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Original Article

Effects of an interactive simulation material for clinical dentistry on knowledge acquisition

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The aim of this study was to examine the effectiveness of interactive simulation materials with decision making in knowledge acquisition and anxiety reduction. Dental students in their fourth year at Tokyo Medical and Dental University were randomly divided into Groups I and D. Participants read a scenario, learned with interactive-type (Group I) or display-type (Group D) learning materials about pulpectomy, and took the State-Trait Anxiety Inventory-JYZ, a quiz for measuring learning effects, and a questionnaire for evaluation of the material. Except for requesting decision making in the interactive-type material, the contents of both materials were the same. The results were compared using the unpaired Student's *t*-test, Fisher's exact test, and the two-way repeated measures ANOVA with the Bonferroni post hoc test. The mean quiz score was significantly higher in Group I than in Group D (I: 75.4±1.4, D: 60.6±2.7, $p<0.001$). There was no significant correlation between the groups and the responses except for one question about operability ($p<0.05$). A significant main effect on state anxiety was found between examination points ($p<0.001$), and state anxiety significantly increased after reading the scenario ($p<0.001$) and reduced after learning ($p<0.001$). Interactive simulation materials with decision making might be effective in knowledge acquisition.

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Introduction

At Tokyo Medical and Dental University (TMDU), in addition to conventional lectures, we have expanded classes with computer-assisted instructions. The evaluation of simulation materials for students in class was found to be favorable, and the materials have been published as e-learning materials[1–5]. Other theoretical simulation learning materials on computers utilized in dental education have improved learning[6–9]. The effectiveness of learning in these studies was assessed using learners' self-evaluations. A few reports have performed objective evaluations[6, 7], however, it remains unknown which characteristic of simulation learning materials, such as interactivity, audio/visual effects, or virtual realism, contributes most to the learning effect.

In general, the learning effect is influenced by psychological factors, such as stress and anxiety. Dentistry is said to be a highly stressful profession compared to other professions, and dentists are generally highly stressed[10–12]. Some reports have indicated that dental students experience considerable stress[13, 14], greater than that experienced by medical and co-medical students[13]. As anxiety may influence performance and practice outcomes, reducing students' anxiety is essential in dental education.

Little is known about what kind of factors would improve learning performance with simulation learning materials. Therefore, we hypothesized interactive programs that prompt learners to make a decision would be effective in improving the learning performance with computer-assisted simulation learning materials. In order to test

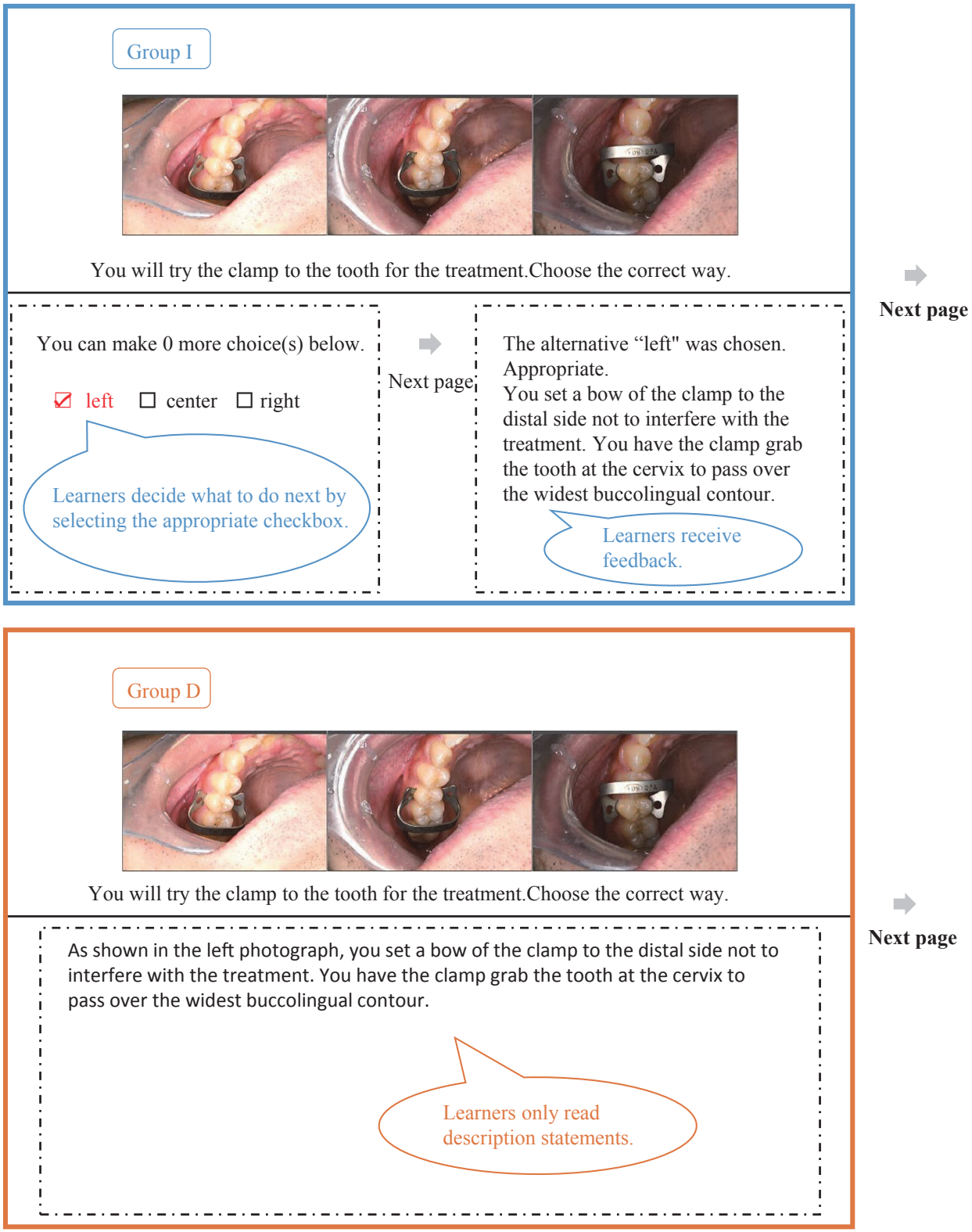

Figure 1: An example of the explanatory text, questions and photographs used in the interactive- and display-type learning materials

Students learning with the interactive-type materials make decisions regarding what seems appropriate among several presented alternatives. Students learning with the display-type materials see the same photographs and read the same description statements without making decisions.

this hypothesis, we developed two computer-assisted simulation learning materials that focus on the same scenario and include the same teaching content and photographs, but differ in terms of the inclusion of the decision-making process by learners, and applied these materials to dental students. In addition, we evaluated the effects of the interactive material on anxiety reduction. To measure learners' anxiety, we utilized State-Trait Anxiety Inventory–JYZ (STAI-JYZ). STAI-JYZ was introduced in 2000 by Hidano[15] and Spielberger et al.[15, 16] and is commonly used in Japan[17]. The STAI-JYZ measures both state anxiety, which refers to the current state of anxiety, and trait anxiety, which refers to the tendency of a stable personality to become anxious.

Materials and Methods

This study was approved by the Ethics Committee of Tokyo Medical and Dental University, Faculty of Dentistry (No. 1146). Informed consent was obtained from all research subjects. Prior to conducting the study, we explained that although the learning materials in this study would count toward the number of materials practiced, the scores of the materials would not contribute to the students' academic achievements.

A total of 94 students in their fourth year (41 students in year 2014 and 53 students in year 2015) at TMDU School of Dentistry participated, and the experiment was run in the course "Computer-Assisted Simulation Training," using more than 150 computer-assisted dental simulation materials.

These learning materials have been created with an authoring tool for clinical simulation material development called "SIMTOOL," which was developed in 2003 at TMDU. Faculty members, even those without any computer expertise, can use SIMTOOL to create and develop simulation learning materials with photographs, audios, and videos for tasks such as clinical treatment and diagnosis.

We created two types of learning materials, interactive-type and display-type, to teach pulpectomy. Each learning material presented knowledge regarding the necessary instruments, procedures, and precautions of pulpectomy to learners. Figure 1 shows an example of the explanatory sentences, questions, and photographs of the interactive- and display-type learning materials. The interactive-type learning material required learners to select an appropriate answer among several presented alternatives to decide what to do next. In the next step, it showed them if the learners' decision was correct or not and gave feedback about their decision. In contrast, the display-type learning material showed only the same photographs and explanatory sentences as in the interactive-type material without requesting learners to make decisions. Except for the request to make decisions on interactive-type materials, all of the descriptions and visual materials were the same in both materials.

We randomly divided the participants into two groups, Groups I and D. The number of participants was 47 (year 2014: n=21, 9 males and 12 females; year 2015: n=26, 16 males and 10 females) in Group I and 47 (year 2014: n=20, 9 males and 11 females; year 2015: n=27, 17 males and 10 females) in Group D. Randomization was stratified according to sex and date of implementation. All participants were blinded to group assignment and learned both types of learning materials on WebClass™ (Data Pacific (Japan) Ltd., Tokyo, Japan), the e-learning system at TMDU. Figure 2 shows the experimental protocol in both groups. First, all participants took STAI-JYZ[15, 16] examinations to assess trait and state anxiety. Subsequently, they read a scenario with oral, X-ray, and facial expression photographs. The content of the scenario was as follows. "In your sixth year, a 36-year-old female patient comes to you complaining of acute pain in the maxillary right second premolar. The tooth was diagnosed with acute pulpitis. Since there was enough time for treatment, the instructor told you to perform pulpectomy without one-on-one instruction." This scenario was developed to create a tense atmosphere among the subjects by imagining clinical practice for their first time. After reading the scenario, they took a STAI-JYZ examination to assess state anxiety. Then, Group I students first learned with the interactive-type material, while Group D students first learned with the display-type material. After learning with their first material, they took a STAI-JYZ examination to assess state anxiety, a quiz for measuring learning effects, and a questionnaire for evaluation of the material on anxiety reduction, building self-confidence, and usability. The quiz was prepared to evaluate the knowledge acquired by learners using different questions from the interactive-type material and consisted of 4 multiple choice questions and 6 written examinations. All questions had a maximum score of 10 points for a possible total of 100 points. Three of the authors (T.M., M.S., and A.K.) graded the written answers anonymously. All participants finally learned with the other type of material.

Comparisons between the groups based on the results of the quiz and trait anxiety were analyzed by the unpaired Student's *t*-test. Comparisons based on the results of the questionnaire were analyzed by Fisher's

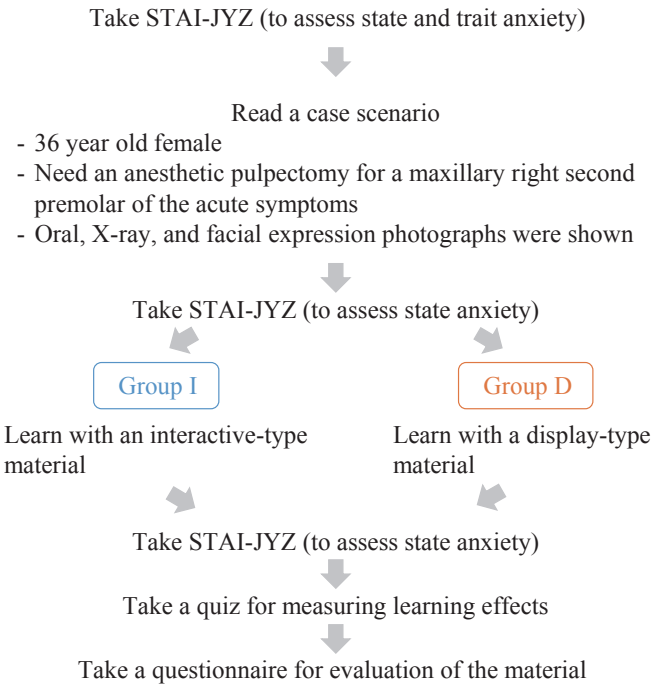

Figure 2: The experimental procedure for Groups I and D

exact test. Changes in state anxiety were compared between examination points and between groups by the two-way repeated measures ANOVA with the Bonferroni post hoc test. The strength and the direction of a linear relationship between pairs of continuous variables were calculated by Pearson's correlation analysis. All statistical analyses were conducted using SPSS Statistics Version 24 (IBM Corp., Chicago, IL, USA) and $p<0.05$ was considered statistically significant.

Results

Of the 47 subjects in Group I and 47 subjects in Group D, valid responses were received from 42 (male: 24, female: 18) and 37 (male: 24, female: 13) participants, respectively. Overall, 5 subjects in Group I and 6 subjects in Group D were absent from the class on the experimental day, and 4 participants in Group D provided incomplete responses.

The mean score of the quiz for measuring learning effects was significantly higher in Group I in which students made clinical decisions in their learning than in Group D in which students did not make clinical decisions (I: 75.4±1.4, D: 60.6±2.7, $p<0.001$) (Figure 3).

Results from the questionnaire for evaluation of the materials are shown in Figure 4. Overall, the content, operability, and photographs of both types of materials were positively evaluated. No significant correlation was found between the groups (Group I or Group D) and the

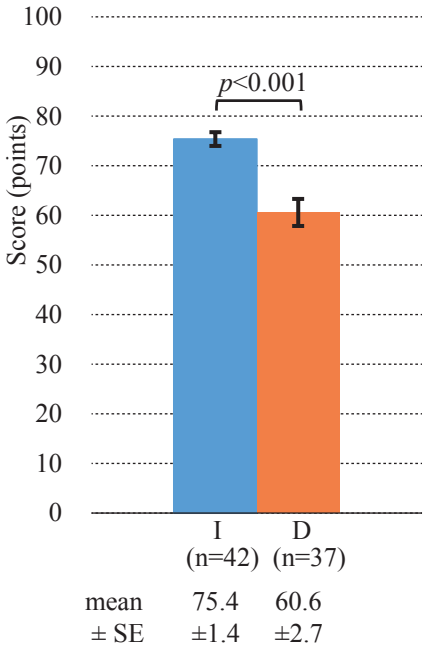

Figure 3: Scores of the quiz for measuring learning effects (mean±SE) in Groups I and D

I: Group I. D: Group D. ($p<0.001$, unpaired Student's t-test)

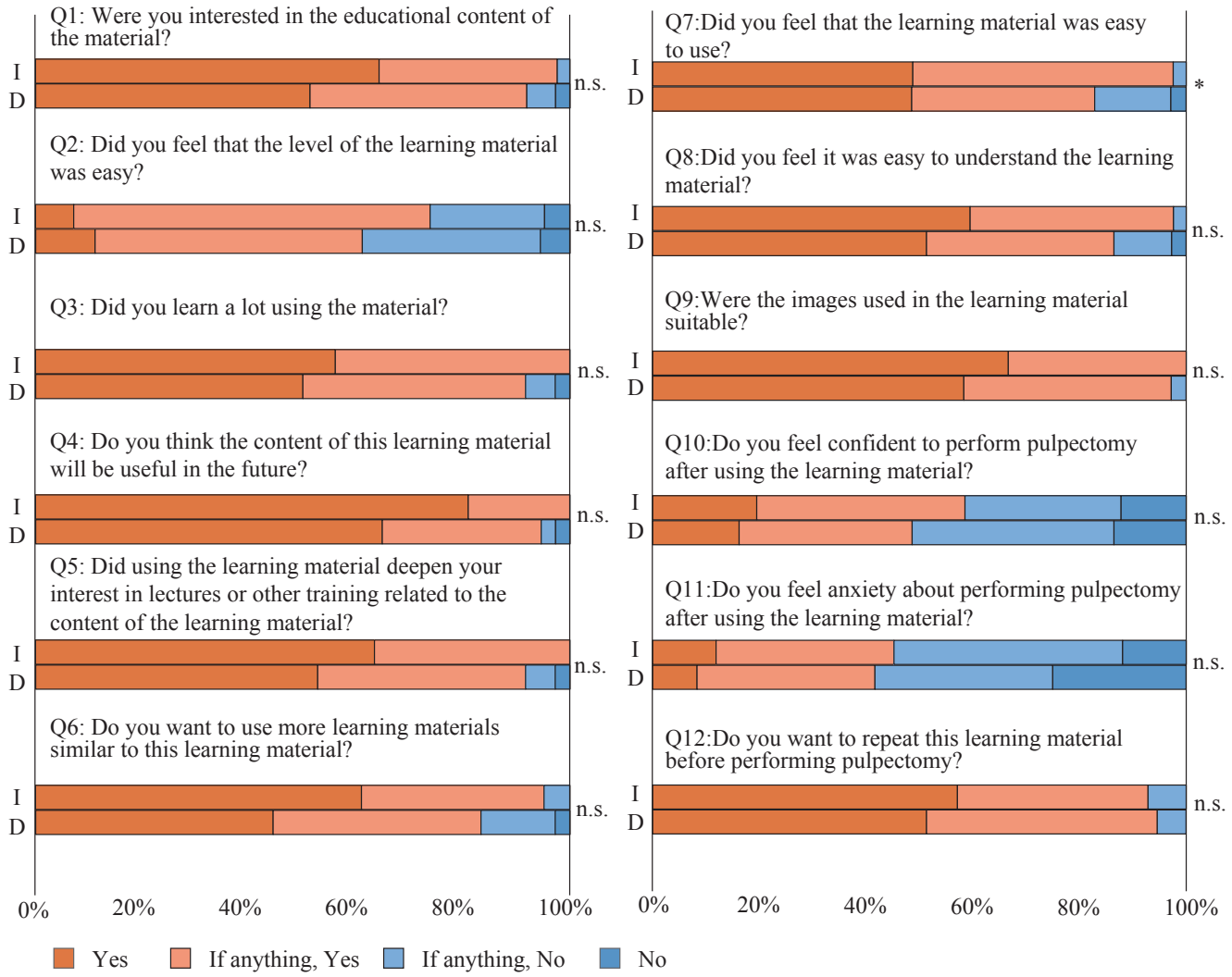

Figure 4: Results of the questionnaire for evaluation of the learning material.
I: Group I (n=42). D: Group D (n=37). (*: $p<0.05$, n.s.: not significant, Fisher's exact test).

responses (positive or negative) to each question except for question 7, "Did you feel that the learning material was easy to use?" (Q7: $p<0.05$, others: $p\geq0.05$, Fisher's exact test).

Figure 5a and 5b show results of trait and state anxiety for Groups I and D. There were significant differences between Groups I and D in trait anxiety (Fig. 5a: $p<0.01$). According to the two-way repeated measures ANOVA, there was no significant interaction between the examination points and the groups for state anxiety (Fig. 5b: $F(2,154)=2.603$, $p=0.077$). A significant main effect was found between the examination points ($F(2,154)=13.707$, $p<0.001$), whereas no significant main effect was found between the groups ($F(1,77)=3.512$, $p=0.065$). According to the Bonferroni post hoc test on the examination points of state anxiety, there were differences between (1) "Before reading the scenario" and "Before learning" ($p<0.001$) and (2) "Before learning" and "After learning" ($p<0.001$), so the mean score of state anxiety significantly increased after reading the scenario and reduced after learning with the material.

Table 1 shows results of Pearson's correlation coefficien. Trait and state anxiety in Group I and state anxiety in Group D were not related to the quiz score. Conversely, trait anxiety in Group D was weakly related to the quiz score. Additionally, trait anxiety was weakly to very strongly related to state anxiety at the three examination points in Groups I and D.

Figure 5a

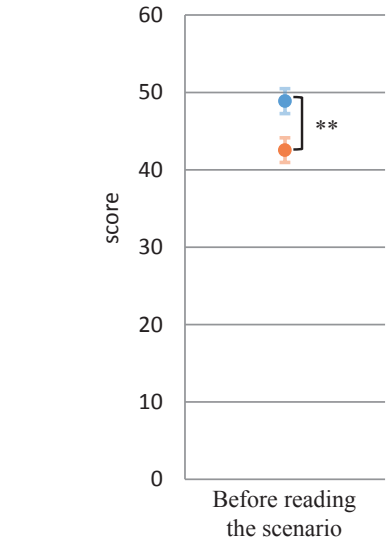

Figure 5b

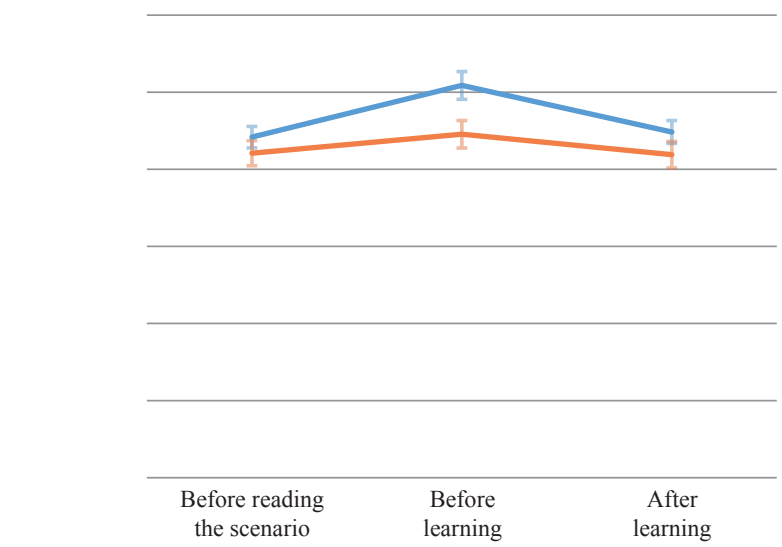

Figure 5: Results of trait and state anxiety for Groups I and D
5a: Results of trait anxiety score. (mean±SE , **: $p<0.01$, unpaired Student's *t*-test)
5b: Changes in state anxiety score in Groups I and D (mean±SE).

Table 1: Results of Pearson's correlation coefficient (*: $p<0.05$; **: $p<0.001$)

Group I		Trait anxiety	State anxiety			Quiz score
			Before reading the scenario	Before learning	After learning	
Trait anxiety		1	–	–	–	–
State anxiety	Before reading the scenario	.780**	1	–	–	–
	Before learning	.584**	.518**	1	–	–
	After learning	.700**	.823**	.695**	1	–
Quiz score		-0.080	-0.208	-0.074	-0.215	1

Group D		Trait anxiety	State anxiety			Quiz score
			Before reading the scenario	Before learning	After learning	
Trait anxiety		1	–	–	–	–
State anxiety	Before reading the scenario	.804**	1	–	–	–
	Before learning	.684**	.727**	1	–	–
	After learning	.385*	.527**	.603**	1	–
Quiz score		.360*	0.259	0.311	0.278	1

Discussion

In this study, the scores of the quiz for measuring learning effects of Group I were significantly better than those of Group D. Students learning using the interactive-type materials were forced to make decisions at each step in the clinical flow, however, students learning using the display-type materials only read explanatory sentences and saw photographs. The significant difference in the quiz scores for measuring learning

effects between the two groups may be because Group I students worked on a solution to the clinical problem, made decisions by themselves, and obtained feedback about their decisions while studying the material. Consequently, the contents of learning materials are easily fixed as knowledge in Group I. However, Group D students read learning materials, such as reviews of lectures and model training, without making decisions; accordingly, the contents of the learning materials were not easily fixed as knowledge. Additionally, because a correlation was observed between trait anxiety and the quiz score in Group D, we presumed students with high trait anxiety using display-type materials might take learning more seriously than those with low trait anxiety. Furthermore, we speculated that learning effects of the interactive-type material might be obtained independent of trait anxiety, as no correlation was found between trait anxiety and the quiz score in Group I. The academic course, during which this study was performed, has 150 computer-assisted interactive simulation materials that cover many fields in dentistry. In this study, we investigated learning effects and reduction of anxiety using endodontic material as the participants had just learned clinical endodontics in their curriculum. Further studies are needed to confirm the same effects in other fields of dentistry. Moreover, to inspect the learning effects more accurately, preliminary examination of academic achievement should be measured in advance.

Both interactive- and display-type materials were rated highly among the students. The targets of this study were students who had learned pulpectomy in endodontics only through lectures and model practices but had not seen the actual procedure. We presumed that the visual effects of clinical photographs presented in proper order in the learning materials would be helpful to understand the procedure. Students in Group I responded more positively than those in Group D to question 7, "Did you feel that the learning material was easy to use?". As learners of the display-type material had to scroll to read all of the text because of the screen design, many Group D learners might respond that the materials were not easy to use.

The present study demonstrated that interactive materials that include clinical decision making are effective in knowledge acquisition. Previously, some reports suggested that educational methods make a difference in learning effects and satisfaction. Specifically, Balslev et al. revealed more significant improvement of verbal interaction among pediatric residents who learned with video than among those who learned with textbooks in problem-based learning[18]. Furthermore, Yeung et al. found that time to review the material, number of attempts at the task, and number of students who expressed understanding when they could not complete the task were significantly greater among medical students who learned laparoscopic surgery with video than among those who learned with text. They demonstrated that video was superior to text in achieving superior conceptual understanding[19]. Peacock et al. compared a lecture, a website, a handout, and a tutorial for medical students and reported that knowledge scores significantly improved with the lecture and website teaching methods. Moreover, the lecture was considered more engaging, clinically relevant, and instilled confidence. The website/podcasts served as additional information to facilitate their learning and increased their knowledge equivalent or superior to other standard media[20]. Schreiber et al. reported no significant difference in multiple choice questioning immediately after the session, and the subjects enjoyed the convenience of the video podcast and the ability to stop, review, and repeat it. However, the subjects found it less engaging as a teaching method and expressed a clear preference for the live lecture format[21]. Zhang et al. examined the utility of interactive videos in e-learning and reported that a non-interactive video and PowerPoint give the same results and same satisfaction compared to traditional lectures, but only interactive videos on e-learning gave better results and higher satisfaction. Experimental results showed that the value of videos for learning effectiveness was contingent upon the provision of interactivity. Students in the e-learning environment that provided an interactive video achieved significantly better learning performance and a higher level of learner satisfaction than those in other settings. However, students who used the e-learning environment that provided a non-interactive video did not improve[22]. The interactivity in their study meant allowing students proactive and random access to video content based on queries or search targets. The interactivity shown to be effective for learning in our present study meant prompting the learners to think and make their own decisions. In this study, we conducted a quiz for measuring learning effects immediately after learning with materials and evaluated the learning effects on knowledge acquisition. To assess whether the memory has been fixed, further studies are necessary to clarify the effects on fixing knowledge by carrying out a quiz a few weeks after learning with materials.

Considering the results of comparison between the examination points and the groups by the two-way repeated measures ANOVA with the Bonferroni post

hoc test in this study, state anxiety might increase after reading the scenario and decrease after learning with both interactive- and display-type materials. Unfortunately, in our study there was a significant difference between Groups I and D in trait anxiety. Trait anxiety may be considered to be a tendency toward anxiety. It is difficult to discuss the results of state anxiety between Groups I and D because trait anxiety would differ at baseline. However, trait and state anxiety were correlated, reinforcing the validity of STAI-JYZ responses. In future investigations, trait anxiety should be measured in advance and participants randomly divided into two groups so that the mean score and distribution of trait anxiety in each group are equivalent.

Conclusion

In the field of clinical dental education, interactive materials that incorporate clinical decision making could be effective in knowledge acquisition.

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