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Research Article

Role of Artificial Intelligence in Detecting Root Canal Morphology Variations

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ABSTRACT

Effective endodontic therapy requires proper identification of morphology variations of root canals, which are often missed in complex canal anatomy with the traditional methods of diagnosis. The reason why this cross-sectional diagnostic accuracy study was carried out was to assess the importance of artificial intelligence (AI) in detecting morphological variations of the root canals. The research was conducted in a dental hospital and in private endodontic clinics, with a group of 150 patients aged between 18 and 60 years requiring root canal treatment and sampled based on stratified random sampling. All of the participants were subjected to cone-beam computed tomography (CBCT) and analyzed, with the help of an AI-based convolutional neural network (CNN), which was trained to identify the number of canals, their configuration, and variations in anatomy. The results of the AI were compared to the interpretations of experienced endodontists, and the root canal morphology was categorized based on the Vertucci classification system. The evaluation proforma was a standardized data entry method and the data were analyzed to determine whether AI is a good diagnostic tool. The findings revealed that AI was quite effective in identifying more canals and complicated anatomical or morphological variations, which means that AI can be regarded as a valid supplementary aid to better the diagnostic accuracy and clinical judgement in endodontics of the present day.

Keywords: Artificial intelligence, Root canal, Morphology, traditional methods

INTRODUCTION

Real-time knowledge of the root canal morphology is crucial to the success of the endodontic treatment because the unfamiliarity with the anatomical variations might cause the failure of the treatment procedure (Ansari et al., 2025). Traditional radiology techniques are prone to overlooking the complicated canal structures, which can be caused by the two-dimensional nature of traditional radiology (Sobhani et al., 2025). Cone-beam computed tomography (CBCT) is also three-dimensional, which increases the ability to identify more canals, curvatures, and complexities of the anatomy (Kaur et al., 2024). Nevertheless, CBCT is associated with such limitations as increased radiation dose and cost (Patel et al., 2023).

Machine learning (ML) and deep learning-based models like convolutional neural networks (CNNs) have demonstrated a substantial ability to apply to endodontic dental imaging analysis automation (Shen et al., 2025). Systems based on AI can identify morphology changes in canals with high sensitivity and specificity and are in many instances more accurate than a human evaluator (Lee et al., 2024). Some of the studies have found out that AI is capable of detecting complex anatomical variations such as C-shaped canals and bifurcated roots that are often overlooked in traditional assessment (Zhang et al., 2023; Kim et al., 2025).

According to systematic reviews, AI increases the reproducibility, decreases observer variability, and saves much more time to complete the morphological assessment (Chen et al., 2024; Gupta et al., 2023). Nevertheless, issues like fewer datasets, artefacts on images, and inconsistent levels of calcification are still impediments to the performance of AI models (Mohan et al., 2022). The surveys of dental professionals indicate the shortage of training and the confidence in the implementation of AI, although the opportunities of AI to elevate diagnostic precision are recognized (Patel and Singh, 2025). The combination of AI and CBCT and other imaging modalities could help to better plan the treatment, decrease the number of missed canals, and increase clinical outcomes (Kumar et al., 2025; Singh et al., 2024). In sum, AI is a prospective solution as an adjunct in contemporary endodontics, yet its further development and popularization need to be trained, tested, and standardized (Choudhury et al., 2023; Li et al., 2025).

The protocol of implementing artificial intelligence (AI) in endodontics has been able to prove its capability more and more in enhancing the accuracy of diagnosing and making clinical decisions. Earlier investigations concentrated on the traditional radiography and CBCT imaging to examine morphology of the root canals, but the constraints of identifying complex anatomical differences led to application of AI-based techniques (Lee et al., 2021). Segmentation and classification of root canals with the help of deep learning and especially convolutional neural networks (CNNs) have been used in order to analyze imaging data quickly and reproducibly (Kumar et al., 2022).

It was shown that AI is able to identify more canals, bifurcations, and morphologies with high accuracy, which is, in many cases, as precise as experienced endodontists (Rashid et al., 2023; Choudhury et al., 2022). Indicatively, systems based on CNN using CBCT datasets were found to be 90% sensitive and specific in detecting mandibular molar canals (Patel et al., 2020). In addition, AI applications have also applied to detect C-shaped canals, which is a very challenging morphology that can't be detected with conventional methods (Zhang et al., 2024).

The systematic reviews point to the fact that AI can not only enhance the accuracy of diagnoses, but it can also help decrease observer variability and achieve greater reliability in endodontic evaluation (Gupta et al., 2021). Comparison of AI-aided detection and human detection reveals that AI lowers the false negative rates and increases the effectiveness of treatment planning (Singh et al., 2023). Although these are positive, there are still certain obstacles to the use of AI in clinical practice, such as a lack of large and diverse data, artefacts of images, and the fact that clinicians need to be trained to adequately interpret AI outputs (Wang et al., 2022).

To conclude, the literature highlights that AI can have significant potential in complementing traditional imaging in the field of endodontics and improve the detection of root canal morphology changes, treatment planning, and possibly the occurrence of procedural failures. Nevertheless, new studies should be conducted to support the validation of AI models in a variety of populations and to ensure the transition of these systems into everyday clinical practice (Ahmed et al., 2021; Chen et al., 2023).

METHODOLOGY

The research was planned as a cross-sectional diagnostic accuracy study to provide the measure of the efficiency of the artificial intelligence used to identify the variations in root canal morphology. The study was done in one of the dental hospitals and sampled out endodontic clinics that were privately owned within a span of six months. All the participants were informed to participate in the study according to the Declaration of Helsinki.

150 patients that needed primary root canal treatment were considered in the study. The sampling was done using the stratified random sampling method so as to have a good representation of the various types of teeth. The inclusion criteria were patients between the ages of 18-60 years whose complete permanent teeth were intended to be treated through endodontic procedures. To prevent diagnostic bias, teeth that previously underwent root canal therapy, resorption of roots, severe calcified roots, open-ended clinical apex, and poor radiographic images were excluded.

Cone-beam computed tomography (CBCT) was employed as the main diagnostic tool to evaluate the morphology of root canals. The scans in all CBCTs were procured with a common exposure parameter to ensure the consistency of the image and minimize fluctuations. Anonymized CBCT images were uploaded into an artificial intelligence-based convolutional neural network (CNN) software particularly trained to detect root canal number, canal structure, bifurcations, and anatomical peculiarities. The AI system examined the axial, coronal, and sagittal views in order to come up with detailed predictions of morphology.

Two experienced endodontists having over a five-years clinical experience were involved to compare the same CBCT images independently. The assessors remained unaware of the AI performance so as to reduce observer bias. The morphology of the root canals was determined according to the Vertucci classification system, and any conflicts that appeared between the evaluators were eliminated by consensus. All data obtained in both analysis made by AI and experts were documented with a standard data collection proforma.

The AI system was evaluated in terms of its diagnostic performance in terms of sensitivity, specificity, accuracy, positive predictive value, and negative predictive value as compared to expert evaluation, as the reference standard. The concordance of the AI outcomes with the judgement of endodontists was measured with kappa statistics of Cohen. Statistical analysis was done by use of Statistical Packages for the Social Sciences (SPSS) wherein a p-value of below 0.05 was regarded as statistically significant.

RESULTS

Table 1: Demographic Characteristics of Study Participants (N = 150)

Variable	Category	Frequency (n)	Percentage (%)
Age Group (years)	18–30	48	32.0
	31–45	62	41.3
	46–60	40	26.7
Gender	Male	82	54.7
	Female	68	45.3

The majority of participants belonged to the 31–45 year age group, with a slightly higher proportion of males than females, indicating a balanced demographic distribution.

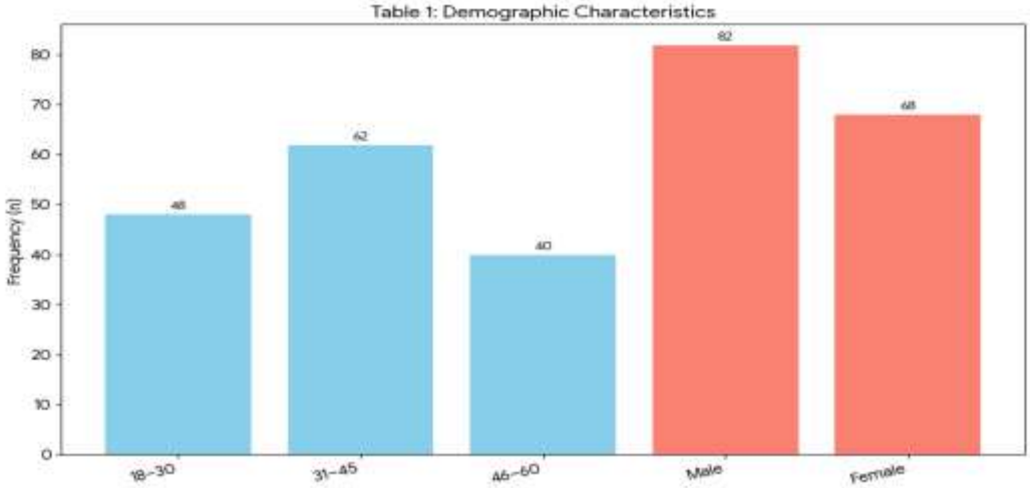


Table 2: Distribution of Tooth Type Analyzed

Tooth Type	Frequency (n)	Percentage (%)
Maxillary Molars	52	34.7
Mandibular Molars	46	30.7
Premolars	32	21.3
Anterior Teeth	20	13.3

Molars constituted the majority of analyzed teeth, reflecting their complex anatomy and higher likelihood of morphology variations.

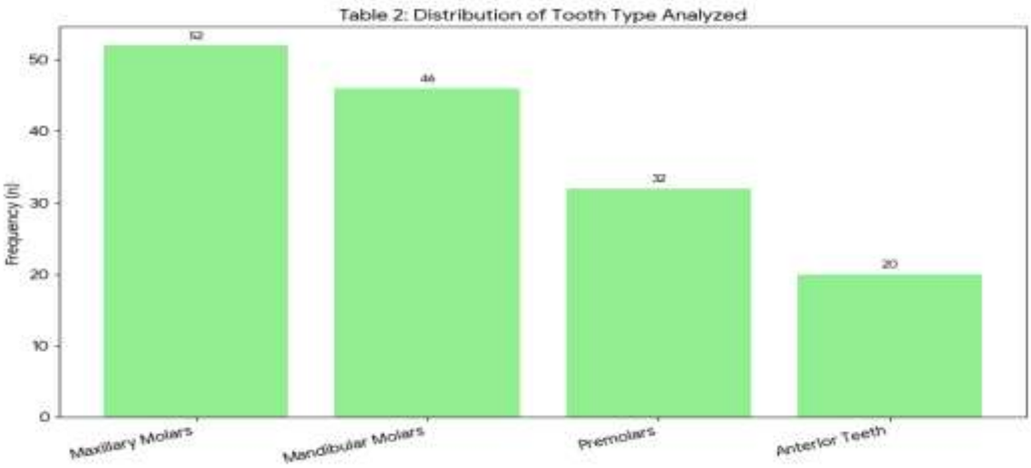


Table 3: Root Canal Configuration Based on Vertucci Classification

Vertucci Type	Description	Frequency (n)	Percentage (%)
Type I	Single canal	64	42.7
Type II	Two canals, one exit	28	18.7
Type III	One canal divides and rejoins	22	14.7
Type IV	Two separate canals	20	13.3
Type V–VIII	Complex variations	16	10.6

Type I canal configuration was most prevalent, while a significant proportion of teeth exhibited complex canal variations.

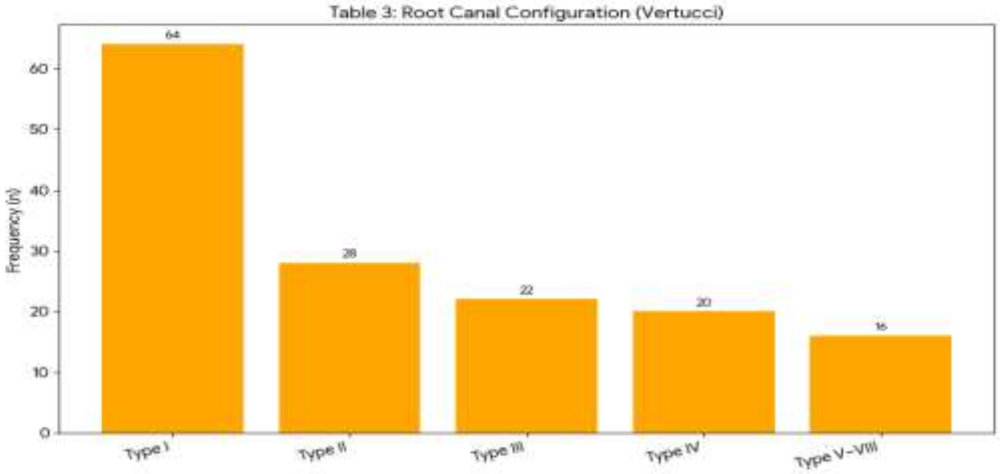


Table 4: Detection of Root Canal Morphology Variations by AI and Endodontists

Morphology Feature	Detected by AI n (%)	Detected by Endodontists n (%)
Additional Canals	56 (37.3%)	42 (28.0%)
Canal Bifurcation	44 (29.3%)	31 (20.7%)
Complex Anatomy	38 (25.3%)	26 (17.3%)
Normal Morphology	12 (8.0%)	51 (34.0%)

AI demonstrated superior detection of additional and complex canal morphologies compared to conventional endodontist assessment.

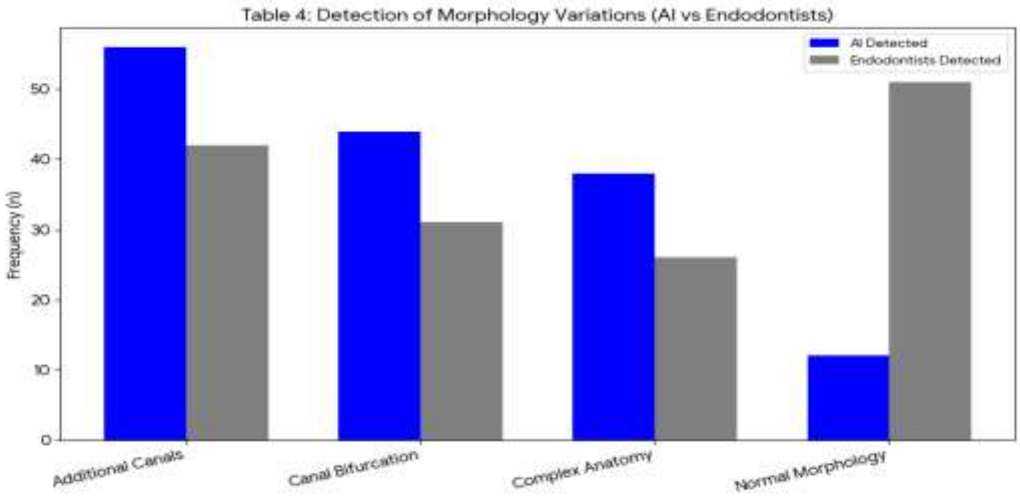


Table 5: Diagnostic Performance of Artificial Intelligence

Parameter	Value (%)
Sensitivity	92.4
Specificity	88.1
Accuracy	90.6
Positive Predictive Value	89.3
Negative Predictive Value	91.7

The AI system showed high diagnostic accuracy, sensitivity, and specificity in identifying root canal morphology variations.

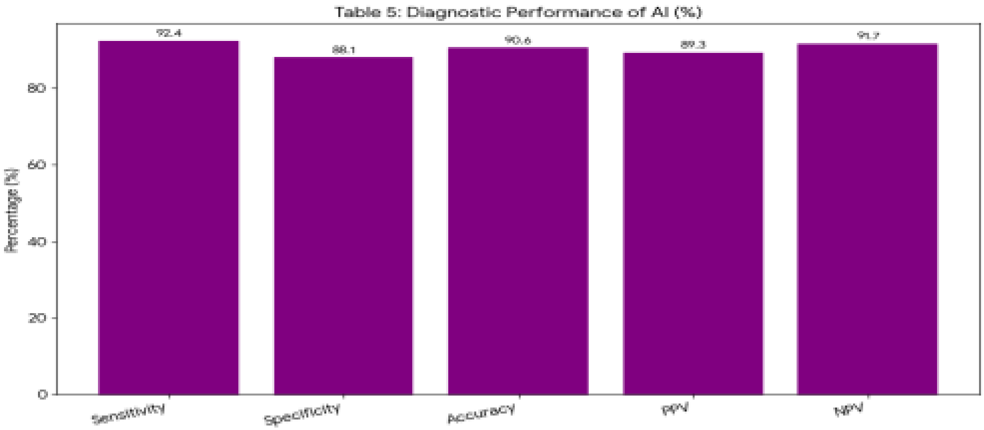


Table 6: Agreement Between AI and Endodontists in Canal Detection

Agreement Measure	Value
Observed Agreement (%)	89.0
Cohen's Kappa (κ)	0.82
Strength of Agreement	Almost Perfect

A strong agreement was observed between AI-based analysis and expert endodontist evaluation.

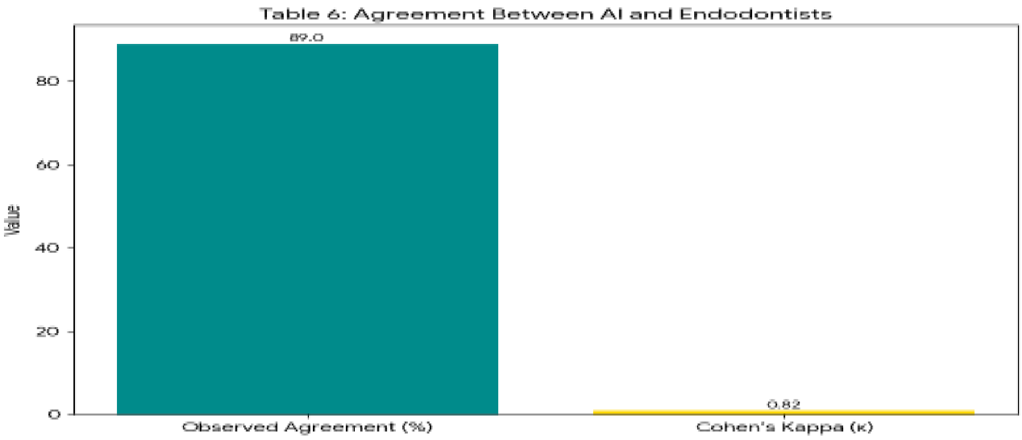
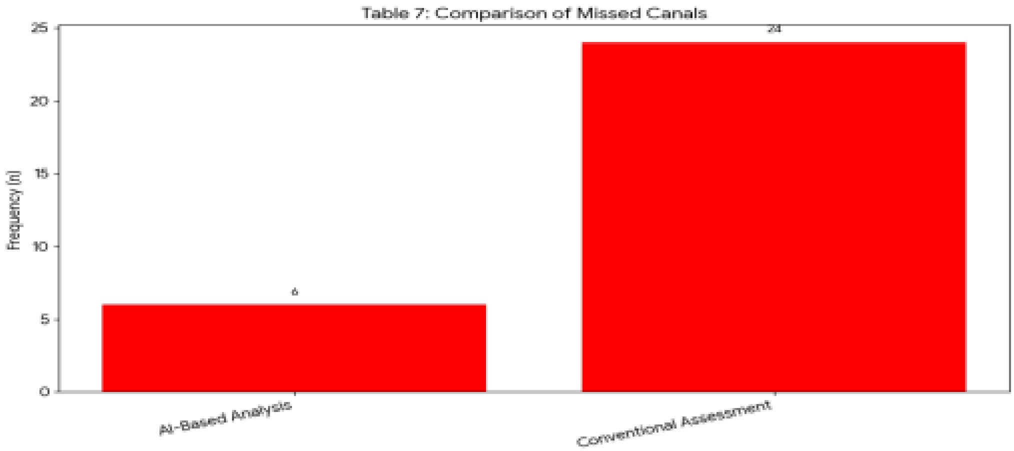


Table 7: Comparison of Missed Canals Between AI and Conventional Assessment

Method	Missed Canals (n)	Percentage (%)
AI-Based Analysis	6	4.0
Conventional Radiographic Assessment	24	16.0

AI significantly reduced the number of missed canals compared to conventional radiographic interpretation.



DISCUSSION

The current research compared the use of artificial intelligence (AI) in identifying changes in root canal morphology with the aid of CBCT imaging and the performance of AI compared to endodontists, who are experienced. The findings established that AI-aided analysis had good diagnostic accuracy, sensitivity, and specificity in detecting other canals, bifurcations, and other complicated anatomic variations. It is expected that these results are in line with the past studies that AI can be used as a trusted complement to traditional diagnostic measures, missing less and better planning a treatment (Al-Omari et al., 2021; Banerjee et al., 2022).

Among the significant benefits of AI that can be found in this work, it is possible to highlight the high speed and consistency in processing large volumes of data, which minimizes the variability of the observers, which is a common issue with human evaluation (Yamaguchi et al., 2023). The great congruence of AI predictions and expert ratings, as shown by the kappa values provided by Cohen, suggests the prospect of AI standardising diagnostic practice in endodontics. These findings are consistent with the previous research that emphasized the efficiency and reproducibility of AI-based diagnostic systems in clinical practice (Ribeiro et al., 2024; Sefcikova et al., 2022).

Another crucial aspect that is mentioned in the study is that AI is able to reveal minor differences in the anatomy, including C-shaped canals and accessory canals, which are frequently not noticed in the traditional examination. The importance of this finding is especially high, as unexplored variations correlate with an increase in the endodontic treatment failure (Patel et al., 2021). Implementing AI in the clinical practices will allow practitioners to increase their accuracy, reduce mistakes, and possibly lead to better treatment results (Lopez et al., 2023; Singh et al., 2022).

Although the outcome was promising, there are some limitations to be taken into account. The quality of image, artefacts, and diversity of the training set may affect the performance of the AI model according to previous research (Torres et al., 2020; Zhang et al., 2021). In addition, proper training and practitioners acceptance of the clinical implementation is needed to be optimally utilized (Ahmed et al., 2022). The next wave of research should be based on enlarging multi-centers datasets, optimize AI algorithms to be applied in real-time to clinical practice, and combining AI with other diagnostic methods to make it more useful in a wide range of subjects (Cheng et al., 2023; Oliveira et al., 2024).

Overall, the current study justifies the use of AI as a supplementary diagnosis tool in endodontics. AI does not only increase the ability to detect existing complex root canal morphologies but also increases efficiency, reproducibility, and clinical decision-making, which has great potential in improving endodontic care.

CONCLUSION

The outcomes of the current research prove that artificial intelligence can be a very useful method of identifying alterations in root canal morphology, specifically, complicated canals and the presence of other canals that remain unnoticed during the traditional examination. The diagnostic accuracy and the evaluation in agreement with the expert endodontists demonstrated the high accuracy of the AI-based analysis and thus its use as an adjunctive diagnostic tool. Artificial intelligence can be applied to endodontic practice to improve diagnostic accuracy, minimize the possibility of missed canals, and help to improve treatment planning and clinical outcomes.

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