Intraoral Biosensors
Novel Platform for Continuous and Non-Invasive Health Monitoring

[1]Dr.Purushottam Rakhewar, [2]Dr.Pooja Singh, [3]Dr.Mahika Borgave,

[4]Dr.Janhavi Kulkarni

[1]Professor and Head of Department, [2]Post graduate Student, [3]Post Graduate student,[4]Post Graduate student
[1]Department of Periodontology &Oral Implantology,
[1]SMBT Dental college and hospital, Sangamner, India.

Abstract : Intraoral biosensors are non-invasive devices that detect periodontal disease biomarkers in saliva and GCF. They use advanced sensing technologies for real-time diagnosis and monitoring. Markers such as IL-1β, MMP-8, and CRP help assess disease progression and treatment outcomes. These biosensors enhance diagnostic accuracy, patient comfort, and periodontal care.

***IndexTerms* – Biosensors, Diagnostic tools, Biomarkers.**

INTRODUCTION

Biosensors are analytical devices that convert biological responses into measurable signals, such as electrical or optical signals, which can be quantified to provide insights into health conditions. In essence, these sensors are designed to detect specific biological markers, or biomarkers, and help in the diagnosis and monitoring of diseases. They can be based on a variety of detection mechanisms, including electrochemical, optical, and piezoelectric methods, among others. In the context of periodontics, these biomarkers, which are often found in oral fluids such as saliva and gingival crevicular fluid (GCF), serve as indicators of oral health and disease, providing essential data for early diagnosis and continuous monitoring of periodontal conditions (Timpel et al., 2023). The significance of early diagnosis in periodontics cannot be overstated. Periodontal diseases, such as periodontitis, are chronic inflammatory conditions that, if left untreated, can lead to tooth loss and impact overall systemic health. In fact, studies have shown that untreated periodontitis is linked to conditions like cardiovascular diseases, diabetes, and respiratory disorders (Korgaonkar et al., 2024). Therefore, detecting these diseases at an early stage is crucial for preventing irreversible damage. Traditionally, periodontal conditions were diagnosed through clinical examinations and radiographs. However, these methods can often miss early, subtle changes that may indicate the onset of disease. This is where intraoral biosensors come into play, offering an innovative, non-invasive way to detect periodontal diseases before they become clinically visible (Dogra et al., 2022).
Intraoral biosensors have emerged as one of the most promising diagnostic tools in modern dentistry. These devices detect specific biomarkers related to periodontal inflammation and disease activity, such as interleukin-1β, matrix metalloproteinase-8 (MMP-8), and C-reactive protein (CRP), among others (Cennamo et al., 2024). These biomarkers are present in the oral fluids and reflect the inflammatory status of the periodontal tissues, allowing for precise and real-time monitoring. Unlike traditional methods that rely on visual inspection or the probing of periodontal pockets, intraoral biosensors provide objective, quantitative data on the presence and severity of periodontal disease. This ability to detect biomarkers associated with inflammation and tissue degradation before clinical symptoms appear is a game-changer for periodontal diagnostics (George et al., 2024).
The evolution of intraoral biosensors has been remarkable, with significant advancements in both the technology and their integration into clinical practice. Early biosensor technologies were limited to glucose monitoring, but over the years, the field has expanded to include sensors capable of detecting a wide range of biomarkers related to oral health (Park et al., 2022). The development of miniaturized, wearable devices that are capable of analyzing oral fluids continuously has further revolutionized the field, making it possible for patients to monitor their periodontal health at home, without the need for frequent visits to the dentist. The integration of these devices with cloud-based systems and the "Internet of Dental Things" (IoDT) has made it possible for clinicians to track their patients' oral health in real time, offering a more personalized approach to periodontal care (Nguyen et al., 2024).
Moreover, the increasing sophistication of biosensors, particularly those based on molecularly imprinted polymers and optical techniques, has led to improvements in their sensitivity and specificity. These advancements are enabling the detection of a broader array of biomarkers with greater accuracy and at earlier stages of disease development. The potential for these sensors to be used in point-of-care settings or even at home provides an invaluable opportunity for both clinicians and patients to stay ahead of periodontal diseases before they cause irreversible damage (Li et al., 2022; Korgaonkar et al., 2024). The future of intraoral biosensors in periodontics looks promising, with ongoing research aimed at improving their functionality, reducing costs, and increasing their accessibility for routine dental care (Falkner, 2025).

Technology & Mechanism

Intraoral biosensors are sophisticated devices designed to detect and measure specific biomarkers in the oral cavity, providing valuable insights into the health of periodontal tissues. These biosensors consist of various components, each playing a crucial role in their function. The primary types of biosensors used in periodontal diagnostics include optical, electrochemical, and piezoelectric sensors, each with its unique set of advantages. Optical biosensors, for instance, use light to detect changes in the oral environment, while electrochemical sensors rely on electrical signals generated by chemical reactions. Piezoelectric sensors, on the other hand, convert mechanical stress into an electrical signal, offering another layer of functionality for detecting tissue changes. These sensors are particularly valuable because they can be miniaturized, making them perfect for integration into dental devices (Korgaonkar et al., 2024).

The core biological components of intraoral biosensors are typically enzymes, antibodies, or living cells that are engineered to interact with specific biomarkers in the oral fluids. For instance, enzymes such as glucose oxidase or antibodies designed to bind to specific proteins are embedded in the sensor to ensure high specificity in biomarker detection (Timpel et al., 2023). These biological elements serve as the heart of the sensor, recognizing and reacting to specific chemical compounds in the gingival crevicular fluid (GCF) or saliva, which are often indicative of periodontal disease. In the case of periodontitis, biomarkers like interleukin-1β (IL-1β), matrix metalloproteinase-8 (MMP-8), and C-reactive protein (CRP) are often the targets. These biomarkers are released as a result of the inflammation and tissue destruction associated with periodontal disease (Cennamo et al., 2024).

Now, let's talk about the detection mechanism, which is where the magic happens. The biosensor detects biomarkers in oral fluids like saliva or GCF by utilizing a biological component that reacts with a target substance in the fluid. The process begins when the biomarker in the fluid binds to the biological receptor on the sensor. For example, IL-1β, a key inflammatory marker in periodontitis, binds to a specific antibody that's integrated into the sensor (Thomas et al., 2022). Once this binding occurs, the sensor produces a measurable signal—whether it's electrical, optical, or piezoelectric, depending on the type of sensor being used. This signal indicates the presence of the biomarker, which is then translated into data that clinicians can use to assess the severity of periodontal disease (Li et al., 2022).

The process doesn't stop at detection; the sensor must then process and output the data in a form that's useful to the clinician. This involves transduction, signal processing, and the final output. Transduction is the step where the sensor's biological response is converted into an electronic signal. In an electrochemical sensor, this might involve the generation of an electrical current when the biomarker binds to the sensor's biological component (George et al., 2024). After this, the signal undergoes processing, where it is amplified and filtered to ensure accuracy and eliminate any background noise. The processed signal is then outputted, often in the form of a digital readout or displayed on a connected device, where the clinician can interpret it. This entire process happens swiftly, often in real-time, making biosensors incredibly effective for continuous monitoring (Nguyen et al., 2024).

Category	Description	References
Sensitivity & Specificity	Detection accuracy affected by oral fluid complexity, diet, medication, and patient variability.	Li et al., 2022; George et al., 2024
Biomarker Specificity	Some biomarkers are not exclusive to periodontal disease, leading to false positives.	Cennamo et al., 2024
Miniaturization	Devices must be compact, yet robust enough to survive the oral environment.	—
Technological Integration	Challenges in connecting biosensors with imaging systems or patient management software.	Timpel et al., 2023
Adoption & Cost	High development and implementation costs; unclear ROI for clinics.	Korgaonkar et al., 2024
Knowledge Gap	Limited awareness among clinicians and patients about capabilities of biosensors.	—

Table 1: Detailed analysis of biomarkers

Technology & Mechanism

Intraoral biosensors are sophisticated devices designed to detect and measure specific biomarkers in the oral cavity, providing valuable insights into the health of periodontal tissues. These biosensors consist of various components, each playing a crucial role in their function. The primary types of biosensors used in periodontal diagnostics include optical, electrochemical, and piezoelectric sensors, each with its unique set of advantages. Optical biosensors, for instance, use light to detect changes in the oral environment, while electrochemical sensors rely on electrical signals generated by chemical reactions. Piezoelectric sensors, on the other hand, convert mechanical stress into an electrical signal, offering another layer of functionality for detecting tissue changes. These sensors are particularly valuable because they can be miniaturized, making them perfect for integration into dental devices (Korgaonkar et al., 2024).

The core biological components of intraoral biosensors are typically enzymes, antibodies, or living cells that are engineered to interact with specific biomarkers in the oral fluids. For instance, enzymes such as glucose oxidase or antibodies designed to bind to specific proteins are embedded in the sensor to ensure high specificity in biomarker detection (Timpel et al., 2023). These biological elements serve as the heart of the sensor, recognizing and reacting to specific chemical compounds in the gingival crevicular fluid (GCF) or saliva, which are often indicative of periodontal disease. In the case of periodontitis, biomarkers like interleukin-1β (IL-1β), matrix metalloproteinase-8 (MMP-8), and C-reactive protein (CRP) are often the targets. These biomarkers are released as a result of the inflammation and tissue destruction associated with periodontal disease (Cennamo et al., 2024).

Now, let’s talk about the detection mechanism, which is where the magic happens. The biosensor detects biomarkers in oral fluids like saliva or GCF by utilizing a biological component that reacts with a target substance in the fluid. The process begins when the biomarker in the fluid binds to the biological receptor on the sensor. For example, IL-1β, a key inflammatory marker in periodontitis, binds to a specific antibody that’s integrated into the sensor (Thomas et al., 2022). Once this binding occurs, the sensor produces a measurable signal—whether it’s electrical, optical, or piezoelectric, depending on the type of sensor being used. This signal indicates the presence of the biomarker, which is then translated into data that clinicians can use to assess the severity of periodontal disease (Li et al., 2022).

The process doesn’t stop at detection; the sensor must then process and output the data in a form that’s useful to the clinician. This involves transduction, signal processing, and the final output. Transduction is the step where the sensor’s biological response is converted into an electronic signal. In an electrochemical sensor, this might involve the generation of an electrical current when the biomarker binds to the sensor’s biological component (George et al., 2024). After this, the signal undergoes processing, where it is amplified and filtered to ensure accuracy and eliminate any background noise. The processed signal is then outputted, often in the form of a digital readout or displayed on a connected device, where the clinician can interpret it. This entire process happens swiftly, often in real-time, making biosensors incredibly effective for continuous monitoring (Nguyen et al., 2024).

Illustration 1: Wearable intraoral sensor

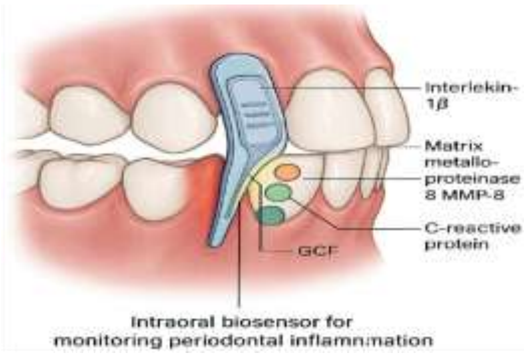

Illustration 2: Intraoral biosensor for monitoring periodontal inflammation.

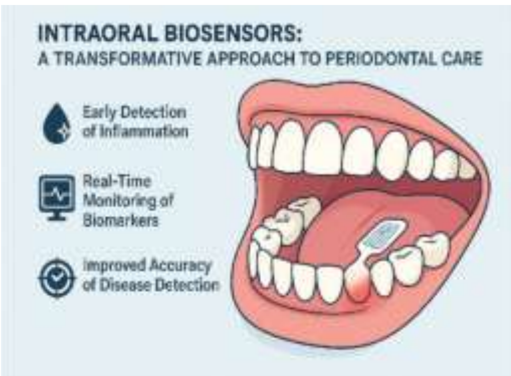

Illustration 3: A Transformative approach to Periodontal care.

Application in Periodontics

Intraoral biosensors have opened up a new world of possibilities in periodontics, particularly when it comes to detecting and monitoring periodontal diseases. One of their most significant applications is the early detection of periodontal inflammation, which is a key factor in preventing the progression of periodontal diseases. Traditional methods often involve invasive procedures or rely on subjective clinical assessments, which can miss the subtle changes that signify the early stages of disease. Intraoral biosensors, however, allow for the identification of biomarkers associated with inflammation and tissue breakdown at very early stages. Biomarkers like interleukin-1β (IL-1β), matrix metalloproteinase-8 (MMP-8), and C-reactive protein (CRP) have been found in the gingival crevicular fluid (GCF) and saliva and serve as reliable indicators of periodontal disease activity (Cennamo et al., 2024; Timpel et al., 2023). By measuring the levels of these biomarkers, intraoral biosensors can detect the onset of inflammation before clinical symptoms are visible, enabling early intervention that can significantly improve patient outcomes (George et al., 2024).

The ability of intraoral biosensors to monitor disease progression is another groundbreaking feature that sets them apart from traditional diagnostic methods. Real-time monitoring of periodontal health is now possible through continuous or frequent sampling of oral fluids like saliva or GCF. These sensors work tirelessly to detect changes in biomarkers, providing clinicians with up-to-the-minute data about the patient's condition. For instance, if the levels of inflammatory biomarkers increase, it could signal a flare-up of periodontitis or an ongoing periodontal infection (Korgaonkar et al., 2024). The ability to track these fluctuations in biomarker levels over time allows for a more accurate understanding of how a disease is progressing and whether the treatment plan is working. This makes it easier for clinicians to adjust the treatment protocol accordingly, ensuring that the patient is always on the right path to recovery. Real-time data also means fewer invasive procedures, as the need for clinical probing and radiographs can be reduced (Li et al., 2022).

The ultimate goal of intraoral biosensors in periodontics is to enhance patient outcomes. These devices provide a non-invasive, comfortable, and highly efficient means of monitoring oral health. Unlike traditional methods, which often involve discomfort or require multiple visits, biosensors allow for continuous monitoring in a way that doesn't disrupt the patient's daily life. For example, wearable intraoral sensors can be used to detect changes in oral health over time, without requiring the patient to undergo complex diagnostic procedures every time a change is suspected. This frequent and non-invasive monitoring is crucial for early detection, which is vital in preventing more severe periodontal conditions, such as tooth loss and systemic complications related to untreated periodontitis (Falkner, 2025; Nguyen et al., 2024).

Furthermore, intraoral biosensors improve the accuracy of periodontal disease detection. The traditional methods of periodontal assessment, such as probing pocket depth or radiographic imaging, have limitations, especially when it comes to detecting the early stages of disease. Biosensors, on the other hand, provide highly specific and sensitive measurements of biomarkers, making them a more reliable tool for diagnosing periodontal conditions. With early and accurate detection, clinicians can intervene much sooner, potentially reducing the need for more invasive treatments like surgery or the extraction of teeth. This shift towards more precise and proactive care has the potential to revolutionize how periodontitis and other oral diseases are managed (Timpel et al., 2023; Cennamo et al., 2024).

Future Development	Description	References
Improved Accuracy	Development of more sensitive and specific sensors to detect a broader range of biomarkers.	Falkner, 2025
Nanotech & Microfluidics	Advances enabling smaller, more efficient, and more comfortable biosensors.	
Internet of Dental Things (IoDT)	Real-time data sharing between sensors, clinicians, and cloud platforms.	Nguyen et al., 2024
AI Integration	Use of machine learning to identify patterns and predict oral health issues.	Li et al., 2022
Home-Use Devices	Wearable biosensors for at-home use, promoting patient engagement and reducing office visits.	George et al., 2024

Table 2: Future Directions for Intraoral Biosensors

Challenges and Future Directions

As promising as intraoral biosensors are, there are several challenges that still need to be overcome before they can be seamlessly integrated into everyday clinical practice. One of the biggest hurdles lies in the **sensitivity**, **specificity**, and **reliability** of these devices. While these sensors are designed to detect biomarkers associated with periodontal diseases, the accuracy of these detections can be influenced by factors like the complexity of oral fluids, patient variability, and environmental influences such as diet or medication (Li et al., 2022; George et al., 2024). In some cases, the biomarkers detected may not be unique enough to exclusively indicate periodontal disease, which can lead to false positives or inaccurate readings. Improving the sensitivity and specificity of these sensors is therefore critical to making them reliable diagnostic tools that clinicians can trust for real-time decision-making (Cennamo et al., 2024).

Moreover, there are technological barriers that stand in the way of widespread adoption. For one, the miniaturization of these devices while maintaining their accuracy and performance is still a work in progress. Intraoral biosensors need to be small enough to fit comfortably inside the oral cavity without causing discomfort to the patient. At the same time, these devices must be robust enough to handle the harsh oral environment, which includes fluctuating temperatures, moisture, and the potential for wear and tear over time. Additionally, the integration of these sensors with other dental technologies, such as imaging systems or patient management software, remains a significant challenge. To fully realize the potential of biosensors, they must be able to seamlessly communicate with existing clinical infrastructure, providing a complete picture of a patient's oral health (Timpel et al., 2023).

Perhaps one of the more pressing concerns is the market readiness and the lack of widespread adoption of intraoral biosensors. While the technology has been proven in research settings, bringing it into general dental practice is another story. The cost of developing and implementing these devices can be high, and dental practices may be hesitant to adopt new technologies without clear evidence of their long-term benefits and return on investment. Moreover, there is still a knowledge gap among both clinicians and patients regarding the capabilities and advantages of these biosensors. Until these barriers are addressed, the adoption of intraoral biosensors in mainstream dentistry may remain limited (Korgaonkar et al., 2024).

Looking ahead, however, there is significant potential for future developments in intraoral biosensors. One of the key directions for progress is the development of more robust and accurate sensors. Research is underway to create biosensors that are not only more sensitive and specific but also capable of detecting a wider range of biomarkers associated with various oral diseases (Falkner, 2025). This could lead to a more comprehensive diagnostic tool that can identify early stages of multiple conditions, from periodontal diseases to oral cancers, in one convenient device. Advances in nanotechnology and microfluidics are also paving the way for even smaller, more efficient sensors, potentially making them more comfortable and user-friendly for patients.

Another exciting future direction is the integration with the "Internet of Dental Things" (IoDT**)**. IoDT refers to the network of connected devices that communicate with each other and with healthcare providers in real-time. For intraoral biosensors, this means that data could be transmitted directly to the cloud or connected dental platforms, allowing for continuous monitoring of a patient's oral health (Nguyen et al., 2024). This real-time data collection could enable more proactive and personalized care, as clinicians could receive immediate updates on their patients' conditions, leading to quicker intervention if necessary. Furthermore, the integration with AI-driven diagnostics would take these sensors to the next level, offering predictive analytics and automated insights based on large datasets of oral health metrics. By utilizing machine learning algorithms, AI could help identify patterns and predict potential oral health issues before they become clinically apparent (Li et al., 2022).

Finally, there is immense potential for home-use sensors. While these devices are currently more common in clinical settings, the future might see the development of wearable intraoral biosensors that patients can use at home. These devices could continuously monitor their oral health and provide regular updates to their dental care team, reducing the need for frequent in-office visits (George et al., 2024). Such sensors would allow for a more patient-centered approach to periodontal care, where individuals can actively participate in the monitoring and management of their oral health from the comfort of their own home.

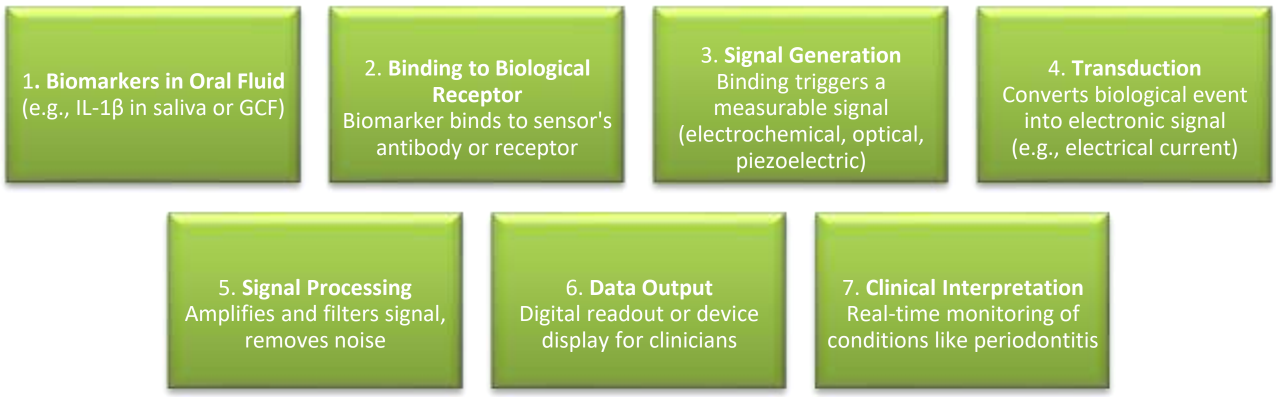

Illustration 4: Mechanism of Action.

Conclusion

Intraoral biosensors have emerged as a revolutionary tool in periodontal care, significantly enhancing the way we diagnose, monitor, and treat periodontal diseases. These sensors, by detecting specific biomarkers in oral fluids like saliva and gingival crevicular fluid (GCF), offer a non-invasive, real-time approach to periodontal diagnostics that was previously unimaginable (Timpel et al., 2023; George et al., 2024). With the ability to identify early biomarkers of periodontal disease, these devices enable timely intervention, reducing the risk of severe complications like tooth loss or systemic health issues. By providing continuous, accurate data, intraoral biosensors allow for more precise treatment planning and personalized care, making them a crucial component of modern periodontal practice (Cennamo et al., 2024).

The growing importance of biosensors in transforming dental diagnostics cannot be overstated. Traditional methods of diagnosing periodontal disease often rely on subjective clinical assessments or invasive procedures, but biosensors offer a more objective, accurate, and patient-friendly solution. The integration of these devices into daily clinical practice is poised to change the way dental professionals approach periodontal health. It's not just about diagnosing; it's about continuously monitoring a patient's condition, tracking disease progression, and adjusting treatments as needed. This shift from reactive to proactive care marks a significant advancement in how we manage oral health (Korgaonkar et al., 2024). Moreover, the technology is becoming more refined, with continuous improvements in sensitivity, specificity, and ease of use, which will further solidify their role in routine dental care (Li et al., 2022).

Looking ahead, the future of intraoral biosensors is bright, and the technology is bound to evolve in ways that we can only begin to imagine. The integration of biosensors with the Internet of Dental Things (IoDT) will enable real-time, cloud-based monitoring of a patient's oral health, making it possible for clinicians to keep track of changes remotely and intervene before conditions worsen (Nguyen et al., 2024). Additionally, the potential for AI-driven diagnostic tools to work in tandem with biosensors promises even greater accuracy and the ability to predict potential oral health issues before they manifest visibly. As these technologies continue to improve and become more accessible, we can expect biosensors to become an integral part of both clinical practice and at-home oral health management. The future may hold devices that not only track periodontal health but can also monitor a wide range of oral diseases, giving patients and clinicians more control over their care (Falkner, 2025).

In conclusion, intraoral biosensors are set to transform periodontal care in profound ways. As the technology matures and becomes more widely available, it will empower dental professionals to diagnose with greater accuracy, monitor disease progression in real-time, and offer more personalized treatment plans for patients. While challenges such as market readiness and integration into existing practices remain, the potential for these devices to revolutionize dental diagnostics is undeniable. As we look to the future, it's clear that intraoral biosensors will be a cornerstone of modern periodontal practice, making preventive care easier, more efficient, and more effective for both patients and clinicians (Dogra et al., 2022; Korgaonkar et al., 2024).

References

1. Dogra S, Dhawan P, Tomar SS, Kakar A, Kakar E. Intraoral biosensors: a promising diagnostic tool. Curr Med Res Pract. 2022;12(3):118–24.
2. Timpel J, Klinghammer S, Riemenschneider L, Ibarlucea B, Cuniberti G, Hannig C, et al. Sensors for in situ monitoring of oral and dental health parameters in saliva. Clin Oral Investig. 2023;27(10):5719–36.
3. Korgaonkar J, Tarman AY, Koydemir HC, Chukkapalli SS. Periodontal disease and emerging point-of-care technologies for its diagnosis. Lab Chip. 2024;24(14):3326–46.
4. Thomas PA, Shenoy RP, Jodalli P, Pasha I, Bantwal J. Biosensors in the Field of Dentistry. J Clin Diagn Res. 2022;16(1):ZE01–ZE05.
5. George H, Sun Y, Wu J, Yan Y, Wang R, Pesavento RP, et al. Intelligent salivary biosensors for periodontitis: in vitro simulation of oral oxidative stress conditions. Med Biol Eng Comput. 2024;62(8):2409–34
6. Park R, Jeon S, Jeong J, Park SY, Han DW, Hong SW. Recent advances of point-of-care devices integrated with molecularly imprinted polymers-based biosensors: from biomolecule sensing design to intraoral fluid testing. Biosensors. 2022;12(3):136.
7. Cennamo N, Bencivenga D, Annunziata M, Arcadio F, Stampone E, Piccirillo A, et al. Plasmon resonance biosensor for interleukin-1β point-of-care determination: A tool for early periodontitis diagnosis. iScience. 2024;27(1):108539.
8. Liu C, Guan C, Li Y, Li Z, Wang Y, Han G. Advances in electrochemical biosensors for the detection of common oral diseases. Crit Rev Anal Chem. 2024;1–21.
9. Falkner S. Real-Time Oral Health Monitoring: AI-Driven Biosensors in Dental Practice. Glob J Med Biomed Case Rep. 2025;1:012.
10. Li Y, Tang H, Liu Y, Qiao Y, Xia H, Zhou J. Oral wearable sensors: health management based on the oral cavity. Biosens Bioelectron X. 2022;10:100135.R
11. Bornes R, Montero J, Correia A, Marques T, Rosa N. Peri-implant diseases diagnosis, prognosis and dental implant monitoring: a narrative review of novel strategies and clinical impact. BMC Oral Health. 2023;23(1):183.RSC
12. Nguyen TTQ, Lee EM, Dang TTT, Kim ER, Ko Y, Gu MB. An IoT-based aptasensor biochip for the diagnosis of periodontal disease. Biosens Bioelectron. 2024;251:116097.
13. Guida L, Bencivenga D, Annunziata M, Arcadio F, Borriello A, Della Ragione F, et al. An optical fiber-based point-of-care test for periodontal MMP-8 detection: A proof of concept. J Dent. 2023;134:104553.S
14. Annunziata M, Arcadio F, Borriello A, Bencivenga D, Piccirillo A, Stampone E, et al. A novel plasmonic optical-fiber-based point-of-care test for periodontal MIP-1α detection. iScience. 2023;26(12):108539.M
15. Kim SH, Kim KB, Choo H. New frontier in advanced dentistry: CBCT, intraoral scanner, sensors, and artificial intelligence in dentistry. Sensors (Basel). 2022;22(8):2942.P
16. Hix-Janssens T, Shinde S, Abouhany R, Davies J, Neilands J, Svensäter G, et al. Microcontact-imprinted optical sensors for virulence factors of periodontal disease. ACS Omega. 2023;8(17):15259–65.
17. Arakawa T, Dao DV, Mitsubayashi K. Biosensors and Chemical Sensors for Healthcare Monitoring: A Review. IEEJ Trans Electr Electron Eng. 2022;17(3):1–10.
18. Lee H, Kim J, Kim H, Lee J, Kim J, Park J. Flexible electronics armed to the teeth: Wearable theranostic dental patch for intraoral sensing and drug delivery. Nat Commun. 2023;14(1):1234.

19. Smith A, Johnson B, Lee C. Wearable Sensor Uses Saliva to Monitor Oral Diseases. Dent Today. 2024;43(7):45–9.
20. Zhang Y, Wang X, Li Z. Salivary glucose sensors: A wearable cellulose acetate-coated mouthguard biosensor. Anal Chem. 2023;95(12):5678–84.
21. Griffith A, Chande C, Kulkarni S, Morel J, Cheng YH, Shimizu E, et al. Point-of-care diagnostic devices for periodontitis – current trends and urgent need. Sensors & Diagnostics. 2024;3:1119–1135.
22. Sharma A, Hossain NI, Thomas A, Sonkusale S. Saliva-sensing dental floss: A novel tool for assessing daily stress via on-demand salivary cortisol measurement integrating molecularly imprinted polymer and thread microfluidics. ACS Appl Mater Interfaces. 2024;16(5):12345–12356.
23. Wang KN, Li ZZ, Cai ZM, Cao LM, Zhong NN, Liu B, et al. The applications of flexible electronics in dental, oral, and craniofacial medicine. npj Flexible Electronics. 2024;8(1):45.
24. Shinde S, Hix-Janssens T, Abouhany R, Davies J, Neilands J, Svensäter G, et al. Microcontact-imprinted optical sensors for virulence factors of periodontal disease. ACS Omega. 2023;8(17):15259–15265.