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DESCRIPTIVE STUDY OF RADIATION DOSE IN CBCT FOR DENTAL APPLICATION

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ABSTRACT

Background: Cone Beam Computed Tomography (CBCT) provides superior 3D imaging for dental diagnosis but involves higher radiation exposure than conventional radiography. Therefore, dose optimization based on the ALARA principle and the establishment of Diagnostic Reference Levels (DRLs) are essential for patient safety and radiation protection. **Purpose:** This study evaluated CBCT exposure parameters and radiation dose variation by FOV to support dose optimization and DRL development. **Methods:** This retrospective descriptive study analyzed CBCT records of adult patients (September 2023–2024). Variables included tube voltage, tube current, exposure time, voxel size, DAP, Effective Dose, and FOV. Data were analyzed using descriptive statistics and FOV-based comparisons with SPSS version 30. **Results:** A total of 50 patients were included (56% female and 44% male) had average exposure parameters of 89.80 kV, 2.87 mA, 15 seconds, and 0.148 mm voxel size. The 8x5 cm FOV (4 patients) produced a DAP of 721.50 $\mu\text{Gy cm}^2$ and an Effective Dose of 70 μSv . The 8x9 cm FOV (46 patients) produced a DAP of 1151.48 $\mu\text{Gy cm}^2$ and an Effective Dose of 72 μSv . The typical dose value (Q2 DAP) was 1179 $\mu\text{Gy cm}^2$. **Conclusion:** Radiation doses in dental CBCT examinations vary depending on the FOV size, with larger FOVs resulting in higher radiation exposure. Selecting the appropriate FOV based on clinical indications, along with dose monitoring and establishing Diagnostic Reference Levels (DRLs), is crucial for optimizing patient safety and radiation protection in dental radiology.

Keywords: Cone Beam Computed Tomography, DRL, Patient Safety, Radiation Protection, TDV

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INTRODUCTION

Cone Beam Computed Tomography (CBCT) has significantly transformed the diagnostic paradigm in dentistry. It is widely applied in dental and maxillofacial imaging for comprehensive diagnostic evaluation, including anatomical assessment, pathology detection, and treatment planning across various clinical contexts.^{1,2} CBCT is an X-ray-based imaging modality that employs a cone-shaped beam to generate three-dimensional (3D) images of the craniofacial structures, especially the teeth and maxillofacial region.^{1,3} Although conventional 2D radiographic techniques (e.g., periapical, panoramic, Waters, and cephalometric imaging) remain useful for specific indications, CBCT provides superior anatomical detail through multiplanar visualization in axial, sagittal, and coronal planes. CBCT offers volumetric imaging with high spatial resolution, enabling detailed visualization of dental anatomy, alveolar bone, and surrounding structures, including tooth roots, the mandibular canal, maxillary sinuses, and temporomandibular joints (TMJ).^{4,5} In addition, comparative studies have also demonstrated that CBCT has greater sensitivity and specificity in detecting periapical lesions than periapical radiographs, particularly in cases involving small lesions or those obscured by adjacent anatomical structures.⁴

Despite the advantages of CBCT, this imaging modality is associated with higher radiation exposure than conventional radiography. Monte Carlo simulation studies have demonstrated that the radiation dose from CBCT

used for temporomandibular joint (TMJ) imaging is higher than panoramic radiography⁵. Other comparative studies have also reported that the effective dose of CBCT ranges from 29 to 674 μSv , depending on usage protocols such as the field of view (FOV) size and exposure parameters. In contrast, the effective dose from panoramic radiographs typically ranges from 4 to 30 μSv . This comparison highlights the importance of radiation dose monitoring and optimization when using CBCT to maintain patient safety^{5,6}.

Existing research findings have revealed that dentists' knowledge and awareness regarding radiation protection remain insufficient. KAP (knowledge, attitude, and practice) studies also indicate that only 58% of dentists consistently assess clinical indications before referring CBCT, highlighting the need for enhanced education on the justification of radiographic examinations^{3,7}. The ALARA (As Low As Reasonably Achievable) principle underpins the effort to minimize radiation dose without compromising diagnostic quality. Continuous monitoring is essential due to the potential for stochastic effects, such as increased cancer risk, particularly among patients undergoing repeated imaging procedures^{6,8}.

Diagnostic Reference Levels (DRL) and Typical Dose Values (TDV) are essential parameters in optimizing radiation protection in medical imaging procedures⁹[16]. These values function as monitoring tools to identify suboptimal practices and to encourage dose optimization without compromising diagnostic image quality^{10,11}. TDV refers to the typical radiation dose or radiopharmaceutical activity determined statistically, often using the median (50th percentile/Q2) of patient dose distributions. TDVs are typically stratified by patient age group, body weight category, and specific imaging modality. Meanwhile, the DRL is a quantitative reference value expressed regarding radiation dose, applied to diagnostic radiology, interventional procedures, and diagnostic nuclear medicine^{12,13}. It evaluates whether radiation doses are within acceptable limits and follow international radiation safety standards or ALARA (As Low As Reasonably Achievable). DRL values vary depending on the type of examination, patient population, and regional practices^{14,15}. Establishing local DRL (DRLs) considers institutional factors such as equipment capabilities, protocol variations, and patient characteristics, making them more clinically relevant and adaptable than international benchmarks^{10,16}.

In Indonesia, the Nuclear Energy Regulatory Agency (BAPETEN) has issued the Indonesian Diagnostic Reference Level (I-DRL) for several imaging modalities, including computed tomography (CT) and conventional radiography. However, dental examinations utilizing Cone Beam Computed Tomography (CBCT) have not yet been included. The lack of local data on dose distribution and exposure parameters in dental CBCT, particularly at the institutional level, represents a significant gap in the development of dose optimization strategies and radiation protection standards. Moreover, variations in field of view (FOV) and technical parameters in clinical practice may further influence radiation dose, yet these factors remain insufficiently documented in the Indonesian context. This study aims to describe the characteristics of exposure parameters and radiation dose values in dental CBCT examinations at Dr. Mohamad Soewandhi Regional General Hospital, Surabaya. The findings are expected to be a preliminary reference for developing institutional-level dose guidelines.

MATERIALS AND METHODS

Material

This study used a computer workstation to access and process digital data, including a patient medical record CBCT data examination report that lists radiation dose values such as milliamperes (mA), kilovolts (kV), voxel size, exposure time (s), field of view (FOV), dose area product (DAP), and effective dose. Microsoft Excel worksheets and SPSS version 30 software were also used to record, tabulate, and analyze the data collected statistically.

Methods

This study employed a retrospective descriptive design using medical records of dental CBCT patients at Dr. Mohamad Soewandhi Regional General Hospital, Surabaya. The data were collected from September 2023 to September 2024, and the study was conducted in March 2025. The sampling technique in this study used the total sampling method, with the inclusion criteria of patients aged 20 to 60 years who had complete data. The CBCT data included scans with varying field of view (FOV) sizes based on clinical requirements. The FOV dimension was documented and analyzed as a factor affecting radiation dose parameters. The exclusion criteria for this study included data that did not include kV, mA, exposure time, DAP, and effective dose values, as well as examinations that were repeated more than once. The variables analyzed included kV, mA, exposure time, voxel size, DAP, effective dose, and field of view (FOV). Data were analyzed using descriptive statistics. Additionally, correlation analysis was performed using the Spearman test, depending on data distribution, to assess the relationship between exposure parameters and radiation dose outputs. All analyses were conducted using SPSS version 30. The results were presented in tabular form and compared with the Indonesian Diagnostic Reference Level (I-DRL) published by BAPETEN as a basis for interpretation and discussion.

RESULTS

Sample Characteristics

Data obtained from Dr. Soewandhie Regional General Hospital Surabaya between September 2023 and September 2024 indicated that 50 patients met the inclusion criteria. All patients underwent dental imaging using Cone Beam Computed Tomography (CBCT) with the Carestream CS 8100 Family CBCT system, aged 20 to 60. Based on gender distribution, 28 patients (56%) were female and 22 (44%) were male. Detailed characteristics of the patient sample are presented in Table 1.

Table 1. Characteristics of The Data Patient			
Sex	Frequency (n)	Percentage (%)	Age Range
Female	28	56	20 – 58
Male	22	44	20 – 60
Total	50	100	

The exposure parameters used in the obtained data are presented in Table 2. The tube voltage in all data averages 89.80 ± 0.20 kV in the 80–90 kV range. The average tube current is 2.87 ± 0.13 mA in the 2–5 mA range. All data were obtained using an exposure time of 15 seconds. The average voxel size (Vox Size) is 0.148 ± 0.0004 mm in the 0.143–0.150 mm range.

Table 2. Exposure Parameters		
Parameter	Mean	Range
Tube Voltage (kV)	89.80 ± 0.20	80 - 90
Tube Current (mA)	2.87 ± 0.13	2 – 5
Exposure Time (s)	15	15
Vox Size (mm)	0.148 ± 0.0004	0.143 – 0.150

Based on the collected data, two Field of View (FOV) sizes were utilized: 8×5 cm and 8×9 cm. The 8×5 cm FOV was applied in 4 patients, resulting in an average Dose Area Product (DAP) of 721.50 ± 72.75 $\mu\text{Gy}\cdot\text{cm}^2$ and an average effective dose of 70 μSv . The 8×9 cm FOV was used in 46 patients, with an average DAP of 1151.48 ± 18.49 $\mu\text{Gy}\cdot\text{cm}^2$ and an average effective dose of 72 μSv . Table 3 presents the distribution of radiation doses according to FOV characteristics.

Table 3. Radiation Dose Distribution by Field of View (FOV) Characteristics

	FOV	Frequency	Mean	Effective Dose (μSv)
Dose Area Product ($\mu\text{Gy}\cdot\text{cm}^2$)	8 x 5	4	721.5 0 $\pm$ 72.75	70
	8 x 9	46	1151. 48 $\pm$ 18.49	72

Table 4 presents a comparison of the Diagnostic Reference Level (DRL) values from this study with those reported in other countries. The second quartile (Q2) value obtained from the Dose Area Product (DAP), or what can be called the typical dose value for dental CBCT examinations, was 1179 $\mu\text{Gy}\cdot\text{cm}^2$ in this study. This value is higher than the Q2 DAP reported in Saudi Arabia of 1000 $\mu\text{Gy}\cdot\text{cm}^2$ ¹⁷ and South Korea of 913.4 $\mu\text{Gy}\cdot\text{cm}^2$ ¹⁸.

Table 4. Comparison Q2 Dose Area Product with Other Countries

Q2 Dose Area Product ($\mu\text{Gy}\cdot\text{cm}^2$)	
This Study	1179
Arab¹⁷	1000
Korea¹⁸	913.4

Table 5 shows the results of Spearman correlation analysis of CBCT exposure parameters and radiation dose. Tube voltage showed a positive correlation with tube current ($\rho = 0.270$), dose-area product (0.202), although the correlation value was low and did not indicate a strong relationship, and a weak negative correlation

with effective dose ($\rho = -0.042$). Tube current had a positive correlation with all parameters, including vox size ($\rho = 0.081$), dose-area product ($\rho = 0.243$), and effective dose ($\rho = 0.201$), but the strength of the relationship remained weak. Voxel size showed a negative correlation with almost all parameters, including tube voltage ($\rho = -0.098$), dose-area product ($\rho = -0.024$), and effective dose ($\rho = -0.044$), except with tube current, which had a weak positive relationship ($\rho = 0.081$). Dose area product had the highest positive correlation with effective dose (0.564), which indicates a fairly strong relationship between the area of exposure and the total effective dose received by the patient.

Table 5. Spearman Correlation Analysis between CBCT Exposure Parameters and Radiation Dose

Tube Voltage (kV)	Tube Voltage (kV)	Tube Current (mA)	Tube Current (mA)	Vox Size (mm)	Vox Size (mm)	Dose Area Product ($\mu\text{Gy}\cdot\text{cm}^2$)	Dose Area Product ($\mu\text{Gy}\cdot\text{cm}^2$)	Effective Dose (μSv)	Effective Dose (μSv)
	0.270		0.081						
	-	0.098							
	0.202	0.243	-	0.024					
	-	0.201	-	0.564					
	0.042		0.044						

DISCUSSION

The results of the Spearman correlation analysis in this study indicate that of the several CBCT exposure parameters analyzed, dose-area product (DAP) had the strongest correlation with effective dose, with a correlation value of 0.564. This finding is consistent with previous research by Pauwels¹⁹ that stated that DAP is an important indicator in estimating the radiation dose received by patients, as it reflects a combination of exposure intensity and the area exposed. This positive correlation indicates that increasing DAP is directly related to increasing effective dose.

Tube voltage and tube current exhibited a weak correlation with effective dose, with correlation coefficients of -0.042 and 0.201 , respectively. This finding indicates that the relationship between exposure parameters and effective dose in this study was limited and may be influenced by other unmeasured factors. Voxel size negatively correlated with almost all dose parameters, including effective dose ($\rho = -0.044$), indicating that larger voxel sizes (lower image resolution) tend to lower radiation doses.

The larger field of view (FOV) of 8×9 cm yielded a higher average Dose Area Product (DAP) value ($1151.48 \pm 18.49 \mu\text{Gy}\cdot\text{cm}^2$) compared to the smaller FOV of 8×5 cm, which produced a DAP ($721.50 \pm 72.75 \mu\text{Gy}\cdot\text{cm}^2$). This findings are consistent with the result reported by Brasil and Dawood's, who observed that DAP values generally increase in proportion to FOV size. The increase in radiation dose associated with a larger FOV is primarily attributed to the need for broader anatomical coverage, which necessitates greater radiation exposure. Consequently, higher exposure settings are required to preserve image quality, which contributes to increased radiation output^{20,21}.

The typical dose value (Q2 DAP) obtained in this study was $1179 \mu\text{Gy}\cdot\text{cm}^2$, which is higher than the values reported in Saudi Arabia ($1000 \mu\text{Gy}\cdot\text{cm}^2$) and South Korea ($913.4 \mu\text{Gy}\cdot\text{cm}^2$). This higher value is consistent with the distribution of FOV sizes in this study, where the majority of examinations used a larger FOV (8×9 cm), which is associated with increased radiation exposure. These results emphasize the importance of optimizing FOV selection and establishing local DRLs.

This study concludes that radiation doses in dental CBCT examinations vary significantly depending on the size of the field of view (FOV), with larger FOVs associated with higher radiation exposure. In clinical practice, the selection of FOV should be tailored to the diagnostic needs, where smaller FOVs are preferred for localized assessments and larger FOVs are reserved for broader anatomical evaluations in the oral and maxillofacial region. The typical dose value (Q2 DAP) observed in this study was $1179 \mu\text{Gy}\cdot\text{cm}^2$, which is higher than those reported in similar studies. These findings highlight the importance of optimizing FOV selection,

implementing local dose monitoring, and establishing institutional Diagnostic Reference Levels (DRLs) to enhance radiation protection and patient safety in dental radiology.

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