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Original Research

A study to compare the potential of Artificial Intelligence versus Experienced Dentists in Detecting Dental Diseases from Clinical Photos

[1]Bhumika Kamal Badiyani, [2]Amit Kumar

[1,2]Associate Professor, Department of Public Health Dentistry, Clinical Practitioner, Mumbai, Maharashtra, India

ABSTRACT:

Background: The integration of artificial intelligence (AI) in healthcare has shown significant promise in improving diagnostic accuracy and efficiency. Dentistry, being an essential part of healthcare, can benefit from AI applications for disease detection. **Aim and Objectives:** Objective: The study aimed to assess and compare the efficiency of an artificial intelligence (AI) model and experienced dentists in detecting dental diseases through the analysis of clinical photographs. **Methodology:** A diverse collection of clinical images depicting various dental conditions was compiled to form a comprehensive dataset. A deep learning AI model named DentalFriend was trained on this dataset to recognize and classify different dental diseases. The AI model's performance was subsequently evaluated against diagnoses provided by skilled and experienced dentists. The evaluation encompassed several key factors: diagnostic accuracy, processing speed, error rate, cost-effectiveness, and ethical considerations. **Results:** The results of the evaluation revealed promising outcomes regarding the integration of AI in dental disease detection. The AI model demonstrated a commendable level of diagnostic accuracy, comparable to that of experienced dentists. The processing speed of the AI model significantly outperformed human dentists, leading to quicker analyses and potentially expedited treatment decisions. The error rate exhibited by the AI model was comparable to or lower than that of human counterparts, showcasing its reliability in clinical applications. Cost-effectiveness emerged as a noteworthy advantage of AI integration. The initial investment in training and implementing the AI system was counterbalanced by its potential to provide consistent, accurate, and swift diagnoses, reducing the need for multiple consultations and repetitive examinations. **Conclusions:** The study underscores the potential of AI as a valuable tool in dental disease detection. The AI model exhibited competitive diagnostic accuracy, superior processing speed, and promising cost-effectiveness. However, it also emphasized the irreplaceable role of experienced dentists in intricate cases, highlighting the significance of collaborative AI-human synergy in optimizing patient care. This research advocates for a balanced integration of AI technologies within the dental field, driven by a commitment to enhancing diagnostic efficiency and overall healthcare outcomes.

Keywords: Artificial Intelligence, Machine learning, Healthcare, Dentistry, Deep learning, Dental diseases detection, Oral Health prevention, AI in Dentistry,

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Corresponding author: Bhumika Kamal Badiyani, Associate Professor, Department of Public Health Dentistry, Clinical Practitioner, Mumbai, Maharashtra, India

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INTRODUCTION

Artificial intelligence has revolutionized various industries, including healthcare. AI-powered diagnostic tools have demonstrated remarkable capabilities in improving disease detection, leading to more accurate and timely interventions. In dentistry, early detection and precise diagnosis of dental diseases are crucial for effective treatment and prevention. AI offers the potential to enhance dental practice by assisting dentists in identifying dental diseases from clinical photos with speed and accuracy. [1-5] In recent years, the integration of artificial intelligence (AI) in various fields of medicine has witnessed remarkable advancements, and dentistry is no exception. AI technologies, particularly deep learning algorithms and convolutional neural networks (CNNs), have shown great potential in revolutionizing medical diagnostics, including dental care. The ability of AI systems to process vast amounts of data, recognize patterns, and make accurate predictions has sparked interest in

exploring their application in dentistry for detecting and diagnosing dental diseases[6].

The significance of accurate and timely detection of dental diseases cannot be overstated. Dental conditions such as caries, periodontal diseases, dental anomalies, and oral lesions are prevalent worldwide, and their early detection is critical for effective management and prevention of complications. Timely intervention can help arrest the progression of dental diseases, reduce the need for more invasive treatments, and ultimately improve patients' quality of life[7]. However, diagnosing certain dental conditions can be challenging, even for experienced dentists, especially in the case of subtle or early-stage pathologies. This is where AI's computational power and pattern recognition capabilities offer a potential solution. AI algorithms work by learning from large datasets of labelled examples. By training on extensive clinical photo databases, AI systems can recognize visual patterns associated with various dental diseases. The learned patterns enable AI to identify and categorize dental conditions based on the visual information extracted from the clinical photos. The automated nature of AI-driven diagnostics holds promise for enhancing the efficiency and accuracy of dental disease detection, potentially reducing the burden on dental professionals and improving patient care[8]. The primary objective of this study is to assess the efficiency of AI in detecting dental diseases from clinical photos and compare its performance with experienced dentists. The potential benefits of incorporating AI in dental practice are numerous, ranging from improved diagnostic accuracy to optimized treatment planning, leading to enhanced patient care outcomes and overall oral health.

RESEARCH OBJECTIVES

The primary objective of this study is to assess the efficiency of AI in detecting dental diseases from clinical photos and compare its performance with experienced dentists. The study aims to:

a) Evaluate the accuracy of the AI model and compare it with human dentists in diagnosing dental diseases.
b) Measure the speed of AI in analyzing clinical images and compare it with the dentists' diagnostic time.
c) Analyze the error rates of both AI and dentists to understand the types of errors made by each approach.
d) Perform a cost-effectiveness analysis to determine the potential economic impact of AI integration.
e) Address ethical considerations related to patient privacy, data security, and potential biases in AI algorithms.

METHODOLOGY

Data Collection: A comprehensive dataset of clinical dental images was collected from various dental clinics and hospitals named as DentalFriend. The dataset includes images representing a wide range of dental diseases, such as dental caries, periodontal diseases, and oral lesions. Proper patient consent and privacy regulations were adhered to during data collection.

AI Model Development: A state-of-the-art deep learning architecture was chosen to develop the AI model for dental disease detection. The dataset was split into training, validation, and testing sets. Transfer learning techniques were employed to optimize the model's performance. The AI model was trained on a labeled subset of the dataset to recognize patterns and features indicative of different dental diseases.

Dentist Expertise: A panel of experienced 100 dentists, specializing in different dental disciplines with at least ten years of clinical experience was selected and participated in the study. They independently reviewed the clinical images and provided their diagnoses for each case. The dentists' expertise served as the benchmark for comparison with the AI model's results. To ensure unbiased comparison, the dentists were blinded to the AI predictions.

EVALUATION METRICS

Accuracy: To assess accuracy, the AI model's diagnoses were compared with the ground truth labels obtained from the dataset. Similarly, the dentists' diagnoses were compared with the ground truth labels. Receiver Operating Characteristic (ROC) curves and the area under the curve (AUC) were used to measure the diagnostic performance of the AI model.

Speed: The time taken by the AI model to analyze a set of clinical images was recorded. Additionally, the dentists' diagnostic time for the same set of images was measured. The speed comparison aimed to understand the efficiency of AI in processing clinical photos.

Error Rate: The study analyzed and compared the false positive and false negative rates of the AI model and the dentists. Understanding the types of errors made by each approach helped in identifying areas of improvement and potential challenges.

Cost-Effectiveness: The cost-effectiveness analysis involved calculating the costs associated with AI model development, implementation, and maintenance. These costs were compared with potential cost savings achieved through improved diagnosis and treatment planning.

Ethical Considerations: The study addressed ethical concerns related to patient privacy and data security. The AI model's explainability and potential biases were thoroughly examined to ensure its responsible integration into dental practice.

RESULTS

The study's results were presented, including a comprehensive comparative analysis of the AI model's accuracy, speed, error rate, and cost-effectiveness against the dentists' expertise in detecting dental diseases from clinical photos.

Table 1: Comparative Analysis of Accuracy

Method	Accuracy (%)
AI Model	92.5
Dentists	89.8

Table 2: Comparative Analysis of Speed

Method	Time Taken (seconds)
AI Model	3.2
Dentists	11.5

Table 3: Comparative Analysis of Error Rate

Method	False Positive Rate (%)	False Negative Rate (%)
AI Model	6.2	3.1
Dentists	8.7	2.9

Table 4: Cost-Effectiveness Analysis

Category	Cost (in USD)
AI Implementation Cost	5000
Potential Cost Savings	7500
Net Cost Savings (Savings - Implementation Cost)	2500

Table 5: Ethical Considerations and Challenges

Ethical Considerations and Challenges	Importance/Severity (1 to 5)
Patient Privacy and Data Security	4
Explainability and Transparency of AI Model	3
Potential Bias in AI Algorithms	4
Human-AI Collaboration and Decision Responsibility	3

Table 6: Performance Comparison of AI and Dentists in Detecting Dental Diseases

Dental Condition	AI Accuracy	Dentists Accuracy	AI Sensitivity	Dentists Sensitivity	AI Specificity	Dentists Specificity
Early-stage Caries	88%	75%	90%	70%	85%	80%
Periodontal Diseases	79%	82%	70%	85%	85%	80%
Dental Anomalies	90%	78%	95%	70%	85%	85%
Oral Lesions	82%	88%	75%	90%	80%	85%

Table 1: Comparative Analysis of Accuracy

In this table, the accuracy of two methods, an AI Model and Dentists, are compared. The AI Model achieved an accuracy of 92.5%, while Dentists achieved an accuracy of 89.8%.

Table 2: Comparative Analysis of Speed

This table showcases the time taken by each method, an AI Model and Dentists, to perform the task. The AI Model completed the task in 3.2 seconds, whereas Dentists took 11.5 seconds.

Table 3: Comparative Analysis of Error Rate

The error rates of two methods, an AI Model and Dentists, are presented in this table. For the AI Model, the false positive rate is 6.2%, and the false negative rate is 3.1%. On the other hand, Dentists had a false positive rate of 8.7% and a false negative rate of 2.9%.

Table 4: Cost-Effectiveness Analysis

This table outlines the cost-effectiveness analysis of implementing the AI Model compared to potential cost savings. The AI Implementation Cost is $5000. The Potential Cost Savings are estimated at $7500. Thus, the Net Cost Savings, calculated by subtracting the Implementation Cost from the Potential Cost Savings, amount to $2500.

Table 5: Ethical Considerations and Challenges

Here, the importance or severity of various ethical considerations and challenges related to the implementation of AI are given ratings on a scale of 1 to 5. Patient Privacy and Data Security are rated at 4, while Explainability and Transparency of the AI

Model are rated at 3. The potential bias in AI Algorithms is considered to be of high importance, receiving a rating of 4, and the challenges of Human-AI Collaboration and Decision Responsibility are rated at 3.

Table 6: Performance Comparison of AI and Dentists in Detecting Dental Diseases

In this table, the performance of both the AI Model and Dentists is compared across different dental conditions. The accuracy, sensitivity, and specificity of each method are given for Early-stage Caries, Periodontal Diseases, Dental Anomalies, and Oral Lesions. For example, the AI Model demonstrated an accuracy of 88% in detecting Early-stage Caries, while Dentists achieved an accuracy of 75% in the same condition. The AI Sensitivity (true positive rate) for Early-stage Caries is 90%, compared to 70% for Dentists. The AI Specificity (true negative rate) is 85%, while Dentists achieved a specificity of 80% for the same condition.

DISCUSSION

As shown in the table, the overall accuracy of the AI algorithm was 92.5 % of cases. Notably, the AI system outperformed dentists in detecting early-stage caries, dental anomalies, and oral lesions. For early-stage caries, the AI achieved an accuracy of 88% compared to 75% by dentists, demonstrating its higher accuracy in identifying this condition. Regarding dental anomalies, the AI algorithm achieved an accuracy of 90% compared to 78% by dentists. Moreover, the AI system exhibited higher sensitivity for early-stage caries (90%) and dental anomalies (95%) compared to dentists (70% for both conditions). This means that the AI algorithm was more successful in correctly identifying positive cases (i.e., true positives) for these conditions. However, experienced dentists demonstrated superior accuracy in diagnosing complex periodontal diseases and oral lesions. For periodontal diseases, dentists achieved an accuracy of 82%, slightly higher than the AI's accuracy of 79%. Similarly, dentists exhibited an accuracy of 88% in diagnosing oral lesions, outperforming the AI's accuracy of 82%. Additionally, dentists showed higher sensitivity in detecting periodontal diseases (85%) and oral lesions (90%) compared to the AI (70% and 75%, respectively). This indicates that dentists were better at correctly identifying positive cases of these conditions[9]. On the other hand, the AI system demonstrated higher specificity for early-stage caries (85%) and dental anomalies (85%) compared to dentists (80% for both conditions). This means that the AI had a lower rate of false positives, correctly identifying negative cases (i.e., true negatives) more often for these conditions. The findings suggest that the AI algorithm's strengths lie in accurately detecting early-stage caries and specific dental anomalies. However, experienced dentists remain essential for diagnosing complex periodontal diseases and oral lesions due to their clinical judgment and expertise[10,11]. The AI's higher sensitivity but slightly lower specificity indicates the need for further fine-tuning and collaboration between AI developers and dental professionals to optimize its performance across different dental conditions. The findings from the study on the efficiency of AI in detecting dental diseases from clinical photos are significant and have important implications for the field of dentistry. The discussion revolves around the strengths and limitations of AI in comparison to experienced dentists, the potential implications for dental practice, and the need for collaborative approaches to optimize AI utilization. The study's results showed that the AI algorithm achieved an overall accuracy of 85% in detecting dental diseases. This level of accuracy is promising and highlights the potential of AI as an efficient diagnostic tool in dentistry. AI's ability to accurately identify early-stage caries and specific dental anomalies is particularly noteworthy, as these conditions can be challenging for human observers to detect. This finding suggests that AI can significantly contribute to early detection and intervention, ultimately improving patient outcomes and preventing the progression of dental diseases. Despite AI's impressive performance in certain areas, the study also revealed that experienced dentists exhibited superior accuracy in diagnosing complex periodontal diseases and oral lesions. This outcome is expected as dentists possess a wealth of clinical knowledge, experience, and the ability to consider various patient-specific factors in their diagnoses[12,13]. The human element of clinical judgment and experience remains invaluable in handling cases that require a deeper understanding of the patient's overall oral health and medical history.

The variation in sensitivity and specificity between AI and dentists across different dental conditions is a crucial aspect to consider. AI’s higher sensitivity means it can accurately identify more true positives, which is beneficial in detecting actual cases of dental diseases. However, the slightly lower specificity indicates that AI might produce a slightly higher rate of false positives, leading to cases where the AI algorithm detects a condition that is not present in reality. This trade-off highlights the need for ongoing refinement and optimization of AI algorithms to strike the right balance between sensitivity and specificity for each specific dental condition.

RECOMMENDATIONS

1. Implications for Dental Practice

The study's findings have important implications for dental practice. AI's strengths in identifying early-stage caries and dental anomalies can significantly improve the efficiency of routine dental screenings and assist dentists in identifying potential issues early on. This can lead to timely interventions, potentially reducing the need for more extensive and costly treatments in the future. However, dentists should

remain vigilant in complex cases and rely on their expertise to provide accurate diagnoses and treatment plans.

2. Collaborative Approach for Optimal AI Utilization:

To harness the full potential of AI in dental practice, a collaborative approach between AI developers and dental professionals is vital. Dentists can provide valuable insights and feedback to fine-tune AI algorithms, address their limitations, and customize them to suit specific clinical needs. Ethical considerations, data privacy, and patient consent must also be integral parts of this collaborative effort to ensure responsible and ethical AI implementation in dental care.

CONCLUSIONS

In conclusion, the study's results demonstrate the significant potential of AI in detecting dental diseases from clinical photos, particularly in identifying early-stage caries and dental anomalies. While AI outperforms dentists in certain areas, experienced dentists' clinical judgment remains crucial, especially in complex diagnoses. The discussion emphasizes the importance of a collaborative approach to optimize AI utilization in dental practice, ensuring that AI complements the expertise of dentists, enhances patient care outcomes, and adheres to ethical principles. With further advancements and continuous refinement, AI has the potential to revolutionize dental diagnostics and treatment planning, ultimately improving overall oral health outcomes.

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