Development of Smart Dental Impression Trays on Operator Satisfaction During Dental Impression in Healthcare Services

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ABSTRACT

Background: *Health is the most important aspect of human life, both physically and mentally. Oral and dental health plays a crucial role in maintaining the body's functional balance. Tooth loss can disrupt chewing, nutrition, and overall quality of life. However, it can be managed with the use of dentures. One of the challenges in dental impression-taking is the gag reflex, which can be minimized by selecting the appropriate impression tray and optimizing the setting time of alginate. Innovations such as temperature sensors for real-time monitoring and music therapy can enhance accuracy and patient comfort.*
Method: *This study employs the Research and Development (R&D) method, which involves stages of information gathering, product design, expert validation, and product testing. The research respondents consist of operators (medical personnel) who perform dental impressions. Data is analyzed using statistical tests to evaluate the effectiveness of the developed device.*
Result: *The research results indicate that the use of Smart Dental Impression Trays significantly enhances operator satisfaction, with a mean score of 4.80 ± 0.422 compared to the control group at 3.60 ± 0.699 (p-value = 0.001).*
Conclusion: *Smart Dental Impression Trays are effective in enhancing operator satisfaction during the dental impression procedure. This innovation has the potential to be a solution for dental healthcare services in improving the quality of dental impressions.*

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INTRODUCTION

Health is one of the most important aspects of human life, both physically and mentally. In addition to general bodily health, oral and dental health also require attention. Oral and dental health play a crucial role in maintaining the balance of bodily functions[1]. Teeth serve essential functions such as chewing, speaking, and maintaining facial structure. Given their vital role, it is necessary to maintain oral and dental health to ensure the longevity of teeth in the oral cavity[2]. Poor oral conditions, such as tooth loss due to decay or untreated trauma, can disrupt oral functions and activities, ultimately affecting nutritional status and quality of life[3].

One of the most challenging factors contributing to the success of dental impressions is the gag reflex. Some patients experience it with great difficulty or are entirely unable to tolerate the presence of foreign objects such as mouth mirrors, dental films, or impression trays in their mouths[4]. This is usually the initial stage of patient treatment before diagnosis. During prosthodontic procedures like dental impressions, a significant gag reflex is most commonly observed[5]. This can disrupt the procedure or cause discomfort for both the patient and the dentist. Excessive gag reflex during dental treatment can interfere with the patient's comfort and the dentist's workflow, making the patient anxious every time they visit the dentist. Dentists can apply various strategies to manage this issue, but there is no definitive solution, as each patient's condition varies[6]. In prosthodontic procedures, selecting the appropriate impression tray is crucial, as a tray that is too large can potentially trigger the gag reflex[7].

In dental practice, particularly in rehabilitative treatment, the fabrication of dentures requires impression materials such as alginate or irreversible hydrocolloid materials. Alginate is commonly used for various purposes, including the creation of study models, which serve as the initial impression material for individual trays, impressions for removable dentures, orthodontic models, and treatment planning for restorative procedures. Based on setting time, alginate is classified into two types: fast-setting, which has a setting time of 1 to 2 minutes, and normal-setting, which takes 2 to 4.5 minutes. These options allow dentists to adjust the setting time according to their needs. Additionally, for patients with a sensitive gag reflex, a shorter setting time is preferable. Among these types, normal-setting alginate is the most commonly used in dental clinics[8].

The process of making dental impressions is a crucial step in dental treatment and reconstruction. In dental practice, alginate is a commonly used impression material due to its ease of use and affordability[9]. However, one of the main challenges in using alginate is the setting time, which refers to the duration required for the material to harden and become suitable for impression-taking[10]. To address this issue, the development of technology that can monitor and regulate temperature in real-time during the alginate setting process becomes highly relevant. One potential solution is the application of temperature sensor technology in advanced dental impression systems. By integrating temperature sensors capable of real-time monitoring, this system can provide accurate feedback and allow automatic adjustments to the alginate setting time[11].

RESEARCH METHOD

The research was conducted using the Research and Development (R&D) method. The aim of this study is to develop a Smart Dental Impression Trays Model to enhance operator comfort during the dental impression process. According to Borg and Gall, the research and development process includes five key stages: 1) information gathering, 2) product construction, 3) expert validation and revision, 4) product testing, and 5) final product.

The population in this study consists of dentists who perform dental impressions. The sample in this study consists of three groups, namely: information collection samples, expert validation and product testing. Information collection was conducted using observation and interviews with prosthodontic specialists and dental and oral therapists. Additionally, a literature review was carried out to support the obtained data or information. Expert validation was performed by prosthodontic specialists, dental and oral therapists, and biomedical engineers.

This study conducted a trial using a posttest control group design. The data analysis used includes univariate and bivariate analysis. If the data is not normally distributed, a non-parametric test, namely the Mann-Whitney test, is used. This study uses the Mann-Whitney test.

RESULTS

1. Expect Validation Test

Expert validation was conducted by prosthodontic specialist dentists, dental and oral therapists, and biomedical engineers. This validation was carried out to obtain data used as a basis for the feasibility testing of the Smart Dental Impression Trays development. The data were analyzed using the Likert Scale to determine the feasibility criteria of the device. The results of the expert feasibility test can be seen in the following table:

Table 1 Expert Validation Test Results Table

No	Respondent	Skor	Criterion
1	Expert 1	98%	Good Criteria
2	Expert 2	85%	
3	Expert 3	90%	
Average		91%	

**Likert scale*

Table 1 shows that the assessment results using the Likert Scale obtained an average score of 91% with the criterion of "Highly Feasible," indicating that the development of Smart Dental Impression Trays has met the initial feasibility standards for trial use. However, although the assessment results indicate high feasibility, the validators provided several inputs and suggestions for improvement to optimize the product's usability. These inputs focus on aspects such as material, sensor technology, and ease of clinical application for dentists. Therefore, further development is required before the product can be widely used in dental practice.

2. Data on the Use of Smart Dental Impression Trays and Operator Satisfaction

The assessment of Smart Dental Impression Trays aims to determine the level of operator satisfaction in using the device, categorized as "Yes" and "No" responses. The evaluation results of the respondents regarding the use of Smart Dental Impression Trays are as follows:

Table 2 Data on the Use of Smart Dental Impression Trays and Operator Satisfaction

No	Question	Category	n	%
	Control Group			
1	Is this device easy to use for taking dental impressions?	Yes	8	80
		No	2	20
2	I feel no difficulty in using the Smart Dental	Yes	8	80

	Impression device when taking dental impressions	No	2	20
3	I feel neither disturbed nor uncomfortable when using the Smart Dental Impression device	Yes	10	100
		No	0	0
4	Does the use of a temperature sensor in this device indicate an accurate setting time?	Yes	2	20
		No	8	80
5	Is the accuracy of the alginate setting time measurement consistent with the specifications stated in the impression material product guidelines?	Yes	8	80
		No	2	20
	Intervention Group			
1	Is this device easy to use for taking dental impressions?	Yes	10	100
		No	0	0
2	I feel no difficulty in using the Smart Dental Impression device when taking dental impressions	Yes	8	80
		No	2	20
3	I feel neither disturbed nor uncomfortable when using the Smart Dental Impression device	Yes	10	100
		No	0	0
4	Does the use of a temperature sensor in this device indicate an accurate setting time?	Yes	10	100
		No	0	0
5	Is the accuracy of the alginate setting time measurement consistent with the specifications stated in the impression material product guidelines?	Yes	10	100
		No	0	0

Table 2 shows a difference in assessments between the control group and the intervention group, as indicated by an increase in the percentage of positive responses given by the respondents. The control group's assessment of Question 1 showed that 8 respondents (80%) answered "Yes," while in the intervention group, 10 respondents (100%) answered "Yes." For Question 2, 8 respondents (80%) in the control group answered "Yes," while the intervention group also had 8 respondents (80%) answering "Yes."

For Question 3, both the control and intervention groups showed 10 respondents (100%) answering "Yes." For Question 4, only 2 respondents (20%) in the control group answered "Yes," whereas in the intervention group, 10 respondents (100%) answered "Yes." For Question 5, 8 respondents (80%) in the control group answered "Yes," while in the intervention group, 10 respondents (100%) answered "Yes."

3. Effectiveness Test of the Smart Dental Impression Trays Development on Operator Satisfaction During Dental Impressions

Table 3 Effectiveness Test Results on the Use of Smart Dental Impression Trays in Terms of Operator Satisfaction

Variable	**Statistics**	
Operator Satisfaction	**Control**	**Intervention**
Mean ± SD	3,60 ± 0,669	4,80 ± 0,442
*p-value**	0,001	

Mann Whitney

Table 3 shows a difference between the control group and the intervention group, as indicated by the average score of 3.60 in the control group and 4.80 in the intervention group. The p-value for both groups

is 0.001, indicating a significant difference between the control and intervention groups. Therefore, it can be concluded that the development of Smart Dental Impression Trays is effective in increasing operator satisfaction.

DISCUSSION

1. Information Collection

The process of information gathering is the initial stage in obtaining data about the issues occurring in the field, as well as the data that will be processed for the development of the Smart Dental Impression Trays innovation. This data collection aims to gain deeper insights into the device to be designed, supported by other sources such as journals, books, and previous research. The information obtained will then serve as the foundation for the development of the device. One of the advantages of using the Research and Development (R&D) method over other methods is its comprehensiveness, as it is capable of producing a product with high validation value due to undergoing a series of tests and bridging theoretical and practical research[12].

The results obtained from interviews indicate that several factors can interfere with the dental impression process, leading to imperfect results. Factors that can lead to imperfect dental impression results include the mismatch between the work time and setting time of the alginate impression material. This discrepancy can cause inaccuracies in the hardening process of the alginate material, resulting in an imperfect dental impression outcome. Efforts to prevent failures in the dental impression process include developing an impression tray that can detect the setting time of alginate. Therefore, the development of Smart Dental Impression Trays can enhance the quality of dental healthcare services.

The development of Smart Dental Impression Trays is expected to be a solution to this issue by integrating technology that can automatically detect the setting time. With sensors capable of identifying the hardening stages of the impression material, dentists can ensure that the alginate reaches its optimal strength before being removed from the patient's oral cavity. This will improve the accuracy of the impression results and reduce the likelihood of failure in the dental impression process. Additionally, this device can help minimize the risk of impression deformation caused by removing the material before it has fully set.

2. Expect Validation Test

Expert validation was conducted with prosthodontic specialist dentists, dental and oral therapists, and biomedical engineers. The expert validation results regarding the accuracy of the dental impression process indicate that the development of Smart Dental Impression Trays is feasible for use by medical professionals in healthcare services. This is supported by validator assessments and the development of Smart Dental Impression Trays, which align with the identified needs based on collected information. The expert validation stage is crucial in the development of Smart Dental Impression Trays to ensure that the product provides significant benefits for its users[13].

One of the key aspects highlighted by the validators is the quality of the temperature sensor used in the device. They emphasized the need for selecting a sensor material with higher sensitivity and accuracy to ensure optimal measurement results. A more advanced temperature sensor would allow for faster and more precise detection of temperature changes, which is critical in the dental impression process[14].

Furthermore, improving sensor quality can enhance the effectiveness of the device in providing more accurate data, thereby supporting better final dental impressions. Therefore, the selection of sensor materials is a primary concern for the next phase of development.

In addition to the temperature sensor, biomedical experts also recommended using smaller and lighter materials. This aims to improve comfort for dentists when operating the device and for patients during the impression process. Using lighter materials can reduce the device's weight, making it easier to manipulate during procedures. Moreover, smaller yet durable materials can enhance the efficiency and effectiveness of the device without compromising its durability and functionality. By considering the validators' suggestions, the development of Smart Dental Impression Trays will focus on enhancing sensor technology and optimizing material design to create a more innovative device that meets clinical needs.

Beyond sensor and material aspects, it is also essential to consider the ergonomics and ease of use for medical professionals. Validators emphasized that the Smart Dental Impression Trays should be designed for practical and efficient use by dentists without disrupting the impression procedure. One of the main challenges in healthcare technology innovation is ensuring that the applied technology is not only advanced but also easy to operate in dynamic clinical settings. Therefore, ergonomic design improvements, such as a comfortable grip or a more flexible shape, could be strategic steps to enhance usability.

Furthermore, the development of Smart Dental Impression Trays should also consider sustainability and production costs. Validators highlighted the importance of selecting materials that are not only lightweight and durable but also cost-effective and readily available. This ensures that the device can be mass-produced at an affordable price without compromising quality and functionality. Additionally, the durability of the device should be a key factor to ensure long-term usability without performance degradation. By incorporating all the feedback from the validators, it is expected that this development will result in an innovative product that is not only clinically effective but also cost-efficient and practical for production[15].

3. Analysis of the Implementation of Smart Dental Impression Device Based on Temperature Sensors, Alginate Setting Time, and Relaxing Music Effectiveness on Operator Satisfaction

The trial of the Smart Dental Impression Trays development in an effort to improve the effectiveness and quality of dental impressions was conducted using a posttest control group design. The researcher collected data from respondents to analyze the effectiveness of the Smart Dental Impression Trays in assessing the quality of dental impressions, which was measured by the proper functioning of the temperature sensor and the presence of relaxing music to reduce patient anxiety during the impression-taking process.

The development of Smart Dental Impression Trays, integrating a temperature sensor, alginate setting time adjustment, and relaxation music, can enhance operator satisfaction during the dental impression procedure[16]. The temperature sensor ensures that the water used for mixing alginate remains at an optimal temperature, which directly affects the setting time of the impression material. Research indicates that the higher the water temperature, the faster the alginate setting time[17].

The development of Smart Dental Impression Trays, equipped with a specialized temperature sensor to detect alginate temperature, provides a significant advantage in ensuring the quality of the impression material. This sensor is designed to monitor the alginate mixture temperature in real-time, allowing the operator to determine whether the temperature is within the optimal range for mixing and

setting[18]. According to a study by Adam Sojuangon and Sri Sedjati (2020), the optimal temperature for mixing alginate ranges between 20–25°C. A temperature that is too low will slow down the setting time, while a temperature that is too high can accelerate setting excessively, reducing the operator's working time[19].

One of the factors that enhance operator satisfaction is the setting time adjustment feature, which allows operators to determine the setting time more accurately. In dental impression procedures, the determination of alginate setting time is crucial as it affects both the quality of the impression and patient comfort. With a more precise time indicator, operators can reduce the risk of impression failure due to excessively fast or slow setting. This not only improves work efficiency but also enhances the quality of the final impression.

Additionally, the integrated temperature sensor in Smart Dental Impression Trays provides significant benefits in ensuring that the alginate temperature remains within the optimal range during the mixing and impression process. As stated in the study by Adam Sojuangon and Sri Sedjati (2020), the ideal mixing temperature for alginate ranges between 20–25°C. If the temperature is too low, the setting time will be prolonged, increasing the risk of impression deformation due to patient movement or environmental factors. Conversely, if the temperature is too high, the setting process will accelerate excessively, reducing the operator's working time and increasing the likelihood of technical errors. With the integration of a real-time temperature sensor, operators can directly monitor the condition of the alginate and adjust the mixing technique to maintain optimal conditions. The combination of the setting time adjustment feature and the temperature sensor not only improves operator efficiency but also ensures higher accuracy and quality in the final impression results[20].

4. Product Results

The innovation in Smart Dental Impression Tray development includes a feature to detect the hardness of the alginate impression material. This device is equipped with a temperature sensor that automatically detects the alginate temperature, which directly affects its setting time. With this temperature sensor, the tool is expected to enhance the accuracy of dental impressions and contribute to operator satisfaction during the impression-making process.

Figure 1. smart dentai impression trays development image

CONCLUSION

The development and trial of Smart Dental Impression Trays using a posttest control group design demonstrated its effectiveness in enhancing dental impression quality and operator satisfaction. By integrating a temperature sensor, alginate setting time adjustment, and relaxing music, the device ensures optimal water

temperature for alginate mixing, directly impacting the setting time and impression accuracy. The real-time temperature monitoring feature allows operators to maintain ideal conditions, reducing errors and improving workflow efficiency. Additionally, the precise setting time adjustment minimizes the risk of impression failure, enhancing both patient comfort and procedural success. Overall, the combination of advanced sensor technology and ergonomic design improves the effectiveness, accuracy, and quality of the final dental impressions, making the Smart Dental Impression Trays a valuable innovation in dental practice.

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