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Effectiveness of Fully Remote Practical Training in Dental Education: A Case Study Using Video Conferencing and Communication Tools for the Preparation of Removable Partial Dentures

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ABSTRACT

Objectives: This study aimed to evaluate the effectiveness of fully remote practical training for the preparation of removable partial dentures, using the video meeting platform Zoom and the communication app. LINE.

Materials and Methods: Remote training was applied for one student using Zoom and LINE at the same time as in-person training for the rest of the class. Consumable and instruments needed were delivered to the student subject to remote training in advance.

The student's work was assessed in front of a web camera, at a pre-determined checkpoint during each step. The actual appliances were then mailed to the instructors and re-evaluated. The extent of agreement among the assessors for the video-based and direct evaluations, as well as the extent of agreement between the video-based and direct evaluations were calculated.

Results: The introduction of Zoom facilitated mutual communication between the student and the instructors. LINE has proven beneficial for practical training. A fully remote practical training class can be conducted smoothly by assigning a dedicated instructor for remote training. The K coefficient for agreement between monitor-based and direct evaluations was 0.704 ± 0.12. The survey results indicated that this practical training style was effective in enhancing knowledge and skills.

Conclusions: Fully remote blended learning practical training is feasible using Zoom and LINE; however, the tasks to be conducted must be carefully selected. This study is a case report of a single student; thus, future studies should involve fully remote training of small groups to evaluate its educational effectiveness.

Keywords: COVID-19, Partial denture, Fully remote practical training, Video meeting system, Communication applications, Dental education.

1. Introduction

Dental lectures, including preclinical lectures and technical training for undergraduate students, are traditionally conducted in-person. However, the outbreak of coronavirus disease in 2019 (COVID-19), a highly contagious disease, has led to significant changes in the conventional teaching methods and the adoption of online teaching and learning in different disciplines (1). Several universities have attempted to implement remote learning (2-8) using e-learning systems and to video meeting systems, such as Zoom (Zoom Video Communications, San Jose, CA, USA) (6,8-10). Studies evaluating the outcomes of remote classes have revealed that compared with in-person learning, online learning has the potential to enhance the knowledge and skill levels of undergraduate students (6,7,11). For instance, Inamochi et al. reported that remote flipped classrooms are more effective than onsite lectures in terms of facilitating knowledge acquisition (10). Garrison et al. and Fodeh et al. demonstrated the effectiveness of blending learning (BL), a combination of face-to-face learning and remote learning, as an education method (12,13). BL enables students to review online materials at their own pace, seek clarifications during in-person classes, and engage in deeper discussions. Furthermore, it enables instructors to focus on advanced instruction and activities during in-person sessions, thereby enhancing efficiency. BL has yielded successful and effective outcomes in the domains of endodontics (14), orthodontics (15), periodontics (16), and the application of local anesthesia (17).

The introduction of virtual reality (VR) dental simulators into the field of dental education to facilitate remote learning has demonstrated effectiveness in improving the knowledge and practical skill levels of the students (18,19). However, VR devices for use at home by the students could not be prepared before commencing practical training. Therefore, a BL-type class was designed in the present study to facilitate instructors to simultaneously conduct fully remote practical training *via* Zoom for one student and in-person practical training for the remaining students. Few studies have reported the use of a remote system to impart practical training in the field of dental education.

This study aimed to evaluate the effectiveness of fully remote practical training in dental education, particularly concentrating on the preparation of removable partial dentures. The study should assess the applicability and limitations of implementing fully remote practical training in dental education.

2. Material and Methods

2.1 Class Arrangements

Remote classes for the fabrication of removable partial denture were arranged for one fourth-year student at the Tohoku University School of Dentistry in 2021. Consumable supplies used for fabricating removable partial dentures, such as wax, instruments, and articulators, were delivered to the student in advance. Setting up the mannequin and rotary cutting instrument would be difficult for the student to perform on their own; therefore, tasks involving their use were omitted. However, an oral assessment was conducted to evaluate whether the student had gained the necessary knowledge regarding the procedures to be followed while performing these omitted tasks when the students attending the in-person classes performed the same tasks. The total duration of the training was 36 hours. Table 1 summarizes the tasks performed in the in-person and remote classes.

BL was implemented while conducting the training classes. Manual and video teaching materials, such as interview videos and survey questionnaires, were distributed electronically in advance (Table 1). All students had free access to the video teaching materials. Furthermore, an environment wherein students could study at their own pace was established. The students who attended in-person classes received a direct demonstration, explanation, and video teaching materials pertaining to the assignment of the day from the instructor before completing the assignment. These students were given instructions during classes and were evaluated by the instructor at pre-determined time-points while fabricating the appliance. The student attending remote classes received instructions through the screen-sharing function of Zoom (Zoom Video Communications, San Jose, CA, USA) at the same time as the in-person classes; the evaluations were also conducted at the same pre-determined time-points. The paid version of Zoom, which does not restrict usage to 40 min, was used to conduct remote classes. The student attending remote classes received a demonstration and explanation of the assignments given by the instructor along with those who attended the in-person classes. Communication with the instructor was established using the breakout room function of Zoom. The student was instructed to use the web camera and the communication tool LINE (Line Corporation, Tokyo, Japan) to present the fabricated appliance at each check-point of the fabrication process. The instructor assessed the assignment and noted the points requiring correction using a check sheet. Two instructors participated in the remote classes throughout the training course. The web camera on the personal computers used by the instructors and student had a resolution of approximately 2 million pixels. The mobile phones used by the instructors and student for Line had a resolution of approximately 12 million pixels.

Table 1: Assignments in face-to-face and remote practical training classes supplied as video teaching materials and direct demonstrations

Assignment		Face-to-Face	Remote
1	Problem extraction from interview videos	○	○
2	Preliminary impression taking	○	Video learning
3	*Planning of prosthodontic treatment	○	○
4	Preparation of research model	Distribution of the finished item	
5	Surveying	○	Video learning
6	Preparation of individual trays	○	○
7	Pre-prosthetic treatment (rest seat preparation)	○	Video learning
8	Precise impression making using individual tray	Demonstration video only	
9	Preparation of working casts	Distribution of the finished items	
10	Preparation of duplicated models	Distribution of the finished items	
11	*Waxing up of metal frame	○	○
12	Investing, casting, and polishing of metal frame	Demonstration video only	
13	Preparation of record base with occlusion rim	○	○
14	Maxillomandibular registration	○	Video learning
15	Articulator setting	○	○
16	*Wire bending	○	○
17	*Tooth arrangement	○	○
18	*Gum forming	○	○
19	Investing, wax elimination, and resin filling	Demonstration video only	
20	Mold breaking, denture adjustment, and denture polishing	Demonstration video only	
21	Denture insertion	Demonstration video only	
22	Denture adjustment	Demonstration video only	

○: Performed by students, *: Evaluated item.

2.2 Evaluation of the Fabricated Appliance

In addition to the assessments conducted at pre-determined check-points during the fabrication process, (1) wire bending, (2) tooth arrangement and gum formation, and (3) waxing up of the RPI clasp were evaluated as measures of the degree of completion. The student attending remote classes was instructed to record the fabricated appliance from all angles using a video camera and a camera and send these images to the instructor through e-mail. Three assessors, comprising one dental technician with over 4 years of experience and two dentists with over 8 years of experience (hereafter referred to as A, B, and C, respectively), evaluated the images using an evaluation sheet (full mark: 46 points). The actual appliances were mailed to our department after 2 months and re-evaluated using the evaluation sheet. The agreement among the assessors for the evaluation criteria was evaluated in advance using a different model. The extent of agreement among the assessors for the video-based and direct evaluations, as well as the extent of agreement between the video-based and direct evaluations, were calculated by cross-tabulation. The weighted kappa coefficient was determined based on these tables in accordance with the method by Kundel and Polansky (20). K-values of <0, 0–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.00 indicated poor, slight, fair, moderate, substantial, and almost perfect agreement, respectively (Table 2). A questionnaire survey was administered to students and instructors who conducted the remote practical training. Tables 3 and 4 present the questionnaires administered to the instructors and students, respectively.

Table 2: Kappa coefficients for the observers and monitor-based *vs.* direct in-hand evaluations

Assessor	**K coefficients**	
	Monitor-based evaluation	Direct evaluation
A vs. B	0.36	0.44
A vs. C	0.28	0.32
B vs. C	0.51	0.71
	K coefficients (monitor-based vs. direct evaluation)	
Average	0.70 ± 0.12	
A	0.76	
B	0.79	
C	0.56	

Table 3: Questionnaire for the instructors (n=2)

Items	**Strongly agree**	**Agree**	**Neutral**	**disagree**	**Strongly disagree**
Do you think that the introduction of a communication application system like Line is useful for matching the imaginations of the completed form of appliance between instructor and students?	2				
Do you think that the photos acquired using a camera for the assessment of the appliance is a useful method in remote training classes?	2				
Do you think that the images acquired in video format for the assessment of the appliance is a useful method in remote training classes?	2				
Do you think it is possible to provide students with the same level of instruction in remote learning as in direct face-to-face classes?			1	1	

Is remote practical training more stressful for instructors than face-to-face practical training?	1		1		

How many students are you teaching synchronously in remote training classes using Zoom system?
Both described Maximum 4.

If you have any comments or opinions, please feel free to share them.

- Zoom was a useful tool to communicate with students, but the instructions were provided orally through Zoom. Thus, the ideal images were not matched between instructor and student. In contrast, the Line software is able to acquire photographs and share the images; thus, it is useful for providing detailed instructions.
- For the assessment, the photo of the appliance was acquired by students. However, the three-dimensional morphology of some parts was difficult to determine and assess in still photographs depending on their angle. The evaluation was possible by video recording, as all parts of the objects could be seen. However, the focus of video record is also important.
- It was challenging for the instructor to conduct remote and in-person classes simultaneously.
- It felt stressful to guide in-person students while simultaneously editing and sending photos to remote students to provide instructions.
- A dedicated instructor to take care of the remote students is needed.
- The instructor has to keep watching the monitor constantly, since it is uncertain when the remote student might reach out. It would be helpful to have a clear signal for when either side wants to initiate contact.
- A quiet environment where the sound from the computer can be clearly heard is necessary, as background noise in in-person classes often drowns out the audio of remote practical training.
- It was difficult to convey delicate techniques through a screen.

Table 4: Questionnaire for the student (n=1)

Items	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Do you think this remote training class using Zoom and Line helped you understand the procedures involved in the fabrication of removable partial dentures?		1			
Do you think that the introduction of a communication application system like Line will aid instructors?	1				
Do you think that the introduction of a video meeting system like Zoom will aid instructors?	1				

Do you think that it is possible to provide students with the same level of instruction through remote learning as in-person practical training?			1		
Do you prefer remote practical training to in-person practical training?				1	
Is remote practical training more stressful for instructors than in-person practical training?			1		

If you have any comments or opinions, please feel free to share them.

- There were times when the instructor on the screen did not notice me, and the practical work could not progress. I felt stressed at those times.
- My practical training went smoothly after the special instructor was assigned.
- A quiet environment where the sound from the computer can be clearly heard is necessary, as background noise in in-person classes often drowns out the audio of remote practical training.
- It was sometimes difficult for me to understand the oral instructions provided by the instructor with Zoom system. However, after the introduction of Line system, the instructions were easy to understand, as the corrections were written directly on the photos.
- It is difficult to align the model with the focus of the camera.
- Having a reference model that can be physically handled, rather than the one displayed on a monitor, would be beneficial.
- I approached the remote practical training with a sense of tension, as I could not receive direct modifications to the physical model from the instructor. Therefore, I thoroughly reviewed the content of the training using e-learning materials in advance before engaging in the practical exercises.

3. Results

Remote practical training was conducted, as depicted in Figure 1. The student was instructed to photograph the fabricated appliance using a web camera at each check-point. The instructor evaluated the appliance using the photographs and provided further instructions. However, the student was not able to gain a sufficient amount of knowledge owing to the difficulty in acquiring in-focus images of the appliance (Figure 2a) and the limitations to the oral instructions provided through Zoom. This finding indicates the importance of students and instructors sharing good-quality images of the completed form of the appliance. Consequently, the student was instructed to send photographs of the appliance being fabricated using the communication tool LINE, which facilitates instantaneous processing of photographs (Figure 2b), while maintaining a connection through Zoom. Instructions regarding the specific points to be corrected were provided by the instructor using these photographs (Figure 2c). This enabled the instructor to provide clear advice to facilitate the identification of the specific points to be corrected by the student.

Depending on the angles, the three-dimensional (3D) morphology of some regions of the fabricated appliance was difficult to determine and assess using still photographs.

Figure 1: Scenes of a remote training class. Left: A student performing wire bending. Right: An instructor demonstrating wire bending

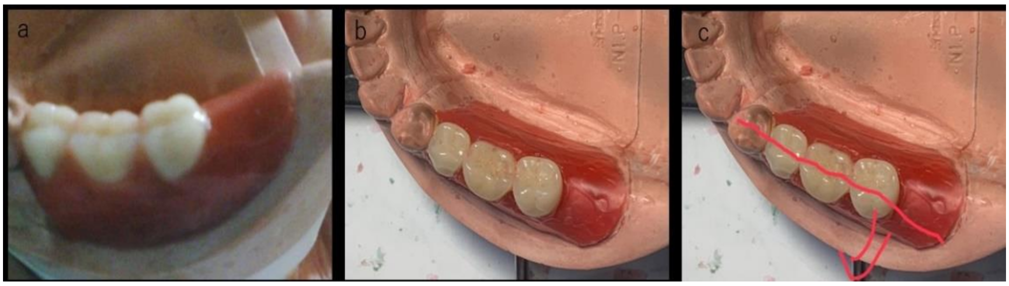

Figure 2: (a): Photographs of an appliance being prepared acquired using a web camera. (b): A photograph sent through LINE. (c): Instruction of correction given on the photograph

However, video recordings enable the visualization of all regions of the appliance, thereby enabling the instructor to complete the evaluation. The scores for monitor-based and direct evaluations of the models were 39 ± 2 and 35 ± 1, respectively. The average score of the 51 students who attended in-person classes was 40 ± 3 (minimum and maximum of 30 and 43, respectively). Table 2 presents the Kappa coefficients. The kappa coefficient for monitor-based and direct evaluations was 0.704 ± 0.12. The Kappa coefficient for the assessors with over 8 years of experience was categorized as 'Moderate' or 'Substantial,' whereas that for the assessors with 4 years and 8 years of experience was categorized as 'Fair' or 'Moderate.' The Kappa coefficient for the monitor-based evaluation was lower than that for direct evaluation. Figures 3 and 4 present the results of the instructor and student questionnaires, respectively.

4. Discussion

4.1 Zoom and Breakout Rooms

A BL environment was created to enable students attending remote classes to access video teaching materials that provide guidance regarding each step in the fabrication of removable denture at any time and communicate with the instructor using Zoom. The survey revealed that the use of Zoom for communication received positive feedback from the students and instructors. The findings of the present study suggest that the introduction of Zoom into remote practical training classes led to the creation of an environment similar to that of traditional in-person practical training classes. The intimate communication environment provided by the breakout room function of Zoom facilitated smooth communication between the instructor and the student during remote practical training class. Moreover, the use of the breakout room ensured the confidentiality of conversations with students. Mansoor et al. reported that students provided highly positive feedback regarding the use of Zoom (8). Live lectures recorded synchronously using Zoom were preferred over non-recorded live lectures in the study conducted by Chen et al. (9).

Instructors may find it challenging to provide effective guidance to students attending remote classes solely through verbal instructions, without an actual model present, while conducting in-person classes simultaneously. Consequently, the quality of the instructions provided may become insufficient for both groups of students. The survey revealed that the instructors found it difficult to guide in-person students while simultaneously editing and sending photos to remote students to provide instructions. Therefore, dedicated instructors were assigned to participate in remote practical training classes to mitigate this issue. Notably, the lags in learning were resolved as monitoring the progress of the assignments became possible (Figure

1). This finding indicates that appointing a dedicated instructor enables smooth progression of remote training sessions.

4.2 Photographic Documentation

Detailed instructions regarding the specific points to be corrected could not be provided using Zoom; however, it facilitated two-way communication between the student and instructor. The instructors and student reported difficulty focusing on objects when using the webcam on the computer at each check-point. The LINE application, which allows the use of mobile phone cameras and image editing, was introduced to address this issue. Only verbal instructions can be provided using Zoom; however, the use of LINE enabled the annotation of the same image with corrections and questions. This enabled the instructor to provide detailed advice. The use of high-performance webcams with high resolution or an autofocus function will help resolve the difficulty in focusing in the future. The ability to share and edit the same image to indicate the points requiring corrections is essential in remote practical training. The survey revealed that one instructor could guide a maximum of four students; this could be attributed to the complexity of editing photos while communicating using a monitor.

4.3 Assessment of the Completed Appliances

Adequate evaluation of the appliance could not be performed using only photographs, as the photographs were acquired by the student rather than by the evaluators. This results in the key areas not being captured in the photographs owing to the students having an insufficient understanding of the evaluation criteria. Video recordings of the appliances were acquired from all angles using a mobile phone camera to address this limitation; this enabled the evaluation to be completed properly.

Three-dimensional scanners and printers have been introduced into the field of dentistry in recent years (19,21). Schepke et al. performed a 3D digitally assisted assessment after scanning a region prepared for a retentive crown and reported that it is useful and effective for providing feedback (21). The present study was conducted during the COVID-19; thus, a 3D scanner could not be acquired. However, the instructors could assess the appliance from any angle, similar to traditional hands-on evaluation, by creating 3D images or physical models using a 3D printer.

The score for monitor-based evaluation was higher than that for direct evaluation in the present study. Yamamoto et al. reported that the tactile characteristics of an object cannot be fully conveyed through the information displayed on a monitor (22). The perception of the three-dimensionality, size, and texture of the object is influenced by visual information and tactile input (23). Thus, the inclusion of tactile information in the direct evaluations may have led to variations from monitor-based evaluation.

The K coefficient for the agreement between monitor-based evaluation and direct evaluation was ‘substantial.’ This finding indicates that monitor-based evaluation is practically equivalent to direct evaluation. Notably, the results of the monitor-based evaluation did not bias the results of the direct evaluation of the actual model owing to the 2-month gap between the evaluations.

This finding is particularly encouraging, as it suggests that remote evaluation using video cameras is a reliable and effective method for grading appliances fabricated by students based on instructions received during remote technical training classes.

Notably, the K coefficient for the monitor was lower than that of the direct evaluation. This finding is in contrast with that reported by Schepke et al. (21), that conducting digital assessments can lead to fewer differences being observed among instructors in terms of opinion, thereby increasing the inter-rater agreement for assessment. The object was assessed using a digital measurement device in Schepke et al.’s study, whereas in the present study it was assessed on the monitor with the naked eye. Achieving complement agreement among the assessors in terms of the evaluation criteria is challenging (24,25). The variations observed among the evaluators who completed the assessment without digital tools may be attributed to insufficient calibration and the influence of evaluators’ experience (26), or that the evaluators were not being accustomed to conducting evaluations using digital screens. Liu et al. reported that users who are less experienced in the use of digital tools may find evaluations more challenging owing to limitations in tactile and spatial feedback (27).

The scores of the appliances fabricated by the student who attended remote training classes were lower than those of the appliances fabricated by students who attended in-person classes. In fact, some mistakes in the appliances fabricated by the students who attended in-person classes were directly corrected by the instructors. However, owing to the nature of remote learning, the instructor could not directly intervene in the fabrication process, and the appliance was fabricated entirely by the student without any corrections being made by the instructor.

4.4 Remote Practicum *vs.* In-person Practicum

The survey revealed that the students considered the traditional in-person practicum superior to the remote practicum. This could be attributed to being provided with a reference model that could be handled physically, rather than a model displayed on a monitor. Thus, preparing physical demonstration models that can be directly observed and handled, rather than relying solely on images, may be more beneficial while conducting emergency remote practicums in the future. Furthermore, the responses to the questionnaire revealed that instructors found it difficult to convey delicate techniques through a screen. These finding are in line with previous studies. Fodeh et al. revealed that 89% of students reported that clinical and practical courses could not be provided online (13). Furthermore, 78.6% of students were against replacing traditional lectures and live demonstrations with online tutorials. Schlenz et al. reported that 36.8% of students favored face-to-face learning over remote learning (6). The student attending remote classes preferred traditional in-person practical training to practical remote training in the present study.

The survey also revealed that the student who attended remote classes thoroughly reviewed the content of the training using e-learning materials before completing the practical exercises, indicating that remote practical training using e-learning is beneficial. Moreover, 82.6% and 72.3% of students receiving clinical and pre-clinical training, respectively, preferred a combination of online and traditional teaching, while more than a half disagreed with the notion that e-learning was not beneficial (13).

4.5 Task Selection

Ready availability of information transmission and reception devices, such as cameras and personal computers, will aid in conducting remote lectures relatively easily (6). However, specialized instruments, such as mannequins, rotary cutting machines, and casting furnaces installed in the technical training room or examination room, are used during in-person technical training. Avramova et al. reported that 80% of students expressed dissatisfaction with online teaching sessions and responded that this would have negative effects on their education (28), as inability to attend practical classes in environments simulating preclinical settings would affect their performance in clinical disciplines.

Technical training using such instruments cannot be imparted if students cannot physically attend training sessions; thus, techniques that require the use of large specialized instruments, such as casting furnaces and mannequins, were omitted from the process for fabricating removable partial dentures in the present study. Furthermore, demonstration videos and live feed of the processes performed by the instructor were provided as an alternative teaching method. Remote practical class may become feasible if tasks using specialized instruments, such as cavity preparation and the preparation of an abutment tooth, can be performed using a VR system. Notably, most students appear to be comfortable with technological adaptations of didactic curriculum (29).

4.6 Full Remote Practical Training Feasibility

Introduced by Tsakeni as a component of e-learning environment, the community of inquiry (CoI) framework (7) comprises three components: teaching presence (the role of educators or facilitators in designing and structuring the learning environment and supporting and guiding the progression of learning), cognitive presence (the process through which learners access information, think critically, and construct knowledge), and social presence (the ability of learners to express themselves as connected individuals, exchange opinions freely, and function as members of a community). These three types of presence have been used as a framework to evaluate the experience of online learning. DeNoyelles et al. (30) reported that instructors can design these three types of presence such that they elicit effective and productive discussions in online classrooms. Freely accessible videos encourage autonomous exploration and analysis of information, as well as problem recognition, by the students. The use of Zoom facilitates two-way communication and trust-building between students and instructors, whereas the use of LINE enables instructors to provide feedback on the progress and achievements of the learners. Thus, the practicum system used in the present study represents a COI framework for remote practical training.

Recent advancements in the fields of VR and augmented reality (AR) technologies have enabled remote practicums to be conducted in various styles (7,19). Previous studies have explored the effects of using VR in remote classes. A systematic review indicated that VR simulators can effectively improve the level of theoretical knowledge and practical skills of dental students (18). AR enabled learners to obtain a 3D visualization of science, technology, engineering, and mathematics phenomena in the study conducted by Mystakidis et al (31). West et al. recommended enhancing the authenticity of online laboratories by combining VR and AR technologies (32). Lingbo et al. developed a fully remote practical teaching and learning method using the DenTeach system, a portable teaching-learning platform, and reported its ability to help students understand. This method yielded significant improvements in terms of tool handling, smoothness of motion, and steadiness of operation (33).

Removable partial dentures, including a denture base, artificial tooth, and metal clasp, were fabricated using Computer Aided Design (CAD) software, a 3D printer, and a laboratory scanner in the study conducted by Akiyama et al (34). These tools can be introduced to fully remote practical training in the future; however, this would require a high investment for the acquisition of equipment and the establishment of clear evaluation criteria for the corresponding artefacts.

4.7 Long-term Impacts on Skill Acquisition

Compared with in-person training, a more dedicated support system was established for remote learning through the recruitment of full-time instructors and the incorporation of Zoom and LINE to facilitate mutual communication. Remote practical training using this system could be an effective alternative for certain tasks. However, the acquisition of clinical skill by the students may be affected by their abilities. The students participating in the present study were relatively skilled; this enabled smooth progression of the remote practical training sessions. However, the inability of the instructor to make direct adjustments to the model may hinder skill acquisition if the students are not skilled.

4.8 Limitation and Future Research

This study had some limitations. First, since only one student was involved, the results of the study may have been influenced by the abilities of the student, potentially introducing a bias. Second, the one-to-one teaching method used in the present study differs from traditional setting, which involves one instructor instructing a small group of students, in terms of instructor dedication. This could affect the workload of the instructor, student satisfaction, and skill acquisition levels. Third, although the present study compared the outcomes of remote work with those of in-person training, statistical analyses were not conducted. Therefore, the impact of this training style on skill acquisition remains unknown. Thus, this case study only serves as a guideline for future research on fully remote practical training. Further studies involving small-group remote practical training, with three to four students per instructor, must be conducted to evaluate skill acquisition more comprehensively.

5. Conclusions

The use of Zoom in remote practical training was effective in enhancing mutual communication between the student and instructors and the use of breakout rooms was also effective. However, its use for providing detailed instruction was less suitable owing to the its reliance on verbal instructions. Software such as LINE demonstrated ability to improve practical training; such applications enable the sharing of the same images, thereby facilitating detailed guidance. A fully remote practical training class can be conducted smoothly by assigning a dedicated instructor for remote training. Fully remote BL-based practical training using Zoom and LINE is feasible; however, careful consideration is needed regarding the tasks to be assigned.

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Conflict of Interests

None of the authors have any conflict of interests to declare.

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