



Periodontal Diagnosis through a Radiographic Lens

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Abstract

Periodontal disease is a chronic inflammatory condition that affects the supporting structures of the teeth, including the gingiva, periodontal ligament, cementum, and alveolar bone. Accurate and timely diagnosis is essential for effective treatment planning, prevention of disease progression, and long-term tooth preservation. While clinical examination remains fundamental in periodontal assessment, radiographic evaluation plays a crucial complementary role by providing essential information regarding the extent, pattern, and severity of alveolar bone loss—one of the key hallmarks of periodontitis. This article reviews the role of radiographic diagnosis in periodontal disease, highlighting conventional imaging modalities such as intraoral periapical, bitewing, full-mouth radiographic surveys, and panoramic radiographs, along with advanced imaging techniques including digital radiography, digital subtraction radiography, cone beam computed tomography, computed tomography, and magnetic resonance imaging. Radiographic features associated with periodontitis, trauma from occlusion, and periodontal and periapical abscesses are discussed to emphasize their diagnostic relevance. In addition, emerging technologies such as artificial intelligence–assisted image analysis, ultra-low-dose CBCT, optical coherence tomography, and ultrasound imaging are explored as future directions in periodontal diagnosis. The integration of radiographic findings with clinical and biological parameters remains essential for accurate diagnosis, improved treatment outcomes, and personalized periodontal care.

Keywords: Periodontal Disease; Radiographic Diagnosis; Alveolar Bone Loss; Intraoral Radiography; Bitewing Radiographs; Cone Beam Computed Tomography; Digital Radiography; Periodontitis; Advanced Imaging Techniques; Artificial Intelligence in Periodontics

Introduction

Periodontal disease is a chronic inflammatory condition affecting the supporting structures of the teeth, including the gingiva, periodontal ligament, cementum, and alveolar bone. Accurate diagnosis is critical for effective treatment planning and prognosis. While clinical examination remains fundamental, radiographic assessment plays a vital complementary role in detecting and evaluating the extent of alveolar bone loss, which is a hallmark of periodontitis [1]. Early and accurate diagnosis is essential for effective management and prevention of tooth loss. Although clinical evaluation provides direct assessment of periodontal tissues, radiographic imaging remains an indispensable tool for diagnosing the extent and pattern of alveolar bone loss associated with periodontitis [2].

Definition

Periodontal disease is described as a group of inflammatory conditions affecting the supporting tissues of the teeth—primarily the gingiva, periodontal ligament, cementum, and alveolar bone [3].

Periodontal disease is initiated primarily by bacterial biofilm (dental plaque), but its progression is influenced by a complex interplay of host immune response, genetic predisposition, systemic factors such as Diabetes mellitus, and environmental influences such as smoking [4].

The disease is broadly classified into two major categories: gingivitis, which is the reversible inflammation of the gingiva without attachment loss, and periodontitis, which is characterized by irreversible destruction of the supporting periodontal structures, including clinical attachment loss and alveolar bone resorption [5].

Significance of diagnosis

The significance of diagnosing periodontal disease in a timely manner lies in how early or late the condition is identified and how this influences treatment outcomes and overall prognosis [6].

Timely diagnosis of periodontal disease is highly significant, as early detection plays a crucial role in preventing irreversible damage. When identified in the early stages, such as gingivitis, the condition is reversible and can be managed with simple treatments

like scaling and improved oral hygiene [7]. This helps preserve the supporting structures of the teeth, such as alveolar bone and periodontal ligament, improves long-term prognosis, and reduces treatment costs.

In contrast, delayed diagnosis often means the disease has progressed to periodontitis, leading to irreversible bone loss, tooth mobility, or even tooth loss [8]. Advanced cases often require complex and invasive procedures and may also be associated with systemic conditions such as Diabetes mellitus and cardiovascular diseases [9]. Therefore, timely diagnosis is essential to ensure effective treatment, maintain oral function and aesthetics, and prevent complications [6,7].

Investigations used in diagnosis

Investigations used in the diagnosis of periodontal disease include clinical examination, radiographic examination, plaque and calculus detection, microbiological tests, histopathological examination, and other adjunctive tests [10].

Clinical examination includes periodontal probing, bleeding on probing, tooth mobility testing, furcation involvement assessment, gingival recession measurement, and clinical attachment loss evaluation [11].

Radiographic examination includes intraoral periapical radiographs (IOPA), bitewing radiographs, and orthopantomograms (OPG). These help assess alveolar bone loss, bone morphology, and furcation involvement [12].

Plaque and calculus detection methods include disclosing agents, plaque index scoring, and calculus index scoring [13].

Microbiological tests are used to identify specific periodontal pathogens such as *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* [14].

Histopathological examination is rarely used and is mainly indicated for unusual lesions or biopsy of gingival tissue. Other adjunctive tests include gingival crevicular fluid (GCF) analysis, salivary diagnostics, and genetic or immune marker assessment [15].

Role of radiographic diagnosis in periodontal disease

Radiographs play a vital role in the diagnosis and management of periodontal disease. They help evaluate the amount and pattern of alveolar bone loss, which is a key indicator of periodontal destruction [16]. Radiographs can detect horizontal and vertical bone defects, furcation involvement, calculus deposits, and changes in the periodontal ligament space [17]. They are also useful for identifying other conditions that may mimic or influence periodontal disease, such as periapical lesions or root anomalies [17].

Commonly used radiographs include intraoral periapical (IOPA) radiographs for localized assessment, bitewing radiographs for detecting crestal bone loss and calculus, and orthopantomograms (OPG) for overall evaluation of the jaws [18]. Although radiographs cannot demonstrate soft tissue changes or active inflammation directly, they provide essential information for diagnosis, prognosis, and treatment planning in periodontal therapy [16,19].

Conventional radiographic aids

Conventional radiographic aids play a critical role in the evaluation of periodontal disease by providing essential information about the bony components of the periodontium [20]. These aids include.

Intraoral Periapical Radiographs (IOPA)

- Intraoral periapical radiographs are most commonly used for assessing individual teeth and surrounding bone. They provide detailed information about bone height, root morphology, and the presence of periapical pathology [21].
- Intraoral periapical radiography is particularly valuable for detecting caries, periapical lesions, periodontal bone loss, and root morphology. Two main techniques are employed: [22].
- Paralleling technique – provides accurate, reproducible images with minimal distortion and is considered the gold standard [22].
- Bisecting-angle technique – used when paralleling is difficult, but may produce some distortion [22].

Bitewing radiographs

Bitewing radiography is an intraoral imaging technique that captures the crowns of the maxillary and mandibular teeth simultaneously along with the alveolar crest [23].

Bitewings are primarily used to:

- Detect proximal caries
- Assess recurrent caries beneath restorations,
- Evaluate alveolar crest height for early periodontal bone loss [23].

They provide excellent detail of the coronal portion of teeth and supporting structures but do not adequately visualize the periapical region. Bitewing radiographs are especially useful for diagnosing interproximal bone loss in periodontitis [24].

Full-mouth radiographic survey (FMX)

A full-mouth radiographic survey (FMX) is a complete set of intraoral radiographs used to comprehensively evaluate the dentition and supporting structures. It usually consists of a combination of periapical and bitewing radiographs covering all teeth and adjacent alveolar bone [25].

Typical components include:

- 14–16 periapical radiographs,
- 4 bitewing radiographs [25].

FMX is useful for: evaluating crowns, roots, periapical regions, and alveolar bone, diagnosing caries, periapical pathology, periodontal disease, impacted teeth, and developmental anomalies, serving as a baseline radiographic examination in patients with significant dental history or periodontal involvement [25].

Panoramic radiograph (Orthopantomogram – OPG)

A panoramic radiograph, or orthopantomogram (OPG), is an extraoral imaging technique that provides a single wide-view image of the maxilla, mandible, teeth, and surrounding structures [26].

Features:

- Captures both jaws and associated structures in one image,
- Quick, simple, and comfortable for the patient,
- Relatively lower radiation dose than a full-mouth survey [26].

Uses:

- Evaluation of impacted teeth, jaw fractures, cysts, tumors, and developmental anomalies,
- Detection of gross caries, periodontal status, and periapical pathology,
- Use in orthodontics, oral surgery, implant planning, and epidemiological surveys [26].

Limitations:

- Lower resolution than intraoral radiographs,
- Possible distortion and overlapping,
- Not ideal for subtle proximal caries or early periodontal bone loss [26].

Advanced radiographic aids

Cone beam computed tomography (CBCT)

- Cone Beam Computed Tomography (CBCT) is an advanced three-dimensional imaging technique that uses a cone-shaped X-ray beam and flat-panel detector to generate volumetric images of the maxillofacial region [27].

Features:

- Provides three-dimensional views of teeth, jaws, and surrounding structures,
- Offers high spatial resolution with relatively lower radiation dose than conventional CT,
- Images can be reconstructed in axial, sagittal, and coronal planes [27].

Uses:

- Implant planning,
- Endodontic diagnosis,
- Periodontal assessment of alveolar bone defects and furcation involvement,
- Oral surgery and orthodontic evaluation [28].

Limitations:

- Higher radiation dose than 2D intraoral radiographs,
- Expensive equipment,

- Image artifacts may affect interpretation [27].

Digital radiography

- Digital radiography is an advanced imaging system that replaces conventional X-ray film with digital sensors to capture radiographic images displayed on a computer screen [29].

Features:

- Uses CCD, CMOS, or PSP sensors,
- Produces instant images,
- Reduces radiation dose compared with film,
- Allows image enhancement and easy storage [29].

Uses:

- Caries detection,
- Periodontal assessment,
- Periapical diagnosis,
- Treatment monitoring and implant planning [29].

Advantages:

- Reduced radiation exposure,
- Faster image acquisition,
- Easy storage and sharing,
- No chemical processing required [29].

Limitations:

- High initial cost,
- Possible patient discomfort from sensors,
- Technical issues may affect image storage [29].

Digital Subtraction Radiography (DSR)

- Digital subtraction radiography is used to detect subtle changes in mineralized tissues by comparing two standardized radiographs taken at different time intervals [30].

Principle:

- Baseline and follow-up radiographs are superimposed,
- Unchanged structures are subtracted,

- Areas of change become visible [30].

Advantages:

- Highly sensitive for minor bone changes,
- Objective quantitative evaluation [30].

Limitations:

- Requires precise standardization,
- Sensitive to movement and angulation errors,
- Limited routine clinical use [30].

Computed tomography (CT) and Magnetic Resonance Imaging (MRI)

- Computed Tomography (CT) uses a rotating X-ray beam to produce cross-sectional images and detailed three-dimensional reconstructions of hard tissues [31].

Advantages:

- Excellent bone detail,
- Accurate three-dimensional assessment [31].

Limitations:

- High radiation dose,
- High cost,
- Limited accessibility [31].

Magnetic Resonance Imaging (MRI) is a non-ionizing imaging modality that uses magnetic fields and radiofrequency waves to produce high-resolution soft tissue images [32].

Advantages:

- Excellent soft tissue contrast,
- No ionizing radiation [32].

Limitations:

- Expensive,
- Time-consuming,
- Contraindicated in some patients with metallic implants or pacemakers [32].

Radiographic diagnosis of trauma from occlusion

Radiographs are an important adjunct in detecting trauma from occlusion (TFO), although clinical findings remain primary. Radiographic changes reflect the adaptive response of the periodontium to excessive occlusal forces [33].

- Radiographic features of TFO include:
- Widening of periodontal ligament space,
- Thickening of lamina dura,
- Localized vertical bone loss,
- Root resorption in severe cases,
- Occasional periapical radiolucency [33].

Radiographic diagnosis of periodontitis

- Radiographic features suggestive of periodontitis include:
- Loss of alveolar crest height,
- Irregular alveolar crest morphology,
- Widening of periodontal ligament space,
- Loss of lamina dura continuity,
- Horizontal bone loss,
- Vertical (angular) defects,
- Furcation involvement,
- Advanced root resorption or periapical changes [34].

Radiographic diagnosis of abscesses

Periodontal Abscess

- Radiographic features include:
- Localized radiolucency along the lateral root surface,
- Angular bone loss,
- Furcation radiolucency in multirrooted teeth,
- Irregular or absent lamina dura [35].

Periapical abscess

- Radiographic features include:
- Radiolucency at the root apex,
- Loss of lamina dura continuity,
- Possible absence of changes in early stages until significant bone loss occurs [35]

Future concepts in periodontal radiographic diagnosis

The future of periodontal radiographic diagnosis is expected to be AI-driven, three-dimensional, minimally invasive, and integrated with biological and clinical data to support personalized care [36].

Wider Application of 3D Imaging (CBCT and Next-Generation 3D Systems)

Selective Use of CBCT Cone-beam computed tomography is increasingly used for:

- Furcation assessment,
- Infrabony defect evaluation,
- Pre-surgical planning [37].

Future improvements may include lower radiation doses, higher spatial resolution, and AI-assisted image reconstruction [37].

Ultra-Low-Dose and Micro-CBCT

Next-generation CBCT systems are being developed to provide high diagnostic accuracy with reduced radiation exposure, potentially allowing safer routine periodontal imaging in selected cases [38].

Integration of Non-Ionizing Imaging Technologies

Magnetic Resonance Imaging (MRI) MRI can visualize gingiva, periodontal ligament, and bone without ionizing radiation. Future dental MRI systems may become faster, smaller, and more clinically practical [39].

Optical Coherence Tomography (OCT) OCT provides high-resolution imaging of:

- Gingival tissues,
- Cementoenamel Junction,
- Crestal bone through transgingival imaging [40].

It may become useful for early detection of micro-defects and soft tissue changes [40].

Ultrasound Imaging Advances in high-frequency ultrasound show promise for:

- Periodontal pocket depth measurement,
- Soft Tissue evaluation,
- Crestal bone level assessment [41].

Ultrasound is non-invasive, radiation-free, and may serve as an adjunct or alternative in selected cases [41].

Artificial Intelligence (AI)-Enhanced Radiographic Analysis

Deep Learning for Automated Detection AI systems trained on large datasets of dental images can:

- Automatically detect alveolar bone loss,
- Classify periodontal defect morphology,
- Assist in staging periodontitis [42].

AI is expected to improve:

- Diagnostic accuracy,
- Inter-examiner consistency,
- Speed of interpretation [42].

It is likely to become integrated into routine dental imaging software in the future [42].

Conclusion

Radiographic diagnosis plays an indispensable role in the comprehensive evaluation and management of periodontal disease. While clinical examination provides essential information about soft-tissue health and periodontal probing depths, radiographs offer critical insight into the extent, pattern, and nature of alveolar bone loss—features that cannot be assessed clinically alone. Conventional imaging methods such as periapical, bitewing, and panoramic radiographs remain fundamental for identifying periodontal breakdown, furcation involvement, and associated pathologies. Advanced imaging modalities—including CBCT, digital radiography, digital subtraction radiography, CT, and MRI—further enhance diagnostic accuracy by delivering three-dimensional visualization, improved resolution, and quantitative assessment of bone changes. Emerging technologies such as AI-assisted analysis, ultra-low-dose CBCT, OCT, and high-frequency ultrasound promise even greater precision, standardization, and non-invasive evaluation in the future. As imaging continues to evolve, radiographs will remain a cornerstone of periodontal diagnosis, guiding accurate assessment, effective treatment planning, and improved long-term outcomes for patients.

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