EDITORIAL

Nanomaterials-based Bioanalytical Sensors for the Detection of Oral Cancer Biomarkers

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Among the several diseases that plague the population, cancer continues to be an eminent cause of morbidity and mortality around the world. Oral cancer comprises 85% of all head and neck cancers, and is the sixth most common cancer worldwide.[1] In India, oral squamous cell carcinoma (OSCC) is the most common cancer in men and the third most common cancer in women.[2] The early stages of this disease manifest as asymptomatic lesions that usually go unnoticed, resulting in a delayed diagnosis when the patient eventually presents with pain during later stages. Despite the decline in the death rate associated with the disease over the past three decades, the lack of routine screening has led to the delayed discovery of these cancers. Although biopsy remains the diagnostic gold standard, it is an uncomfortable and invasive technique with limited potential for early diagnosis.[3] Other diagnostic techniques like cytological smears cannot compare to the specificity and sensitivity provided by a biopsy, making them less preferable. Enzyme-linked immunosorbent assay (ELISA) is yet another commercially available tool that provides good sensitivity but the assay time is much longer than the rapid response provided by biosensors.

A biosensor is a tool to monitor biological or chemical reactions by producing signals that are proportionate to the analyte's concentration in a specific reaction.[4] The field of biosensing has recently garnered great interest as this technology could be instrumental in the early detection of cancer biomarkers. Biosensors operate on the principle of a biological element reacting with an analyte to produce a physical or chemical change which is then sensed by a detector to produce a signal that is proportional to the concentration of the analyte. Nanoparticles (NPs) can be organic (liposomes, dendrimers, polymers) or inorganic (gold, magnetic, quantum dots, carbon nanotubes) and have diameters less than 100 nm which helps them cross biological barriers and assess sites that are normally inaccessible to other agents, providing the advantage of early detection and visualization of the tumor cells.[5]

"A biomarker is a biological molecule found in blood, other body fluids or tissue that is a sign of a normal or abnormal process, or of a condition or disease".[6] These biomarkers can be used to screen for specific cancers at the initial stages, monitor disease status and progression and develop targeted therapies. L-Phenylalanine is one such salivary biomarker that is detected during the early stages of OSCC. Other potential biomarkers are Interleukin-6, 8, 1α, 1β, and cell-free DNA and microRNA that are released directly from the tumor cells.[7] Telomerase was another protein biomarker that was reported by LP Zhong et al.[8] with positive telomerase activity detected in 75% of OSCC patients. The detection of these biomarkers with the help of nanoparticle-based biosensors demonstrates high sensitivity and enhanced specificity. Electrochemical biosensors can be easily integrated into miniature devices and can be utilized for the detection of any kind of biomarker. They show great promise due to their high sensitivity, lower detection limits, capacity to work with small volumes of the sample and the ability to be developed into disposable devices. Gold NPs are one such electrochemical biosensors. El Sayed et al. developed a biosensor that permitted the detection of over-expression of epidermal growth factor receptor (EGFR) for oral cancer. It was demonstrated that anti-EGFR-antibody-conjugated gold NPs bind uniformly and specifically to the surface of the cancer cells via target cell recognition and bind non-specifically and randomly to noncancerous cells.[9] Gold NPs can strongly scatter light that is irradiated upon their surface and this can be viewed under dark field microscopy to aid in the diagnosis of oral cancer. Chakraborty et al. developed a gold-particle-based ELISA system for the detection of Osteopontin that is overexpressed in tumors of the tongue, and this was shown to exhibit high sensitivity.[10] Guerrero et al. developed an electrochemical sandwich-type immunosensor for the detection of interleukin 1β in saliva, which showed substantially superior results when compared with commercially available ELISA kits.[11]

The most important goal of biosensing technology is to provide point-of-care-testing (POCT) or on-site diagnostic testing.[12] This

method allows immediate diagnosis due to the rapid delivery of results and may potentially reduce the cost of testing. To discern whether a patient is healthy or suffering from oral cancer, the detection of multiple biomarkers gives more precise and predictable outcomes than the detection of a single marker. This concept of multiplexing must be honed to replicate the accuracy that laboratory testing provides.[13] Biosensors that are based on nanoparticles are advantageous in the sense that they not only help in tracking the tumor cells but also aid in the precise delivery of drugs to the target sites. The use of this advanced technology is yet to be explored in the clinical setting as the lack of an absolute specific marker limits its applicability to a pure laboratory setting. The limited findings must be validated against pre-existing standards and studies must be conducted on a larger scale to yield results that can be correlated significantly. The probability of obtaining false positives or negatives further acts as a barrier when it comes to the incorporation of this technology in daily clinical practice.[14]

India reports a massive number of oral cancer cases every year, many of which go undiagnosed due to the lack of screening and access to healthcare in several isolated regions. Nanoparticle-based biosensors are a sophisticated approach to oral cancer diagnosis, that is still in the early stages of development. This technology could hold great promise in the future for the early diagnosis and management of oral cancer once the accessibility, sustainability, and economic concerns are addressed. Biosensing can aid the clinician in accurate diagnosis, prognosis, and targeted drug delivery with minimal adverse reactions. Further research can make this technology accessible on a wide scale, revolutionizing cancer diagnosis and therapy.

To summarize, cancer biomarkers can play an important role in indicating the presence and the growth rate of tumors such as OSCC. These biomarkers can be detected using biosensors, which can be nanoparticle-based. Biosensing is a highly sensitive and specific method for the early detection of cancers. These cancers spread at the nanoscale level hence it goes without saying that this disease must also be tackled using nanoparticulate technology. Although oral cancer is a disease with a complex etiology and diverse presentation, biosensing technology may potentially be the superior diagnostic alternative that can aid in overcoming this challenge.

References

1. Vigneswaran N, Williams MD. Epidemiologic trends in head and neck cancer and aids in diagnosis. Oral Maxillofac Surg Clin North Am 2014;26(2):123–141. DOI: 10.1016/j.coms.2014.01.001.
2. Borse V, Konwar AN, Buragohain P. Oral cancer diagnosis and perspectives in India. Sens Int 2020;1:100046. DOI: 10.1016/j.sintl.2020.100046.
3. Sciubba JJ. "Oral cancer. The importance of early diagnosis and treatment." Am J Clin Dermatol 2001;2(4):239–251. DOI: 10.2165/00128071-200102040-00005.
4. Bhalla N, Jolly P, Formisano N, et al. Introduction to biosensors. Essays Biochem 2016;60(1):1–8. DOI: 10.1042/EBC20150001.
5. De Jong WH, Borm PJ. Drug delivery and nanoparticles: applications and hazards. Int J Nanomedicine 2008;3(2):133–149. DOI: 10.2147/ijn.s596.
6. Mishra A, Verma M. Cancer biomarkers: Are we ready for the prime time? Cancers (Basel) 2010;2(1):190–208. DOI: 10.3390/cancers2010190.
7. Goldoni R, Scolaro A, Boccalari E, et al. Malignancies and biosensors: A focus on oral cancer detection through salivary biomarkers. Biosensors (Basel) 2021;11(10):396. DOI: 10.3390/bios11100396.
8. Zhong LP, Chen GF, Xu ZF, et al. Detection of telomerase activity in saliva from oral squamous cell carcinoma patients. Int J Oral Maxillofac Surg 2005;34(5):566–570. DOI: 10.1016/j.ijom.2004.10.007.
9. Singh P, Pandit S, Mokkapati VRSS, et al. Gold nanoparticles in diagnostics and therapeutics for human cancer. Int J Mol Sci 2018;19(7):1979. DOI: 10.3390/ijms19071979.
10. Chakraborty D, Viveka TS, Arvind K, et al. A facile gold nanoparticle–based ELISA system for detection of osteopontin in saliva: Towards oral cancer diagnostics. Clinica Chimica Acta 2018;477:166–172.
11. Guerrero S, Agüí L, Yáñez-Sedeño P, et al. Design of electrochemical immunosensors using electro-click chemistry. Application to the detection of IL-1β cytokine in saliva. Bioelectrochemistry 2020;133:107484. DOI: 10.1016/j.bioelechem.2020.107484.
12. Bohunicky B, Mousa SA. Biosensors: The new wave in cancer diagnosis. Nanotechnol Sci Appl 2010;4:1–10. DOI: 10.2147/NSA.S13465.
13. Wang Q, Gao P, Wang X, et al. The early diagnosis and monitoring of squamous cell carcinoma via saliva metabolomics. Sci Rep 2014;4:6802. DOI: 10.1038/srep06802.
14. Singh A, Sharma A, Ahmed A, et al. Recent advances in electrochemical biosensors: Applications, challenges, and future scope. *Biosensors* 2021;11(9):336. Available from: https://doi.org/10.3390/bios11090336.