

REVIEW ARTICLE

Dental education practices during COVID-19: A scoping review

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Abstract

Introduction: Dental education was brought to a halt with the emergence of coronavirus disease (COVID-19). Traditional dental education comprised students working closely with instructors in a clinical laboratory setting; however, public health precautions necessitated a shift to a virtual learning platform. A scoping review of dental education practices since the start of the pandemic will help to understand approaches instructors have taken to provide dental education during this unprecedented time and suggest future applications of virtual learning in dental education.

Methods: We performed an exhaustive scoping literature search of primary peer-reviewed intervention articles published between December 2019 and April 2021 using the following databases: Academic Search Premier, Cochrane Library, Embase, ERIC, LitCovid, MedEdPortal, MedRxiv, Medline, Scopus, and Web of Science. The selection process included two independent reviewers through each phase of review. Articles were categorized and analyzed by domain.

Results: A total of 629 articles were identified; after titles and abstracts were reviewed, 66 articles were selected for full-text review. Following full-text review, 41 articles met eligibility criteria and comprised our study sample. Articles were arranged within domains of assessment, instruction, instructional technology, and software. The advantages to online dental education included improved accessibility, willingness to accept new assessment techniques, and lower anxiety levels. Barriers included problems with technology, classroom time management, lack of student interaction, and absence of hands-on training.

Conclusion: Evidence suggests emerging best practices in dental education during COVID-19, and recommendations for the future of virtual and distance learning in dental education.

KEYWORDS

assessment, best practices, COVID-19, dental education, dental hygiene, distance learning, instruction, instructional technology, pandemic, scoping review, software

1 | INTRODUCTION

The emergence of the COVID-19 pandemic changed how dental education was delivered in early 2020.¹ Quarantine and lockdown regulations required many dental and dental hygiene programs and schools to close with only hours' notice to minimize the spread of COVID-19. The inability to social distance in lecture classrooms, as well as the clinic laboratory classrooms, required dental instructors and students to leave campuses for an indefinite amount of time, necessitating a shift to completely virtual education. The rate of COVID-19 transmission rose quickly, producing student and community concerns of safety in dentistry forcing dental education to immediately shift from an in-person education to an online format.

Dental and dental hygiene education involves both didactic and clinical skills training. Students work in close proximity to instructors to observe step-by-step procedures, and then students demonstrate the procedure on patients.² Questions about the health risks for instructors and students performing clinical work, as well as concern over the transmission of COVID-19 through aerosols, forced direct contact clinical instruction to cease in most cases until updated guidelines for personal protective equipment (PPE) in dentistry were established, and the rate of infection decreased.^{3,4} Thus, most training aspects of dental and dental hygiene education were shifted to a virtual learning platform.⁵ Virtual clinical skill training was more problematic, as it was difficult to mimic the in-person clinical environment. Student preparedness is linked to an adequate amount of hands-on practical experience in order to graduate dentist and dental hygienist who are capable and confident in their ability to safely treat patients.⁶ COVID-19 initiated shifts in dental and dental hygiene education that is still ongoing and presenting challenges, especially given the delta variant and slow progress of global vaccination efforts.⁷

It is essential to understand and education practices in the virtual era, so practices can be integrated when returning to in-person learning or in place where COVID-19 still exists. To date, only one systematic review on this topic has been published; however, it was limited by strict inclusion and exclusion criteria, a short period of observation, and a relatively small sample size.⁸ The scoping review approach was chosen to answer the research question using multiple types of resources. The objective of our scoping review was to sample a large body of research over a broader period of time to understand approaches instructors have taken to provide dental education during COVID-19 and suggest future applications of virtual learning in dental education.

2 | METHODS

2.1 | Literature search

A scoping search of the literature was conducted by a medical librarian in the Academic Search Premier, BioRxiv, Cochrane Library, Ovid Embase, Proquest ERIC, Google Scholar, LitCovid, MedEdPortal, MedRxiv, Ovid Medline, Pubmed, Scopus, and Web of Science Core Collection databases to find relevant articles published from January 1, 2019 to April 12, 2021. Databases were searched using a combination of controlled vocabulary and free text terms for COVID-19 and dental education. The search was peer-reviewed by a second medical librarian using peer review of electronic search strategies.⁹ Details of the full search strategy are listed in Online Appendix B. The preferred reporting items for scoping reviews and meta-analyses statement for reporting was used for this study¹⁰ (Online Appendix A). The protocol was registered a priori on Open Science Framework (<https://osf.io/b9em3/>).

2.2 | Study selection criteria

Citations from all databases were imported in an Endnote x9 library (Clarivate Analytics, Philadelphia, PA). After removing duplicates using the Yale Reference Deduplicator, the remaining set of articles was imported into Covidence (Covidence, Melbourne, Victoria, Australia), a screening and data extraction tool.¹¹ Two authors independently screened the titles and abstracts to determine which studies would undergo full-text review. The full text of the resulting papers was then reviewed for inclusion by two authors independently. In both screenings, a third author resolved any disagreements. Studies were included if they comprised original quantitative research and described an intervention of any design. Studies were excluded if they were not available in English, were the incorrect study design (e.g., commentaries, letters to the editor, or conference abstract), duplicates, secondary analyses, or no original data reported.

2.3 | Article review and data extraction

Data extraction was done by the authors using the Covidence app from the primary articles. Any inconsistencies observed were settled after a scrupulous discussion. The articles were segregated in the domains based on the types of interventions used in the studies. In this way, we were able to meaningfully synthesize the data. Then, information from these articles was extracted relative to the study

characteristics: author, type of intervention, date received by the journal, country, sample description, intervention delivery, intervention description, results, and notes. Studies lacking information about sample size and intervention type were also included in our review. To overcome this discrepancy and gather the missing details, we emailed the authors of those studies to collect additional details about the sample. A second data matrix was created, identifying the best virtual practices in dental education along with their merits and demerits.

2.4 | Data synthesis

Studies were categorized based on the four domains developed after the sample was created: assessment, instruction, instructional technology, and software. We batched according to the predominant domain of a given study to more fully synthesize the findings. Where available, outcomes for each study were summarized and compared in terms of the promising strategies, merits, and demerits. We were unable to perform a meta-analysis due to significant variations in study design, participants, outcomes, and intervention design.

3 | RESULTS

A total of 629 articles were identified from the literature search. In all 522 articles, titles and abstracts were deemed irrelevant to the topic of study. After full-text review of 107 articles, 20 duplicates and 66 full-text reviews were eliminated primarily due to wrong study design (Online Appendix C). Overall, 41 articles met the eligibility criteria and informed our study sample (Figure 1).¹²

3.1 | Selected studies characteristics

Twenty-five of the selected studies were conducted in North America, and eight, seven, and one studies were conducted in Asia, Europe, and South America, respectively. Almost three-quarters of eligible studies were published in the *Journal of Dental Education*, a journal focused on peer-reviewed scholarly work in dental education.

After extracting the data, we identified four domains for the studies: assessment ($n = 9$), instruction ($n = 13$), instructional technology ($n = 10$), and software ($n = 9$). In terms of time frame of journal submission, two studies were sent for review between December 2019 and March 2020, 17 studies between April and July 2020, 15 between

August and November 2020, and seven between December 2020 and April 2021. Table 1 summarizes the study characteristics by domain.

Four of five studies included dental students as the subjects as well as seven additional studies included instructors, administrative staff, and dentists. Of all, Zoom, as a virtual platform, was used in 15 of the studies. The other platforms used included Canvas ($n = 3$), Moodle ($n = 3$), Microsoft Teams ($n = 6$), Blackboard ($n = 1$), Big Blue Button ($n = 1$), FlipGrid ($n = 1$), Webex/Cisco ($n = 1$), DenTeach ($n = 1$), Kobra simulator ($n = 1$), Echo60 ($n = 1$), Learning Management Space ($n = 1$), and Humanoid robots ($n = 1$).

3.2 | Domains

3.2.1 | Assessment

Assessment is operationalized as summative techniques used to understand students' knowledge acquisition. Nine articles were categorized in this domain, with each study assessing students virtually.^{12–20} Three of the studies were related to objective structured clinical examination (OSCE), a case-based summative examination used for clinical assessment.^{12,17,18} The remaining six articles focused on general online assessment, excluding the OSCE.^{13–16,19,20}

The OSCE assessment shifted to an online format due to COVID-19 using Canvas, Moodle, and Zoom as the virtual platforms to deliver assessments to dental students.^{12,17,18} Overall, the OSCEs were implemented successfully by determining competency through demonstration of knowledge.^{12,18} Additionally, students had an overall positive attitude toward the new assessment modality.¹⁷ Drawbacks included technical issues, lack of “hands-on” activities, and image quality issues.^{12,17,18}

In terms of general online assessment, studies employed oral health interviewing, treatment planning, recorded lectures, laboratory for anatomy assessment, case studies for a periodontal senior clinical case challenge, instrumentation assessment with video, and program exit exams.^{13–16,19,20} Zoom was primarily used as the virtual platform to deliver the general online assessments along with Microsoft Teams, Blackboard, Big Blue Button, and Flipgrid. Largely, the general online assessments had positive outcomes, and instructors felt students were given the opportunity to demonstrate their knowledge.^{13,14,20} Nevertheless, challenges consisted of poor student attire and professionalism during exams, lack of in-person activities to increase retention of material, multiple skill sets were hard to assess, and Flipgrid was found to not be suitable for video management.^{14–16,20}

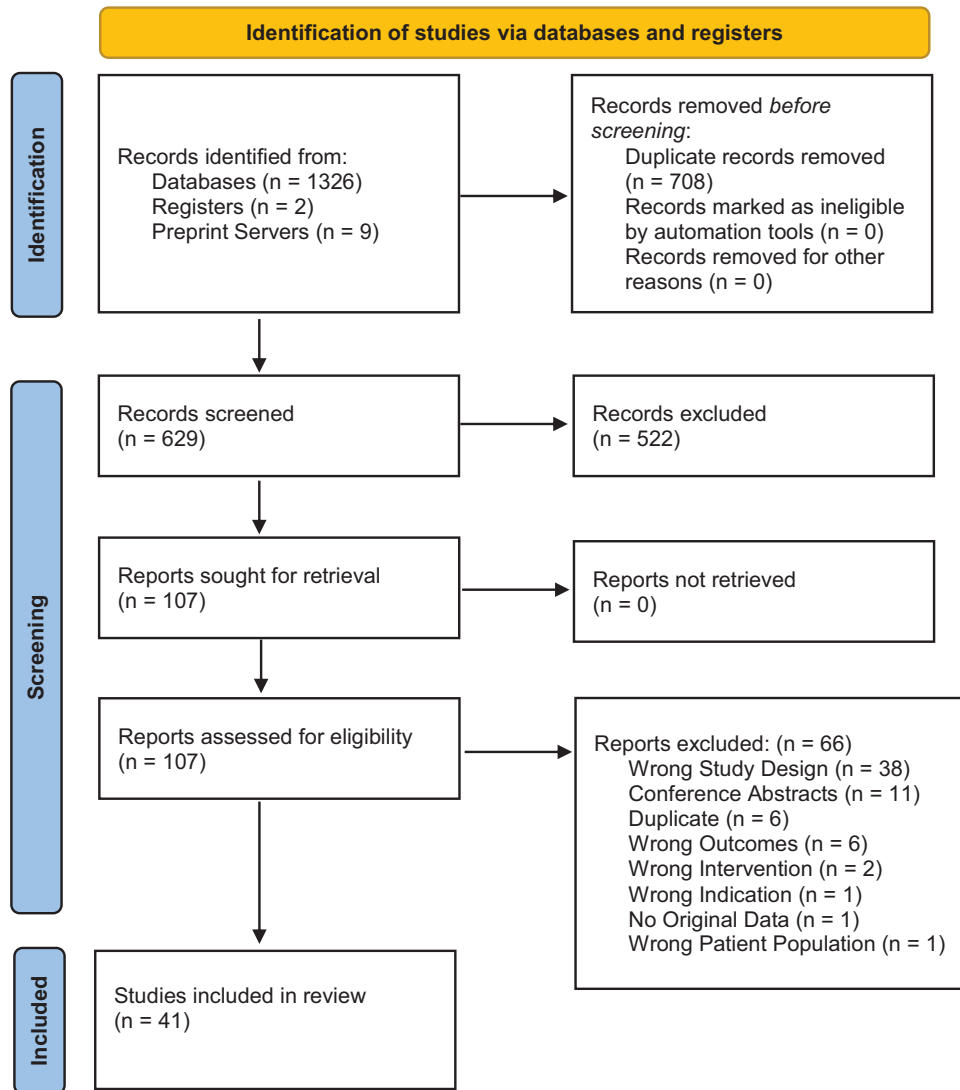


FIGURE 1 PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and registers only.¹² For more information, visit: <http://www.prisma-statement.org/>

3.2.2 | Instruction

For our study, instruction was defined as changes made to the course design to facilitate new learning environments. Thirteen of the 41 articles were primarily related to instruction.^{21–33} Four articles were dedicated to the flipped classroom approach^{22–24,31}; five articles were generally grouped for multi-faceted online instruction formatting and delivery;^{21,25,27,28,33} and four articles focused on the return to in-person clinical and general dental education.^{26,29,30,32}

Flipped classrooms replaced traditional in-class lecture with individual or group discussion-based activities to support online prerecorded lectures.³⁴ The flipped classroom approach in dental education was facilitated through Zoom breakout rooms, virtual polls, Kahoot, Canvas, Webex, and the Moodle skills laboratory. Individual

or group discussion-based activities were held online with instructors after prerecorded lectures were viewed by students. Course topics included caries risk assessment, community health, periodontal recall visit, and a peer-based teaching skills laboratory. Investigators reported that moving courses to a flipped classroom design was received well by instructors and students due to the ease of use with online modules and the pace of learning.^{22–24,31} For example, according to Banava et al., 95% of students who used Kahoot found it to be an interactive online teaching strategy.²² However, many studies addressed barriers to online instruction including Wi-Fi connectivity and a lack of adequate online class time for reflection discussions.²⁴

Regarding multifaceted online instruction formatting and delivery, online modules were created to deliver public health courses in rapid oral health deterioration and early childhood oral health training.^{21,27,28} Tan et al.

TABLE 1 Descriptive characteristics, intervention description, and results by Study ($n = 41$)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Assessment: Summative techniques to understand students' knowledge acquisition							
Aloni; Amato	Objective structured clinical examination (OSCE)	May 12, 2020	USA	Endodontic department instructors	Canvas	A virtual OSCE was created through Canvas to mimic an in-person endodontic competency exam. The type of questions was structured to include topics related to materials, diagnosis, treatment planning, clinical procedure, emergencies, complications, and communication. Best pedagogical practices were implemented through multiple ways of assessment: open-ended questions, multiple choice questions, and "fill in the blank" questions.	Positive: The "virtual" OSCE conducted was overall successful, and the majority of the students were deemed competent and were able to clear from the endodontic department in a timely manner. This virtual platform can be used for future clinical exercises and to expose students to "real-life" endodontics. Negative: A negative aspect to this virtual format was that it did not allow for any "hands-on" activities, which are essential for the endodontic profession.
Garcia et al.	Case-based virtual assessment	July 13, 2020	USA	Fourth-year dental students ($n = 48$)	Zoom	The periodontal senior case clinical challenge (PSCCC) was conducted with a combination of case-based and written clinical assessment followed by online small group discussions using virtual meetings on Zoom. The objective was to provide fourth-year students an alternative for in-person senior case presentations in a formative assessment structure where student opinions would be provided and analyzed to apply didactic periodontal knowledge to patient-based experiences.	Positive: The instructors, who had previous experience with the in-person Periodontal Senior Case Clinical Challenge (PSCCC), agreed this was an effective alternative. The formative assessment experience was positive for all participants and is being considered as a permanent addition to the dental school curriculum. Negative: No comparison could be made to the in-person assessment scores because this student group did not meet in-person. An additional limitation was this type of assessment was very limited in its scope. In support of authors' hypothesis, for each of the six statements in the satisfaction survey, $\geq 94.44\%$ (34/36) of the scores given by the students were considered exceptionally strong clinical support for our pedagogical strategy that combines educational resources and can be successfully implemented in other programs.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Herr; Nelson	Recorded lecture and laboratory with photos and labels for anatomy assessment	May 4, 2020	USA	First year dental students	Unspecified	First-year students were given a stay-at-home anatomy practical in lieu of the in-person cadaver dissection laboratory time due to COVID-19. Forty labeled images were provided to the students to identify. To help students name the identified structures, the authors provided a "hit list" of identifiable structures as well as allowing students to use the laboratory manual to understand the dissections.	Positive: Students scored well on the stay-at-home anatomy practical for 2020. The average class score for the practical was above the previous 3-year average by 9.71 percentage points. Modification of the "hit list" to represent the actual laboratory requirements was recommended to help students understand the written material. Negative: A negative aspect of this virtual lecture and laboratory assessment included students concern information would not be retained due to the lack of in-person, active dissections. Interested students could be invited back with the 2021 class to relearn material in person.
Holloway et al.	Online assessment in dental technology decision making	June 10, 2020	USA	Dental students ($n = 40$)	Zoom	Critical thinking related to how to use technology during dental treatment as well as principles associated with the technology was evaluated via Zoom online assessment. Technologies knowledge assessed included: soft tissue lasers, Invisalign, electric handpieces, digital radiography, Vita Easy Shade V, Omnicroma, hard tissue laser, Prime Scan impressions, intra-oral cameras, Dexis CariVu, and Zoom whitening. Students developed PowerPoint presentations to demonstrate their knowledge with each of the technologies being assessed.	Positive: With eight presentations made from five groups of students, a total of 112 assessments were completed. Each presentation contained seven categories of skill sets that were assessed by two instructors. From this small sample, it was concluded critical thinking, for this structured skill set occurs on as high a level as face-to-face facilitation. This study shows critical thinking skills in technology decision making can be taught by Zoom. Additionally, other critical thinking skills sets may be able to be taught by Zoom. Negative: Different skill sets were not assessed using zoom.
Horne et al	Synchronous and asynchronous instrumentation instruction and assessment using video	January 7, 2021	USA	First-year dental hygiene students at University of Mississippi Medical Center School of Dentistry ($n = 17-20$ students)	Big Blue Button and Flipgrid	Instruction was provided using FlipGrid and Big Blue Button. Live sessions were held through Big Blue Button, and prerecorded videos were developed and posted on FlipGrid. Students used FlipGrid to submit self-recorded videos of instrumentation practice for feedback. Additionally, exploring and calculus removal practical exams were scheduled in FlipGrid.	Positive: Results comparing final practical exam performance compared to previous 3 years (interquartile ranges of 9.3 in 2020, 5.7 in 2019, 4.6 in 2018, and 5.8 in 2016) as expected of new approaches. Exam scores indicate students continued to progress even though learning was disrupted. Negative: Flipgrid was not designed as a reliable video management system. A second lesson learned was internet availability was not consistent.

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TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Hytönen et al.	OSCE	July 13, 2020	Finland	Fourth-year dental students ($n = 179$)	Moodle virtual learning environment	Because this exam is required to fulfill the criteria for dental school completion, the authors modified the in-person national OSCE to an online OSCE with eight question categories, each including 1–6 questions. Students had to pass all eight categories to pass the OSCE. If they did not, they had to retake the exam.	Positive: The pass rate in the eight question categories ranged from 50% to 70%. Students had on average a positive attitude toward the online examination beforehand, and they felt that they received adequate information concerning the examination. Negative: The virtual OSCE included technical issues, time management, and clarity/quality issues with example pictures used.
Kakadia et al.	OSCE	June 11, 2020	USA	Instructors and students Harvard School of Dental Medicine ($n = 36$ students and $n = 20$ examiners [two for each of the 10 disciplines])	Zoom breakout rooms	The Zoom platform was used for the OSCE with the “breakout room” feature, which allows private mini sessions (one-on-one) between host-selected participants. Twenty-one preassigned rooms were created with two examiners assigned to each room. Students were given 6 min in each room to present discipline-specific cases. Examiners used Qualtrics or hard copy to grade.	Positive: Most students felt the online OSCE compared similarly to the traditional OSCE because students were able to fully demonstrate their knowledge. Examiners noted calibration and pre-OSCE run-throughs were important to the success of the OSCE. Negative: The virtual OSCE was related to technical difficulties.
Khalaf et al.	Online assessment/exit exam	July 20, 2020	UAE	Final-year dental students ($n = 65$)	Microsoft Teams and Blackboard	The online assessment, exit exam, was created to replace the in-person assessment that measures students' knowledge, clinical skills, attitudes, professional qualities, and expertise for safe and competent dental practice. This is a high stakes exam given prior to graduation from dental school. Online written exams (MCQ, MEQ, and OSCE) were created and administered with Blackboard, and the oral exam component was given using Microsoft Teams. In addition to using Respondus Monitor for exam honesty, instructors required students to join Teams meetings via mobile phones, so students could be monitored for cheating and/or IT help live while taking the exit exam.	Positive: The high-stakes exam was implemented online and accepted by all stakeholders. Authors noted the outcomes for the online exit exam were similar to the previous in-person, pen, and paper exam. No formal analysis was compared. Negative: The exam from students' perspectives included inadequacy of time for the MEQ part, prevention of backtracking in the MCQ part, and minor technological issues. Those raised by instructors were increased time required to complete the exam setup and grading compared to the paper-based exam and minor technological issues. Both students and instructors were satisfied with the online exam with the latter being more satisfied than the former.

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TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Meyer et al.	Video recordings to simulate in-person oral health interviews assessment	May 23, 2020	USA	Second-year dental students in a pediatric dentistry course (<i>n</i> = 83)	Zoom	Second-year dental students recorded themselves delivering oral healthcare counseling and pediatric dental treatment plans using a Zoom platform. An asynchronous teledentistry format was used as a replacement for in-person interviews. Students responded to standardized patient questions and delivered a prioritized list of treatment options. They had 24 h to prepare and submit a 5–10-min video for grading. Examiners used rubric with a four-point Likert scale to assess students' performance.	<p>Positive: This modification was successful in providing students an opportunity to demonstrate oral health counseling and treatment planning. Additionally, peer-to-peer reflection helped students understand important concepts.</p> <p>Negative: The virtual standardized patient experience included poor attire and professionalism during the recorded patient encounter. This can be remedied with more guidance regarding assessment expectations.</p>
Instruction: Changes to course design to facilitate new learning environments							
Aguilar-Galvez et al.	Virtual learning object (VLO)	August 18, 2020	Peru	10 expert pediatric dentists and 25 dental students with the diagnosis of dental caries	Virtual/unspecified	VLO was created to learn the diagnosis for dental caries. The VLO included flexibility, personalization of teaching, modularity, adaptability, reuse in other contexts, durability, and gamification. The complete process of construction of the VLO to be used in managing learning in dentistry included four main stages: (1) construction of the VLO, (2) validation by 10 specialists, (3) assessment of learning, and (4) assessment of the VLO by students.	<p>Positive: The 13 dental students exposed to the VLO group correctly answered 90% of the questions evaluated, in relation to the 12 students exposed to the virtual synchronous class group who correctly answered 40% of the same questions evaluated. The students' opinions were very favorable. Negative: None were noted.</p>
Banava et al.	Flipped classroom approach	November 23, 2020	USA	Dental students with caries risk assessment (<i>n</i> = 119)	Zoom breakout rooms, Zoom polls, Kahoot	A flipped classroom approach was used to move the caries risk assessment (CRA) case-based scenarios and treatment planning to an online format. Students were preassigned a reading assignment and a quiz prior to the online session. A short presentation on Zoom including "polls" was used to engage students. Kahoot was used to assess students' knowledge with multiple choice questions before the case-based scenarios were presented. Students were divided into teams and assigned	<p>Positive: The survey results measured the use of Kahoot in the CRA workshop. Of the 119 students who rotated through the workshop in three sessions, 113 students (95%) found CRA virtual workshop engaging and fun; 99 students (83%) suggested using Kahoot in other topics; 103 students (86.5%) agreed on Kahoot being an easy-to-use game. A few students needed additional instructions to use Kahoot to complete the quiz, but overall, the interactive online strategies worked to engage dental students. Negative: None were noted.</p>

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TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Iyer et al.	Flipped classroom approach	June 21, 2019	USA	Dental students with a periodontal recall visit ($n = 144$)	Webex/Cisco	<p>A flipped classroom approach was used for the instruction of treatment planning a periodontal recall visit. This included videos and questions that were discussed with instructors in a synchronous seminar.</p> <p>to Zoom breakout rooms to collaborate and formulate a treatment plan based on their case scenarios. The teams then presented their cases and treatment plans to their peers and instructors.</p>	<p>Positive: Students appreciated the benefit of one person posing a question and having multiple faculties offer responses in real time. Students gave positive feedback on the pace, efficiency, and the learning effectiveness. Negative: Instructors and students were unable to use cameras due to connectivity issues.</p>
Miller et al.	Flipped classroom approach	September 17, 2020	USA	Dental students with community health	Canvas	<p>A community health field project was converted to a fully online flipped classroom approach. Students were broken up into teams of three and instructed to choose a community social agency or dental clinic to conduct a virtual tour and create a case presentation. After each team presented their case information to peers and instructors, students individually submitted reflections using the 4Fs framework: facts, findings, feelings, and future.</p>	<p>Positive: The flipped classroom approach worked well for the topic and style of instruction. The individual thoughtful reflections showed astonishment by some students on the harsh community conditions, poverty, and their discovery of the challenging aspects of the social determinants of health. Negative: Lack of enough class/Zoom time to fully discuss each student's reflection.</p>
Moore et al.	Transition to ExamN/eProctor for students, instructors, and staff as described by the Academic Support Center	May 20, 2020	USA	Dental students, instructors, staff	Zoom, Echo360, eProctor	<p>Facilitating and recording live virtual meetings, Zoom and Echo360, software minimally used by the school, were maximally used. By March 15, CODA announced a requirement for testing to include identity verification and online proctoring. The current secure testing solution ExamN, by Allofe in the eMedley suite, contained an option for online proctoring called eProctor. The team assessed the product and alternatives for compliance. eProctor was selected and implemented with the first examination on April 1.</p>	<p>Positive: The academic support center team recommends continued training to have a best practice with remote instruction and to help instructors ensure engaging educational experiences for students. Student satisfaction with Zoom: –35% extremely satisfied, 42% satisfied, 19% neither satisfied nor dissatisfied, 4% dissatisfied; instructors' satisfaction with Zoom: –22% extremely satisfied, 67% satisfied, 11% neither satisfied nor dissatisfied. Negative: None were noted.</p>

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Mupparapu et al.	Dental radiology hybrid program for lecture and laboratory components	August 12, 2020	USA	D3 students at Penn Dental School ($n = 162$)	Canvas	D3 students completed a 2-h remote "introduction to radiology clinics" with Canvas. Following students were required to pass a summative examination conducted via Examsoft. Remote radiology training also included individualized instruction in Axiom, MIPACS software, and intraoral position using RINN XCP instrumentation and several direct acquisition digital intraoral imaging systems when clinical operations resumed. DXTR-based radiographic training sessions resumed on July 7 continued until October 1, 2020. Each hour-long training session included a radiographic study of 18 images using a CCD sensor. Students received training in recording radiographic findings using a templated interpretation form (RADCON), which prompted students to input data regarding caries, crestal bone levels, marginal, and apical periodontium.	Positive: All students had prior knowledge of XCP assembly, radiation hygiene, disinfection protocols, appropriate use of personal protective equipment (PPE) in a radiology setting, and exposure parameters. This hybrid program was designed to prepare D3 students for clinical activities without compromising the quality of dental care. Negative: None were noted.
Nair et al.	Extramural Program	May 26, 2020	USA	Fourth-year dental students at The University of Iowa College of Dentistry and Dental Clinics ($n = 20$)	Rapid oral health deterioration (ROHD) risk assessment tool	A virtual educational approach was created to replace the canceled extra-mural training including the geriatric and special-needs program. Students identified all relevant information from the patient's medical, oral, and socioeconomic condition and used these to determine the patient's risk for rapid oral health deterioration (ROHD) risk assessment tool and provide rationale treatment plans. Their responses were detailed and reflected individual decision-making styles.	Positive: Students identified all relevant information from the patient's medical, oral, and socioeconomic condition and used these to determine the patient's risk for rapid oral health deterioration (ROHD) risk assessment tool and provide rationale treatment plans. Their responses met the standard for the virtual assignment. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Nelson et al.	Virtual early childhood oral health training program (EChOTrain)	November 17, 2020	USA	Second-year pre-licensure dental hygiene students ($n = 37$)	Zoom	The in-person didactic content for the EChOTrain program was moved to remote synchronous lecture in 2020. The 2019 cohort ($n = 8$) received all content via in-person lecture. The 2020 cohort ($n = 29$) received all content via synchronous remote lecture. Prior to the beginning of the program, students receive pre- and postassessment surveys to gauge knowledge pediatric hygiene procedures. Self-assessments were scored on a numerical Likert scale, de-identified, and calculated for each question using MS Excel.	Positive: The synchronous from our lecture was received well by students and allowed the course to expand from 8 to 29 students. Both cohorts showed improvement based on readiness for clinical practice. This study demonstrated lectures were effective in teaching EChOTrain course content. Negative: One was technical challenges with the software. A second negative aspect was the instructors' perceived lack of interaction with students when their video was turned off.
Pastan; Zandona	Diaphragmatic breathing/deep breathing	July 13, 2020	USA	D4 students with Tufts University of Dental Medicine ($n = 16$ students, $n = 16$ instructors, $n = 12$ staff)	In-person huddles pre-clinic sessions	Diaphragmatic breathing is a technique that involves slow breathing when the exhale is twice the length of the inhale. Diaphragmatic breathing research shows a calming effect on the autonomic nervous system, as well as relaxing the muscles of the body and decreasing feelings of stress and anxiety. Starting on the first day, the fourth year (D4) students returned to the clinic after the mandated closure of clinic due to COVID-19, the diaphragmatic exercise was implemented in the clinic by the instructors before each clinic session.	Positive: This unconventional activity in the dental school environment was welcomed by all participants with appreciation and strong interest for it to be continued. The trained instructors began guiding their own versions of this exercise in the huddles. The staff and administration benefitted as the students did from the calming and anxiety lowering effects that created a more relaxed clinical environment better suited for operator performance and patient care. Negative: Some of the instructors lacked confidence in leading the breathing exercises; however, they were open to additional training to become more comfortable.
Ramesh et al.	Think-pair-share activity on a virtual curricular retreat	November 24, 2020	USA	Students, instructors, administrators at Tufts University School of Dental Medicine curriculum committee ($n = 37$)	Zoom breakout rooms	The curricular adaptations made in response to COVID-19 during the spring and summer 2020 terms were assessed through the lens of Miller's Pyramid using a "think-pair-share" format to engage participants in dialog. The preassigned teams used the breakout features of Zoom to discuss the pandemic-related	Positive: This virtual retreat provided a starting point for innovative and unprecedented curricular enhancements for the future of dental education. Results from the retreat included identifying that online course can facilitate delivery of basic fundamental content. Using supplemental videos can be useful to facilitate class discussions. The objective

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Ramesh et al.	Think-pair-share activity on a virtual curricular retreat	November 24, 2020	USA	Students, instructors, administrators at Tufts University School of Dental Medicine curriculum committee (<i>n</i> = 37)	Zoom breakout rooms	curriculum changes for a specific year and assess their short and long-term impact in terms of what worked, what did not, and lessons learned. A live Google doc was set up for the teams to enter discussion notes in real time. An assigned reporter of the team reported their summary to the entire committee after the discussion.	of discussing successful curriculum adaptations and deciding on the permanent additions was met. Negative: None were noted.
Rohle et al.	Inverted classroom (flipped classroom) model integrated with peer-based teaching skills laboratory using Moodle	August 4, 2020	Germany	Medical and dental students at Technische Universität Dresden (<i>n</i> = 1012)	Skills laboratory via moodle	Undergraduate human medical training for medical and dental students was moved to an online format using an existing skills laboratory based on a peer teaching format. Students learned basic communication and manual skills through an inverted classroom practice. Three e-learning modules were incorporated through Moodle: (1) self-learning phase I: access to occupational health and safety instructions. (2) Self-learning phase II: acquisition of learning content using Mitz-mobil. (3) Constructive teaching and learning approach in Moodle.	Positive: This pilot of implementing an inverted classroom model during “emergency mode” due to COVID-19 with peer-based teaching was successful. The teaching modules were feasible, and the peer instructors accepted the inverted classroom well. Exploratory evaluation of the interviews with the instructors revealed that there were no major problems. Didactic learning objectives should differentiate between online/Moodle classroom objectives and in-person classroom objectives. Authors determined the inverted classroom model will be further developed as an integral part of regular teaching. Negative: None were noted.
Siqueira et al.	Synchronous remote lectures and shortened clinic sessions	December 8, 2020	Canada	Dental students	Virtual/unspecified	Due to COVID-19, clinic sessions were compressed to shorten the day to help avoid commuters traveling to campus multiple times a day. Additionally, all in-person lectures shifted to synchronous remote lectures.	Positive: A total of 67.5% of students reported being either satisfied or very satisfied with the new preclinic/clinic scheduling times. Also, 66.3% of students reported the timing of the sessions provided more time in the evening to study and for personal activities. Instructors reported the quality of dental work did not decline. Additionally, some of the appointment prescreening questions were done via phone call to preserve in-person clinic time for patient treatment. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Tan et al.	Home-based simulation learning (HBSL) for oral hygiene instruction	October 15, 2020	Singapore	Dental hygiene students at Nanyang Polytechnic School of Health and Social Sciences ($n = 70$)	Zoom	In class sizes of 22–26 students, synchronized lectures and demonstrations were conducted by dental hygiene and therapy coordinators and supervisors during scheduled timeslots over 3 weeks. Following discussions, students split into groups of six and used the breakout room function in the Zoom teleconferencing platform to practice on the manikin heads, with real-time feedback from dedicated clinical supervisors observing through remote supervision, following completion of the 3-week HBSL program, an online survey was sent out to all oral health therapy (OHT) students using the online clinical diagnostic and research support system (CDRSS), Medisys, Singapore) platform. The target population included 70 students, of which 69 returned complete responses for the survey, yielding a response rate of 98.6%.	Positive: The top three aspects that students were satisfied with for the HBSL program include (1) clear understanding of the purpose and objectives of the simulation (95.7%), (2) provision of constructive feedback (92.8%), and (3) support during the learning process (91.3%). The most important factor to virtual oral health therapy students was feedback and reflection. There was a moderate positive linear correlation between the importance and satisfaction with factors in simulation design for the domains of support (0.59), problem solving (0.58), and feedback and guided reflection (0.61), but low positive to negligible linear correlation for the other domains. All correlations were statistically significant ($p < 0.05$). In terms of overall student satisfaction and self-confidence with learning, mean satisfaction with HBSL was 3.90 ± 0.36 . A statistically significant difference was noted between cohorts. The median SCLS scores for first-year, second-year, and third-year OHT students were 3.83 (IQR 3.58–4.00), 3.92 (IQR 3.67–4.08), and 4.08 (IQR 3.92–4.25), respectively. Post hoc tests revealed a statistically significant difference between the first- and third-year cohorts ($p < 0.01$). This difference was mainly attributed to differences in “satisfaction with instruction.” The beta coefficient for the third-year cohort was 0.29 (95% CI 0.09–0.49). No differences in SCLS scores were noted for other sociodemographic variables. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Instructional technology: Virtual platforms for collaboration							
Aulakh et al.	Virtual monthly oral and maxillofacial surgery (OMFS) journal club	October 15, 2020	United Kingdom	Dental trainees taking part in journal club meetings at Bradford Teaching Hospitals NHS Trust (<i>n</i> = 14)	Microsoft Teams	Microsoft Teams what is used to facilitate the virtual monthly OMFS journal club which typically met in-person. A satisfaction survey consisted of a mix of Likert scale and multiple-choice questions aimed to ascertain the differences in experience between online and face-to-face settings for the club, along with opinions regarding the setting for future meetings.	<p>Positive: 100% response rate was received. Results from the survey and statistical analysis indicate that the majority of trainees found it significantly easier ($p < 0.05$) to attend the club after it had been moved to an online setting, with only one participant indicating more difficulty in accessing it currently. Trainees generally reported that learning through the virtual journal club was more effective than it was face-to-face. Negative: None were noted.</p>
Buchbender et al.	Kobra surgery simulator	January 15, 2020	Germany	<p>Cohort 1: A total of 59 students from Friedrich-Alexander University of Erlangen-Nuremberg (FAU) (third-year, $n = 29$, with 22 women and seven men/group 1; fourth-year, $n = 20$, with 17 women and three men/group 2) and dentists ($n = 10$, with five women and five men/control group) participated, left-handed individuals were had also excluded. Average age of 24.59. Cohort 2: 17 female and three male students. Average age of 24.40</p>	Oral surgery simulators (Kobra). This simulator consists of a phantom head, a 3D screen, a tablet for selecting the patient case insight of relevant virtual patient data (i.e., X-rays), two 3D glasses (Nvidia 3D and Vision 2), a foot control for the handling of the surgical handpiece and an advanced joystick with touch feedback, a so-called haptic device	<p>Group 1 performed an apicoectomy on a front tooth; group 2 performed an extraction of a lower wisdom tooth, and the control group all performing surgeries within a 10-min time limit. Comparisons were made. They study hypothesized that dental students will perform more accurate surgery simulator when compared to instructor dentists.</p> <p>Positive: Primary outcome—objective parameters</p> <ul style="list-style-type: none"> • Simulation of an apicoectomy of an upper front tooth (group 1 vs. control group). The hypothesis was not met. Students did not perform more accurate surgery using the simulator. The Mann-Whitney <i>U</i> test revealed no significant differences ($p < 0.0083$) in both groups concerning the removal of gutta-percha ($p = 0.020$), dentin ($p = 0.010$), and tooth ($p = 0.009$). The students tended to have higher amounts of removal in the parameters, except the parameter of infected tissue, where dentists had a higher amount of removal. • Simulation of wisdom tooth extraction (group 2 vs. control group). The differences between group 2 and the control group showed no significance according to the Mann-Whitney <i>U</i> test. However, the median values between the two groups differed concerning the ablation of the pulp (group 1, 6.40 vs. group 2, 1.55) as well as the bone (128.7 vs. 124.75) and dentin (97.50 vs. 63.95). 	

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Laurence et al.	Software Epidemix 2 for infectious disease modeling	June 26, 2020	USA	Undergraduate dental students and policymakers (in each session on average 20 students participated, of which 16 completed course evaluation)	Zoom	The Epidemix 2 software was used to develop a virtual course in infectious disease modeling where students explored trends in the transmission of COVID-19. Virtual instruction was provided on Zoom. A demonstration of software Epidemix 2 was done after primary course content had been covered.	Overall, students showed less precise surgical skill than dentists, especially in the younger age group. Between the older group of students and dentists, there was no statistical difference. Kobra simulator may provide more clinical experience for students and may offer new opportunities for practical examination offering benefits for the instructors as well. Negative: Computer surgical simulation cannot replace hands-on training.
Lee et al.	Process to prevent cheating during online assessments	June 27, 2020	South Korea	86 students	A tablet PC with a face-tracking function, a Zoom video, and a random question sequencing function in a Computer-Based Test	Remote assessment is proctored and, therefore, presents challenges with cheating and fairness. Authors implemented before, during, and after strategies to deter cheating during remote assessments. Students took a test ethics pledge before testing. During testing, they recorded themselves with a tablet PC camera to record the room, a Zoom video recording the face, and a random ordered computer-based test. After providing a list of cheating behaviors, penalties were imposed on students who cheated.	Positive: For 92% ($n = 79$), the facial movements were within the acceptable range. A Zoom video analysis for the seven remaining students was conducted, two of whom were given penalties for suspected cheating. Postassessment student surveys indicated that the face tracking technology, Zoom monitoring, and random question sequencing were perceived as effective ways to control cheating by 32%, 95%, and 67% of students, respectively. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Mahima et al.	Google classroom	October 06, 2020	India	Undergraduate medical and dental students ($n = 163$)	Google Apps	Anatomy virtual class was created in Google classroom individually for medical and dental students, and students were asked to join the class by means of class code. Instructors created lesson materials like videos and voice over PowerPoint presentations. The materials were uploaded daily based on the syllabus. Assignments and assessments were also given and graded.	<p>Positive: About 163 students responded to the questionnaire, which was based on a five-point Likert scale with 5 as strongly agree. Seventy-nine (48.2%) students were males, and 85 (51.8%) students were females. Overall, the students gave positive response toward their learning experience in Google classroom.</p> <p>Negative: A few problems also have been found out like issues regarding accessing course materials and navigating the system, difficulty in submission of assignments, poor internet connection, and they also wanted to make the classes more interactive.</p>
Mansoor	Live videoconferencing for remote education with Zoom	May 24, 2020	UK	Dental students at Manchester University Dental Hospital ($n = 40$)	Zoom	Manchester University dental hospital focuses on enquiry-based learning (EBL) where the teacher is seen as more of a facilitator to guide the students. This type of learning was implemented using video conferencing with the Zoom. Other virtual platforms considered for EBL were FaceTime and Adobe Connect. FaceTime did not have as many useful features as Zoom, and Adobe Connect required a registration fee before being allowed to register for a virtual class.	<p>Positive: Results from the Google Form questionnaires showed none of the students believed the Zoom education meetings were better than their standard dental education. Additionally, a small minority of the 40 students did not attend the remote educational meetings, and the pattern of absence is consistent with some individuals. Ninety percent of the allocated dental students have stated they find the remote educational meetings beneficial academically and report to enjoy them. This demonstrates a high satisfaction among the respondents.</p> <p>Surprisingly, almost half of the responding students reported that the remote educational meetings have been beneficial clinically, despite the lack of face-to-face contact or the ability to learn physically with their dental instructor. Over half of the allocated dental students revealed they found the remote educational meetings "better" than the normal delivery of their academic dental education. Negative: None were noted.</p>

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Murata et al.	Problem-based learning for research using Microsoft Teams	December 2, 2020	USA	First-year dental students at East Carolina University ($n = 52$)	Microsoft Teams	Microsoft Teams was used to facilitate problem-based learning (PBL) to teach evidence-based research to dental students. Dental students worked as a group to address a specific problem by using the PBL approach: defining the problem, structure a hypothesis, construct a learning objective, independent resource collection, knowledge application, case presentation and assessment, and self and peer evaluation. After 3 weeks of 2-h sessions each week, students presented their case to the class and instructors.	Positive: Instructors and students reported positive feedback for the Microsoft Teams platform related to PBL online critical skills development. Microsoft Teams worked well in allowing students to share documents and work interactively. Negative: None were noted.
Nishioka et al.	Patient simulation with a robot-SIMROID	December 3, 2020	Japan	International students at Tohoku University Hospital ($n = 9$)	Humanoid robot that simulates a patient for dental training	The SIMROID has the ability to interact with students through movements, speech, and expressions. It can also respond to pressure for pain feedback. Because the SIMROID can respond to a clinician's voice in Japanese or English, it could be used to build communication skills with patients.	Positive: Feedback from the international students revealed that most (97.7%) answered that the SIMROID was "effective in dental training" because "the robot's ability to mimic the patient's response, answer questions, open mouth more realistically, and respond to any uncomfortable procedure." Negative: High cost of the SIMROID robot, time-consuming maintenance, its need for a specified area for its installation, and only a few students can practice at a time.
Telang	Asynchronous e-learning using YouTube, Google Classroom, WhatsApp	May 18, 2020	Malaysia	Dental students ($n = 225$) and instructors ($n = 35$)	Learning management system (LMS)	A YouTube channel was created with access for the instructors to upload voice over lectures and linked on the LMS. Clinical and preclinical procedures videos were posted on YouTube for student understanding. Google classroom was used to conduct discussion forums quizzes and assessments. WhatsApp was used by instructors and students to encourage personalized interaction and ensure wellbeing.	Positive: Using freely available online resources showed an engagement of 90%–95% for all the teaching and learning, as well as 100% compliance to assessments. Take-home exams have shown higher scores while the overall achievement of outcomes is similar to a face-to-face assessment. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Trowbridge et al.	Microsoft Teams for private channels and student rotations in a simulation (SIM) clinic	November 21, 2020	USA	Midwestern University College of Dental Medicine-Arizona (MWU-CDMA-AZ) second-year dental students (groups of 20 students on five-six benches)	Microsoft Teams	In order to accommodate multiple rotations simultaneously in the SIM clinic, MWU-CDMA-AZ has implemented the use of private channels in Microsoft Teams software. A separate private channel is created for each rotation. Only the instructors teaching the rotation and students participating in the rotation are added to the channel. Students are required to bring an electronic device with the downloaded Microsoft Teams software and a set of headphones. This allowed each instructor to communicate with their student group without distractions and while adhering to social distancing.	Positive: Our use of the private channels in the Microsoft Teams software has allowed us to continue effective hands-on instruction while complying with COVID-19 social distancing requirements. Negative: Need of good Wi-Fi connection to use Microsoft Teams. Having all the students turn off their videos and mute their audio appeared to improve the speed of Wi-Fi.
Software: Digital programs and tools to facilitate learning in new virtual environments							
Cheng et al.	DenTeach remote teaching-learning platform for dental tasks and skills	September 29, 2020	Canada	One instructor and one student	DenTeach platform	The DenTeach platform is made of an instructor workstation (DT-Performer software, DT-Rightway articulator, DT-RealFeel Sensors, and four mini cameras), a student workstation (instructor videos, drill model to mimic the instructor, two typodonts, a DT-RealFeel handpiece, monitor), wireless technology, and cloud-based data storage and retrieval. This platform provides opportunity to continue teaching and learning from a remote location. The platform synchronizes the instructor and the studio with real time video, audio, feel, and posture. DenTeach has three modes. In the teaching mode, tactile feedback for students can enhance their dental skills while learning from the instructor. In the shadowing mode, students download videos to view before beginning to practice. In the practice mode, students use	Positive: Teaching and shadowing modes can help the students understand their work and need for improvement. Negative: Results for the feasibility of DenTeach show that key performance indicators, video views, and graphical reports were a bad combination.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Corte-Real et al.	Cone-beam computed tomography (CBCT) images for dental anatomy, in-person lectures versus webinar lectures	March 02, 2021	Portugal	First-year undergraduate dental students from the University of Coimbra, Coimbra, Portugal ($n = 40$)	Zoom for webinar lectures	<p>DenTeach to perform dental skills and have the skills evaluated by both the student and the instructor using key performance indices included with the platform. DenTeach is portable and housed in a small suitcase. It can be used anywhere by connecting to Wi-Fi and cloud-based storage. Research compared key performance indicators taught and learned with DenTeach versus traditional delivery.</p> <p>Two teaching approaches were implemented: (T1 cohort) received traditional face-to-face lectures with physical models; and (T2 cohort) experienced webinar lectures with CBCT images. Each lecture lasted for 50 min and was conducted twice a week. Both teaching methods were implemented for the same period of time (45 days). Teaching was performed in a sequential order for all the students, first the T1 cohort and then T2 cohort, separated by the introduction of the disrupted procedures of actual and real pandemic context (restricted movement and social distancing requirements). Students were voluntarily recruited via an email invitation, in the Zoom video conferencing platform accessed through the student number of the University of Coimbra.</p>	<p>Positive: Among the 59 first-year Master students, 40 dental students participated in this study (67.8%). Their mean age was 19.2 (± 1.2) years old, ranging from 18 to 23 years. Male students comprised 27.5% ($n = 11$) and females 72.5% ($n = 29$) of the total participants. The T2 cohort with the higher learning outcome, in theoretical (75.12% \pm 6.15%) and spatial orientation (68.75% \pm 0.83%) contexts, ensures higher students' satisfaction. The results from Pearson's correlation found a statistically significant gain of learning outcomes from T1 to T2. Negative: None were noted.</p>

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Gali	Microsoft Paint (MS Office) and Pocket Paint mobile apps used for preclinical complete denture prosthodontics	September 12, 2020	India	Second-year dental graduates ($n = 54$)	Microsoft Teams platform	The online course delivery for preclinical complete denture prosthodontics was held on a Microsoft Teams platform using Microsoft Paint and Pocket Paint mobile apps. Students prepared a PowerPoint on a specific topic (occlusal rims and anatomical landmarks), which was reviewed by the instructors and further presented online to their peers ($n = 54$). The peer-teaching process was followed by interactive instructors' discussions, with the instructors asking leading questions randomly to the students, explaining and summarizing the content. The student group PowerPoint presentations and demonstration videos of occlusal rims were made available to the class to facilitate asynchronous e-learning.	Positive: Pocket Paint mobile app was an alternative for students who were unable to access MS Paint by desktop or laptop. Students agreed (65.3%) group activity made them feel responsible and confident. Most students agreed (61.2%) virtual exercises helped in understanding the content. Negative: Instructors' discussions took time and patience, as there was difficulty in assessing the nonverbal responses of the non-participating students. Instructors and students faced technical issues while creating and submitting the quizzes and assignments.
Goodacre et al.	Three-dimension (3D) Tooth Atlas app from eHuman for at-home waxing projects	November 23, 2020	USA	First-year dental students ($n = 99$)	Zoom	Students in a 3-week intensive course for tooth morphology were provided with the instrumentation and materials required to complete five waxing projects at home using the 3D Tooth Atlas app. At the same time, the didactic content was presented via 11 webinar sessions. A postcourse survey provided student perspectives regarding this new experience.	Positive: Students were able to effectively complete high-quality waxing projects at home by using step-by-step images and videos, but the survey indicated an overwhelming preference for in-person instructors' feedback. Webinars based on the students having studied the 3D Tooth Atlas and an instructor reviewing content in the Atlas was effective in teaching the didactic aspect of tooth morphology as evidenced by the student grades and survey results. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Iwanaga et al.	Three-dimension (3D) virtual reality (VR) used for an online lecture on a surgery and related anatomy	January 9, 2021	USA	Instructors from the United States and attendees from Japan	Spatial virtual workspace	To join the workspace, all attendees including the instructors used the VR headset. The lecturers used regular teaching slides and videos to show the dental surgical procedures and related anatomy in the VR workspace. In addition, other contents such as a PDF file, an mp4-formatted video, and glb-formatted accessory VR assets were uploaded in the same workspace to help attendees understand. The instructors could use these additional tools any time during their lecture. Multiple items could be displayed simultaneously in addition to the main teaching slides. The instructors could also stand anywhere in the Spatial workspace, for example, beside the slides or away from them. A postlecture discussion was conducted in another environment in Spatial.	Positive: Ability to take a closer look at the slides/images in various directions by attendees, which cannot be achieved with other virtual teaching methods. The use of VR technology with a live communication tool could be an alternative teaching method. Negative: Limited data can be uploaded in Spatial. In Spatial, only limited types of 3D formatted data are available. It would be challenging to use 3D anatomy data with precise anatomical features in Spatial.
Mladenovic et al.	Dental Simulator v1.13 for iOS and Android for local anesthetic simulation	August 17, 2020	Serbia	Fourth-year dental students at the Department of Dentistry, instructors of medicine University of Pristina ($n = 11$)	Mobile platform	Instructors for fourth-year dental students teaching a local anesthetic decided to provide students education through a mobile platform. Students used a mobile simulator in Serbia over a mobile phone during a pandemic from their home. Through the "Simulation" mode, students are able to simulate the procedure of maxillary infiltration and inferior alveolar nerve block (IANB) anesthesia in a 3D environment, with feedback. The instructor followed the educational process through the "University Mode" application, which recorded all the attempts and mistakes of the students during the 3D simulation.	Positive: All respondents (100%) believe (agree and strongly agree) that the application helped them to better understand the techniques of local anesthesia and that it can be of great help in learning in other disciplines. Negative: None were noted.

(Continues)

TABLE 1 (Continued)

Study/lead author	Type of intervention	Date received by journal	Country	Sample description	Intervention delivery/virtual communication app	Intervention description	Results
Omar et al.	CAE Learning Space for standardized patient experience	July 15, 2020	USA	Dental students (D1 [$n = 60$] and D2 [$n = 41$])	Zoom	D1 and D2 students were required to have patient encounters where they could gather medical and dental history information as well as formulate a treatment plan based on a standardized patient. The software CAE Learning Space linked each encounter to a recorded Zoom meeting. The ability of the software to capture the recorded encounters enabled the instructors to observe these encounters and to provide feedback. This also enabled the students to revisit their encounters for self-improvement.	Positive: Students' feedback was positive for the activity. Negative: None were noted.
Patterson et al.	Mentimeter for embedded quizzing with PowerPoint presentations	May 14, 2020	Four pediatric dentistry residency programs across three states and two time zones	Pediatric dental residents ($n = 50$)	Zoom, Microsoft PowerPoint	Mentimeter is a cloud-based package that allows presenters and recipients to interact in real time during an uploaded presentation by incorporating various formats of quiz questions and polling queries. Response anonymity eliminates intimidation while fostering participation for small groups, whereas for larger programs, the data collected assist presenters in restructuring real-time content delivery for improved efficacy.	Positive: Data recorded during the multilocation interactive session showed participants answered 61% of 13 questions queried during the presentation correctly, and 83% of seven questions following the presentation correctly. Participating pediatric dentistry residents reported a valuable learning experience. Authors noted Mentimeter was unique because it promoted learning activities among different levels of learners. Negative: None were noted.
Rath et al.	Microsoft Whiteboard for teaching periodontal surgery principles	December 2, 2020	Malaysia	Final-year undergraduate dental students of SEGi University ($n = 50$)	Microsoft Teams	Authors evaluated students' perception of using Microsoft whiteboard as a learning resource compared to other resources such as PowerPoints and video with Kahoot. Students are not aware of the research to prevent the Hawthorne effect, as the lesson plans were part of the regular curriculum. Each session lasts 120 min.	Positive: One hundred percent of students responded showing that 92% of the students agreed that "students benefited" from Whiteboard sessions, followed by 8% for the video and Kahoot. Negative: None were noted.

Abbreviations: CCD, charged couple device sensor; CODA, commission on dental accreditation; DXTR, dental X-ray teaching and training replica; HBSL, Home-based simulation learning; IQR, interquartile range; IT, information technology; MCQ, multiple choice questions; MiPACS, Medcor Imaging, Charlotte, NC; MWU-CDMA-AZ, Midwestern University College of Dental Medicine-Arizona; PDF, portable document format; RADCON, Defined as a "templated interpretation form" in the article; RINN, RINN XCP is an instrument used in dental radiography by Dentsply-Sirona company, Charlotte, NC; SIM, simulation.

shifted instruction and demonstration of oral hygiene instruction with dental hygiene students to a fully virtual platform using manikin heads with real-time feedback from instructors.³³ A statistically significant positive correlation was established between the online course design for problem-solving and guided reflection with the most important factor to students being feedback and reflection.³³ Moore et al. polled student satisfaction at 77% and identified Zoom as a preferred platform for virtual learning.²⁵ Yet, technical challenges were encountered such as difficulty interacting with students who did not have their cameras on.²⁸

The third area in this domain focused on returning to in-person clinical and general dental education.^{26,29,30,32} In one study, radiology course material was front-loaded online to lighten the in-person clinic requirements and assist with completing the course requirements within the semester.²⁶ In another, curriculum committees met using a think-pair-share activity to evaluate long-term changes to the curriculum based on what had transpired during the pandemic.³⁰ Advantages included identifying that fundamental topic knowledge can be successfully delivered online, and videos can be used to help enable online discussions.³⁰ Lastly, a nontraditional addition to the dental clinic coursework was diaphragmatic breathing to help calm pandemic-related anxiety.²⁹ The breathwork was led in huddles by instructors before patient treatment. Instructors and students expressed benefits from the calming effects and a more relaxed clinical environment for patient care.²⁹ One disadvantage was some instructors were not as comfortable leading the breathwork due to lack of confidence in the technique, but were willing to learn.²⁹

3.2.3 | Instructional technology

We operationalized instructional technology as the virtual platforms used for collaboration. In total, 10 studies met these criteria.^{35–44} Epidemix 2, robot-SIMROID, Kobra Surgery simulator, and asynchronous e-learning tools like Google Classroom, Microsoft Teams, YouTube, and WhatsApp were used to deliver the interventions. E-learning tools allowed students and instructors to engage in “beyond the classroom” learning during the pandemic. In Malaysia, free online resources, quizzes, discussion forums, and assessments related to clinical and nonclinical procedures were posted on YouTube for a better student understanding.³⁵ In a study by Lee et al., before-during-after strategies which included signing a test ethics pledge before the exam, automated face tracking on Zoom, and listing cheating behaviors along with their consequences were implemented. These strategies helped to avoid cheat-

ing when using remote assessments.³⁷ Postassessment student surveys indicated that the face tracking technology, Zoom monitoring, and random question sequencing were perceived as effective ways to control cheating by 32%, 95%, and 67% of students, respectively.³⁶ In another study, Microsoft Teams helped facilitate the monthly oral and maxillofacial surgery journal club, rotations in a simulation clinic, and problem-based learning.⁴³

In another study by Mansoor, enquiry-based learning was implemented using Zoom.⁴⁴ Ninety percent of the dental students stated they found the remote educational meetings beneficial.⁴⁴ Over half of the dental students agreed that distant education is better than the regular delivery of their academic dental education, despite the lack of face-to-face contact. A few barrier arose including difficulty accessing the course material, navigating the system, submitting assignments, and poor internet connection.⁴⁴

Buchbender et al.⁴² devised a pioneering method for oral surgery simulation using a Kobra Surgery Simulator. Overall, students showed less precise surgical skills than dentists, especially the younger group. The observations show that computer surgical simulation cannot replace hands-on training, but the Kobra simulator may provide more clinical experience for students and may offer new opportunities for practical examination, offering benefits for the instructors as well.⁴² In another study by Nishioka et al., a humanoid robot-SIMROID simulated as a patient was utilized for the international students.⁴¹ This robot could interact with students through movements, provide pain feedback, and help students build communication skills with patients. Overall, 97.7% of students revealed that SIMROID was “effective in dental training” because of the robot’s ability to mimic the patient response, open the mouth realistically, and respond to any uncomfortable procedure. However, barriers include expense, lack of space, maintenance, and only a few students were able to practice at one time.

3.2.4 | Software

The domain software was operationalized as the digital programs and tools used to facilitate learning in new virtual environments.^{45–53} In studies by Gali and Rath et al., Microsoft Paint, Pocket Paint, and Whiteboard were used for teaching preclinical prosthodontics and periodontal surgeries.^{46,49} In both studies, most of the students benefited from this type of instruction using the noted software platforms. However, instructors found it difficult to assess the nonverbal responses of the nonparticipating students, and the technical issues involved with creating and submitting quizzes and assignments.^{46,49}

First, Omar et al. used CAE Learning Space to link each encounter of participants with patients and enable the instructors to observe these encounters and provide feedback.⁴⁵ Using the online platform, they created opportunities for all students to complete the planned standardized patient encounters. The feedback by students ($n = 81$) was positive for the activity.⁴⁵ In another study, students in Serbia used a mobile dental simulator from their home to simulate the procedure of maxillary infiltration and inferior alveolar nerve block in a 3D environment, with feedback.⁴⁷ All respondents (100%) believed that the application helped them understand the techniques of local anesthesia.⁴⁷ Next, the 3D Tooth Atlas app was used for at-home waxing projects.⁴⁸ A postsurvey revealed an overwhelming preference for in-person instructors feedback for waxing projects.⁴⁹ In a study by Iwanaga et al., the online virtual reality (VR) required a VR headset for lectures to show the dental surgical procedures and related anatomy in a VR Spatial workspace.⁵¹ Authors found VR with a live communication tool could be an alternative teaching method. However, data storage is limited, and access to precise anatomical features posed challenges.⁵¹

Lastly, in a study by Patterson et al., a cloud-based package, Mentimeter allowed presenters and recipients to interact in real-time during a presentation by incorporating various formats of quiz questions and polling queries.⁵⁰ Knowledge attainment was high, and participating pediatric dentistry residents reported a positive learning experience.⁵⁰

4 | DISCUSSION

This is among the first scoping reviews of its kind to examine dental education practices during COVID-19. We sought to identify benefits and barriers to techniques as well as determine best practices that can be incorporated in dental education. This information can be used for countries still under the constraints of pandemic protocols, in addition to determining which virtual practices can be incorporated once traditional educational practices continue.

Although COVID-19 emergency guidelines required dental education programs to shift to a virtual education format, dental instructors rose to the challenge with creativity and new pedagogical planning and delivery. Instructors incorporated lectures, videos, and group discussions to engage critical thinking based on the patient treatment being mindful of complying with guidelines established by the American Dental Education Association for remote learning during the pandemic.⁵⁴ Many dental and dental hygiene programs included workshops and webinars incorporating formative and summative

assessments.⁵⁵ The shift to online education was met by using a platform like Zoom to hold synchronous and asynchronous didactic coursework.² Assessments were viewed positively due to the ability to assess student competence using adapted course objectives. Instructors modified online instruction to include flipped classroom pedagogy and recorded lectures to facilitate new learning environments during COVID-19. Providing students with pre-recorded lectures in the flipped classroom format allowed for more time for synchronous discussions with instructors. One unconventional instructional delivery included diaphragmatic breathing to help decrease student's anxiety returning to clinic work during a pandemic which served as a springboard to enrich relationships between community, students, and instructors.²⁹ The most successful virtual platforms used for instruction collaboration included Google Classroom, Microsoft Teams, and Zoom. Specific software programs, such as CAE Learning Space, Microsoft Paint, Mentimeter, and VR, were used to facilitate learning in new virtual environments.

Transitioning to fully online education using virtual platforms was not without issues, as noted in another review.⁸ First, studies found a general lack of the essential hands-on training for the dental professional, which cannot be replicated in a virtual setting. Second, technical difficulties made online education especially challenging for instructors and students, and Wi-Fi connections were consistently lost or interrupted. Third, time management during synchronous online coursework was difficult to manage, and instructors found it difficult to fully engage students in discussion or reflection. Last, there was a lack of perceived interaction between instructors and students when students did not turn on video cameras.

Finally, several best practice recommendations are provided for dental schools and programs to consider if interested in pursuing virtual and distance learning. First, the OSCE could be used for clinical exercises and "real-life" clinical cases, and online assessment. Second, student presentations and simulation demonstrations held virtually can be effective tools for evaluation and reflection. Third, consider implementing the flipped classroom approach for courses with lecture heavy material, which will allow for more peer-to-peer interaction to foster critical thinking through group work. Fourth, continue training instructors to establish best online practices and ensure engaging educational experiences for students. Fifth, incorporate online platforms for practical patient encounters to enhance dental students' communication skills. Sixth, create and implement interactive learning approaches to overcome student passivity. Seventh, mobile applications can successfully be used with conventional learning to teach specific dental techniques. Finally, for online learning, create pre-, mid-, and postcourse evaluations to rate

TABLE 2 Best practices summary by domain

Domain	Promising strategies for virtual dental education	Merits	Demerits
Assessment	Objective structured clinical examination (OSCE)	Students had a positive attitude toward the exam	Lack of hands-on activity, technical and time management issues, picture clarity/quality issues
	Online assessments	Accepted by all	Other skill sets not assessed, minor technological issues
	Recorded lectures	Help students understand the written materials	Poor attire and professionalism during recorded patient encounter, lack of in-person and active dissections
Instruction	Flipped classroom technique	Easy to use	Less discussion time, connectivity issues
	Virtual early childhood oral health training program (EChOTrain)	Effective in teaching course content	Technical issues, less interaction between students and faculties
	Think-pair-share activity on a virtual curricular retreat	Fundamental content can be taught	None were noted
	Diaphragmatic breathing/deep breathing	Lowering anxiety in students	Instructors lacked confidence in teaching breathing exercise
Instructional technology	Asynchronous learning tools: Google Classroom, YouTube, and WhatsApp	Freely available	Internet issues, navigating, accessing course, and assignment submission issues
	Microsoft Teams in simulation clinics and for problem-based learning	Development of critical skills	Internet issues
	SIMROID-robot	Robot effective in mimicking a patient	High cost and maintenance, time consuming, can be used by one person at a time, need special areas for installation
Software	Microsoft Paint and Pocket Paint mobile apps	Enabled understanding of course content, made students feel confident	Technical issues, difficulty in assessing nonverbal responses
	Three-dimension (3D) virtual reality	Images can be easily viewed as compared to other apps	Limited data can be uploaded

student learning and engagement, especially given the known challenges of knowledge attainment in a virtual setting. These have also been outlined in Table 2.

5 | LIMITATIONS

Our findings must be interpreted in the context of the following limitations. First, although exhaustive search methods were used to eliminate any potential bias, it is possible that not all quantitative studies were identified. Second, the primary articles used a variety of experimental and quasi-experimental designs, and reported numerous outcomes, limiting the potential for a meta-analysis. Furthermore, the sample characteristics were omitted from

several of the reviewed studies, potentially influencing the generalizability of the findings to other contexts. Despite an extensive search, a publication bias could also be possible due to the omission of nontraditional or unpublished literature. Many studies focused more on proof of concept than employing a rigorous experimental design given the fast-changing nature of the pandemic and need for virtual education platform. For this reason, important study details were missing from primary articles, limiting our ability to perform a formal assessment of bias. Furthermore, as only one study took place in a dental hygiene program, more evidence is needed in areas of dental hygiene and dental assisting. Finally, studies lacked important comparative outcomes, such as grades, pertinent to student academic performance.


6 | CONCLUSION

Dental education halted with the emergence of COVID-19, and instructors across the world transitioned from traditional way of students working in clinical laboratories to fully online education. A review of dental education practices since the start of pandemic will help to understand nontraditional approaches instructors have taken to provide dental education during this unprecedented time to establish recommendations for best practices going forward. Future work should be done to validate novel teaching methods in online dental education with virtual platforms using a more robust design. It is advisable to consider publications outside of dental such as medical and nursing to enhance future discussion. Studies should also seek to compare traditional versus virtual education by student grades. In addition, increased representation from dental hygiene and dental assisting programs is needed to broaden the scope of virtual dental education. In summary, the COVID-19 pandemic was a challenging period in dental education for instructors and students. Despite the challenges, our scoping review illuminated emerging best practices in dental education during COVID-19 and recommendations for the future of virtual and distance learning in dental education in postpandemic times.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

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