Press Report

Digital cone-beam computed tomography

Minimum dose for maximum safety

Modern imaging processes such as cone-beam computed tomography (CBCT) also represent the basis for successful therapy in dentistry. In everyday practice, the decision for or against a CBCT unit is frequently reached depending on acquisition costs, space requirements and operation – the most relevant aspects for dental applications, however, are primarily the field of view (FOV) and radiation exposure. Alongside radiation protection measures, reducing this exposure is one of the primary objectives of modern x-ray diagnostics, because the dosage to which patients are exposed during dental/medical procedures makes up the largest part of artificial radiation exposure. An objective of dosage minimization is to be seen, among others, in keeping the FOV as small as possible and as large as necessary – and in achieving an optimum in diagnosis and dosage safety.

One name is inseparable from modern-day imaging processes: Wilhelm Conrad Röntgen. The rays he discovered (“x-rays”) made it possible to do what was unimaginable in his days – for the first time it was possible to “see” inside a body without having to carry out a surgical procedure. This signaled a revolution in medical diagnostics and the following years saw the development of film strip technology, image intensifier equipment and contrast media with which even the smallest blood vessels could be shown in great detail. Finally, computer tomography (CT) made it possible to reproduce anatomical structures without any dimensional loss, whilst the relatively young and – in comparison to CT – radiation-reduced digital cone-beam computed tomography (CBCT) [1] is currently tapping into more and more areas of application in dentistry. The damaging effects of x-rays, however, also became apparent in the course of their discovery which is why to this day the benefits of an x-ray examination are weighed up against the risks from radiation.

CBCT – The justifying indication also applies here

As with any form of x-ray imaging, the ALARA principle (As Low As Reasonably Achievable) also applies for CBCT. The application always takes place with the smallest possible radiation dosage having the appropriate informative value according to the respective indication. The X-Ray Ordinance applicable here in Germany (Röntgenverordnung / RöV) lists three radiation principles with regard to the production of images: Justification (Section 2a), Dosage Limitation (Section 2b) and the Avoidance of Unnecessary Radiation Exposure and Dosage Reduction (Section 2c). Justified indication is regulated in greater detail in Section 23 (1) and calls for “the determination that the health benefit of the application for the patient outweighs the radiation risk” [2]. In addition, it is also recognized that children and adolescents are subject to a significantly higher risk of subsequent health damage following an exposure to ionizing radiation (such as x-rays) [3] which is why a particularly diligent risk-benefit assessment has to be made in their case – as with expectant mothers. From an international point of view, the ICRP (International Commission on Radiological Protection) provides the practicing dentist with recommendations for the appropriate use of imaging processes. In Germany, guidance in this respect is provided among other things by the current directive of the German Society for Dental, Oral and Orthodontic Medicine (Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde / DGZMK) which also specifies the recommended range of indications [4].

Effective dose as reference value

The term “effective dose” was introduced for comparison of the various radiation exposures. It takes into account the differing sensitivity of organs and tissue with regard to radiation-induced cancer and genetic defects (unit: Sievert or Sv). Fundamentally, everyone is subject to a certain level of radiation (dose). This occurs naturally in the ground (terrestrial radiation) and from space (cosmic radiation). The extent of natural radiation exposure therefore increases at greater height – according to Zurich University it amounts to 0.012 mSv at 11,000 m above sea level. On a ten-hour flight at this height, a person is therefore subject to a radiation dose of 0.12 mSv [5] which – according to the figures of the Federal Office for Radiation Protection (Bundesamtes für Strahlenschutz / BfS) – is approximately the same as for an x-ray of the cervical spine or taking about ten x-ray images of teeth [6]. According to the BfS, natural radiation exposure is around 2.1 mSv per annum, with artificial radiation at about 1.8 mSv. The majority of artificial radiation comes from medical diagnosis and therapy processes. Whilst the percentage of dental and temporomandibular diagnostics is 37 % in this respect, it is only 0.2 % with regard to the overall effective radiation dose [7]. Consequently, the highest civilisatory radiation exposure by a long way comes from the medical sector which is why maximum attention needs to be paid to radiation protection and exposure minimization – in dental medicine as well.

Radiation protection first and foremost

Whilst personnel operating x-ray equipment are protected by lead-glass goggles, thyroid protectors, lead-rubber aprons and additional lead covers, parts of a patient's body not being examined are subject to radiation in addition to those areas being x-rayed. For this reason, protecting patients with lead aprons and covers shielding reproductive organs is not only absolutely vital in this case, it also has to be carried out expertly in a professional manner. The necessity and benefits of the planned CBCT have to be explained to the patient – as well as the corresponding risks. Information about the endeavor to achieve the greatest possible radiation protection and the smallest possible radiation exposure, as well as the informative value of a CBCT scan, can be beneficial. Keeping a record in an x-ray passport is a sensible means of self-control for patients; although this is voluntary, it is highly recommended (dental practices and clinics that carry out x-ray examinations must keep x-ray passports available and offer them to their patients in accordance with Section 28 of the German X-Ray Act (RöV – Röntgenverordnung). The benefits are obvious; in addition, the practitioner avoids unnecessary x-ray examinations.

Dosage-minimizing unit functions

Equipment manufacturers are also working continuously on further reducing the dosage for CBCT examinations and providing various functions for the reduction of radiation. As CBCT is a relatively new technology, the volume of available data with a high level of evidence on radiation exposure tends to be rather small. Nevertheless, it can be said without doubt that the radiation dosage depends on the type of instrument and the technical parameters (among others: tube voltage/current), as well as the selected FOV. The more FOVs that are available, the better the operator is able to localize the area being examined and minimize radiation exposure – modern systems offer a wide range of FOVs (e.g. 3D Accuitomo 170, Morita). With the 3D Accuitomo 170, for example, practitioners have at their disposal nine different scanning volumes ranging from Ø 40 x 40 mm through Ø 80 x 80 mm to Ø 170 x 120 mm. A comparison of values on the basis of existing measurements by the manufacturer Morita with the CTDIw value for scanning head and throat areas shows that the radiation exposure for an 18 second scan in standard mode amounts to less than 1/7 of the corresponding value with a conventional CT scan [8]. In high-speed mode, the operator can carry out a 360° scan in only 10.5 sec. and a 180° scan in just 5.4 sec., representing a further reduction in radiation exposure and motion artefacts.

Another approach is to adjust the FOV to the region of interest, e.g. in the form of an innovative "Reuleux triangle", to increase congruency with the natural dental arch (FOV R100, with the "R" standing for Reuleaux). With the Veraviewepocs 3D R100 (3D, panorama and cephalometric scans, Morita), this available field of view keeps the irradiated area as small as possible and radiation exposure at a low level (fig. 1). In figures, the R100 field of view corresponds to Ø 100 × 80 mm in the molar region – with regard to dosage, however, to Ø 80 × 80 mm. With this system, a panorama scout is also available for dosage minimization; this determines the necessary section for a CBCT scan before x-raying, as well as a dosage reduction program which minimizes the effective dose by up to 40 % in comparison to a standard program. By turning the C-arm through 180°, the patient is only subjected to x-rays for a relatively short period with a radiation exposure time of 9.4 sec. whilst the effective dosage only corresponds to only 1/8 of the radiation exposure of conventional panorama x-ray units with film processing [9] and the CTDIw value only represents 1/5 in comparison to conventional CT units [10] (values based upon measurements by the manufacturer). Irrespective of the make of unit, all quality assurance steps relating to both technology and procedure must be taken during application – and, naturally, the x-ray equipment should also be in a technically perfect condition. In addition, all measures to reduce dosage are advisable insofar as there is no impairment to the relevant image quality for the examination.

Conclusion

In the meantime, CBCT has established itself as advanced x-ray diagnostics in dentistry and particularly in cases “where above all reduced radiation exposure is concerned whilst consciously accepting the resulting system-immanent changes to image parameters, preference should be given to CBCT” [4]. The focus of everyone involved continues to be on endeavoring to keep exposure as low as possible and minimizing it even further. After all, despite the radiation risk, the benefits of CBCT are undisputed for a widespread dental medicine indication range – and these benefits are continuously spreading into further areas of use.

Literature

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[8] Comparison of the CTDIw value pursuant to IEC 60601-2-44 with the scanning settings and the CTDIw reference value specified in Appendix A to ICRP Publication 87 for face, maxillary and paranasal sinuses.

[9] The effective dose was calculated on the basis of ICRP 2007 for scanning the mandibular molar region with the values recommended by Morita (80 kv, 3 mA, 9.4 sec., ø 40 x H 40 mm); Veraviewepocs Film (75 kV, 8 mA, 16 sec.) was used for comparison. http://www.jmoritaeurope.de/3d-imaging/img/veraviewepocs3d_de.pdf

[10] CTDIw value was calculated according to IEC 60601-2-44 m with the values recommended by Morita. The CTDIw value for maxillofacial and paranasal sinuses in ICRP Pub. 87 Appendix A (scan for ø 40 x H 40 mm) was used for comparison. http://www.jmoritaeurope.de/3d-imaging/img/veraviewepocs3d_de.pdf

Illustrations

Fig. 1: Minimizes dosage by convering the natural form of the dental arch: FOV R100 (Morita)