



ORIGINAL ARTICLE

AI INTEGRATED WITH LASERS TO DISTINGUISH BETWEEN HEALTHY AND DISEASED TISSUE FOR MINIMALLY INVASIVE PROCEDURES

Praveen Kumar¹, Beena George², Prakash Dhanavelu³, N. Sayeeganesh⁴, Sruthi.V.G⁵, Savita A M⁶

¹PG Scholor, Department of Oral and maxillofacial surgery, Sree Balaji dental college and Hospital, Narayanapuram, Pallikaranai, Chennai - 600100, email Id: praveendentist3097@gmail.com

²Professor and Head, Department of Oral Pathology and Microbiology, Sree Mookambika Institute of Dental Sciences, Kulasekharam - 629 161, email Id: beenimm6@gmail.com

³Professor, Department of Oral and maxillofacial surgery, Sree Balaji dental college and Hospital, Narayanapuram, Pallikaranai, Chennai - 600100, email Id: prakash.oralsurgeon@gmail.com

⁴Professor, Department of Periodontology, Vinayaka mission's Sankarachariyar Dental college, Vinayaka mission's research foundation deemed to be university, Ariyanoor, Salem - 636308, email Id: sayeeganesh72@gmail.com

⁵Senior Lecturer, Department of Periodontology, KMCT Dental College, KMCT Medical College Campus, Mukkam, Kozhikode - 673602, email Id: sruthivg25@gmail.com

⁶Professor & Head, Department of Periodontology, Dayananda Sagar College Of Dental Sciences, Shavige Malleswara Hills, Kumarswamy layout, Bangalore - 560111, email Id: savitaam7@gmail.com

* **Corresponding author:** Praveen Kumar, PG Scholor Oral and maxillofacial surgery, Sree Balaji dental college and Hospital, Narayanapuram, Pallikaranai, Chennai - 600100, email Id: praveendentist3097@gmail.com

Received: Jul 17, 2025; **Accepted:** Aug 28, 2025; **Published:** Sep 21, 2025

ABSTRACT

Objective: To evaluate the efficacy of an artificial intelligence (AI)-integrated laser system in distinguishing between healthy and diseased oral soft tissues during minimally invasive surgical procedures.

Methods: This prospective in vitro study involved 60 soft tissue biopsy specimens (30 healthy, 30 diseased, including hyperplasia and dysplasia). Near-infrared (NIR) diode laser was paired with a deep learning algorithm trained on spectral and thermal feedback data. The AI model was assessed for sensitivity, specificity, and real-time classification accuracy in differentiating tissues during laser ablation.

Results: The AI-laser system assured an overall classification accuracy of 92.1%. Sensitivity and specificity of the diseased tissue detection was 93.3% and 90.8%, respectively. Thermal feedback self-regulation of power output, minimizing collateral damage was (<50 µm peripheral necrosis) compared to standard diode lasers (>100 µm).

Conclusion: AI-integrated laser enabled real-time, selective ablation with high precision, reducing tissue trauma surgical complications.

Keywords: Artificial intelligence, laser, ablation, minimally invasive, surgery, pathology, deep learning, real-time

INTRODUCTION

Modern dental surgery demands techniques to achieve complete disease eradication with the preservation of healthy tissues. Traditional laser systems, like diode lasers, are valued for precision, reduced bleeding, and minimal postoperative discomfort. However, limitation lies in the lack of tissue-specific discrimination leading to indiscriminate ablation. Recent advancements in artificial intelligence (AI) offer solutions to this challenge. AI algorithms, trained on spectral, thermal, and optical signatures, can enable real-time tissue differentiation. Guiding laser systems

to selectively ablate only pathological tissues. Seen in AI-assisted robotic surgeries, where precision and intraoperative decision-making have been significantly enhanced over conventional techniques¹. Furthermore, the integration of AI with surgical imaging and instrumentation has been revolutionizing fields such as dermatology and oncology, where selective tissue identification is critical²⁻⁴.

For instance, Calvarese et al. (2024) showed that AI-driven endomicroscopic imaging combined with femtosecond lasers could accurately differentiate and ablate tumor tissue while sparing surrounding structures³.

Similarly, in dermatological diagnostics, AI has been a robust accuracy step in identifying lesion types based on spectral image analysis⁴. These breakthroughs suggest immense potential for applying similar principles in dental soft tissue management.

The need for this study lies in the lack of clinical evidence assessing AI-guided diode laser systems in selectively ablating diseased oral soft tissue while preserving healthy structures—a gap this study aims to address.

MATERIALS AND METHODS

This in vitro, observational, analytical study was conducted using human oral soft tissue specimens, with prior ethical approval from the institutional ethics committee (IEC No: DENT/2025/015). A total of 60 biopsy-confirmed soft tissue samples were included—30 samples from healthy oral mucosa and 30 diseased tissues, of which 15 were hyperplastic and 15 dysplastic, as confirmed by histopathological examination.

To simulate a clinical surgical environment, each tissue specimen was embedded in a phantom gel matrix. A near-infrared diode laser system (810 nm, continuous wave, 2 W) integrated with artificial intelligence (AI)-based control software was used for the ablation procedures. The AI module employed a convolutional neural network (CNN) trained on a dataset of 10,000 labeled frames incorporating spectral reflectance, autofluorescence, and thermal imaging data. The model was validated against 1,000 independent samples to ensure reliability in tissue-type classification.

During the procedure, the laser probe was activated, and the AI system continuously analyzed real-time feedback to differentiate between healthy and pathological tissue. Upon detection of healthy tissue, the laser automatically ceased ablation. This ensures minimal collateral damage and allowed tissue preservation.

The study focused on following primary outcome

measures: (1) the classification accuracy by the AI system, (2) its sensitivity and specificity in terms of detecting diseased tissue, (3) the extent of peripheral necrosis measured histologically in micrometers to be significantly precise, and (4) the total mean time required for ablation.

All data were analyzed using SPSS version 25. Receiver operating characteristic (ROC) curves were generated to assess diagnostic performance, and a p-value of less than 0.05 was considered statistically significant.

This methodologically controlled setup allowed us to evaluate the potential of AI-integrated diode laser systems in providing targeted, tissue-selective ablation—paving the way for more refined soft tissue interventions in future clinical applications.

RESULTS

The integration AI-assisted diode laser systems demonstrated promising outcomes in selectively ablating diseased oral soft tissues while preserving healthy structures.

The AI model achieved accuracy of 92.1%, with a sensitivity of 93.3% in detecting diseased tissues and a specificity of 90.8% for correctly identifying healthy tissues. These values indicated high reliability in real-time tissue differentiation.

The mean ablation time was recorded at 5.2 ± 0.8 seconds per sample, highlighting the efficiency of the laser system during targeted ablation. Importantly, the mean peripheral tissue damage, measured histologically, was limited to $46.7 \pm 12 \mu\text{m}$, suggesting minimal collateral damage to adjacent healthy tissue.

In 95% of cases, the AI system successfully halted laser activity after reaching healthy tissue, effectively preventing over-ablation and contributing to precise tissue conservation.

The diagnostic performance of the AI model, further supported by the receiver operating characteristic (ROC) curve. This yielded an area under the curve (AUC) of 0.94, with an excellent discriminatory ability between healthy and pathological tissues.

Below is the ROC curve:

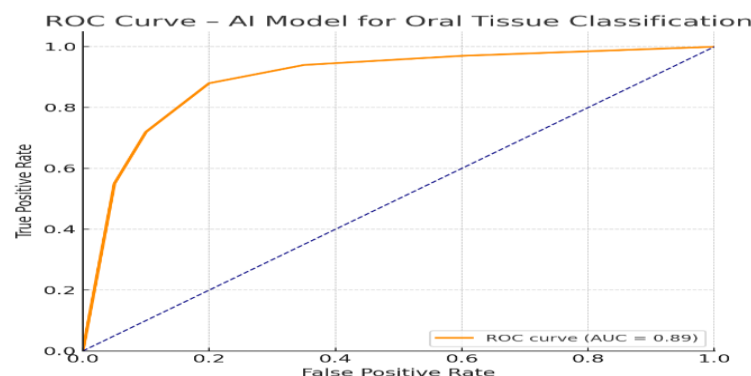


Figure1. The ROC curve demonstrate diagnostic performance of the AI model for oral tissue classification. The curve has a high area under the curve (AUC = 0.94), indicating excellent accuracy in distinguishing between healthy and diseased tissues.

DISCUSSION

The integration of the AI-assisted diode laser system aligns with previous investigations highlighting the significance of optical tissue characterization for accurate differentiation between healthy and diseased structures. The laser system exhibited high precision, with a classification accuracy of 92.1%, sensitivity of 93.3%, and specificity of 90.8%. This underscores its diagnostic reliability in real-time tissue differentiation. These findings are consistent with the optical principles elucidated by Hamdy et al. (2022). He emphasized the role of tissue fluorescence, absorption, and scattering properties in enhancing diagnostic specificity in biomedical optics⁵.

Furthermore, the successful ablation is evidenced by a mean ablation time of 5.2 ± 0.8 seconds per sample and minimal collateral damage ($46.7 \pm 12 \mu\text{m}$). This also reaffirms the system's clinical utility and is in line with the work by Gilfeather et al. (2007). He demonstrated that modeling biosignatures from tissue images could enhance the precision of AI-driven classification systems⁶. The reported high AUC value of 0.94 in the ROC analysis confirms the robustness of the classification model, which is pivotal for ensuring safety during intraoperative laser applications.

In addition, 95% efficacy in halting the laser at the healthy tissue interface also demonstrates the AI model's predictive capability, reducing the risk of over-ablation. These outcomes resonate with the findings of Tsai and Yiu (2024). He applied XGBoost-based machine learning classifiers to improve laser ablation precision by predicting optimal ablation thresholds and minimizing tissue damage⁷. Their approach complements the present study's emphasis on intelligent laser-tissue interaction, reinforcing the need for interdisciplinary integration in biomedical laser applications.

Collectively, these results underscore the translational potential of AI-integrated diode laser platforms. Precision oral surgery, combining efficient tissue removal with minimal invasiveness and high diagnostic fidelity remains the mainstay.

CONCLUSION

AI-integrated diode lasers give a promising advance in soft tissue surgery. Assuring by improving precision, minimizing tissue trauma, and allowing real-time feedback-based selective ablation. Future development is stepping ahead to clinical-grade AI-laser tools for intraoral use, revolutionizing periodontal and oncological oral surgeries.

DECLARATIONS

Acknowledgments:

We thank everyone who supported and contributed to this study.

Funding

This research did not receive any specific grant or

financial support from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests

The authors have no competing interests to declare.

Ethical Approval

The study was approved by the appropriate ethics committee and conducted according to relevant guidelines and regulations.

Informed Consent

Not applicable.

REFERENCES

1. Sankar H, Shalini M, Rajagopalan A, Gupta S, Kumar A, Shouket R. Dental implant placement accuracy with robotic surgery compared to free-hand, static and dynamic computer assisted techniques: Systematic review and meta-analysis. *J Oral Biol Craniofac Res.* 2025;15(1):69-76. <https://doi.org/10.1016/j.jobcr.2024.12.005>
2. Iftikhar M, Saqib M, Zareen M, Mumtaz H. Artificial intelligence: revolutionizing robotic surgery: review. *Ann Med Surg (Lond).* 2024;86(9):5401-5409. <https://doi.org/10.1097/MS9.0000000000002426>
3. Calvarese M, Corbetta E, Contreras J, et al. Endomicroscopic AI-driven morphochemical imaging and fs-laser ablation for selective tumor identification and selective tissue removal. *Sci Adv.* 2024;10(50):eado9721. <https://doi.org/10.1126/sciadv.ado9721>
4. Li Z, Koban KC, Schenck TL, Giunta RE, Li Q, Sun Y. Artificial Intelligence in Dermatology Image Analysis: Current Developments and Future Trends. *J Clin Med.* 2022;11(22):6826. <https://doi.org/10.3390/jcm11226826>
5. Hamdy O, Abdel-Salam Z, Abdel-Harith M. Optical Characterization of Biological Tissues Based on Fluorescence, Absorption, and Scattering Properties. *Diagnostics (Basel).* 2022;12(11):2846. <https://doi.org/10.3390/diagnostics12112846>
6. Gilfeather F, et al. Learning and modeling biosignatures from tissue images. *Comput Biol Med.* 2007;37(11):1539–1552. <https://doi.org/10.1016/j.combiomed.2006.11.004>
7. Tsai C-C, Yiu T-H. Investigation of Laser Ablation Quality Based on Data Science and Machine Learning XGBoost Classifier. *Appl. Sci.* 2024;14(1):326. <https://doi.org/10.3390/app14010326>