RESEARCH ARTICLE

Smartphone use and schema-based learning in dentomaxillofacial radiology practice: a case report from one College of Dentistry

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Objectives: This study investigates the students' satisfaction and awareness of competency towards smartphone use and schema-based learning in dental radiology practice.

Methods: Third year students undertaking a dental radiology practicum at a dental school were divided into two groups: one group received traditional clinical training, whereas the other group used smartphones in classes and received new training using schema assignments. At the end of the course, students' satisfaction with the training and self-awareness of their competency were surveyed, and their achievement was assessed.

Results: Although students' satisfaction with smartphone-based training was generally high, it was less than that of students trained by traditional instruction. However, most students that received smartphone-based training had higher self-scored competency before than after training. The smartphone group scored higher on true/false or multiple-choice questions, whereas the traditional group scored higher on short-answer questions.

Conclusions: Smartphone education with schema based assignment proved to be attractive in dental radiology, but students showed less satisfaction, and need to meet the requirements of evidence-based practice. Although the full use of smartphone education with schema is not recommended in dental education, we think that it could be try to use as a supplementary approach with traditional didactic method to facilitate student's exploration and self-study to cope with rapid change in educational environment.

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Introduction

Radiographic examinations are necessary in dental clinics for diagnosing oral diseases and establishing treatment plans, and the use of panoramic images and CBCT, in addition to intraoral radiography, has increased in recent years.¹ In undergraduate dental education, especially in radiology, clinical procedures are important and audiovisual materials are often used. Therefore, it is preferable to adopt a flipped

learning approach, in which educational materials are provided to students in advance to promote group discussion with lecturers in classes.²⁻⁴ Undergraduate dental radiology education in Korean dental schools is often offered between years two and four and is led by full-time professors who are also trained dental radiologists. Moreover, some joint training with other departments (e.g. at clinical pathological conferences) is also conducted. The lecture materials cover basic aspects of physics and radiation protection, clinical contents of selection criteria of radiographic examination, intra- and extraoral radiography including panoramic

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imaging, lesion interpretation, and radiographic differential diagnosis. Clinical practice consists of acquisition and interpretation of radiographic images from patients, and aims to cultivate the minimum clinical competency of knowledge and skill required for graduation.⁵

In 2016, a White Paper of a radiology curriculum for undergraduate medical education was published in Germany. Its main purpose was to suggest important radiology core principles, so that students can obtain practical knowledge, skills and abilities related to radiology. It is suggested that principles of problem-based learning and teaching concepts such as flipped classroom are highly suitable for competency-based education in radiology related medical courses.⁶⁻⁹ The reason these education methods are appropriate for radiology education is that the concept of “knowing what you do and don’t know” is being suggested as the most important core competence in medical education of the ubiquitous era. Metacognition,¹⁰ which is the understanding of one’s own thought processes, plays important role in enriching this idea—and it can be developed through educationally proven practice and feedback, such as creating a schema for what one has learned from self-study.¹¹

The use of smartphones has increased across all generations and in all countries. Due to its characteristic immediacy and interactivity and also the spread of social networking services, smartphone technology has brought significant changes to mankind. Moreover, this trend has also influenced educational environments, as can be seen in recent cases where various social networking services, including Facebook, Twitter, Instagram, and MySpace, have been used in education.¹²⁻¹⁴

Some studies of smartphone-based training at universities have shown that professors and students receive immediate feedback and interact actively.^{15,16} Moreover, environments where students can learn in a self-directed manner according to their individual interests and motivations are provided to students.¹⁷ Various smartphone-based teaching methods have been researched in the medical field, but no specific case in which this technology was effectively used has been researched.

Rather than systematically inferring and noting patients’ information, students are often known to list questions that have been memorized in the medical education.¹⁸ To overcome this attitude of seeking to resolve patients’ problems through memorization, an education that trains students to collect and judge information systematically within courses is required. Schemas are very effective in organizing knowledge and applying it to cases. Moreover, schemas have two important functions: to serve as frameworks around which students could learn new information and to provide an approach to clinical problem-solving.¹⁹ Education based on clinical presentation requires highly sophisticated problem-solving-based cognitive processes to resolve clinical problems. Thus, the use of

special training methods that utilize schemas should be encouraged.²⁰

Accordingly, we here introduced an attempt at education utilizing schemas to reach educational goals in dental radiology by means of smartphone-based training. Moreover, we conducted surveys to assess students’ satisfaction with the training and their self-awareness of their own competency, and compared these between students that received smartphone-based training and those that received traditional lecture-based training.

Methods and materials

The participants were selected, and the study was subsequently conducted through the methods outlined as follows.

Subjects

In this study, 83 students enrolled in “Preclinic Courses of Dentomaxillofacial Radiology Practice,” which is a required course for third year students in Wonkwang Dental College, were divided into two groups: one group consisting of 40 students who received smartphone-based training, and another group of 43 students who received traditional lecture-based training.

The 40 students in the experimental group who underwent smartphone-based training received focused lectures for 1 week (5 days) in groups of 10, and the training comprised provision of learning materials in advance, schema assignments, group discussion activities, professor feedback, peer-review, and tests (quizzes). During total of 4 weeks, students were trained in other clinics of periodontics, prosthodontics and endodontics in other 3 weeks. Although the students in the control group (lecture-based training group) also received lectures for a time per 1 week regularly, no smartphone-based training or schema-based learning was conducted.

Methods

We aimed to develop training that could consolidate the understanding of radiography and image analysis and could promote the effective clinical reasoning of students who typically received only dental radiology lectures, prior to them starting their own clinical practices. Thus, rather than traditional lectures, we sought to implement instructional methods that promoted the interest and motivation of the students via student-centered education. In this respect, the educational platform used is very important for self-directed learning.²¹ In this study, Google Classroom was used, in order that students using smartphones could receive learning materials in advance and interact with the materials in self-directed learning. This integrative educational solution is optimized for flipped learning, and allows one-to-one communication between students and professors. When

Figure 1 Design of the smartphone-based training with platform of Google Classroom.

this platform is used, professors can effectively manage their students by analysing the students' assignments, grading them easily, and obtaining results statistics. Moreover, video materials, such as those available on YouTube, are effective in discussing various radiographic methods in dental radiology.

Only students who belong to the experimental group were invited to Google Classroom and had access to shared data, and the actual course involved the students tackling the given problem in groups and carrying out their schema assignment. Students in the control group who took part in traditional lectures participated in regular classes only. The two groups had different lecture times and locations, and after 1 week of dental radiology practice, the students took part in other training courses (e.g.: prosthodontics, periodontics), leaving both experimental and control groups with very little time to exchange data. And schema diagram is a process that must be performed independently by individual students, so it is difficult for experimental group to share any information with the control group participating in traditional course. Figure 1 shows the design of the smartphone-based training developed for this study.

Also in classes, small group studies were conducted while the students used Google Classroom along with the professor. Moreover, professor and peers gave feedback on each student's assigned homework prior to the start of the classes. 4 weeks after the course had ended, both the experimental and control groups completed surveys on their satisfaction with the course and their self-awareness of their own competency. Furthermore, those that were in the smartphone-based training group were asked to submit an assignment in which they had to prepare schemas on problem-solving processes during the 1 week focused education. Both the experimental and control groups were also evaluated on their achievements by means of quizzes.

To compare the overall self-awareness of the education and satisfaction with the training, the results obtained from the groups were analysed through an independent samples *t*-test. The *t*-test yielded the following results.

Results

Surveys of satisfaction with training and self-awareness of competency as well as quizzes for investigation of achievement were conducted, and the results were analysed.

For surveys, first, our students' satisfaction with the training was investigated. All participants were surveyed on their satisfaction with the training using a 7-item questionnaire (Table 1). For smartphone-based training participants, nine questions were added to the survey (Table 2). Second, students' self-competency regarding nine competency items that were meant to be achieved during the course was measured before and after the training (Table 3). Third, quizzes were conducted after the classes to compare achievement between students in the experimental and control groups (Table 4). To survey the satisfaction and achieved competency, online surveys were conducted on Google Docs. Quizzes were conducted at the same time in an offline setting in a classroom.

35 individuals from the experimental group (missing data = 5) and 42 from the control group (missing data = 1) were surveyed on their satisfaction with the training and self-awareness of their own participation. On a 5-point scale, the experimental group scored 3.74 in terms of their interest in participation in classes whereas the control group had a score of 4.02. This difference was significant ($p = 0.035$); but no statistically significant difference was found in terms of other opinions.

Table 1 Comparison of satisfaction with the training between the smartphone-based and traditional method-based training groups

Questions items	Mean		Standard deviation		<i>t</i>	<i>p</i>
	Smartphone-based training (<i>n</i> = 35)	Traditional training (<i>n</i> = 42)	Smartphone-based training (<i>n</i> = 35)	Traditional training (<i>n</i> = 42)		
Expression of opinions in classes	3.83	3.86	0.664	0.718	−0.180	0.858
Interest in participation in classes	3.74	4.02	0.505	0.644	−2.145	0.035
Learning and completion of assignments	3.77	3.95	0.690	0.805	−1.049	0.298
Interaction with the professor	3.79	4.14	0.770	0.751	−1.990	0.050
Own participation in classes	3.86	4.12	0.692	0.706	−1.639	0.106
Motivation for further in-depth learning	3.51	3.79	0.702	0.717	−1.670	0.099
Overall satisfaction with the training	3.74	4.00	0.610	0.698	−1.702	0.093

$p < 0.05$.

Through this process, we attempted to induce problem-solving processes in self-directed learning. Next, the participants' satisfaction with smartphone-based training was analysed.

As shown in Table 2, the students were able to gain a better understanding of their learning by means of schema diagram assignments (mean satisfaction score = 3.71).

There were nine questions regarding smartphone-based training, and the students were found to have high satisfaction regarding their overall frequency of use of Google Classroom, their perceived usefulness of Google Classroom in academic activities, and their understanding of previewed materials and assignments. Overall, the students had above-average satisfaction regarding all question items. Moreover, the students also perceived that the schema diagram assignment helped them to understand the clinical thinking required for problem-solving. In this process, students created and submitted a schema diagram as a task to confirm their metacognition. This was conducted as part of the process and procedure for identifying the students' intended

competencies throughout the course. For each lesson, the students created a schema of their problem-solving outcomes in accordance with the metacognition instructional method, and the generated schema was used as a discussion material for each offline classes, for which the instructor provided feedback. The Figure 2 shows a part of the schema submitted by a student.

Next, the pre- and post-training self-awareness of students that received the smartphone-based training, in terms of the nine competency items that were set as the goals of the course, were compared.

Out of nine competency items set as goals by the professors, students perceived that they had improved in eight after the training. In particular, students became able to understand their own treatment and diagnosis capabilities objectively, and were able to consult other specialists when necessary, to diagnose and treat patients based on evidence-based dental knowledge, and to select, conduct, and interpret the necessary tests.

To compare the achievement of the group that received smartphone-based training and the group that received traditional training, a quiz consisting of 25 questions [(12 true/false () or multiple-choice questions and 13 short-answer questions)] was developed and the test results compared by an independent samples *t*-test (Table 4).

No statistically significant difference was found between the groups. However, overall, the experimental group scored higher on true/false or multiple-choice questions, whereas the control group scored higher on short answer questions. This could indicate that students with traditional training receiving higher scores on questions that required memorization.

Discussion

The purpose of this study was to introduce a case in which a smartphone-based training and schema-based learning were applied to a dental radiology course at a dental school. Through the findings, this study aimed to investigate the applicability of online platform in future dental education programs.

Table 2 Participant satisfaction with the smartphone-based training

Question items	Mean	SD
Frequency of use of Google Classroom	3.86	0.733
Communication through Google Classroom	3.31	0.676
Open emotional interaction with the professor or students	3.29	0.957
Usefulness of Google Classroom in academic activities	3.89	0.583
Immediate feedback compared to face-to-face lecture learning	3.40	0.914
Understanding of their learning through the schema diagram assignment	3.71	0.860
Understanding of previewed materials and assignments	3.80	0.719
Previous experience with similar smartphone-based training	3.11	0.993
Motivation for application of smartphone-based classes in curricula	3.54	0.919

SD, standard deviation.

Table 3 Self-awareness of competencies in students that received smartphone-based training (N = 35)

Competency item	Category	Mean	SD	t-value	p-value
Competence in cultivating critical acceptance of medical knowledge and information	Pre-class	3.15	0.755	-3.814	.001 ^a
	Post-class	3.72	0.719		
Competence in continuously participating in training to maintain optimum diagnosis and treatment performance	Pre-class	3.40	0.694	-2.915	.006 ^a
	Post-class	3.80	0.632		
Competence in objectively understanding my diagnosis and treatment capabilities and consulting other specialists when necessary	Pre-class	3.20	0.686	-4.936	0.000 ^b
	Post-class	3.76	0.496		
Competence in cultivating the ability to obtain and maintain patients' trust	Pre-class	3.25	0.780	-2.420	0.021
	Post-class	3.60	0.774		
Competence in diagnosing and treating patients based on evidence-based dental knowledge	Pre-class	3.28	0.788	-4.842	0.000 ^b
	Post-class	3.85	0.648		
Competence in writing, issuing, and managing medical documents	Pre-class	2.87	0.912	-3.174	0.003 ^a
	Post-class	3.31	0.866		
Competence in understanding patients' main concerns and obtaining their overall medical history	Pre-class	3.31	0.866	-2.944	0.006 ^a
	Post-class	3.77	0.598		
Competence in preparing diagnosis and treatment records related to tests and diagnosis	Pre-class	3.14	0.845	-3.311	0.002 ^a
	Post-class	3.6	0.603		
Competence in selecting, conducting, and interpreting necessary tests	Pre-class	3.11	0.900	-3.636	0.001 ^a
	Post-class	3.71	0.621		

SD, standard deviation.

^a $p < 0.01$.^b $p < 0.001$.

This study shows that the students represent a high awareness of their understanding of learning material through the schema diagram assignment and improved attitude of self-directed learning. However, when the overall satisfaction with training was compared, the students who received smartphone-based training reported less satisfaction in terms of their interest in participation in classes than those who received traditional training. The reason was investigated through an additional focus group interview; students were found to feel more comfortable with the traditional lecture-based teaching and were unaccustomed to smartphone-based training. Furthermore, the lack of immediate feedback by the professor in this form of training also reduced the students' satisfaction. It may be that insufficient time for self-directed learning was allowed, although the students received many assignments during the smartphone-based training. This results implicated considerable debate about smartphone-based education, and attitudes towards the approach vary considerably. Additionally, a lack of evidence supporting the superiority of

smartphone education over traditional methods should be emphasized, although smartphone education seems to be innovative and attractive, because previous study about smartphone is rare.

In addition, the satisfaction may have been lowered because the students' expectation of their interaction with the professor was not met, although smartphone-based training is often expected to involve much interaction with professors.

A previous study also suggested that professors should improve their teaching methods further to enhance medical education, including competency training and evaluation.²² As such, professors who want to use smartphone-based training should first improve their expertise. Furthermore, in order to increase students' acceptance of and adaptability to new, unfamiliar teaching methods, previous education on the use of smartphones and platforms, such as Google Classroom, and preparation of schema diagrams is necessary. Therefore, professors need to develop their own competency to bring about effective training.

Table 4 Comparison of the groups' quiz results

Category	Mean		Standard deviation		t-value	p-value
	Smartphone-based training (n = 40)	Traditional training (n = 43)	Smartphone-based training (n = 40)	Traditional training (n = 43)		
Comparison of overall quiz results	58.75	60.14	2.627	1.856	-0.437	0.663
True/false or multiple-choice questions	28.10	26.97	6.688	6.653	0.757	0.451
Short-answer questions	30.10	33.67	11.982	9.257	-1.527	0.131

 $p < 0.05$

Interpretation of Periapical (PA) Radiograph: about observation of healing process of periapical lesion after the endodontic treatment

Figure 2 An example of schema diagram of radiographic interpretation (4 day assignment) on the healing process of periapical lesion. PA, periapical.

Also, this study investigated students' perceived competency developed in a smartphone-based class through self-reported competency evaluation. Among the nine competency items that were set as goals in the present study, students' perception of their own competency improved significantly after the class, as compared to before the class, in eight competency items. This is likely related to the schema diagram assignment used in the training. Students confirmed that schema diagrams helped to improve their understanding of how to resolve problems. Moreover, they also reported that their experience of active learning through critical thinking, rather than assignments focused on filling out set amounts, helped them to remember the study material longer. However, since the students were not used to this type of instruction and had no previous experience of writing schemas, the assignment was not sufficient to induce deeper thinking. Moreover, since the training was relatively short (1 week), it will be necessary to develop long-term schema-based education systems.

According to a finding consistently made in research in education over the past 20 years, students should acquire self-directed learning for their own academic achievement.²³ Furthermore, to evaluate students' clinical reasoning strategies in medical education, professors should provide students with opportunities to learn the process of organizing knowledge in clinical settings.²⁴ Therefore, dental radiology clinical practice should also focus on the use of higher cognitive skills that allow students to approach patients' problems systematically. Compared to other dental classes, dental radiology clinical practice mainly consists of radiograph acquisition and image interpretation centered on real clinical cases.

Thus, it is imperative to provide radiographs to the students in advance, to give assignments on active self-directed learning and problem-solving in image analysis, and to apply training methods involving peer-review or professor feedback. Accordingly, this study emphasized the importance of education that organizes and systematizes knowledge, rather than memorization-based education, and encouraged students to confirm their clinical reasoning and problem-solving through schema-based assignments. This may facilitate the ability of clinicians to resolve their patients' problems successfully in future.^{25,26}

As a result of this study, the schema diagram education performed by the students provide a contextual understanding of the students' performance in problem-solving. It is important to receive feedback during the self-monitoring process and on the process itself.²⁷ In this study, students are given the opportunity to solve the problem and prepare a schema diagram, so they can metaidentify the problem-solving process on their own and organize their knowledge—after the submission of the assignment, feedback will be given by the instructor through discussion. The additional questionnaire given to the students about schema education showed that the students found it helpful in sorting out the contents of the lecture as opposed to memorization-oriented studying, and felt that their participation in the learning activities.

Important themes in undergraduate education in dental radiology include appropriateness of selection criteria of radiographs, understanding of radiograph acquisition, and cultivation of the ability to analyse radiographs. During 1 week course of dentomaxillofacial

radiology practice course in this study, students used smartphone education to learn principles of radiography such as localization of intraoral X-ray taking, ghost image formation of panoramic taking. We also could reaffirm the principle of radiographic image interpretation following step-by-step analysis of radiographic characteristics such as lesion shape, internal structure, border, effect of surrounding structure, and tried to categorize different lesion (e.g. inflammatory or tumorous nature). For the discussion of topic of selection criteria of radiographic examination, students should read the articles regarding the concept of justification and optimization related to radiation protection and should submit of schema diagram in advance.

Traditional didactic lecturing is often criticized but still constitutes a major mode of teaching in most dental courses. Even with the introduction of new methods such as problem-based learning, team-based learning, and the use of simulation when teaching dental students, the net effect has been proved to be limited in previous studies. One of such innovative method is to use digital education using smartphone with schema-based assignment, but this method has yet to meet the requirements of evidence-based practice. We think that although the full use of smartphone education with schema is not recommended in dental education, it could be effectively used as a supplementary approach with traditional didactic method to facilitate student's exploration and self-study, to cope with rapid change in educational environment.

This study had several limitations. First, the study was conducted in only one dental radiology class. Moreover, although the students were in their third year with

some background in dentistry, they still had no previous experience with smartphone-based education. Therefore, the study was conducted while the students were unused to the new method, and this exerted a significant influence on their satisfaction. As a result, only surveys on self-awareness of competency were conducted, and the professors were unable to evaluate the students' achievement in terms of their true competency. Thus, it could not be confirmed whether the students' competency improved in the various learning outcomes. Future studies would need to develop more detailed evaluation criteria for the competency items that are meant to be achieved through training and to evaluate these competency items in order to compare and evaluate students' achievement.

Conclusions

The dental radiology schema education using smartphone suggested in the present study is not a method often used in dental education, and its effects have not been verified. Nevertheless, the training requires the interest of dental educators of the current generation as a new teaching method that could be introduced in preparation for the fourth industrial revolution for dentomaxillofacial radiology practice.

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