The Role of Radiographic Imaging in the Diagnosis and Management of Periodontal and Peri-Implant Diseases

Abdo Ismail, DDS, MS[a], Firas Al Yafi, DDS, MS[b,*]

KEYWORDS

• Radiography • Cone-beam computed tomography • Periodontitis • Peri-implantitis • Dental implants

KEY POINTS

- Radiographic imaging serves as an indispensable tool for diagnosing and managing periodontal disease, identifying bone loss, defects, and formulating treatment strategies.
- Radiographic examination plays a crucial role in implant planning, as it is essential for evaluating bone dimensions and ensuring proper implant placement to achieve successful outcomes.
- CBCT provides a comprehensive view of the implant site and becomes especially important when traditional radiographs do not offer sufficient information.
- Radiographs also play a significant role in diagnosing peri-implant diseases, helping identify complications, and enabling timely intervention to preserve the of dental implants.

INTRODUCTION

Periodontal diseases are conditions that affect the periodontium, which comprises the supportive structures surrounding a tooth, including gingival tissue, alveolar bone, cementum, and periodontal ligament.[1] Gingivitis is the milder form of periodontal disease, affecting up to 90% of the population and reversible with improved oral hygiene. On the other hand, periodontitis is a chronic, irreversible, and more severe inflammatory disease state.[1] It is the most prevalent chronic oral disease affecting the adult population in the United States, with 64.7 million (42.7%) American adults diagnosed with mild, moderate, or severe periodontitis.[2] Periodontal disease initiation and propagation is caused by dysbiosis of the commensal oral microbiota present in the dental plaque, which disrupts the balance and interactions with the host's immune defenses,

[a] Private Practice, 726 Crystal Oak Lane, Arlington, TX 76005, USA; [b] Private Practice, Diplomate of the American Board of Periodontology, Arab Board of Oral Surgery, 5625 Saint Thomas Dr, Plano, TX 75094-4617, USA
* Corresponding author. 8000 Coit Road, Suite 200, Plano, TX 75025.
E-mail address: firasyafi@hotmail.com

Dent Clin N Am 68 (2024) 247–258
https://doi.org/10.1016/j.cden.2023.09.002
dental.theclinics.com

ultimately leading to inflammation and disease.[3] A comprehensive clinical and radiographic examination is crucial for effectively diagnosing and managing patients with destructive periodontal diseases. Attachment level should be assessed clinically through periodontal probing. However, radiographic examination is still necessary to evaluate bone levels and morphology.[4]

RADIOGRAPHIC IMAGING IN PERIODONTAL DISEASE

Conducting an Initial assessment of periodontal tissues establishes a diagnostic baseline, while periodic evaluations monitor disease progression and treatment outcome.[5,6] Radiography plays a vital role in assessing the status of hard tissues and identifying various pathologies.[5] It also allows for assessing the condition, planning, and executing appropriate treatment.[6] Two-dimensional (2D) radiographic techniques including bitewing, periapical, and panoramic radiographs are commonly employed for the diagnosis of periodontal disease.[7] Panoramic radiographs can be utilized to obtain an overall view of the patient's entire dentition, jaws, and related structures (**Fig. 1**A–C, **2**A–C). Despite the improved image quality of intraoral images, which are typically favored for assessing bone level and morphology, the literature suggests that the panoramic image is sufficient only if supplemented by vertical or horizontal bitewings.[4] The vertical bitewing is the most useful intraoral radiograph (IR) for assessing periodontal disease and bone levels due to its thorough visibility and minimal distortion.[4] 2D radiographs are commonly employed due to their ease of acquisition, cost-effectiveness, and ability to produce high-resolution images.[7] Nevertheless, they come with limitations, including overlapping anatomic structures, challenges in standardization, and potential underestimation of bone defects.[8,9] To overcome the limitations of 2D radiographs, three-dimensional (3D) imaging techniques, such as cone-beam computed tomography (CBCT) are employed. CBCT provides 2D and 3D images essential for diagnosing and planning treatment for intra-bony defects, furcation involvements, and buccal/lingual bone destructions.[8,10] While periapical radiographs are limited in providing information about the extent of furcation bone loss, CBCT images offer high-resolution views that enable accurate assessment of defects, roots involved, and lesion dimensions, making it valuable in evaluating furcations and interradicular bone in periodontics.[11] In cases with extensive bone loss that led to furcation involvement, an accurate diagnosis of interradicular bone loss is an important factor before deciding on the appropriate treatment.[12] Previous studies indicated that CBCT images were more effective in detecting periodontal defects compared to other radiograph types. Furthermore, CBCT showed higher diagnostic accuracy than periapical radiographs in identifying interradicular bone loss.[13,14] Another study concluded that CBCT images of maxillary molars offer comprehensive details on furcation involvement, providing a dependable foundation for making treatment decisions.[11] Additionally, 2D radiographs may not be sufficient in detecting intra-bony alveolar defects because the cortical plate can obstruct changes in spongy bone. Therefore, 3D imaging is necessary to accurately outline the alveolar defects.[8] It can be concluded that CBCT images offer extra details, including the dimensions of bony defects in the buccolingual direction, the number of bony walls present at different levels of the defect, and the presence or absence of dehiscences and/or fenestrations[15,16] (**Fig. 3**A and B).

The 2017 American Academy of Periodontology consensus supports a combination of 2D radiographic series and clinical probing as the gold standard for periodontal evaluation. However, CBCT imaging is recognized as beneficial in specific cases, such as detecting advanced furcation lesions, assessing dental implant options, and diagnosing complex conditions.[17] Ongoing research demonstrates the increasing

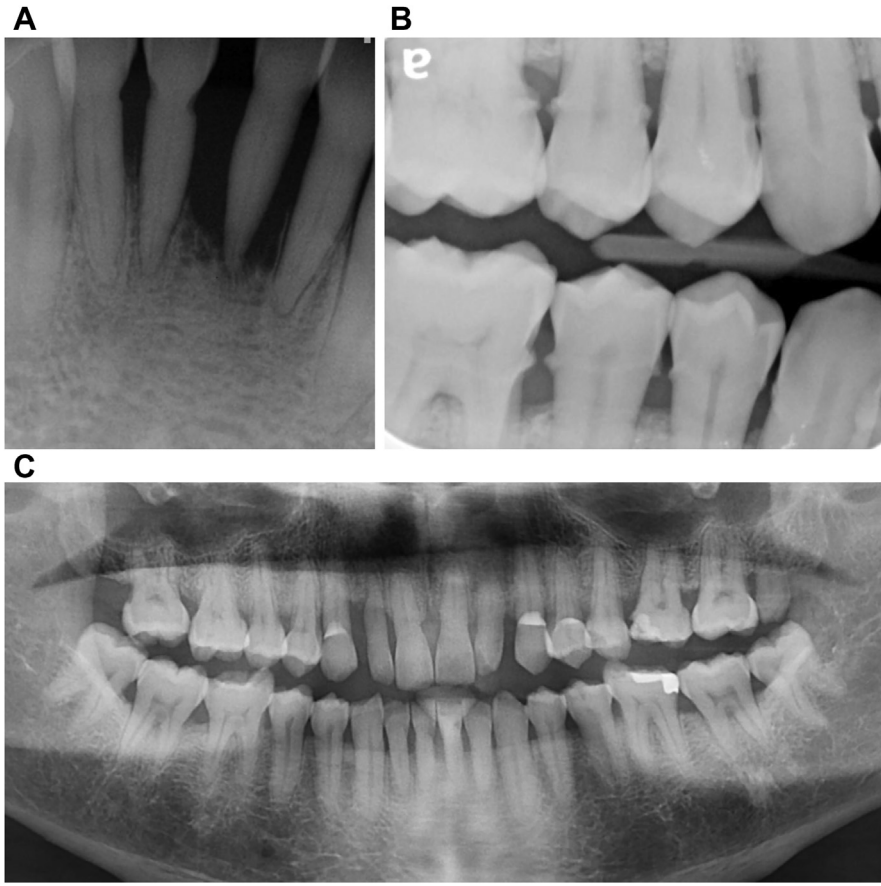

Fig. 1. Conventional 2D Radiographs. (*A*) Periapical view showing severe marginal bone resorption around the mandibular incisors. (*B*) Horizontal bitewing showing generalized interproximal calculus buildup. (*C*) Panoramic view provides a broad view of the dentition and marginal periodontium.

value of CBCT in certain clinical scenarios, providing valuable insights for the profession.[17] More research is needed to validate its benefits and address potential limitations. While offering valuable information, thorough evaluation of the expenses and radiation exposure compared to the conventional radiographs is essential before incorporating CBCT into routine clinical practice.[4,12]

RADIOGRAPHIC IMAGING IN DENTAL IMPLANT

Radiographic examination is a fundamental step in implant planning because it provides essential information about the patient's anatomy, bone quality, and dimensions of the implant site. It helps to determine the most accurate Implant position and plan the procedure accordingly.[18–21] While panoramic and intraoral periapical radiographs can provide valuable information, they have limitations (**Fig. 4**A–C, **5**A and B). 2D imaging can suffer from distortion, magnification, and elongation, which may affect the accuracy of dimensional measurements and can lead to potential errors during treatment planning. CBCT addresses the limitations of 2D imaging and offers superior

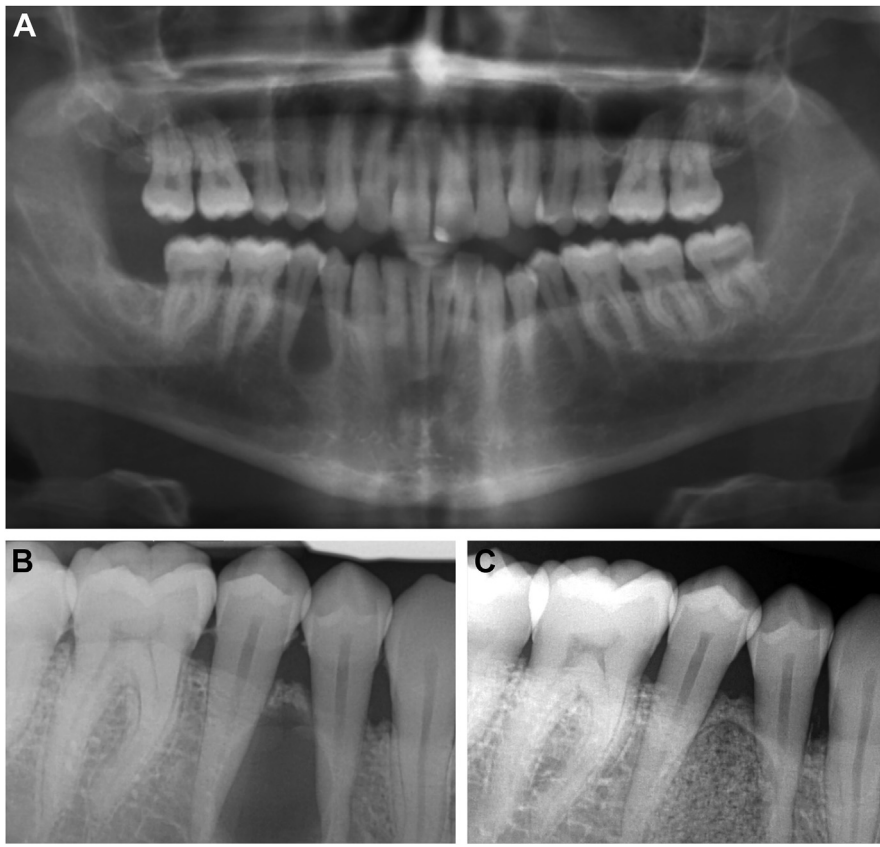

Fig. 2. (*A*) Panoramic view shows a well-defined, radiolucent lesion between the mandibular right premolars. (*B*) Periapical image shows the same lesion. (*C*) Periapical image shows the bone healing 3 months after enucleation and bone grafting. The histologic study revealed a lateral periodontal cyst.

image quality. It provides detailed cross-sectional images that enable precise measurements of alveolar ridge width, height, and angulation.[19,20] CBCT is particularly useful in assessing complex anatomy where accurate measurements are crucial for successful and safe implant placement (**Fig. 6**A–D). Moreover, CBCT when combined with computer guidance is a powerful tool that enhances the entire implant therapy process. It facilitates proper coordination between the diagnostic, surgical, and prosthetic aspects, leading to more predictable outcomes for patients undergoing dental implant treatment[22] (**Fig. 7**A–D, **8**A–E). The choice of radiographic modality for postoperative assessment of dental implants depends on the complexity of the case and the specific clinical circumstances. Intraoral periapical radiographs are suitable for routine assessment of individual implants, while panoramic radiographs can provide an overview of multiple implants. However, in cases of complications like local infection or nerve injury, CBCT imaging is indicated to obtain more detailed information and aid in appropriate management.[23] There is a consensus among dental implant societies that thorough clinical examination and 2D radiographs are the first steps in assessing an implant site.[18–22,24,25] However, when more detailed information is required for complex cases, CBCT is considered superior to 2D radiographs.[19,20,24]

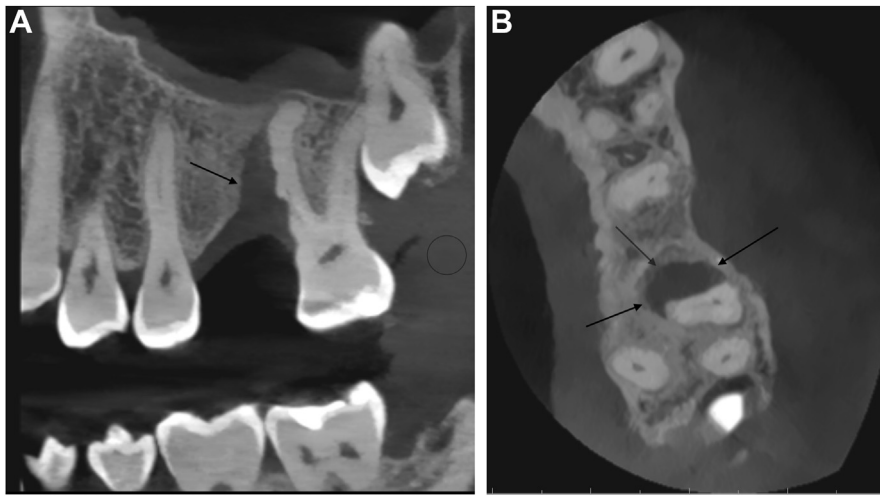

Fig. 3. Limited field-of-view (FOV) CBCT scan. (*A*) Sagittal CBCT image shows a deep, infrabony defect along the mesial root of the maxillary second M (*arrow*). (*B*) Axial CBCT section reveals a three-walled vertical defect (*arrow*).

The use of CBCT should be justified based on the individual patient's needs, and radiation dose optimization is essential to minimize risks.[18,20,26] Reviewing the CBCT data by a skilled healthcare provider is also emphasized to ensure accurate interpretation and diagnosis.[18,20,25] Different organizations have specific recommendations for when to use CBCT, with some suggesting it only in critical anatomic situations and guided surgery,[18–20,22,24] while others advocate for its use in most treatment cases.[25]

PERI-IMPLANTITIS

Dental implants are widely regarded as a viable and enduring solution for the replacement of missing teeth.[27] High survival rates, ranging from 95% to 98% over a 10-year period, have been reported.[28] Nevertheless, their utilization is accompanied by a range of complications, with biological complications being the most frequently encountered. These include soft tissue dehiscence, marginal bone loss, peri-implant mucositis, and peri-implantitis.[29] Peri-implantitis refers to a persistent inflammatory condition that leads to the deterioration of the tissues encompassing the dental implant.[30] The

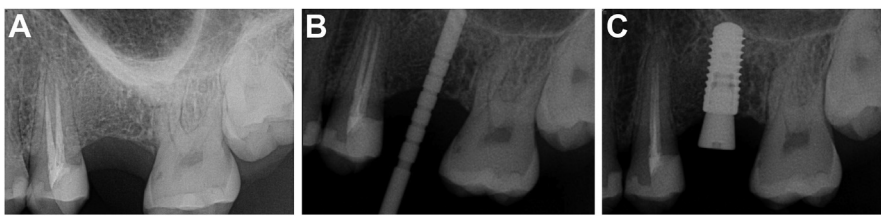

Fig. 4. (*A*) Periapical view shows the available alveolar bone height and mesiodistal width at the proposed implant site. (*B*) Radiographic stent indicating the intended implant's mesiodistal angulation and osteotomy depth. (*C*) Immediate postoperative evaluation of implant placement.

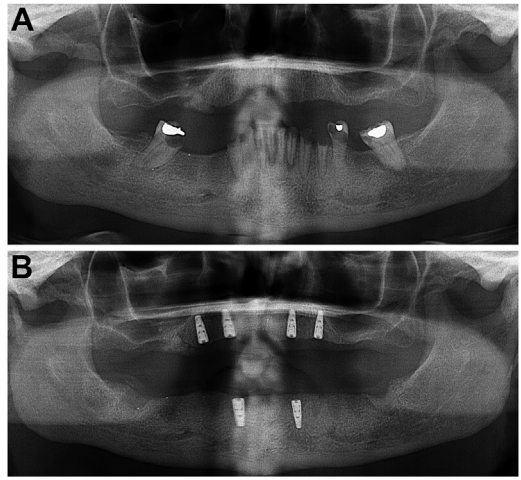

Fig. 5. (*A*) Panoramic radiograph shows multiple missing and grossly decayed teeth associated with generalized alveolar bone resorption. (*B*) Postoperative image showing multiple implant placement in both arches for overdentures.

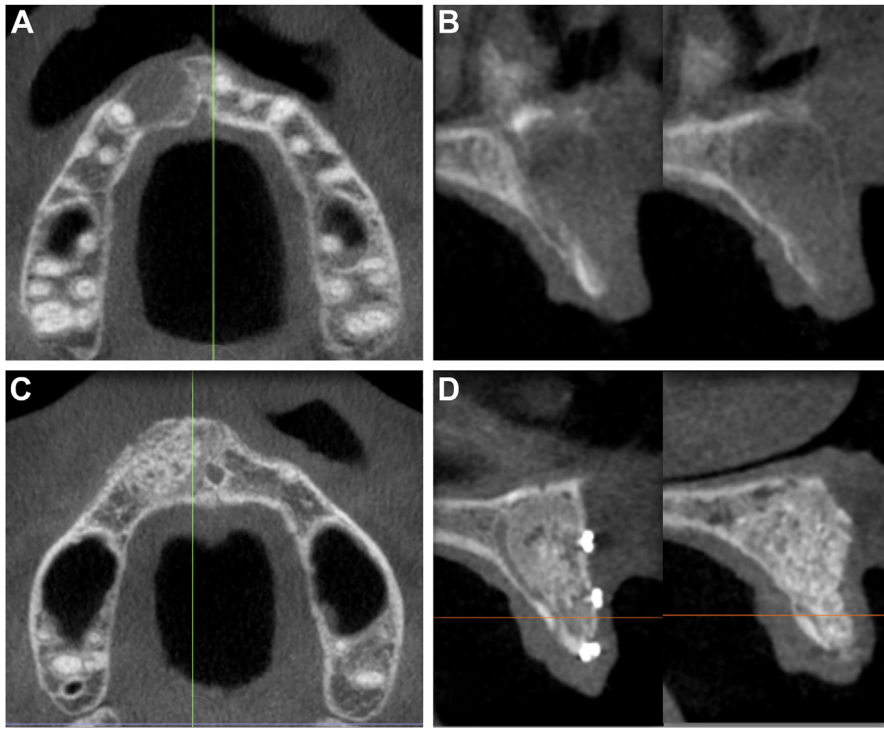

Fig. 6. (*A*) Axial CBCT view shows a large cyst in the right anterior maxilla. (*B*) Cross-sectional CBCT images show the cyst has caused expansion and erosion of the facial plate. (*C* and *D*), Axial and cross-sectional images show bone healing 6 months after a successful guided bone regeneration procedure.

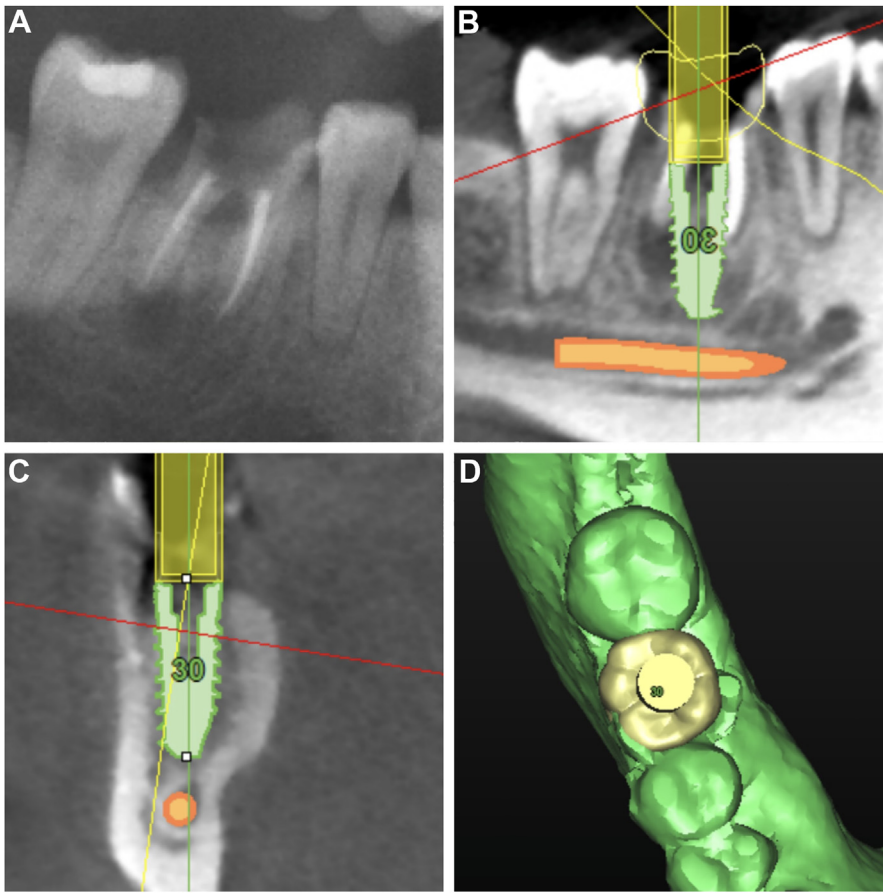

Fig. 7. (*A*) Periapical image shows a non-restorable mandibular first molar. (*B-D*), CBCT images show virtual digital planning taking into consideration the future crown and site anatomy.

prevalence of peri-implantitis varies significantly, spanning from 2.7% to 47.1%. This wide range can be attributed to various etiologic factors and different disease definitions related to peri-implant conditions.[27] Signs of peri-implant tissue inflammation, such as deep probing depth or bleeding upon probing, in conjunction with progressive bone loss, are commonly observed in implants affected by this ailment.[31] Tissue inflammation, which involves symptoms like redness, swelling, and enlargement of the mucosal tissue, is commonly observed in both peri-implant mucositis and peri-implantitis. However, the key distinguishing factor for peri-implantitis is the presence of radiographic bone loss.[32] Previous study by Derks and colleagues (2016) demonstrated that peri-implantitis might develop soon after implant placement. Fifty-two percent of the implants showed early signs of bone loss (>0.5 mm) after the second year of placement, while 66% of implants exhibited bone loss after the third year in function.[33] The 2017 world workshop established that peri-implantitis diagnosis requires the presence of bleeding and/or suppuration on gentle probing, increased probing depth compared to previous examinations, and bone loss beyond crestal bone level changes resulting from initial bone remodeling.[34] In the absence of previous

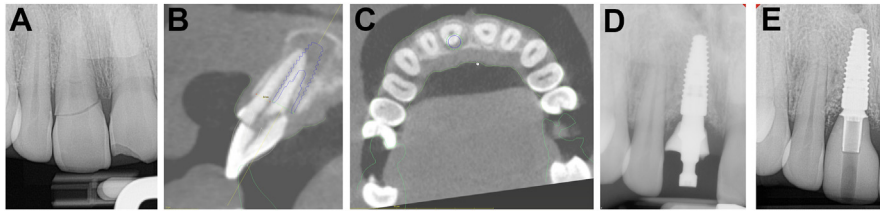

Fig. 8. (*A*) Periapical image shows a horizontal fracture in the maxillary right central incisor caused by a traumatic injury. (*B*) Cross-sectional CBCT image provides additional details about the buccal bone and root position in the alveolar bone. (*C*) Axial CBCT section demonstrates bucco-palatal position of the proposed implant site. (*D*) Immediate postoperative periapical view showing placed implant with a customized healing abutment attached. (*E*) 13-month follow-up periapical view demonstrating crestal bone stability.

examination data, peri-implantitis can be diagnosed based on the combination of bleeding and/or suppuration on probing, probing depths of more than or equal to 6 mm, and bone levels more than or equal to 3 mm apical to the intra-osseous part of the implant.[34]

RADIOGRAPHIC IMAGING IN PERI-IMPLANTITIS

The marginal bone around the implant crestal region serves as a crucial indicator of implant health. Measurement of the crestal bone level during initial surgery and subsequent radiographic evaluations are common methods to assess bone loss.[35] According to Froum and colleagues (2012), peri-implantitis severity was classified into 3 main categories based on probing depth and the amount of bone loss: early, moderate, and advanced. In the early stage, bone loss is less than or equal to 25% of the implant length, in the moderate stage, it ranges from 25% to 50% of the implant length, and in the advanced stage, bone loss exceeds 50% of the implant length.[36] The shape of the peri-implant defect plays a crucial role in interventions aimed at stopping and managing peri-implantitis.[37] Various radiographic techniques are available to assess the success of dental implants.[38] IRs are currently considered the standard method for assessing the marginal bone level around implants, which serves as the key indicator of peri-implantitis.[34] Additionally, panoramic radiographs can also be used for diagnosing peri-implantitis.[26] While IRs are sufficient for displaying the superimposed interproximal bone level, they lack the capability to visualize the facial and lingual/palatal bone[39] (**Fig. 9**A and B). However, 3D radiographs such as CBCT, enable the evaluation of all 4 bony walls of the defect, are considered superior to the 2D radiographs.[35] Moreover, CBCT provides enhanced information by allowing the evaluation of buccal and lingual bone plates around implants in both vertical and horizontal dimensions[40] (**Fig. 10**A–C). A study by Ritter and colleagues (2017) evaluated the accuracy of 3D CBCT and IRs in visualizing peri-implant bone when compared to histology. The study indicated that both CBCT and IR showed similar results in assessing medial and distal bone levels. However, CBCT proved to be superior in evaluating the oral and buccal bone, though with some limitations.[40] To comprehensively evaluate peri-implant bone dimensions, cross-sectional imaging becomes imperative. Conversely, while CBCT provides 3D images of peri-implant tissues; nonetheless, artifacts from metallic restorations and implants limit image quality and interpretation, particularly in cases with thin bone or potential fenestration/dehiscence.[41]

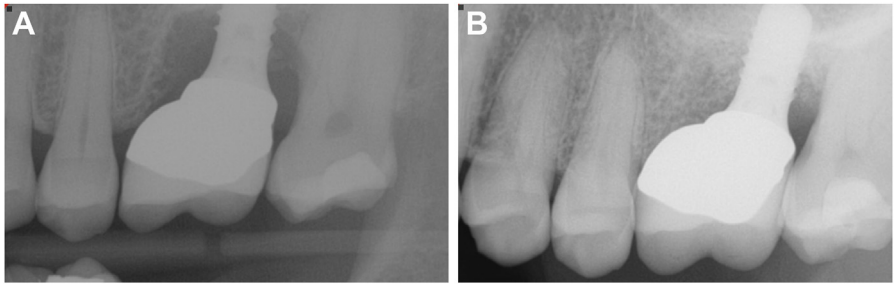

Fig. 9. (*A*) Periapical image for a tissue-level implant showing vertical bone loss on the mesial and distal aspects up to the second thread. (*B*) Six-months postoperative image showing significant bone regeneration following a regenerative procedure.

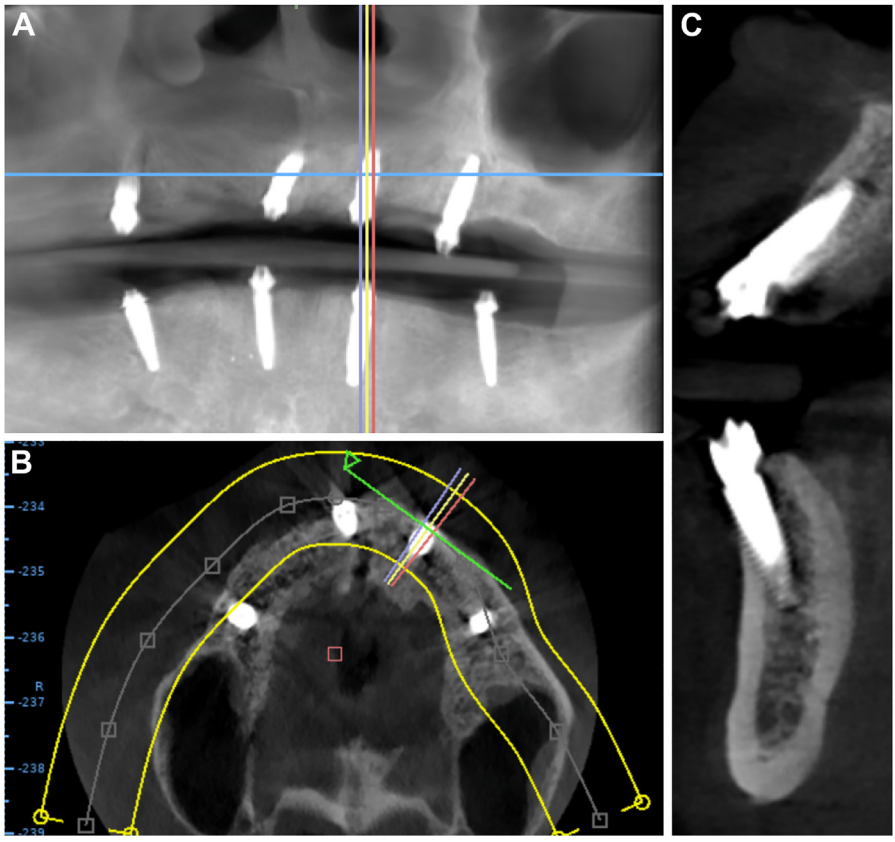

Fig. 10. Follow-up CBCT study for a case of full-arch implant restoration. (*A*) CBCT-reformatted panoramic image. (*B*) Axial view. (*C*) Cross-sectional views show bone loss on the facial aspect of dental implants.

SUMMARY

In conclusion, 2D and 3D radiographic imaging are valuable tool for periodontal and peri-implant disease management. It provides detailed information that can significantly enhance patient care and treatment outcomes. However, its use should be judicious and based on clinical indications to maximize benefits and minimize risks.

CLINICS CARE POINTS

- Radiographic imaging plays a crucial role in diagnosing and managing periodontal diseases. Two-dimensional (2D) radiographs, including bitewing, periapical, and panoramic images are commonly used. However, they have certain limitations, such as overlapping structures and potential underestimation of bone defects. To overcome these limitations, 3-dimensional imaging techniques, such as cone beam computed tomography (CBCT), have been introduced. CBCT offers high-resolution and detailed views. CBCT is particularly valuable in cases with extensive bone loss and furcation involvement.
- Radiographic examination is fundamental for planning and evaluating implant sites. While panoramic and intraoral periapical radiographs can provide valuable information, CBCT is considered superior for complex cases. It also facilitates proper coordination between diagnostic, surgical, and prosthetic aspects, leading to more successful outcomes for dental implant treatment.
- In the context of peri-implantitis, radiographic evaluation of the crestal bone level is crucial. Intraoral radiographs are commonly used for this purpose, but they may not fully visualize the facial and lingual/palatal bone. CBCT, provides a comprehensive evaluation of all bony walls of the defect and allows for better assessment of the buccal and lingual bone plates around implants in both vertical and horizontal dimensions.

REFERENCES

1. Gasner NS, Schure RS. In: Periodontal Disease. Treasure Island, FL: StatPearls Publishing; 2023.
2. Eke PI, Dye B, Wei L, et al, CDC Periodontal Disease Surveillance workgroup: James Beck University of North Carolina, Chapel Hill, USA, Gordon Douglass Past President, American Academy of Periodontology, Roy Page University of Washin. Prevalence of periodontitis in adults in the United States: 2009 and 2010. J Dent Res 2012;91(10):914–20.
3. Kinane DF, Stathopoulou PG, Papapanou PN. Periodontal diseases. Nat Rev Dis Prim 2017;3(1):1–14.
4. Korostoff J, Aratsu A, Kasten B, et al. Radiologic assessment of the periodontal patient. Dental Clinics 2016;60(1):91–104.
5. Scarfe WC, Azevedo B, Pinheiro LR, et al. The emerging role of maxillofacial radiology in the diagnosis and management of patients with complex periodontitis. Periodontology 2000 2017;74(1):116–39.
6. Tugnait A, Clerehugh V, Hirschmann P. The usefulness of radiographs in diagnosis and management of periodontal diseases: a review. J Dent 2000;28(4):219–26.
7. de Faria Vasconcelos K, Evangelista K, Rodrigues C, et al. Detection of periodontal bone loss using cone beam CT and intraoral radiography. Dentomaxillofacial Radiol 2012;41(1):64–9.
8. Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. J Periodontol 2006;77(7):1261–6.

9. Eickholz P, Kim T-S, Benn DK, et al. Validity of radiographic measurement of interproximal bone loss. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998; 85(1):99–106.
10. Du Bois A, Kardachi B, Bartold P. Is there a role for the use of volumetric cone beam computed tomography in periodontics? Aust Dent J 2012;57:103–8.
11. Walter C, Kaner D, Berndt DC, et al. Three-dimensional imaging as a pre-operative tool in decision making for furcation surgery. J Clin Periodontol 2009;36(3): 250–7.
12. Acar B, Kamburoğlu K. Use of cone beam computed tomography in periodontology. World J Radiol 2014;6(5):139.
13. Mengel R, Candir M, Shiratori K, et al. Digital volume tomography in the diagnosis of periodontal defects: an in vitro study on native pig and human mandibles. J Periodontol 2005;76(5):665–73.
14. Noujeim M, Prihoda T, Langlais R, et al. Evaluation of high-resolution cone beam computed tomography in the detection of simulated interradicular bone lesions. Dentomaxillofacial Radiol 2009;38(3):156–62.
15. Braun X, Ritter L, Jervøe-Storm P-M, et al. Diagnostic accuracy of CBCT for periodontal lesions. Clin Oral Invest 2014;18:1229–36.
16. Leung CC, Palomo L, Griffith R, et al. Accuracy and reliability of cone-beam computed tomography for measuring alveolar bone height and detecting bony dehiscences and fenestrations. Am J Orthod Dentofacial Orthop 2010;137(4): S109–19.
17. McAllister BS, Eshraghi VT. Commentary: Cone-Beam Computed Tomography: An Essential Technology for Management of Complex Periodontal and Implant Cases. J Periodontol 2017;88(10):937–8.
18. Academy Of Osseointegration. 2010 Guidelines of the Academy of Osseointegration for the provision of dental implants and associated patient care. Int J Oral Maxillofac Implants 2010;25(3):620–7.
19. Harris D, Horner K, Gröndahl K, et al. EAO guidelines for the use of diagnostic imaging in implant dentistry 2011. A consensus workshop organized by the European Association for Osseointegration at the Medical University of Warsaw. Clin Oral Implants Res 2012;23(11):1243–53.
20. Benavides E, Rios HF, Ganz SD, et al. Use of cone beam computed tomography in implant dentistry: the International Congress of Oral Implantologists consensus report. Implant Dent 2012;21(2):78–86.
21. White SC, Scarfe WC, Schulze RK, et al. The Image Gently in Dentistry campaign: promotion of responsible use of maxillofacial radiology in dentistry for children. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology 2014;118(3): 257–61.
22. Bornstein MM, Scarfe WC, Vaughn VM, et al. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. Int J Oral Maxillofac Implants 2014;29(Suppl):55–77.
23. Omami G, Al Yafi F. Should cone beam computed tomography be routinely obtained in implant planning? Dental Clinics 2019;63(3):363–79.
24. Rios HF, Borgnakke WS, Benavides E. The use of cone-beam computed tomography in management of patients requiring dental implants: an American Academy of Periodontology best evidence review. J Periodontol 2017;88(10):946–59.
25. Fokas G, Vaughn VM, Scarfe WC, et al. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: A systematic review. Clin Oral Implants Res 2018;29:393–415.

26. Ramanauskaite A, Juodzbalys G. Diagnostic principles of peri-implantitis: a systematic review and guidelines for peri-implantitis diagnosis proposal. J Oral Maxillofac Res 2016;7(3):8.
27. Ismail AY, Shaddox LM, Santamaria MP, Al Sabbagh M, Peri-implantitis. A Review to Simplify a Mystifying Disease. Med Res Arch 2022;10(10).
28. Lang NP, Berglundh T, HeitzMayfield LJ, et al. Consensus statements and recommended clinical procedures regarding implant survival and complications. Int J Oral Maxillofac Implants 2004;19(Suppl):150–4.
29. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. J Clin Periodontol 2002;29:197–212.
30. Monje A, Galindo-Moreno P, Tözüm TF, et al. Into the Paradigm of Local Factors as Contributors for Peri-implant Disease: Short Communication. Int J Oral Maxillofac Implants 2016;31(2):288–92.
31. Schwarz F, Derks J, Monje A, et al. Peri-implantitis. J Clin Periodontol 2018;45: S246–66.
32. Lindhe J, Meyle J, GDotEWo Periodontology. Peri-implant diseases: consensus report of the sixth European workshop on periodontology. J Clin Periodontol 2008;35:282–5.
33. Derks J, Schaller D, Håkansson J, et al. Peri-implantitis–onset and pattern of progression. J Clin Periodontol 2016;43(4):383–8.
34. Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol 2018; 89:S313–8.
35. Misch CE, Perel ML, Wang H-L, et al. Implant success, survival, and failure: the International Congress of Oral Implantologists (ICOI) pisa consensus conference. Implant Dent 2008;17(1):5–15.
36. Froum SJ, Rosen PS. A proposed classification for peri-implantitis. Int J Periodontics Restor Dent 2012;32(5):533.
37. Macías Y, Gañán Y, Macías Y, et al. Diagnostic Accuracy of Cone Beam Computed Tomography in Identifying Peri-implantitis–Like Bone Defects Ex Vivo. Int J Periodontics Restorative Dent 2021;41:e223–31.
38. Monsour P, Dudhia R. Implant radiography and radiology. Aust Dent J 2008;53: S11–25.
39. Monje A, Pons R, Insua A, et al. Morphology and severity of peri-implantitis bone defects. Clin Implant Dent Relat Res 2019;21(4):635–43.
40. Ritter L, Elger M, Rothamel D, et al. Accuracy of peri-implant bone evaluation using cone beam CT, digital intra-oral radiographs and histology. Dentomaxillofacial Radiol 2014;43(6):20130088.
41. de-Azevedo-Vaz SL, Peyneau PD, Ramirez-Sotelo LR, et al. Efficacy of a cone beam computed tomography metal artifact reduction algorithm for the detection of peri-implant fenestrations and dehiscences. Oral surgery, oral medicine, oral pathology and oral radiology 2016;121(5):550–6.