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# Development of Mirror Biosensor in Saliva pH Measurement in Health Services

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**Abstract: The Indonesian population suffers from oral and dental problems, with caries being the main problem. One of the contributing factors is salivary pH imbalance. Salivary pH measurement can help in the prevention and treatment of teeth, with conventional methods such as litmus paper and pH strips, as well as the latest technology such as pH meters, but the drawback of pH meters is that the measurement is still outside the oral cavity. To improve measurement efficiency, a mirror biosensor was developed that combines a pH sensor with a mouth glass, allowing measurement directly in the oral cavity without requiring a large volume of saliva. This study uses the Research and Development (R&D) method which involves the stages of information gathering, product design, expert validation, and product trials. The research respondents were patients who visited Nadira Dental Clinic as many as 50 respondents. The data were analyzed using the Wilcoxon statistical test to assess the effectiveness of the developed tool. The results showed that there was no significant difference between the results of salivary pH measurements using a pH meter and mirror biosensor with an average salivary pH measurement result in the control group of 6.49, while in the intervention group it was 6.52 with a p-value of 0.058 (p > 0,05). The development of a mirror biosensor tool is effective and feasible to use in measuring salivary pH. This innovation has the potential to be a solution for dental health services in improving time efficiency in measuring salivary pH.**

***Keywords:*** *Mirror Biosensor; pH Meter; Saliva pH Measurement.*

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## I. INTRODUCTION

Oral health refers to a condition in the mouth that does not have pain, congenital abnormalities, tooth decay, or periodontal disease. Serious health problems in the mouth can result in a decrease in a person's quality of life[1]. The results of the Indonesian Health Survey (SKI) in 2023 showed that the biggest dental health problem that occurred in Indonesia was tooth decay or cavities at 43.6%[2]. The target in 2030 is a caries-free Indonesia, so strategic measures need to be taken to overcome dental health problems, but before that it is necessary to know the causes of the problem[3].

The mechanism of caries begins with a complex interaction between carbohydrates and Streptococcus mutans bacteria which results in a decrease in the pH of the saliva in the oral cavity, thus facilitating the demineralization of enamel in the early stages of dental caries. Saliva is a biological fluid that contains a variety of biomarkers that make saliva a diagnostic medium, one of which is to determine the pH in the oral cavity[4].

The purpose of measuring salivary pH is to evaluate and monitor oral health conditions and prevent serious dental problems. By knowing the pH of saliva, a dentist or dental therapist can identify pH imbalances in the mouth that can lead to various problems, such as dental caries, enamel erosion, and periodontal disease. Salivary pH measurement also helps in determining an individual's risk for tooth decay and provides important information that can be used to design more effective treatment strategies, such as dietary adjustments, use of special oral products, or remineralization treatments[5].

Generally, simple indicators used to measure salivary pH are litmus paper[6] and Along with the development of technology and science to date, pH measurement has been carried out using more sophisticated indicators, namely the use of an arduino uno based pH meter to measure the pH of a liquid, one of which is salivary pH. However, the arduino uno pH meter also has disadvantages, namely that the measurement must be outside the oral cavity which requires time from taking saliva in the oral cavity to the pH checker so that it allows changes in saliva pH during the measurement process[5]. To overcome this problem, a mirror biosensor tool was developed where sample measurements on this mirror biosensor are carried out directly in the oral cavity. So that the use of this mirror biosensor does not require a lot of saliva volume because this tool only needs to

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be attached to the part of the oral cavity where there is salivary fluid and simultaneously the pH value will appear on the monitor.

## II. RESEARCH METHODS AND SAMPLE

This research uses the Research and Development (R&D) development method. The purpose of this research is to produce Mirror Biosensor development products that are feasible to use and analyze their effectiveness as a tool in measuring salivary pH. The research and development procedure has 5 (five) main steps, namely: 1) information gathering, 2) product design, 3) expert validation and revision, 4) product trial and 5) product results.

The information gathering stage is carried out to be able to identify problems in health services. The implementation of information collection was carried out by means of observation and interviews as well as through literature review. The expert validation test is carried out to test the feasibility of the product to experts before the product is used. The feasibility test data collection was carried out by giving a questionnaire to the expert, then the revision stage was carried out on the mirror biosensor tool. Meanwhile, the product trial stage is carried out on patients visiting health care facilities. This stage was carried out to test the effectiveness of the mirror biosensor in measuring salivary pH. The product trial was conducted using the true experiment research method and posttest only design with control group design.

The sampling technique at the information collection stage using purposive sampling technique obtained respondents consisting of the person in charge of the clinic, dentist, and dental and oral therapist. Samples were selected based on the inclusion criteria, namely patients visiting the Nadira MT.Haryono Dental Clinic. The sample at the expert validation test stage used purposive sampling technique. Respondents of the expert validation test sample were electormedical experts, dentists, and dental and oral therapists. The sample selection at the product trial stage used random sampling techniques on patients visiting the Nadira MT.Haryono Dental Clinic who met the inclusion criteria. The number of samples in this study were 50 samples.

The informed consent given contains a statement of willingness to participate or not participate in the study which is affixed to the signature of the prospective respondent. Respondents who are willing will be measured salivary pH with the following stages:

- Respondents enter the examination room, then collect saliva in the cup that has been provided until a certain volume.
- After the volume of saliva collected is sufficient, then the pH of the saliva is measured using a pH meter.
- Record the results of measuring salivary pH.
- After the measurement using the pH meter has been completed, the next step is to measure the pH of saliva using a mirror biosensor.
- Prepare the mirror biosensor tool then the respondent is invited to lean on the dental unit.
- Invite the patient to open his mouth then insert the mirror biosensor tool and attach the tool under the tongue for 10 seconds.
- After 10 seconds, the results will come out on the monitor

The data analysis used includes descriptive statistical analysis by describing the results of data collection obtained, interclass correlation correlation (ICC) and Aiken V tests. Data analysis on information collection uses descriptive analysis because the data obtained is quantitative data from the results of interviews and observations. Data from expert validation tests used the ICC and Aiken V tests to assess the validity and reliability between experts and assess the extent to which test scores are consistent if given to different experts. While the results of data collection at the product test stage use descriptive statistical analysis by describing the percentage results of data acquisition. Before the analysis test is carried out, the data that has been obtained is checked for completeness, then coding is given to the data to facilitate data processing. Furthermore, the data tabulation stage was carried out into a predetermined table and carried out the analysis test. The data normality test uses Kolmogorov Smirnov because the sample is more than 30. The data is not normally distributed, so the data analysis used is a non-parametric test using the Wilcoxon test.

## III. RESULTS

### *A. Result of Information Gathering*

Information collection was obtained from interviews with the person in charge of the clinic, dentists, and dental and oral therapists of Nadira Dental Clinic MT. Haryono. Information collection using an open questionnaire instrument of 6 items. Based on the results of interviews with 3 informants, it can be concluded that Nadira Dental Clinic MT. Haryono until now has not measured salivary pH because there is no suitable tool for fast service. The main obstacle faced is that the existing tools are not practical and require a long time in sampling, so that it can hamper service to patients. In fact, measuring salivary pH is considered important, especially for patients who are prone to dental caries and calculus. Therefore, innovation of tools that are more practical, fast, accurate, and comfortable to use is needed to improve the quality of service in this clinic. There is full support for the development of new tools that can help the process of measuring salivary pH more efficiently. One innovation that has received a positive response is the mirror biosensor, which is considered to provide benefits in the world of health, especially in the field of dental health. This tool is expected to be able to provide fast results without disturbing patient comfort and smooth service. With this innovation, it is hoped that salivary pH examination can

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become part of the standard procedure in dental health services.

*B. Product Design of Mirror Biosensor Tool Development in Saliva pH Measurement*

➢ *Compilation of Mirror Biosensor Tool Development*

The results of the data obtained from information collection are used as a tool design. Based on information obtained by researchers through interviews and several previous studies, it is found that the use of existing saliva pH meters has several problems in the field. A common problem that often occurs in measuring salivary pH is that the pH meter is large and less flexible for use in a health care environment that requires speed and efficiency in examining patients, so a smaller salivary pH meter is needed so that its use can be directly in the oral cavity, flexible, and fast measurement results.

➢ *Output Mirror Biosensor*

Mirror Biosensor is an innovative pH meter sensor that is packaged together with a mouth glass. This Mirror Biosensor develops a capacitive pH sensor using Printed Circuit Board (PCB) Fiber. Sample measurements on this mirror biosensor are carried out directly in the oral cavity, this sensor is combined with mouth glass so that the use of this mirror biosensor does not require a large volume of saliva because this tool only needs to be attached to the bottom of the tongue in the oral cavity.

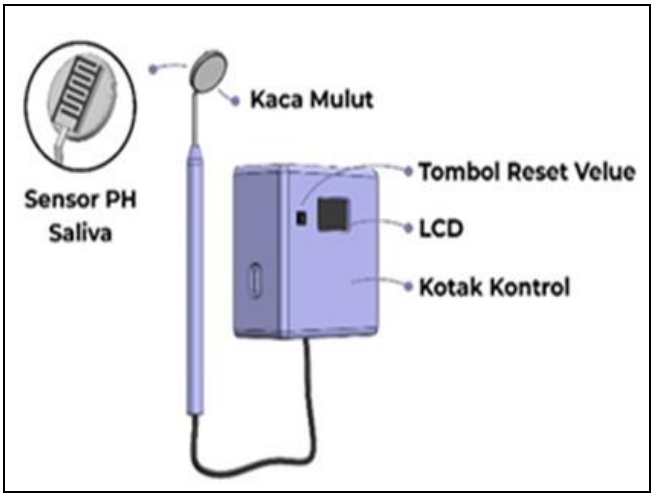


Fig 1 Overview of Mirror Biosensor Tool Development

➢ *Expert Validation*

Expert validation was carried out by 3 experts, namely electromedical experts, dentists, and Dental and Oral Therapists. This validation was carried out with a questionnaire containing 20 questions from each expert validator. The data was analyzed using the Intraclass Correlation Coefficient (ICC) and AIKEN V tests to determine the eligibility criteria for the tool. The results of the expert feasibility test can be seen in the following table:

- *Validity Test*

Table 1 Expert Validation

| No. | Test Results | Interpretation | Follow-up |
|---|---|---|---|
| 1 | 0,83 | Valid | Accepted/used |
| 2 | 0,92 | Valid | Accepted/used |
| 3 | 0,92 | Valid | Accepted/used |
| 4 | 0,75 | Valid | Accepted/used |
| 5 | 0,83 | Valid | Accepted/used |
| 6 | 1 | Valid | Accepted/used |
| 7 | 0,83 | Valid | Accepted/used |
| 8 | 1 | Valid | Accepted/used |
| 9 | 0,83 | Valid | Accepted/used |
| 10 | 0,83 | Valid | Accepted/used |
| 11 | 0,67 | Valid | Accepted/used |
| 12 | 0,67 | Valid | Accepted/used |
| 13 | 0,75 | Valid | Accepted/used |
| 14 | 1 | Valid | Accepted/used |
| 15 | 0,92 | Valid | Accepted/used |
| 16 | 0,83 | Valid | Accepted/used |
| 17 | 0,92 | Valid | Accepted/used |
| 18 | 0,75 | Valid | Accepted/used |
| 19 | 0,92 | Valid | Accepted/used |
| 20 | 0,92 | Valid | Accepted/used |
| **Average Total Rating 0,8545** | | | |

Table 1 Based on the assessment results from 3 expert validators, it is known that the results of the expert validation test obtained the average feasibility value of 0.8545 with a high validity category, which means that the mirror biosensor tool can be tested

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- *Reliability Test*

Table 2 Expert Validation

| | Intraclass Correlation | Sig |
|---|---|---|
| Single measures | 0,919 | ,000 |
| Average Measures | 0,926 | ,000 |

Table 2 Based on the results of the expert validation reliability test on one expert has an Intraclass Correlation value of 0.919, because the value> 0.50, the reliability has adequate r, and overall from the 3 experts has an Intraclass Correlation value of 0.926 because the value> 0.50, it can be interpreted that the mirror biosensor tool has high reliability

➢ *Univariate Analysis*

Table 3 Frequency Distribution of Gender and Age of Respondents

| No | Characteristics | N | % |
|---|---|---|---|
| 1. | Gender | | |
| | Male | 19 | 38 |
| | Female | 31 | 62 |
| 2. | Age | | |
| | 5 – 15 years | 1 | 2 |
| | 16 – 25 years | 2 | 4 |
| | 26 – 35 years | 13 | 26 |
| | 36 – 45 years | 17 | 34 |
| | 46 – 55 years | 12 | 24 |
| | 56 – 65 years | 4 | 8 |
| | 66 – 75 years | 1 | 2 |

Table 3 shows that the frequency distribution of respondents based on gender is female with the highest percentage of 62% (31 people). The frequency of respondents based on age, the highest percentage is 36-45 years old at 34% (17 people).

➢ *Normality Test*

This test uses the Kolmogorov-smirnov method because the number of respondents in this study was 50 respondents.

Tabel 4 Normality Test on Salivary pH Measurement Result Data

| Variabel | *p-Value |
|---|---|
| Control group (pH Meter) | 0,003 |
| Intervention Group (Mirror Biosensor) | 0,002 |

Table 4 shows the results of the normality test in both groups are 0.003 and 0.002, respectively. The p-value <0.05 so that the data is not normally distributed, so it can be continued with a non-parametric test using the Wilcoxon test.

➢ *Effectiveness of Using Mirror Biosensor in Saliva Ph Measurement*

The product trial in this study was conducted on 50 respondents at Nadira Dental Clinic MT.Haryono.

Table 5 Test Results of Differences in Salivary pH Measurement Using pH Meter with Mirror Biosensor

| Variables | Statistics | |
|---|---|---|
| | Control Group | Intervention Group |
| Mean | 6,49 | 6,52 |
| Std. Deviation | 0,95 | 0,96 |
| p-value | 0,058 | |

Table 5 shows that the average result of salivary pH measurement in the control group was 6.49, while in the intervention group it was 6.52. The test results above also show that the p-value of the difference in the results of measuring salivary pH using a pH meter with a mirror biosensor is 0.058. (p> 0.05), this indicates that there is no significant difference between the results of measuring salivary pH using a pH meter and a mirror biosensor. Because both measurement methods have relatively comparable results in measuring salivary pH, this means that the development of a mirror biosensor tool is effectively used in measuring salivary pH.

## IV. DISCUSSION

➢ *Result of Information Collection*

Information gathering is the first step in gaining an understanding of the problems in the field and the data that will be used in the development of the Mirror Biosensor tool innovation. Through this process, a deeper insight into the tool to be designed is obtained, supported by various sources

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such as journals, books, and previous research. The information that has been collected then becomes the basis for designing the tool. The advantages of the Research and Development (R&D) research method over other methods are that it is comprehensive, able to produce products with high validation through a series of tests, and can connect theoretical research with practical research[7].

Based on the results of information collection regarding salivary pH measurement in health care facilities, it shows that this procedure is still rarely performed. One of the main causes is the limitation of currently available pH meters, which are considered less practical for use in a health care environment that requires fast and efficient service. Conventional pH meters have a large size, complicated operating procedures, and a relatively long measurement time, which does not support the needs of health workers in conducting rapid examinations.

In addition, health workers revealed that current pH meters still require a certain amount of saliva samples and additional processing before obtaining results, which can potentially cause discomfort for patients and slow down the diagnosis process. Therefore, an innovative solution is needed that allows salivary pH measurement to be done more easily, conveniently, and efficiently.

The innovation in the form of a mirror biosensor is expected to be a solution to the limitations of the current pH meter. The mirror biosensor is designed to be easy to use, does not cause discomfort for patients, and has a small and flexible size so that it can be used in various health service conditions. In addition, this tool is also expected to be able to provide measurement results quickly and accurately, thus helping health workers make more informed decisions in patient care.

- *Development of Mirror Biosensor Tool*

The use of inadequate medical devices can cause various complaints, both from health workers and patients. The use of inadequate tools can also cause losses, both in terms of time, accuracy of examination results, and the effectiveness of the examination process for patients[8]. Based on the data that has been collected and the results of interviews in the field, health workers need a smaller, flexible salivary pH measurement tool, as well as a fast measurement duration. Therefore, researchers created an innovative salivary pH measuring device in the form of a mirror biosensor which is expected to be a more efficient alternative in measuring salivary pH.

- *Expert Validation*

The product feasibility test was carried out by 3 expert validators, namely electromedical experts, dentists, and dental and oral therapists. This aims to determine the feasibility of the mirror biosensor tool to be used as a saliva pH measurement tool. This feasibility test plays an important role in the development of mirror biosensor tools to ensure that the tools developed can provide optimal benefits for their users. The assessment of this tool is carried out by experts in their fields based on predetermined indicators[9]. One of the main aspects of concern for the validators in this feasibility test was the quality of the pH sensor used in the device. Validators emphasized the importance of selecting sensor materials with high sensitivity and accuracy to ensure more precise pH measurement results. A good quality pH sensor not only produces more accurate data but also speeds up the process of measuring salivary pH. In addition, the improved quality of the sensor contributes to the effectiveness of the device in providing more reliable data, thus supporting a more optimized end result.

The validator also provided input regarding the durability of the sensor, which is an important factor in ensuring that the mirror biosensor can function for a long time without experiencing a decrease in performance. In addition to the above emphasis, expert validators also emphasized the importance of periodic tool calibration to maintain the accuracy of measurement results. By integrating all input from expert validators, it is hoped that the development of this tool can produce an innovative product that is not only clinically effective, but also efficient in measuring salivary pH.

pH meter is a device used to measure the acidity or basicity of a liquid. The basic concept in pH measurement is to measure the concentration of hydrogen ions (H +) in the liquid. pH meters used today are digital versions, which are equipped with a numeric display to show the pH value of the liquid. pH meters can easily measure and monitor the acidity or basicity of a liquid. pH meters provide accurate measurements by displaying the pH value in the form of digital numbers[10].

- *Effectiveness of Using Mirror Biosensor in Saliva pH Measurement*

Measurement of salivary pH using a pH meter and mirror biosensor produces almost the same measurement value because both tools work with a similar principle, which is to detect the electrochemical potential of hydrogen ions in saliva. pH meters use glass electrodes that are sensitive to hydrogen ions which produce a potential difference which is then converted into a pH value. Meanwhile, mirror biosensors also rely on electrochemical principles where PCB electrodes capture potential changes caused by the concentration of hydrogen ions in the sample being measured. This similarity in working principle makes the measurement results of the two tools tend to be close together, especially in controlled environmental conditions.

The accuracy and accuracy of reading the results of measuring salivary pH using a mirror biosensor is superior to that of a pH meter, because in the use of a mirror biosensor the measurement of salivary pH is carried out directly under the tongue in the oral cavity and in a fast duration of time so as to reduce the possibility of pH changes due to aeration and interaction with outside air. The higher measurement speed on the mirror biosensor provides an advantage in maintaining the accuracy of pH measurements that are closer to the original conditions of saliva in the mouth. Whereas the measurement of salivary

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pH using a pH meter is carried out outside the oral cavity, which means that the measurement is carried out outside the body after the saliva is taken from the oral cavity [11][12]. This process takes time from saliva collection until the pH meter is used to measure pH which provides an opportunity for pH changes in the saliva itself[12].

Basically, the pH of saliva in the oral cavity can be very dynamic and change over time. After saliva is collected if not measured immediately there is a possibility that the pH can change due to the activity of microorganisms in saliva, the influence of temperature, or even changes in chemical content due to interaction with air. This is different from the use of mirror biosensors where salivary pH measurements are made directly in the oral cavity and in a short duration of time, reducing the possibility of pH changes that can occur[13]. This is different from the use of mirror biosensors where salivary pH measurements are made directly in the oral cavity and in a short duration of time, reducing the possibility of pH changes that can occur.

Saliva samples that are stored for a long time before being measured, bacteria and microorganisms in the saliva can begin to multiply which changes the chemical composition and pH of the saliva. A decrease in sample quality during storage can cause changes in pH that make measurements less accurate. This is certainly not the case with mirror biosensors which are designed to measure pH directly thus avoiding the possibility of changes in chemical composition during the measurement process.

In terms of practicality or ease of use, mirror biosensors have the advantage of being faster and more practical. Measurements only need to be taken under the tongue in the oral cavity directly, without requiring a long time or special attention to the condition of the device. This makes the mirror biosensor more efficient in measuring salivary pH, especially for routine use or in situations that require rapid measurement. However, both devices require proper usage techniques to keep the measurement results accurate.

In terms of work efficiency, mirror biosensors are also more ideal for routine monitoring such as in healthcare environments that deal with patients every day, but must still be balanced with regular calibration. With mirror biosensors, the measurement process becomes faster and easier without requiring high technical skills, thus increasing productivity and providing more convenience for users. Therefore, in measuring salivary pH, mirror biosensors are a superior alternative to pH meters.

Overall, although pH meters are tools that have been widely used in pH measurements and have been tested internationally, there are still limitations such as limitations in measurement time and changes in pH during storage or sample processing making them more susceptible to differences in results. Meanwhile, mirror biosensors have advantages in terms of measurement speed, ease of use and maintaining the accuracy of measurement results. This makes mirror biosensors a more practical choice in measuring saliva pH.

- *Product Results*

Innovation of mirror biosensor, a tool integrated with a mouth mirror. This tool uses a capacitive pH sensor based on Printed Circuit Board (PCB) Fiber to measure saliva pH directly in the oral cavity. Mirror Biosensor is designed to be more practical, because it does not require a large volume of saliva. Simply attached to the area under the tongue that contains saliva, this tool can take measurements in 10 seconds, after which the pH results will be displayed on the monitor. How this tool works is that the sensor will read analog values with values 0 to 700, then the analog value is converted into a digital value from 4 to 8 by dividing the analog value by 50.

Fig 2 Development of Mirror Biosensor Device

## V. CONCLUSION

The development of a mirror biosensor tool is feasible for application in measuring saliva pH as proven by the results of expert tests using the Aiken V test with a high validity category and the ICC test with a high reliability category. The development of a mirror biosensor tool is effective for use in measuring saliva pH. Mirror biosensor has advantages in terms of measurement speed, ease of use and maintaining the accuracy of measurement results. This makes the mirror biosensor a more practical choice in measuring saliva pH.

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