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Journal of Oral Medicine, Oral Surgery, Oral Pathology and Oral Radiology

Journal homepage: [www.joooo.org](http://www.joooo.org)



## Review Article

# The rise of artificial intelligence in teledentistry: A comprehensive review

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### ARTICLE INFO

#### Article history:

Received 17-09-2024

Accepted 02-11-2024

Available online 18-12-2024

#### Keywords:

Artificial intelligence

Teledentistry

Machine learning

Deep learning

AI in dentistry

Virtual dental visits

### ABSTRACT

The integration of Artificial Intelligence (AI) into teledentistry represents an unprecedented step towards increased accessibility in dental care, given India's diversity and vast population. This comprehensive review attempts to outline the practical applications of AI in teledentistry, from patient education, remote diagnosis, treatment planning, to follow-up care. It critically analyses works relating to AI's effectiveness on the detection of caries, monitoring orthodontic, and the preliminary screening of OPMDs in relation to improving health care outcomes, especially in underserved regions. It also highlights challenges such as data privacy, accuracy, acceptance, and need for regulatory clarity among dental professionals and patients. This review primarily proposes the recommendations that we should be attempting to fuse AI based solutions with a human touch as a fixture of provider of dental rendering, based on peer-reviewed study evidence. The practice will change as collaboration is required with AI to pursue a teledental practice that is ethical, effective and accessible to everyone.

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## 1. Introduction

Artificial Intelligence (AI) is rapidly transforming various sectors of healthcare, and dentistry is no exception. One area where AI shows immense potential is in teledentistry, particularly in a country like India, where disparities in access to dental care are significant. From bustling urban centers to remote rural areas, AI-driven teledentistry is revolutionizing how dental professionals approach diagnosis, treatment, and patient management.

For a dentist practicing in India, this shift is not just a theoretical concept but a practical necessity. AI-powered teledentistry is emerging as a vital tool to bridge the gaps in dental care, offering solutions to both accessibility and affordability challenges that have long plagued the Indian healthcare system. In this review, I will critically

explore the current applications, challenges, and future possibilities of AI in teledentistry, drawing on key studies and developments that have shaped this emerging field.

AI in teledentistry has improved the capability to diagnose and access, especially for homebound and aged patients.<sup>1</sup> The best tool improving accuracy in diagnosis is computer-aided diagnosis systems, which detects primary dental issues like cavities and periodontal diseases at early stages.<sup>2</sup> These developments have enabled attaining much more accurate diagnoses and intervention at the right time.

AI in teledentistry allows for remote diagnosis and follow-up care with a personalized treatment plan, which is vital in the management of chronic conditions among elderly patients.<sup>1,3</sup> Additionally, AI chatbots and virtual assistants improve patient communication and education because of enhancing patient engagement.<sup>2</sup> A significant challenge AI overcomes in teledentistry is access to high-quality dental images in remote, underserved areas. Others

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include security of data breaches, privacy violation, and big data requirements for large datasets to train AI models on.<sup>1,3</sup>

## 2. Artificial Intelligence and Dentistry

Artificial intelligence means machines that can solve problems and make decisions, which normally would require one's human intelligence. The systems are powered with algorithms, which enables it to learn from many data quantities and adapt well over time. Since its proposal by John McCarthy in 1956, artificial intelligence has been growing rampantly, especially in healthcare, where it is being applied to enhance diagnoses, treatment plans, and results. It can closely match human cognitive abilities with the help of machine learning, artificial neural networks, and deep learning. Using trend discovery with answering capabilities, AI makes it possible to examine such a huge number of data that would benefit many sectors including dental care.<sup>4,5</sup>

In turn, integration with AI has started to become increasingly used with procedures in the dental field to better improve both diagnostic effectiveness and clinical results. And that is precisely why models of AI, such as CNNs and ANNs, are applied to advance diagnostic processes regarding conditions diagnosed under endodontic specialties. For example, while conducting research on root canal anatomy, AI is used to predict the viability of stem cells in pulp and to identify the cases of the root fractures and periapical lesions. Therefore, it makes AI an emerging diagnostic technology since even minor changes in images of the teeth are detected by it. Other procedures can be offered-from the measurement of working lengths during root canal treatments to the retreatment success rate. Of more importance, though, is the fact that AI models are being researched for use in scheduling and managing patient care with robotic endodontic surgery. It has been capable of high accuracy and precision with regard to disease detection and assessment, which can be nothing short of revolutionary in the history of endodontic diagnosis and treatment itself.<sup>4</sup>

## 3. History of Teledentistry

Tele dentistry is a subset of telemedicine that has developed remarkably since its introduction in the 1990s in its infancy, teledentistry was defined strictly as the ability to facilitate professional consultations only between dental professionals. The first applications of teledentistry were created by the U.S. Army under the Comprehensive Health and Manpower Expansion Program in 1994, with the intent of providing oral healthcare for military patients located in rural or remote settings.<sup>6</sup> Over the last few decades, teledentistry and the field of oral healthcare, in general, have expanded to facilitate and enable opportunities for diagnosis, treatment planning, and education; including anything that utilized information and communications

technologies to reduce the negative impact of access to myriad types of care. Worldwide improvements of digital imaging technologies and global access to internet services that continued to develop and expand upon during the COVID-19 pandemic, which introduced, again, the potential utility of assessing need for emergency dental care and associated continuity of necessary oral healthcare otherwise, under regularly visitations associated with teledentistry, without restriction, and limitations associated with a temporary shutdown of face-to-face healthcare visits either for patient safety or practice access restrictions.<sup>7</sup>

## 4. History of AI in Teledentistry

With a professional acceptance of dental AI technologies and early implementation of AI systems into dental practice during the early 21st century, it continued to demonstrate possible applications of AI - initially in support of diagnosis and patient management. Since then, various avenues for the use of machine-learning and deep learning technologies to inform, support, affect, and enable improved diagnostic evaluation, diagnosis, and planning have been studied. For example, clinical studies of AI applications for monitoring orthodontic therapy, showed the efficacy of the system.<sup>8</sup> The early implementation AI application in teledentistry quickly developed further utility and applications for detection of caries, included systems for remote orthodontic monitoring, and for consideration of many applications where AI for diagnostic discussion with patients could be conducted over telehealth platforms to increase utilization of related dental specialties. As AI continues to develop and train to recognizing patterns in large data sets, AI technologies with powerful algorithms have demonstrated robust efficiency and outcomes performing tasks, such as interpreting dental radiographs.<sup>9</sup>

## 5. Requirements to Establish Teledentistry

Establishing teledentistry in India involves much more than just moving technology forward; it requires a multifaceted set of requirements that cater to our diverse population, especially in rural and underserved areas.

### 5.1. Technology infrastructure

It goes without saying that the basis of teledentistry has to be rock-solid technology infrastructure. In the Indian context, this would include high-speed internet; secure digital communication platforms; and the critical challenge for a small village in Rajasthan or a remote hill of the North East would be stable Internet connectivity. For a city, it is how to insert this technology in the current practice seamlessly. The task is to not let this infrastructure lag behind this technology if the best AI diagnostic tools falter in and large without dependable data transmission.<sup>10</sup>

### 5.2. Regulatory compliance and data security

Well, in our country, data privacy is not strictly a technical issue—it is much built on trust. One should understand that all of their data, including sensitive health information, is completely secure and not misused. Today, India needs regulators to catch up with these changes at light speed. Clear guidelines will ensure the protection of the patient data, avoiding the digital leap from compromising the confidentiality and security that is at the bedrock of the patient-dentist relationship.<sup>11</sup> Clarity about regulations is a critical step in developing trust and encouraging adoption amongst the practitioners as well as the patients.

### 5.3. Training and education

In fact, education would be critical to success in teledentistry. Beyond knowing how to use new software, it will be important for the provider side to understand nuances of virtual consultation, set reasonable expectations with patients, and assimilate AI recommendations into the treatment plan. Some would believe that knowledge of how to be efficient on these platforms also becomes important for patients at least for those not exactly tech-friendly. In rural India, it would be the organizing of camps at the local level, and even workshops on the mechanics of virtual consultations, not to let anyone get left behind.<sup>12</sup>

### 5.4. Convergence with traditional care

Teledentistry is not replacing the care which existed; it has added onto the care. Keeping in mind the context of India and its importance placed on personal touch and one-on-one engagements, generally speaking, this transition assures that the best value is drawn from both paradigms. There are the necessary in-office visits when feasible with general support of AI-driven diagnostics and follow-ups that are needed for the success of the hybrid models. This will enhance the trust building and sustenance of a personal relation that is crucial for the care of patients.<sup>13</sup>

## 6. Applications of AI in Teledentistry

### 6.1. Patient education and communication

Patient education is an integral part of dental practice in India, as often, awareness of oral health is low. It would thus be impossible to exaggerate the role of AI in delivering personalized, consistent, and accessible education. Imagine an AI chatbot speaking in Hindi, Marathi, or Tamil educating a patient about brushing techniques, dietary advice, or post-treatment care. According to Batra et al.,<sup>14</sup> the AI-based chatbots and virtual assistants can already answer frequent queries, explain procedures, and provide post-operative instructions. But there is a larger question at play here: Can AI realistically mimic the subtlety of interaction of humans, particularly in a country like India,

where empathy and human connection matter a lot? As such, while Mahapatra et al.,<sup>15</sup> observed that AI has dramatically enhanced treatment compliance by having AI send reminders, many patients still choose to speak directly to their dentist and do not really mind receiving a reassuring human voice rather than a "cold" digital one. In patient education, AI is also integrated with the Internet of Dental Things (IoDT), where sensors in dental devices collect data in real time. For example, smart toothbrushes connected to AI platforms can analyse brushing patterns, and the data is transmitted to dentists who can remotely monitor their patients' oral health.<sup>16</sup>

### 6.2. Diagnosis and treatment planning

It is revolutionary that AI could aid in remote assistance for dental diagnosis and treatment planning. For example: Detection of Dental Caries Duong et al.,<sup>9</sup> illustrated how algorithms based on AI can identify dental caries using photographs taken by smartphones. It can make a revolution in the dentistry field for India, where many patients won't be going to a dentist due to financial or geographical constraints. Imagine an AI-based app that allows someone from a remote village in Bihar to check his teeth without going miles to the nearest dentist. Practical challenges are still there: can low-tech patients with fewer resources make proper use of these AI models? One of the major advancements in AI applications in teledentistry is the Internet of Dental Things (IoDT). Through AI-powered platforms, patients can now engage in preliminary diagnosis by sharing high-quality images or data with dentists, allowing immediate feedback. For example, AI-based dental apps can provide users with insights into their oral health, recommend preventive measures, and even schedule appointments with dental professionals. Furthermore, AI can assist dentists by triaging cases, prioritizing urgent consultations, and even guiding treatment protocols based on patient data trends, enhancing operational efficiency.<sup>16</sup>

### 6.3. Orthodontic monitoring

Ferlito et al.,<sup>8</sup> demonstrated how AI could monitor the stage of clear aligner therapy by using patient-uploaded images to reduce the number of compulsory visits to the clinic. That saves time and cost associated with traveling for Indian orthodontic patients. But all of us are aware that this Indian context does pose certain challenges: poor-quality image, misinterpretation or simply due to technical errors, makes things complicated thereby requiring a balance of AI monitoring with in-clinic visits at regular intervals.

### 6.4. Screening for oral potentially malignant disorders (OPMD)

With a country ranking top in the world's oral cancer incidence in respect of tobacco usage, there is an acute need

to begin early detection. According to Vetchaporn et al.,<sup>15</sup> in the early detection of OPMDs with intraoral cameras having fluorescent aids, lives could have been saved.

These issues of poor internet connectivity in rural areas or lack of proper training on how best to deploy these devices cannot be overcome by technology alone.

### 7. Distant Monitoring and Follow-up Treatment

AI-based distant monitoring is also picking up rapidly on the side of the treatment of patients for long periods. Ozsunkaret al.,<sup>13</sup> have demonstrated that AI algorithms, such as YOLOv5x, can be applied in identifying white spot lesions on post orthodontic photographs. Follow-up management of care from home is precisely what teledentistry promises. But the problem in India is very real-most patients do not have the benefits of high-resolution cameras or stable internet connections, which is this kind of technology requires to work properly.

### 8. Caries Detection and Comparison of Diagnostics

AI was tested against human dental experience to evaluate its diagnostic ability. Daniel, S. J., et al.,<sup>17</sup> published a study demonstrating AI's ability to identify dental caries equivalent to that of a trained dentist. This is promising; however, it must be kept in mind that AI cannot think through patient history, lifestyle, or slight clinical signs that a more experienced dentist may pick up on in an in-person examination. AI is very good for additive purposes, not a replacement for intuitive judgment of an experienced practitioner. The study by Bhargava A. et al.,<sup>18</sup> It focused on the role of AI in teledentistry, emphasizing how artificial intelligence can improve the diagnostic accuracy of dental issues like caries through radiographs, achieving success rates of up to 95%.

### 9. Platforms of Teledentistry

There are various platforms which have integrated various artificial intelligence with teledentistry, which include Dentulu,<sup>19</sup> which is a teledentistry, where there is a patient signup and the patients are able to interact with real dentists through virtual meets and there are various AI powered tools which help patients in uploading their x-rays and able to come to diagnosis and various image analysis where Dentulu AI helps in analyse the various diseases such as malocclusion, periodontal diseases and most importantly dental caries, this works by the pattern recognition, where the AI bot is trained by dentists to recognize the diseases by annotating them, There is also triage and symptom checker prior to the consultation with dentist, the AI also helps in curating the treatment plan, There are various other platforms which provide similar results such as mouthwatch's TELEDENT<sup>20</sup> which has similar workflow and designed to meet HIPAA standards,

ensuring that patient data remains secure during remote consultations and data-sharing between providers.

### 10. Workflow of AI in Teledentistry

This workflow is based on Dentulu AI<sup>19</sup>

1. Patient Registration and symptom input: The patient registers on the Dentulu platform and provides basic information, including dental history and current symptoms.
2. AI-powered pre-screening: AI tools guide the patient through a preliminary assessment by analysing the input symptoms and identifying potential issues that may need attention.
3. Image and data upload: Patients upload images or videos of their oral cavity using their smartphone or Dentulu's intraoral camera. Additional medical and dental data may also be provided.
4. AI-Assisted diagnosis and recommendations: AI algorithms analyse the uploaded images and data to detect dental issues such as cavities, gum disease, or other abnormalities. The AI then provides preliminary diagnostic suggestions.
5. Remote dentist consultation: The patient consults with a licensed dentist via video call or phone. The dentist reviews the AI's recommendations, assesses the patient's condition, and discusses possible treatments.
6. AI-supported treatment planning: Based on the consultation and AI insights, the dentist creates a personalized treatment plan for the patient, utilizing AI-driven recommendations where applicable.
7. Prescription or referral for in-person care: If needed, the dentist prescribes medications through the platform or refers the patient for in-person care with a local dental professional for more complex treatments.
8. AI-driven follow-up and monitoring: AI tools help monitor the patient's progress, send reminders for follow-ups or hygiene practices, and provide continuous support for managing oral health.

### 11. Benefits of AI in Teledentistry

There are various benefits of AI in teledentistry, In a country like India, where digitalization and lower price internet services have led to a boom in the smartphone markets, due to which, almost every hand from the rich to the poor everyone has a smartphone, but the access to a healthcare facility is still out of reaches to some, and in this busy bustling world many cant spend time for a general dental checkup, to bridge this teledentistry comes in hand, a healthcare for all, where people can use their mobile phones to capture their dental problems and AI can help them diagnosing the disorders and help them connect to an dentist virtually, which makes a way for improved access to care to all, it also helps in reducing time

taken for diagnosing. Various platforms also have features which helps in curating personalized treatment plans to patients. As dental professionals we know most of the dental establishments aren't 24/7, AI in teledentistry can help patient to connect to various dentists across the world to take care of dental ailments at time of emergencies.

## 12. Drawbacks and Limitations of AI in Teledentistry

### 12.1.

#### 12.1.1. Privacy and data security

With the passage of time, people of India have not gained so much confidence in digital platforms, majorly due to privacy and data security. According to Ansarian, Met al.,<sup>11</sup> patient data privacy is very important. Being at the first step of a digital healthcare revolution, one breach of trust due to mishandled data would retrograde the same progress for years in AI-based teledentistry. It should have robust security controls and clear data policies so as to gain confidence and then create a widespread adoption of the service, there are various privacy preserving technologies which aim to protect the patient data such as Blockchain technology, for instance, ensures data immutability and traceability, reducing the risk of fraud and data tampering. Homomorphic encryption allows encrypted data to be processed without exposing sensitive information, although it is resource-intensive. Watermarking algorithms are also mentioned, which embed patient information into digital records to prevent unauthorized access. However, implementing these technologies comes with challenges, including high costs, complexity, and the need for standardization. These barriers highlight the need for regulatory frameworks that encourage the adoption of these privacy-preserving technologies while ensuring that they are accessible and scalable for widespread use.

#### 12.2. Trustworthiness and credibility of AI systems

Although AI is highly accurate, it is never 100% foolproof. Diagnoses through AI may even conflict with expert professionals, mainly due to low-quality image presentations or extraneous considerations that the machine may not have considered. Such instances make it a high-risk factor in India, with many using cameras in phones without confirmed quality and unreliable internet connections. AI should always be accompanied by human surveillance to prevent such cases of misdiagnosis.

#### 12.3. Acceptance and adoption by dentists and patients

The intention to adopt AI-based solutions is very low. Indian patients and even practitioners want to have comfort in face-to-face meetings. According to. Bahanan Let al.,<sup>12</sup> ease of simplicity and perceived to be effective are strong drivers of acceptance. Such trust will take significant time with

simple AI-based interfaces and trainings for both dental professionals and patients.

### 12.4. Legal and regulatory issues

Regulatory development in India did not keep pace with the rapid technology developments in health care. According to. Ansarian, Met al.,<sup>11</sup> a clear hole for the regulation of AI use in teledentistry leads to ambiguity in laws which does not encourage its adoption. Developing stringent regulations for the safety, accuracy, and responsible use of AI would be a cornerstone to push the teledentistry forward in India.

## 13. Current Legal Framework of AI in Healthcare in India

The guideline follows the evolution of ethics in AI in health care, which is specifically drawn from global standards as well as Indian national policies. Among the key considerations are transparency, fairness, data privacy, accountability, and informed consent. Transparency refers to an important characteristic of an AI system-that is, how it arrives at its decision-making, while avoiding the "black-box" problem. Providers and patients must be able to see how a diagnosis or treatment recommendation is developed. Deployment of ethical AI should also reduce biases to provide fairness, as pointed in NITI Aayog's National Strategy for Artificial Intelligence and the Responsible AI for All, which states non-discrimination in healthcare that is driven by AI. It's significant to hold informed consent as health data is highly sensitive to disclose, so consent must be taken from patients before processing their information.<sup>21</sup> The DPDP Bill, 2023 explicitly requires consent and positions the application of data protection measures.<sup>22</sup>

At this moment, India does not have any standalone laws specifically for AI in healthcare, though there exist enacted laws like the Information Technology Act, 2000, and sectoral policy advice such as the Telemedicine Practice Guidelines and the National Digital Health Mission (NDHM) that provides some governance. These ensure privacy of data, security, and ethics in health care. AI, particularly those dealing with huge patient data, requires such clauses in guidelines for implementation. Ethical standards also recommend human oversight-this is that AI shall only supplement the work of healthcare professionals and not their substitute.<sup>23</sup> Since AI is gradually becoming an integral part of the healthcare sector, frameworks such as those by NITI Aayog, introduced through the DPDP Bill, will significantly form the rich legal and ethical structure for AI within the sector.

## 14. Future Directions and Potential Applications

With AI, the scope of teledentistry is enormous, provided we solve the present issues. AI-Based Predictive Models:

AI-based predictive models could form a landmark shift in the course of preventive care through timely identification of individuals at the highest risk of suffering from oral diseases long before these symptoms manifest. Ferlito et al.,<sup>8</sup> highlighted the fact that such models adapted for the peculiar demographics and problems related to oral health of India could be helpful in developing tailored, preventative care strategies designed to ease the burden of oral diseases.

Increased Patient Involvement: Artificial intelligence merged with a wearable device can offer real-time feedback about the hygiene of the oral cavity. Such technology would be very helpful in promoting preventive care in a country with diverse oral health habits mostly governed by regional practices, as said by Duong et al.<sup>9</sup> Virtual Dental Assistants AI-based virtual dental assistants can be used in scheduling and follow-up consultation to tackle the wide linguistic and cultural diversity in India. Such systems could, in principle, enhance patient interaction provided they are adapted appropriately to local requirements, said Batra et al.<sup>14</sup>

## 15. Conclusion

The incorporation of AI into teledentistry is not merely about an advancement in technology, but can be a revolution for India's dental healthcare system. This can possibly bring better diagnostic accuracy, streamline the flow of treatment, and enhance access to dental care in the remote areas of the country, particularly rural areas. All these are some of the vital advancements in dental practice made possible through AI. Yet, the road ahead is anything but smooth. Data privacy and cyber risks require severe attention, given that these issues pertain to patient data. What's more, the rules in India are still in a state of flux, and clear directions have to be brought in so that AI applications can plough on safely without compromising the well-being of patients. Most importantly, human expertise should not be underpaid. Even though AI can provide unprecedented support, it cannot replace this single nuanced judgment and personal care that only skilled dental professionals can bring in. In order to fully exploit the potential of AI in teledentistry, there is a significant need for technologists, healthcare professionals, policymakers, and educators to collaborate. Together, they can begin working through the barriers that exist today, help establish robust frameworks for proper use of AI ethics, and develop training programs so that dentists are sufficiently empowered to use AI technologies alongside them. By doing this, India will unlock the revolutionary power of AI for dental healthcare and ensure that it is a supportive tool rather than an antagonistic one, always positioned alongside human skills and wisdom.

## 16. Source of Funding

None.

## 17. Conflict of Interest


None.

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**Cite this article:** Babu B, Divya VC, Ganesh C, Mathialagan S, Backiyalakshmi A, Haripriya S. The rise of artificial intelligence in teledentistry: A comprehensive review. *J Oral Med, Oral Surg, Oral Pathol, Oral Radiol* 2024;10(4):247-253.