure"" [4]. The progress made in X-ray technology has led to a significant reduction in the effective dose in past decades – in particular, digital systems, compared to conventional X-ray technology using X-ray film, have contributed to reducing radiation (digital sensors require a shorter exposure time). As a rule, CBCT exhibits a reduced radiation exposure compared to CT [5]. However, the effective dose ranges of individual CBCT devices differ so widely that they actually cannot be classified as one single class of devices [6]. Nonetheless, the collimation of the useful X-ray beam (= limiting the field of view (FOV) to the region of interest) applies for CBCT because it has been proven that radiation exposure is reduced when the X-ray beam is collimated to the required field size while other parameters remain unchanged [7].

**Efforts of manufacturers to reduce radiation exposure with CBCT**

The radiation dose with CBCT essentially depends on the construction of the device as well as technical parameters and the FOV that is selected. The objective is to keep the region of interest as small as possible and as large as necessary. Manufacturers of X-ray units have taken different approaches in order to satisfy this demand. One innovative approach is to adjust the FOV to the natural dental arch in the form of a “Reuleaux triangle” (FOV R100, with the “R” standing for Reuleaux). This option is available in the combination unit Veraviewepocs 3D R100 (Morita). By excluding the areas lying outside the region of interest, the radiated volume is kept as small and the effective dose as low as possible (Fig. 1). In the molar area, R100 corresponds to an FOV of Ø 100 × 80mm; however, as regards the dose, it is less than with volumes having a height of 50mm. With the help of a panorama scout, the section for which a CBCT scan is required can be determined prior to the X-ray procedure. In addition, a dose reduction program is available which minimizes the effective dose by up to 40% compared to the standard program. So, for example, as compared to the standard mode, the scan of soft tissue (e.g. sinus membrane in the upper jaw) is sharper than ever before with minimal artifacts. Cephalometric X-rays can be taken in just 4.9 seconds – thanks to this high speed, Veraviewepocs guarantees high-quality scans any time. The shorter scan time is particularly helpful with children, since movement artifacts are significantly reduced [8].

Another example is the availability of a wide range of FOVs to delimit the region of interest as far as possible. The CBCT unit 3D Accuitomo 170 (Morita), for example, offers nine different scan volumes (e.g. Ø 40 × 40mm, Ø 80 × 80mm or Ø 170 × 120mm). In addition, a comparison of values based on measurements taken by the manufacturer with the CTD Iw value for scans of the head and throat or neck regions shows that the effective dose of an 18-second standard scan comes to less than 1/7 of the corresponding value of a conventional CT scan [9]. Moreover, in the so-called high-speed mode, a 360° scan can be taken in just 10.5s and a 180° scan in just 5.4s. This reduces the effective dose and movement artifacts even more. And to round things off, the systems mentioned above are compatible with the DICOM standard for exchanging and archiving image data. In connection with digital systems, attention must be given to the fact that the team will have to familiarize itself with several software programs when devices made by different manufacturers are purchased. Modern software applications should be clearly structured and it should be possible to work with them intuitively (e.g. i-Dixel and i-Dixel Web, Morita) so that correct CBCT scans can be made after just a few times. Nonetheless, besides special technical skills, experience gained with numerous patients is required to attain an intuitive diagnostic sureness with respect to the evaluation and diagnosis of CBCT.

**Conclusion**

In the meantime, CBCT has gained a foothold as a useful X-ray procedure in many dental disciplines. Nevertheless, as with every form of X-ray technology, weighing the benefits and risks takes utmost priority when deciding to take an X-ray. Besides radiation protection, users, professional associations and manufacturers still are concentrating on minimizing the effective dose. As far as the technical side is concerned, many innovative approaches and further developments are helping to minimize the radiation exposure. In the final analysis the objective is: maximum number of patients with the highest possible diagnostic safety at the same time.

**Literature**

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**Figures**

Fig. 1: Reuleaux field of view R100: Greater congruence with the natural dental arch minimizes the dose