

CONE-BEAM COMPUTED TOMOGRAPHY IN DENTISTRY AND
MAXILLOFACIAL IMAGING: CLINICAL APPLICATIONS, RADIATION DOSE,
OPTIMIZATION AND LIMITATIONS: A LITERATURE REVIEW

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Abstract

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Background: Cone-beam computed tomography (CBCT) has become an important three-dimensional imaging modality in dentistry, but radiation exposure, dose variability and appropriate indications remain concerns. To review the clinical applications, diagnostic advantages, radiation dose, dose-optimization strategies and limitations of dental CBCT. **Methods:** A narrative literature review of published studies, guidelines and systematic reviews on dental and maxillofacial CBCT was conducted; dose values

were taken from a published meta-analysis and summarized descriptively. **Results:** CBCT was most useful for implant planning, impacted teeth, endodontic pathology, root resorption, orthodontics, temporomandibular joint assessment and maxillofacial surgery, and its advantage depended on the indication. Reported adult effective doses were 46–1,073 μ Sv (large field of view), 9–560 μ Sv (medium) and 5–652 μ Sv (small), with means of approximately 212, 177 and 84 μ Sv, respectively. Dose varied substantially between units and protocols. Adjusting tube voltage and tube current–exposure time product reduced dose while maintaining acceptable image quality in selected applications, and diagnostic reference levels (DRLs) varied internationally, with few countries having national values. **Conclusion:** CBCT offered important advantages in selected conditions but was associated with variable exposure. Justification, field-of-view limitation, parameter optimization and adoption of DRLs are essential.

Keywords: Cone-Beam Computed Tomography; Dentistry; Radiography, Dental; Maxillofacial Imaging; Radiation Dosage; Diagnostic Imaging

INTRODUCTION

Cone-beam computed tomography (CBCT) has become a key three-dimensional imaging modality in dentomaxillofacial radiology.[1,2] Unlike conventional two-dimensional intraoral and panoramic radiography, which compress three-dimensional anatomy onto a flat image, CBCT provides multiplanar, high-resolution visualization of osseous structures and is increasingly used in implant planning, endodontics, orthodontics, oral surgery, temporomandibular joint (TMJ) assessment and maxillofacial diagnosis.[3,4]

Despite these benefits, concerns about ionizing radiation exposure, image quality, dose variability and appropriate clinical indications remain important.[3,5] Dose varies with the field of view (FOV), exposure parameters, scanner and patient characteristics, and published guidelines stress that each examination must be justified and optimized.[3,6] Dose and dose-optimization data are scattered across many unit-specific studies, and diagnostic reference levels (DRLs) for dental CBCT are still developing internationally.

The aim of this review was to evaluate the clinical applications, diagnostic advantages, radiation dose, dose-optimization strategies and limitations of dental CBCT based on evidence reported in previous literature.

METHODS

Study design

A narrative, literature-based review was conducted. No new primary data were collected from human participants; all numerical findings were taken from previously published literature.

Search strategy

Published literature on dental and maxillofacial CBCT was searched in PubMed/MEDLINE, Scopus and Google Scholar for studies. Search terms combined "cone-beam computed tomography" OR "CBCT" with "dental" OR "dentomaxillofacial" OR "maxillofacial" and with "effective dose", "radiation dose", "diagnostic reference level", "dose optimization", "exposure parameters", "image quality", "clinical indications" and "guidelines". Reference lists of key articles were hand-searched.

Eligibility criteria

Systematic reviews, meta-analyses, clinical guidelines, position statements, dosimetry studies and optimization studies in English addressing dental or maxillofacial CBCT were considered. Case reports, opinion pieces without data, studies of non-dental CT and studies not reporting dose, image quality or clinical application were excluded.

Data Extraction And Synthesis

Information on clinical applications, diagnostic performance, radiation dose, image quality, exposure parameters, dose optimization and radiation-protection practice was extracted and synthesized narratively. Quantitative adult effective doses by FOV were taken from a published meta-analysis[7] and summarized descriptively using tables and figures; no new statistical pooling was performed. Because the source reported ranges and means only, the histogram presented here depicts the overlap of reported ranges and not patient-level distributions.

Ethical Considerations

Ethical approval was not required because this review used only published literature and involved no human participants or patient data.

RESULTS

Clinical applications and diagnostic value

The literature showed that CBCT was particularly useful when conventional two-dimensional imaging was insufficient for diagnosis or treatment planning.[3,5,6] It provided improved three-dimensional visualization and multiplanar assessment compared with conventional radiography, although the size of the diagnostic advantage varied with the clinical indication. The main applications are summarized in Table 1.

Table 1. *Principal clinical applications of dental CBCT reported in the literature*

Application	Principal contribution of CBCT	Comment
Dental implant planning	Bone height, width and density estimation; relation to the inferior alveolar canal and maxillary sinus	Established indication[5]
Impacted teeth	Three-dimensional localization; relation to adjacent roots and canals; resorption	Where 2D images are inconclusive[3]
Endodontics	Periapical pathology, root morphology, additional canals, resorption, fractures	Use limited FOV[3,6]
Orthodontics	Treatment planning in selected cases (e.g. impacted canines, skeletal discrepancy)	Not for routine use[6]
TMJ assessment	Osseous condylar and fossa changes	Soft tissue limited[3]
Oral & maxillofacial surgery	Pathology, trauma and surgical planning	Case-dependent[3,6]

FOV, field of view; TMJ, temporomandibular joint. Summary of indications described in guidelines and reviews.

Effective radiation dose by field of view

Reported adult effective doses varied widely (Table 2; Figures 1–4). A published meta-analysis reported ranges of 46–1,073 μSv for large, 9–560 μSv for medium and 5–652 μSv for small FOV, with mean doses of approximately 212, 177 and 84 μSv , respectively.[7] The large-FOV mean was about 2.5 times, and the medium-FOV mean about 2.1 times, the small-FOV mean. The ranges overlapped extensively (Figure 3), so FOV alone did not determine dose. The same analysis noted large differences between units and that low-dose and high-definition protocols extended the range of doses.[7] Earlier work across scanners likewise showed a wide spread of effective doses.[8]

Table 2. Adult effective dose by FOV (published meta-analysis)[7]

FOV	Range (μSv)	Mean (μSv)	Range width (μSv)	Mean $\div$ small-FOV mean
Small	5–652	84	647	1.00
Medium	9–560	177	551	2.11
Large	46–1,073	212	1,027	2.52

Range width and ratio were calculated from the reported values. FOV, field of view.

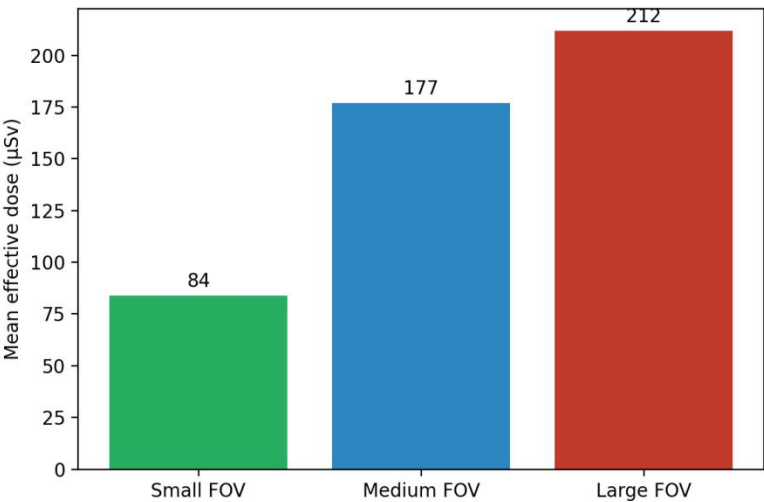


Figure 1. Bar chart of mean adult effective dose by FOV.

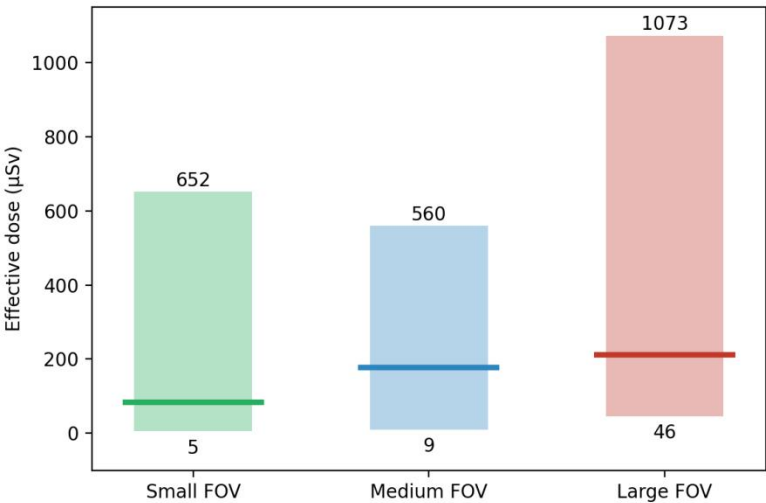


Figure 2. Reported dose range (shaded bar, minimum–maximum) and mean (line) by FOV.

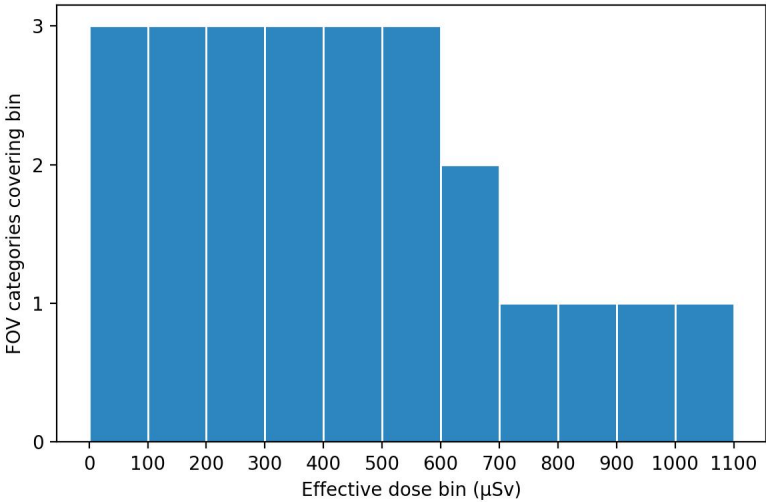


Figure 3. Histogram of dose-range overlap: number of FOV categories (of three) whose reported range spans each 100-μSv bin. Derived from reported ranges, not patient-level data.

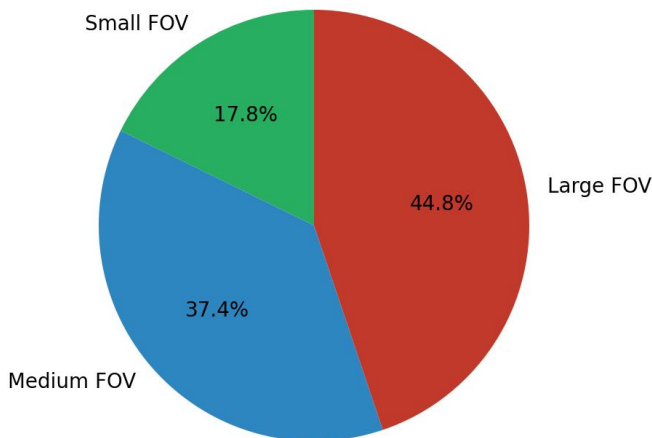


Figure 4. Pie chart of each FOV category's share of the summed mean doses (84 + 177 + 212 = 473 μ Sv); illustrates relative magnitude only.

Dose optimization

A systematic review of altering tube voltage (kV) and tube current–exposure time product (mAs) found that most studies showed patient dose could be reduced without a clinically relevant loss of image quality, although nearly 75% of the studies were of low or very low methodological quality and results were often specific to the unit and task studied.[9] An experimental study of mAs reduction similarly found that clinical image quality often remained acceptable below manufacturer-recommended settings for several protocols, while minimally acceptable mAs values differed between scanners and applications (from 9 to 70 across criteria and applications) and could not be generalized across models.[10] Substantial variability between CBCT units and protocols therefore limited generalization of any single dose value.

Diagnostic reference levels

Recent evidence showed considerable international variation in DRLs for dental CBCT.[11–13] An international survey reported that most countries had not established national DRLs, and that FOV-based values ranged from 500 mGy·cm² for FOV $\leq$ 25 cm² in Germany to 1,960 mGy·cm² for FOV >100 cm² in Japan.[11] Differences in classification, measurement and statistical derivation hampered international comparison,[12] and a national survey in Switzerland suggested that protocols for some indications required optimization when compared with UK values.[13]

DISCUSSION

This review indicates that CBCT provides important diagnostic and treatment-planning advantages in selected dental and maxillofacial conditions, particularly implant planning, impacted teeth, endodontic problems, TMJ osseous assessment and surgery, provided the clinical question cannot be answered by conventional imaging.[3,5,6] The benefit is indication-specific; guidelines caution against routine or screening use.[3,6]

The dose data illustrate the central difficulty in applying CBCT safely. Mean dose rose from small to large FOV, supporting FOV limitation as the most direct dose-saving measure. However, the very wide range within each category (for example 5–652 μ Sv for small FOV) showed that unit, protocol, resolution and exposure settings may matter as much as FOV, which is why a single dose value cannot be generalized.[7] Optimization of kV and mAs can lower dose in selected applications, but the supporting evidence is mostly of low quality and device-specific, so protocols should be validated locally.[9,10] DRLs offer a practical means of benchmarking and optimization, but few countries have established national values and methods differ.[11,12] Dental CBCT should be incorporated into DRL frameworks that weigh dose together with diagnostic image quality. Practical measures are summarized in Table 3.

Table 3. *Radiation-protection and optimization measures for dental CBCT*

Principle	Practical measure
Justification	Use CBCT only when clinical need is established and 2D imaging is inadequate; avoid routine and screening use[3,6]
Optimization	Smallest FOV that covers the region of interest; lowest kV/mAs and resolution that answer the diagnostic question; validated task-specific protocols[9,10]
Benchmarking	Compare local doses with national or regional DRLs; audit periodically[11,12]
Reporting	Review the entire volume and issue a report by a trained clinician[6]
Vulnerable patients	Use child-specific protocols with particular care[6]

FOV, field of view; DRL, diagnostic reference level.

The limitations of CBCT include radiation dose, image artifacts (for example from metallic restorations), limited soft-tissue contrast, cost, and variability in equipment and protocols.[1–3] Strengths of this review are its focus on dose and optimization together with clinical indications and its use of a recognized meta-analysis for quantitative values.

Limitations include the narrative design, reliance on a single meta-analysis for dose figures, heterogeneity and mostly low-quality evidence in the optimization literature, and the descriptive nature of the figures, which do not represent a new statistical analysis.

CONCLUSION

CBCT offers important diagnostic and treatment-planning advantages in selected dental and maxillofacial conditions but is associated with variable radiation exposure that cannot be summarized by a single value. Appropriate patient selection, justification of every examination, limitation of the field of view, optimization of exposure parameters and application of radiation-protection principles are essential. National and regional DRLs for dental CBCT, with standardized dose metrics, are needed, and further high-quality studies on task-specific optimization are recommended.

DECLARATIONS

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

Data availability: All data analysed were obtained from the published sources cited in the reference list.

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