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ARTIFICIAL INTELLIGENCE AND NANOTECHNOLOGY: TRANSFORMING ORAL CANCER DIAGNOSIS, PROGNOSIS AND TREATMENT

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Abstract
Artificial Intelligence (AI) and nanotechnology are emerging as transformative tools in the diagnosis, prognosis, and treatment of oral cancer. AI enhances early detection and clinical decision-making through advanced imaging, histopathological analysis, and survival prediction models, while nanotechnology enables targeted drug delivery, biomarker identification, and precision theranostics. Together, these innovations address the limitations of conventional approaches by improving sensitivity, specificity, and therapeutic efficacy, while reducing adverse effects. Their integration represents a paradigm shift toward personalized and patient-centered oral oncology. Continued research and clinical translation will further establish their role in improving outcomes and quality of life for oral cancer patients.
Keywords: Artificial Intelligence; Nanotechnology; Oral Cancer; Diagnosis; Prognosis; Biomarkers; Drug Delivery; Theranostics; Personalized Medicine

INTRODUCTION:

Artificial Intelligence (AI) and nanotechnology are revolutionizing the landscape of oral cancer management by integrating precision diagnostics, predictive analytics, and targeted therapeutics. AI enables early detection through advanced imaging, pattern recognition, and prognostic modeling, enhancing clinical decision-making. Meanwhile, nanotechnology provides innovative drug delivery systems, biosensors, and theranostic platforms to improve treatment specificity and reduce side effects. Together, these technologies bridge gaps in early diagnosis, prognosis accuracy, and therapeutic efficacy. This convergence holds immense promise for personalized, patient-centered oral cancer care [1, 2].

The detection, diagnosis, and treatment of oral cancer have all been shown to be significantly improved by these two technologies, which have shown promise in this regard.

Through the application of artificial intelligence, it has been possible to successfully handle both the identification and prognosis of oral cancer. In order to uncover patterns that are indicative of the disease and to provide a diagnostic approach that does not include any intrusive procedures, artificial intelligence models have been utilised in the analysis of mouth cancer histopathology photos. Furthermore, artificial intelligence models have been utilised to estimate the five-year survival rate for persons who have been diagnosed with oral cancer. This facilitates the evaluation of the effectiveness of treatments [3].

In spite of this, there have been significant developments in the field of nanotechnology, namely in the creation of biomarkers for the early identification of oral cancer. Nanoparticles, which accumulate in specific locations of cancer, making it feasible to identify biomarkers and enable precise planning for the administration of drugs [4]. By utilising nanotechnology in the process of diagnosing oral cancer, both the sensitivity and specificity of cancer diagnosis have been significantly improved (Figure 1).

Nanotechnology has enhanced the accuracy and precision of cancer diagnosis by improving both sensitivity and specificity. Nanoparticles accumulate in specific cancerous regions, enabling the detection of biomarkers and facilitating precise planning for treatment administration. The limited accuracy and precision of standard non-invasive techniques like as molecular imaging, exfoliative cytology, and vital staining hinders their practical application.

Hence, there is an urgent need to explore diagnostic approaches that are non-invasive, highly sensitive, and specifically focused. "Nano detection systems" are advanced methods that allow the detection of biomarkers at the nanoscale in a non-invasive manner [5]. In addition, nanoparticles have the ability to specifically target particular surface molecules and are easier to produce than the imaging contrast chemicals now in use. Nanoparticles generate localised surface plasmon resonances at near-infrared wavelengths, enhancing image contrast and resolution. Therefore, by utilising nano-based techniques, healthcare practitioners can enhance their ability to accurately detect and monitor diseases at different stages of oral cancer [6].

AI has made significant progress in the field of oncology, particularly in the diagnosis and prognosis of oral cancer. AI models have been utilised to assess histopathology images of oral cancer for the purpose of diagnosis. These models provide a non-intrusive diagnostic approach by detecting patterns in the images that could indicate the presence of cancer. Research on deep learning has produced promising results, with reported accuracies for segmentation, object detection, and classification ranging from 85.0% to 100%. AI has also been used to both non-cancerous and malignant oral pictures obtained from real-time and histopathologic datasets [7].

AI algorithms have been employed to predict the 5-year survival rate of individuals diagnosed with mouth cancer. The reported accuracy percentages for the decision tree classifier, logistic regression, and boosted decision tree models were 76%, 60%, and 88.7% respectively. Deep learning models have also been utilised for prognostic prediction, with Concordance indices ranging from 0.78 to 0.952, as stated. These AI models have the capacity to improve well-informed clinical assessments of oral cancer. While these advancements are promising, it is important to note that they are still in the research phase and are not widely available as therapeutic options [8].

Artificial intelligence is a useful technique for the production of nanoparticles that have better efficacy for the diagnosis and treatment of cancer. This is due to the fact that AI is able to analyse enormous amounts of data promptly and accurately. Nanotechnology, on the other hand, allows for the exact targeting of cancer cells while simultaneously sparing healthy ones. As a result of this selectivity, the undesirable effects that are usually associated with conventional cancer treatments are reduced. The fact that these advancements are still being explored and do not yet offer a wide variety of treatment possibilities is an essential point to keep in mind, despite the fact that they have the potential to be beneficial. It is also discussed how the application of artificial intelligence and nanotechnology to health could have implications for both morality and security [9].

In conclusion, the combination of artificial intelligence and nanotechnology is, in a nutshell, the driving force behind the future of oral oncology. Because of their precision, accuracy, and ability to be personalised, these technologies are preferable for the identification and treatment of cancer. It is anticipated that these technologies will increasingly play a crucial role in the treatment of oral cancer as research continues to grow. This will ultimately result in improved patient outcomes and quality of life standards.

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Figure 1. Different nanomaterials such as nanoparticles, scaffolds, hydrogels, and nanodevices are applied in cancer therapy. They offer advanced strategies for precise drug delivery, controlled release, and enhanced treatment efficacy.

Technology	**Application in Oral Cancer**	**Key Outcomes**	**References**
Artificial Intelligence (AI)	Histopathology image analysis	Non-invasive diagnosis with accuracy 85–100% for segmentation, detection, and classification	[3, 7]
AI	Prognosis prediction (5-year survival rate)	Decision tree (76%), logistic regression (60%), boosted decision tree (88.7%); deep learning C-index 0.78–0.952	[3, 8]
Artificial Intelligence (AI) + Nanotechnology	AI-assisted nanoparticle design	Enhanced efficacy in diagnosis and treatment; reduced side effects	[9]
Nanotechnology	Biomarker detection (nanoparticles, aptasensors)	Improved sensitivity and specificity; non-invasive nano-detection systems	[4, 5]
Nanotechnology	Nano-biosensing & imaging	Localized plasmon resonance for enhanced image contrast and resolution	[6]
Nanotechnology	Drug delivery & theranostics	Targeted delivery to cancer cells, minimizing damage to healthy tissue	[2, 4]

Table 1. Summarizing the applications of Artificial Intelligence and Nanotechnology in oral cancer diagnosis, prognosis, and treatment. These approaches enhance accuracy, sensitivity, and therapeutic precision while minimizing side effects.