Original Article

Development, application, and evaluation of interactive simulation materials for learning the dental hygiene process of care

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Abstract

Dental hygiene students find it challenging to understand and perform the dental hygiene process of care (DHPC) after only a limited amount of clinical training; they generally improve their DHPC skills through clinical experience after graduation. In this study, we developed and evaluated interactive learning materials that simulate the DHPC. We divided the learning contents of the DHPC into six components and created five simulation materials. Using these materials, students could experience a typical DHPC virtually. In total, 30 third-year university dental hygiene students were divided into two groups (A and B), and then pre-quizzes were carried out for each group (group A: Quiz I, group B: Quiz II). Next, the students learned using the developed materials and took post-quizzes (group A: Quiz II, group B: Quiz I) to clarify their understanding of the DHPC. After the post-quizzes, a questionnaire survey was conducted. Both groups showed significantly higher scores on the post-quiz than on the pre-quiz (Group A: $p = 0.0451$ vs. Group B: $p = 0.0090$, paired Student's t-test). In addition, more than 80% of the responses to the questionnaire were favorable. These results suggest that the simulation materials developed in this study are effective for learning the DHPC.

Key Words: Dental hygiene education, computer-assisted instruction, simulation training, interactive learning materials, dental hygiene process of care

Introduction

The dental hygiene process of care (DHPC) is a model for providing quality, systematic and individualized dental hygiene care. The six components of the DHPC include assessment, dental hygiene diagnosis, planning, implementation, evaluation, and documentation[1†]. Supporting patients in solving their problems based on the DHPC could help identify the causes of various problems faced by patients and meet their individual needs. The DHPC also provides appropriate care for each patient, regardless of the experience of the dental hygienist. As dental hygienists need to understand and perform the DHPC in routine clinical practice, they must acquire DHPC skills.

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† American Dental Hygienists' Association. Standards for Clinical Dental Hygiene Practice. Available at: https://www.adha.org/resources-docs/2016-Revised-Standards-for-Clinical-Dental-Hygiene-Practice.pdf. (accessed 26 August 2022)

Moreover, dental hygienists must integrate their individual knowledge and skills in order to support patients' efforts to solve their problems through the application of the DHPC. Hence, dental hygiene students are required to acquire the abilities to "analyze," "evaluate," and "apply" by integrating the individual "knowledge" and "skills" they have learned in various subjects. However, as dental hygiene students find it extremely difficult to understand and perform the DHPC in clinical practicums on actual patients, they generally improve their DHPC skills through clinical experience after graduation. Therefore, we developed original interactive computer-assisted learning materials for dental hygiene students to acquire those abilities.

In 1985, the American Dental Hygienists' Association (ADHA) proposed a basic DHPC policy in their Dental Hygiene Diagnosis Position Paper. Darby and Walsh further developed this paradigm and, in 1993, proposed the Dental Hygiene Human Needs Conceptual Model (DH HNCM) for dental hygiene[2, 3]. Patient needs were categorized into eight categories in the DH HNCM (Table 1) so that dental hygienists could find appropriate interventions by analyzing, clarifying, and fitting patients' problems derived from medical interviews and clinical examinations into one of the eight categories in practicing the DHPC. The Standards for Clinical Dental Hygiene Practice, published by the ADHA in 2008 and revised in 2016, describe the contents of dental hygienists' work based on the framework of the DHPC.

In Japan, the DHPC began to be taught in some dental hygienist training institutions in 2001 as part of dental hygienist education[4]. Currently, most training institutions are based on or related to the DHPC. Therefore, current dental hygienist practice and education are entirely based on the DHPC. However, many dental hygiene students cannot carry out tooth brushing instruction and record the SOAP (subjective-objective-assessment-plan) notes according to each situation or make decisions based on the information obtained in some dental hygiene cases.

Table1. Dental Hygiene Human Needs Conceptual Model (DH HNCM)

Wholesome facial image
Protection from health risks
Biologically sound and functional dentition
Skin and mucous membrane integrity of the head and neck
Freedom from head and neck pain
Freedom from anxiety and stress
Responsibility for oral health
Conceptualization and problem-solving

Dental hygiene students have learned about the DHPC and how to use it through lectures and case studies, respectively, while in school. However, although they can acquire knowledge, they cannot foster clinical reasoning regarding the DHPC through lectures. On the other hand, case studies allow students to learn their own thought processes and solve problems. Case study classes, however, are difficult to complete through self-study. Furthermore, the classes require many human resources; consequently, the number of classes for case studies is limited. For these reasons, existing dental hygiene education is said to be insufficient, and thereby requires new teaching methods to be devised. Therefore, we decided to develop computer-assisted simulation materials that would enable students to integrate what they had learned in various subjects to solve patients' problems. That is, learning materials can give students the ability to put the DHPC into practice through learning. In other words, by having a simulated experience of a clinical situation, students can gain the abilities of "application," "analysis," and "evaluation," according to Bloom's revised taxonomy.

Computer-assisted simulation learning materials are widely considered helpful for medical and dental students, as they allow students to experience a limited number of patients during their education. Tokyo Medical and Dental University (TMDU) has been developing interactive computer-assisted simulation materials delivered via a learning management system (LMS) for many years in the field of medical and dental education. The use of these materials has proven beneficial in terms of knowledge acquisition and memory retention[5-9]. In addition, these materials have been reported to be beneficial for dental hygiene students in acquiring knowledge and skills[10, 11].

Some reports have suggested the learning effectiveness of virtual patients in computer-assisted dental education[12-14]. For example, Allaire[15] reported that dental hygiene students considered virtual patients helpful in building their critical thinking skills and confidence in making good clinical decisions.

Several studies have reported on the effectiveness of learning materials incorporating dental practice simulations for dental students and dentists[5-9, 12-14] and the effectiveness of simulation learning materials for dental hygiene students[10-11]. However, few reports have evaluated the learning effects of interactive computer-assisted simulation materials on the DHPC. Therefore, in the present study, we developed and evaluated interactive learning materials to simulate the DHPC.

Materials and Methods

This study was approved by the Ethics Committee of Saitama Prefectural University (No. 27074).

Developed learning materials
We developed original interactive computer-assisted learning materials that simulate the DHPC using SIM-TOOL, an authoring tool for clinical simulation materials developed by TMDU in 2003. These materials require students to select the appropriate option(s) among several presented alternatives to decide what should be done. It then shows the correct option(s) and provides feedback regarding the student's decision. Figure 1 shows example screenshots with explanatory sentences, questions, and photographs from the developed learning materials. Students make decisions as dental hygienists working in a dental clinic regarding each situation presented in the materials. As shown in Table 2, we created five simulation materials to allow students to practice components of the DHPC.

The first and second materials are for the initial clinical interview, the third for classifying data from the clinical interview, the fourth for analyzing the data, and the last for clinical care during the second visit. Using these simulation materials, students can experience the typical DHPC virtually. Similar to actual clinical practice, learners can make decisions by restructuring six components of the DHPC—assessment, dental hygiene diagnosis, planning, implementation, evaluation, and documentation—and describing what they have learned in terms of knowledge, techniques, and attitudes. For example, a student performs a medical interview and periodontal examination to obtain some data from a patient, classifies

these data as either subjective or objective, lists various problems, and thinks about how to explain them to the patient. The learning materials consist of 10 to 20 multiple-choice questions (MCQs) each. In the materials, students make decisions by answering MCQs along with the DHPC while referring to photos, videos, and patient data presented step-by-step on the screen.

Participants and methods
In April 2017, 30 third-year dental hygiene students at the School of Health and Social Services, Saitama Prefectural University, implemented the simulation learning materials for the DHPC on the LMS (WebClass; Data Pacific (Japan) Ltd., Tokyo, Japan) as a part of the "Preventive Treatment of Periodontal Disease III." At the time of implementation, the students had hardly any clinical practice in the curriculum and had just received lectures and paper case practices on the DHPC. Figure 2 shows the outline of the experimental procedure. Before this study, written and verbal explanations of the research were given to obtain informed consent, and the consent was confirmed via the LMS.

The students were sorted in descending order by scores for the "Preventive Treatment of Periodontal Disease II," which was related to the "Preventive Treatment of Periodontal Disease III." Then, the students were grouped into groups A, B, B, A, A, B, B, , , A, A, B, B, A, A, and B, in descending order. The mean scores of groups A and B were 65.8 and 65.9, and the standard deviations were 6.95 and 6.40, respectively. Therefore, there could be no difference between the groups regarding the educational contents at baseline. To compare the quiz scores of the same students before and after learning the materials, we divided them into two groups and had

Table2. Outline of the five developed learning materials and DHPC components about which students can practice with the materials

| No.	Title	Outline	DHPC component
1	DHPC 1 (initial medical interview)	Medical interview on the first visit, data collection, documentation, charting	Dental hygiene assessment
2	DHPC 2 (initial medical interview)	Report the data to the dentist in charge, explain the initial dental examination, TBI	Dental hygiene assessment, dental hygiene diagnosis, dental hygiene implementation
3	DHPC 3 (arrangement of data)	Classification of the data according to the dental hygiene human needs conceptual model	Dental hygiene assessment
4	DHPC 4 (analysis/synthesis of data)	Analysis of each dental hygiene need, setting short- and long-term goals	Dental hygiene diagnosis, dental hygiene planning
5	DHPC5 After the second visit	Explanation of dental hygiene intervention plans, motivation for maintenance	Dental hygiene implementation, dental hygiene evaluation
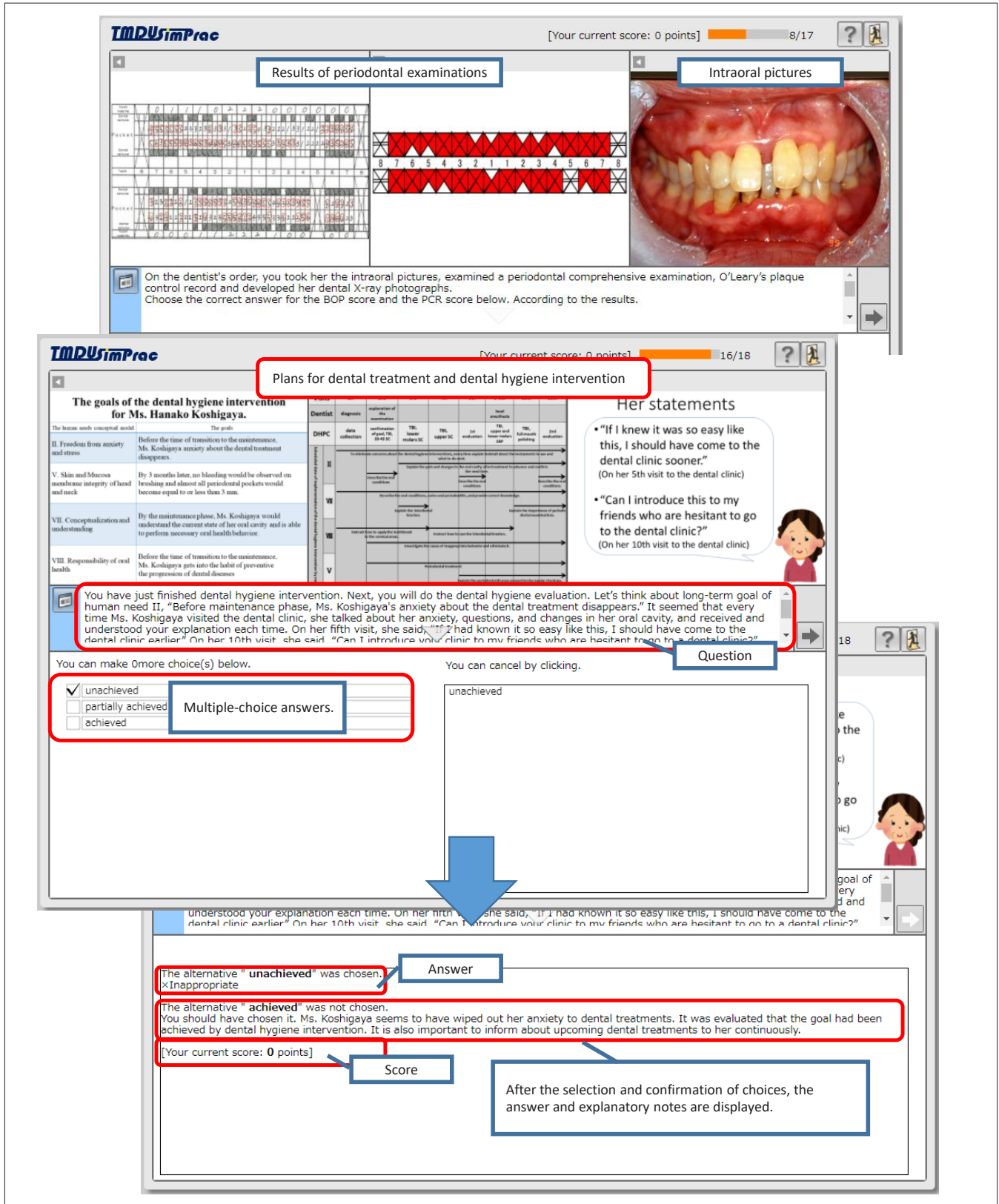
Figure 1. Screenshots of the materials. All sentences were originally written in Japanese and translated into English by the authors
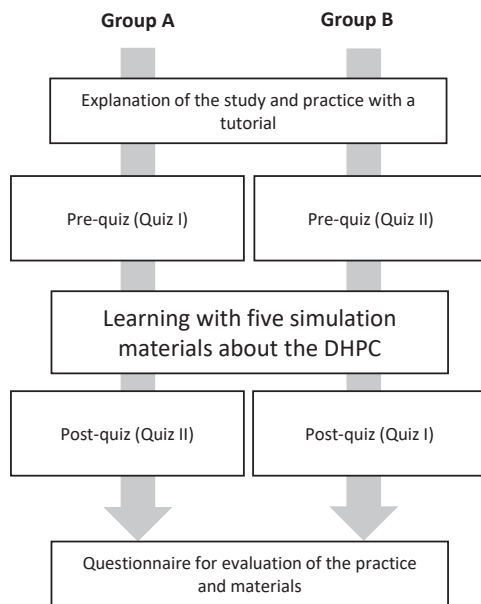
Figure 2. Outline of the experimental procedure

them take different quizzes at the same level and format. Since the students had not previously learned to use the simulation materials, they first learned how to operate them through a tutorial. After the tutorial, pre-quizzes were conducted on each group (group A: Quiz I, group B: Quiz II) to examine their level of understanding of the DHPC at baseline. Next, the students learned using the five learning materials developed by the authors at their own pace without any time limits. After completing the five learning materials, to examine the understanding of the DHPC after implementation of the materials, quizzes that had not been assigned to each group as pre-quizzes were carried out as post-quizzes (group A: Quiz II, group B: Quiz I). If students took the same quiz measuring their analysis abilities of the DHPC for the same clinical case before and after learning, their scores were expected to rise on the second quiz, regardless of their learning, because they had already experienced the analysis method for the same case during the first quiz. Therefore, we decided to implement different quizzes before and after learning in the same format with similar difficulty levels for different clinical cases. The first author created the quizzes, reviewed them with the two coauthors, and administered them to the students. The developed learning materials were constructed so that students could acquire the skills of "application," "analysis," and "evaluation" in Bloom's revised taxonomy through experiencing a simulated clinical situation. To evaluate these abilities, the quiz asked whether students could adequately understand the patient's situation from the given information, set the patient's goal, and assume the status of achieving that goal.

In the DHPC, correctly classifying patient data collected from medical interviews or examinations according to the DH HNCM affects the quality of dental hygiene assessment and implementation. Therefore, the proper classification of patient data was included as content in the pre- and post-quizzes. In addition, some questions related to the DHPC were included in the pre- and post-quizzes. Figure 3 shows an example of questions on the pre- and post-quizzes. Quiz I was related to the human need (HN), "Responsibility of oral health," and Quiz II was related to the HN "Conceptualization and understanding." The tests were descriptive, with 100 possible total points. Table 1 shows eight HNs[16]. Among the eight HNs, "Responsibility of oral health" and "Conceptualization and understanding" were considered to be closely related to patients' behavior and knowledge and to have high educational effects in acquiring "application," "analysis," and "evaluation" abilities, as the themes of the quizzes. After the post-quiz, the students completed a questionnaire survey that evaluated the practice using the developed learning materials. The questionnaires and learning records for the learning materials from the students who consented to participate in the study were then analyzed. After anonymization, free descriptive answers in the pre- and post-quizzes were marked according to predetermined scoring criteria for the keywords and contents to be included. The final scores were decided by three evaluators. The scores before and after learning with the materials were compared using a paired Student's t-test. Statistical analyses were performed using IBM SPSS 28 Statistics Base (IBM Japan, Ltd., Tokyo, Japan), with p values < 0.05 considered statistically significant.

Results

All 30 students (15 in Group A and 15 in Group B) agreed to participate in this study, completed all five learning materials, and answered the evaluation questionnaire about the learning materials. Figure 4 shows the results of comparisons between the pre- and post-quiz scores in the two groups. Both groups showed significantly higher scores on the post-quiz than on the pre-quiz (Group A: $p = 0.0451$ vs. Group B: $p = 0.0090$, paired Student's t-test).

The students' answers were generally appropriately written in the questions to enumerate the patient's subjective and objective data in both the pre- and post-quizzes. However, in the questions to describe their dental hygiene diagnosis, long-term goals, and achievement

Quiz related to the dental hygiene process of care

<u>Information obtained in the initial clinical interview</u>

A 60-year-old female, Ms. T, a housewife, came to the clinic with a detached inlay in the lower right second premolar as her chief complaint. Her last dental examination was 10 years ago, and gingivitis was observed in her mouth. Since no secondary caries were observed in the lower right second premolar, the dentist bonded the detached inlay to the teeth. After performing an oral examination, some periodontal pockets deeper that 4 mm were observed. PCR was 78% and BOP was 45%. Since 2 or 3 years ago, she has been experiencing bleeding gums when brushing, but has been unsure from where the bleeding is originating. She brushes her teeth only once before going to bed and does not use interdental brushes or dental floss. You asked her to brush her teeth as usual when providing instructions on how to brush, and she has been able to remove most of the dental plaque from her teeth. She listens and nods to your explanations, but never spontaneously asks questions.

Q1: Regarding the above, with respect to the dental hygiene need "Responsibility of oral health", enumerate Ms. T's S data (Subjective data) and O data (Objective data).

Q2: With respect to the dental hygiene need "Responsibility of oral health", enumerate the diagnostic and etiological statements.

Q3: With respect to the hygiene need "Responsibility of oral health", set Ms. T's long-term goal for after the end of her initial periodontal treatment (about 3 months later).

Q4: With respect to the dental hygiene need "Responsibility of oral health", enumerate the patient's status and actions that can be considered "achievement" in the dental hygiene assessment.

＊The quiz carried out follows the dental hygiene human needs conceptual model.

Figure 3. Examples of questions in Quiz I. All sentences were originally written in Japanese and translated into English by the authors

evaluation criteria, the student's answers were found to be described more appropriately according to the DHPC methods in the post-quiz after learning with the materials than in the pre-quiz.

Figure 5 shows the results of the questionnaire conducted to evaluate the practice and learning materials. More than 80% of the students gave favorable responses to most of the questions, including "This practice using these simulation materials was interesting," "I deeply understand the DHPC through this practice," and "I was interested in related lectures and practical training because of the practice." In addition, more than 90% of the students gave a favorable response to "The practice will be useful to me in the future." However, more than 80% of the students did not agree with "I felt that the course materials were easy." The respondents' general comments to Q10 ("Please share any general comments") are shown in Table 3.
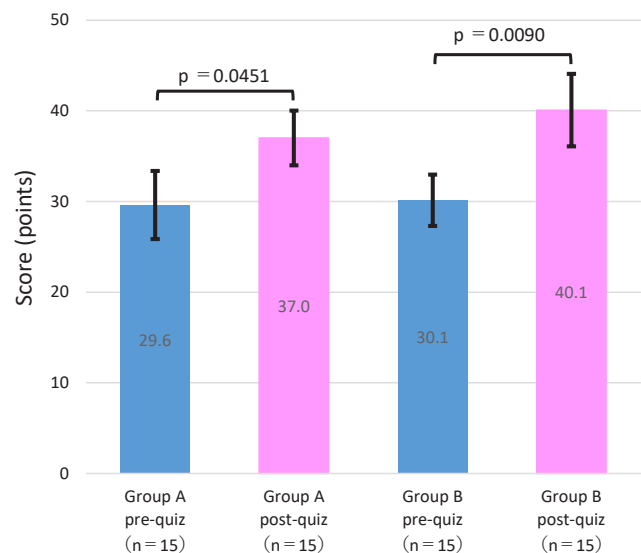

Figure 4. Results of comparisons between the pre- and post-quiz scores in the two groups

Both groups showed significantly higher scores on the post-quiz than on the pre-quiz. (Group A: $p = 0.0451$ vs. Group B: $p = 0.0090$, paired Student's t-test)

Q1 : This practice using these simulation materials was interesting.

| 8 | 6 | 10 | 5 | 1 |

Q2: I felt that the course materials were easy.

| 6 | 18 | 5 | 1 |

Q3 : I deeply understand the DHPC through this practice.

| 1 | 7 | 16 | 2 | 3 | 1 |

Q4: The practice will be useful to me in the future.

| 9 | 11 | 8 | 1 | 1 |

Q5: I was interested in related lectures and practical training because of the practice.

| 3 | 12 | 10 | 4 | 1 |

Q6: I would like to learn with more simulation materials like these.

| 4 | 12 | 10 | 1 | 2 | 1 |

Q7: This practice should be continued in the future.

| 5 | 10 | 11 | 2 | 2 |

Q8: This practice improved my self-learning skills in relation to the DHPC.

| 1 | 8 | 17 | 3 | 1 |

Q9: The material operation was user-friendly.

| 1 | 11 | 6 | 9 | 3 |

0% 50% 100%

■ Strongly agree ■ Agree ■ Somewhat agree ■ Somewhat disagree ■ Disagree ■ Strongly disagree
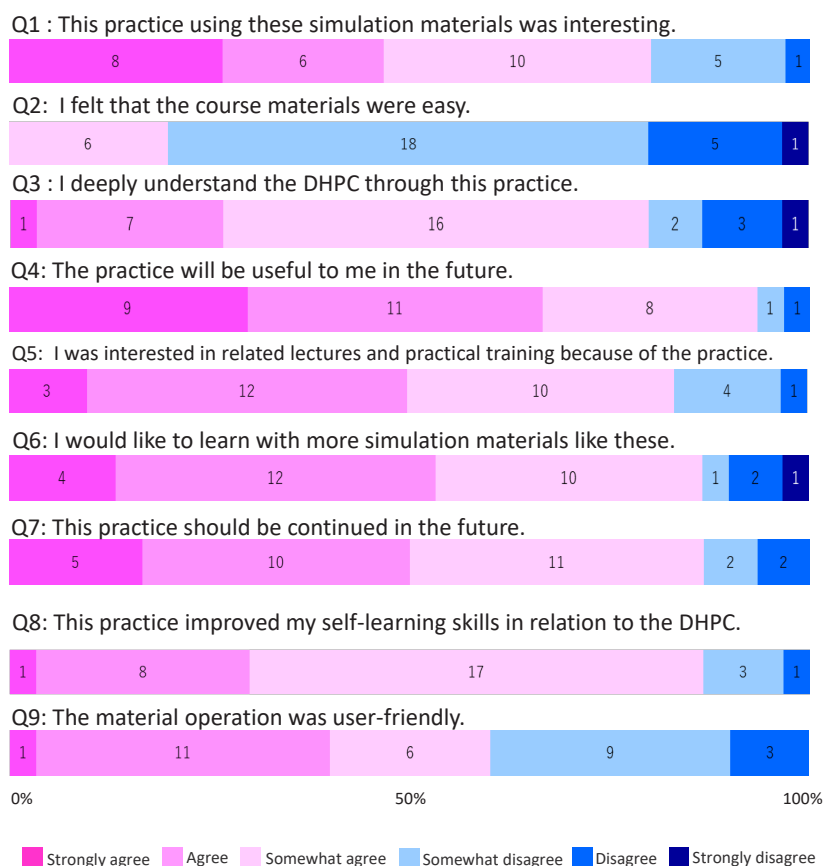
Figure 5. Results of the questionnaires for evaluating the practice and learning materials (n=30).

The original questionnaire was written in Japanese

Table3. General comments to Q10 ("Please share any general comments") (n = 13)

Favorable comments
- I felt that the pre- and post-quizzes were difficult for me. I thought it was good to deepen my understanding of the dental hygiene process of care using the simulation learning materials with multiple-choice questions and to give the correct answers immediately.
- I felt that I was able to understand the dental hygiene process of care better than before by learning it with the materials.
- I want to try other materials. I thought it would be a good review if I could learn it whenever I want.
- I realized that I still didn't understand the dental hygiene process of care very well.
- I understood the dental hygiene process of care.

Unfavorable comments
- In the question to find problems in the video in which a patient is brushing their teeth, the most important part was not clear in the video, so I had to watch it many times. As I felt like my score would not be affected if I made an inappropriate decision, I thought that I could get a good score by checking all options.
- The video and image quality was relatively low, and some parts were difficult for me to understand.
- My eyes got tired because there were many questions and I had to stare at the screen for a long time.
- The questions should be easier to read.
- Some images should be clearer.
- My eyes became tired and sore.

Both favorable and unfavorable comments
- It was easy to learn how the data and dental hygiene needs were classified. The explanations were also concise. I thought that an inappropriate decision should affect the score. Even when the image was enlarged, the characters were sometimes compressed. I would like to learn more using these kinds of materials.
- I thought the materials would be effective if I were accustomed to them, but I need to be ready to deal with system troubles quickly.

All sentences were originally written in Japanese and translated into English by the authors.

Discussion

In this study, we developed and evaluated five interactive learning materials that simulate the DHPC. The results suggested that these materials are effective for helping students learn the DHPC. Furthermore, as most students gave favorable responses to the evaluation questionnaire, the developed materials can be feasibly applied to third-year dental hygiene students.

The pre- and post-quiz questions were based on the DHPC used in actual clinical situations. The simulation materials were also developed so that students could learn the DHPC while making decisions in actual clinical situations. Therefore, the quiz questions and learning materials helped measure or practice the students' application, analysis, and evaluation abilities at a higher cognitive level according to Bloom's revised taxonomy, as shown in "The Learning Target Level in the Cognitive Domain"[17].

According to the questionnaire evaluating the learning materials, more than 80% of the students responded favorably to most items. Hence, their evaluations of the learning materials were generally favorable. Regarding the usability of the learning materials, more negative evaluations were seen than in previous studies[5-9,11]. The participants in previous studies have provided more favorable evaluations because they had experience with the simulation materials before the research implementation. On the other hand, in the present study, the students were learning with the simulation materials for the first time, which likely explains the increased number of negative evaluations. The usability of the learning materials may be influenced by computer literacy and getting accustomed to the operation, so prior explanations and practice may be needed, in addition to an improved support system for students using the learning materials. Although 80% of the students did not consider the learning contents to be easy, we still consider them to have been at an adequate level of difficulty because even the students with no clinical training experience could learn effectively using the simulation materials. Some students gave favorable comments (e.g., "I would like to learn more with these kinds of learning materials," "I thought it was good to deepen my understanding"), which suggested that they would be motivated to learn more and could learn more effectively. However, further improvements are needed because some students gave unfavorable comments about the video and image quality. Eyestrain was also pointed out in the general comments.

In this study, all students learned at the same time and place. As a result, they took several hours to complete the pre-quiz, implement the learning materials, and take the post-quiz. The long duration of these activities caused some students to experience eyestrain, which might have influenced the evaluation results. These learning materials should therefore be implemented by students at their own pace and in an appropriate environment.

Some methods used in previous DHPC education include case studies with both paper[18] and standardized patients and role-play practice between students. Learning as a case study with paper patients makes it relatively easy for teachers to prepare for class and is an effective way to allow students to simulate the experience of clinical decision-making. However, some drawbacks are involved, such as difficulties in training for collecting information about patients.

Although role-play practice is realistic, only some students can have homogeneous learning experiences. In particular, role-play practice between students is effective for learning the basics of patient treatment, but it lacks tension. In role-play practice with standardized patients, a sense of presence and tension in the clinical setting can be experienced; however, it is impractical to practice frequently because of the substantial cost involved.

The advantages of the simulation materials developed in the present study are as follows: 1) learners can get feedback immediately; 2) learners can learn while making decisions as they would in actual clinical situations; 3) learners can learn whenever they want and use the materials for self-study; and 4) learners can experience various cases homogeneously[5-11]. Furthermore, if a computer environment is available, the cost and burden of education can be reduced compared with conventional teaching methods, such as paper patients, role-play, and standardized patients. Therefore, the learning materials developed for this study can be one strategy to overcome the shortcomings of traditional dental hygiene education for learning the DHPC.

Crossover tests should have been adopted to clarify the effects of the learning materials. However, due to restrictions involving the curriculum and timetable, such tests could not be conducted. Moreover, this study was carried out with limited learning and examination times; therefore, the simulation materials focused on learning content about the following specific HNs: "Freedom from anxiety and stress," "Skin and mucosa membrane integrity of the head and neck," "Conceptualization and understanding," and "Responsibility of oral health." In addition, the pre- and post-quizzes measured the application, analysis, and evaluation abilities regarding only the HNs "Conceptualization and understanding" and

"Responsibility of oral health." In the future, we plan to increase the number of learning materials to enable students to learn the DHPC for all eight dental hygiene HNs. Furthermore, we plan to examine the adequate stage of the curriculum in dental hygiene education, develop an effective education system for the DHPC, and implement methods for the learning materials and the contents of clinical cases.

In this study, we only examined the effectiveness of the evaluation before and after learning with the computer-assisted simulation learning materials; we were not able to conduct comparisons with other teaching methods. We consider this to be an issue for future research.

Conclusion

Our developed interactive simulation materials can feasibly be applied to third-year dental hygiene students and appear to be effective for helping students learn the DHPC.

Conflict of Interest

The authors declare no conflicts of interest.

Acknowledgments

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