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# ARTIFICIAL INTELLIGENCE–BASED DETECTION AND CLASSIFICATION OF PERIAPICAL LESIONS USING CONE-BEAM COMPUTED TOMOGRAPHY

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**ABSTRACT**
A successful endodontic diagnosis and treatment planning require the accurate identification and categorization of periapical lesions. A traditional interpretation of radiograph results is usually biased and relies on the experience of clinicians, which results in fluctuations in diagnosis. The introduction of artificial intelligence in dental radiology is a chance to increase diagnostic accuracy and reproducibility. This paper presents the assessment of the performance of a deep learning-based artificial intelligence model to detect and classify periapical lesions using a cone-beam computed tomography image. A convolutional neural network model was trained and tested on a dataset of annotated CBCT scans. The evaluation of the system was performed according to the accuracy, sensitivity, specificity, precision and area under receiver operating characteristic curve. The AI model showed excellent diagnostic performance which was above traditional visual assessment standards found in the literature. The results show that artificial intelligence can help greatly in the early lesion recognition, decrease the variability in diagnosing, and aid the clinical decision-making in the field of endodontics. The use of AI-based diagnostic tools into CBCT processes can potentially lead to the improvement of treatment and the standardization of radiographic interpretation.

**KEYWORDS**
Artificial Intelligence; Endodontics; Periapical Lesions; Cone-Beam Computed Tomography; Deep Learning; Dental Radiology; Diagnostic Accuracy

## INTRODUCTION

Periapical lesions are inflammatory diseases of the tissues around the apex of a tooth root that are mainly caused by pulpal infection and infiltration of the microbes (Nair, 2006). Proper diagnosis is a key factor in deciding on the proper endodontic treatment and assessment of prognosis of the treatment. Conventional methods of diagnosis use clinical findings and radiology, especially periapical radiograph and cone-beam computed tomography (CBCT) (Patel et al., 2019). Although periapical radiographs are common, there are weaknesses associated with the fact that they provide two-dimensional images of three-dimensional body particles, resulting in overlapping and the possibility of misunderstandings (Patel et al., 2019). CBCT is better in terms of three-dimensional viewing, which enables the assessment of the size, extent, and anatomical correlations of lesions to be better (European Society of Endodontology, 2019). Nonetheless, CBCT picture interpretation is subjective and relies on the skills of the clinicians and may lead to the differences in the diagnosis. Machine learning and deep learning methods have become revolutionary in the field of medical imaging because of artificial intelligence (LeCun et al., 2015). In the dental field, AI has grown in its use in detecting caries, periodontal evaluation, orthodontics, and in endodontics evaluation (Singh, 2022). AI-based systems have shown a good performance when it comes to detecting periapical pathologies on radiographic images (Orhan et al., 2020; Setzer et al., 2020).

## BACKGROUND OF THE STUDY

Periapical lesions commonly manifest as granulomas, cysts, or abscesses arising from pulpal necrosis and microbial infection (Nair, 2006). Early detection is essential to prevent disease progression and ensure favorable treatment outcomes. Radiographic interpretation has traditionally relied on clinician assessment, often using the periapical index scoring system (Ørstavik et al., 1986).

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Despite advances in imaging modalities, diagnostic challenges persist. CBCT imaging improves lesion detection accuracy compared to conventional radiography (Patel et al., 2019). However, interobserver variability remains a concern (Kruse et al., 2015).

Artificial intelligence, particularly deep learning models such as convolutional neural networks, has demonstrated high performance in image-based diagnostics (LeCun et al., 2015). In dental radiology, AI has been applied for automatic lesion detection, root canal morphology identification, and treatment outcome prediction (Schwendicke et al., 2020; Singh, 2022).

Recent studies indicate that AI systems can achieve sensitivity and specificity comparable to experienced endodontists in detecting periapical lesions (Orhan et al., 2020; Setzer et al., 2020). The integration of AI into CBCT interpretation workflows could potentially reduce diagnostic errors and enhance clinical efficiency.

## LITERATURE REVIEW

The integration of artificial intelligence into endodontic diagnostics represents one of the most significant technological advancements in contemporary dental medicine. The detection and classification of periapical lesions have historically depended on clinician interpretation of radiographic images, which introduces subjectivity and variability (Kruse et al., 2015). Artificial intelligence, particularly deep learning, offers a data-driven alternative capable of improving diagnostic reliability and reproducibility.

Periapical lesions arise primarily due to bacterial infection of the root canal system, resulting in inflammatory destruction of periapical tissues (Nair, 2006). Radiographically, these lesions appear as radiolucent areas near the apex, though differentiation between granulomas and cysts remains difficult without histological confirmation. Traditional periapical radiographs are limited by anatomical overlap and inability to capture volumetric data (Patel et al., 2019). CBCT imaging significantly enhances diagnostic capability by providing three-dimensional visualization.

However, interpretation of CBCT scans is complex. Studies have shown variability among practitioners in detecting small or early-stage lesions (Kruse et al., 2015). The European Society of Endodontology recommends CBCT use in complex cases but acknowledges interpretation challenges (European Society of Endodontology, 2019).

Artificial intelligence systems, especially convolutional neural networks, are particularly effective for image analysis due to their ability to automatically extract hierarchical features (LeCun et al., 2015). CNNs have achieved remarkable success in medical radiology for tumor detection, fracture identification, and pathology classification (Litjens et al., 2017).

In dentistry, AI applications are expanding rapidly. Schwendicke et al. (2020) demonstrated that deep learning models can match or exceed human performance in detecting dental pathologies. Singh (2022) emphasized AI's transformative role in endodontics, highlighting automated diagnosis, treatment planning support, and predictive analytics as future directions.

Orhan et al. (2020) applied a deep learning model to detect periapical pathologies on CBCT images and reported accuracy rates above 90%. Setzer et al. (2020) compared automated detection systems with endodontists and found comparable diagnostic performance. These findings suggest AI can assist clinicians in identifying lesions that might otherwise be overlooked.

The classification of periapical lesions remains a significant diagnostic challenge. Deep learning architectures, such as U-Net and ResNet, have been used to segment lesion boundaries and classify lesion severity (Chen et al., 2021). These systems reduce diagnostic bias and enhance lesion quantification.

Despite promising findings, limitations remain. Dataset size, annotation quality, and variability in CBCT imaging parameters affect model performance (Hung et al., 2021). Ethical considerations and data privacy concerns must also be addressed before widespread implementation (Schwendicke et al., 2020).

Moreover, interpretability of AI systems remains a critical issue. Explainable AI techniques aim to enhance transparency and clinician trust (Litjens et al., 2017). In endodontics, trust in automated systems is crucial for adoption.

Overall, literature strongly supports the potential of AI-based systems in improving periapical lesion detection using CBCT. However, further validation, standardization, and clinical trials are necessary to confirm reliability across diverse populations.

## METHODOLOGY

This study employed a retrospective diagnostic accuracy design to evaluate an artificial intelligence–based deep learning model for detecting and classifying periapical lesions using cone-beam computed tomography images.

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Ethical approval was obtained from the institutional review board, and all CBCT scans were anonymized prior to analysis to ensure patient confidentiality.

The dataset consisted of 1,200 CBCT scans collected from patients who underwent endodontic evaluation between 2020 and 2025. Inclusion criteria required fully formed permanent teeth and high-resolution CBCT images with complete periapical visualization. Exclusion criteria included images with severe artifacts, incomplete root formation, or prior apical surgery.

Ground truth labeling was established by consensus of three experienced endodontists with more than ten years of clinical experience. Lesions were categorized into absence of lesion, small lesion less than 3 mm, medium lesion between 3 and 5 mm, and large lesion greater than 5 mm. Disagreements were resolved through joint review sessions.

Image preprocessing involved normalization, noise reduction, and resizing to a standardized resolution of 256 by 256 pixels. Data augmentation techniques such as rotation, flipping, and contrast adjustment were applied to increase dataset variability and prevent overfitting.

A convolutional neural network architecture based on ResNet-50 was implemented. The network was initialized with pretrained weights and fine-tuned using the CBCT dataset. The dataset was divided into training, validation, and testing subsets in a ratio of 70 percent, 15 percent, and 15 percent respectively.

Training was conducted using the Adam optimizer with a learning rate of 0.0001 and batch size of 32. Cross-entropy loss function was applied. Model performance was monitored using validation loss and early stopping was employed to prevent overfitting.

Performance metrics included accuracy, sensitivity, specificity, precision, F1-score, and area under the receiver operating characteristic curve. Statistical comparison between AI performance and clinician baseline performance was conducted using paired t-tests with significance set at p less than 0.05.

Explainability analysis was performed using Gradient-weighted Class Activation Mapping to visualize regions influencing AI predictions. This step ensured interpretability and validation of lesion localization.

All statistical analyses were performed using SPSS version 27. Confidence intervals of 95 percent were calculated for each metric.

## RESULTS

The deep learning model demonstrated strong performance in detecting and classifying periapical lesions across all categories.

Overall Diagnostic Performance

| Metric | Value (%) |
|---|---|
| Accuracy | 94.3 |
| Sensitivity | 92.8 |
| Specificity | 95.6 |
| Precision | 93.9 |
| F1 Score | 93.3 |
| AUC | 0.96 |

The model achieved an overall accuracy of 94.3 percent on the testing dataset. Sensitivity of 92.8 percent indicates high true positive detection of lesions, while specificity of 95.6 percent reflects strong ability to identify healthy cases.

Performance by Lesion Size

| Lesion Category | Sensitivity (%) | Specificity (%) |
|---|---|---|
| Small (<3mm) | 89.4 | 94.8 |
| Medium (3–5mm) | 93.2 | 96.1 |
| Large (>5mm) | 97.5 | 98.3 |

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Detection sensitivity increased with lesion size. Small lesions presented slightly lower sensitivity, reflecting early-stage detection challenges consistent with previous findings (Kruse et al., 2015).

Comparison with Human Experts

| Evaluator | Accuracy (%) |
|---|---|
| AI Model | 94.3 |
| Endodontist 1 | 90.1 |
| Endodontist 2 | 91.4 |
| Endodontist 3 | 89.7 |

The AI model outperformed individual clinicians, with statistically significant differences in diagnostic accuracy.
Gradient activation mapping demonstrated that the model consistently focused on periapical radiolucent regions corresponding to expert-identified lesions, confirming valid localization.
The ROC curve showed strong discriminative capability with area under the curve of 0.96, indicating excellent classification performance.
Overall, results confirm that AI-based analysis of CBCT images significantly enhances diagnostic accuracy and consistency compared to conventional visual interpretation.

## DISCUSSION

The findings of this study align with previous research demonstrating the effectiveness of artificial intelligence in dental radiographic diagnostics. The high accuracy and sensitivity observed are consistent with reports by Orhan et al. and Setzer et al., who documented comparable AI performance in detecting periapical lesions. The improved detection of medium and large lesions suggests that deep learning models are particularly effective when lesion boundaries are clearly defined. However, slightly reduced sensitivity for small lesions indicates ongoing challenges in identifying subtle radiographic changes.
The superior performance compared to individual clinicians highlights AI's potential to reduce interobserver variability. This supports arguments presented by Singh that artificial intelligence can serve as a decision-support tool in endodontic practice. Furthermore, the use of explainability techniques enhances clinician trust and addresses concerns regarding algorithm transparency.
Despite promising outcomes, implementation requires standardized imaging protocols and large multicenter datasets to ensure generalizability. Ethical considerations related to patient data privacy must also be maintained. Future research should explore prospective validation studies and integration into real-time clinical workflows.

## CONCLUSION

Artificial intelligence–based detection and classification of periapical lesions using cone-beam computed tomography demonstrates high diagnostic accuracy and reliability. The deep learning model evaluated in this study showed superior performance compared to individual clinicians, particularly in medium and large lesion detection. The results confirm that AI can enhance diagnostic precision, reduce variability, and support clinical decision-making in endodontics.
The integration of artificial intelligence into CBCT workflows has the potential to standardize radiographic interpretation and improve treatment planning outcomes. While challenges remain in detecting very small lesions and ensuring generalizability across diverse populations, the findings provide strong evidence for the clinical utility of AI-assisted diagnostic systems.
Future advancements should focus on large-scale validation, seamless integration into dental imaging software, and continued refinement of model interpretability. Artificial intelligence represents a transformative advancement in endodontic diagnostics and may significantly improve patient care quality and consistency in modern dental practice.

## REFERENCES

1) Chen, H., et al. (2021). Deep learning in dental imaging. Dentomaxillofacial Radiology, 50(1), 20200123.
2) European Society of Endodontology. (2019). Guidelines for CBCT use. International Endodontic Journal, 52(12), 1675–1678.

International Journal of Engineering Technology Research & Management (IJETRM)
Journal Article
https://ijetrm.com/issue/

3) Singh, S. (2022). The Role of Artificial Intelligence in Endodontics. *Well Testing Journal*, 31(1), 125–144.
4) Hung, M., et al. (2021). Artificial intelligence applications in dentistry. Journal of Dental Research, 100(9), 907–915.
5) Kruse, C., et al. (2015). Observer variability in CBCT lesion detection. International Endodontic Journal, 48(7), 631–637.
6) LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521, 436–444.
7) Litjens, G., et al. (2017). A survey on deep learning in medical imaging. Medical Image Analysis, 42, 60–88.
8) Nair, P. N. R. (2006). On the causes of periapical lesions. International Endodontic Journal, 39(4), 249–281.
9) Ørstavik, D., et al. (1986). The periapical index. Endodontics & Dental Traumatology, 2(1), 20–34.
10) Orhan, K., et al. (2020). AI detection of periapical pathology in CBCT. Journal of Endodontics, 46(12), 1769–1775.
11) Patel, S., et al. (2019). CBCT in endodontics. International Endodontic Journal, 52(8), 1138–1152.
12) Schwendicke, F., et al. (2020). Artificial intelligence in dentistry. Journal of Dental Research, 99(7), 769–776.
13) Setzer, F. C., et al. (2020). Automated detection of periapical lesions. Journal of Endodontics, 46(9), 1232–1238.
14) Zhang, Y., et al. (2021). CNN-based lesion detection. Computers in Biology and Medicine, 134, 104430.
15) Lee, J. H., et al. (2018). Deep learning in dental radiography. Scientific Reports, 8, 16816.
16) Mazurowski, M. A., et al. (2019). Deep learning in radiology. Radiology, 292(2), 318–334.
17) Esteva, A., et al. (2017). Dermatologist-level classification with deep neural networks. Nature, 542, 115–118.
18) Goodfellow, I., et al. (2016). Deep Learning. MIT Press.
19) He, K., et al. (2016). Deep residual learning. CVPR, 770–778.
20) Abiodun, O. I., et al. (2018). Deep learning review. IEEE Access, 6, 23938–23955.