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ORIGINAL ARTICLE

Virtual clinic: Applying technology to expand dental school walls

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Abstract

Dental education traditionally requires the use of dedicated fixed preclinic facilities to provide clinically relevant experiences to support the development of dexterity, critical thinking, and self-assessment skills that are essential for excellent patient care. As a result of the social distancing guidelines instituted at the height of the COVID pandemic, dental education was severely affected when education pivoted to remote instruction and had significant restrictions on in-person training. This study evaluated a novel application of modern technology to allow students to perform clinically relevant hands-on exercises away from dental school and, most importantly, receive feedback on their performance as an aid in their development. Student surveys and a comparison of pre- and post-COVID grades were used to evaluate the effectiveness of the virtual clinic to support remote dental education.

KEYWORDS
distance learning, faculty feedback, operative, predental, teaching methods

1 | INTRODUCTION

Competent technical skills are necessary to allow students to progress toward clinical proficiency and excellence and allow them to graduate to lifelong learning and safe practice of general dentistry. These hands-on skills depend on procedural repetition associated with the ability to identify and correct mistakes in the process and, are normally taught in the simulation laboratories (preclinic). The development of these skills require expert coaching and guidance so they are consistently reinforced and improved during student's supervised clinical care.

The unprecedented COVID-19 pandemic created significant challenges for dental schools to teach hands-on clinical skills. The changes in onsite, in-person preclinic, and clinic operations significantly impacted the number of potential opportunities available for students to develop their manual dexterity, critical thinking, and self-assessment skills that are critical for excellent patient care.

A number of reports have evaluated a variety of online distance learning tools. One group reported on the relative success of distance learning techniques for orthodontic residents by using recorded interactive seminars and video

conference follow-up discussions for in-office continuing education.[1] The participants reported that it was an enjoyable, effective way to learn, and that they would like to participate in this type of learning in the future. One systematic review of teledentistry for education evaluated the impact of tele-education in the field of orthodontics.[2] The results showed that orthodontic distance learning is an effective but complementary element, with no significant differences, to the traditional method of teaching. Both of these studies reveal that participants see the value in these techniques and appreciate their potential impact.

A survey of eight countries was done to determine the current status of online learning tools being adopted at dental schools and the barriers that thwart the potential of adoption of these tools.[3] The results showed that many online learning tools are being successfully adopted at dental schools, but computer-based assessment tools are the least successful.

The existing distance learning tools primarily focus on information dissemination and transfer as opposed to hands-on skill development. Remote communication systems, such as Zoom (Zoom Video Conferencing, Inc.), Skype (Microsoft), and BlueJeans (Verizon), allow for effective person-to-person communication from remote locations. However, no existing platform was identified for providing hands-on exercises to be completed with a remote communication capability.

The significant reduction in onsite, in-person spaces for use in dental school preclinic facilities instigated the development of the Michigan Virtual Clinic. This project developed, implemented, and evaluated a virtual clinic environment to create opportunities for hands-on exercises to be completed remotely from the dental school facilities, while providing synchronous and asynchronous student–faculty assessment and feedback using remote communication. The Michigan Virtual Clinic activities attempted to mitigate the loss of student in-school preclinic opportunities by allowing the students to participate in clinically relevant exercises that would continue to develop manual dexterity, reinforce operator hand skills, and clinical judgment remotely from the dental school.

2 | METHODS AND MATERIALS

The Michigan Virtual Clinic course assessment was submitted to the Institutional Review Board (IRB) at the University of Michigan and considered a project exempt from IRB monitoring as it involved an anonymous student evaluation of educational processes, and the evaluation was not a consideration in the student's course grade. Exempt projects are not assigned HUM numbers.

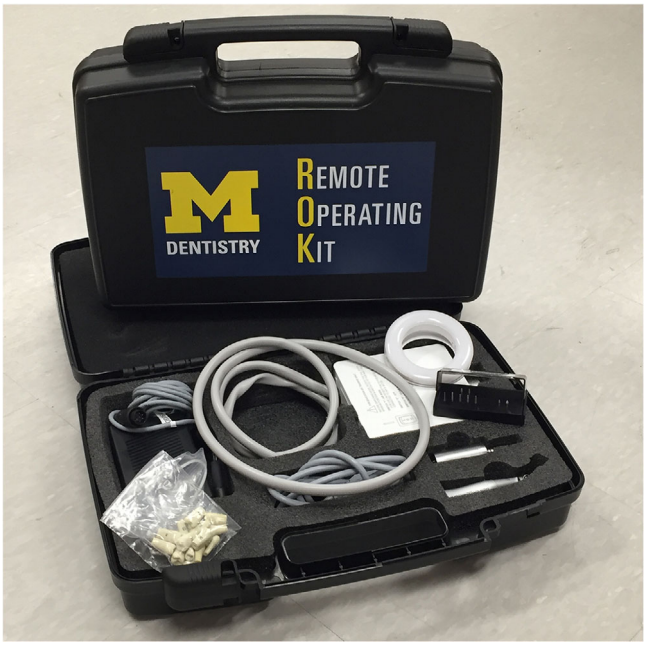

FIGURE 1 The portable case for the remote operating kit (ROK) included the handpiece motor and attachments, supplemental light for the iPad, bur block and diamonds, and replacement typodont teeth for the virtual clinic exercises.

The Michigan Virtual Clinic environment involved three key elements; equipment to complete hands-on exercises remotely from the School of Dentistry preclinic, video camera recording capability for transmitting video images remotely, and a communication platform to facilitate faculty assessment and feedback as well as student self-assessment of the exercises.

An essential element of the Michigan Virtual Clinic was to secure portable equipment to allow students the opportunity to complete the typodont exercises outside the preclinic facilities at the School of Dentistry. Remote operating kits (ROKs) contained an electric handpiece motor unit (Optima/Bien Aire) with a friction grip handpiece attachment (Figure 1). The unit only requires an electrical outlet for power. The ROK avoided any restrictions on student practice due to COVID-imposed limitations on use of the preclinic facilities. Students could use the ROK at any location of their choosing as long as it had an electrical outlet to run the unit. Students used their own typodonts to complete the exercises and the needed replacement teeth, diamond burs, and additional supplies were already available from the preclinic.

The second essential element was to identify a predictable technique for recording macro-videos of the typodont preparations for student and faculty assessment. Students had previously been provided an iPad (Apple) for use in their coursework. The iPad records video at 30 fps

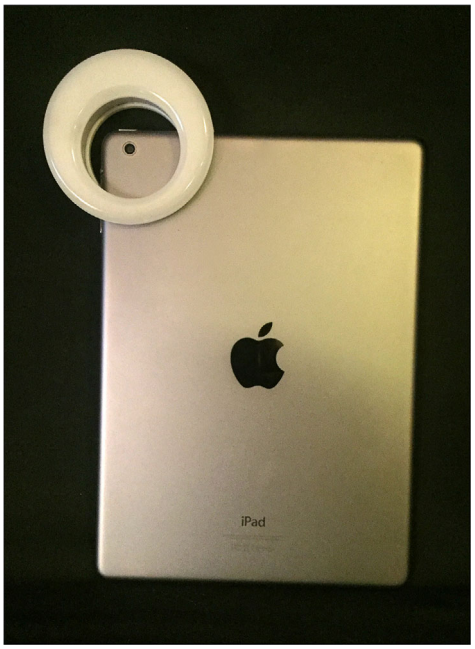

FIGURE 2 The simple supplemental ring light for use with an iPad to record videos.

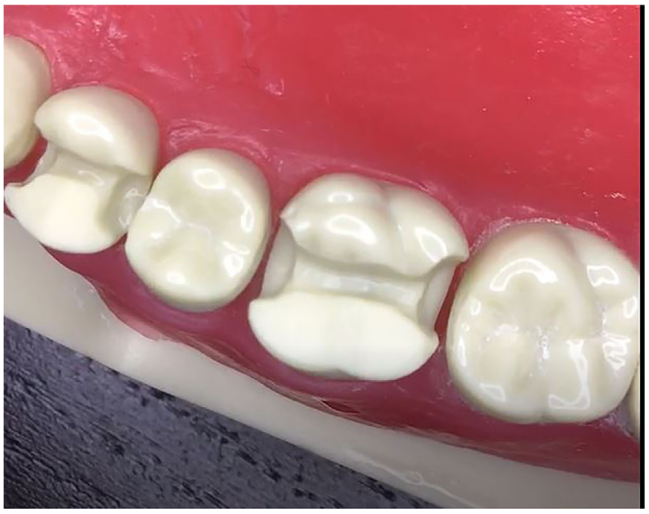

FIGURE 3 Example screen capture of a student's video recorded with an iPad of their molar onlay preparation.

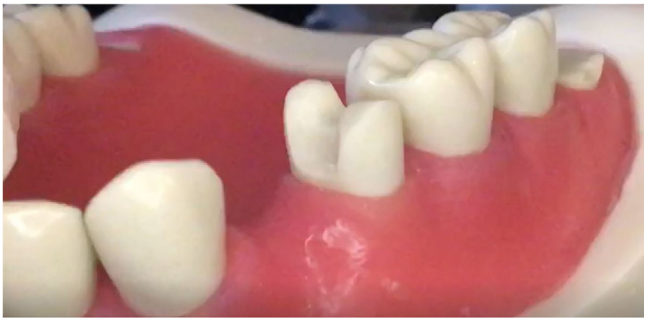

FIGURE 4 Example screen capture of a student's video recorded with an iPad of their premolar onlay preparation.

(frames per second) and an inexpensive ring light attachment was secured for each iPad to improve the quality of the video recordings (Figure 2). Specific instructions on how to record a video, save the video, and example videos were provided to the students. Students were taught to record a consistent series of views of the exercises in each short video. The video began with a focused image form the occlusal along the preparation path of insertion to evaluate draw and undercuts in the axial walls. The iPad was rotated for a facial view of the preparation to view angles and adjacent teeth. The angle of view was rotated to view down the buccal corridor to evaluate the two-plane reduction of the preparation. The iPad was rotated to a view of the occlusal from a lingual perspective and then rotated to a direct lingual view to see the lingual half of the preparation. And the video concluded with a view of the typodont in maximum intercuspation to vie the occlusal reduction and clearance. The video could be paused by faculty at any time to evaluate surface details such as smoothness, margin fidelity, and extensions. The videos were generally less than 5 min in length and allowed for easy upload to Canvas (Instructure) and review through Zoom. Examples of screen captures from the videos are included in Figures 3 and 4.

Canvas (Instructure) is the learning management system used by the School of Dentistry. A virtual clinic Canvas site contained specific, detailed instructions on how to use the ROK, recording, and uploading the videos used for assessment during the virtual clinic, instructions for completing the all-ceramic crown and onlay typodont exercises and due dates, as well as the location for all student uploads for completion of the exercises. Zoom (Zoom Video Communications) was used to schedule synchronous meetings for all students and faculty in the course to review exercises, answer questions on project issues, and ensure consistency in communication during the course.

A total of 45 ROKs were purchased through an educational grant. This allowed the entire third year dental class to complete the series of hands-on exercises in a single term by dividing them into three separate cohorts. Each cohort of students had seven groups of students mentored by a faculty member which was a similar ratio as in the undergraduate clinics. Two additional faculty members were responsible for the virtual clinic project, managing the overall course content, Canvas instructional site, and securing supportive materials for the virtual clinic.

Distance communication was the third and last essential element for the Michigan Virtual Clinic. The University of Michigan School of Dentistry, implemented Zoom for

online communication in both synchronous and asynchronous applications. Dental students and faculty use this communication software routinely for didactic courses as well as online meetings. The familiarity of the faculty and students with Zoom facilitated easy implementation of the platform for the Michigan Virtual Clinic.

Third-year dental students at the University of Michigan School of Dentistry usually complete a didactic course (DENT #732) on adhesive ceramic and digital restorations during the Fall Term. This course was moved earlier in the curriculum to the Spring/Summer 2020 term as part of the curriculum shifted due to the COVID-19 pandemic. The hands-on typodont exercises usually associated with the course could not be completed in-person during the summer term due to social distancing limitations on use of the preclinic facilities. These students were enrolled in the virtual clinic (DENT #720b) course during the Fall Term 2020 to supplement their clinical activities. An internal school Digital Dentistry website containing an extensive series of instructional videos with detailed information on tooth preparation principles for a variety of all-ceramic restorations was used as the reference material for the exercises.

All student groups were assigned the same amount of contact hours and dedicated practice hours. Each student group was scheduled for the virtual clinic 2 half-days per week. One half-day was dedicated time for students to work on the assigned typodont exercises, video record their exercises, complete a self-assessment, and focus their questions for discussion. Realizing that students had significant flexibility in scheduling their time since they had the ROK for the entire rotation, this half-day was primarily to communicate the virtual clinic was part of their coursework. The second half-day was a mandatory synchronous Zoom meeting with the faculty mentor for each student group. This Zoom meeting followed a specific format. Students had three or four tooth preparations to complete each week. The first assigned preparation was recorded by the student and uploaded to the Canvas site prior to the weekly Zoom synchronous meeting. The initial part of the Zoom meeting (approximately 1 h) focused on reviewing the initial videos as a group, discussing common improvements to be made, and clinical questions relating to the type of preparation. The second portion of the synchronous Zoom meeting, after a break, was focused on individual student feedback on any of the additional exercises students had completed and videos submitted. Students would submit a final video of all their completed assigned preparations prior to the subsequent Zoom meeting. Faculty would use the final videos to evaluate and grade asynchronously as part of the course grading plan.

It was expected that some students would require additional faculty feedback time than scheduled during the Zoom meeting each week. Additional Zoom meetings were scheduled by faculty that allowed any student from any group to have additional feedback on their preparations.

The Michigan Virtual Clinic was evaluated using student questionnaires and student grades to test if this strategy promoted the development of students' manual dexterity, resulted in engagement in clinically relevant hands-on exercises, enhanced critical thinking, and reinforced self-assessment. The course final grades were compared to previous years' in-person cohorts. Pre- and post-clinic questionnaires were also used for the assessment of student's perception on their full remote experience.

3 | RESULTS

The virtual clinic effectiveness was assessed using two datasets: student's grades and student's answers to pre- and post-virtual clinic surveys.

Similar typodont exercises were completed during DENT #732 during previous years the course was offered. These all-ceramic preparation exercises were completed by students with no assigned preclinic time. Students generally used the preclinic to complete the exercises and sought feedback from faculty in the clinic. Students were provided an incentive for doing well on the exercises in that if they scored an A or A-grade on the exercises, they would not be required to take the course final exam and receive the grade for both the exercises and final exam grade. The grades from 2019 were compared to those earned during the virtual clinic rotation.

The final grades for the virtual clinic and DENT #732 are compared in Table 1. The all-ceramic preparations for years 2016–2018 included two posterior ceramic crowns, one adhesive ceramic onlay, and two anterior veneer preparations. Since anterior crown preparations were not included in 2019 and 2020, these grades were not used for comparison. The all-ceramic preparations for 2019 included one lithium disilicate crown preparation, one full zirconia crown preparation, and two adhesive ceramic onlay

TABLE 1 Typodont all-ceramic preparation exercise grades for DENT #732 and the virtual clinic

Final grade	MVC 2020	DENT 732 2019
A	106	106
A−	10	17
B+	8	6
B	2	0
B−	1	0
Total students	127	129

preparations. The virtual clinic included three full contour zirconia crown preparations, three lithium disilicate crown preparations, three adhesive ceramic onlay preparations, and two endocrown preparations. The group of students in the Michigan virtual clinic achieved similar grades and distribution compared to students from the previous year with similar tooth preparation exercises supporting the hypothesis that the virtual environment was as effective in teaching the hands-on exercises.

A pre- and post-rotation questionnaire to identify student perceptions and concerns on the virtual clinic were reviewed. The precourse questionnaire revealed that student's felt the videos would be useful for discussion (72%; 29% strongly agree, 43% somewhat agree), but were less convinced they would be of value for grading (58%; 22% strongly agree, 36% somewhat agree).

The postcourse questionnaire showed a shift in student's perceptions about the videos. More than half of the students (60%) reported that recording the videos of their preparations was easy to do and 90% of the students reported it was easy to share their videos over Zoom. A significant number of students (84%) reported that the use of the videos generated faculty feedback that was easily interpreted as both the students and faculty viewed the same video. Overall, 67% of the students felt that the remote teaching design helped in better learning of ceramic preparations.

Student attitudes about the Michigan Virtual Clinic evolved as well. Before the course, students were understandably upset that their patient treatment time was reduced due to the COVID-19 restrictions. They were less than enthusiastic that distance learning experiences were substituted. Students' perception of the virtual clinic became quite positive after the course. The post-questionnaire indicated that most students were satisfied (strongly agree and agree responses) with the format of the course as they believed that the remote design of the class helped in better learning of ceramic preparations (66.9%) and helped prepare them for future clinical treatment (69.2%). Seventy-seven percent of the students felt that evaluating other student's preparations in a group setting was useful to their understanding of the hand-on exercise.

Students sometimes complain about faculty availability during preclinic courses but during the virtual clinic there was sufficient faculty for both asking questions (95.0%) and receiving feedback (90.9%). Interestingly, students agree that the faculty feedback they received via Zoom was as useful as what they usually receive in the preclinic (71.1%) or clinic (64.5%).

Students reported that the hands-on exercises were more beneficial when practicing new concepts or preparations that they have not had a chance to practice before such as onlays and endo crowns. Eighty-seven percent of students found the onlay exercises to be beneficial compared to 65% for zirconia crowns and 64% for lithium disilicate crowns.

4 | DISCUSSION

The goal of dental education is to bring students to a level of safe, independent, and effective work performance prior to graduation from dental school.[4] Students must develop and consistently practice fine motor skills with proper faculty feedback and coaching to achieve this goal. During the course of the COVID-19 pandemic, the practice of fine motor skills was abruptly interrupted and limited due to stay-at-home orders or social distancing restrictions, respectively. The Michigan Virtual Clinic was developed and implemented to allow the continuation of student education and training at sites remotely from the School of Dentistry.

The ROK was essential to the virtual clinic as it allowed students to practice hands-on technical skills remote from the dental school. Most of the students (59%) felt the equipment to be easy to use for completing their exercises. A few obstacles to using the ROKs were reported by the students. The accumulation of dust and debris generated without a high volume suction was a common complaint. Students used several techniques to overcome this problem, with the most common ones including using a small vacuum nearby to collect dust periodically and using wet towels under the typodont to collect the dust while preparing teeth. The friction grip handpiece tended to heat up relatively quickly (within 10 min of continuous use) without the use of water coolant, necessitating stopping to let the handpiece cool before continuing. Although these kits were implemented in response to distance learning during a pandemic, the ROKs may prove useful in the future to expand preclinic activities without the need for actual preclinic spaces. The ROKs may also provide an alternative for students to increase their practice time in the development of manual skills if access to the preclinic is limited.

Receiving feedback is the single most influential and basic factor that affects student's professional growth.[5] Without feedback from faculty, errors cannot be rectified and students cannot reach their professional goals.[6] During the mandatory weekly synchronous Zoom sessions students and faculty reviewed the student videos of their exercises together, promoting an experience of group and peer learning. The ensuing discussions included technical skills, problem solving, and questions related to the mechanics, properties and characteristics of each material or preparation which encourages critical thinking.

Being able to see a small part of a preparation, magnified in size on the computer monitor, aided the visualization of details not easily perceived in the preclinic and clinic environment. At least six or seven videos (exercise 1 from each student) were reviewed during the mandatory synchronous meetings. These reviews were important in allowing both enough repetitions to emphasize important points but also allowing differences to be seen, fomenting a rich discussion environment.

The weekly synchronous meetings were the first time most students were exposed to peer review of their clinical work as preclinic courses were primarily one-to-one faculty to student reviews. Most students were surprised that they had similar technical abilities, questions, and problems to overcome. These similarities helped minimize stress and encouraged an anxiety-reduced atmosphere for the faculty feedback discussions

Developing excellent clinical skills also depends on the clinician's ability to critically self-assess outcomes in order to identify areas for improvement and implement efforts toward that goal. The ability to identify critical errors comes with the development of a student's self-assessment skills, allowing for improved outcomes and lifelong learning. The joint assessment by the faculty member and the student opens a discussion dialogue, providing opportunities to improve student performance and self-directed learning. When students provide accurate self-assessments, it becomes an important part of critical thinking and improves learner outcomes.[7] The joint assessment by the student and faculty often occurs in one-on-one interactions and may lead to similar repetitive discussions with other students. One goal of the virtual clinic was to provide these opportunities for effective and valuable faculty and self-assessment discussions in a virtual setting and explore the value of the virtual setting for student feedback.

One limitation of the Remote Operating Clinic is that it may not be an optimum technique for learning ergonomics for clinical dentistry as mounted mannikin heads were not used for the tooth preparations. Students were allowed to use typodonts sitting on table tops instead. The unpredictable nature of what students may have available for mounting the mannikin heads was the primary factor in not attempting to use them in this experience. The Remote Operating Clinic was developed to create supplemental opportunities for hands-on exercises when onsite laboratories were not available. And it was shown to be valuable for this application.

A challenge of preclinic courses and early learners is the desire to copy an "ideal" preparation as opposed to gaining an understanding of the underlying concepts and principals especially for all-ceramic preparations. Peer discussion groups have shown to enhance learning experiences.[8] The Michigan Virtual Clinic project explored faculty facilitated peer discussion groups to enhance the development of the principles of all-ceramic restorations and subsequently to improve both critical thinking skills and manual skills needed for patient care. The creation of small virtual learning groups provided the structure for peer discussion and faculty feedback.

5 | CONCLUSIONS

The Michigan Virtual Clinic was developed, implemented, and evaluated as a response to facility limitations imposed as a result of the COVID-19 pandemic. Student pre- and post-course questionnaires showed that this innovative teaching strategy utilizing video recordings transmitted via a distance learning platform was well-received by students. Similar grades when comparing the virtual clinic with the in-person environment demonstrated that the virtual clinic was effective in teaching all-ceramic tooth preparation skills while providing facility and student's flexibility.

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CONFLICT OF INTERESTS

The authors have no conflict of interests to report.

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