

Clinical Decision Support Systems Using AI for Endodontic Retreatment vs. Extraction

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ABSTRACT

Clinical decision-making in endodontics often hinges on whether to pursue nonsurgical retreatment or proceed with extraction and prosthetic replacement. Traditional approaches rely heavily on clinician experience, radiographic interpretation, and patient-specific factors such as periodontal status, coronal integrity, and systemic health. However, these processes can be subjective and prone to variability. The integration of artificial intelligence (AI) into Clinical Decision Support Systems (CDSS) offers a novel framework for improving the objectivity, consistency, and accuracy of treatment planning in complex endodontic cases. AI technologies including machine learning, deep learning, and radiomics are increasingly capable of analyzing cone-beam computed tomography (CBCT) scans, periapical radiographs, and electronic health records to predict treatment outcomes with high precision. Early studies demonstrate that AI-driven models can identify prognostic indicators for both retreatment success and implant survival, enabling clinicians to weigh therapeutic options more systematically. Despite these advances, challenges remain regarding data standardization, algorithm transparency, and medico-legal accountability. Furthermore, patient-centered considerations, including cost-effectiveness and individual preferences, must be integrated into AI-supported recommendations. Looking ahead, the convergence of multimodal data, validated predictive models, and user-friendly interfaces may foster collaborative human–AI decision-making, supporting clinicians while preserving the primacy of professional judgment. Ultimately, AI-enabled CDSS has the potential to enhance clinical outcomes, optimize resource allocation, and promote shared decision-making in the management of teeth requiring complex restorative or surgical interventions.

Keywords: Clinical Decision Support Systems, Artificial Intelligence, Endodontic Retreatment, Tooth Extraction, Implant Dentistry, Prognosis, Decision-Making.

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INTRODUCTION

Two major possible solutions to the failure of initial root canal therapy are endodontic retreatment and tooth extraction followed by the implantation of an implant. The identification of the most optimal pathway is usually a complicated process that demands biological, mechanical, and patient factors. Conventionally, clinicians have employed the use of radiographic interpretation, clinical judgment and experience, which might be subjective and can vary. The latest developments in artificial intelligence (AI) have brought new possibilities of aiding clinical decision-making with the help of predictive modeling and data-sharing. AI-driven Clinical Decision Support Systems (CDSS) are able to analyze radiographs, cone-beam computerized tomography scans, and electronic health records to offer objective information about prognosis. The AI-based tools can improve the treatment planning process, decrease variability, and encourage evidence-based care by balancing the rates of retreatment against the rates of implant survival. This combination of technology with clinical skills

can enhance the outcomes as well as patient-centered decision-making in complex cases of endodontics.

Clinical Considerations in Retreatment vs. Extraction

The decision between nonsurgical retreatment and extraction with subsequent prosthetic replacement is one of the most critical in endodontic practice. Retreatment aims to preserve the natural tooth and restore periapical health, while extraction and implant placement are often considered when the long-term prognosis of the tooth is compromised. A comprehensive understanding of prognostic factors is essential to guide clinicians toward the most predictable outcome.

Retreatment Prognostic Factors

Successful retreatment depends on factors such as the extent of periapical pathology, presence of missed canals, adequacy of the coronal seal, and the quality of the initial root canal filling. Teeth with favorable root morphology, manageable canal anatomy, and minimal iatrogenic complications generally present a higher likelihood of healing. The presence of a high-

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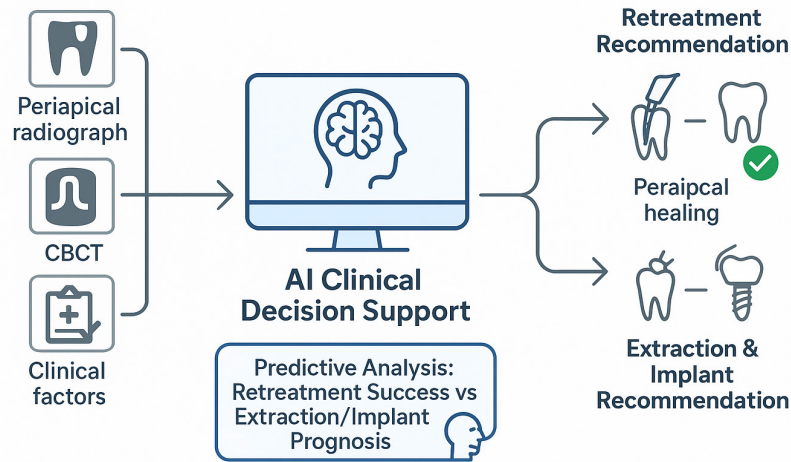


Figure 1

quality coronal restoration significantly enhances success rates by minimizing reinfection. Patient-related factors, including systemic health conditions, caries risk, and oral hygiene status, further influence retreatment outcomes.

Extraction and Prosthetic Considerations

Extraction is often indicated when structural compromise, vertical root fractures, or severe periodontal involvement limit the predictability of retreatment. Prosthetic planning must evaluate alveolar bone availability, periodontal support, and the potential need for grafting procedures prior to implant placement. Implant survival rates are high under ideal conditions, but success is influenced by host factors such as smoking, systemic disease, and parafunctional habits. Additionally, cost, treatment time, and patient preference weigh heavily in the decision-making process.

Ultimately, the choice between retreatment and extraction requires a holistic evaluation of tooth-specific, patient-related, and prosthetic factors. Integrating these considerations into a structured framework lays the foundation for applying artificial intelligence-driven decision support, which can provide more consistent and evidence-based recommendations.

AI in Clinical Decision Support Systems

Artificial intelligence (AI) has emerged as a transformative tool in healthcare, offering new possibilities for precision diagnostics, prognostic modeling, and decision-making support. In endodontics, where treatment decisions often involve complex prognostic assessments such as retreatment versus extraction, AI-powered Clinical Decision Support Systems (CDSS) provide an opportunity to standardize evaluation and augment clinician judgment.

Overview of AI Technologies

AI in dentistry primarily utilizes machine learning (ML), deep learning (DL), and radiomics. ML algorithms, including

decision trees, support vector machines, and ensemble models, have been applied to classify outcomes based on clinical and radiographic datasets. DL approaches, particularly convolutional neural networks (CNNs), excel in image interpretation tasks such as detecting periapical lesions or identifying missed canals on radiographs and cone-beam computed tomography (CBCT) scans. Radiomics extends this capability by extracting quantitative features from imaging data, enabling predictive models that move beyond subjective interpretation. Natural language processing (NLP) has also been applied to analyze clinical notes and extract meaningful prognostic information from electronic health records (EHRs).

Applications in Endodontics

AI has shown promising performance in diagnostic tasks, such as identifying periapical pathology, assessing root canal morphology, and differentiating between treatment options. Predictive models have been developed to estimate the probability of healing after nonsurgical retreatment, incorporating variables such as preoperative lesion size, root filling quality, and restoration status. Similarly, AI models trained on implant datasets can forecast survival rates and complication risks, providing a comparative framework for tooth preservation versus extraction. Importantly, these systems allow for individualized recommendations that integrate patient-specific data including systemic health indicators, habits, and restorative needs into the decision-making process.

Integration with Clinical Workflows

For AI-driven CDSS to be clinically useful, seamless integration with existing diagnostic tools and electronic systems is crucial. Chairside software capable of analyzing periapical radiographs or CBCT scans in real time could provide clinicians with immediate prognostic feedback. Linking AI outputs with

EHRs ensures that systemic factors such as diabetes or smoking history are automatically incorporated into treatment recommendations. Furthermore, user-friendly interfaces and visualization dashboards are essential to facilitate clinician trust and understanding of AI-derived outputs.

Advantages of AI in CDSS

The primary benefit of AI integration lies in enhancing objectivity, reducing variability between clinicians, and supporting evidence-based recommendations. By analyzing large datasets, AI can identify subtle patterns not readily apparent to human observation, thereby refining prognostic accuracy. In addition, AI systems can serve as educational tools, supporting less-experienced practitioners in complex decision-making and promoting consistency in care delivery.

Overall, the role of AI in CDSS for endodontics is rapidly evolving. While still in the early stages of clinical adoption, these technologies show considerable promise in assisting clinicians when weighing the relative merits of retreatment versus extraction, laying the foundation for more predictive, patient-centered treatment planning.

AI for Retreatment vs. Extraction Decision-Making

The application of AI to support clinical decision-making in endodontics extends beyond diagnostic accuracy, offering the ability to generate outcome-based treatment recommendations. In the context of retreatment versus extraction, predictive modeling can provide a systematic framework to evaluate prognosis, compare therapeutic options, and incorporate patient-centered variables into the decision-making process.

AI Models for Retreatment Prognosis

Machine learning and deep learning models have been trained to predict nonsurgical retreatment outcomes based on radiographic and clinical parameters. Variables such as preoperative lesion size, root canal filling density, periapical radiolucency, and coronal seal integrity are frequently

incorporated. AI systems can quantify these factors with greater consistency than human evaluation, yielding probabilities of periapical healing and identifying high-risk cases.

AI Models for Extraction and Implant Prognosis

In parallel, AI has been applied to implant dentistry, with algorithms predicting implant survival and complication risks based on bone density, systemic health, and prosthetic design. Such models offer clinicians an evidence-informed perspective when weighing the long-term benefits of extraction followed by implant placement. By comparing retreatment and implant outcome predictions side by side, AI systems create a decision environment that is less subjective and more data-driven.

Comparative Decision Frameworks

One of the most promising approaches is the development of hybrid CDSS platforms that integrate retreatment and implant datasets, providing dual prognostic outputs for a given case. For example, an AI system could suggest a 78% likelihood of retreatment success versus an 85% implant survival probability, while also factoring in patient-specific modifiers such as smoking, systemic conditions, or cost considerations.

Patient-Centered Integration

Ultimately, AI-derived predictions should not dictate treatment in isolation but instead contribute to a shared decision-making process. Patients value different outcomes such as tooth preservation, treatment cost, esthetics, and recovery time and AI can present personalized projections that facilitate informed discussions.

AI-enabled frameworks hold the potential to balance biological, prosthetic, and patient-related considerations in a single platform. By quantifying retreatment and extraction outcomes side by side, clinicians are empowered to guide patients through complex decisions with greater transparency, consistency, and confidence.

Table 1: Comparative Features of AI Models for Endodontic Retreatment vs. Extraction/Implant Prognosis

<i>Domain</i>	<i>AI for Retreatment</i>	<i>AI for Extraction/Implants</i>
Primary Data Sources	Periapical radiographs, CBCT, clinical records	CBCT scans, bone quality metrics, systemic health records
Key Variables Used	Lesion size, root filling quality, coronal restoration, canal anatomy	Bone density, periodontal support, systemic health, prosthetic plan
Common Algorithms	CNNs, decision trees, random forests	CNNs, support vector machines, ensemble models
Predictive Outputs	Probability of periapical healing, risk of reinfection	Implant survival probability, complication risks (peri-implantitis, failure)
Strengths	Focus on tooth preservation, objective lesion analysis	High long-term survival rates, structured datasets
Limitations	Complex variability in retreatment cases, lack of standardized datasets	Costly treatment, invasive procedures, influenced by host factors
Integration Potential	Useful for borderline retreatment cases	Supports long-term prosthetic planning
Role in Shared Decision-Making	Highlights natural tooth retention prospects	Provides implant survival comparisons for informed consent

CHALLENGES AND LIMITATIONS

While artificial intelligence holds considerable promise in guiding decisions between endodontic retreatment and extraction, several challenges and limitations must be addressed before widespread clinical adoption can occur. These challenges span technical, clinical, ethical, and practical dimensions.

Data Quality and Standardization

AI systems rely on large, high-quality datasets to produce reliable predictions. In endodontics, the availability of standardized datasets is limited, with many studies relying on retrospective clinical records and radiographs of variable quality. Inconsistent annotation protocols and heterogeneous imaging parameters (e.g., different CBCT machines or exposure settings) undermine model generalizability. Additionally, limited representation of diverse populations risks bias in AI predictions, reducing accuracy when applied to underrepresented patient groups.

Algorithm Transparency and Interpretability

Many AI models, particularly deep learning systems, function as “black boxes,” providing predictions without clear explanations of underlying reasoning. For clinicians to trust and adopt these tools, AI systems must evolve toward explainable AI (XAI), where outputs are accompanied by transparent indicators of the key factors influencing predictions. Without interpretability, medico-legal accountability and patient communication remain problematic.

Integration into Clinical Workflows

In practice, AI applications must integrate seamlessly with diagnostic software, CBCT systems, and electronic health records. Currently, many models exist only in research settings and lack user-friendly clinical interfaces. Technical barriers such as interoperability across platforms, data privacy concerns, and compliance with healthcare regulations further complicate deployment.

Ethical and Medico-Legal Considerations

The use of AI in clinical decision-making raises questions of responsibility and accountability. If an AI-derived recommendation contributes to an unfavorable outcome, determining liability between the clinician, the software developer, and the institution becomes complex. Ethical concerns also extend to data use and patient consent, as AI systems often require large volumes of sensitive health data for training.

Patient Acceptance and Perception

Successful adoption depends not only on clinician trust but also on patient acceptance. Some patients may be hesitant to rely on AI-derived recommendations, perceiving them as impersonal or overly technological. Ensuring that AI is positioned as a supportive tool complementing but not replacing the clinician’s expertise is crucial for patient confidence and informed consent.

Cost and Accessibility

Finally, the development, validation, and implementation of AI systems entail significant costs. Practices in resource-limited settings may find adoption challenging, raising concerns of unequal access to advanced decision-support tools. Addressing these disparities is vital to ensure that AI does not inadvertently widen the gap in oral healthcare delivery.

In sum, while AI-driven Clinical Decision Support Systems have the potential to revolutionize decision-making in endodontics, their effective implementation requires overcoming obstacles in data quality, interpretability, clinical integration, ethical governance, and equitable access.

FUTURE DIRECTIONS

The integration of artificial intelligence into Clinical Decision Support Systems (CDSS) for endodontic retreatment versus extraction is still in its formative stages. To unlock its full potential, future research and development must address current limitations while advancing toward more comprehensive, reliable, and patient-centered systems.

Multimodal Data Integration

Future AI systems will benefit from incorporating diverse data sources beyond radiographs and CBCT scans. Combining clinical records, periodontal assessments, systemic health parameters, genomic markers, and even salivary biomarkers could provide a more holistic understanding of prognosis. Multimodal datasets will enable predictive models that reflect the multifactorial nature of treatment outcomes, enhancing precision in individualized recommendations.

Explainable AI and Transparency

Improving interpretability is a priority for fostering clinician trust. Explainable AI (XAI) approaches, such as heatmaps on radiographs highlighting regions of interest or decision trees showing weighted prognostic factors, can help clinicians and patients understand the reasoning behind predictions. Such transparency not only facilitates medico-legal accountability but also strengthens shared decision-making.

Integration with Clinical Infrastructure

Next-generation CDSS should be seamlessly embedded into everyday workflows. Chairside AI tools capable of real-time image analysis, coupled with EHR-integrated predictive dashboards, would allow clinicians to receive instant decision support without disrupting practice efficiency. Cloud-based platforms may also facilitate continual updates as new data and algorithms emerge.

Personalized and Patient-Centered Care

Future systems must prioritize the incorporation of patient-specific preferences, values, and socioeconomic factors. AI-driven tools that present patients with comparative visualizations of retreatment versus extraction outcomes highlighting probabilities of success, treatment duration, costs, and esthetic implications can empower patients to actively participate in their care choices.

Collaborative Human–AI Decision-Making

The vision for AI in dentistry is not to replace clinicians but to augment their expertise. Future models should be designed for collaborative decision-making, where AI provides data-driven insights while the clinician contextualizes these outputs within the broader clinical picture. This human–AI partnership has the potential to enhance diagnostic accuracy, reduce treatment variability, and improve long-term outcomes.

Standardization and Global Accessibility

Efforts should also focus on building large, standardized, and diverse datasets to improve model generalizability across populations. International collaborations, open-access repositories, and consensus-driven annotation protocols can accelerate this process. Additionally, ensuring affordability and accessibility of AI tools will be crucial for equitable implementation, especially in low-resource settings.

In summary, the future of AI in endodontic decision-making lies in advancing predictive accuracy, transparency, and integration, while centering care around the patient. As innovations mature, AI-driven CDSS could become indispensable in balancing tooth preservation against extraction and prosthetic replacement.

CONCLUSION

Endodontic retreatment or extraction is an unresolved dilemma that is determined by anatomical, biological, prosthetic, or patient-centered factors. Using Clinical Decision Support Systems, artificial intelligence can provide a new avenue of improving these decisions with the incorporation of multimodal data, predictive results, and improvements in transparency during the treatment plan. Although the data standardization, interpretability, and ethical governance issues still exist, the future design of innovation is toward AI as an addition to the knowledge of clinicians. It is important to note that AI is not meant to completely replace professional judgement, rather it is meant to complement it, which should result in collaborative, evidence-based, and patient-centered care. With the advancement of predictive models and their ability to be integrated into clinical workflows, AI-based CDSS will be essential in terms of making retreatment versus extraction decisions and eventually enhancing patient outcomes in the long term.

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