# Application of Artificial Intelligence to Diagnose the Complex Split Canals in Endodontics: a preliminary retrospective study

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## ABSTRACT

**Aim:**
The aim was to evaluate the application of artificial intelligence (AI) system for detecting splitting canals (Vertucci's type V) pre-operatively.
**Methods:**
Four hundred images containing a total of 366 teeth with clearly visible bifurcation of canals were selected from our imaging database. Confirmation of splitting canals was performed by one radiologist and two endodontists. A total data set of (N = 366) intra-oral periapical images with age group 14-99 years were included. The Machine learning (ML) and Deep learning (DL) based architectures for teeth identification were applied. During training, the models were applied to classify the teeth into split and non-split root canal system, based on transfer learning architectures. In testing phase, the teeth detection model took radiograph as an input and classify them accordingly.
**Result & Conclusion:**
The performance evaluation parameters, precision, recall, F1 score, and accuracy were evaluated for the study. The confusion matrices based on the dataset for split canals radiographic images was prepared and analysed for Residual Network **(**Resnet50), K - Nearest Neighbour (KNN), Decision tree (DT). The ML and DL based models were able to diagnose splitting canals.
**Keywords:** artificial intelligence, splitting canals, Vertucci's type V

## Introduction

In endodontics, each tooth has its own internal anatomy, and it is partly unsighted, which makes it a challenging procedure. The success of endodontic treatment depends on the practitioner's clinical acumen and skills as well as the technique employed. Each clinician relies on tooth anatomy before commencing root canal treatment. A thorough understanding of the root canal system is essential for effective endodontic procedures. The root canal systems are intricate and one kind of root canal system that present a special challenge to and treat is the splitting canal system, bifurcation/ trifurcation of the root canal. The configuration at which a single canal splits into two or three smaller canals that follow different courses is known as the bifurcation or trifurcation of a root canal. It is known as a Weine's Class IV canal, or Vertucci's type V canal. This canal system has one orifice exiting the pulp chamber and may split into two canals anywhere throughout the root, each with its own apical foramina [1].

A reliable endodontic procedure begins with a clear understanding of the internal anatomy. Subsequently finding the canal's divide and where it occurs is the next step. When using traditional 2-dimensional imaging with the "fast-break" phenomenon, we can occasionally infer deep splits [2]. Radiographs showing a sudden narrowing or disappearance of pulp space indicate that the canal is either divided into two parts or merges before reaching its apex. Coronally, the image will first show a clear canal, but later the canal will disappear. To precisely count the number of roots, a series of preoperative radiographs must be acquired using a paralleling technique, both angled and straight. Even so, it is impossible to determine with certainty if a split happens buccally, lingually, palatally, etc. Undoubtedly, 3-dimensional imaging becomes crucial to aid in both identifying these cases and illuminating the path forward. CBCT imaging is critical especially in unique anatomy. When CBCT images are seen in conjunction with multiple periapical radiographs, they should be interpreted judiciously. Although CBCT is more accurate than other radiographic techniques in detecting the root and root canal geometries, radiation issues prevent it from being recommended in normal clinical practise [3]. Finding the split canals is crucial for the endodontic success of a tooth in situations like these. By allowing tissue or bacteria to remain in those canal areas without locating, shaping, and obturating them, we run the danger of not getting the results we want from our endodontic treatments.

One of the most fascinating aspects of the human body is the brain, which till date remains a mystery to science because no perfect model that accurately replicates the brain has yet been developed [4]. Artificial intelligence (AI), a subset of which includes machine learning and deep learning, was first described by John McCarthy in 1956. AI is capable of carrying out human-like tasks such as critical thinking, decision-making, and intelligent behaviour [5]. For every device, application language, or environment, AI has been utilised to create intelligent conversational user interfaces in voice command devices like Siri, Alexa, or Bixby. A neural network that is built to resemble human brains and can mimic human reasoning is the fundamental building block of artificial intelligence technology. The brain's architecture, which is made up of tightly coupled neurons, serves as a mechanism for processing data to deal with a specific problem. AI, particularly in endodontics, can be helpful for diagnosis, clinical decision-making, and treatment planning. The scientists have found that clinical evaluation done with AI is accurate, effective, and rapid for as compared to CBCT and periapical radiography. Artificial Intelligence has gained more relevance in endodontics diagnosis, & treatment planning [6,7]. The benefit of AI-based networks is that they can identify even the smallest, most minute changes at the level of a single pixel that the human eye can miss [8]. This study was designed to evaluate the use of different architect models of deep learning system for detecting splitting canals (Vertucci's type V) in periapical radiographic images. The objective was to investigate expert level performance, technical feasibility and real-world clinical performance of artificial intelligence in split canal recognition through periapical radiographs.

## Materials and Methods

### Dataset Acquisition

The ethical clearance was obtained from the institute ethical committee of SMBT Institute of Dental Sciences and Research, (IDSR), Nasik (544/SMBT/04/SS/IEC/21/14). This retrospective study had sample selection of intra-oral periapical (IOPA) images collected from Private Practice and SMBT IDSR over a period of last one year. Sample selection was done and validated by two endodontists with an expertise of more than 5 years and a radiologist. Inclusion criteria was IOPA radiograph images of posterior teeth with split canals, IOPA radiograph images of posterior teeth without split canals. Exclusion criteria were IOPA images with artifacts generated due to any technical errors or ghost images, IOPA images with clinical ambiguity, IOPA images of anterior teeth and deciduous teeth. Sample Size, n= 366 IOPA radiographic images were divided into following groups: Training and testing group (80:20).

## 2. Materials and Methods

### Dataset Acquisition

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### Classification Models

In this study, Machine learning (ML) and Deep learning (DL) based models were employed to classify the provided dataset whether it has splitting canal configuration or not. The data was fed into classifiers as shown in (figure 1). Thus, we examined a few ML and DL based classifiers which will be explained further in depth. Each model is evaluated on both testing and training datasets, with a maximum of 40 epochs and a batch size of 32 and categorical cross entropy loss function was used.

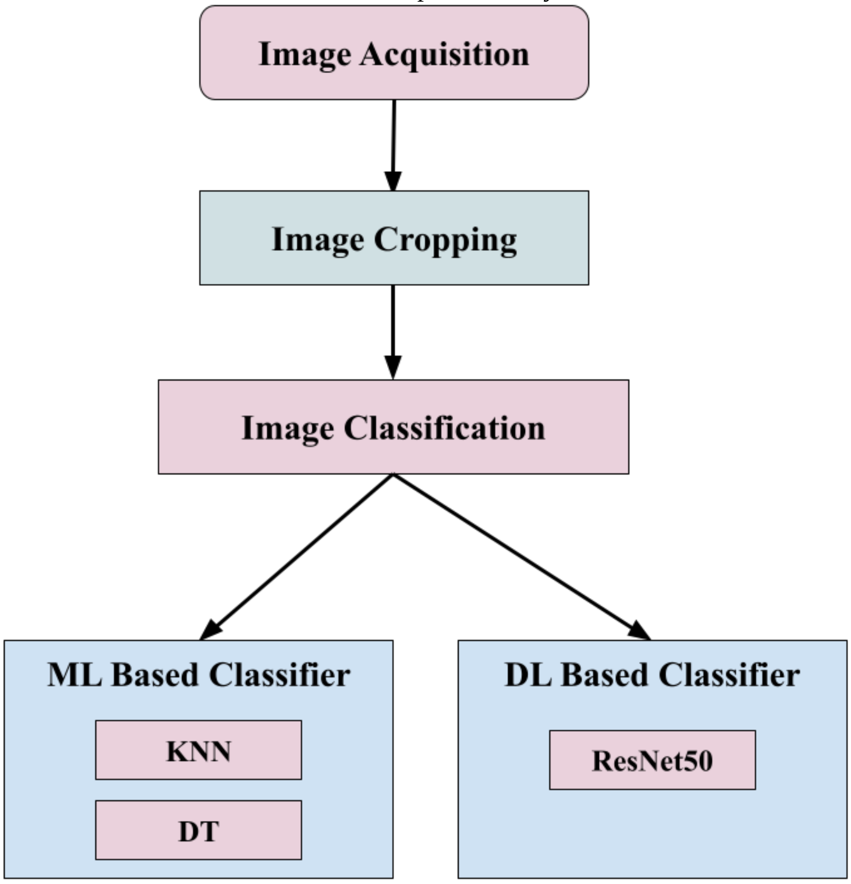



Figure 1. Flow chart for detection of Splitting canal

**Image Acquisition** was done by acquiring 366 IOPA images and were labelled by the expert of Postgraduate Graduate institute of Medical Education and Reserach (PGIMER) and SMBT IDSR.

**Image Cropping** was automatically done to improve the system's efficiency. Accordingly, to fit the needs of the system, images were cropped to size of (128,128).

**Image classification** was done for machine learning and deep learning.

**ML Based Classifier:**

**K - Nearest Neighbour (KNN):** the KNN, is a non-parametric, supervised machine learning classifier, which uses proximity to make classifications or predictions about the grouping of an individual data point, we can use the KNN algorithm for applications that require high accuracy but that do not require a human-readable model. The objective of KNN is to define various visual characteristics to each pixel in a picture and then place them into one of several classes. The KNN model learned using a labelled dataset of split canal. The algorithm works by computing the distance between the features of a given pixel and the features of other pixels in the dataset. Pixels are classified using a majority vote among their k closest neighbours [9].

**Decision Tree (DT):** A decision tree is a straightforward and efficient tool for classification. The decision tree method constructs a model by repeatedly partitioning the data into subsets determined by the value of a feature, with the goal of creating subsets that are increasingly similar with regard to the dependent variable of interest. After the decision tree is built, it then can be used to categorize additional data by navigating from the root node to a leaf node, with each node representing a possible outcome depending on the weights of the input characteristics. The input data is then labelled with the class that corresponds to the leaf node [10].

**DL Based Classifier:**

**Residual Network (ResNet50):** The convolutional neural network architecture i.e., ResNet50 is frequently employed in image categorization projects. It is a 50-layer deep neural network that has surpassed all previous results on numerous benchmarks of picture categorization. Root canals that have been cut in half lengthwise can be categorized with the help of ResNet50's split canal classification feature. A huge collection of similar photos may be used to train the network, with each image labelled with one type of canal specifically bifurcation. To accurately identify the split canal contained in a new picture, the ResNet50 architecture may be trained to extract valuable characteristics from these images. ResNet50 capacity to extract meaningful information from pictures can be utilized to boost the precision of split canal categorization and, by extension, the efficacy of endodontic treatments [11].

## 3. Result and Analysis

### Performance Metrics

Our dataset was divided into training and test 80:20 to evaluate the efficiency of our prediction models and prevent overfitting. In this study, the most popular forms of evaluation were compared for ML and DL models. These are described below:

**Accuracy:** (True positives + True Negatives)/ (True positives + True negatives + False positives + False negatives)

**Precision:** True Positives / (True Positives + False Positives)

**Recall:** True Positives / (True Positives + False Negatives)

**F1 Score:** (2 * Precision * Recall) / (Precision + Recall) **[12]**

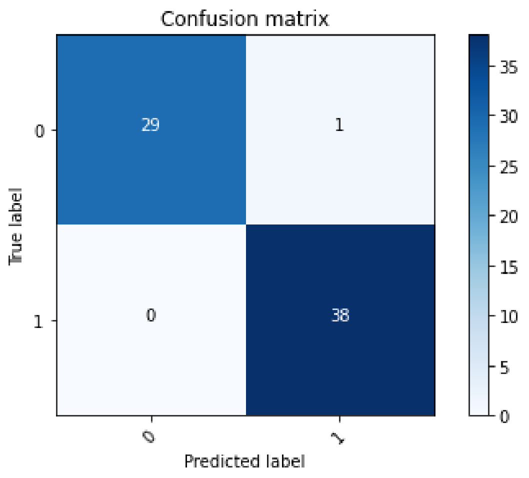
**Result evaluation of models:**

The performance of ML and DL based approaches after feature selection and training was evaluated to select the suitable model. In this research, binary classification of splitting problem was done as present or absent. The following parameters, precision, recall, F1 score, and accuracy were evaluated for the ML and DL based classifier on test dataset as shown in table 1. The ML based DT outperformed the KNN and ResNet50 with 98% of accuracy, 97% of precision, 100% of recall and 99% of F1 Score. As the dataset was very less so the results of DL based model Resnet50 with 89% accuracy was comparatively low as compared to ML based model. The confusion matrix based on the ML and DL models were also analysed.

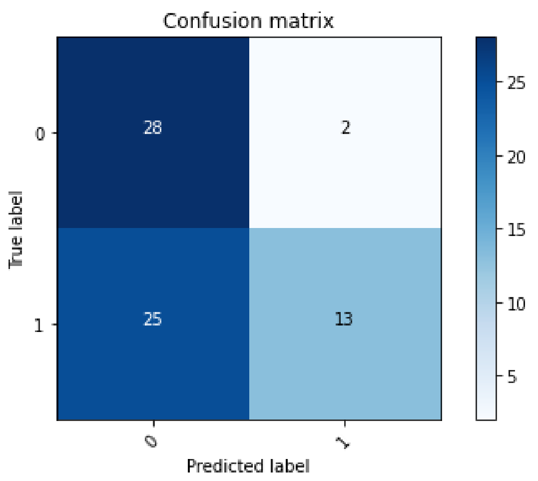
| **Classifier** | **Models** | **Performance Metrics** | | | |
|---|---|---|---|---|---|
| | | Precision | Recall | F1 Score | Accuracy |
| ML Classifier | KNN | 87 | 34 | 49 | 60 |
| | DT | 97 | 100 | 99 | 98 |
| DL Classifier | Resnet50 | 85 | 100 | 92 | 89 |

**Table 1 Evaluation of ML and DL classifier**

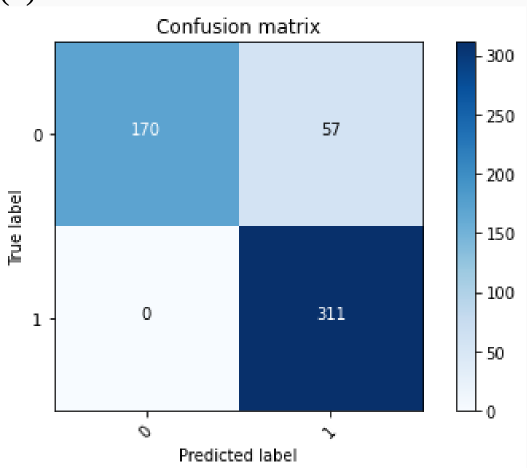
**Confusion Matrix:** In circumstances where the data set is imbalanced, accuracy results may be unfair. As can be seen in figure 2 we utilized a confusion matrix to graphically represent the proportions of correct and incorrect diagnoses. The following are the confusion matrices for the KNN, DT and Resnet50 (figure 2).




(a)




(b)




(c)

Figure 2: Confusion matrix for (a) KNN (b) DT (c) Resnet50

## Discussion

Understanding the root and root canal systems, as well as their variations, is a key element in the success of nonsurgical endodontic treatment. Periapical radiographs and CBCT imaging are generally used for this purpose. CBCT imaging has demonstrated higher accuracy to assess canal configurations and internal anatomy as compared with radiographs. However, it is not possible to advise in routine clinical practice due to radiation issues. Scientists have found that artificial intelligence is accurate, effective, and faster for clinical evaluation as compared to CBCT and periapical radiography.

The algorithm developed by using AI has shown the ability to diagnose and locate the split in a root canal. In the current study, it is shown that contemporary CNN architectures can provide precise split canal diagnoses. The use of various AI models, frameworks, and algorithms can improve the precision with which clinicians can identify and treat dental issues. From the results we see there is higher true positive and true negative which indicates Logical Regression has performed with highest accuracy. Our models showed highest accuracy at 60 epochs after that no improvement in accuracy graph seen, thus data used was very clean. To overcome the problem of overfitting and under fitting we used the call back function during the training process.

Interestingly, findings from the literature review suggest that AI-based networks have a higher degree of accuracy than conventional methods, in accordance with the results from the present study. For a good clinical practice to be effective and accurate, a precise diagnosis is considered as a solid basis. The use of competently skilled neural networks can be an asset for dentists, especially when managing underlying causes or contributing factors. As a result, AI can be used to diagnose and plan treatment or treat dental issues with greater accuracy [13].

Based on these findings, it is suggested that the application of AI for automated dental radiograph analysis has the potential for real-world intervention and future investigation. The suggested method exhibits sufficient quality to be incorporated into a software application that may be used for clinical practice and implemented into routine dental work [2].

Artificial neural networks have been applied to determine working length by Saghiri et al [14] and when compared to professional endodontists, it showed exceptional accuracy of 96%. These results were consistent with another study by Saghiri et al., [15] where 93% accuracy was achieved for locating the minor apical foramen using the ANN system. Results of the study by Johari et al [16], to diagnose vertical root fractures with probabilistic neural network (PNN), 96.6% of accuracy is been achieved. Similarly in a study by Fukuda et al [17] convolutional neural network (CNN) showed significant precision in detecting vertical root fracture. These study result indicate that AI-based models are incredibly effective for diagnostic applications in endodontics as compared to CBCT images and radiographic techniques.

It is imperative that endodontists handling complex anatomy should have a great deal of patience because prolonged and multiple appointments are certain to occur. Endodontists' clinical skill, expertise, and proficiency are primarily responsible for the time required to treat these challenging cases of unusual tooth anatomy. Additionally necessary armamentarium of magnification and ultrasonics is needed to achieve optimum clinical outcome. It is therefore important to have a comprehensive understanding of the normal anatomy of the tooth, interpret differently angulated radiographs preoperatively, apply CBCT imaging, modify access cavities, and explore the internal morphology of the tooth, followed by precise cleaning, shaping, and obturation, so that endodontic success is ensured. And artificial intelligence can give the entire assessment pre-operatively to make the endodontic treatment minimally invasive.

## Conclusion

The algorithm based on ML and DL were reported to diagnose the bifurcation or trifurcation in a root canal. The ML based model KNN and DT acquired accuracy of 60% and 98% respectively and DL based model Resnet50 acquired 89% accuracy. The system achieved high-performance results for diagnosing splits that are close to the expert level. Based on these findings the method has the potential for practical application and further evaluation for automated dental radiograph analysis. As we perform experimentation on a minimum number of dataset in future AI based models can be applied on large amounts of dataset. AI based models show high enough quality to be integrated into a software used for real-life problems and introduced into daily practice.

**Authorship Declaration:**

All authors have contributed significantly, and all authors are in agreement with the manuscript.

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**Disclosure Statement:**

No conflict of interest to be disclosed.

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