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Comparing artificial intelligence-based detection of periapical lesions using CBCT and intraoral radiographs

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Abstract:
Accurate detection of periapical lesions is essential for endodontic diagnosis and artificial intelligence may improve interpretation of dental radiographs. Therefore, it is of interest to evaluate the artificial intelligence-assisted detection of periapical lesions on CBCT and digital intraoral periapical radiographs against consensus diagnoses by expert radiologists. Artificial intelligence showed higher sensitivity (95.2% vs. 83.9%), specificity (94.7% vs. 89.5%) and diagnostic accuracy (95.0% vs. 86.0%). Agreement with expert radiologists was almost perfect for CBCT (κ=0.90) and substantial for intraoral radiographs (κ=0.73), indicating greater diagnostic reliability with CBCT. These findings advance knowledge by supporting artificial intelligence-assisted cone-beam computed tomography interpretation as a reliable adjunct for accurate detection of periapical lesions in endodontic diagnosis.

Keywords: Artificial intelligence (AI), cone-beam computed tomography (CBCT), periapical lesion, intraoral periapical radiography, deep learning, endodontic diagnosis

Background:
Periapical lesions are very common inflammatory condition of the periapical tissues and are commonly caused by pulpal infection. It is important to accurately identify these lesions to provide an effective treatment strategy, track disease progression and assess treatment effectiveness **[1]**. Failure to diagnose the condition and treatment of the tooth in a timely and accurate manner can lead to continued infection, an unnecessary endodontic intervention, or loss of the tooth **[2].** In spite of the high magnification associated with periapical lesions and the increase in radiation dose, intraoral periapical radiography is the most frequently ordered imaging modality for the diagnosis of periapical lesions, mainly because it is inexpensive and readily available **[3]**. It suffers, however, from the fact that it is a two-dimensional imaging technique and therefore, in certain cases, the anatomical superimposition and geometric distortion render it less accurate than could be wished and early bone changes can be missed, as long as the cortical bone is intact **[4].** Recent advances in the development of Cone-beam computed tomography (CBCT) have greatly enhanced the radiographic evaluation of periapical pathology in three dimensions, which allows a much better understanding of the teeth and the structures around them **[5].** CBCT is better than conventional intraoral radiographs in terms of sensitivity in detecting periapical lesions and evaluation of the size, extent and the relationship of the lesion to other bone structures. However, the interpretation of CBCT images can be time consuming, subject to interobserver variance and a high level of expertise is required to interpret CBCT images **[6].** The recent advances of artificial intelligence (AI), especially deep learning and convolutional neural networks, have been revolutionary in diagnostic imaging in dentistry **[7].** Automated detection of different oral diseases using AI based system has shown promising results in dental caries, periodontal bone loss, root fractures and periapical lesions. These technologies can help in the routine interpretation of a radiograph, enhance diagnostic consistency and minimize observer-dependent variability **[8].** Multiple systematic reviews and recent clinical investigations have shown that AI algorithms can accurately diagnose periapical lesions on CBCT and intraoral radiographs **[9].** While the evidence is promising, there are remaining questions about inter-relationships between the different imaging modalities in terms of image characteristics, diagnostic performance and clinical applicability. Comparative evaluation of the performance of AI on CBCT and intraoral radiographs is therefore needed to establish its clinical value and potential for incorporating it into regular endodontic practice **[10].** Therefore, it is of interest to compare the diagnostic accuracy of AI in detection of periapical lesions using CBCT and intraoral radiographs as well as to assess the potential of using AI in improving the diagnostic accuracy in endodontic imaging.

Methodology:
Retrospective comparative observational study was done in the Department of Oral Medicine & Radiology, Tertiary care hospital following approval of the Institutional Ethics Committee. The study aimed to compare the diagnostic accuracy of an artificial intelligence (AI) system for the identification of periapical lesions from cone-beam computed tomography (CBCT) and digital intraoral periapical radiographs (IOPA).Retrospective search of patient's data from the institutional radiographic database was conducted and eligible

patients were selected who had both CBCT examination and digital intraoral periapical radiography for endodontic evaluation between January 2022 and December 2024. A consecutive series of patients with the inclusion criteria were enrolled in the study. Only patients older than 18 years with complete clinical records and good diagnostically acceptable CBCT scans as well as intraoral periapical radiographs of the same tooth were selected. Images with poor image quality or extensive motion artefact, beam-hardening artefact, incomplete clinical records were excluded. Standardized departmental imaging protocols had been used for all radiographic examinations. The paralleling technique with a digital sensor was used to obtain digital intraoral periapical radiographs, while CBCT examinations were conducted using a limited field-of-view protocol that is dedicated to endodontic assessment. To ensure patient confidentiality, all images were anonymised prior to evaluation by giving anonymous coding. The anonymized CBCT scans and intraoral radiographs were analysed separately using an artificial intelligence (AI)–based deep learning software for automated detection of periapical lesions. The AI system classified if a periapical lesion was present or not and localised the lesion for each image. All AI outputs were featured as is. All of the images for the reference standard were examined independently by two oral and maxillofacial radiologists with over 5 years of experience who were unaware of the AI results and clinical data. Where there was disagreement, a consensus was achieved through joint evaluations. Consensus diagnosis was used as the gold standard. The sensitivity, specificity, positive predictive value, negative predictive value, overall diagnostic accuracy and area under the receiver operating characteristic (ROC) curve of the AI system for diagnostic performance of CBCT and intraoral radiographs were computed. The interrater agreement between AI and expert diagnosis was calculated using Cohen's kappa coefficient. IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp, Armonk, NY, USA) was used to perform statistical analysis. Categorical variables were presented as percentages and frequencies, continuous variables were presented as mean ± standard deviation. McNemar's test was used to compare the diagnostic performance of AI on CBCT and intraoral radiographs and Cohen's kappa statistics were used to determine interobserver agreement. Statistically significant p-values <0.05 were set. The study was approved by the Institutional Ethics Committee of tertiary care teaching hospital and was performed according to the ethical principles of the Declaration of Helsinki. This was a retrospective image-based study without any radiation exposure or intervention for research purposes because the radiographic records were anonymised.

Results:

In the present retrospective study, 100 patients (100 teeth) were included that met the eligibility criteria. The mean age at study was 39.8 ± 12.6 years ranging from 18 to 72 years. There were 56 males (56%) and 44 females (44%) among the participants. Sixty two (62%) teeth were diagnosed as periapical lesion and 38 (38%) teeth as no periapical pathology **(Table 1)** based on the consensus diagnosis of two experienced oral and maxillofacial radiologists. The artificial intelligence (AI)-based system's diagnostic performance of cone-beam computed tomography (CBCT) images was excellent relative to expert consensus diagnosis. The AI system correctly identified 59 of the 62 teeth with periapical lesions and classified 36 of the 38 teeth without periapical lesions correctly. Calculated sensitivity was 95.2%, specificity 94.7%, positive predictive value (PPV) 96.7%, negative predictive value (NPV) 92.3% and overall diagnostic accuracy 95.0%. Moreover, the receiver operating characteristic (ROC) curve analysis revealed a good performance of the AI algorithm on CBCT images with a good area under the curve (AUC) value of 0.96 **(Table 2).** The performance of AI system with digital IOPA was comparatively low as compared to the CBCT. The AI showed 52 out of the 62 teeth with periapical lesions with good results and 34 out of the 38 teeth without periapical lesions with good results. The corresponding sensitivity, specificity, PPV, NPV and overall diagnostic accuracy were 83.9%, 89.5%, 92.9%, 77.3% and 86.0%, respectively. CBCT had greater diagnostic performance than MRI with a ROC-AUC value of 0.94, followed by the value of 0.87 for MRI **(Table 3).**When comparing the diagnostic performance of the two imaging modalities, the AI system showed significant difference while analysing CBCT images as compared to intraoral periapical radiographs. CBCT exhibited higher sensitivity (95.2% vs. 83.9%), specificity (94.7% vs. 89.5%), positive predictive value (96.7% vs. 92.9%), negative predictive value (92.3% vs. 77.3%), overall diagnostic accuracy (95.0% vs. 86.0%) and ROC-AUC (0.96 vs. 0.87) compared with intraoral radiographs. The difference in diagnostic performance achieved a p-value of 0.018 (McNemar's test) with the AI showing superiority in detecting periapical lesion on CBCT images **(Table 4).** The agreement analysis was performed between the AI-based diagnosis and the consensus diagnosis by the experts for both imaging modalities, revealing high level of agreement between both diagnoses. CBCT images showed a Cohen's kappa coefficient (κ) of 0.90, which signified that there was almost perfect agreement between expert diagnosis. AI assessment of intraoral periapical radiographs, on the other hand, scored a κ of 0.73, indicating moderate agreement. Such results suggest that when interpreting CBCT images the AI system had a higher rate of diagnostic agreement with the expert radiologists when compared to intraoral radiographs **(Table 5).** The results from this current study showed that the AI-powered deep learning system had a higher diagnostic performance for CBCT images than digital intraoral periapical radiographs overall. As showed in the tables, the three-dimensional imaging platform (CBCT) showed considerably higher sensitivity, specificity, diagnostic accuracy and ROC-AUC and interobserver agreement values, suggesting the potential use of CBCT as an adjunctive diagnostic tool in endodontic imaging.

Table1: Demographic characteristics of the study population (age, gender, race, ethnicity and nationality).

Variable	Value
Total patients	100
Mean age (years)	39.8 ± 12.6
Age range (years)	18–72

Male	56 (56.0%)
Female	44 (44.0%)
Teeth with periapical lesions	62 (62.0%)
Teeth without periapical lesions	38 (38.0%)

Table 2:AI performance on CBCT

Parameter	Value (%)
Sensitivity	95.2
Specificity	94.7
Positive predictive value	96.7
Negative predictive value	92.3
Diagnostic accuracy	95.0
ROC-AUC	0.96

Table 3: The AI performance on intraoral periapical radiographs

Parameter	Value (%)
Sensitivity	83.9
Specificity	89.5
Positive predictive value	92.9
Negative predictive value	77.3
Diagnostic accuracy	86.0
ROC-AUC	0.87

Table 4: Comparison of diagnostic performance

Parameter	CBCT	IOPA
Sensitivity (%)	95.2	83.9
Specificity (%)	94.7	89.5
Positive predictive value (%)	96.7	92.9
Negative predictive value (%)	92.3	77.3
Diagnostic accuracy (%)	95.0	86.0
ROC-AUC	0.96	0.87
McNemar test	p = 0.018	

Table 5: Cohen's kappa agreement

Imaging modality	Cohen's κ	Interpretation
CBCT	0.90	Almost perfect agreement
IOPA	0.73	Substantial agreement

Discussion:

The periapical lesions are one of the most frequently seen sequelae of pulpal infection; their early and correct diagnosis is crucial to successful endodontic diagnosis and treatment planning. Due to its low radiation dose, accessibility and cost-effectiveness, conventional intraoral periapical radiography continues to be the imaging modality of choice in routine dental practice. It is, however, a two-dimensional image and the ability to detect periapical bone changes is often hindered by anatomical superimposition and geometric distortion, thus limiting the detection of early periapical bone changes. Cone-beam computed tomography (CBCT), on the other hand, allows 3D visualization of the periapical tissue and has demonstrated to increase lesion detection; however, interpretation is more challenging and takes longer **[1–4].** With recent advancements in artificial intelligence (AI), in particular, deep learning algorithms, new opportunities have emerged for automated image interpretation, such as in endodontic diagnosis **[5–8].**The present study highlights the difference in the diagnostic accuracy of an AI-based DL system in locating periapical lesions on CBCT and DIPA radiographs. The results showed that there was a significant difference in all diagnostic parameters (sensitivity, specificity, overall diagnostic accuracy, ROC-AUC) between the CBCT and intraoral groups of AI application. Additionally, the agreement rate between the AI and the expert radiologists was close to 100% for CBCT and reasonable for intraoral radiographs, showing that the AI is more reliable in interpreting three-dimensional data sets. In the present study, the performance of AI on CBCT was found to be superior, which is in accordance with previous studies. Schwendicke highlighted that deep learning algorithms show excellent diagnostic performance for dental radiology especially if good 3D datasets are available **[5].** In a similar manner, Raj emphasized that artificial intelligence (AI) systems, coupled with cone beam computed tomography (CBCT) imaging, are more accurate in diagnosing endodontic pathologies, as the three-dimensional volumetric information offers more detailed anatomical information than a two dimensional radiograph **[6].** This increased sensitivity can thus be explained by the ability to better visualize the cancellous and cortical bone, allowing the AI algorithm to detect subtle osseous changes that might not be detected on conventional radiographs as observed in the present study. The results are also in line with the systematic review performed by Khanagar who determined that the diagnostic accuracy of AI models was high especially when they were trained from CBCT datasets **[9].** Similarly, the latest systematic review conducted by Soltani indicated that AI based algorithms always showed higher sensitivity and specificity in CBCT compared to traditional intraoral radiographs, yet the heterogeneity among the datasets and AI architectures was a drawback **[11].** The diagnostic values that were achieved in the current study are similar to the findings of these reviews, adding to the evidence that AI can be a valuable tool in endodontic imaging. The accuracy of AI in diagnosis of intraoral periapical radiographs, as seen in the present study, is also in agreement with previous literature **[12, 13].** Meanwhile, conventional radiographs can only detect periapical lesions after substantial loss of the surrounding cortical bone and that both for clinicians and AI algorithms **[14–16].** Despite advancements in the technology, Kazimierczak and Cotti and Schirru and pointed out that 2D imaging still has some constraints and hence affect the diagnostic accuracy, especially when the lesion is limited to the cancellous bone **[17, 18].** Nardi *et al.* also showed that CBCT has a great benefit in detection of apical periodontitis, especially when avoiding the overlap of anatomical structures with periapical radiography **[19].** This result may be a possible explanation for the relatively poor sensitivity and diagnostic accuracy of AI noted with intraoral radiograph obtained with the present investigation. The consistency showed between AI and oral radiologists with clinical experience in CBCT imaging further highlights the potential for AI support in diagnosis. Nearly perfect agreement was observed in the Cohen's kappa coefficient for the CBCT and substantial agreement was observed for intraoral radiographs in this current study. The same was observed by Sherwood who achieved good agreement between AI-assisted diagnosis and expert interpretation for the detection of endodontic lesions on CBCT images **[14].** The high agreement indicates that the AI could potentially minimize observer variation and enhance consistency in radiographic

interpretations, especially in busy clinical environments. Recent books and articles have emphasized that AI has become important in dental radiology not just for periapical lesion detection. According to Alzaid AI systems have demonstrated potential accuracy in the diagnosis of several oral diseases such as dental caries, periodontal bone loss, periapical lesions and root fractures comparable to that of trained clinicians **[7].** In the same vein, Ossowska recommended that AI will probably become a valuable instrument in oral radiology for assisting decision-making as this will facilitate greater uniformity in diagnoses and reduce the time taken to interpret the results **[8].** The results of the current study, showing strong AI performance, especially in conjunction with CBCT imaging, corroborate these findings. Recent narrative reviews also highlight the growing clinical use of AI in oral and maxillofacial radiology, which corroborates the present findings. Aloufi acknowledged that the use of AI in analyzing CBCT images is one of the most promising advancements in modern dental diagnostics and that AI could significantly streamline dental workflows and enhance diagnostic accuracy in the future **[11].** Likewise, recent articles in the Journal of Endodontics underscore the growth of AI applications in endodontic imaging and that AI algorithms are making continuous strides with the ongoing improvement in deep learning architectures and vast amounts of annotated imaging data **[12, 13].** While the encouraging results speak for themselves, at present, AI must be considered an ancillary tool and not a substitute for clinician expertise. Authors have pointed multiple times to the importance of image quality, diversity of the dataset, accuracy of the annotation and external validation for the performance of an AI **[20–22].** Nagareddy *et al.* commented that, despite the excellent diagnostic performance of AI, there is still a need for multicenter studies with heterogeneous populations and standardized imaging protocols before AI can be widely introduced into clinical practice **[23].** The same holds true for the present study. The strengths of the current study are the adoption of expert consensus as reference, execution of AI assessment of image data from the same patients on two imaging modalities, uniformity of imaging protocols and the blinded interpretation of the images. However some cautions need to be pointed out. Because of the retrospective single-center design, the findings might not be generalizable. The sample size was relatively small and a single AI software platform was assessed. Additionally, the performance of AI could vary with different deep learning architectures or imaging systems. Future multicenter prospective studies with larger datasets, external validation cohort and between multiple commercially available AI algorithms are recommended to further validate the clinical applicability of AI-assisted diagnosis in endodontics **[24–26].** The study results of the present study seem to corroborate the previous studies finding excellent diagnostic performance of AI, especially when used for the diagnosis of periapical lesions with CBCT imaging. AI also showed strong performance in the digital intraoral radiographs but had much more accurate diagnostic results on CBCT, which has the benefit of three-dimensional imaging. Thus, AI-driven CBCT interpretation holds great promise in enhancing diagnostic precision, minimizing the variability among observers and aiding in clinical decision-making within the realm of endodontics **[5, 6 and 9–11].**

Conclusion:

AI showed much greater diagnostic accuracy in the detection of periapical lesions in CBCT images as compared to digital intraoral periapical radiographs. The results show that AI-assisted CBCT interpretation had excellent agreement with expert radiologists, highlighting its potential as a reliable adjunctive tool in endodontic diagnosis. Large-scale prospective multicenter studies are needed to confirm these results and to advance the introduction of AI into clinical practice.

Advancement of knowledge:

This study allows direct comparison of AI performance on CBCT and intraoral periapical radiographs using the same patient population and shows that AI-assisted CBCT interpretation greatly enhances the diagnostic performance for periapical lesion detection and agreement with expert radiologists.

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