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Savitha B Naik
Government Dental College and Research Institute, Bangalore, Karnataka, India

Kiran Kumar N
Government Dental College and Research Institute, Bangalore, Karnataka, India

Bhargavi H
Government Dental College and Research Institute, Bangalore, Karnataka, India

Biji Brigit
Government Dental College and Research Institute, Bangalore, Karnataka, India

Seema Merwade
Government Dental College and Research Institute, Bangalore, Karnataka, India

Corresponding Author:
Bhargavi H
Government Dental College and Research Institute, Bangalore, Karnataka, India

Artificial intelligence in detecting periapical lesion: A systematic review

Savitha B Naik, Kiran Kumar N, Bhargavi H, Biji Brigit and Seema Merwade

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Abstract
Objective: Artificial intelligence plays a very important role in diagnosis and treatment planning in dentistry. The aim of this systematic review is to analyze the accuracy of artificial intelligence in detecting periapical lesions in endodontics.
Material and Methods: Using the MeSH keywords: Artificial intelligence (AI), AI in endodontics, neural networks and endodontics, machine learning, deep neural network and periapical lesion, AI dental imaging, and AI treatment diagnosis and endodontics electronic search was performed in four databases - PubMed/Medline (National Library of Medicine), Scopus (Elsevier), ScienceDirect databases (Elsevier), Web of Science (Clarivate Analytics). The English language articles reporting on AI in different dental specialities were screened for eligibility and chosen for analysis based on set inclusion criteria.
Results: A total of seven full-text articles were selected and systematically analysed. Artificial intelligence technology was found to have greater accuracy in detecting periapical lesions when compared to clinicians.
Conclusion: Artificial intelligence is a reliable tool in the diagnosis of periapical lesions in endodontics, with the use of which accuracy and precision of diagnosis can be enhanced.

Keywords: Artificial intelligence, diagnostic accuracy, endodontics, periapical lesion.

Introduction
Artificial intelligence, once considered a dream came into reality during the summer of 1956 at Dartmouth College in Hanover. Soon after its discovery many experiments were carried out to utilize AI (Artificial Intelligence) but a lack of resources and data lead to reduced funding of AI, period was called as AI winter (1974-93). With the new advances in the discovery of AI it once again gained popularity in the late 1990s [1, 2].
The introduction of AI has blurred the boundaries between digital, virtual, and real world. AI began with simple algorithms which later with the advancement of technology became more complex involving higher level algorithms. AI finds its application in the various fields such as banking, agriculture, healthcare, education, marketing, security systems and so on [2].
AI is a branch of computer science where computers perform certain tasks which were previously meant to be done by only humans. It comprises of certain sequence of events leading to a program. [3] Artificial intelligence in medicine has two arms: Virtual and physical; virtual is represented by machine learning while physical is represented by delivery of services by robots [4]. Artificial intelligence has neural network which acts like structural and functional units of AI. With the advancement in science and technology there has been tremendous increase in the application of AI in dentistry for the tasks like diagnosis, treatment planning and assessing the prognosis of the diseases [4, 5, 6].
Dental Caries, when left untreated tend to invade pulp and results in the periapical lesions [7]. These periapical lesions manifest as periapical radiolucency on radiographs. Various modalities like intraoral periapical radiograph, panoramic radiograph and CBCT can be used to assess the pulp and periapical changes. Regardless of their ability to distinguish the various pathology they are always prone to inter and intra examiner reliability. Reliability of these modalities mainly depend on the experience of the trained examiner [8].

Artificial intelligence can be used to detect the periapical lesion using Intra oral periapical radiograph, panoramic radiograph and CBCT. That is done by training the deep learning models in detecting the lesion. Based on the data fed during training period software detects the lesion. Utilizing AI in detecting periapical lesion has reduced the occurrence of bias and also increases the accuracy of the diagnosis [8].

The present systematic review shall focus on assessing efficiency of AI in detecting periapical lesion using modalities like IOPAR and panoramic radiographs (PR) and Cone bean computed tomography (CBCT) in comparison with expert clinicians [9].

Material And Methods Data sources

The systematic review was started after referring the guidelines for preferred reporting items for Systematic reviews and Meta analyses extension for Diagnostic Test Accuracy (PRISMA-DTA). The literature for this paper was identified and selected by performing a thorough search in the electronic data bases like PubMed, Medline, Embase, Google scholar, Scopus, Web of science, published over the past two decades (January 2000 to 2022) by using keywords such as artificial intelligence in dentistry, deep learning, machine learning, artificial neural networks, convolutional neural networks, peri apical radiolucency and computer-aided diagnosis. This search was based on the PICO (problem/patient/population, intervention / indicator, comparison, and outcome) elements. (Table 1)

Table 1: PICO (problem/patient/population, intervention / indicator, comparison, and outcome)

Research question	Efficacy of AI in detecting peri apical pathology
Population	Patients CBCT, IOPAR, Panoramic radiograph
Intervention	Used for periapical diagnosis
Comparison	With expert clinicians
Outcome	Measurable or predictive outcomes such as accuracy, sensitivity, specificity.

Search strategy

Full length articles were searched by hand and through computer generated search, The medical subject heading (MeSH) terms are artificial intelligence (AI), endodontics, AI in endodontics, neural networks and endodontics, machine learning, AI dental imaging, and AI treatment recommendations; a total of 225 articles were collected which were relevant to the topic. Out of which 36 articles were removed due to duplication. The remaining articles were further filtered based on inclusion and exclusion criteria.

Inclusion criteria

1. The article must be focused on AI and its application in detecting peri apical lesion.
2. There must be some predictive or measurable outcomes so they can be quantified.
3. There has to be a proper mention of datasets that are used to assess a model.

Exclusion criteria

1. The articles that are related to non-AI areas.
2. Articles that were unpublished.
3. Articles that consisted of only abstracts without the full text.
4. Articles that were not written in English.

Quality Assessment

Quality/ risk of bias assessment was performed based on checklist by the work of QUADAS2 (quality assessment tool for diagnostic accuracy studies) team at Bristol University.

Result

Systematic review was done on seven articles which showed that there is sequential increase in the rate of research in the field of AI in endodontics. It was found that AI has a greater accuracy in detecting the periapical lesion in comparison to expert clinician. Thus, AI can be used to aid in the diagnosis in endodontics and increase the accuracy of endodontic treatment.

The primary search identified 225 articles based on key terms. Following those, 36 duplicates were removed, and 189 articles were screened based on title and abstracts. The search was further narrowed down, and 182 irrelevant articles were excluded. The 7 relevant articles were finally included and analyzed in the review. The PRISMA flow diagram for the literature search strategy is described in Figure 1.

General Characteristics of Included Studies

The general characteristics of the included studies are summarised in Table 2. The data were extracted from articles about the proposed study design: The authors' ID, year of publication, algorithm used, objective of the study, type and number of radiographs used, accuracy in detecting the periapical lesion, and outcome of the study.

General Outcomes of Included Studies

The neural network system used in detecting the periapical lesion has shown greater accuracy in comparison to expert clinician in the studies. Peri apical radiographs, panoramic radiographs and CBCT are the modalities used in the studies in combination with neural networks such as CNN, modified U net architecture, and siamese network. In all of the studies considered in the review sensitivity and accuracy in diagnosing the periapical lesion was higher for the artificial neural network than the clinicians.

Quality Assessment

Based on the utilization of QUADAS2 tool following observations were done.

Patient Selection/ Domain 1 – All the included studies showed low risk of bias in terms of utilization of case-control method and inappropriate exclusions. Three of the studies showed high risk of bias in terms of random or consecutive selection of subjects to the study.

Index Test/Domain 2: In terms of interpretation of results of index test without knowledge of results of reference standard, all the studies show low risk of bias. However, studies lack clarity on pre-specified threshold. With regard to the index test, its conduct and its interpretation studies show clarity of their applicability.

Reference Standard/Domain 3: All the studies show low risk in terms of reference standard being able to correctly identify the target condition. With regards to – 'reference standard results are interpreted without knowledge of the results of the index test', all the studies show low risk of bias.

Flow and timing/ Domain 4 - There is lack of clarity on appropriate interval between the index test and reference

standard. It is found that in all the studies, all patients received same reference standard, indicating low risk of bias. Among the seven studies, in four studies all patients included in the study were considered for analysis. Overall, quality assessment reveals acceptable level of bias. In terms of applicability, studies display some form of indirectness that warrants further studies to confirm the currently available evidences.

Table 2: The table contains a detailed summary of the selected studies on the application of artificial intelligence in detecting the peri apical lesion

Sr. No	Authors name	Year published	Algorithm architecture	Objective of the study	No of radiographs	Modality used	Accuracy of AI	Comparison	Results	Authors suggestions
1	Ibrahim *et al.* [10]	2022	D-CNN	Detecting apical lesion	470	Panora mic radiograph	91.0%	Dental Radiologists	Sensitivity=0.92 Precision=0.8 4	None
2	Vo TN Ngoc *et al.* [11]	2021	CNN	Detecting apical lesion	130	Bitewing	95.6%	Endodontists	Sensitivity= 89.5 Specificity=9 7.9	Further studies with high sample size required to increase accuracy
3	Maria alice *et al.* [12]	2022	CNN (Siamese network)	Detecting apical lesion	885	CBCT Scans	70%	Oral and maxillofacial radiologist	NA	None
4	Chun-Wei Li [13]	2021	CNN	Detecting apical lesion	476	Periapical radiograph	92.5%	Dentists	Sensitivity=9 4.87 Specificity=90.00	None
5	Barbar a kirnbauer *et al.* [14]	2022	Modified U net architecture	Detecting apical lesion	144	CBCT	97%	Endod Ontists	Sensitivity=97.1% Specificity=8 8%	Further studies are encouraged
6	Thom as ekert *et al.* [15]	2019	CNN	Detecting apical lesion	85	Panora mic radiographs	0.85	Experienced dentists	Sensitivity= 0.65 Specificity=0.87	None
7	Seok song *et al.* [16]	2022	CNN using U net	Detecting Apical lesion	100 0	Panora Mic radiographs	NA	oral and maxillofacial radiologist	Sensitivity=0.826 Precision=0.8 [31]	Use of artificial intelligence can increase the accuracy of diagnosis

Discussion

Diagnosis of disease involves precise recording of case history, clinical and radiographic examinations. At certain instances, despite all the procedures, diagnosis can be inconclusive. In this regard, AI models have brought greater accuracy and efficiency in diagnosis and prediction of dental diseases [17] Radiographs play a significant role in the detection of periapical pathology but there is possibility of bias which is associated with inter or intra examiner reliability [18]. Studies have shown AI can aid in correct interpretations and thereby reduce human errors [19]. The present systematic review evaluated the role of artificial intelligence in detection of periapical lesion from radiographs.

A study by Patel *et al.*, compared the presence of periapical lesions on individual roots of teeth assessed using intra oral periapical radiographs and CBCT of teeth. Interestingly, it was revealed that periapical lesions were found in only 55 (20%) of paired roots with periapical radiographs compared to 130 (48%) with CBCT images, that is a 28% more periapical lesions were detected with CBCT when paired roots were compared 20 Further, a systematic review concluded that CBCT possesses higher accuracy in detection of periapical lesion when compared to two-dimensional imaging methods. However, authors have emphasized that there is no sufficient evidence to justify routine use of CBCT in diagnosis of periapical lesions [21].

Role of AI in detection of periapical lesions using different radiographic modalities have been tested. In a recent study, the possibility of automatically detecting the periapical lesions with a success rate of as high as 92.75% was reported. Authors also highlight the utility of commonly used periapical radiographs in conjunction with CNN model of AI, which could possibly reduce the time for endodontic diagnosis and overall treatment [22].

A recent comparative study on diagnostic performance of CNN with human observers revealed superiority of CNN model in detection of periapical lesions. Similarly, majority of the studies included in the present review utilised CNN model and have reported sensitivity ranging from 65-97%, specificity ranging from 83-97%. Overall, CNNs show promising results in detection of periapical lesions [23].

When CBCT imaging is subjected to AI systems, the diagnostic accuracy of detection of periapical lesions has shown better results. A study done by Kirnbauer *et al.*, showed that using neural network to detect periapical lesion has accuracy of 97 % comparing to human observer [24]. Similar trend has been observed in the studies that are included in the present systematic review. However, considering the cost, radiation exposure and availability of CBCT when compared to conventional periapical radiographic systems are major factors to be considered to translate the research into clinical practice.

Overall, the accuracy of CBCT, peri apical radiograph and panoramic radiographs themself differ which is reflected in similar manner when they are used with AI models for detection of periapical lesions. Interestingly, the current trend in radiologic AI research reveals that when adequate ground truth is available for data labeling, trained CNNs can reach or surpass the diagnostic performance of experienced clinicians. This can eventually help in reduction of time for endodontic diagnosis and the delay in execution of treatment.

The limitations of the present review include the limited number of studies available currently for comparison and the difference in AI models used and modality of radiographic investigations performed. Further studies are warranted, wherein all the major modalities of diagnostic imaging be combined to assess and compare the accuracy in more meaningful manner. Notably, considerable efforts are needed to bring AI models into routine clinical practice.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

The primary search identified 225 articles based on key terms. Following those, 36 duplicates were removed, and 189 articles were screened based on title and abstracts. The search was further narrowed down, and 182 irrelevant articles were excluded. The 7 relevant articles were finally included and analyzed in the review. The PRISMA flow diagram for the literature search strategy is described in Figure.

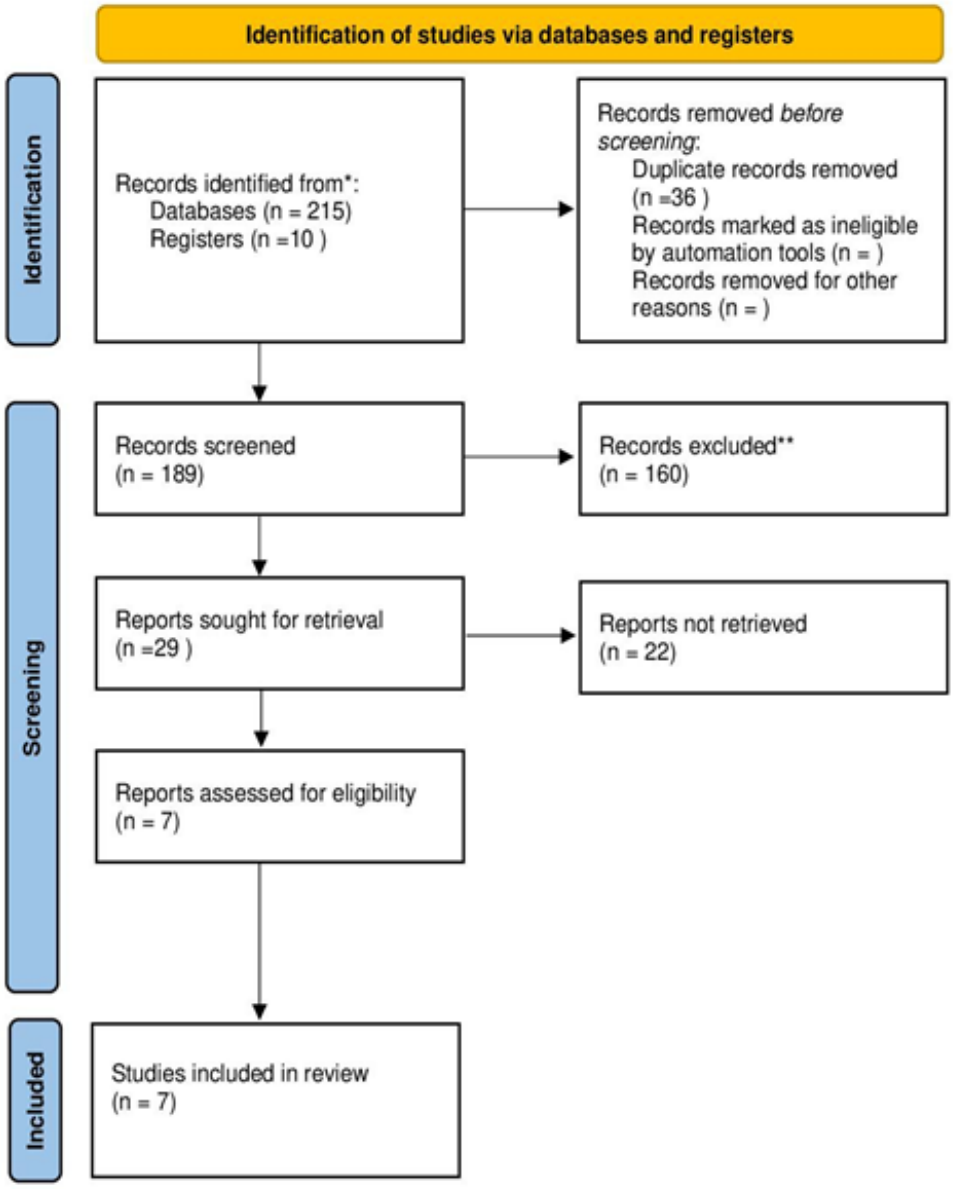

Fig 1: The PRISMA flow diagram for the literature search strategy

Conclusion

Although periapical radiographs are the most commonly used modality for the diagnosis of periapical lesions, it carries the risk of human error. With the use of technology, artificial intelligence systems have shown promising results in enhancing the accuracy of diagnosing periapical lesions from radiographs. However, there is a need to improve the quality of studies and design of AI models that are available to use in routine clinical practice.

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Conflict of Interest

The authors declare no conflict of interest

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