AAE and AAOMR Joint Position Statement: Use of Cone-Beam Computed Tomography in Endodontics 2025 Update

The following statement was prepared by the Special Committee to Revise the Joint Position Statement on Cone-Beam Computed Tomography of the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR), and was approved by the AAE Board of Directors and the AAOMR Executive Council in the spring of 2025. (Oral Surg Oral Med Oral Pathol Oral Radiol 2026;141:126−135)

INTRODUCTION

This revised joint position statement from the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) aims to highlight recommendations on applications of cone-beam computed tomography (CBCT) during the various stages of endodontic treatment, incorporating the current evidence-based advancements since the 2015 statement.[1,2] It is important to note that although this position statement provides valuable insights, clinicians should always exercise independent judgment tailored to the unique conditions and individualities of each patient.

It is known that endodontic disease adversely affects the quality of life and can produce significant morbidity in afflicted patients. The success and longevity of an endodontic procedure starts with a correct diagnosis and appropriate treatment planning. The various imaging modalities available to dental practitioners are essential in all stages of the endodontic procedure, including the diagnosis of odontogenic and nonodontogenic pathoses, treatment of the root canal systems of a compromised tooth, biomechanical instrumentation, evaluation of final canal obturation, and assessment of healing.

Contemporary imaging modality options are no longer limited to intraoral and panoramic radiography. Though 2D imaging modalities are still extremely relevant, complex anatomy and surrounding structures can render interpretation of planar images difficult. In those situations, CBCT scans have been proven useful, giving providers the ability to assess the relationship of anatomic structures in three dimensions. It is paramount to emphasize that CBCT should still not be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. Dental practitioners should use CBCT only when they have reasonably concluded that the need for imaging cannot be met by lower dose 2D radiography.

Scanning protocols

Given the diversity of more than 270 CBCT scanner models from more than 45 manufacturers worldwide, the variations in CBCT features and technical specifications may seem overwhelming.[3] To ensure that examinations achieve the desired diagnostic image quality at the lowest possible radiation dose while fully utilizing the equipment's capabilities, it is crucial to adopt well-established, evidence-based CBCT scanning protocols. These protocols primarily focus on selecting the appropriate field of view (FOV) and voxel sizes but also consider the additional parameters of tube current (mA), exposure time (s), tube potential (kVp), degrees of scanner rotation, and the number of projections or basis images.[4,5]

FOV can be defined as the anatomical content visible within the borders of a given 3D scan volume. To the extent practical, it should slightly exceed the dimensions of the region of interest (ROI). The FOV is dependent on the detector size and shape, beam projection geometry, and beam collimation. In general, CBCT scanners can be categorized according to the FOV size that the device can capture into large (>100 cm^2), medium (40 to 100 cm^2) and limited (<40 cm^2) FOV units, with most devices allowing multiple FOV combinations.[6] Generally, the FOV size is directly related to the radiation dose associated with the study. The reported effective doses range from 5 to 652 μSv for limited and from 46 to 1,073 μSv for large FOV.[7] In conjunction with the higher effective doses for the patients, large FOV scans often result in lower image resolution due to scatter radiation generated by the large area being irradiated which then interacts with the active portion of the image detector.[8]

CBCT scanners can also be categorized according to the size of the voxel. The majority of currently available scanners provide isotropic voxel sizes varying between 0.05 mm and 0.6 mm.[3] The smaller the voxel size, the higher the spatial resolution but also the higher the image noise. To maintain an adequate signal-to-noise level, the exposure will automatically increase as the voxel size is reduced to create higher resolution images. Generally, the demand for a very high level of detail and accuracy requires a smaller voxel size to be selected.[9]

Endodontics clinical case imaging usually involves a ROI limited to a few teeth and the adjacent supporting structures. Limited FOV CBCT scans with their lower effective dose, inherently higher spatial resolution, and smaller volume sizes requiring interpretation may therefore be the most appropriate. If it is apparent or

suspected that pathoses extend beyond the associated area surrounding the root apices or the borders of the volume, a larger FOV scan may be indicated. Similarly, if a multifocal lesion with possible systemic etiology is noted, and/or a nonendodontic etiology for devitalization of one or more teeth is established clinically, appropriate larger FOV protocols may be employed on a case-by-case basis.

In recent years, there has been growing interest in optimizing CBCT protocols to reduce patient radiation exposure, with increasing attention to low-dose and ultra-low-dose settings. However, this trend must be balanced with diagnostic needs. Two studies reported that high-resolution CBCT protocols, which are typically associated with an increase in radiation dose, were preferred by endodontists for diagnostic clarity[10] as well as in vitro research settings where image detail is critical.[11] Another study demonstrated that using a limited FOV combined with high-resolution settings improved the detection of fine endodontic structures and root fractures, particularly in the absence of high-density objects that may cause artifacts.[12] In contrast, a separate investigation shows that low-dose protocols could still maintain acceptable diagnostic efficacy for a range of endodontic tasks.[13] These findings underscore the importance of tailoring CBCT acquisition parameters to the clinical task at hand, balancing the trade-off between dose reduction and diagnostic quality.

Image artifacts

The diagnostic quality of a CBCT scan can be adversely affected by artifacts that are inherent to the image capture process. Characteristic artifacts such as scatter, partial volume averaging and the cone beam effect are due to a combination of the lower energy X-ray beam spectrum used, the geometry of the beam, FOV size, and/or the lack of postpatient collimation employed in multidetector computed tomography scans. Selecting smaller acquisition voxels can reduce partial volume averaging artifacts, and positioning the ROI in the axial plane of the X-ray beam will reduce the cone beam effect.

Scanner component-related artifacts can be seen in the radiographic images as ring or circular-shaped distortions that result from imperfections in the detector or lack of proper detector calibration.[14] Periodic calibration of CBCT units is necessary and should follow the manufacturer's recommendations. Motion artifacts are one of the most common causes necessitating the retake of CBCT scans.[15] These artifacts are caused by voluntary or involuntary patient movement during image acquisition and can be best minimized by using head stabilizers, chin cups, and having the patient seated during the scan.

The presence of high-density materials, such as metallic restorations and gutta-percha, can cause significant image artifacts that compromise the assessment of root canal anatomy, the diagnosis of relevant pathoses, and the detection of root fractures, especially in endodontically treated teeth. These introduced artifacts are due to beam hardening (absorption of low energy X-ray photons from the beam) that appear as hypodense (very dark/radiolucent) areas or lines and metal streaking artifact (nearly complete absorption of the beam photons) that appears as hyperdense (very light/radiopaque) rays radiating out from dense materials.[16] Positioning the ROI in the center and closer to the anterior portion of a limited FOV volume has been shown to improve the detection of root fracture by decreasing artifact interferences.[5]

Metal artifact reduction can be addressed by the use of postprocessing algorithms that smooth the volume images and approximate the density of the structures overlaid by the artifact streaks and rays as seen in the affected images.[17] These correction algorithms function best with scans captured using 360 degrees rotation[18] and when the dense object is positioned in the center of the FOV.[19] These programs are effective for compensating artifacts generated by metal objects and provide limited compensation for artifacts associated with gutta-percha root-filling materials.

Radiation safety

Dental practitioners should consider that the effective radiation dose associated with a CBCT study is inherently higher than that of intraoral radiography. However, it is important to recognize recent studies, including those utilizing CBCT scans in pediatric populations, have demonstrated that although low doses of ionizing radiation can induce DNA double-strand breaks in some instances, the resulting DNA damage can be effectively repaired and may not impair cell cycle progression or induce premature cellular senescence.[20,21]

With that in mind, contemporary discourse has increasingly emphasized the importance of optimization rather than mere minimization of radiation doses.[22] This shift underscores the need to maintain radiation exposure at levels that are as low as diagnostically acceptable, ensuring sufficient diagnostic quality while considering clinical indication and patient-specific factors.[23] By implementing this approach, providers can achieve a balance between radiation safety and the diagnostic utility of CBCT imaging.[24]

To attain this level of personalized optimization, CBCT protocols must be tailored to balance diagnostic efficacy (image quality) with radiation safety (dose reduction), particularly in pediatric patients.[25] Research has demonstrated that reductions in tube current and exposure time (mAs) can be implemented without compromising the diagnostic utility of CBCT

images. Therefore, individualized imaging protocols should be employed based on patient age and size to optimize the trade-off between radiation exposure and diagnostic accuracy.[13,25,26] Challenging endodontic diagnostic tasks requiring high-resolution images may need a slightly higher dose to yield appropriate signal-to-noise ratio, but this may not be a requirement in all cases. Standard protocols may be sufficient for routine diagnosis, thus enabling dose optimization. However, there is a lack of studies that unequivocally support the use of standard protocols for all applications.[11,27,28]

Although the emphasis on exposure parameters seems to be the main focus of published studies aimed at optimizing dose protocols, the use of lead aprons has recently been the subject of discussion by the American Dental Association (ADA) and AAOMR, with both organizations concluding that the use of lead aprons and thyroid collars for radiation protection in maxillofacial imaging has become obsolete and is no longer recommended.[29,30] However, it must be borne in mind that some states still require the use of lead aprons and/or thyroid collars, and dental practitioners should be aware of and in compliance with the guidelines, practice acts, and laws in the states in which they practice.

There is a special concern with overexposing patients younger than 18 years of age to radiation, especially with the increased use of CT in medical imaging. The AAE and AAOMR are member organizations and continue to support the Image Gently Alliance, which advocates for safe, high-quality pediatric imaging through optimization of imaging doses for each patient.

Training and interpretation

Effective utilization of CBCT in dental practice requires advanced knowledge and skills beyond conventional 2D radiography. A primary challenge is differentiating image artifacts from anatomical structures and pathologic findings. Practitioners must also recognize normal anatomic variations and radiographic presentations of pathological changes in dental and supporting structures.[31,32]

To maximize diagnostic efficacy, clinicians must understand CBCT acquisition, software manipulation, sequential viewing techniques, and structured radiographic reporting. Important training areas could include CBCT fundamentals, case selection, exposure optimization, 3D anatomical interpretation, artifact recognition, and familiarity with emerging advancements in CBCT technology.[33,34]

The AAE and AAOMR strive to aid practitioners in developing their radiographic imaging and interpreting expertise so they may provide evidence-based dental care for their patients. Both organizations support cooperation among the endodontic and oral and maxillofacial radiology programs at dental education institutions to develop teaching content addressing the concepts presented in this statement for the predoctoral, postdoctoral, and current dental health care practitioner audiences.[35,36] The AAE and AAOMR also encourage their members to participate in accredited continuing dental education CBCT courses and consult certified oral and maxillofacial radiologists for the identification, clarification, and significance of visible findings within the images of any imaging modality, when necessary.

RECOMMENDATIONS

CBCT imaging provides additional information when compared to periapical radiographs and has a significant impact on the diagnosis, treatment planning, and outcome assessment of endodontic disease. The following recommendations are for limited FOV CBCT scans and are predicated on the completion of a comprehensive clinical evaluation.

Diagnosis and preoperative treatment

Endodontic diagnosis is dependent upon thorough evaluation of the patient's chief complaint, history and clinical and radiographic examination. Preoperative radiographs are an essential part of the diagnostic phase of endodontic therapy. Accurate diagnostic imaging supports clinical diagnosis.

Recommendation 1: *Limited FOV CBCT should be the preferred imaging modality for preoperative diagnosis in patients who present with contradictory or nonspecific clinical symptoms and/or radiographic signs associated with untreated or previously endodontically treated teeth. Bitewings and/or periapical radiographs may be utilized to complement CBCT imaging when there are limitations in caries detection and/or extent due to image artifact.*

Rationale

- Preoperative imaging plays a critical role in the diagnostic and treatment processes for endodontic cases.
- In some cases, clinical and planar radiographic examinations are inconclusive. The inability to confidently determine the etiology of endodontic pathosis may be attributed to limitations in both vitality testing and intraoral radiographs to detect odontogenic pathoses. CBCT imaging provides the ability to detect periapical pathosis before it is apparent on 2D radiographs.[37]
- Preoperative factors determined by CBCT imaging such as the presence and true size of a periapical lesion play an important role in the endodontic treatment outcome.[38]
- Several clinical studies have validated that CBCT imaging is more sensitive to primary endodontic

disease detection by more than 50% when compared to intraoral radiographs.[39,40]
- Ex vivo experiments in which simulated periapical lesions were created yielded similar results.[41,42]
- Results of in vivo animal studies, using histologic assessments as the gold standard, also showed similar results observed in human clinical and ex vivo studies.[43]
- CBCT imaging is crucial in the diagnosis of persistent intraoral pain (i.e., atypical odontalgia) following root canal therapy.[44]
- When comparing the diagnostic yield of conventional intraoral radiographs and CBCT imaging, CBCT imaging provided a higher diagnostic yield in differentiating between patients presenting with suspected atypical odontalgia versus symptomatic apical periodontitis when compared to periapical radiographs.[45]

Intraoperative treatment

Recommendation 2: *Limited FOV CBCT should be the preferred imaging modality for intraoperative identification and localization of calcified canals and management of iatrogenic errors.*

Rationale

- Anatomical variations exist among different types of teeth. The success of nonsurgical root canal therapy depends on the identification of canals, cleaning, shaping and obturation of root canal systems, as well as the quality of the final restoration.
- 2D imaging does not consistently reveal the actual number of roots and canals. In studies, data acquired by CBCT showed a very strong correlation between sectioning and histological examination.[46]
- CBCT showed higher mean values of specificity and sensitivity when compared to intraoral radiographic assessments in the detection of extra canals.[47,48]

Postoperative treatment

Recommendation 3: *Intraoral radiographs should be the preferred imaging modality for immediate postoperative imaging. However, in cases with complications, a limited FOV CBCT is considered the preferred imaging modality.*

Nonsurgical retreatment

Recommendation 4: *Limited FOV CBCT should be the preferred imaging modality if clinical examination and 2D intraoral radiography are inconclusive in the detection of vertical root fracture.*

Rationale

- In nonsurgical retreatment, the presence of a vertical root fracture significantly decreases prognosis. In the majority of cases, the indication of a vertical root fracture is more often due to the specific pattern of bone loss and periodontal ligament space widening than direct visualization of the fracture.[49] CBCT may be recommended for the diagnosis of vertical root fracture in unrestored teeth when clinical signs and symptoms exist.
- Higher sensitivity and specificity were observed in a clinical study where the definitive diagnosis of vertical root fracture was confirmed at the time of surgery to validate CBCT findings, with sensitivity being 88% and specificity 75%.[50] Several case series studies have concluded that CBCT is a useful tool for the diagnosis of vertical root fractures. In vivo and laboratory studies[51,52] evaluating CBCT in the detection of vertical root fractures agreed that sensitivity, specificity, and accuracy of CBCT were generally higher and reproducible. The detection of fractures was significantly higher for all CBCT systems when compared to intraoral radiographs. However, these results should be interpreted with caution because the detection of vertical root fracture is dependent on the size of the fracture, presence of artifacts caused by obturation materials and posts, and the spatial resolution of the CBCT.

Recommendation 5: *Limited FOV CBCT should be the preferred imaging modality when evaluating the nonhealing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical, or extraction.*

Recommendation 6: *Limited FOV CBCT should be the preferred imaging modality for nonsurgical retreatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.*

Rationale

- It is important to evaluate the factors that impact the outcome of root canal treatment. The outcome predictors identified with periapical radiographs and CBCT have previously evaluated,[53] and the results showed that periapical radiographs detected periapical lesions in 18 roots (12%) as compared to 37 on CBCT scans (25%). Eighty percent of apparently short root fillings based on intraoral radiograph images appeared flush on CBCT. Treatment outcome, length and density of root fillings, and outcome predictors determined by CBCT showed different values when compared with intraoral radiographs.

- CBCT allows for the identification of individual roots of multirooted teeth associated with periapical pathosis to initiate selective nonsurgical retreatment. A retrospective study demonstrated that selective nonsurgical retreatment resulted in a favorable outcome for 92.6% of individual roots and 86.7% of teeth after a minimum 1-year follow-up.[54]
- Targeted nonsurgical retreatment using guided techniques relies on CBCT for treatment planning. Guided approaches for complicated retreatment scenarios may be advantageous by preserving dentin compared to conventional retreatment.[55]
- Accurate treatment planning is an essential part of endodontic retreatment. Incorrect, delayed, or inadequate endodontic diagnosis and treatment planning place the patient at risk and may result in unnecessary treatment. Treatment planning decisions using CBCT versus intraoral radiographs were compared to the gold standard diagnosis.[56] An accurate diagnosis was reached in 36%-40% of the cases with intraoral radiographs compared to 76%-83% with CBCT. A high level of misdiagnosis was noted in invasive cervical resorption and vertical root fracture. In this study, the examiners altered their treatment plan after reviewing the CBCT in 56%-62.2% of the cases, thus indicating the significant influence of CBCT.

Surgical retreatment

Recommendation 7: *Limited FOV CBCT should be the preferred imaging modality for presurgical treatment planning to localize the root apex/apices and evaluate the proximity of adjacent anatomical structures.*

Rationale

- It is important to evaluate the factors that impact the outcome of root canal treatment. The use of CBCT has been recommended for treatment planning for endodontic surgery.[57,58] CBCT visualization of the true extent of periapical lesions and their proximity to important vital structures and anatomical landmarks is superior to that of periapical radiographs.
- Accurate measurements of the dento-alveolar structures are imperative for advances in endodontic microsurgery, such as the use of guided surgical retreatment techniques, including static[59,60] or dynamic navigation[61] approaches, and the application of piezo-surgery supported bone window/lid techniques[62,63] facilitating access to areas surrounded by vital anatomical structures or with limited accessibility.

Special conditions

Implant Placement

Recommendation 8: *Limited FOV CBCT should be the preferred imaging modality for surgical placement of implants.*[64]

Traumatic Injuries

Recommendation 9: *Limited FOV CBCT should be the preferred imaging modality for diagnosis and management of localized dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth, in the absence of other extensive maxillofacial or soft tissue injuries that may require other appropriate advanced imaging modalities.*[65]

Rationale

- Facial CT remains the gold standard for characterizing facial fractures in blunt trauma cases within the United States. Extensive evidence supports its efficacy as a screening tool, including recent considerations for pediatric patients. CT has replaced radiographs for the initial imaging evaluation of suspected bone injury because 2D radiographs cannot characterize the full extent of fractures and luxations.[66,67]
- The American Association of Physicists in Medicine's (AAPM) 2023 Position Statement states "there is a theoretical bioeffect associated with any level of radiation dose. . . . The anticipated benefits to the patient from necessary diagnostic imaging substantially outweigh any potential radiation effect."[68]
- Recent research, including in vivo investigations, underscores the superiority of CBCT imaging over conventional radiographic techniques (periapical radiographs and occlusal radiographs) in diagnosing and managing traumatic dental injuries as proposed in the Trauma Guidelines.[69-71]
- Notably, CBCT imaging is indispensable in diagnosing injuries such as luxation injuries and alveolar fractures, which may go undetected with traditional radiographic methods. Periapical radiographs' limited FOV poses risks of misdiagnosis, especially in cases involving multiple teeth or foreign body presence in soft tissues. Misdiagnosis of alveolar fracture (not detected with periapical radiographs) and root fractures will influence the decision for splinting treatment and splinting times.[65,69,72]
- CBCT consistently exhibits higher sensitivity, particularly in identifying traumatic dental injury cases, lateral luxation, extrusions, and cortical plate fractures. Additionally, CBCT enhances

clinician confidence, intra-examiner agreement, and significantly alters management decisions in most cases.[17,69]

Resorptive defects

Recommendation 10: *Limited FOV CBCT should be the preferred imaging modality for the localization and differentiation of external and internal resorptive defects and the determination of appropriate treatment and prognosis.*[73-75]

Outcome assessment

Recommendation 11: *In the absence of clinical signs or symptoms, intraoral radiographs should be the preferred imaging modality for the evaluation of healing following nonsurgical and surgical endodontic treatment.*

Recommendation 12: *In the absence of clinical signs and symptoms, limited FOV CBCT may be the most appropriate modality for follow-up evaluation if it was indicated for the initial evaluation. In the presence of signs and symptoms, refer to Recommendation 5.*

Rationale

- Use of limited FOV CBCT for evaluation of healing following nonsurgical and surgical treatment must be considered on a case-by-case basis, with due consideration given to the risks and benefits of exposing the patient to ionizing radiation, the patient's history, clinical findings, mode of endodontic intervention, pre-existing radiographic appearance, temporal changes, and any other systemic or extraneous factors that could confound the healing process.[76]
- Accurate diagnosis of complete and uneventful healing as determined radiographically, with unequivocal clinical correlation supporting the radiographic diagnosis, is challenging.[77-80] The healing process is dependent on various factors, both extraneous and host related. In the future, once the parameters associated with healing are fully confirmed by evidence-based studies, the use of limited FOV CBCT for outcome assessment can be substantiated.

Future directions

The Digital Imaging and Communications in Medicine (DICOM) standards provide interoperability among various CBCT systems and promote seamless communication and data transfer with upcoming clinical applications, such as augmented and virtual reality enabled devices, and technology based on artificial intelligence.[81] These solutions driven by artificial intelligence for clinical practice have already demonstrated successful applications, such as complete CBCT segmentation and periapical lesion detection,[82,83] the detection of cracks and fractures[84] or external cervical root resorption,[85] the identification of the mandibular nerve canal,[86] or the classification of root canal morphology such as for the mesiobuccal root of first maxillary molars[87] or C-shapes in second mandibular molars.[88] Moreover, CBCT imaging will be indicated for treatment planning, outcome assessment[89] and prognostication, and execution of clinical procedures supported by augmented reality, such as for nonsurgical[90] or surgical retreatment,[91] or autonomous robotic procedures.[92]

CONCLUSION

Over the past decade, CBCT has significantly influenced endodontic practice, serving as a tool to enhance diagnostic accuracy and treatment planning. These updated recommendations on the application of CBCT at various stages of endodontic treatment have integrated the latest evidence-based advancements since our 2015 statement.[1,2] Although CBCT offers valuable 3D imaging, its use should be guided by a case-by-case assessment, considering the risks and benefits of ionizing radiation, the patient's medical and dental history, clinical findings, and any existing radiographs. Dental practitioners must exercise independent judgment to ensure that CBCT is applied judiciously, optimizing patient care while adhering to the principles of responsible imaging.

ACKNOWLEDGMENT

Special Committee to Revise the Joint AAE/AAOMR Position Statement:

Saulo L. Sousa Melo, DDS, MSD, PhD, MS, AAOMR Co-Chair, Oregon Health and Science University School of Dentistry, sousamel@ohsu.edu;

Scott Makins, DDS, MS, AAE Co-Chair, University of Texas School of Dentistry at Houston, scott.r.makins@uth.tmc.edu;

Mohamed Fayad, DDS, MS, PhD, AAE Representative, University of Illinois Chicago College of Dentistry, mfayad1@uic.edu;

Anita Gohel, BDS, PhD, AAOMR Representative, University of Florida College of Dentistry, agohel@dental.ufl.edu;

Bradford R. Johnson, DDS, MHPE, AAE Representative, University of Illinois Chicago College of Dentistry, bjohnson@uic.edu;

Sajitha Kalathingal, BDS, DDS, MS, AAOMR Representative, Augusta University Dental College of Georgia, skalathingal@augusta.edu;

Mina Mahdian, DDS, MDSc, AAOMR Liaison, Stony Brook University School of Dental Medicine, mina.mahdian@stonybrookmedicine.edu;

Madhu Nair, BDS, DMD, MS, PhD, AAOMR Representative, Texas A & M University College of Dentistry, mknair@tamu.edu;

Frank Setzer, DDS, DMD, MS, PhD, AAE Representative, University of Pennsylvania School of Dental Medicine, fsetzer@upenn.edu.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Saulo L. Sousa Melo: Conceptualization, Writing – original draft, Writing – review & editing. **Mohamed I. Fayad:** Conceptualization, Writing – original draft, Writing – review & editing. **Anita Gohel:** Conceptualization, Writing – original draft, Writing – review & editing. **Bradford R. Johnson:** Conceptualization, Writing – original draft, Writing – review & editing. **Sajitha Kalathingal:** Conceptualization, Writing – original draft, Writing – review & editing. **Mina Mahdian:** Conceptualization, Writing – original draft, Writing – review & editing. **Madhu Nair:** Conceptualization, Writing – original draft, Writing – review & editing. **Frank C. Setzer:** Conceptualization, Writing – original draft, Writing – review & editing. **Scott R. Makins:** Conceptualization, Writing – original draft, Writing – review & editing.

Saulo L. Sousa Melo, DDS, MSD, PhD,
School of Dentistry, Oregon Health and Science University, Portland, OR, USA
Mohamed I. Fayad, DDS, MS, PhD,
College of Dentistry, University of Illinois Chicago, Chicago, IL, USA
Anita Gohel, BDS, PhD,
College of Dentistry, University of Florida, Gainesville, FL, USA
Bradford R. Johnson, DDS, MHPE,
College of Dentistry, University of Illinois Chicago, Chicago, IL, USA
Sajitha Kalathingal, BDS, DDS, MS,
Dental College of Georgia, Augusta University, Augusta, GA, USA
Mina Mahdian, DDS, MDSc,
School of Dental Medicine, Stony Brook University, Stony Brook, NY, USA
Madhu Nair, BDS, DMD, MS, PhD,
College of Dentistry, Texas A & M University, Dallas, TX, USA
Frank C. Setzer, DDS, DMD, MS, PhD,
School of Dental Medicine, University of Pennsylvania, Philadelphia, PA, USA
Scott R. Makins, DDS, MS
School of Dentistry, University of Texas of Houston, Houston, TX, USA

Corresponding author: Saulo L. Sousa Melo.
sousamel@ohsu.edu

REFERENCES

1. Special Committee to Revise the Joint AAE/AAOMR Position Statement on use of CBCT in Endodontics. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update. *J Endod*. 2015;41(9):1393-1396. https://doi.org/10.1016/j.joen.2015.07.013.
2. Special Committee to Revise the Joint AAE/AAOMR Position Statement on Use of CBCT in Endodontics. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2015;120(4):508-512. https://doi.org/10.1016/j.oooo.2015.07.033.
3. Gaêta-Araujo H, Alzoubi T, Vasconcelos KF, et al. Cone beam computed tomography in dentomaxillofacial radiology: a two-decade overview. *Dentomaxillofac Radiol*. 2020;49(8):20200145. https://doi.org/10.1259/dmfr.20200145.
4. Medical Physics Practice Guideline Task Group-225 of the Professional Council of the AAPM. AAPM Medical Physics Practice Guideline 1.a: CT Protocol management and review practice guideline. *J Appl Clin Med Phys*. 2013;14:3-12. https://doi.org/10.1120/jacmp.v14i5.4462.
5. de Oliveira Pinto MG, Melo SLS, Suassuna FCM, et al. Influence of size of field of view (FOV), position within the FOV, and scanning mode on the detection of root fracture and observer's perception of artifacts in CBCT images. *Dentomaxillofac Radiol*. 2021;50(6):20200563. https://doi.org/10.1259/dmfr.20200563.
6. 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;29:55-77. https://doi.org/10.11607/jomi.2014suppl.g1.4.
7. Ludlow JB, Timothy R, Walker C, et al. Effective dose of dental CBCT - a meta-analysis of published data and additional data for nine CBCT units. *Dentomaxillofac Radiol*. 2015;44:20140197. https://doi.org/10.1259/dmfr.20140197.
8. Pauwels R, Jacobs R, Bogaerts R, et al. Reduction of scatter-induced image noise in cone beam computed tomography: effect of field of view size and position. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2016;121(2):188-195. https://doi.org/10.1016/j.oooo.2015.10.017.
9. Schulze RKW, Drage NA. Cone-beam computed tomography and its applications in dental and maxillofacial radiology. *Clin Radiol*. 2020;75(9):647-657. https://doi.org/10.1016/j.crad.2020.04.006.
10. Cheung MC, Peters OA, Parashos P. Global cone-beam computed tomography adoption, usage and scan interpretation preferences of dentists and endodontists. *Int Endod J*. 2024;57(2):133-145. https://doi.org/10.1111/iej.14000.
11. Candemil AP, Salmon B, Vasconcelos KF, et al. Cone beam CT optimisation for detection of vertical root fracture with metal in the field of view or the exomass. *Sci Rep*. 2021;11(1):19155. https://doi.org/10.1038/s41598-021-98345-6.
12. Pinto JC, Vasconcelos KF, Leite AF, et al. Image quality for visualization of cracks and fine endodontic structures using 10 CBCT devices with various scanning protocols and artefact conditions. *Sci Rep*. 2023;13:4001. https://doi.org/10.1038/s41598-023-31099-5.
13. Yeung AWK, Salmon B, Oenning AC. Lack of testing and adherence to optimized low-dose CBCT protocols for children.

Int J Paediatr Dent. 2025;35:7-10. https://doi.org/10.1111/ipd.13253.
14. Nasseh I, Al-Rawi W. Cone beam computed tomography. *Dent Clin North Am*. 2018;62(3):361-391. https://doi.org/10.1016/j.cden.2018.03.002.
15. Hung K, Hui L, Yeung AWK, et al. Image retake rates of cone beam computed tomography in a dental institution. *Clin Oral Investig*. 2020;24(12):4501-4510. https://doi.org/10.1007/s00784-020-03315-3.
16. Shokri A, Jamalpour MR, Khavid A, et al. Effect of exposure parameters of cone beam computed tomography on metal artifact reduction around the dental implants in various bone densities. *BMC Med Imaging*. 2019;19:34. https://doi.org/10.1186/s12880-019-0334-4.
17. Patel S, Brown J, Pimentel T, et al. Cone beam computed tomography in endodontics - a review of the literature. *Int Endod J*. 2019;52(8):1138-1152. https://doi.org/10.1111/iej.13115.
18. Queiroz PM, Santaella GM, Groppo FC, et al. Metal artifact production and reduction in CBCT with different numbers of basis images. *Imaging Sci Dent*. 2018;48:41-44. https://doi.org/10.5624/isd.2018.48.1.41.
19. Queiroz PM, Santaella GM, da Paz TDJ, et al. Evaluation of a metal artefact reduction tool on different positions of a metal object in the FOV. *Dentomaxillofac Radiol*. 2017;46:20160366. https://doi.org/10.1259/dmfr.20160366.
20. Belmans N, Gilles L, Vermeesen R, et al. Quantification of DNA double strand breaks and oxidation response in children and adults undergoing dental CBCT scan. *Sci Rep*. 2020;10(1):2113. https://doi.org/10.1038/s41598-020-58746-5.
21. Belmans N, Gilles L, Welkenhuysen J, et al. In vitro assessment of the DNA damage response in dental mesenchymal stromal cells following low dose X-ray exposure. *Front Public Health*. 2021;9:584484. https://doi.org/10.3389/fpubh.2021.584484.
22. Oenning AC, Jacobs R, Pauwels R, et al. Cone-beam CT in paediatric dentistry: DIMITRA project position statement. *Pediatr Radiol*. 2018;48:308-316. https://doi.org/10.1007/s00247-017-4012-9.
23. Bushberg JT. Eleventh annual Warren K. Sinclair keynote address-science, radiation protection and NCRP: building on the past, looking to the future. *Health Phys*. 2015;108(2):115-123. https://doi.org/10.1097/HP.0000000000000228.
24. Oenning AC, Jacobs R, Salmon B, et al. ALADAIP, beyond ALARA and towards personalized optimization for paediatric cone-beam CT. *Int J Paediatr Dent*. 2021;31:676-678. https://doi.org/10.1111/ipd.12797.
25. Oenning AC, Pauwels R, Stratis A, et al. Halve the dose while maintaining image quality in paediatric Cone Beam CT. *Sci Rep*. 2019;9(1):5521. https://doi.org/10.1038/s41598-019-41949-w.
26. Yeung AWK, Jacobs R, Bornstein MM. Novel low-dose protocols using cone beam computed tomography in dental medicine: a review focusing on indications, limitations, and future possibilities. *Clin Oral Investig*. 2019;23(6):2573-2581. https://doi.org/10.1007/s00784-019-02907-y.
27. Portelli M, Militi A, Lo Giudice A, et al. 3D assessment of endodontic lesions with a low-dose CBCT protocol. *Dent J (Basel)*. 2020;8(2):51. https://doi.org/10.3390/dj8020051.
28. McGuigan MB, Theodorakou C, Duncan HF, et al. An investigation into dose optimisation for imaging root canal anatomy using cone beam CT. *Dentomaxillofac Radiol*. 2020;49(7):20200072. https://doi.org/10.1259/dmfr.20200072.
29. Benavides E, Bhula A, Gohel A, et al. Patient shielding during dentomaxillofacial radiography: Recommendations from the American Academy of Oral and Maxillofacial Radiology. *J Am Dent Assoc*. 2023;154(9):826-835. https://doi.org/10.1016/j.adaj.2023.06.015.
30. Benavides E, Krecioch JR, Connolly RT, et al. Optimizing radiation safety in dentistry: Clinical recommendations and regulatory considerations. *J Am Dent Assoc*. 2024;155(4):280-293. https://doi.org/10.1016/j.adaj.2023.12.002.
31. Carter L, Farman AG, Geist J, et al. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106(4):561-562. https://doi.org/10.1016/j.tripleo.2008.07.007.
32. Brown J, Jacobs R, Levering Jähagen E, et al. Basic training requirements for use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology. *Dentomaxillofac Radiol*. 2014;43:20130291. https://doi.org/10.1259/dmfr.20130291.
33. Oser DG, Henson BR, Shiang EY, et al. Incidental findings in small field of view cone-beam computed tomography scans. *J Endod*. 2017;43:901-904. https://doi.org/10.1016/j.joen.2017.01.033.
34. Langella J, Finkelman MD, Alon E, et al. Incidental findings in small field of view cone-beam computed tomography scans, Part 2: Interpretation with aid of a checklist. *J Endod*. 2023;49(4):390-394. https://doi.org/10.1016/j.joen.2023.01.006.
35. Beacham JT, Geist JR, Yu Q, et al. Accuracy of cone-beam computed tomographic image interpretation by endodontists and endodontic residents. *J Endod*. 2018;44(4):571-575. https://doi.org/10.1016/j.joen.2017.12.012.
36. Rabiee H, McDonald NJ, Jacobs R, et al. Endodontics program directors', residents', and endodontists' considerations about CBCT-related graduate education. *J Dent Educ*. 2018;82(9):989-999. https://doi.org/10.21815/JDE.018.098.
37. De Paula-Silva FW, Wu MK, Leonardo MR, et al. Accuracy of periapical radiography and cone-beam computed tomography scans in diagnosing apical periodontitis using histopathological findings as a gold standard. *J Endod*. 2009;35(7):1009-1012. https://doi.org/10.1016/j.joen.2009.04.006.
38. Friedman S. Prognosis of initial endodontic therapy. *Endod Topics*. 2002;2:59-98. https://doi.org/10.1034/j.1601-1546.2002.20105.x.
39. Patel S, Wilson R, Dawood A, et al. The detection of periapical pathosis using periapical radiography and cone beam computed tomography – part 1: preoperative status. *Int Endod J*. 2012;8:702-710. https://doi.org/10.1111/j.1365-2591.2011.01989.x.
40. Sogur E, Grondahl H, Bakst G, et al. Does a combination of two radiographs increase accuracy in detecting acid-induced periapical lesions and does it approach the accuracy of cone-beam computed tomography scanning. *J Endod*. 2012;38(2):131-136. https://doi.org/10.1016/j.joen.2011.10.013.
41. Cheung G, Wei L, MvGrath C. Agreement between periapical radiographs and cone-beam computed tomography for assessment of periapical status of root filled molar teeth. *Int Endod J*. 2013;46(10):889-895. https://doi.org/10.1111/iej.12076.
42. Abella F, Patel S, Duran-Sindreu F, et al. Evaluating the periapical status of teeth with irreversible pulpitis by using cone-beam computed tomography scanning and periapical radiographs. *J Endod*. 2012;38(12):1588-1591. https://doi.org/10.1016/j.joen.2012.09.003.
43. Patel S, Dawood A, Mannocci F, et al. Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *Int Endod J*. 2009;42(6):507-515. https://doi.org/10.1111/j.1365-2591.2008.01538.x.

44. Nixdorf D, Moana-Filho E. Persistent dento-alveolar pain disorder (PDAP): Working towards a better understanding. *Rev Pain*. 2011;5(4):18-27. https://doi.org/10.1177/204946371100500404.
45. Pigg M, List T, Petersson K, et al. Diagnostic yield of conventional radiographic and cone beam computed tomographic images in patients with atypical odontalgia. *Int Endod J*. 2011;44(12):1365-2591. https://doi.org/10.1111/j.1365-2591.2011.01923.x.
46. Blattner TC, Goerge N, Lee CC, et al. Efficacy of cone-beam computed tomography as a modality to accurately identify the presence of second mesiobuccal canals in maxillary first and second molars: a pilot study. *J Endod*. 2010;36(5):867-870. https://doi.org/10.1016/j.joen.2009.12.023.
47. Michetti J, Maret D, Mallet J-P, et al. Validation of cone beam computed tomography as a tool to explore root canal anatomy. *J Endod*. 2010;36(7):1187-1190. https://doi.org/10.1016/j.joen.2010.03.029.
48. Aung NM, Myint KW. Diagnostic accuracy of CBCT for detection of second canal of permanent teeth: A systematic review and meta-analysis. *Int J Dent*. 2021;2021:1107471. https://doi.org/10.1155/2021/1107471.
49. Alaugaily I, Azim AA. CBCT patterns of bone loss and clinical predictors for the diagnosis of cracked teeth and teeth with vertical root fracture. *J Endod*. 2022;48(9):1100-1106. https://doi.org/10.1016/j.joen.2022.06.004.
50. Edlund M, Nair MK, Nair UP. Detection of vertical root fractures by using cone-beam computed tomography: a clinical study. *J Endod*. 2011;37(6):768-772. https://doi.org/10.1016/j.joen.2011.02.034.
51. Metska ME, Aartman IH, Wesselink PR, et al. Detection of vertical root fracture in vivo in endodontically treated teeth by cone-beam computed tomography scans. *J Endod*. 2012;38(10):1344-1347. https://doi.org/10.1016/j.joen.2012.05.003.
52. Brady E, Mannocci F, Wilson R, et al. A comparison of CBCT and periapical radiography for the detection of vertical root fractures in non-endodontically treated teeth. *Int Endod J*. 2014;47(8):735-746. https://doi.org/10.1111/iej.12209.
53. Liang H, Li G, Wesselink P, et al. Endodontic outcome predictors identified with periapical radiographs and cone-beam computed tomography scans. *J Endod*. 2011;37(3):326-331. https://doi.org/10.1016/j.joen.2010.11.032.
54. Brochado Martins JF, Guerreiro Viegas O, Cristescu R, et al. Outcome of selective root canal retreatment - a retrospective study. *Int Endod J*. 2023;56(3):345-355. https://doi.org/10.1111/iej.13871.
55. Rohra MR, Shah PB, Arora AV, et al. Evaluation of volumetric substance loss and precision in targeted endodontic re-treatment with guided versus conventional access cavity preparations: an in vitro study. *J Conserv Dent*. 2023;26(2):221-225. https://doi.org/10.4103/jcd.jcd_618_22.
56. Ee J, Fayad IM, Johnson B. Comparison of endodontic diagnosis and treatment planning decisions using cone-beam volumetric tomography versus periapical radiography. *J Endod*. 2014;40(7):910-916. https://doi.org/10.1016/j.joen.2014.03.002.
57. Low KM, Dula K, Bürgin W, et al. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. *J Endod*. 2008;34(5):557-562. https://doi.org/10.1016/j.joen.2008.02.022.
58. Venskutonis T, Plotino G, Tocci L, et al. Periapical and endodontic status scale based on periapical bone lesions and endodontic treatment quality evaluation using cone-beam computed tomography. *J Endod*. 2015;41(2):190-196. https://doi.org/10.1016/j.joen.2014.10.017.
59. Giacomino CM, Ray JJ, Wealleans JA. Targeted endodontic microsurgery: a novel approach to anatomically challenging scenarios using 3-dimensional-printed guides and trephine burs - a report of 3 cases. *J Endod*. 2018;44(4):671-677. https://doi.org/10.1016/j.joen.2017.12.019.
60. Ahn SY, Kim NH, Kim S, et al. Computer-aided design/computer-aided manufacturing-guided endodontic surgery: guided osteotomy and apex localization in a mandibular molar with a thick buccal bone plate. *J Endod*. 2018;44(4):665-670. https://doi.org/10.1016/j.joen.2017.12.009.
61. Martinho FC, Griffin IL, Tordik PA. Piezoelectric device and dynamic navigation system integration for bone window-guided surgery. *J Endod*. 2023;49(12):1698-1705. https://doi.org/10.1016/j.joen.2023.09.013.
62. Lee SM, Yu YH, Wang Y, et al. The application of "bone window" technique in endodontic microsurgery. *J Endod*. 2020;46(6):872-880. https://doi.org/10.1016/j.joen.2020.02.009.
63. Niemczyk SP, Barnett F, Johnson JD, et al. PRESS and piezo microsurgery (bony lid): a 7-year evolution in a residency program part 1: surgeon-defined site location. *J Endod*. 2022;48(6):787-796. https://doi.org/10.1016/j.joen.2022.02.013.
64. Tyndall D, Price J, Tetradis S, et al. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2012;113(6):817-826. https://doi.org/10.1016/j.oooo.2012.03.005.
65. May JJ, Cohenca N, Peters OA. Contemporary management of horizontal root fractures to the permanent dentition: diagnosis, radiologic assessment to include cone-beam computed tomography. *Pediatr Dent*. 2013;35:120-124.
66. Yu BH, Han SM, Sun T, et al. Dynamic changes of facial skeletal fractures with time. *Sci Rep*. 2020;10(1):4001. https://doi.org/10.1038/s41598-020-60725-9.
67. Hanaoka M, Alkhatib S, Deng F, et al. Navigating complex facial trauma: a comprehensive guide to CT-based fracture detection and analysis. In: Knollmann F, ed. *Trauma Computed Tomography*, Springer; 2023:31-41. https://doi.org/10.1007/978-3-031-45746-3_3.
68. American Association of Physicists in Medicine. PS 4-B: AAPM position statement on radiation risks from medical imaging procedures. 2023. https://www.aapm.org/org/policies/details.asp?id=3615.
69. Patel S, Puri T, Mannocci F, et al. Diagnosis and management of traumatic dental injuries using intraoral radiography and cone-beam computed tomography: An in vivo investigation. *J Endod*. 2021;47(6):914-923. https://doi.org/10.1016/j.joen.2021.02.015.
70. Luz LB, Vizzotto MB, Xavier PNI, et al. The impact of cone-beam computed tomography on diagnostic thinking, treatment option, and confidence in dental trauma cases: a before and after study. *J Endod*. 2022;48(3):320-328. https://doi.org/10.1016/j.joen.2021.12.011.
71. Sha X, Jin L, Han J, et al. Comparison between periapical radiography and cone beam computed tomography for the diagnosis of anterior maxillary trauma in children and adolescents. *Dent Traumatol*. 2022;38(1):62-70. https://doi.org/10.1111/edt.12706.
72. Long H, Zhou Y, Ye N, et al. Diagnostic accuracy of CBCT for tooth fractures: a meta-analysis. *J Dent*. 2014;42:240-248. https://doi.org/10.1016/j.jdent.2013.11.024.
73. Durack C, Patel S, Davies J, et al. Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. *Int Endod J*. 2011;44(2):136-147. https://doi.org/10.1111/j.1365-2591.2010.01819.x.
74. Sousa Melo SL, Vasconcelos KF, Holton N, et al. Impact of cone-beam computed tomography scan mode on the diagnostic yield of chemically simulated external root resorption. *Am J*

Orthod Dentofacial Orthop. 2017;151(6):1073-1082. https://doi.org/10.1016/j.ajodo.2016.10.041.
75. Dao V, Mallya SM, Markovic D, et al. Prevalence and characteristics of root resorption identified in cone-beam computed tomography scans. *J Endod*. 2023;49(2):144-154. https://doi.org/10.1016/j.joen.2022.11.006.
76. Sharma G, Abraham D, Gupta A, et al. Comparison of healing assessments of periapical endodontic surgery using conventional radiography and cone-beam computed tomography: a systematic review. *Imaging Sci Dent*. 2022;52(1):1-9. https://doi.org/10.5624/isd.20210195.
77. Tanomaru-Filho M, Jorge EG, Guerreiro-Tanomaru JM, et al. Two- and tridimensional analysis of periapical repair after endodontic surgery. *Clin Oral Investig*. 2015;19(1):17-25. https://doi.org/10.1007/s00784-014-1225-2.
78. von Arx T, Janner SF, Hanni S, et al. Agreement between 2D and 3D radiographic outcomes assessment one year after periapical surgery. *Int Endod J*. 2016;49(10):915-925. https://doi.org/10.1111/iej.12548.
79. Schloss T, Sonntag D, Kohli MR, et al. A comparison of 2- and 3-dimensional healing assessment after endodontic surgery using cone-beam computed tomographic volumes or periapical radiographs. *J Endod*. 2017;43(7):1072-1079. https://doi.org/10.1016/j.joen.2017.02.007.
80. Zhang MM, Fang GF, Chen XT, et al. Four-year outcome of nonsurgical root canal retreatment using cone-beam computed tomography: A prospective cohort study. *J Endod*. 2021;47(3):382-390. https://doi.org/10.1016/j.joen.2020.10.020.
81. Setzer FC, Li J, Khan AA. The use of artificial intelligence in endodontics. *J Dent Res*. 2024;103(9):853-862. https://doi.org/10.1177/00220345241255593.
82. Setzer FC, Shi KJ, Zhang Z, et al. Artificial intelligence for the computer-aided detection of periapical lesions in cone-beam computed tomographic images. *J Endod*. 2020;46(7):987-993. https://doi.org/10.1016/j.joen.2020.03.025.
83. Kirnbauer B, Hadzic A, Jakse N, et al. Automatic detection of periapical osteolytic lesions on cone-beam computed tomography using deep convolutional neuronal networks. *J Endod*. 2022;48(11):1434-1440. https://doi.org/10.1016/j.joen.2022.07.013.
84. Sahu P, Vicory J, McCormick M, et al. Wavelet guided 3D deep model to improve dental microfracture detection. *Appl Med Artif Intell (2022)*. 2022;13540:150-160. https://doi.org/10.1007/978-3-031-17721-7_16.
85. Mohammad-Rahimi H, Dianat O, Abbasi R, et al. Artificial intelligence for detection of external cervical resorption using label-efficient self-supervised learning method. *J Endod*. 2024;50(2):144-153. https://doi.org/10.1016/j.joen.2023.11.004.
86. Hiraiwa T, Ariji Y, Fukuda M, et al. A deep-learning artificial intelligence system for assessment of root morphology of the mandibular first molar on panoramic radiography. *Dentomaxillofac Radiol*. 2019;48(3):20180218. https://doi.org/10.1259/dmfr.20180218.
87. Duman ŞB, Çelik Özen D, Bayrakdar IŞ, et al. Second mesiobuccal canal segmentation with YOLOv5 architecture using cone beam computed tomography images. *Odontology*. 2024;112(2):552-561. https://doi.org/10.1007/s10266-023-00864-3.
88. Sherwood AA, Sherwood AI, Setzer FC, et al. A deep learning approach to segment and classify c-shaped canal morphologies in mandibular second molars using cone-beam computed tomography. *J Endod*. 2021;47(12):1907-1916. https://doi.org/10.1016/j.joen.2021.09.009.
89. Kazimierczak W, Kazimierczak N, Issa J, et al. Endodontic treatment outcomes in cone beam computed tomography images-assessment of the diagnostic accuracy of AI. *J Clin Med*. 2024;13(14):4116. https://doi.org/10.3390/jcm13144116.
90. Martinho FC, Qadir SJ, Griffin IL, et al. Augmented reality head-mounted device and dynamic navigation system for post-removal in maxillary molars. *J Endod*. 2024;50(6):844-851. https://doi.org/10.1016/j.joen.2024.02.004.
91. Remschmidt B, Rieder M, Gsaxner C, et al. Augmented reality-guided apicoectomy based on maxillofacial CBCT scans. *Diagnostics (Basel)*. 2023;13(19):3037. https://doi.org/10.3390/diagnostics13193037.
92. Isufi A, Hsu TY, Chogle S. Robot-assisted and haptic-guided endodontic surgery: a case report. *J Endod*. 2024;50(4):533-539. https://doi.org/10.1016/j.joen.2024.01.012.