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Summative assessments of web-based patient simulations of pre-clinical local anaesthesia and non-surgical extraction

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Abstract

Introduction: The purpose of this study was to evaluate the use of web-based patient simulations, a whole-task simulation, in oral surgery education for second-year pre-clinical dental students on learning outcomes regarding cognitive, psychomotor and professional interpersonal skills for two topics: local anaesthesia and non-surgical extractions.

Materials and Methods: In 2018–19, using an experimental design in a live course, we evaluated two web-based patient simulations on student learning outcomes in an introductory course on oral maxillofacial surgery. The study was repeated across two semesters, Fall (N = 109) and Spring (N = 112), on two different topics, namely local anaesthesia and extractions, respectively. Learning outcomes were evaluated for each topic with two different assessment formats: a student-recorded role-play video project and a fifty-item multiple-choice test.

Results: For both topics, local anaesthesia and non-surgical extractions, students in the group, *Web Sim*, who used the web-based patient simulation over and above the online lesson material earned significantly higher scores in the role-play patient video project compared with the group, *No Web Sim*, who only used the online lesson materials. However, scores on the fifty-item multiple-choice test did not differ significantly between groups.

Conclusions: The results suggest that the web-based patient simulation as a formative assessment type is a useful scaffolding tool for the summative student-recorded role-play patient video project due to the similarity in activity types that support clinical learning objectives.

KEYWORDS
assessment, experiential learning, local anaesthesia, oral surgery, simulations

1 | INTRODUCTION

Dental education has traditionally employed two principal methods of teaching: the dissemination of information—through a combination of books, lecture, in-person demonstrations and videos—and the development of psychomotor skills—through manikin laboratories and apprenticeship models.[1] First- and second-year students (D1 and D2) at New York University's College of Dentistry digest large bodies of knowledge through lecture and textbooks as well as observe and practice procedures of psychomotor skills in pre-clinical laboratories on part-task trainers (e.g., manikin heads and typodonts). Third- and fourth-year students (D3 and D4) are

exposed to a smaller group apprenticeship model with faculty in a clinical setting. Success for D1 and D2 students is measured mainly at the course/grade level according to foundational and pre-clinical learning objectives, using traditional examinations.

Beyond knowledge and psychomotor skills, clinical practice includes clinical decision-making, communication, professionalism, leadership, teamwork, management and care with varied challenges and situations.[2] However, students do not begin to learn or integrate these skills until they enter the supervised clinical environment.[2] Simulation for clinical contexts is "an attempt to replicate some or nearly all essential aspects of a clinical situation so that the situation may be more readily understood and managed when it occurs for real in clinical practice"(p.3).[3] They can be used in addition to traditional examinations as summative assessments as well as practice for formative assessment to go beyond the measurement of knowledge to include other skills. Whilst ample research has investigated the use of simulations to train technical maxillofacial procedures and surgical skills on part-task trainers such as plastic and virtual manikins,[4,5] there is a shortage of experimental designs in dentistry education on the use of patient simulations to develop the combination of cognitive, psychomotor and interpersonal skills needed to address the whole patient.[6,7] This study evaluates the use of web-based patient simulations, a whole-task simulation, in oral surgery education for second-year pre-clinical dental students on learning outcomes to integrate knowledge and skills for topics: local anaesthesia and non-surgical extractions.

1.1 | Rationale for simulations in dental education

Using patient simulations as a method for teaching and learning in the topics of local anaesthesia and non-surgical extractions support an ethical perspective in terms of patient safety as well as a theoretical perspective in terms of teaching, learning and assessment.

There is an ethical responsibility to provide optimal treatment under safe conditions for the well-being of the patient.[8] At New York University's College of Dentistry, students are not permitted to practice injections on each other when there is no indication for the procedure or medication to be given. Such injections may lead to more complications and may not promote confidence or competence. Survey studies reveal that many students do not feel adequately prepared to perform their first injection in a live patient in a clinical setting.[5,9,10] Moreover, this lack of preparation is associated with low confidence reports and increased anxiety levels, not only from the students but also from the patients.[5,9,10] The same lack of preparation extends beyond the technical skills to interpersonal skills, communication related to pre- and post-operative patient care, and treatment management plans. For example, if a student does not accurately take or refer to the patient's medical history or perform necessary vital signs (e.g., blood pressure, respiratory rate and pulse), the health of the patient may be at risk during local anaesthesia injection, non-surgical or surgical extractions. Lack of adequate preparation to provide "whole" patient contact is due to a gap in the curriculum to offer a "controlled, safe and forgiving" environment to practice these skills.[11]

There are two major simulation techniques used in dental and medical education, namely simulated laboratories and patient simulations. Simulated laboratories usually focus on part-task skill development using plastic typodonts or manikin heads whereas patient simulations tend to focus on whole-task skill development using live or virtual patients. This study focuses on simulations that fall under the umbrella of patient simulations. Patient simulations aim to "replicate as closely as possible an authentic clinical scenario."[1] Learning with real patient context aims to simulate the "whole patient care" from the first examination to the outcome treatment.[12] It also aims to smooth out the transition from pre-clinical to clinical apprenticeship setting.[1,13] Patient simulation-based learning includes techniques that are varied in complexity such as case-based simulations, standardised patients, web-based patients and role-play simulations to meet several learning objectives defined under cognitive, psychomotor and interpersonal skill levels.[7,14–16,16,17] These skills may also include clinical decision-making, reasoning, ethics, empathy and compassion.[4] Learning with real patient context surrounding the psychomotor skills aims to promote a deeper understanding of the profession and develop critical thinking skills.[1] It aims to simulate the "whole patient care" from the first examination to the outcome treatment.[18] This study focuses on simulations that fall under the umbrella of "whole-task" patient simulations as opposed to part-task simulations (e.g., plastic typodonts and manikin heads).

Prior research on the use of patient simulations in dental education has produced some positive results, and more research is needed to evaluate them.[7,18,19] In one study, researchers surveyed undergraduate student perceptions on the use of the Web-SP to develop critical reasoning skills using case studies and an oral surgery simulator to develop psychomotor skills. Student perceptions reported positively to the Web-SP and that it should be included in the curriculum but rated their possible learning outcomes lower than expected given the lack of instructor feedback and limited number of cases. Students rated the oral surgery simulator high in terms of perceptions of improved skills.[7] Researchers evaluating the use of a patient simulation to teach decision-making skills and treatment planning over and above regular teaching found that students who received regular teaching and practiced with the patient simulator scored higher on a performance test compared with student who only received regular teaching.[18] In another study, researchers compared with lecture-based teaching to the Web-SP demonstrated statistically significant learning gains between a pre- and post-test for the majority of students but not all students. Lower performing students improved most from the use of the Web-SP experience.[19]

In 2014, Introduction to Maxillofacial Surgery (OMFS), a D2 two semester long course with roughly three hundred and eighty students enrolled each year, was transformed from a traditional lecture format into a blended learning design, providing a mix of in-class lectures, manikin-based practice laboratories, online multimedia lessons, role-play patient video projects and traditional tests. In 2016, web-based patient simulations, designed and

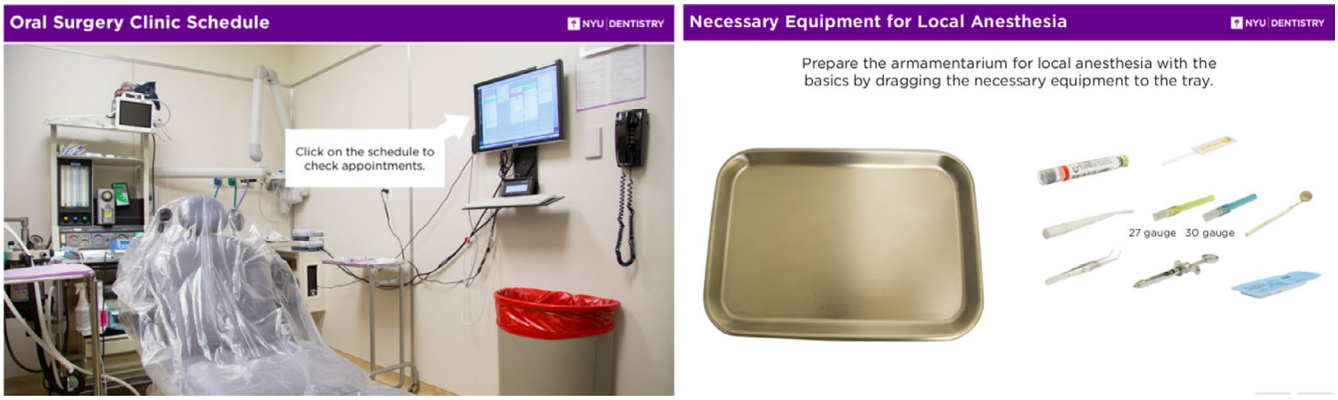

FIGURE 1 Two frames from the web-based patient simulation (local anaesthesia)

developed using 2D images, video and Adobe Captivate software, were added to the course in order to bridge foundational content in the online multimedia lessons and the role-play patient video projects. Other development software options such as unity for a 3D virtual reality experience was cost prohibitive, and thus, the less expensive Adobe Captivate software was chosen. Explicit goals in the course are for D2 level students to integrate knowledge with interpersonal and psychomotor skills around the topics of local anaesthesia and exodontia in order to prepare for a supervised clinical setting in the following 2 years. Refinement of materials over several years led to this investigation into the effects of these materials on student learning.

The purpose of this study is to evaluate the use of web-based patient simulations, a whole-task patient low fidelity simulation, in oral surgery education for second-year pre-clinical dental students (D2) and to assess its impact on learning outcomes covering cognitive, psychomotor and professional interpersonal skills. The study evaluates the web-based simulation using two summative assessment types: a student video-recorded role-play project and a written fifty-item multiple-choice test. Of these two types of assessments, the role-play patient video project is more closely aligned with the web-based patient simulation insofar as they are both designed to situate the learner in a clinical case and it represents a "near transfer" test of the new knowledge learned from the web-based simulation.[20] The multiple-choice test assesses the same knowledge and content but decontextualised from a clinical case. The specific study questions are:

1. What is the effect of a web-based patient simulation on a knowledge task measured by a fifty-item written test?
2. What is the effect of a web-based patient simulation on a performance task measured by a role-play patient video project?

2 | METHODS

The Formal Internal Review Board (IRB-FY2018-2227) at New York University approved this study.

2.1 | Setting

The study was conducted at New York University's College of Dentistry with undergraduate, second-year, students during regular class time for the Introduction to Maxillofacial Oral Surgery (OMFS). The course was one a credit course that spans two semesters with three hundred and sixty-five students enrolled. This study commenced in the Fall 2018 and ended in Spring 2019. This course was predominantly an online course with one online pre-course diagnostic, three online lessons, two online web-based simulations, two online quizzes, two video role-play sim assignments submitted online, four recommended in-person lectures and two required in-person laboratory sessions. The study focused on the online components of the course. Online components were accessed through the university's learning management system.

2.2 | Materials and measurements

Materials and measurements for this study from the OMFS course covered topics in local anaesthesia during the Fall 2018 and extractions Spring 2019. For each topic introduced in each semester, there were online multimedia lessons, a web-based patient simulation, a fifty-item test and a role-play patient video project. Additionally, at the start of the Fall 2018 course, students completed a fifteen-item pre-course diagnostic test covering mainly the topic, local anaesthesia, to measure prior knowledge.

The pre-course diagnostic test contained fifteen multiple-choice questions on the topic of local anaesthesia and delivered online through the LMS. It was timed to 30 min. Each question was randomly delivered and answer choices randomly displayed. Students received a final score the next day but did not receive feedback on individual items.

The online multimedia lessons contained a mix of video demonstrations, text and images, and knowledge check questions. They covered core course content and procedural skills demonstrated by the instructor. The content provided breadth of information rather

FIGURE 2 Two frames of the role-play patient video project (local anaesthesia)

than specific to a clinical case. All students accessed the online multimedia lessons prior to other course materials.

The two web-based patient simulations (Figure 1), one on local anaesthesia and one on non-surgical extractions were storyboarded for images and scripted for audio recordings using PowerPoint, developed using *Adobe Captivate* authoring software and accessed in the course site managed by the university's LMS. Both follow a real patient case scenario that engages the student to interact and respond as if they were the doctor with a patient in a clinical dental operatory room. Each patient case requires about 20–30 min to complete. Each patient case was constructed using photographs taken of a clinical dental office, dental equipment, the AxiUm patient system, a patient in a dental chair, as well as short video and audio clips and programmed interactions. The learner progresses through the narrative case by advancing the "next" button or responding to a prompt. Students are provided a practice version and an assessment version. The practice and assessment versions are exactly the same cases except for the completion requirements. Students are required to achieve 100% on the assessment version to pass but can access the practice version as often as desired. The practice version provides immediate feedback after each assessable interaction and a final score at the end whilst the assessment version only provides a final score.

In the web-based patient simulations, the learners are guided with prompts to click on equipment in the dental office to initiate an action, select correct answers to questions that assess their knowledge of information presented, determine next steps in the clinical process, demonstrate knowledge of anatomy and procedural steps for local anaesthesia or non-surgical extraction, or make clinical decisions. Students are assessed specifically on their knowledge of pre-operative procedures such as how to review patient medical history, assess vital signs and anxiety levels, explain procedures and consent information to a patient. To assess their knowledge of procedural steps, they are also prompted to drag instruments to target spots such as setting up an armamentarium tray, anatomical locations for injections in the patient mouth or non-surgical extractions. They are also assessed on post-operative procedures such as confirming anaesthesia, providing walk-out instructions and prescribing medications. For each web-based patient simulation, the learner is guided and assessed through the entire patient care process.

For example, the web-based simulation for local anaesthesia starts by providing the learner instructions and learning objectives. The first scene is the clinical dental room with a prompt for the learner to click on the clinic scheduler located on a computer in the dental office to determine who the next patient is for a visit. Next, the simulation prompts the learner to determine the reason for the visit by reading about the patient from screens taken from the AxiUm patient system. The learner is then assessed for the reason for the visit by selecting a choice out of three presented on the screen. If the learner answers in correctly or incorrectly, they are provided explanatory feedback in the practice version but not in the assessment version until the very end. Next, the learner is prompted to review the patient's medical history based on the information on the AxiUm screens and prepare to ask questions to the patient in person about their medical history. Next, the learner is prompted to click on the phone in the office to call the patient in. The next screen shows the patient sitting in the dental chair. The simulation prompts the learner to type into an artificial intelligence (AI) chat box a question to the patient, about the reason for her visit and chief complain. The patient responds with "I have pain in my lower left tooth." The learner is then prompted to ask the patient about her medical conditions and allergies by typing into the AI chat box. The patient responds "I have hypertension." The interactions between patient and doctor continue until complete. The scenario continues to guide the learner through each detailed step assessing their knowledge at each step until the very last where the learner is assessed on where and how to confirm the anaesthesia has sufficiently numbed the patient.

The role-play patient video project, like the web-based patient simulation assignment, aimed to engage students in an authentic whole patient case scenario. Students worked in teams of three to role-play a given patient case (Figure 2). The role-play assessment evaluates student learning using the web-based simulation over and above the other online lesson materials and the effort applied to planning and organising information for the role-play patient video project. The student video-recorded role-play project aimed to assess students' ability to communicate professionally and accurately with patients, to perform pre- and post-operative procedures, and to demonstrate knowledge of anatomy as well as doctor to patient positioning whilst holding and using paper instruments. Each student took turns being the doctor, the patient and the video-recorder. To preserve student safety, paper instruments and long Q-tips were provided to simulate a syringe and other instruments. Students were also encouraged to perform their video projects using dental office equipment at [*Institution*]. These rooms were equipped with dental chairs, lights and trays for students to feel more immersed in an authentic scenario. Students were encouraged to use the online

materials to help prepare their role-play patient video projects. Teams submitted through the university's learning management system (LMS).

Figures 3 and 4 provide the patient case and list of skills to be performed by students in each team. Each case, one for local anaesthesia and one for non-surgical extractions, varies slightly from the cases presented in the web-based patient simulation. For example, in the local anaesthesia case for the video project the patient must have three teeth removed whereas in the web-based patient simulation only one tooth requires removal. Patient information also varies from these two cases in terms of vital measurements since students are required to take the vital measurements of their live patient for the video project compared with the web-based patient simulation that provides the reading from the fictional patient.

The instructor and trained teaching assistants (TAs) for the OMFS course were randomly and blindly assigned team videos to score using a rubric (15-point total score) and provided meaningful feedback. A second evaluator reviewed the evaluations by the instructor and TAs for quality assurance and made any necessary adjustments such as additional point deductions and specific feedback. The TA's attended a training session conducted by one of the researchers of this study on how to evaluate the videos using the rubric. There was no partial credit for each item in the rubric. For each item in the rubric, students receive a zero or a point value.

The two fifty-item multiple-choice tests cover core instructional material based on the semester; local anaesthesia in the Fall and exodontia in the Spring. The multiple-choice test evaluates student learning using the web-based simulation over and above the online lesson materials. Each summative multiple-choice test aimed to assess student knowledge of core content and procedural steps. The test was delivered online through the LMS and timed to 1 h. Each question was randomly delivered and answer choices randomly displayed. Students received a final score the next day but did not receive feedback on individual items.

Whilst no assessment is truly perfect both assessments aim to maintain reliability and validity. The student video-recorded role-play project maintains reliability and validity by providing students clear written instructions, only focuses on material taught and does not introduce any new skills or information. It also maintains reliability in terms of evaluation by using a rubric scored by trained teaching assistants and the course instructor in order to control for grader bias. Both the assignment and rubric were developed and refined over prior years from student and colleague feedback. The fifty-item test maintains reliability and validity by only presenting questions that capture the material taught, provides a good number of questions, automatically scored by a testing tool, and was also developed and refined over prior years from data analysis of student performance on each item. Given that the fifty-item test is automatically scored by an online testing tool, it is error-free compared with the rating process of the role-play project that can increase error.

2.3 | Recruitment procedures

At the start of the semester, an online message and in-person class announcement introduced the study and provided instructions on how to participate to both Fall 2018 and Spring 2019. After the introduction to the study, students received an email with a link to the consent form using Docusign software. All students who consented to participate in this study were ascribed a unique identifier in order

Case: Below are **screenshots** of your patient's record from the Axium System (Jane Smith, a 34-year-old female with hypertension). Review the case carefully to help you determine the procedure plan, classify the patient, assess the treatment setting, and determine clearance for treatment. This information will be helpful to communicate conclusions in your video during the pre-operative assessment and management section.

You will be assessed on how well you verbalize and demonstrate your knowledge and skill of the following:

1. **Pre-operative management of the case (Include all below in video)**
   a) Wear Proper PPE (Each Student)
   b) Review the Referral Screen from Axium. Why is the patient here today? Which approach or approaches to anesthesia are needed? (Student 1)
   c) Review Past Medical History from Axium. How is the patient classified? Note important findings that may have implications for treatment. (Student 1)
   d) Interview your patient for their medical conditions and any medical requirements. (Student 1)
   e) Take New Vital Signs & Interpret Vital Results (Bring your own equipment) – (In real clinic, you would enter these new results in Axium under Column Vital Sign 02) (Student 2)
   f) Assess Treatment Setting & Clearance for treatment (Provide verbal conclusions based on AXIUM Screenshots below & New Vital Results) Is the patient optimized for treatment today? Based on the medical history and today's vital results, where should the treatment occur (e.g., Hospital or NYUCD)? (Student 2)
   g) Obtain Informed Consent (*Discuss with the patient the contents of the consent forms before asking patient to sign*) (Student 3)
   h) Assess & Manage Patient Anxiety (Student 3)
   i) Discuss the Local Anesthesia Procedure with Patient (Student 3)

2. **Local Anesthesia (Each Student performs all listed below; Student 1 covers Tooth #30; Student 2 covers Tooth #3; Student 3 covers Tooth #20)**
   a) Assemble the Local Anesthesia Armamentarium (Use Paper Armamentarium) (Each Student)
   b) Position Patient in Chair and Position Dentist Properly (Each Student)
   c) Name the relevant injection/s for the case (Each Student)
   d) Identify anatomical landmarks for this injection (do not use images, show & name the area of the planned injection site). What is the target nerve/s for the injection/s? Show the landmark/s using a q-tip in the patient's mouth. (Each Student)
   e) Demonstrate proper technique for the injection as well as the rationale. Where will you be injecting the needle? What are the steps through the procedure? (Use a long q-tip to simulate the needle.) (Each Student)
   f) Demonstrate how you will know the patient is anesthetized (Each Student)
   g) Demonstrate disassembly of the armamentarium & technique for recapping the needle safely (Each Student)

FIGURE 3 Role-play patient video project case (local anaesthesia)

Case: Below are **screenshots** of your patient's record from the Axium System (John Doe, a 22-year-old Male). Review the case carefully to help you determine the procedure plan, classify the patient, assess the treatment setting, and determine clearance for treatment. The patient's vitals have already been taken but you need to interpret them from the screenshots of the system. This information will be helpful to communicate conclusions in your video during the pre-operative assessment and management section. **For this video, you do not need to demonstrate the local anesthesia section.** After completing the pre-operative section move to Operative management of the case and finish with the Post-operative management.

You will be assessed on how well you verbalize and demonstrate your knowledge and skill of the following:

1. **Pre-operative management of the case (Include all below in video)**
   a) Review Past Medical History & Classify Patient; Assess Treatment Setting & Clearance for treatment (Provide verbal conclusions based on Axium Screenshots);
   b) Assess & Manage Patient Anxiety
   c) Interpret Vital Signs from Axium (Based on Screenshots below)
   d) Discuss Procedure, Risks, Benefits & Alternatives with Patient
   e) Obtain Informed Consent
   f) Indicate the type of anesthesia and injection you will give to patient and how you will confirm numbness

~~2. Local anesthesia~~ (ALREADY COMPLETED - DO NOT INCUDE IN VIDEO)

3. **Operative management of the case – Non-Surgical Extraction (Include all below in video)**
   a) Armamentarium (Set up)
   b) Proper Patient & Dentist Position for Procedure
   c) Identify Anatomy & Landmarks. Explain what can be damaged during the procedure? Explain how you safely navigate / avoid vital structures?
   d) Identifying relevant instruments (elevators, forceps) and describe usage
   e) Demo (simulate) Core Extraction Technique Steps & rationale. Display core technique for the nonsurgical extraction on the tooth including managing the socket post-operatively

4. **Post-operative management and Rationale (Include all below in video)**
   a) Review post-operative instructions with patient
   b) Determine & Discuss Post-Operative Antibiotic (ABX) (if necessary)
   c) Determine & Discuss Post-Operative Analgesics (if necessary)
   d) Answer any questions the patient may have
   e) Schedule a post-operative visit in one week with patient
   f) Provide an emergency contact (in case of emergency) for patient

FIGURE 4 Role-play patient video project case (non-surgical extractions)

to anonymise their data and protect their identity. Analysed data resided in the university's approved secure server.

2.4 | Participants

This experimental in situ study during regularly scheduled instructional time. For the 2018–2019 academic term, students who registered for the course and consented to participate in the study were randomly assigned to one of two groups, a *Web Sim* (experimental) and a *No Web Sim* (control) group.

Effect sizes in related studies in medical/nursing/dental education comparing media or simulation-based learning strategies[12,13,21,22] were in the range of 0.228 and 0.6. Using G*Power[23] to calculate a power of 0.8 with an effect size of 0.28, the study required at least 103 students divided in to two groups (Web Sim vs. No Web Sim). The Fall 2018 study covering the topic on local anaesthesia totalled 109 participants out of 380 enrolled students. The *No Web Sim* group had fifty-five participants whilst the *Web Sim* group had fifty-four participants. A new call for participation in the Spring 2019 portion of the study occurred in January. Many students who participated in the Fall 2018 study consented to participate again in the Spring 2019 study. All consenting students were randomised into new groups. The Spring 2019 study covering the topic on extractions totalled 112 participants out of 380 enrolled students agreed to participate. The *No Web Sim* group fifty-four participants whilst the *Web Sim* group had fifty-seven participants.

The male to female ratio on each group and group was very similar. The average age was 24. The distribution of ethnic groups was predominantly Asian/Pacific Islander or White with percentages between 30% and 40%. Other ethnic percentages in the treatment groups such as Hispanic, Black or other were very small with percentages around 3%–5%. The distribution of nationalities in total and each group was predominantly from the United States with about 14%–16% International students. The average GPA for all participants was 3.3 out of 4.0 which translates to a B average. Each group had similar GPA mean and standard deviation values: No Web Sim (M = 3.3, SD =0.4) and Web Sim (M = 3.3, SD =0.4).

2.5 | Study design

As a subset of a larger experimental study conducted live during the course, this study investigated the use of a web-based patient simulation covering two topics consecutively across two semesters. The study was identically repeated across two semesters: Fall 2018 topic on Local Anesthesia and Spring 2019 topic on non-surgical extractions. For each repeat study, the measurements were a written multiple-choice Test#1 and a role-play patient video project. Students were divided into two groups, *Web Sim* and *No Web Sim*. To minimise disruptions to this live course, each group was subdivided into two groups: *Web Sim* (subgroups 2 and 4) and *No Web Sim* (subgroups 1 and 3). The group, *No Web Sim*, accessed online lesson material consisting of video demonstrations of core techniques and instructional content in the form of text and images, whilst the *Web Sim* only accessed the same online lesson materials in addition to a web-based patient simulation whilst the group to prepare for the assessments (Table 1).

Table 2 shows the groups by test. Since the fifty-item test was not part of the regular course schedule and part of a larger study, we evaluated only one group from each group on the fifty-item test, so as to minimise disruption during the course and reduce testing interference. Subgroup 1 from the *No Web Sim* group and subgroup 2 from the *Web Sim* group took the test. The role-play patient video project was assigned according to the regular course schedule and completed by all groups. The delivery of materials for both semesters covering different topics followed the same sequence by both groups:

- A pre-course diagnostic used as a covariate during analysis to control for prior knowledge differences.
- Required online lessons covering core instructional content. In addition, the *Web Sim* group completed the web-based patient simulation.
- Only *Web Sim* (subgroup 2) and *No Web Sim* (subgroup 1) took on a fifty-item test (Test #1).
- Required role-play patient video projects.

In addition to collecting scores for each measurement, completion time was also collected. Differences in completion time may also suggest differences in learning gains. In other words, how quickly one can respond to a question to demonstrate memory recall may indicate how well the learner knows the material (e.g. encoding specificity).[24]

3 | RESULTS

Mean (M), standard deviation (SD) and *t* test for scores and test time provide descriptive statistics and establish preliminary differences between groups. To establish differences between *Web Sim* vs. *No Web Sim*, whilst controlling for pre-course diagnostic scores, an ANCOVA was carried out for the scores on Test #1 and for the role-play patient video project.

3.1 | A. Pre-course diagnostic (covariate)

Descriptive statistics for average scores and test time duration on the pre-course diagnostic are shown in Table 3, displayed by group and semester. We also examined testing duration because differences in time spent can indicate differences in ability. Based on *t* test (Table 3), results demonstrated no statistically significant difference between the two groups in terms of scores and test time on the diagnostic, for groups in both semesters.

3.2 | B. Written test #1

Groups *No Web Sim* (subgroup 1) and *Web Sim* (subgroup 2) completed a fifty-item multiple-choice test, Test #1, covering separate topics in local anaesthesia and extractions, respectively, across semesters. Each subgroup was encouraged to use the online materials to prepare for the test. The *No Web Sim* (subgroup 1) used the online course lesson materials whilst the *Web Sim* (subgroup 2) used the web-based patient simulation in addition to the online course lesson materials.

For Fall 2018, *t* test differences revealed no statistically significant difference between scores on the fifty-item test for the two treatment groups, *No Web Sim* (subgroup 1) ($M = 32.77$, $SD = 6.3$) and *Web Sim* (subgroup 2) ($M = 34.92$, $SD = 6.9$), $t(50) = -1.180$, $p = .244$. For Spring 2019, *t* test differences showed no statistically significant

TABLE 1 Study design #1 for Fall 2018 and Spring 2019

Sequence of treatment resources and assessments	Groups				
	No Web Sim		*Web Sim*		
	Subgroup 1A	Subgroup 3C	Subgroup 2B	Subgroup 4D	Variables
Pre-course diagnostic	X	X	X	X	Covariate
Online multimedia lessons	X	X	X	X	N/A
Web-based patient simulation			X	X	Independent variable
MC Quiz #1	X		X		Dependent variable
Role-play patient video project	X	X	X	X	Dependent variable

TABLE 2 Groups by test type

		Test type (in order of completion)		
		1) Pre-course diagnostic	2) 50-item test #1	3) Role-play patient video project
Groups	No Web Sim	Subgroups 1 and 3	Subgroup 1	Subgroups 1 and 3
	Web Sim	Subgroups 2 and 4	Subgroup 2	Subgroups 2 and 4

TABLE 3 Diagnostic (*t* test) FA 18 and SP 19

		No Web Sim (Subgroups 1 and 3)	Web Sim (Subgroups 2 and 4)	*t* test differences
Semester indicator	Measure	Mean (SD), (*N*)	Mean (SD), (*N*)	*t*-value, *p*-value
FA 18 performance	Score out of 15	8.02 (2.01), (55)	7.55 (1.90), (54)	1.256, .212
FA 18 time	Test time	13.71 (5.24), (55)	13.64 (5.12, (54)	0.60, .945
SP 19 performance	Score out of 15	7.65 (2.22), (54)	7.78 (1.91), (57)	−0.322, .748
SP 19 time	Test time	14.22 (5.58), (54)	13.69 (4.37), (57)	0.552, .582

TABLE 4 ANCOVA test #1 (No Web Sim subgroup 1 vs. Web Sim subgroup 2) FA 18 and SP 19

Measure	Variable	df	Type 1 sum of squares	Mean square	F	*p*-value	Partial eta squared
FA18 test 1	Diagnostic	1	182.174	182.174	4.499	.39	0.084
	Group	1	75.735	75.735	1.870	.178	0.037
	Residuals	49	1984.288	40.496			
SP19 test 1	Diagnostic	1	134.108	134.108	1.736	.194	0.033
	Group	1	1.526E−5	1.526E−5	0.000	1.000	0.000
	Residuals	51	3940.461	77.264			

Note: FA 18 R squared = 0.109 (Adjusted R squared = 0.073) SP 19 R squared = .033 (Adjusted R squared = −.005)

difference between the two groups in terms of scores on the fifty-item quiz, *No Web Sim* (subgroup 1) (*M* = 28.5, *SD* = 9.2) and *Web Sim* (subgroup 2) (*M* = 28.2, *SD* = 8.5), *t* (52) =0.117, *p* = 0.907. Based on *t* test differences, there was also no statistically significant difference between the groups in terms of time to complete the test across both semesters.

Pre-course diagnostic results revealed small mean differences between subgroup 1 and subgroup 2 across both semesters. The addition of a covariate into an ANCOVA model as a control measure provides adjusted results (Table 4). For Fall 2018, there was no statistically significant difference in mean test #1 scores, *F* (1,46) = 1.870, *p* = .178 between groups *No Web Sim* (subgroup 1) and *Web Sim* (subgroup 2) whilst adjusting for pre-course diagnostic scores. For Spring 2019, there was also no statistically significant difference in mean test #1 scores, *F* (1,51) = 0, *p* = 1.0 between *No Web Sim* (subgroup 1) and *Web Sim* (subgroup 2), whilst adjusting for pre-course diagnostic scores.

We also combined results for each group across combined semesters to increase the sample sizes and power the results were the same. There was no statistically significant difference in mean quiz #1 scores, *F* (1,103) = 0.501, *p* = .481 between the groups *No Web Sim* and *Web Sim* from combined semesters, whilst adjusting for pre-course diagnostic scores.

3.3 | C. Results for role-play patient video project

For the role-play patient video project, group *No Web Sim* (subgroups 1 and 3) accessed online lessons materials to prepare whilst group *Web Sim* (subgroups 2 and 4) also accessed online the web-based simulation to prepare for the video role-play project assignment.

For Fall 2018, *t* test differences were not statistically significant between the two groups, *t* (107) = −1.884, *p* = .062, *No Web Sim* (*M* = 10.94, *SD* = 2.24) and *Web Sim* (*M* = 11.69, *SD* = 1.96). For Spring 2019, *t* test differences were statistically significant between the two groups on role-play scores, *t* (110) = −2.324, *p* = .022, *No Web Sim* (*M* = 10.34, *SD* = 1.73) and *Web Sim* (*M* = 10.99, *SD* = 1.19).

The addition of a covariate into an ANCOVA model as a control measure provides adjusted results (Table 5). For Fall 2018, there was a statistically significant difference in mean video project scores, *F* (1,106) = 4.264, *p* = .041 between the *Web Sim* group compared the *No Web Sim* group, whilst adjusting for pre-course diagnostic scores. The partial eta squared is small, 0.039.

The narrative is similar for Spring 2019 covering the topic non-surgical extractions. There was a statistically significant difference in mean video project scores, *F* (1,109) = 5.34, *p* = .023 between the *Web Sim* compared with *No Web Sim*, whilst adjusting for

TABLE 5 ANCOVA video project scores (No Web Sim vs. Web Sim) FA 18 and SP 19

Measure	Variable	df	Type 1 sum of squares	Mean square	F	*p*-value	Partial eta squared
FA18 scores	Diagnostic	1	10.119	10.119	2.321	.131	0.021
	Group	1	18.589	18.589	4.264	.041	0.039
	Residuals	106	462.116	4.36			
SP19 scores	Diagnostic	1	17.560	17.560	8.618	.004	0.73
	Group	1	10.890	10.890	5.344	.023	0.047
	Residuals	109	222.098	2.038			

Note: FA 18 R squared = 0.053 (Adjusted R squared = 0.035) SP 19 R squared = .117 (Adjusted R squared = .100).

pre-course diagnostic scores (Table 5). The partial eta squared is small, 0.047.

Combining results for each group across combined semesters to further increase the sample sizes and power the results also showed a statistically significant difference in mean video project scores, $F(1, 218) = 9.678$, $p = .02$ between the *Web Sim* group compared with the *No Web Sim* group whilst adjusting for pre-course diagnostic scores.

4 | DISCUSSION

Simulation as a method of learning is by no means new to dentistry or the world of medical and health professional education. Many studies have supported the efficacy of simulation tools and approaches ranging from computerised mannequins to web-based programs to virtual reality environments.[1,11–17] Simulation-based learning has significantly impacted several domains in medical education including specific areas of dentistry such as endodontics, periodontics, dental hygiene and operative dentistry.[6,11,25,26] Often the success of these results depend on how well the simulation is designed, aligned with learning objectives and implemented in an educational setting.

Broadly in the field of medicine, a systematic review and meta-analysis of medical simulations researchers found in clinical medicine that technology-enhanced simulation training compared with other instructional modalities showed higher learning outcomes with small to moderate pooled effect sizes.[27] Differences were statistically significant for satisfaction, knowledge, process skills and product skills with pooled effect sizes smallest for knowledge outcomes and higher for skill outcomes.[27] They found that "standardised patients and real patients had effects similar to technology-enhanced simulations for all outcomes except process measure of skills, whereas lecture, small-group discussion and video training were frequently inferior."[27] Researchers also observed subgroup analyses with "strong instructional design, rather than simulation training per se, is at least partially responsible for the observed effects."[27]

In a more recent systematic review and meta-analysis of virtual patient simulations, researchers found low to moderate and mixed results for virtual patient simulations compared with traditional forms of education.[28] They found that virtual patient simulations can improve skills such as clinical reasoning, procedural skills, and a mix of procedural and team skills. They also found that virtual patient simulations were at least as effective to improve knowledge. In another systematic review and meta-analysis of non-technical skills and knowledge in postgraduate medical training, results found evidence to support the utilisation of computer-based simulation.[29]

Whilst the field of dentistry is often underrepresented in systematic reviews of simulations and tends to focus on evaluating part-task trainers, this study focused on simulations that fall under the umbrella of whole-task patient simulations and contributes to this particular body of literature. The results of this study whereby the web-based patient simulation showed statistically significant learning gains on the role-play patient video project supports the tenets of simulation based-learning. Specifically, simulation base theories recommend designing simulations to progress from simple to complex like a mental scaffold to best support learning.[30,31] Both these formative and summative forms of whole-task patient simulations were designed to support the learning processes of pre-clinic novices as they continue to develop towards becoming clinical experts in the field of dentistry. The web-based patient simulation initiates pre-clinic students into the professional practice and prepares them for the role-play patient video project, a more challenging assessment activity. Design of the materials for this study also supports the literature that advocates analysing the combination of knowledge, interpersonal and psychomotor skills in a contextualised simulated assessment in lieu of decontextualised traditional assessments.[1,29,32] It supported practice in a safe environment that provided feedback, access to experts for guidance (scaffolding), and aligned with actual clinical practice objectives. The implication is that simulation, particularly at the undergraduate pre-clinical level, should be systematically woven in the design of learning and practice.

5 | CONCLUSION

This study evaluated the impact of two web-based patient simulations on different summative assessment types: a traditional fifty-item multiple-choice test and a role-play patient video project. The study was repeated across two semesters on two different topics, namely local anaesthesia and extractions. For both topics across both semesters, the web-based patient simulation revealed usefulness as a scaffolding tool to help students prepare for their role-play patient video project but did not aid in the outcomes

on the fifty-item multiple-choice tests compared with groups that did not use the web-based patient simulation. These statistically significant results on the student-recorded role-play patient video project suggest that the web-based patient simulation as a formative assessment type is a useful scaffolding tool to prepare students for this summative assessment. Learning theorists suggest that students perform better when the design of formative assessments are similar to the summative assessments in order to align with learning objectives.[30,31] Likewise, from a situated theory of learning perspective, scaffolding or sequencing the level of complexity of simulated tasks in terms of fidelity, guidance and feedback impact learning differently.[33] In support of these theories, the web-based patient simulation, a formative assessment, was positioned as a bridge between the online lessons that covered breadth and the role-play patient video project that was safe and aligned to clinical practice. The web-based patient simulation offered learners a simplified version of a real clinical task with opportunities to self-pace through the practice with immediate feedback. The role-play video project, a summative assessment, was positioned as a more complex task with less direct guidance and delayed feedback.

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CONFLICT OF INTEREST

No conflict of interests and nothing to disclose from all authors of this article. See attached form.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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