

Radiographic assessment of caries severity, periodontal disease, and endodontic treatment – a narrative review of contemporary diagnostic indicators

Katarzyna Lewusz-Butkiewicz¹, Stanislav Vorobiov², Aleksandra Kulas-Bařaban¹, Marta Rogocka¹, Kinga Kaczor-Wiankowska¹

¹Department of Conservative Dentistry and Endodontics, Pomeranian Medical University, Szczecin, Poland

²Students' Scientific Society of Endodontics at the Department of Conservative Dentistry and Endodontics, Pomeranian Medical University, Szczecin, Poland

Medical Studies

DOI: <https://doi.org/10.5114/ms.2026.161294>

Key words: dental caries, diagnostic imaging, artificial intelligence, root canal obturation, periapical diseases.

Abstract

Radiology facilitates the imaging of two- and three-dimensional structures of hard tissues. Therefore, knowledge of radiological imaging techniques, their proper use, and knowledge of the latest advances have a significant impact on the efficiency of the dentist's work. A comprehensive literature review was conducted based on available publications. Articles describing methods of radiological assessment of dental caries, periodontal disease, and endodontic treatment utilising using two-dimensional and three-dimensional imaging were included. The following diagnostic indices were introduced: ICCMS, PAI, CBCTPAI, and PESS. The potential of using artificial intelligence in radiological diagnostics were also presented. The necessity of two- and three-dimensional methodologies in contemporary dental diagnostics was also emphasised. Despite the enormous progress in spatial imaging, represented by CBCT, there are still some limitations in dental caries diagnostics. Furthermore, the integration of artificial intelligence in the domain of radiological diagnostics in dentistry is a promising field of science that requires further research.

Introduction

In 2019, 3.5 billion people were afflicted by one of the many oral diseases, which have been identified as the most common human diseases. Dental caries occupies a significant position within the spectrum of dental diseases, with one-third of the global population living with untreated tooth decay [1]. Untreated caries can lead to a number of severe complications, including, but not limited to, pulpitis and pulp necrosis. These conditions can progress to apical periodontitis and, in severe cases, even tooth loss. Due to the structure of the teeth and surrounding tissues, dental caries and other pathologies frequently go undetected during basic clinical examinations. Radiographic imaging, in conjunction with clinical examination, plays a pivotal role in the diagnosis of oral and dental pathologies. Both basic intraoral radiographs and advanced imaging techniques, such as cone beam computed tomography (CBCT), are employed in contemporary dentistry, with notable success. It is important to note that dental caries lesions must undergo a minimum of 40% mineral loss before they become radiographically visible [2]. The transition from analogue to digital radiography has facilitated dental

diagnostics, reducing the time required for such procedures. This transition has also made it possible to store and manipulate images more efficiently. Perhaps most significantly, it has reduced the amount of radiation used in dental procedures by 80% [3, 4]. Two-dimensional (2D) radiographic imaging, which is used to evaluate tooth structure and adjacent tissues, is divided into two categories: intraoral, such as periapical or bitewing radiographs, and extraoral, including panoramic radiography (OPG). In the realm of three-dimensional (3D) radiological imaging in dental diagnostics, CBCT is employed.

Periapical radiographs represent a prevalent 2D technique utilised predominantly for the evaluation of teeth and associated tissue anatomy, as well as pathologies. This methodology facilitates the identification and evaluation of periapical pathologies, along with the assessment of crown and root fractures. The utilisation of these radiographic images remains a pivotal component in the field of endodontics, particularly for the purpose of evaluating root and canal anatomy. These radiographs play a crucial role in the preparation for endodontic treatment, as they facilitate the assessment of various parameters such as canal curvature, canal obliterations, working length

determination, the evaluation of root canal obturation quality, and the monitoring of periapical lesion healing. Bitewing radiographs are primarily utilised for the detection and monitoring of caries progression. This diagnostic approach permits the detection of incipient proximal carious lesions, with particular efficacy in the early demineralisation phase. Furthermore, it facilitates the identification of recurrent caries, assessment of marginal overhangs of restorations, and evaluation of the alveolar bone level within the interproximal regions [4, 5]. The employment of OPG enables the acquisition of a more extensive imaging field. This technique provides a comprehensive visualisation of the entire maxilla, mandible, temporomandibular joints, and associated structures. It is recommended for initial assessment as a preliminary screening radiograph to assess the dentition and bone support, identify impacted teeth, and provide a basic assessment of the osseous status of the temporomandibular joints. It is also used to diagnose maxillary and mandibular fractures [4].

Two-dimensional images are subject to inherent limitations due to their intrinsic properties. Firstly, they represent 3D objects on a 2D image. Secondly, the aforementioned techniques visualise objects in the mesio-distal plane, while the bucco-lingual plane remains uncharted. Thirdly, a 2D projection of a 3D object can only provide suggestive, not definitive, evidence when evaluating a clinical problem. Finally, anatomical structures surrounding the teeth may overlap, causing anatomical or background noise, which complicates the interpretation of radiographs. Two-dimensional radiographs have been shown to underestimate the severity of bone destruction and fail to accurately depict the relationship between soft and hard tissues. It is imperative to acknowledge the inherent limitations of radiographs in assessing clinical status, irrespective of the employed 2D or 3D technique. These limitations include the inability to determine the bacterial status of hard and soft tissues, as well as the inability to distinguish inflammatory tissues from healed fibrous scar tissue. Furthermore, radiographic imaging is incapable of providing information regarding the composition of the tissue that has replaced the bone. In most cases, abscesses, granulomas, or cysts manifest as radiographically identical osteolytic lesions [4, 6–8].

According to the European Society of Endodontology (ESE) and the American Association of Endodontists (AAE) recommendations, the utilisation of CBCT in endodontic diagnostics may be considered in the following clinical situations:

- diagnosis of pathology in periapical tissues visible on radiographic images in the presence of conflicting, non-specific clinical symptoms;
- confirmation of non-odontogenic causes of pathology in the maxilla and mandible;

- diagnostics in dental traumatology (tooth dislocation, suspected fracture of the alveolar process of the maxilla or the alveolar part of the mandible, and root fractures not visible in 2D imaging);
- assessment of the complex anatomy of the root canal system prior to planned primary treatment and endodontic retreatment, e.g. in maxillary and mandibular premolars and molars, or class III and IV invaginated teeth;
- assessment of complications after endodontic treatment, e.g. perforation, non-healing chronic apical periodontitis (CAP), to manage these complications when conventional images do not provide sufficient information;
- diagnosis of root resorption that appears to be potentially treatable;
- analysis prior to endodontic microsurgery, e.g. for multi-rooted teeth [9, 10].

It is imperative to acknowledge the inherent limitations of the 3D imaging technique. The presence of metallic fillings or gutta-percha can cause significant radiographic artifacts, sufficient to obscure details of the root canal anatomy and important pathologies such as root resorption and root fractures. It is fortunate, therefore, that metal artifact reduction algorithms are becoming increasingly common in image-processing and viewing software, thus allowing for the successful overcoming of this limitation [11].

The extensive utilisation of radiological diagnostics in dentistry and the increasing number of radiological assessment methods underscores the necessity for the standardisation of radiological indicators. The objective of this paper is to provide a comprehensive overview of the radiological indexes currently employed in the diagnosis of dental caries, periodontal disease, and endodontic treatment and to present a range of radiological assessment tools that leverage artificial intelligence in the field of dentistry.

Two-dimensional radiological imaging

The indication for bitewing or interproximal radiographs is to evaluate the proximal tooth surfaces. During the procedure, the film or sensor is positioned horizontally within the oral cavity, enabling the imaging of the proximal surfaces of multiple upper and lower teeth with a single X-ray exposure [4]. Bitewing radiography has been demonstrated as a highly effective diagnostic tool for detecting proximal caries – especially in its early stages – occlusal caries, secondary caries, filling overhang, as well as evaluating the interproximal bone condition [5]. The literature indicates that the bitewing radiograph can detect 60–85% of proximal caries [12]. Conversely, the utilisation of bitewing radiographs for the evaluation of caries on occlusal surfaces, particularly in its early stages, remains a subject of debate due to its limited sensitivity [13, 14]. A specific variety of this radiographic procedure is the external

bitewing radiograph, a technique that is particularly recommended for patients in whom the acquisition of intraoral radiographs is difficult. However, the literature is inconclusive regarding the effectiveness of this technique compared to intraoral bitewing radiographs; therefore, its utilisation should be reserved for exceptional circumstances [15, 16].

Periapical radiographs are an essential tool in endodontic treatment planning. Two primary radiographic techniques are employed for the acquisition of periapical radiographs: the paralleling technique and the bisecting angle technique. The paralleling technique involves the direction of the central X-ray beam perpendicular to the receptor and tooth. This is achieved by positioning the receptor parallel to the long axis of the tooth. In the bisecting angle technique, the film receptor is positioned as close as possible to the palatal/lingual side of the tooth so that the central X-ray beam is perpendicular to an imaginary line that bisects the angle formed between the long axis of the tooth and the receptor [17]. Periapical radiographs are a valuable source of information regarding tooth anatomy and the presence of CAP. Radiographs are 2D images of 3D structures, and unfortunately some features of the area being examined are not visible. Additionally, variations in the density of the surrounding bone, along with challenges in achieving repeatable images, can also compromise the reliability of radiographic interpretations [18, 19].

Orthopantomogram is a routine radiologic diagnostic instrument in the field of dentistry. It facilitates the simultaneous imaging of multiple structures at a low cost and with a relatively low radiation dose [20, 21]. However, this technique is not without its disadvantages, including the superimposition of anatomical structures, magnification of the image in horizontal and vertical dimensions, or 2D imaging [20].

Three-dimensional radiological imaging

Cone beam computed tomography is a modification of the computed tomography concept in which a single rotation of the X-ray source is made around the patient. The information is analysed and reconstructed using an algorithm to produce data that can be viewed in three conventional planes (sagittal, coronal, and transverse), as well as several alternative planes that can be used when manipulating the dataset. The production of a CBCT image is a rapid process that utilises technology that is becoming increasingly accessible. The 3D visualisation of the area of interest allows for the picturing of teeth and adjacent structures in a manner that is not possible with conventional 2D imaging [9]. The introduction of CBCT into routine clinical practice has enabled 3D imaging of the teeth and maxillofacial skeleton, and the relationships between anatomical structures [22]. However, CBCT imaging has its drawbacks. These include

an increased radiation dose absorbed by the patient, the generation of artifacts, and high levels of scatter and noise [23].

The utilisation of CBCT for the detection of dental caries is controversial and is not universally recommended. The efficacy of this method is contingent upon the capabilities of the software used [24, 25]. The diagnosis of proximal caries based on non-artifact CBCT is characterised by higher specificity and sensitivity compared to intraoral radiographs, and thus could be an accurate tool for assessing caries depth [25]. On the other hand, the diagnosis of secondary caries using this type of imaging can be difficult due to the presence of artifacts from some fillings [24]. According to the literature, it is far more difficult to identify healthy tooth tissue next to amalgam restorations than next to other fillings, such as ceramic crowns or metal-ceramic restorations on CBCT images [25]. The presence of composite, resin-modified glass ionomer or lithium disilicate fillings should have no effect on the detection of proximal caries on CBCT [26].

The ESE and AAE agree that the most important principle to follow when determining indications for the use of CBCT in endodontics is the ALARA (as low as reasonably achievable) principle, which states that the dose of ionising radiation should be as low as possible to obtain a clear radiological image. Cone beam computed tomography should only be considered when 2D radiographs do not provide the necessary information during the diagnostic and treatment process [10, 27].

Cone beam computed tomography allows for the utilisation of diverse field of view (FOV) sizes, ranging from 3 cm to 20 cm. In CBCT endodontic diagnostics, the principle of using the smallest FOV, the smallest voxel size, and the shortest feasible patient exposure time during an examination with pulsed emission should be followed. Converting a divergent beam of radiation into a parallel beam limits radiation exposure of the area of interest and facilitates the selection of the appropriate FOV. Furthermore, a reduced scan volume and voxel size yield enhanced image resolution [10, 27].

Evaluation of caries lesions

One of the most widely utilised classifications for radiographic staging of coronal caries lesions on 2D radiographic images is the International Caries Classification and Management System (ICCMS), which classifies the depth of caries penetration as follows:

0 = no radiolucency (Figure 1 A);

RA: Initial stages

1 = radiolucency in the outer ½ of the enamel (Figure 1 B);

2 = radiolucency in the inner ½ of the enamel ± enamel-dentin junction (EDJ) (this stage is recommended for restorative care in the US, if the radiolucency touches the EDJ) (Figure 1 B);

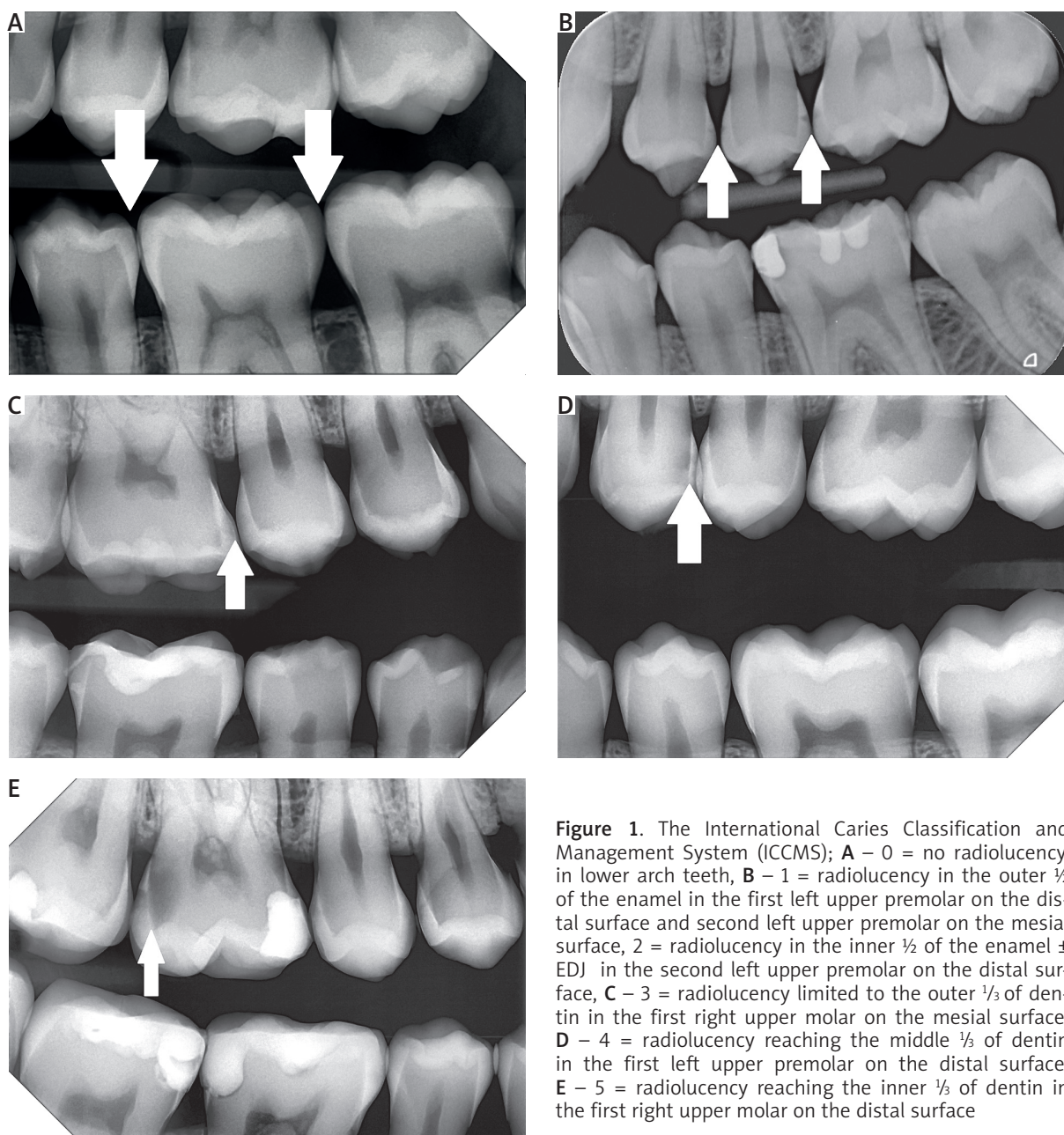


Figure 1. The International Caries Classification and Management System (ICCMS); **A** – 0 = no radiolucency, in lower arch teeth, **B** – 1 = radiolucency in the outer $\frac{1}{2}$ of the enamel in the first left upper premolar on the distal surface and second left upper premolar on the mesial surface, 2 = radiolucency in the inner $\frac{1}{2}$ of the enamel $\pm$ EDJ in the second left upper premolar on the distal surface, **C** – 3 = radiolucency limited to the outer $\frac{1}{3}$ of dentin in the first right upper molar on the mesial surface, **D** – 4 = radiolucency reaching the middle $\frac{1}{3}$ of dentin in the first left upper premolar on the distal surface, **E** – 5 = radiolucency reaching the inner $\frac{1}{3}$ of dentin in the first right upper molar on the distal surface

3 = radiolucency limited to the outer $\frac{1}{3}$ of dentin (in some countries, especially the US, this stage is classified as moderate) (Figure 1 C);

RB: Moderate stages

4 = radiolucency reaching the middle $\frac{1}{3}$ of dentin (Figure 1 D);

RC: Extensive stages;

5 = radiolucency reaching the inner $\frac{1}{3}$ of dentin, clinically cavitated (Figure 1 E) [28, 29].

The American Dental Association Caries Classification System for Clinical Practice (ADA CCS) employs the ICCMS classification to integrate clinical judgment with radiologic diagnosis. The ADA CCS

combines clinical findings with radiographic images, facilitating a more precise diagnosis of caries, taking into account the activity of the lesion and the loss of hard tooth tissue, thereby indicating the appropriate therapeutic measures [30].

Evaluation of endodontic treatment

In the literature, several measures have been used to evaluate the outcome of endodontic treatment based on radiographic assessment of the periapical status and the quality of root canal filling [31]. The quality of the root canal filling is one of the fac-

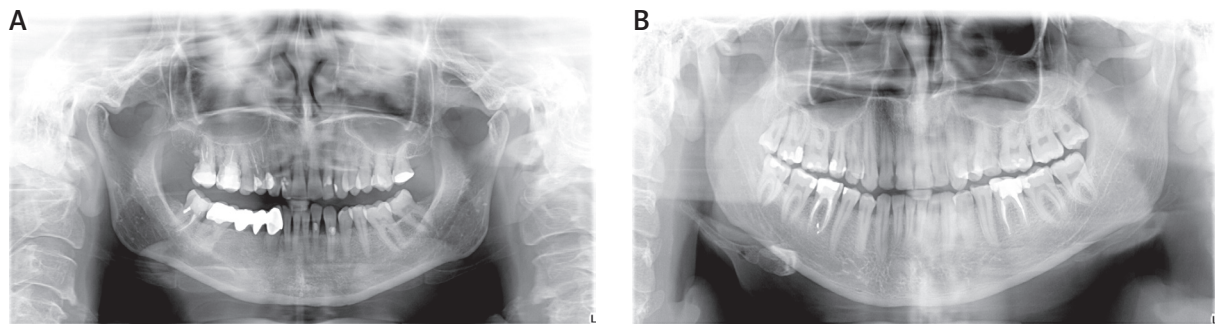


Figure 2. Assessment of endodontic treatment on orthopantomograms. **A** – Underfilled distal canal and correct endodontic treatment of mesial canal in right second lower molar, **B** – overfilled mesial canal in right first lower molar

tors that is taken into account in the radiographic evaluation of the endodontic treatment. The evaluation of the homogeneity of the root canal filling and the acceptable distance of the root canal filling from the radiological apex, including overfilling of the root canal, was performed in both 2D [32, 33] and 3D [34] radiographic imaging.

The acceptable distance that the end of the root canal filling material should be in relation to the radiographic apex varies in the literature. In a study based on OPG images, Huumonen *et al.* considered root canal filling to be adequate when the distance from the end of the filling to the radiographic apex was less than 3 mm [35]. A similar method of assessment was employed in the research conducted by Van der Veken *et al.* based on CBCT, and by Kamberi *et al.* based on OPG images. Their method differed only in the acceptable distance of the end of the filling from the radiographic apex, which was equal to or less than 2 mm (Figure 2) [36, 37].

Evaluation of chronic apical periodontitis

A primary objective of endodontic treatment is to prevent or eliminate apical periodontitis. Over the years, numerous classifications and diagnostic methods of CAP lesions have been developed based on 2D imaging. The Periapical Index (PAI) scale, introduced by Ørstavik *et al.*, was the first classification to be recognised and widely used. This five-stage classification system evaluates the progression of CAP lesions based on 2D radiographic images. Stage I determines normal periapical structures, stage II – small changes in bone structure, stage III – changes in bone structure with some mineral loss, stage IV – periodontitis with well-defined radiolucent area, and stage V – severe periodontitis with exacerbating features (Figure 3) [38].

In 2008, the PAI scale was adapted for use in CBCT. The previous five-point PAI scale has been replaced by the six-point CBCTPAI scale, where a score of 0 indicates intact bone structure in the periapical area, score 1: CAP lesion diameter 0.5–1 mm, score 2: CAP lesion diameter 1–2 mm, score 3: CAP lesion diameter 2–4 mm, score 4: CAP lesion diameter 4–8 mm, and

score 5: CAP lesion diameter > 8 mm. Two variables were added to the CBCTPAI scale, with score E indicating periapical cortical bone expansion caused by chronic apical periodontitis and score D indicating destruction of the cortical bone (Figure 4). Comparison of the PAI and CBCTPAI indices revealed greater accuracy of CBCT images compared to dental images [18]. However, it should be noted that the PAI and CBCTPAI indices are only designed to assess CAP. These indices do not evaluate the quality of endodontic treatment and the quality of crown reconstruction, both of which have a direct impact on the development and treatment of CAP [39, 40]. Consequently, the Periapical and Endodontic Status Scale (PESS) was developed to assess changes in periapical tissues, endodontic treatment, and the quality of crown reconstruction [41]. The PESS index is composed of two components: the Endodontically Treated Tooth Index (ETTI) and the Complex Periapical Index (COP). Table 1 presents the PESS scale, and Figure 5 offers an illustration of its application.

Perspectives of deep learning technologies in dental radiology

Recent years have marked a rapid development of artificial intelligence (AI). The efficacy of this technology is currently being thoroughly evaluated through rigorous testing and implementation in numerous disciplines, including dental radiology. This field of medicine is of considerable importance for enabling AI integration, as billions of radiological images are now stored in digitised form and can be effectively transformed in different ways as needed, providing a suitable basis for enhancing its capabilities [42].

The predominant approach in the field of radiography involves the integration of deep learning (DL) technology [43]. Deep learning is a field of AI focused on developing resource-intensive neural network models that can make decisions based on available data without human intervention [44]. Deep learning has demonstrated efficacy in a variety of applications, including speech recognition, language processing, and image analysis. With regard to the third option,

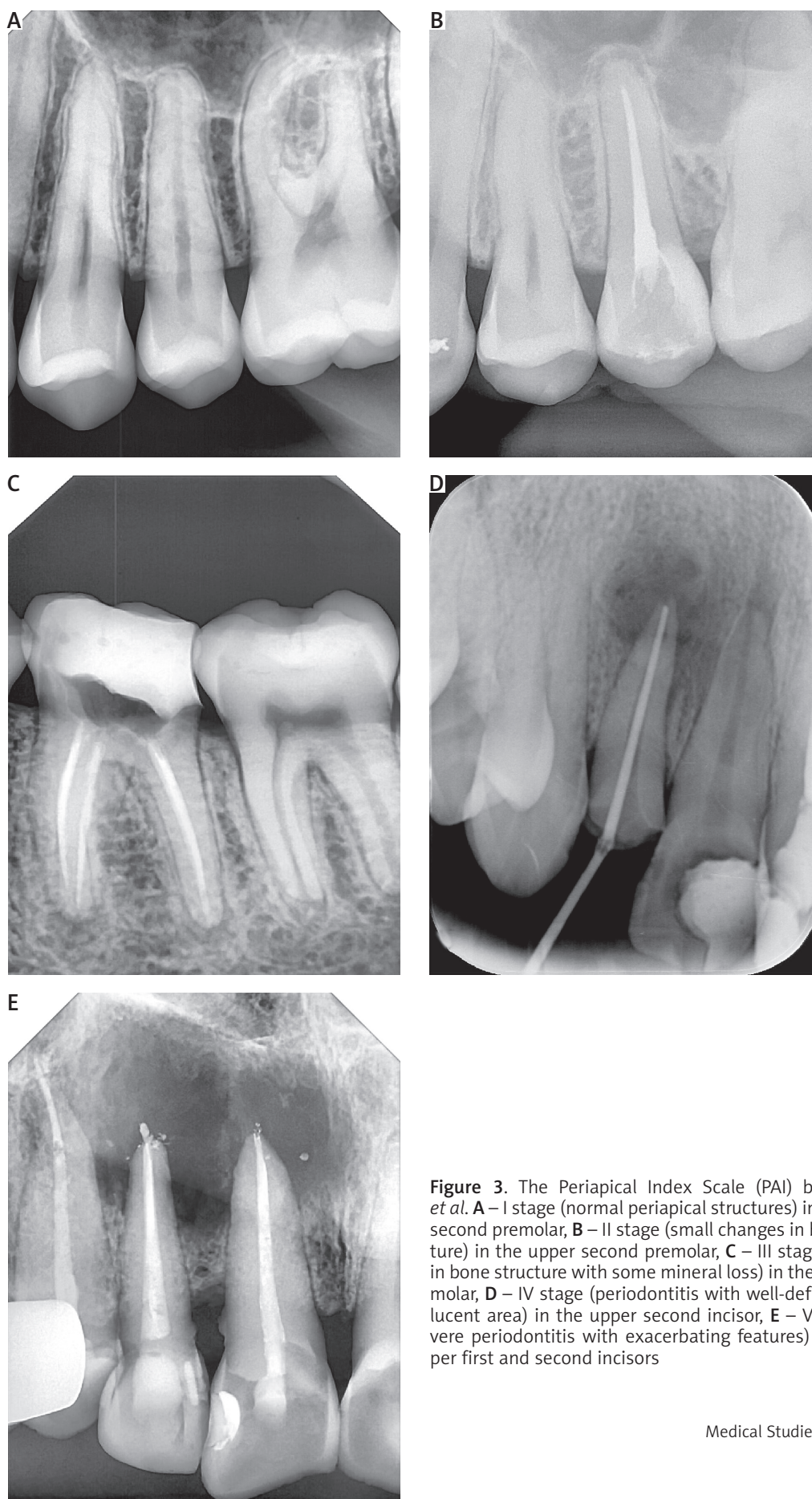


Figure 3. The Periapical Index Scale (PAI) by Ørstavik *et al.* **A** – I stage (normal periapical structures) in the upper second premolar, **B** – II stage (small changes in bone structure) in the upper second premolar, **C** – III stage (changes in bone structure with some mineral loss) in the lower first molar, **D** – IV stage (periodontitis with well-defined radio-lucent area) in the upper second incisor, **E** – V stage (severe periodontitis with exacerbating features) in the upper first and second incisors

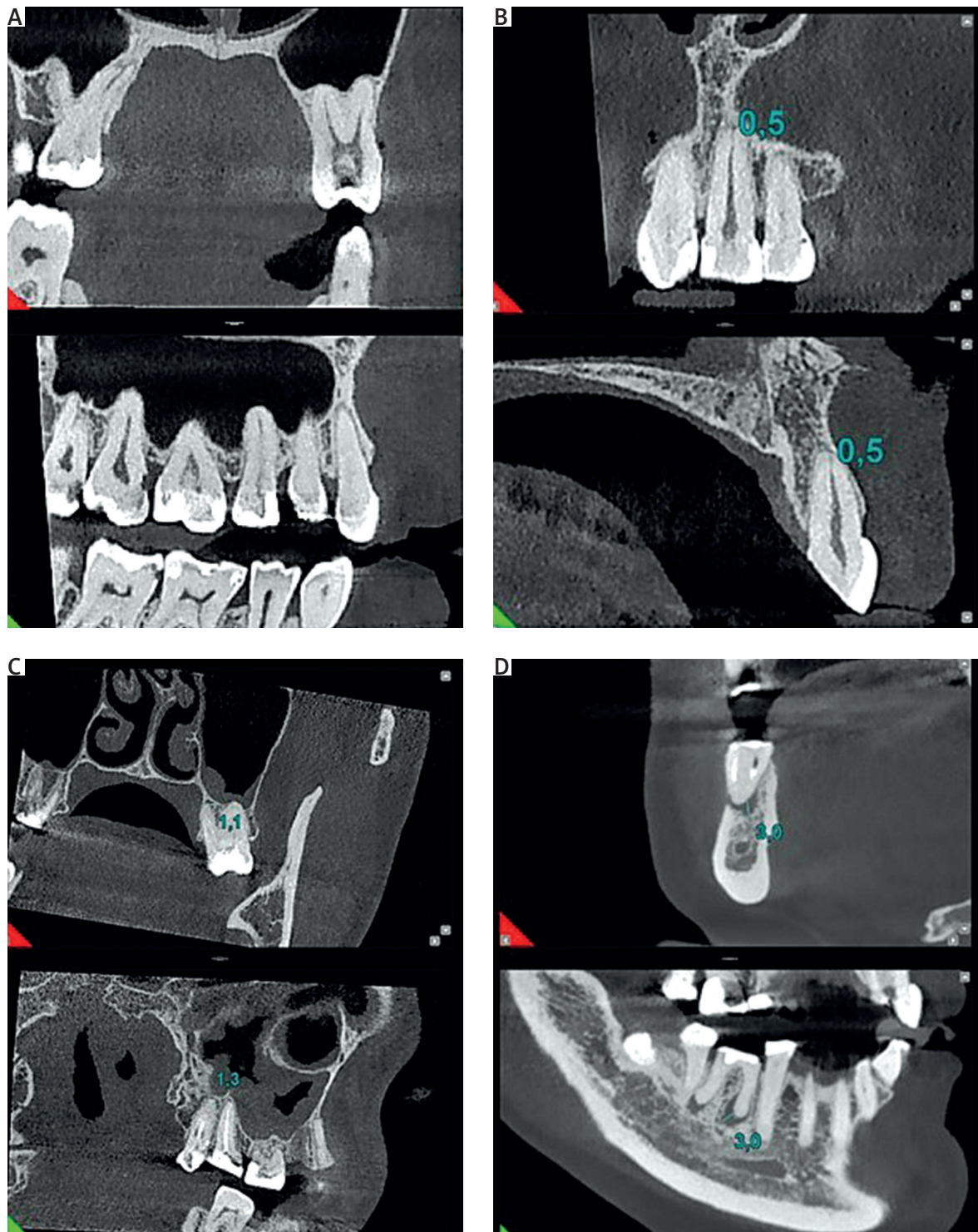


Figure 4. CBCTPAI scale. **A** – grade 0: intact bone structure in the periapical area in the upper second premolar, **B** – grade 1: diameter of the CAP lesion 0.5–1 mm in the upper first incisor, **C** – grade 2: diameter of the CAP lesion 1–2 mm in the upper second premolar, **D** – grade 3: diameter of the CAP lesion 2–4 mm in the lower first molar

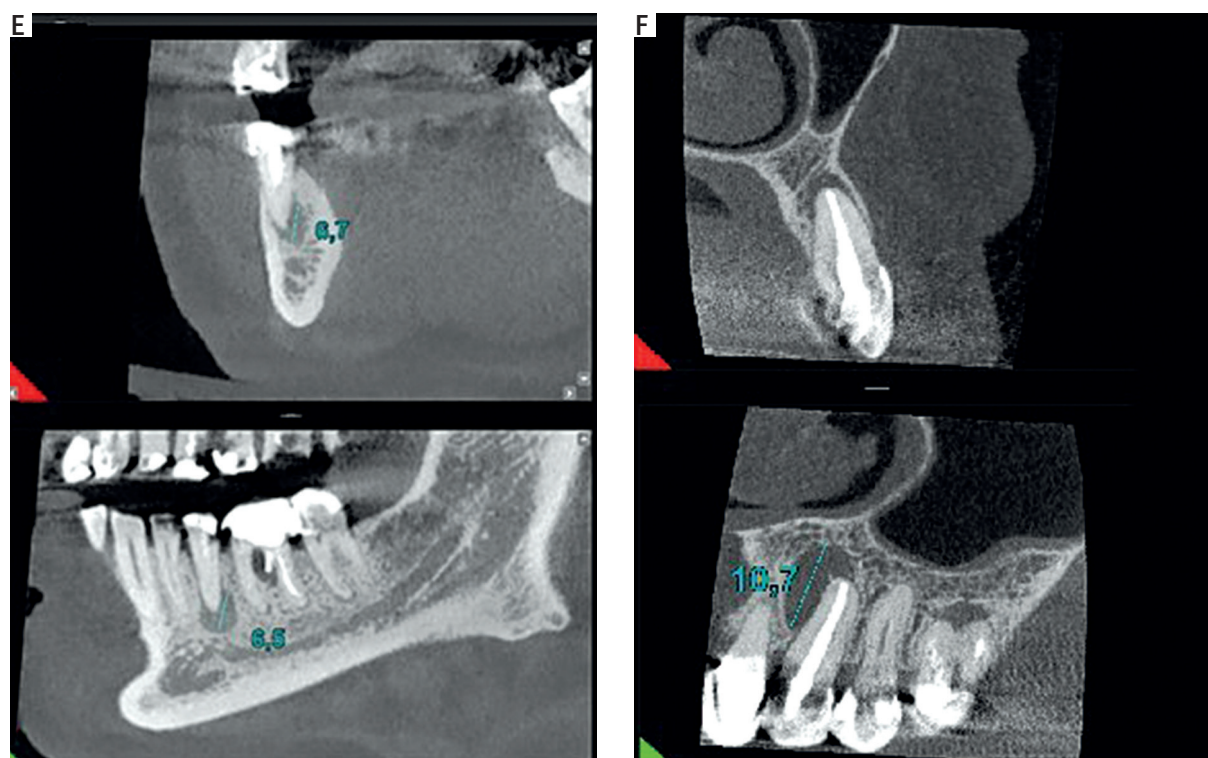


Figure 4. Cont. **E** – grade 4: diameter of the CAP lesion 4–8 mm in the lower first premolar, **F** – grade 5: diameter of the CAP lesion 8 mm in the upper canine

which concerns radiographs, the most appropriate DL algorithm is the convolutional neural network (CNN). This mechanism possesses a distinctive neural connection structure and through a series of multi-layered mathematical operations it can perform such tasks as classifying provided images into designated categories. It also identifies objects within the images and segments them into specific regions of interest [45, 46]. In the context of dental caries, initial CNN models have been demonstrated to exhibit a lack of diagnostic accuracy when compared to that of medical specialists in detecting and classifying the disease. However, the findings have indicated a promising avenue for future decision-making processes [47, 48]. Recent models, such as those based on YOLO architectures in combination with the ICCMS™ staging system, have exhibited a marked enhancement in the balance between precision and recall. This enhancement is evidenced by an F1 score of approximately 85%, which approaches the results attained by experienced researchers [49]. Moreover, a DL architecture called Caries Net was recently developed and dedicated entirely to detecting dental caries. It has been demonstrated to facilitate more precise segmentation of the affected area in comparison to other CNNs [50]. Deep learning has also been employed for the detection of CAP. Convolutional neural network architecture demonstrated satisfactory results in classifying CAP on OPG [51]. In

the field of endodontics, DL is being evaluated for its capacity to detect root fractures, assess root length and morphology, and differentiate CAP [52].

Currently, there are numerous programs available on the market that employ AI infrastructure to analyse radiographic images. These tools allow dental professionals to use the latest advances in AI to interpret dental radiographs without the necessity of additional programming skills. The following AI-powered platforms have been incorporated into clinical practice: VideaAI from Videa Health®, Second Opinion® from Pearl, Inc®, Diagocat®, and Overjet®. Furthermore, a multitude of platforms are available for individuals and institutions wishing to create their own DL models from the ground up or utilise the existing ones. Among these are Roboflow®, which is used to prepare and manage datasets for AI models with a focus on object recognition, and Tensorflow®, where the models can be built, deployed, and refined. Two models, based on the “YOLO-NAS Object Detection (Accurate)” and “Roboflow 3.0 Instance Segmentation (Fast)” algorithms, were tested. In the initial model, OPG were utilised as samples, while the second referenced model relied on bitewing radiographs. The results are presented in Figures 6 and 7. The website <https://checkdent.com/ai-scan/> enables the evaluation of radiographs without the necessity of acquiring the software (Figure 8).

Table 1. The Periapical and Endodontic Status Scale

The Periapical and Endodontic Status Scale (PESS)	
The Endodontically Treated Tooth Index (ETTI)	
L (length of the root canal filling)	
L1	0–2 mm from radiographic apex
L2	> 2 mm from radiographic apex
L3	Overfilling (extrusion of material through the apex)
L4	Filling material visible only in pulp chamber
L5	Filled canal of a surgically treated root
H (homogeneity of the root canal fillings)	
H1	Complete obturation (homogenous appearance of the root canal filling)
H2	Incomplete obturation (voids and porous appearance of the root canal filling)
CS (coronal seal)	
CS1	Adequate (coronal restoration appears intact radiographically)
CS2	Inadequate (detectable radiographic signs of overhangs, open margins, recurrent caries, or lost coronal restoration)
CF (complications/failures)	
CF0	No complications
CF1	Root perforation
CF2	Root canal not treated/missed
CF3	Root resorption
CF4	Root/tooth fracture
CF5	Endodontically treated root with radiolucency
The Complex Periapical Index (COP)	
S (size of the radiolucent lesion)	
S0	Widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament
S1	Diameter of small well-defined radiolucency up to 3 mm
S2	Diameter of medium well-defined radiolucency 3–5 mm
S3	Diameter of large well-defined radiolucency > 5 mm
R (Relationship between root and radiolucent lesion)	
R0	No radiolucency, when widening of the periodontal ligament is not exceeding two times the width of the lateral periodontal ligament
R1	Radiolucent lesion appears on one root
R2	Radiolucent lesion appears on more than one root
R3	Radiolucent lesion with involvement of furcation
D (location of bone destruction)	
D0	No radiolucency, when widening of the periodontal ligament is not exceeding two times the width of the lateral periodontal ligament
D1	Radiolucency around the root
D2	Radiolucency is in contact with important anatomical structures
D3	Destruction of cortical bone

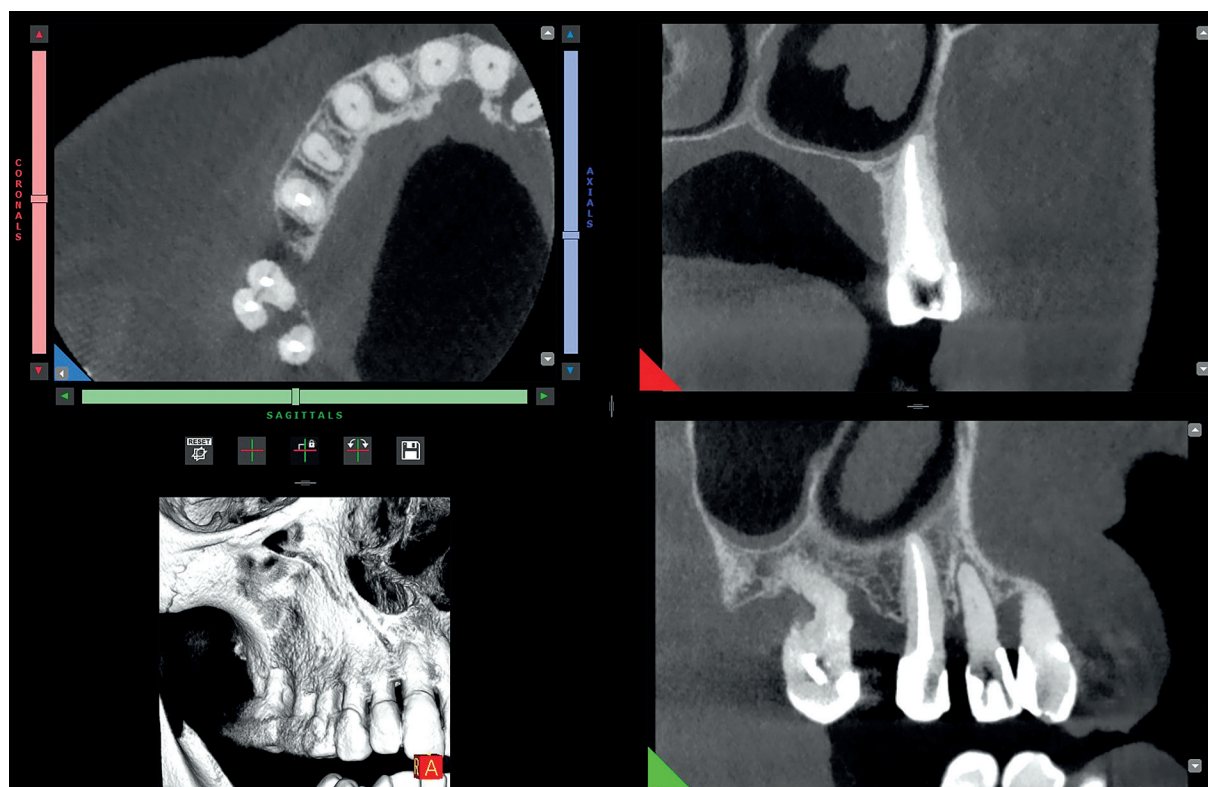


Figure 5. An example of utilising the PESS scale – right upper second premolar L1H1CS1CF0S0RxD1

(L1 – root canal filling 0–2 mm from radiographic apex, H1 – complete obturation of the canal, CS1 – adequate coronal seal, CF0 – no complications, S0 – no radiolucency, widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament, Rx – single-root tooth, no possibility of assessment, D0 – no radiolucency)

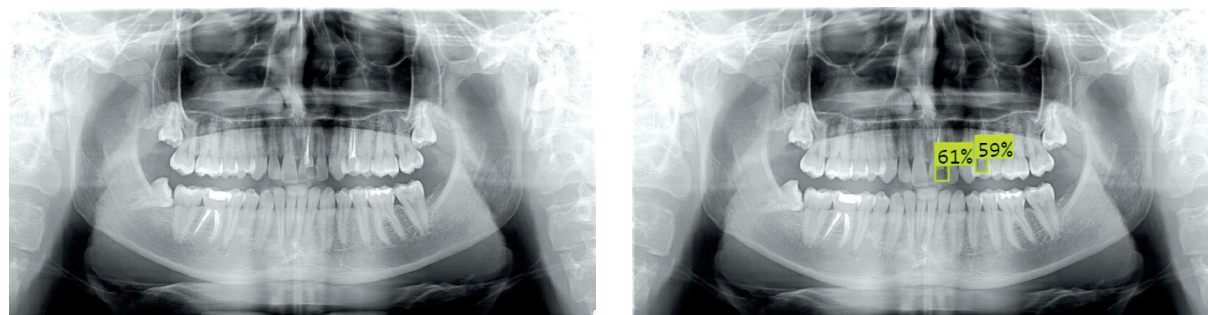


Figure 6. Panoramic radiograph, analysed by the model based on the “YOLO-NAS Object Detection (Accurate)” algorithm, aimed at detecting foci of non-physiological demineralisation. The percentages provided above indicate the confidence level of the model

Nonetheless, despite the encouraging prospects outlined above, AI continues to exhibit substantial limitations that prevent its comprehensive integration into the dentist’s routine work with radiological images. These include the necessity for increased quantity and quality of data. Inappropriate sample size can lead to elevated results. Furthermore, various ethical concerns and information security protocols have been identified as substantial constraints in acquiring the optimal number of radiographs [43, 53].

Nevertheless, should these challenges be overcome, AI has the potential to serve as a valuable instrument for dentists, thereby reducing the cost of dental care and significantly enhancing the quality of dental diagnostics [54].

Discussion

The present-day approach to dental management ought to be founded upon individualised prophylactic and treatment plans. A correct diagnosis and treatment

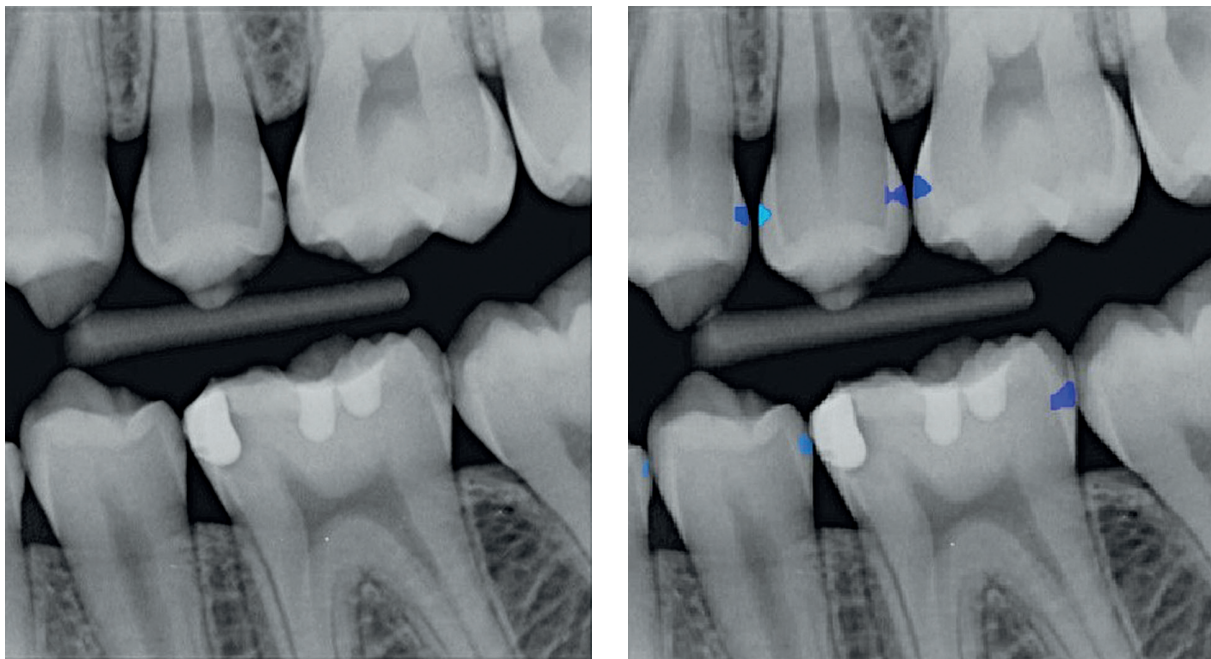


Figure 7. The bitewing X-ray analysed by a model based on the “Roboflow 3.0 Instance Segmentation (Fast)” algorithm, aimed at detecting caries lesions on the proximal surfaces. The degree of colour obscuration indicates the confidence level of the model

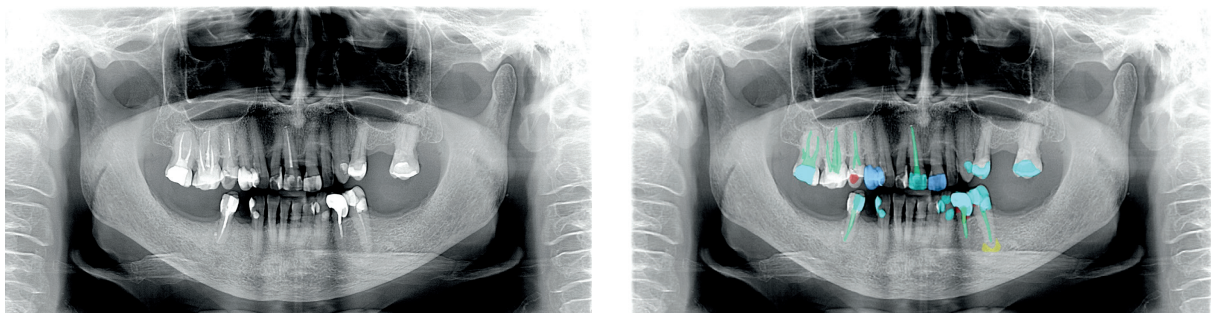


Figure 8. Panoramic X-ray evaluated at <https://checkdent.com/ai-scan/>

planning that takes into account the patient’s individual caries risk, as well as determining the periodontal status and surgical treatment needs, must be done in conjunction with radiographic diagnosis [4, 47, 49].

It is considered good practice to initiate the diagnostic process with a OPG [4, 23]. While it lacks sufficient resolution to detect early carious lesions or inflammatory lesions of the apical periodontium, it establishes the foundation for a more comprehensive diagnosis through the utilisation of additional 2D and/or 3D radiographic techniques [8, 23, 47, 55, 56]. Due to its wide availability in many dental offices, affordable price, and low radiation dose to which the patient is exposed, 2D radiography is the most widely used method in modern dentistry. The use of 2D images has already been demonstrated to facilitate successful detection and staging of carious lesions (bitewing ra-

diographs), assessment of the extent of inflammatory periapical lesions, planning of endodontic treatment, and evaluation of the quality of its performance (periapical radiographs) [4, 6]. The two aforementioned imaging techniques have been demonstrated to facilitate the successful determination of the prognosis for a given affected tooth, thereby assisting in the decision-making process regarding the necessity of tooth extraction.

It has been widely accepted that, despite the many conveniences provided by 3D imaging of hard tissues within the oral cavity, the use of CBCT is limited only to cases where traditional imaging with 2D techniques is not feasible or insufficient to make a correct diagnosis [9, 19]. The indications for the use of 3D technique are constrained by the ALARA rule, and the detailed scope is defined by scientific societ-

ies [9, 10, 27]. However, it should be noted that due to the high level of specialisation in various fields of dentistry, which allows for the preservation of teeth with advanced pathological lesions that require complex treatment procedures, the use of CBCT is imperative for diagnosis.

While dentists frequently refer to and interpret X-rays taken with 2D and 3D techniques in their daily practice, there is often no available assistance from a radiologist. Doctors frequently depend exclusively on their own experience when interpreting radiographs, with no reliance on objectified indicators. Such interpretation can vary considerably among physicians, resulting in divergent prognoses, and prophylactic and therapeutic management plans [47, 50]. The popularisation of radiographic indices that determine the severity of carious lesions (2D) and indices to assess the endodontic treatment performed and the extent of periapical inflammatory lesions (2D and 3D) could systematise the diagnostic process and standardise the therapeutic decisions made by doctors.

Despite their indisputable advantages, the referenced radiological indicators, particularly the extensive endodontic indicators, can pose challenges for clinicians in their daily work due to the time required to perform a complete “staging”. The utilisation of indicators in scientific publications is not a cause for concern; however, in routine clinical practice, their implementation can pose substantial challenges. The utilisation of computer programs based on deep learning models with convolutional neural networks (CNNs) may prove beneficial in this regard. Presently, a lot of these models are in the research phase, and although their results appear to be promising, it is not yet feasible to discuss their widespread use in the clinical practice of doctors.

To facilitate the detection of caries at the proximal surfaces of teeth, Lee *et al.* have proposed a model for the detection of carious lesions on bitewing radiographs [47]. The model under consideration does not include an assessment of the severity of carious lesions. Consequently, it is impossible to automatically assign the lesion to known carious lesion classification systems. Moreover, the findings yielded by the model (precision, 63.29%; recall, 65.02%; and F1-score, 64.14%) are not aligned with the expected outcomes. Consequently, the model's utility is limited to providing a reference point for dental professionals. Alsolamy *et al.* [49] proposed a model aimed at enhancing the detection of caries on bitewing radiographs. This model utilises the ICCMS™ classification system to determine the severity of detected lesions. Utilising YOLO-based instance segmentation, coupled with a larger database of radiographs as training sets, ensured high performance metrics (precision: 84.4%, recall: 86.4%, F1-score: 85.1%). Zhu *et al.* presented the results of a study indicating the high performance of a model referred to as CariesNet [50]. The researchers presumed that

pantomographic images are a sufficient instrument for evaluating caries, even in its initial stages. However, this supposition is questionable in light of contemporary assumptions. This is because the OPG demonstrates increased geometric distortion, reduced spatial resolution, and diminished contrast when compared to bitewing radiographs. Consequently, it is not recommended as a primary instrument for the detection of early caries [55].

The endodontic model proposed by Ekert *et al.* is highly sensitive and specific, but it does not consider the extent of the observed inflammatory lesion classification [51]. It only provides a tool to assist in the final clinical evaluation. More sophisticated neural network models may demonstrate greater clinical utility by classifying lesions detected on radiographs by size. Applying segmentation-based approaches to convolutional neural network (CNN) models, such as U-Net or U²-Net, enables the detection of pathological lesions on radiographs, the precise delineation of their extent, and the assessment of disease progression over time [56, 57].

It is important to keep in mind that, in all cases of training data input in the form of radiographs evaluated by researchers, the CNN model learns the pixel patterns corresponding to the labels given by humans. If the label is incorrect and the lesion is misinterpreted, the model will learn the incorrect pattern and replicate the error. Less sophisticated models are ineffective at interpreting low-quality radiographs and are more sensitive to error than experienced examiners [47]. Therefore, when using AI-based tools in daily clinical work, clinicians should bear in mind that they still need to critically evaluate the results proposed by CNN models. The integration of artificial intelligence into the domain of dental radiology raises important medico-legal implications. Despite the high diagnostic performance of deep learning models in detecting caries and apical lesions [47, 49, 51, 56], these systems are currently regarded as decision-support rather than decision-making tools. In accordance with applicable legal standards, dentists bear full responsibility for interpreting radiographs and determining further treatment options. This holds true even in instances involving the utilisation of AI systems [42, 53]. They also need to combine the data obtained from the radiographic examination with the patient's medical history and existing individual disease risk factors before implementing therapy. In light of the ethical considerations in the domain of AI-assisted radiology, it has been observed that physicians cannot shift responsibility solely to the algorithm used. This is because AI does not possess clinical responsibility or full transparency [53, 54]. Accordingly, professional guidelines such as those of the American Dental Association emphasise that radiographic interpretation must remain under the control of the dentist [55]. To mitigate legal risk, dentists should critically appraise AI outputs, document the diagnostic process, and in-

tegrate algorithmic suggestions with clinical expertise and patient-specific factors [43, 52].

Conclusions

Cone beam computed tomography is less useful in assessing caries than bitewing radiographs. The indications for CBCT in endodontic treatment are limited; however, in certain clinical cases, the benefits of its use are greater than those of 2D radiography. The integration of AI in the domain of dental radiological diagnostics is a rapidly evolving field, necessitating ongoing research and development.

Funding

No external funding.

Ethical approval

Not applicable.

Conflict of interest

The authors declare no conflict of interest.

References

1. WHO. Global oral health status report: towards universal health coverage for oral health by 2030. WHO, Geneva 2022.
2. Senel B, Kamburoglu K, Uçok O, Yüksel SP, Ozen T, Avsever H. Diagnostic accuracy of different imaging modalities in detection of proximal caries. *Dentomaxillofac Radiol.* 2010; 39(8): 501-511.
3. Mouyen F, Benz C, Sonnbend E, Lodter JP. Presentation and physical evaluation of RadioVisioGraphy. *Oral Surg Oral Med Oral Pathol.* 1989; 68: 238-242.
4. Shah N, Bansal N, Logani A. Recent advances in imaging technologies in dentistry. *World J Radiol.* 2014; 6(10): 794-807.
5. Kidd EA, Pitts NB. A reappraisal of the value of the bitewing radiograph in the diagnosis of posterior approximal caries. *Br Dent J.* 1990; 169: 195-200.
6. Setzer FC, Lee SM. Radiology in endodontics. *Dent Clin North Am.* 2021; 65(3): 475-486.
7. Cotti E, Vargiu P, Dettori C, Mallarini G. Computerized tomography in the management and follow-up of extensive periapical lesion. *Endod Dent Traumatol.* 1999; 15(4): 186-189.
8. Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: part 1. Conventional and alternative radiographic systems. *Int Endod J.* 2009; 42(6): 447-462.
9. Patel S, Brown J, Pimentel T, Kelly R, Abella F, Durack C. Cone beam computed tomography in endodontics: a review of the literature. *Int Endod J.* 2019; 52(9): 1138-1155.
10. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics – 2015/2016 Update. *J Endod.* 2015; 41(9): 1393-1396.
11. Queiroz PM, Santaella GM, Groppo FC, Freitas DQ. Metal artifact production and reduction in CBCT with different numbers of basis images. *Imaging Sci Dent.* 2018; 48(1): 41-44.
12. Bader JD, Shugars DA, Bonito AJ. Systematic reviews of selected dental caries diagnostic and management methods. *J Dent Educ.* 2001; 65(10): 960-968.
13. Fasihinia H, Khalesi M, Gholami L. Dental caries diagnostic methods. *Avicenna J Dent Res.* 2010; 1(2): 1-2.
14. Saffarpour A, Tonkaboni A, Pareshkooch MK, Nazari SOA, Manafi S, Kharazifard MJ. Comparison of diagnostic effects of infrared imaging, visual inspection, and bitewing radiography in primary occlusal caries of permanent teeth. *Dent Res J (Isfahan).* 2023; 20: 68.
15. Kamburoglu K, Kolsuz E, Murat S, Yüksel S, Ozen T. Proximal caries detection accuracy using intraoral bitewing radiography, extraoral bitewing radiography and panoramic radiography. *Dentomaxillofac Radiol.* 2012; 41: 450-459.
16. Abu El-Ela WH, Farid MM, Mostafa MS. Intraoral versus extraoral bitewing radiography in detection of enamel proximal caries: an ex vivo study. *Dentomaxillofac Radiol.* 2016; 45(4): 20150326.
17. Biggerstaff RH, Phillips JR. A quantitative comparison of paralleling long-cone and bisection-of-angle periapical radiography. *Oral Surg Oral Med Oral Pathol.* 1976; 62(5): 673-677.
18. Estrela C, Bueno MR, Azevedo BC, Azevedo JR, Pécora JD. A new periapical index based on cone beam computed tomography. *J Endod.* 2008; 34(11): 1325-1331.
19. Aminoshariae A, Kulild JC, Syed A. Cone-beam computed tomography compared with intraoral radiographic lesions in endodontic outcome studies: a systematic review. *J Endod.* 2018; 44(11): 1626-1631.
20. Sharan A, Madjar D. Correlation between maxillary sinus floor topography and related root position of posterior teeth using panoramic and cross-sectional computed tomography imaging. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006; 102(3): 375-381.
21. Shahbazian M, Vandewoude C, Wyatt J, Jacobs R. Comparative assessment of panoramic radiography and CBCT imaging for radiodiagnostics in the posterior maxilla. *Clin Oral Investig.* 2014; 18(1): 293-300.
22. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lambrechts P, Lemberg K. Cone beam computed tomography in endodontics – a review. *Int Endod J.* 2015; 48(1): 3-15.
23. Suomalainen A, Pakbaznejad EE, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. *Insights Imaging.* 2015; 6(1): 1-16.
24. Lindfors N, Ekestubbe A, Frisk F, Lund H. Is cone-beam computed tomography (CBCT) an alternative to plain radiography in assessments of dental disease? *Clin Oral Investig.* 2024; 28(2): 127.
25. Mosavat F, Ahmadi E, Amirfarhangi S, Rafeie N. Evaluation of diagnostic accuracy of CBCT and intraoral radiography for proximal caries detection in the presence of different dental restoration materials. *BMC Oral Health.* 2023; 23: 419.
26. Abu El-Ela WH, Farid MM, Abou El-Fotouh M. The impact of different dental restorations on detection of proximal caries by cone beam computed tomography. *Clin Oral Investig.* 2022; 26(3): 2413-2420.
27. Patel S, Durack C, Abella F, Roig M, Shemesh H, Lambrechts P, Lemberg K. European Society of Endodontology position statement: the use of CBCT in endodontics. *Int Endod J.* 2014; 47(5): 502-504.
28. Agustsdottir H, Gudmundsdottir H, Eggertsson H, et al. Caries prevalence of permanent teeth: a national survey

- of children in Iceland using ICDAS. *Community Dent Oral Epidemiol.* 2010; 38(4): 299-309.
29. Ekstrand KR, Luna LE, Promisiero L, Cortes A, Cuevas S, Reyes JF, Torres CE, Martignon S. The reliability and accuracy of two methods for proximal caries detection and depth on directly visible proximal surfaces: an in vitro study. *Caries Res.* 2011; 45(2): 93-99.
 30. Young DA, Nový BB, Zeller GG, Hale R, Hart TC, Trulove EL; American Dental Association Council on Scientific Affairs. The American Dental Association Caries Classification System for clinical practice. *J Am Dent Assoc.* 2015; 146(2): 79-86.
 31. Azarpazhooh A, Sgro A, Cardoso E, Elbarbary M, Lagharpour Lighvan N, Badewy R, Malkhassian G, Jafarzadeh H, Bakhtiar H, Khazaei S, Oren A, Gerbig M, He H, Kishen A, Shah PS. A scoping review of 4 decades of outcomes in nonsurgical root canal treatment, nonsurgical retreatment, and apexification studies – Part 2: outcome measures. *J Endod.* 2022; 48(1): 29-39.
 32. Archana D, Gopikrishna V, Gutmann JL, Savadamoorthi KS, Kumar AR, Narayanan LL. Prevalence of periradicular radiolucencies and its association with the quality of root canal procedures and coronal restorations in an adult urban Indian population. *J Conserv Dent.* 2015; 18(1): 34-38.
 33. Kielbassa AM, Frank W, Madaus T. Radiologic assessment of quality of root canal fillings and periapical status in an Austrian subpopulation – an observational study. *PLoS One.* 2017; 12(12): e0176724.
 34. Paes da Silva Ramos Fernandes LM, Ordinola-Zapata R, Húngaro Duarte MA, Alvares Capellozza AL. Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation. *Dentomaxillofac Radiol.* 2013; 42(1): 80179163.
 35. Huuonen S, Suominen AL, Vehkalahti MM. Prevalence of apical periodontitis in root-filled teeth: findings from a nationwide survey in Finland. *Int Endod J.* 2017; 50(3): 229-236.
 36. Kamberi B, Hoxha V, Stavileci M, Dragusha E, Kuçi A, Kqiku L. Prevalence of apical periodontitis and endodontic treatment in a Kosovar adult population. *BMC Oral Health.* 2011; 11: 32.
 37. Van der Veken D, Curvers F, Fieuws S, Lambrechts P. Prevalence of apical periodontitis and root-filled teeth in a Belgian subpopulation found on CBCT images. *Int Endod J.* 2017; 50(4): 317-329.
 38. Ørstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endod Dent Traumatol.* 1986; 2(1): 20-34.
 39. Ng YL, Mann V, Gulabivala K. Outcome of secondary root canal treatment: a systematic review of the literature. *Int Endod J.* 2008; 41(12): 1026-1046.
 40. Ng YL, Mann V, Rahbaran S, Lewsey J, Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – part 2. Influence of clinical factors. *Int Endod J.* 2008; 41(1): 6-31.
 41. Venskutonis T, Plotino G, Tocci L, Gambarini G, Mamin-skas J, Juodzbalys G. Periapical and endodontic status scale based on periapical bone lesions and endodontic treatment quality evaluation using CBCT. *J Endod.* 2015; 41(2): 190-196.
 42. Thrall JH, Li X, Li Q, Cruz C, Do S, Dreyer K, Brink J. Artificial intelligence and machine learning in radiology: opportunities, challenges, pitfalls, and criteria for success. *J Am Coll Radiol.* 2018; 15(3 Pt B): 504-508.
 43. Putra RH, Doi C, Yoda N, Astuti ER, Sasaki K. Current applications and development of artificial intelligence for digital dental radiography. *Dentomaxillofac Radiol.* 2022; 51(1): 20210197.
 44. Kelleher JD. *Deep learning.* Cambridge (MA): MIT Press; 2019.
 45. Li Z, Liu F, Yang W, Peng S, Zhou J. A survey of convolutional neural networks: analysis, applications, and prospects. *IEEE Trans Neural Netw Learn Syst.* 2022; 33(12): 6999-7019.
 46. Yamashita R, Nishio M, Do RKG, Togashi K. Convolutional neural networks: an overview and application in radiology. *Insights Imaging.* 2018; 9(4): 611-629.
 47. Lee S, Oh SI, Jo J, Kang S, Shin Y, Park JW. Deep learning for early dental caries detection in bitewing radiographs. *Sci Rep.* 2021; 11: 16807.
 48. Moran M, Faria M, Giraldo G, Bastos L, Oliveira L, Conci A. Classification of approximal caries in bitewing radiographs using convolutional neural networks. *Sensors (Basel).* 2021; 21(15): 5192.
 49. Alsolamy M, Nadeem F, Azhari AA, Ahmed WM. Automated detection, localization, and severity assessment of proximal dental caries from bitewing radiographs using deep learning. *Diagnostics (Basel).* 2025; 15(7): 899.
 50. Zhu H, Cao Z, Lian L, Ye G, Gao H, Wu J. CariesNet: a deep learning approach for segmentation of multi-stage caries lesion from oral panoramic X-ray image. *Neural Comput Appl.* 2022; 34: 13425-13438.
 51. Ekert T, Krois J, Meinhold L, Elhennawy K, Emara R, Golla T, Schwendicke F. Deep learning for the radiographic detection of apical lesions. *J Endod.* 2019; 45(7): 917-922.e5.
 52. Aminoshariae A, Kulild J, Nagendrababu V. Artificial intelligence in endodontics: current applications and future directions. *J Endod.* 2021; 47(9): 1352-1357.
 53. Brady AP, Neri E. Artificial intelligence in radiology – ethical considerations. *Diagnostics (Basel).* 2020; 10(4): 231.
 54. Bonny T, Al Nassan W, Obaideen K, Al Mallahi MN, Mohammad Y, El-Damanhoury HM. Contemporary role and applications of artificial intelligence in dentistry. *F1000Research.* 2023; 12: 1179.
 55. ADA Council on Scientific Affairs. The use of dental radiographs: update and recommendations. *J Am Dent Assoc.* 2012; 143(5): 573-575.
 56. Boztuna B, Yilmaz E, Kaya M, Demircioglu Y, Ozkan S, Aydin H. Segmentation of periapical lesions with automatic deep learning on panoramic radiographs. *BMC Oral Health.* 2024; 24(1): 5126.
 57. Azad R, Aghdam EK, Rauland A, Jia Y, Avval AH, Bozorgpour A, et al. Medical image segmentation review: the success of U-Net. *IEEE Trans Pattern Anal Mach Intell.* 2024; 46(5): 1234-1256.

Address for correspondence

Katarzyna Lewusz-Butkiewicz

Department of Conservative
Dentistry and Endodontics
Pomeranian Medical University
Szczecin, Poland
E-mail: katarzyna.lewusz.butkiewicz@pum.edu.pl

Received: 4.02.2025

Accepted: 21.08.2025

Online publication: 23.04.2026