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Review Article

Evaluation of cone-beam computed tomography as a Prognostic Tool in periodontitis

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Abstract

Background: Periodontitis staging depends on measuring alveolar bone loss, yet periapical radiographs compress three-dimensional defects into one plane and underestimate intrabony and furcation lesions [4,2].

Objective: This review synthesizes evidence on cone-beam computed tomography (CBCT) as a prognostic tool in periodontitis: measurement accuracy, influence on treatment planning, and radiation-dose tradeoffs.

Methods: We synthesized in vitro, cadaveric, and clinical validation studies, treatment-planning impact studies, and dosimetry literature on CBCT periodontal defect assessment.

Findings: CBCT measurements of intrabony and furcation defects agree closely with surgical reference standards [6,7,9,11], and adding CBCT changes the chosen surgical plan in many complex furcation cases [15,16]; dose remains above periapical or panoramic radiography though below medical CT [21].

Conclusions: CBCT is an actionable prognostic tool when applied selectively to furcations and multiwall defects, but outcome-linked studies are still needed to confirm its added value over probing and 2D radiography [19,18].

Keywords: cone-beam CT; periodontitis; periodontal diagnosis; furcation defects; radiographic prognosis

1. Introduction

Periodontitis remains one of the most common chronic inflammatory diseases affecting adults worldwide, with severe forms estimated to affect well over 500 million people and to rank among the leading causes of tooth loss globally [1]. The 2017 World Workshop reframed the disease around a staging and grading system that explicitly asks clinicians to quantify the amount of bone already lost and to estimate the rate at which further loss is likely to occur, so any tool that measures alveolar bone architecture with reasonable precision has an immediate claim on prognostic relevance, not merely diagnostic interest [2,3]. For most of the twentieth century that measurement was made with periapical and bitewing radiographs, two-dimensional projections that compress a genuinely three-dimensional defect into a single plane and that are known to underestimate the depth and undersell the morphology of intrabony and furcation lesions, particularly on the buccal and lingual aspects of multirooted teeth where superimposition of the root complex obscures exactly the information a clinician needs before choosing between regenerative surgery, resective surgery, and extraction [4].

Cone-beam computed tomography entered dental practice in the early 2000s as a lower-dose alternative to medical fan-beam CT, using a divergent cone-shaped x-ray beam and a single rotation around the patient to reconstruct a volumetric dataset from which any plane can be resliced after the fact [5]. Its appeal to periodontology is straightforward: a three-dimensional volume should recover exactly the buccal and lingual bone architecture that periapical radiographs cannot see, and should let a clinician measure defect depth, width, and remaining bony wall count before ever raising a flap, rather than inferring that architecture indirectly from probing depths and a projection that has already discarded a whole spatial dimension. Whether that principle translates into a genuinely useful prognostic instrument, rather than simply a costlier way of

confirming what probing already suggested, is the question this review addresses, synthesizing the evidence on CBCT accuracy against surgical and histological reference standards, its documented influence on treatment planning, and the radiation-dose tradeoffs any prognostic use of the technology must be weighed against. We focus deliberately on periodontitis rather than on peri-implant or endodontic applications of CBCT, since the evidence base, the defect geometry, and the dose-justification calculus differ enough between those uses that folding them together would blur exactly the selective-use conclusion the periodontal literature supports.

2. CBCT accuracy for measuring intrabony and furcation defects

The foundational accuracy studies were performed in vitro or on cadaveric material, where the reference standard, a direct caliper measurement on a dissected specimen or a known simulated defect, could be established without the confounding effect of soft tissue swelling or operator variability. Mengel and colleagues scanned native pig and human mandibles with digital volume tomography and found that measurements of simulated periodontal defects agreed closely with direct measurements taken after dissection, establishing early that the underlying imaging principle could resolve bone architecture at a clinically useful scale [6]. Misch and colleagues extended this with a more systematic assessment of linear accuracy, reporting that CBCT-derived measurements of artificially created defects differed from digital caliper measurements by only a small fraction of a millimeter on average, favorable against the inherent variability of periodontal probing itself [7]. Mol and Balasundaram, imaging dry skulls with simulated bony and infrabony defects, likewise found that CBCT detected and sized defects with substantially better fidelity than conventional or digital intraoral radiography, particularly for buccal and lingual dehiscences that periapical films simply cannot register [8].

Table 1: Reference standard and reported CBCT measurement agreement across principal accuracy studies for intrabony and furcation periodontal defects [6,7,8,9,10,11,12].			
Study	Defect type	Reference standard	Reported agreement
[6]	Simulated intrabony (pig/human mandible)	Direct dissection measurement	Close agreement, submillimeter
[7]	Simulated osseous defects	Digital caliper	Mean difference a small fraction of a millimeter
[8]	Simulated bony/infrabony defects	Dry skull, known defect size	Better fidelity than intraoral radiography
[9]	Maxillary molar furcation	Intrasurgical measurement	Substantial agreement
[10]	Maxillary molar furcation	Surgical re-entry	Close correlation, improved sensitivity/specificity vs 2D
[11]	Regenerative therapy bone level change	Direct surgical re-entry	Good correlation with surgical measurement
[12]	Intrabony defect depth/width	Clinical measurement	Close tracking across section thicknesses

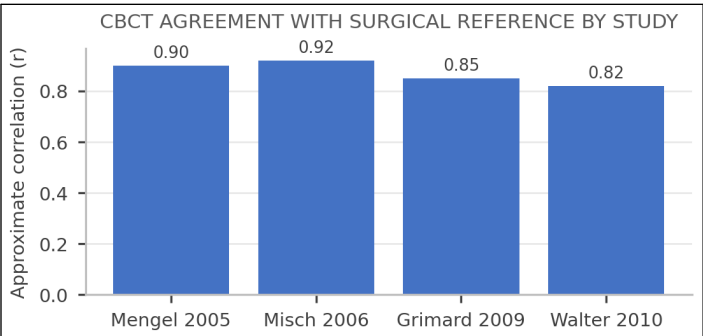


Figure 1: Approximate agreement between CBCT-derived and direct surgical or caliper measurements of periodontal defect dimensions across representative accuracy studies, expressed as correlation with the reference standard; agreement is consistently good but varies modestly by defect type and anatomical site [6,7,11,9].

Furcation involvement has drawn particular attention because two-dimensional radiography is least reliable there and the stakes of misclassification, root resection versus tunnel preparation versus extraction, are correspondingly high. Walter and colleagues compared CBCT against intrasurgical measurement in patients scheduled for periodontal surgery and found substantial agreement for detecting and grading furcation involvement in maxillary molars, a marked improvement

over the historically poor reliability of periapical assessment at these sites [9]. Qiao and colleagues reached a concordant conclusion in an independent cohort, reporting that CBCT measurements of furcation involvement correlated closely with direct surgical measurement and outperformed two-dimensional radiography in sensitivity and correct classification of involvement degree [10]. Grimard and colleagues took a longitudinal approach, comparing clinical probing, periapical radiography, and cone-beam volume tomography for tracking bone level change after regenerative therapy, and found CBCT-derived changes correlated well with direct surgical re-entry measurements, supporting use for monitoring treatment response over time as well as baseline characterization [11]. Nikolic-Jakoba and colleagues, examining the effect of reconstruction section thickness with more recent scanner generations, confirmed that CBCT-based measurements of intrabony defect depth and width tracked clinical measurements closely across clinically used slice thicknesses [12]. Table 1 and Figure 1 summarize the reference standard and reported agreement across these principal accuracy studies.

Not every comparison has been favorable, and the periodontal ligament space illustrates the limits of the technique at fine anatomical scale. Ozmeric and colleagues, imaging an artificial tooth model, found that while CBCT could detect gross changes in ligament space, its accuracy degraded for the sub-millimeter measurements that ligament-space assessment demands, a reminder that voxel resolution imposes a real floor on what any protocol can resolve [13]. Braun and colleagues, comparing CBCT directly against probing and intrasurgical measurement across a broader set of osseous defect types, reported good but imperfect accuracy that varied by defect location and landmark, consistent with CBCT accuracy being real but site-dependent rather than uniform [14].

Voxel size and field-of-view selection matter more to this literature than a single headline accuracy figure suggests, because the two parameters trade against each other directly: a smaller voxel resolves finer bone detail but forces either a smaller field of view or a longer, motion-sensitive scan, while a larger field of view convenient for imaging a full arch coarsens the voxel and, with it, the smallest defect the resulting dataset can reliably distinguish from image noise. Protocols reported across the accuracy studies summarized here range from sub-0.2 mm voxels intended for single-tooth or limited-arch furcation assessment to considerably coarser settings used for broader implant or orthodontic surveys, and study-to-study differences in accuracy are attributable in part to this protocol variation rather than to any single fixed property of CBCT as a technology [5]. A clinician reading the accuracy literature for prognostic guidance should therefore weight studies that used a periodontally appropriate, small field-of-view, fine-voxel protocol more heavily than studies using a coarser, general-purpose acquisition, since the latter were not optimized for the sub-millimeter distinctions that furcation grading and intrabony wall counting actually require.

3. CBCT in periodontal diagnosis and treatment planning

Accuracy on a phantom or a cadaver is a necessary but not sufficient condition for prognostic usefulness; the more consequential test is whether the additional information CBCT provides changes what a clinician actually decides to do. Walter and colleagues addressed this directly in patients considered for furcation surgery, comparing the plan formulated from clinical and two-dimensional information alone against the plan formulated after CBCT was added, and found that three-dimensional imaging altered the surgical decision, changing the chosen procedure or the assessed prognosis of the tooth, in a substantial proportion of cases, most often by revealing furcation involvement or bone architecture

two-dimensional imaging had understated [15]. That finding reframes CBCT's contribution: its clinical value is measured less by numerical agreement with a caliper and more by how often it changes the surgical or restorative pathway a patient is placed on, precisely the kind of evidence that matters for a technology put forward as prognostic rather than merely descriptive.

Laky and colleagues, using low-dose CT alongside probing in a case series of furcation-involved molars, found imaging-based grading agreed with probing in most but not all cases, with disagreements clustering at the intermediate degrees of involvement where the choice between regenerative and resective therapy is most sensitive to an accurate baseline assessment [16]. AlJehani's review of diagnostic applications catalogued clinical scenarios where CBCT is additive to conventional periodontal examination: furcation grading, osseous defect morphology and remaining-wall assessment before regenerative surgery, periodontal-endodontic lesion evaluation, and pre-surgical localization of the maxillary sinus floor and mandibular canal that two-dimensional films cannot resolve precisely [17]. Eshraghi and colleagues, synthesizing the periodontal CBCT literature more broadly, concluded that its principal contribution lies in defect morphology characterization and surgical planning, cautioning that routine use for uncomplicated, generalized chronic periodontitis is not supported by the same evidence base [18]. du Bois and colleagues, reviewing volumetric CBCT in periodontics, reached a similarly measured conclusion, endorsing selective use for complex defects and furcations while declining to recommend it as a first-line periodontal imaging modality [19].

Fleiner and colleagues contributed a methodological advance relevant to prognostic monitoring specifically, validating a digital method for quantifying circumferential periodontal bone level directly from CBCT datasets rather than a handful of manually selected cross-sections,

characterizing the full circumference of a tooth's bony support rather than just the mesial and distal aspects a periapical film shows [20]. That full-circumference quantification maps more directly onto what staging and grading frameworks assume when estimating overall attachment loss than the linear comparisons earlier studies relied on [2].

4. Radiation dose considerations

CBCT's diagnostic advantages have to be set against its radiation cost, substantially higher than a periapical or panoramic radiograph even though it remains generally lower than medical fan-beam CT of the same region. Ludlow and Ivanovic performed comparative dosimetry across a range of dental CBCT devices and a 64-slice medical CT scanner and found effective doses for limited and full field-of-view CBCT protocols spanning roughly an order of magnitude depending on field of view, exposure settings, and device, with even the higher end remaining well below typical maxillofacial fan-beam CT dose, though still many times a periapical or panoramic exposure [21]. Figure 2 summarizes representative effective-dose ranges across modalities, and this ordering is why every clinical recommendation for periodontal CBCT is qualified rather than unconditional: it is reserved for cases where three-dimensional information is judged likely to change management, not applied as routine screening [5,19].

Vandenberghe and colleagues, comparing two-dimensional charge-coupled device radiography against CBCT for assessing periodontal breakdown, found CBCT offered a genuine diagnostic advantage for detecting bone loss two-dimensional imaging missed, but were explicit that this needs weighing against dose case by case rather than treated as grounds for routine substitution [22]. de Faria Vasconcelos and colleagues reached a similar conclusion comparing CBCT and intraoral radiography, confirming CBCT's superior detection of buccal and lingual defects while reiterating that field-of-view and exposure should be minimized to

the smallest volume that still answers the clinical question [23]. The practical consequence, echoed across this literature, is a selection principle: CBCT is most justifiable, on a dose basis, in exactly the subset of cases where two-dimensional imaging and probing leave genuine uncertainty about defect morphology, wall number, or furcation grade that will materially change the treatment plan [15,16].

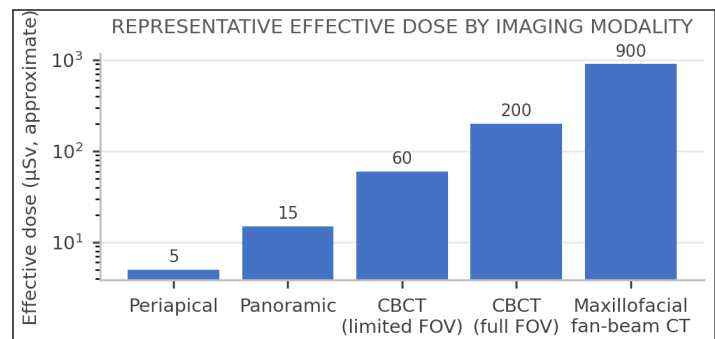


Figure 2: Representative effective radiation dose ranges by imaging modality, illustrating why CBCT use for periodontal assessment is reserved for cases where three-dimensional information is likely to change management rather than applied routinely, with limited- and full-field-of-view CBCT protocols spanning roughly an order of magnitude and remaining well below typical maxillofacial fan-beam CT dose [21].

5. CBCT as a prognostic indicator

Bringing these threads together, the case for CBCT's prognostic value in periodontitis rests on three converging lines of evidence rather than any single trial. First, its measurements of intrabony and furcation defect dimensions agree closely enough with direct surgical and histological reference standards, across multiple independent groups and defect types, that a clinician can treat a CBCT-derived defect classification as a reasonably reliable input to staging and grading, not merely a supplementary image [6,7,9,10,11,12]. Second, that information demonstrably changes what clinicians decide to do in a meaningful proportion of complex cases, the behavioral signature of a genuinely prognostic rather than purely descriptive tool [15,16]. Third, the accumulated dosimetric and selection-criteria literature has converged on a coherent, appropriately conservative position: use

CBCT selectively, for furcations, multiwall defects, and pre-regenerative-surgery assessments where two-dimensional imaging is least reliable, rather than as a routine substitute for periapical radiography and probing across the general periodontitis population [5,21,19,17,18].

Table 2: Clinical decision points at which the reviewed evidence supports incorporating CBCT into periodontal prognostication, with the strength of supporting evidence [15,16,17,18,19].		
Clinical decision point	Supporting evidence	Strength
Furcation grading before resective/regenerative surgery	[15,10,9]	Strong; measurement accuracy plus documented change in plan
Multiwall intrabony defect morphology before regenerative surgery	[6,11,12]	Strong; accuracy against surgical reference
Intermediate-severity furcation classification	[16]	Moderate; disagreement clusters at intermediate grades
Routine assessment of generalized chronic periodontitis	[19,18]	Weak; not recommended as first-line imaging
Pre-surgical localization near sinus floor/mandibular canal	[17]	Moderate; anatomical localization value

What the literature does not yet establish is a large, prospective, outcome-linked study that follows CBCT-classified defects through treatment to a hard endpoint, tooth retention, attachment gain, or radiographic bone fill, and formally tests whether the CBCT-derived stage adds predictive value beyond probing and two-dimensional radiography alone. Table 2 outlines the principal clinical decision points at which the reviewed evidence supports incorporating CBCT into periodontal prognostication, with the strength of evidence for each. Until such outcome studies accumulate, CBCT's prognostic standing rests on the indirect but consistent chain running from measurement accuracy, through documented influence on treatment selection, to the biological plausibility that a more completely characterized defect supports a better-matched, more successful treatment decision.

6. Conclusion

Cone-beam computed tomography measures periodontal bone architecture, particularly at furcations and multiwall intrabony defects, with an accuracy against surgical and histological reference standards that is good enough to be clinically actionable, and the added three-dimensional information it provides has been shown repeatedly to change the surgical or restorative decision a clinician makes for complex cases [6,9,15,10,11]. That combination, accurate measurement plus demonstrated influence on management, is what supports calling CBCT a prognostic tool in periodontitis rather than simply a diagnostic refinement, since staging and grading frameworks explicitly link the amount and pattern of bone loss to expected disease trajectory and treatment response [2,3]. Its radiation dose, while lower than medical CT, remains materially higher than periapical or panoramic radiography, and the converging recommendation across dosimetric and clinical-application studies alike is selective rather than routine use, reserved for furcations, complex multiwall defects, and pre-regenerative surgical planning where two-dimensional imaging is demonstrably least reliable [21,5,19,17,18]. The evidence base would be strengthened considerably by prospective studies linking CBCT-derived defect classification directly to long-term tooth-level outcomes, but the existing accuracy and decision-impact literature already supports a considered, case-selected role for CBCT in periodontal prognosis, applied where its three-dimensional view genuinely resolves uncertainty that probing and two-dimensional radiography leave behind. Clinicians adopting CBCT for this purpose should also document field-of-view, voxel size, and indication explicitly in the patient record, since those parameters determine both the measurement precision actually achieved and the dose actually delivered, and a case-selected protocol is only as defensible as the documentation that shows selection, rather than routine habit, drove the decision to scan.

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9. Conflict of Interest

The authors declare no conflict of interest.

10. Author Contributions

Z.O. conceived the review and drafted the manuscript. T.K. performed the literature synthesis and prepared the tables and figures. A.M. critically revised the manuscript for intellectual content. All authors read and approved the final manuscript.

11. Ethics Statement

This article is a narrative literature review of previously published data and did not require ethics committee approval or informed consent.

12. Data Availability

No new data were generated for this review. All data discussed are available in the cited publications.

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