Original research article

ANALYSIS OF THE DOSE AREA PRODUCT (DAP) SIZE IN DENTAL PATIENTS UNDERGOING CBCT AND OPG EXAMINATIONS

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Abstract

Despite relatively low radiation doses, dental diagnostic methods pose a particular health risk to patients. The results of recent developments are the so-called cone-beam computed tomography (CBCT) devices; the main principle of which is to create a 3D image using a cone beam of radiation. The most significant benefit is the possibility of increasing the anatomical accuracy of the position of the imaged location in the patient's body. The presented study aimed to analyse the data, especially the Dose Area Product (DAP) size in patients undergoing dental examinations using CBCT and panoramic X-ray equipment. A comparison of CBCT examinations with the prevailing panoramic dental examinations (OPG) indicated an increased risk of radiation exposure during CBCT examinations. Therefore, it is necessary to consistently consider the indications for CBCT examinations in connection with their increasing number.

Keywords: *CBCT; DAP; Dentistry; Medical radiation; OPG; Patient*

INTRODUCTION

In medicine, the current requirement is to obtain satisfactory diagnostic information with the lowest possible dose of ionising radiation for the patient. Therefore, it is necessary to deepen the knowledge of prescribing physicians about the size of the applied radiation dose, which does not exceed the prescribed diagnostic reference levels (Súkupová, 2018).

The first cone-beam computed tomography was installed in the angiography department at the Mayo Clinic in Rochester, New York in 1982 (Higgins, 2021).

According to available data, 208 workplaces in the Slovak Republic (Public Health Authority of the Slovak Republic, 2025) use registered cone-beam dental devices.

The number of CBCT procedures has been increasing recently, and this is closely related to higher radiation exposure for patients (Chart 1) (Public Health Authority of the Slovak Republic, 2025). Dentistry diagnostic methods that use new ionising radiation technologies have recently increased. Hence it is necessary to pay attention to protection patients from radiation, especially paediatric patients (IAEA, 2024; Rozylo-Kalinowska, 2020).

The main issue of debate on the use of CBCT is the correlation between the benefits and potential risks for the patient in everyday dentistry. To optimise imaging conditions, it is vital to understand the relationship between the diagnostic output of the X-ray imaging process and its physical and technical characteristics. A significant benefit of CBCT is the possibility of increasing the anatomical accuracy of the location of the imaged site in the patient's body. Cone-beam computed tomography is currently used in medical fields such as radiotherapy, classical and interventional radiology, and dentistry (Horner et al., 2015; IAEA, 2022).

Cone-beam computed tomography is a 3D radiological examination that gives the doctor a spatial overview of the patient's teeth. The CBCT imaging method represents a significant advance in dental diagnostics, mainly because radiation exposure is lower than in classical computed tomography (CT). CT works on the principle of fan-shaped radiation. In contrast, CBCT works on the principle of a cone beam of radiation (Fig. 1). As a result, the patient's radiation exposure is reduced when using CBCT compared to CT. However, it is strongly recommended that the use of CBCT be limited to cases where it is clinically necessary. This limitation is fundamental in paediatric patients, who are more sensitive to the effects of ionising radiation. In orthodontics, where the examination is often indicated as early as 6 years of age, it is imperative to consider the risk-benefit ratio for the patient (Ismayılov and Özgür, 2023). CBCT should only be indicated if other, less invasive methods cannot obtain the desired diagnostic information. CBCT examinations are mainly used in implantology and orthodontics.

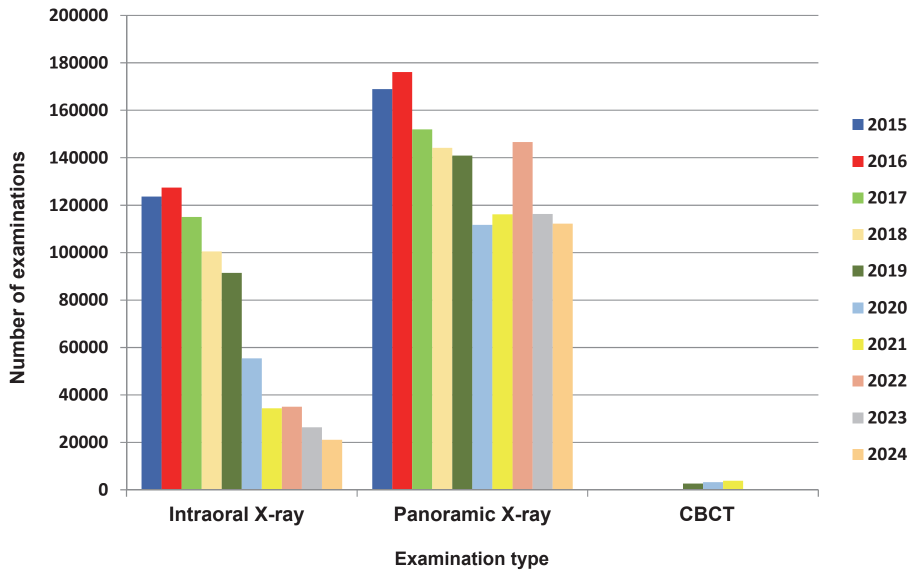

Chart 1 – Number of dental X-ray examinations for the period 2015–2024 in the Slovak Republic (Public Health Authority of the Slovak Republic, 2025)

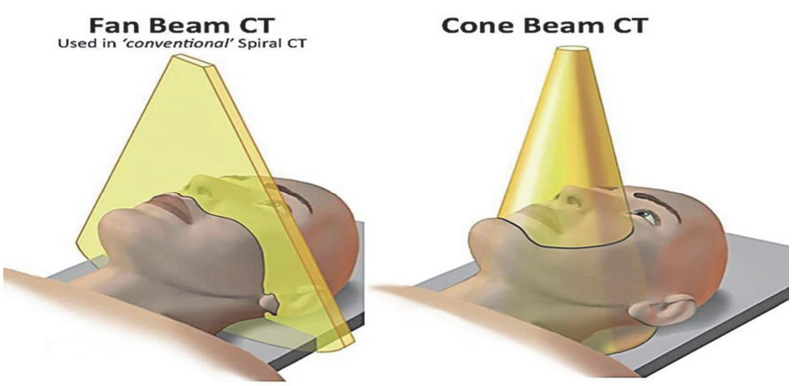

Fig. 1 – The principle of 3D image creation in dentistry (MacDonald-Jankowski and Orpe, 2006)

Imaging techniques in dentistry

Orthopantomogram (panoramic image – OPG)

Dental X-ray examination can be divided into extraoral or intraoral. Extraoral images are mainly intended for dental surgery. Extraoral orthopantomographic images show dentitions, alveolar processes of the jaw and canines, temporomandibular joints, nasal cavity, and maxillary sinuses in one examination (Fig. 2) (Kovaľová et al., 2005; Lorenzoni et al., 2012).

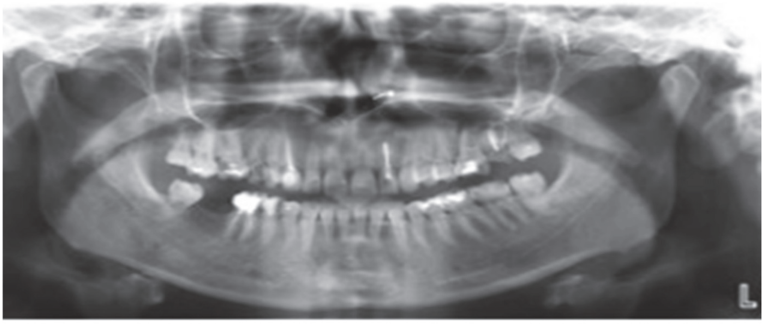

Fig. 2 – Orthopantomogram (Kovaľová et al., 2005)

CBCT imaging

CBCT imaging is quite often used in orthodontics. The most important information obtained is mainly data on the position of the teeth (Higgins, 2021). Three-dimensional imaging of the teeth allows a view of the scanned area from all sides (Fig. 3). Using 3D scans, orthodontists determine morphology, inclination, dystopia, root position, impacted or supernumerary teeth, and oral cavity morphology (Ghanbarnezhad Farshi et al., 2019; Lin, 2019; Rozylo-Kalinowska, 2020).

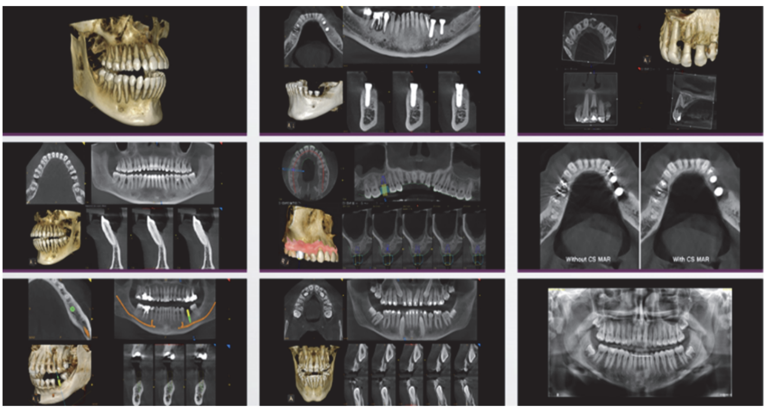

Fig. 3 – Viewing the entire dentition using a CBCT image
(John G. Plummer & Associates Dental Surgeons, 2024)

In general, the smaller the scan volume, the higher the spatial resolution of the image and the lower the required radiation dose and reconstruction time. Therefore, small field of view sizes (FOV) are recommended for endodontic diagnosis and treatment, which reduce the dose per volume of tissue exposed to radiation, and also reduce the scattering of X-ray radiation, which favourably affects the quality of the images (Brasil et al., 2023; IAEA, 2024; Súkupová, 2018).

MATERIALS AND METHODS

The study compared the doses of patients who underwent examination with a panoramic X-ray machine and a CBCT machine at workplaces A, B, C, D, and E. In the first part of the study, data from 357 patients undergoing CBCT examinations in 2021–2023 at workplaces A–E were evaluated, where patient age and gender, exposure time, mA, dose size in DAP, FOV, and diagnosis were monitored.

104 patients who underwent CBCT examination and 104 patients undergoing OPG examination in 2021–2023 were randomly selected at site E. Gender, age, field size, diagnosis, and area dose were monitored and evaluated.

The age limit of the patients in the study was not specified, but it was necessary to include both paediatric and adult patients. We were also interested in the youngest and oldest patients who underwent OPG and CBCT examination (16–90 years).

The study used a SIRONA Axeos CBCT device at workstation E (Fig. 4).

Fig. 4 – CBCT device used during the study (EUDENT, 2025)

Anonymized data were used in the study, which were processed into tables and graphs using Microsoft Office Excel 2010. The results were evaluated using IBM SPSS 28 statistical software. The non-parametric Mann–Whitney *U* test was used to compare the values of continuous random variables in two samples. To compare the values of continuous random variables in more than two samples, the non-parametric Kruskal–Wallis test was used. The reason for using non-parametric tests was the rejection of the hypothesis of normal distribution of the compared continuous random variables. To determine the relationship between two discrete variables, we used the chi-square test in contingency tables.

RESULTS

Age analysis of patients examined with CBCT and OPG device

The average age of patients undergoing CBCT was 45 years, and in patients undergoing OPG it was 40 years. The average age of patients undergoing OPG and CBCT was 35–45 years (Charts 2 and 3).

Analysis of patients undergoing CBCT-OPG examination by gender

Our results show that more men (55%) than women (45%) undergo diagnostic dental examinations. 46% of women and 54% of men underwent CBCT examinations. 44% of

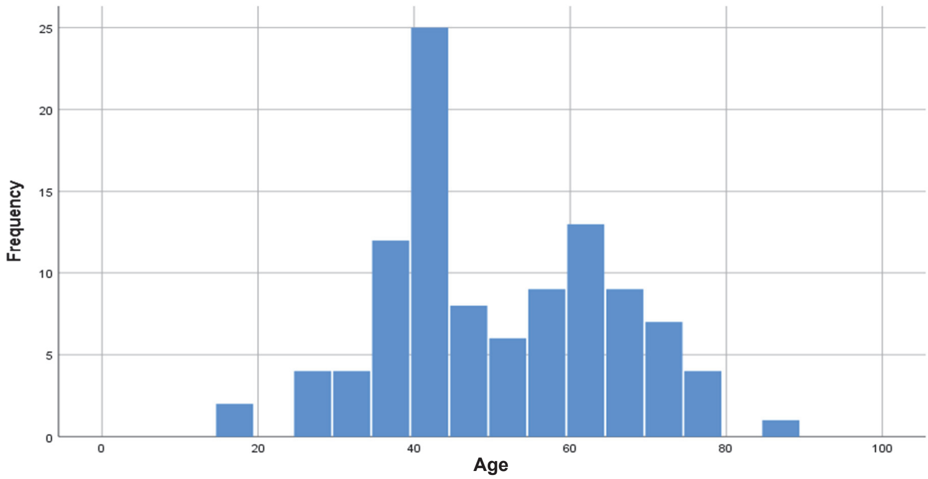

Chart 2 – Age distribution of patients undergoing CBCT examination

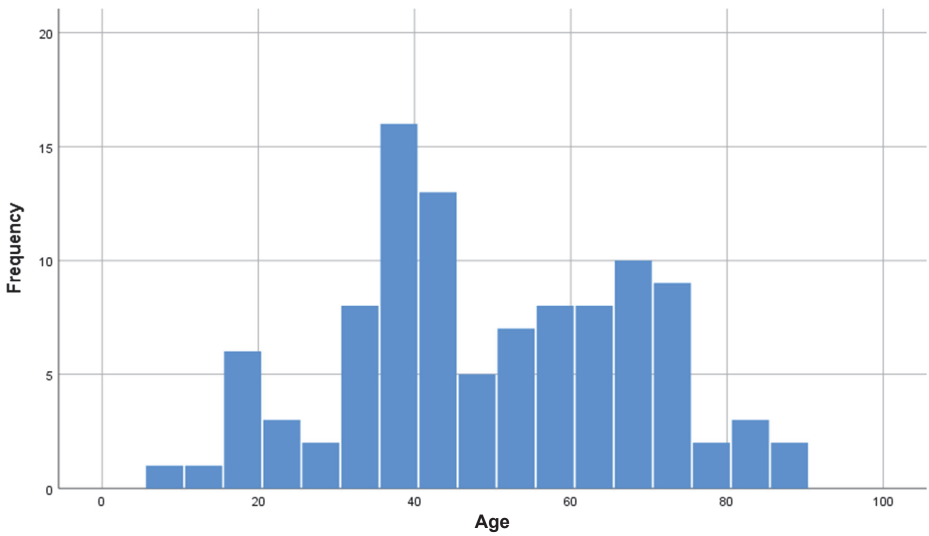

Chart 3 – Age distribution of patients undergoing OPG examination

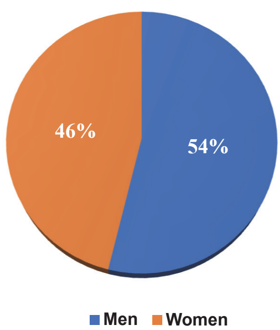

Chart 4 – Distribution of patients undergoing CBCT examination by gender

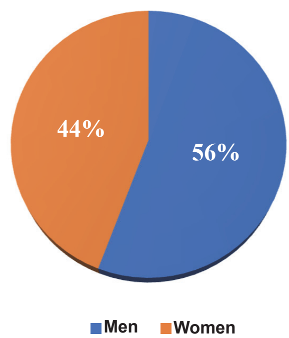

Chart 5 – Distribution of patients undergoing OPG examination by gender

female and 56% of male patients underwent OPG examinations (Charts 4 and 5).

Field of View (FOV) analysis in patients undergoing CBCT examination

The results show that the most frequently used FOV for CBCT (35%) was 8 × 8 cm. The second most frequently used field size was 11 × 10 cm. The 5 × 5 cm FOV, which is used when exposing a small field – one tooth, was used in only 11%, which suggests that in most cases, CBCT is used in dentistry to display a larger volume (Chart 6).

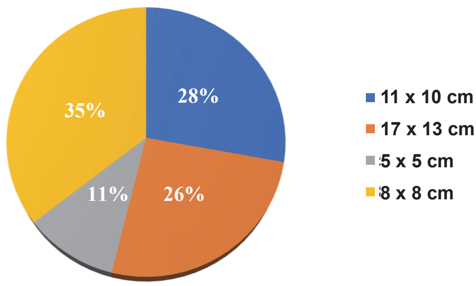

Chart 6 – Analysis of patients by FOV size (cm × cm) in CBCT examinations

The most frequently used diagnoses (Dg.) that were given in the indication for CBCT examination (National Health Information Centre, © 2024):

- K02.8 – other tooth decay
- K02.9 – tooth decay, unspecified
- K05.2 – acute periodontitis
- K05.3 – chronic periodontitis
- K08.1 – tooth loss caused by injury, extraction, or local periodontal disease

The most frequently used diagnosis for CBCT examination was Dg. K02.9 – dental caries, unspecified, in 44%. The least commonly used diagnosis for CBCT examination

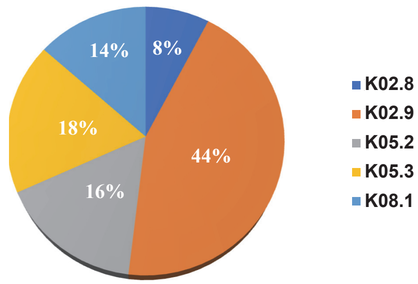

Chart 7 – Analysis of the most frequently used diagnoses in patients undergoing CBCT examination

was K02.8 – other dental caries, in 8% of examinations. The other diagnoses, K05.2, K05.3, and K08.1, were used for examination indications in 14 –18% of the cases (Chart 7).

Dose Area Product (DAP) analysis applied to patients during CBCT and OPG examinations

We analysed the Dose Area Product (DAP) applied during CBCT and OPG examinations. According to the results, we concluded that patients undergoing OPG examinations have a significantly lower radiation dose than patients undergoing CBCT examinations. The DAP for CBCT examinations ranged from 150–1,250 mGy·cm², and for OPG examinations, it was 30–135 mGy·cm². The maximum DAP for CBCT examinations was 1,250 mGy·cm², representing an increase in dose of approximately 10 times compared to the maximum Dose Area Product for OPG examinations of 104 mGy·cm² (Charts 8, 9, 10).

Despite this, it is necessary to state that the examination must be indicated if CBCT is justified and when the diagnostic benefit outweighs the possible risk of a higher dose of ionising radiation. CBCT examination is more informative than OPG, especially in orthodontics and tooth extraction.

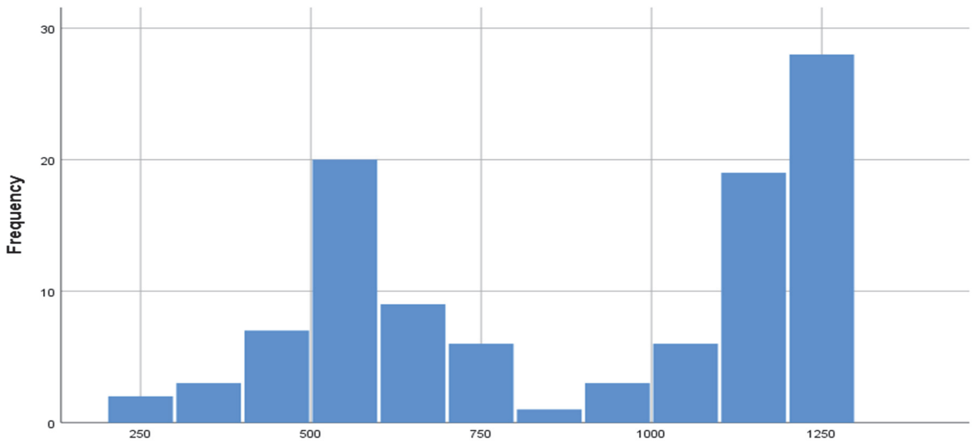

Chart 8 – Dose Area Product to patients (mGy·cm²) during CBCT examinations

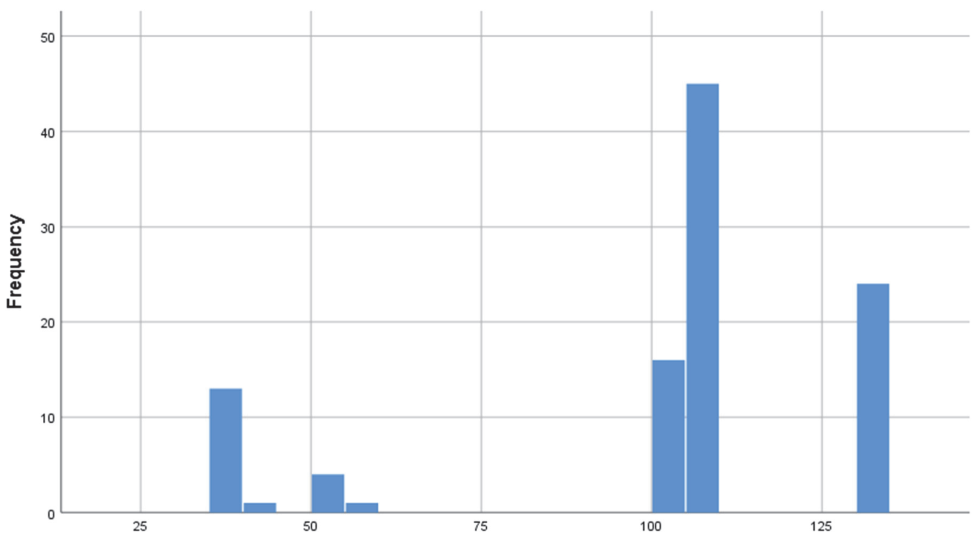

Chart 9 – Dose Area Product to patients (mGy·cm²) during OPG examination

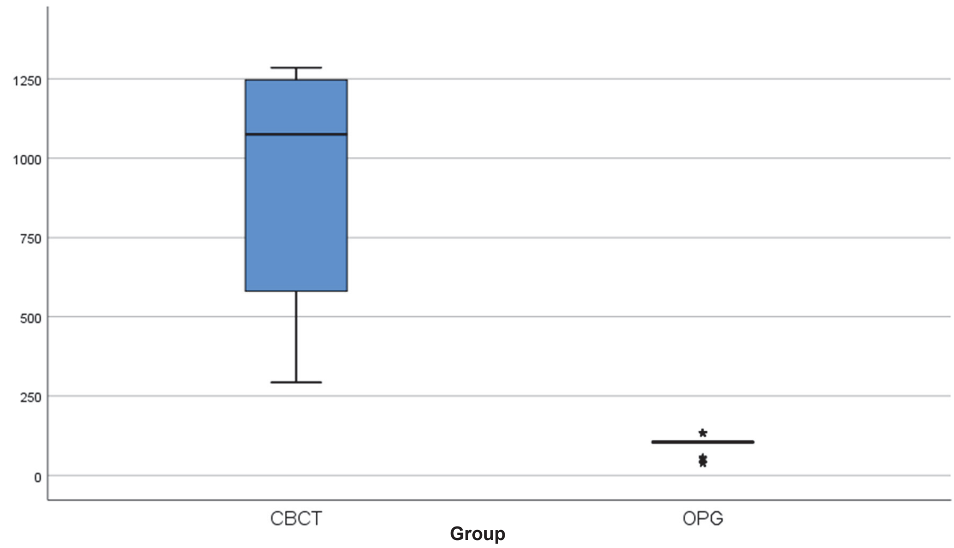

Chart 10 – Analysis of Dose Area Product (mGy·cm²) during CBCT and OPG examinations

DISCUSSION

While CBCT imaging involves higher radiation doses than traditional dental radiology, recent advances in CBCT technology are leading to developing new protocols with lower doses that will minimise patient exposure to ionising radiation (Baccher et al., 2024). CBCT has transformed the use of imaging and diagnosis in dentistry and offers avant-garde 3D visualisation capabilities that revolutionise treatment planning and patient care across various dental specialities. While CBCT presents significant advantages in diagnostic accuracy and treatment planning, carefully considering its limitations is essential, particularly regarding radiation safety and appropriate use (Baccher et al., 2024).

The potential for using CBCT with lower doses will bring several advantages compared to conventional 3D radiological methods. The main advantage will be lower radiation exposure, which is especially important for paediatric patients and those who require repeated examinations. The advantage of CBCT is that it provides high-quality and accurate 3D images of the oral and maxillofacial region. This is especially important for planning orthodontic and maxillofacial surgery in periodontology, planning furcation defects in clinical and surgical endodontics, and evaluating the temporomandibular joint. CBCT is faster and more efficient than traditional radiological methods, reducing the time required for scanning and analysing the imaged area (Distefano et al., 2023).

A study conducted by Brasil et al. (2023) in Belgium, in which 5,163 CBCT examinations from 2023 were analysed, entitled Monitoring cone-beam CT radiation dose levels in a University Hospital, found that effective doses ranged from 35.1 to 300 µSv and 9.26–117 µSv during the examination using the 3D Accuitomo 170 and Newtom VGI EVO devices. In general, adequate doses decreased with increasing age and decreasing FOV size. Adequate dose levels varied significantly depending on the ionising radiation source and irradiation parameters. The study pointed to the more frequent use of medium and large FOVs. As a justification, the study states that about 2/3 of the indications are surgery-oriented and anatomical reference data are often required for virtual preoperative patient planning. However, it should be noted that the study sample also included maxillofacial surgery patients undergoing complex maxillofacial procedures related to oncology and congenital deformities. In conclusion, the study by Brasil et al. (2023) indicated that radiation doses showed a decreasing trend, which was related to patient age and reduced FOV size (IAEA, 2024).

A study titled *Comparing Radiation Doses in CBCT and Medical CT Imaging for Dental Applications* (Khader et al., 2024), which aimed to compare the radiation doses associated with CBCT and computed tomography in dental examinations, found that CBCT imaging results in significantly lower radiation doses compared to CT, which is essential for clinical practice and patient safety. Dentists must carefully consider the choice of imaging modality to optimise diagnostic quality while minimising radiation risk. CBCT can be a valuable tool in this regard, offering a radiation dose reduction of approximately 29.6% compared to CT, as demonstrated in this study. Dentists should use CBCT to increase patient safety without compromising diagnostic quality (Khader et al., 2024).

A published study by Kaaber et al. (2024) stated that low-dose protocols result from reducing the exposure parameters kV, mA, resolution (through increased voxel size), exposure time and scan trajectory. The use of low-dose CBCT in implantology should be considered a matter of compliance with the main principle of ALARA, as the balance of radiation dose and diagnostic image quality is essential and beneficial for both patients and dentists. Based on the results of this systematic review, the balance between dose and quality should be discussed. This is a significant topic due to the different exposure factors selected by the healthcare professional, which play an essential role in determining the scanning dose and image quality while maintaining an adequate diagnostic response for the referring physician (IAEA, 2022).

Dental diagnostic radiological procedures form a specific part of diagnostic radiology. Due to the increased use of dental CBCT devices in healthcare providers' clinics, it is necessary to increase control over the performance of these procedures to prevent unjustified or duplicate procedures (especially in examinations of paediatric patients), and thereby reduce the radiation burden on the population.

Although the use of dental diagnostic procedures results in only minimal radiation exposure to the patient, it was necessary, from the perspective of radiation protection of patients and medical personnel, to verify the extent of the contribution to the radiation exposure of the population in the Slovak Republic from this source of medical radiation.

CBCT and OPG represent different imaging modalities with different clinical indications and benefits. CBCT offers a more detailed display of three-dimensional structures and is especially suitable for more complex diagnostic and therapeutic procedures. OPG, on the other hand, is the first-choice method for basic dental diagnostics with minimal radiation exposure for the patient. The key factor in choosing the appropriate method remains the principle of justification, i.e., an activity leading to radiation may only be performed if it is justified. A justified activity leads to radiation in which the expected benefit to the individual or to society outweighs the health harm that this activity may cause (Act No. 87/2018 Coll.).

CONCLUSION

The results of our CBCT analysis, as well as those of the OPG examinations, show that the maximum size of the dose area product for CBCT examinations in dental radiology is approximately ten times higher than the maximum dose area product for OPG examinations.

In the future, it will be necessary to pay special attention to those areas of medical exposure in the Slovak Republic, where there are still no relevant data on the number of CBCT examinations in individual age categories. A serious analysis of the size of the irradiation between the child and the adult population is lacking, and until now, there has been no available procedure for optimization of ionizing radiation in children. This can be achieved by establishing suitable national diagnostic reference levels for the most frequent types of dental CBCT examinations.

Ethical aspects and conflict of interest

The authors have no conflict of interest to declare.

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