REVIEW OF EXISTING SALIVA SENSORS AND THEIR APPLICATIONS

[1]Yakhshiboev R.E., [2]Yakhshiboyeva D.E., [3]Siddiqov B.N.
[1,3] Tashkent University of Information Technology named after Muhammad al-Khwarizmi
[2]Tashkent Medical Academy
https://doi.org/10.5281/zenodo.7820990

Abstract. *This article discusses existing human saliva sensors and their applications. Human saliva is a unique biological material that can contain a lot of useful information about human health. Various biomarkers in saliva can be used to diagnose various diseases, including oral diseases, immune disorders, infectious diseases, diabetes, cancer, and others. Currently, there are many human saliva sensors on the market designed to collect, analyze and interpret biomarkers contained in human saliva. The latest achievements in the development and application of these sensors in medicine, biomedical research and sports are also described.*
Keywords: *human saliva, saliva sensor, biomarker, medicine, biomedicine, biotechnology.*

I. INTRODUCTION

Saliva sensors are devices that are used to analyze the composition of saliva and determine the concentration of various biomarkers. These devices are often used in medical research and diagnostics to assess the health of patients.

Some of the biomarkers that can be found in saliva include hormones, enzymes, antibodies, microbes, and other molecules that can indicate a person's health status.

Saliva sensors can be used to detect and diagnose conditions such as gum disease, oral infections, Alzheimer's disease, diabetes, and even some types of cancer.

In addition, saliva sensors can be used in health and fitness monitoring, such as assessing body hydration levels, stress levels, and even assessing exercise endurance potential.

One of the advantages of saliva sensors is their non-invasive nature, since their use does not require blood sampling or other painful procedures. In addition, saliva is easily accessible for the sample, which facilitates the process of diagnosis and health monitoring.

Saliva sensors can also be used to monitor treatment progress and drug efficacy. For example, they can help determine if the dose of a drug is effective enough or if it needs to be adjusted. They can also be used to assess the side effects of medications.

Saliva sensors are already being used in some clinical trials, and they may become an important tool for diagnosing and monitoring diseases in the future. In addition, the development of saliva sensor technology may lead to the creation of portable devices that are easily accessible to a wide audience and can be used at home [1-4].

However, it should be noted that the use of saliva sensors is still under development, and their wider application requires further research and testing. In addition, there is a need to develop standards for the processing and analysis of data obtained from saliva sensors in order to ensure the accuracy and reliability of the results.

It is also worth noting that some biomarkers in saliva can change depending on the time of day, the health of the patient, and other factors, which can affect the accuracy of the results. Therefore, these factors must be taken into account when interpreting data obtained with saliva sensors.

Some examples of saliva sensors already in development include devices that can measure glucose, the hormone cortisol, amyloid, and other biomarkers. In addition, some devices can measure the pH of saliva, which can be useful for monitoring oral health and preventing cavities and other diseases.

Overall, saliva sensors represent a promising technology that could become an important tool for diagnosing and monitoring diseases in the future. However, for their wide application, it is necessary to continue research and testing to ensure the accuracy, reliability and safety of use [4-8].

II. ANALYSIS OF DIFFERENT TYPES OF SENSORS IN HUMAN SALIVA

There are several types of saliva sensors that can be used to monitor human health. Some of them include:

1. Electrochemical sensors - they measure the concentration of various substances in saliva using electrochemical reactions. Such sensors can be used to measure glucose, lactate, acetone, and other metabolites.

2. Optical sensors - These are used to measure certain biomarkers in saliva using optical methods. Some of these biomarkers include cortisol, amyloid, cytokines, and other proteins.

3. Micro Electromechanical Sensors (MEMS) - These are used to measure physical parameters such as pH, temperature and pressure. Such sensors can be used to monitor the state of the oral cavity and prevent the development of caries.

4. Nanosensors - These are used to measure very small amounts of substances in saliva, such as certain proteins and DNA molecules. Such sensors are highly sensitive and can be used to diagnose certain diseases, including cancer and infectious diseases.

Each of these types of sensors has its own advantages and limitations, and the choice of a particular type depends on the purpose of the monitoring and the biomarkers to be measured. However, all of them can become an important tool for diagnosing and monitoring diseases in the future [9–12].

Several types of human saliva sensors are considered, such as electrochemical, optical, microelectromechanical (MEMS) and nanosensors. The main advantages and disadvantages of saliva sensors are listed below.

1. Saliva electrochemical sensors:

Advantages:

- High sensitivity and specificity;
- Low production cost;
- Ease of use.

Flaws:

- Requires calibration before each use;
- May be influenced by the environment and other factors that may affect the accuracy of the results.

2. Optical saliva sensors:

Advantages:

- High sensitivity and specificity;
- Do not require calibration before each use;
- Does not require contact with saliva.

Flaws:

- Higher manufacturing cost compared to electrochemical sensors;
- May be more sensitive to the environment.

3. Microelectromechanical (MEMS) saliva sensors:

Advantages:

- Can be very compact and portable;
- Provide fast and accurate measurement;
- Can be easily integrated into other medical devices.

Flaws:

- Higher production cost compared to other types of sensors;
- They require high precision manufacturing and processing.

4. Saliva nanosensors:

Advantages:

- Very high sensitivity and specificity;
- Can detect very low concentrations of substances;
- Does not require contact with saliva.

Flaws:

- More complex production and functionalization of nanomaterials;
- The influence of environmental factors may affect the accuracy of the results.

In general, all types of saliva sensors have their own advantages and disadvantages, and the choice of a particular type will depend on specific tasks and requirements. However, in general, saliva sensors can provide valuable information for diagnosing various diseases and monitoring a person's health. They can also be used in medical devices and portable health monitoring devices.

One of the possible applications of saliva sensors is the diagnosis of various diseases such as diabetes, cancer, Alzheimer's disease and others. Some sensors can measure glucose levels in saliva, which can help diagnose diabetes. Certain markers of proteins in saliva can also indicate the presence of cancer or other diseases. Saliva sensors can also be used to track health status and monitor the effectiveness of treatments.

In addition, saliva sensors can be used to detect drugs and other substances that may be hazardous to health. This can be useful, for example, when conducting drug tests at work or in sports.

Despite all the advantages of saliva sensors, they are not a universal solution for all medical problems. Some diseases or conditions may be better diagnosed with other methods, such as a blood or tissue test. However, saliva sensors may be a useful addition to existing diagnostic and health monitoring methods.

In general, saliva sensors represent an important tool in medical diagnostics and health monitoring. Due to their high sensitivity and specificity, they can detect even very low concentrations of substances and help in the diagnosis of various diseases. However, the choice of a specific type of saliva sensor will depend on the specific requirements and tasks to be solved.

III. APPLICATION OF SALIVIA SENSORS IN CLINICAL PRACTICE AND RESEARCH

Electrochemical sensors. Electrochemical saliva sensors are one of the most common types of sensors used to monitor human health. They work by measuring the electrochemical reactions that occur between substances in saliva and electrodes in the sensor.

One of the most commonly measured parameters with electrochemical sensors is the level of glucose in saliva. Measurement of salivary glucose can be useful for diagnosing diabetes and for monitoring glucose levels in diabetic patients, especially those who have problems with blood glucose control.

Electrochemical sensors can also be used to measure other salivary metabolites such as lactate, acetone, and others. For example, measuring lactate levels can help monitor physical activity levels in athletes, and measuring acetone levels can be helpful in diagnosing diabetic ketoacidosis.

One of the advantages of electrochemical sensors is their high sensitivity and specificity, which makes it possible to measure the concentration of substances in saliva at very low concentrations. In addition, electrochemical sensors are easily integrated with portable devices and can be used at home.

However, electrochemical sensors also have some limitations. For example, they may be affected by external factors such as temperature and humidity, which can affect the accuracy of the results. In addition, not all biomarkers can be measured with electrochemical sensors, and some substances may be present in saliva at concentrations that are too low to measure.

Saliva electrochemical sensors are used to measure the electrical activity of substances contained in saliva such as ions, metabolites, proteins and other molecules. They are based on the principle that when interacting with ions and molecules of a substance, the electrodes inside the sensor generate an electrical signal that can be measured and analyzed.

One of the most common types of saliva electrochemical sensors are ion-selective electrodes, which react specifically to a certain type of ions, such as sodium, potassium, chlorine, and others. These sensors can be used to measure the level of electrolytes in saliva, which can help in the diagnosis and monitoring of diseases associated with electrolyte imbalance in the body.

In addition, electrochemical sensors can be used to measure salivary glucose levels, which can be useful for diagnosing diabetes and monitoring glucose levels in patients, as well as for optimizing training programs in sports.

However, as with other types of saliva sensors, electrochemical sensors also have limitations related to the variability of saliva composition between people and at different times of the day, as well as problems with the duration of storage of saliva samples and measurement accuracy.

However, saliva electrochemical sensors are a promising tool for many fields, such as medical diagnostics and sports science, and continue to attract the interest of researchers.

Optical sensors. Optical saliva sensors use optical techniques to measure the concentration of molecules in saliva such as proteins, hormones, metabolites, and others. They are based on the principle that certain molecules of a substance can interact with an optical field, changing the properties of the light passing through them. These changes can be measured and analyzed, which makes it possible to determine the concentration of substance molecules in saliva.

One of the most common types of saliva optical sensors are fluorescent sensors, which use a light emitter to excite the fluorescence of certain molecules in saliva. These sensors can be used to measure levels of metabolites such as glucose and lactate, as well as hormones such as cortisol and adrenaline.

In addition, optical sensors can also be used to measure the level of nitric oxide in saliva, which can help in the diagnosis and monitoring of cardiovascular diseases and other diseases associated with dysfunction of the vascular endothelium.

However, as with other types of saliva sensors, optical sensors also have limitations due to the variability of saliva composition from person to person and time of day, as well as problems with saliva sample retention and measurement accuracy.

However, saliva optical sensors are a promising tool for many fields such as medical diagnostics, research and sports science and continue to attract the interest of researchers.

Another type of saliva optical sensors are plasmonic nanoparticle based sensors that use plasmon resonance to measure the concentration of molecules in saliva. These sensors are highly sensitive and can detect very low concentrations of molecules, making them useful for many applications, including disease diagnosis and patient monitoring.

One example of the application of saliva optical sensors is the diagnosis of Alzheimer's disease. Some studies have shown that the level of amyloid beta peptide in saliva can serve as an indicator of the risk of developing Alzheimer's disease. Optical sensors such as plasmonic nanoparticles can be used to measure the concentration of this peptide in saliva, which can help in the diagnosis and monitoring of this disease.

Another example of the application of saliva optical sensors is the monitoring of salivary glucose levels in diabetic patients. These sensors can be used for real-time glucose monitoring without the need for blood glucose measurements. However, like other types of saliva sensors, optical sensors also have limitations related to measurement accuracy, as well as the reliability and durability of the sensor itself.

Thus, saliva optical sensors represent a promising technology that can be used for disease diagnosis and monitoring, as well as for scientific research and sports science. However, for their further development and application in practice, it is necessary to solve a number of technical and methodological problems.

Microelectromechanical sensors. Microelectromechanical sensors (MEMS) are miniature devices that use mechanical, electrical and/or optical principles to measure various parameters such as pressure, temperature, vibration, force, etc. MEMS sensors are used in a variety of applications, including the automotive and aviation industries, medical diagnostics, industrial automation, and more.

Saliva MEMS sensors are used to measure various parameters of saliva such as pH, glucose, proteins and other biochemical markers. Saliva MEMS sensors use microelectromechanical sensors that measure changes in the physical properties of saliva, such as its viscosity and ion concentration.

One example of the application of saliva MEMS sensors is the diagnosis of periodontitis. MEMS sensors capable of measuring the concentration of biomarkers associated with inflammatory processes in gum tissue can be used to diagnose and monitor periodontitis. These sensors can provide fast results, making them useful as a non-invasive diagnostic procedure.

Another example of the application of saliva MEMS sensors is the monitoring of salivary glucose levels in diabetic patients. MEMS sensors can be used to continuously monitor salivary glucose levels, which can help diabetic patients monitor their condition in real time and take appropriate action to maintain normal glucose levels.

However, like other types of saliva sensors, MEMS sensors also have limitations related to measurement accuracy, as well as the reliability and durability of the sensor itself. Also, MEMS sensors can be sensitive to external factors such as temperature, humidity, and pressure, which can affect measurement accuracy.

However, the development of MEMS technologies continues, and the accuracy, reliability and durability of MEMS sensors are improving every year. This opens up new prospects for the use of MEMS sensors in medicine and other industries.

For example, recent studies have shown that saliva MEMS sensors can be used to diagnose certain neurological diseases such as Parkinson's disease and Alzheimer's disease. This is because saliva composition can be altered in these diseases, which can be detected using MEMS sensors.

Thus, saliva MEMS sensors have great potential for application in various fields of medicine and science, and their development and improvement can lead to new methods for diagnosing and treating various diseases.

Nanosensors. Nanosensors are sensors that use nanomaterials to detect and measure various chemical and biological compounds. They have high sensitivity and specificity, which makes them effective tools for diagnosing and monitoring various diseases.

Saliva nanosensors can be used to detect proteins and other biological markers that may indicate the presence of certain diseases. For example, studies have shown that nanosensors based on quantum dots can detect proteins associated with breast cancer with high sensitivity and specificity.

In addition, saliva nanosensors can be used to detect markers of stress and fatigue, which can be useful in various fields such as sports, medicine, and psychology. For example, research has shown that nanosensors based on carbon nanotubes can measure levels of cortisol, the stress hormone, in saliva.

Nanosensors also have potential for use in the pharmaceutical industry, such as detecting drug residues in saliva or monitoring drug levels in the blood.

Despite the fact that nanosensors have high sensitivity and specificity, their development and production remain technologically complex and expensive. In addition, more research is needed to evaluate their safety and efficacy in clinical practice.

Various types of nanomaterials are used to create saliva nanosensors, such as quantum dots, nanowires, nanotubes, nanoparticles, etc. They can be functionalized with various molecules, such as antibodies, aptamers, or peptides, in order to detect specific biological markers.

There are several methods to create saliva nanosensors, including electron lithography, chemical deposition, vacuum deposition, self-assembly, etc. In addition, new methods such as nanoimprinting and nanostructuring have been developed in recent years, which can improve the manufacturing process and efficiency of nanosensors.

One of the main advantages of saliva nanosensors is their ability to measure non-contact, which can be especially important in human studies. In addition, saliva is an accessible biological material that can be easily collected without painful procedures, making it more attractive for use in medical research.

However, as with other types of sensors, various factors such as stability, reliability, sensitivity, specificity, and safety must be considered when using saliva nanosensors. You also need to take into account the possibility of environmental factors affecting the operation of sensors, such as humidity, temperature, etc.

Thus, saliva nanosensors represent a promising area of research in medicine and science, and may have significant potential for diagnosing, monitoring, and treating various diseases. However, for their use in clinical practice, more research is needed to establish their safety and efficacy.

Saliva sensors have many potential applications in various fields, including medicine, sports, food processing, materials science, and others. The following are some of the possible applications for saliva sensors.

1. Health monitoring

Saliva sensors can be used to monitor various diseases such as diabetes, cancer, Alzheimer's and others. They can also be used to monitor stress levels, as well as diagnose gum and dental disease.

2. Sports applications

Saliva sensors can be used to monitor the level of physical activity in athletes and to assess their level of hydration. They can also be used to monitor salivary lactate levels, which can help optimize training programs.

3. Food industry

Saliva sensors can be used to measure taste, as well as to determine the content of certain substances, such as salts and sugars, in foods.

4. Materials science

Saliva sensors can be used to study material properties such as adhesion and corrosion by analyzing saliva in contact with the material.

5. Safety

Saliva sensors can be used to check for drugs and alcohol in drivers, which could help improve road safety.

CONCLUSIONS

Saliva sensors represent a promising direction in the development of diagnostic and monitoring technologies in medicine, sports, the food industry, and other fields. These sensors can measure various parameters of saliva, such as glucose, lactate, acetone and other molecules, which can help diagnose and monitor diseases, as well as optimize training programs in sports.

However, there are several limitations to the use of saliva sensors, such as the effect of food and drink on saliva composition, and differences in saliva composition between individuals and at different times of the day. In addition, there are problems with the duration of storage of saliva samples and with the accuracy of measurements.

Despite these limitations, saliva sensors continue to attract the interest of researchers in various fields, and their potential applications show that they can become a valuable tool for diagnosing, monitoring and optimizing processes in various industries.

REFERENCES

1. Chiadò A., Domenici C., Becherini F., Barillaro G. Saliva-based biosensors: Noninvasive monitoring tool for clinical diagnostics // Sensors and Actuators B: Chemical. 2018. Vol. 260. P. 328-349.
2. M.P. Ferrara, A. Chiadò, G. Barillaro. A paper-based salivary cortisol test for the non-invasive assessment of adrenal function // Sensors and Actuators B: Chemical. 2021. Vol. 329.

3. Punyadeera C., Dimeski G. et al. Innovative diagnostics: saliva as a diagnostic fluid // Handbook of Innovative Nanomaterials. 2014. P. 477-500.
4. Kaczor-Urbanowicz K.E., Martin Carreras-Presas C., Aro K., Tu M., Garcia-Godoy F., Wong D.T.W. Saliva diagnostics - Current views and directions // Experimental Biology and Medicine. 2017. Vol. 242. P. 459-472.
5. Li Y., Lee J., Ren J., Zhang R., Wang S., Li W. et al. Saliva as a promising diagnostic tool for COVID-19: current status and future direction // Clinical Chemistry. 2021. Vol. 67. P. 154-162.
6. Kudratillaev M. B., Yakhshiboev R. E. ANALYSIS OF INNOVATIVE EQUIPMENT FOR THE DIAGNOSIS OF GASTROENTEROLOGICAL DISEASES //Open Access Repository. – 2023. – Т. 4. – №. 03. – С. 13-23.
7. Yakhshiboyev R. E., Kudratillayev M. B., Siddikov B. N. FORSCHUNG VON INNOVATIVER AUSRÜSTUNG FÜR DIE DIAGNOSE VON MAGEN-DARM-ERKRANKUNGEN //International Bulletin of Applied Science and Technology. – 2023. – Т. 3. – №. 3. – С. 100-105.
8. Яхшибоев Р. Э. РАЗРАБОТКА АППАРАТНО-ПРОГРАММНОГО КОМПЛЕКСА “SALIVA” ДЛЯ ПЕРВИЧНОЙ ДИАГНОСТИКИ ЖЕЛУДОЧНО-КИШЕЧНЫХ ЗАБОЛЕВАНИЙ //International Bulletin of Applied Science and Technology. – 2023. – Т. 3. – №. 2. – С. 25-33.
9. Yakhshiboyev R. E. HARDWARE-SOFTWARE COMPLEXES FOR THE PRIMARY DIAGNOSIS OF GASTROENTEROLOGICAL DISEASES //Eurasian Journal of Mathematical Theory and Computer Sciences. – 2023. – Т. 3. – №. 1. – С. 120-127.
10. Yakhshiboyev R. E. Development of Software and Hardware Complex for Primary Diagnosis of Gastroenterological Diseases on the Basis of Deep Machine Learning //Nexus: Journal of Advances Studies of Engineering Science. – 2023. – Т. 2. – №. 1. – С. 9-20.
11. Яхшибоев Р. Э. РАЗРАБОТКА ПРОГРАММНО-АППАРАТНОГО КОМПЛЕКСА НА ОСНОВЕ НЕЙРОННОЙ СЕТИ ДЛЯ ПЕРВИЧНОЙ ДИАГНОСТИКИ ГАСТРОЭНТЕРОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ //Journal of new century innovations. – 2023. – Т. 20. – №. 1. – С. 108-119.
12. Яхшибоева Д. Э., Эрметов Э. Я., Яхшибоев Р. Э. РАЗВИТИЕ ЦИФРОВЫХ ТЕХНОЛОГИИ В МЕДИЦИНЕ //Journal of new century innovations. – 2023. – Т. 20. – №. 1. – С. 100-107.
13. Яхшибоев Р., Сиддиков Б. ЦИФРОВЫЕ ТЕХНОЛОГИИ ДЛЯ ПЕРВИЧНОЙ ДИАГНОСТИКИ РАЗНЫХ МЕДИЦИНСКИХ ЗАБОЛЕВАНИЙ //Innovations in Technology and Science Education. – 2022. – Т. 1. – №. 4. – С. 94-105.
14. Yakhshiboyev R. DEVELOPMENT OF A “SALIVA” HARDWARE-SOFTWARE COMPLEX MODULES FOR THE PRIMARY DIAGNOSIS OF GASTROINTESTINAL DISEASES //Science and innovation. – 2023. – Т. 2. – №. A2. – С. 27-34.
15. Yakhshiboyev R. E. DEVELOPMENT OF A HARDWARE MODULES FOR THE PRIMARY DIAGNOSIS OF GASTROINTESTINAL DISEASES //Proceedings of International Conference on Scientific Research in Natural and Social Sciences. – 2023. – Т. 2. – №. 1. – С. 84-90.