Assessing Critical Thinking Outcomes of Dental Hygiene Students Utilizing Virtual Patient Simulation: A Mixed Methods Study

Joanna L. Allaire, RDH, MDH

Abstract: Dental hygiene educators must determine which educational practices best promote critical thinking, a quality necessary to translate knowledge into sound clinical decision making. The aim of this small pilot study was to determine whether virtual patient simulation had an effect on the critical thinking of dental hygiene students. A pretest-posttest design using the Health Science Reasoning Test was used to evaluate the critical thinking skills of senior dental hygiene students at The University of Texas School of Dentistry at Houston Dental Hygiene Program before and after their experience with computer-based patient simulation cases. Additional survey questions sought to identify the students' perceptions of whether the experience had helped develop their critical thinking skills and improved their ability to provide competent patient care. A convenience sample of 31 senior dental hygiene students completed both the pretest and posttest (81.5% of total students in that class); 30 senior dental hygiene students completed the survey on perceptions of the simulation (78.9% response rate). Although the results did not show a significant increase in mean scores, the students reported feeling that the use of virtual patients was an effective teaching method to promote critical thinking, problem-solving, and confidence in the clinical realm. The results of this pilot study may have implications to support the use of virtual patient simulations in dental hygiene education. Future research could include a larger controlled study to validate findings from this study.

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While treating patients, dentists and dental hygienists are required to analyze clinical situations in order to solve complex clinical problems, and there is general agreement among health professions educators that critical thinking is a desirable attribute for students to develop. The American Dental Education Association Commission on Change and Innovation in Dental Education (ADEA CCI) defined critical thinking as “the reflective process in which individuals assess a situation or evaluate data by using mental capacities characterized by adjectives such as compare, analyze, distinguish, reflect, and judge.” An individual with strong critical thinking skills will be adept at asking pertinent questions, linking new knowledge to prior knowledge, finding solutions to problems, and making and defending decisions based on evidence.

The importance of critical thinking for the dental hygienist has been emphasized by numerous organizations. The National Dental Hygiene Research Agenda of the American Dental Hygienists’ Association (ADHA) documented the need for studies on educational methods that can validate and test measures that evaluate students’ critical thinking and decision-making skills. The Commission on Dental Accreditation (CODA) states in its Accreditation Standards for Dental Hygiene Education Programs (Standard 2-22) that graduates “must be competent in problem-solving strategies related to comprehensive patient care and management of patients.” CODA explains the intent of this standard by affirming that “critical thinking and decision-making skills are necessary to provide effective and efficient dental hygiene services.” The ADEA CCI lists critical thinking as one of the eight core principles essential to dental education.

Critical thinking has been recognized as an essential attribute for health care professionals. Clinical reasoning can be described as the integration of critical thinking and data collection directed toward patient care. While treating patients, dentists and dental hygienists are required to analyze clinical situations in order to solve complex clinical problems. Critical thinking skills equip students to connect the dots between what they have learned in the classroom and their ability to provide comprehensive patient care. To this end, dental hygiene educators seek teaching methods that enhance critical thinking.
skills to prepare future dental hygienists to keep pace with diverse and ever-changing developments in the delivery of oral health care. Dental hygienists use clinical reasoning while working through the dental hygiene process of care as they analyze relevant information, use inductive and deductive reasoning to determine a dental hygiene diagnosis, create a care plan, and evaluate patient outcomes. Studies have found that health professions students’ critical thinking skills may be a predictor of success in clinical performance and judgment.

Dental hygiene educators use strategies to foster critical thinking in students to help them attain the capacity to function as an entry-level hygienist and to possess the skills necessary to become self-directed learners. However, Williams’s study was rare in its evaluation of whether these strategies are effective in developing dental hygienists who are good critical thinkers. Effective clinical practice requires students to be able to convert information they have collected from lectures or textbooks into applied knowledge. Dental and hygiene education has traditionally focused on the teaching of psychomotor skills. Educators aspire to include instructional approaches that go beyond these two pedagogies to ensure that students can integrate and apply their knowledge and skills in successful clinical practice.

Simulation is a learner-centered teaching method that uses innovative techniques to promote a deeper understanding of didactic content. Simulation has been defined as “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.” Simulation has been used in medical and nursing education for decades and includes techniques that are varied in complexity such as case-based discussions, standardized patients, virtual patients, and high-fidelity manikins with the goal of developing students’ higher level cognition and improved psychomotor skills in a non-threatening environment. Simulation builds on the scientific knowledge of the learner and puts additional emphasis on clinical decision making, reasoning, ethics, empathy, and compassion.

Virtual patient simulation is an active learning strategy that uses computer-based virtual patients to create a simulated patient experience that replicates as closely as possible an authentic clinical scenario. Formats range from simple computer-based simulations to animated virtual patients that are able to interact with the user and respond to the student’s questions. These computer-based simulations are constructed with techniques borrowed from the gaming industry. Another format for virtual patients utilizes a combination of media (e.g., audio, video, interactive computer exercises). The most sophisticated format employs manikins that can be programmed to interact with the clinician and are able to display physiological responses to assessments and treatment modalities.

Little research has been conducted to evaluate the impact of virtual patients on the critical thinking skills of health care providers. A review of the literature seeking to clarify the role of virtual patients in medical education suggested that the use of virtual patients can facilitate learning and potentially improve clinical reasoning, a skill that is dependent on critical thinking. A quantitative study investigating the effect of simulation as an instructional strategy on critical thinking abilities of nursing students found an increase in critical thinking scores as measured by the Health Science Reasoning Test. Qualitative studies in medical and nursing education have sought to discover student perceptions of the value of virtual patients. For example, a study that used focus groups found that medical students identified virtual patients as an important educational tool that fostered clinical reasoning skills, and a study of graduate nurses found that the use of simulation resulted in increased confidence in their critical thinking skills. A recurrent theme is the need for well-designed virtual patient cases that reflect the reality of clinical practice. The difficulty level of the cases must be appropriate for the learner, and each session should include debriefing by a facilitator to assist with the reflective process.

Simulation in dentistry and dental hygiene has traditionally focused on the teaching of psychomotor skills emphasizing structured practice with feedback. To take research in this area beyond procedural knowledge, the aim of this small pilot study was to determine whether the use of virtual patient simulation had an effect on the critical thinking skills of dental hygiene students. Specifically, the objectives of the study were to 1) measure the critical thinking ability of senior dental hygiene students before their virtual patient experience and after two semesters of utilizing virtual patient simulation and 2) assess the students’ perceptions of those experiences.
Methods

Approval (with exempt status) for the study was obtained from the Institutional Review Board at The University of Texas School of Dentistry at Houston. The same exempt status was granted by the Institutional Review Board at the University of Tennessee Health Science Center, where the investigator was enrolled in the Master of Dental Hygiene program.

The University of Texas School of Dentistry at Houston introduced computer-based patient simulation into its dental hygiene curriculum in 2011 to fulfill one of the goals of the school’s strategic plan. The purpose of virtual patients at this dental school is to provide a virtual learning environment as close to reality as possible with facilitation by faculty. The experience challenges students’ critical thinking skills as they “treat” virtual patients. The program’s specific objectives for virtual patients are to 1) provide students with a common and consistent clinical education experience supplementing the variety of experiences in direct patient care; 2) integrate biomedical and clinical sciences in a standardized, case-based clinical setting; 3) provide a more frequent and consistent experience for students in performing and refining psychomotor skills; and 4) teach medical management, ethics, patient management, public health, and other relevant topics to all students in a patient care setting.

To introduce this methodology, a core working group of dental hygiene faculty members began by developing two computer-based cases that would be utilized by fourth-year Bachelor of Science in Dental Hygiene degree-seeking students over several sessions (Table 1). Specific learning objectives were created for each module. The goal of the cases was to allow the students to work through the dental hygiene process of care with the virtual patient. While doing so, students had to make choices and decisions that impacted the outcome. The virtual patients presented realistic problems that the learners had to identify by interpreting pertinent patient data and were designed to replicate as authentically as possible real-life clinical scenarios. The faculty members sought to develop cases that integrated students’ basic science knowledge with their clinical knowledge as a way to help them bridge the gap between what they learned in the classroom and the provision of patient care. The two cases offered scenarios that the students may not have experienced in clinic and included situations that incorporated all aspects of clinical practice.

Table 1: Virtual patient sessions used in study

<table>
<thead>
<tr>
<th>Session</th>
<th>Semester</th>
<th>Patient: “EJ”</th>
<th>Patient: “PF”</th>
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<tbody>
<tr>
<td>Session 1</td>
<td>Fall</td>
<td>Complex medical history findings, patient interview</td>
<td>DH care plan</td>
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<tr>
<td>Session 2</td>
<td>Fall</td>
<td>1. Apply information obtained from the medical consultation report to the patient’s case. 2. Identify systemic conditions or medical history that may impact the patient’s health. 3. Compare Type I and Type II diabetes. 4. Summarize the goals of diabetic control.</td>
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The experience challenges students’ critical thinking skills as they “treat” virtual patients. The program’s specific objectives for virtual patients are to 1) provide students with a common and consistent clinical education experience supplementing the variety of experiences in direct patient care; 2) integrate biomedical and clinical sciences in a standardized, case-based clinical setting; 3) provide a more frequent and consistent experience for students in performing and refining psychomotor skills; and 4) teach medical management, ethics, patient management, public health, and other relevant topics to all students in a patient care setting.

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<thead>
<tr>
<th>Session 1</th>
<th>Patient “EJ”</th>
<th>Fall</th>
<th>Risk assessment</th>
<th>Introduction to dental hygiene</th>
<th>Video from Dr. Oz TV show about diabetes</th>
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<td>Nutrition</td>
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<td>Website explaining HbA1C</td>
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<td>Plaque index</td>
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<tr>
<td>Patient “EJ”</td>
<td>Medical emergency</td>
<td>Fall</td>
<td>Oral hygiene aids</td>
<td>Dental emergencies</td>
<td>Videos</td>
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<td>Session 3</td>
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<td>Ethical dilemma</td>
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<td>Guided questions from faculty for group discussion</td>
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<tr>
<td>Patient “EJ”</td>
<td>DH diagnosis</td>
<td>Spring</td>
<td>DH care plan</td>
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<td>Self-assessment rubric</td>
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<td>Session 1</td>
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<td>Periodontitis</td>
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<td>Patient “EJ”</td>
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<td>Cultural sensitivity</td>
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<td>Periodontal diagnosis worksheet</td>
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<td>Session 2</td>
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<td>Self-assessment rubric</td>
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### Patient “EJ” Session 3
- Fall
- Risk assessment
- Nutrition
- Plaque index

### Patient “EJ” Session 4
- Fall
- Oral hygiene aids
- Cultural sensitivity

### Patient “EJ” Session 5
- Spring
- DH diagnosis
- Periodontitis patient
- Ethical dilemma
- Tobacco sensitivity

### Patient “PF” Session 1
- Spring
- DH diagnosis
- DH care plan
- Periodontitis patient
- Ethical dilemma
- Tobacco sensitivity

### Patient “PF” Session 2
- Spring
- Cultural sensitivity
- Instrumentation

### Patient “PF” Session 3
- Spring
- DH diagnosis
- DH care plan
- Periodontitis patient
- Ethical dilemma
- Tobacco sensitivity
Since treating a patient is more than scaling and root planing or preparing a tooth for a crown, virtual patient cases also simulated nonclinical components of patient care including communication, cultural sensitivity, ethics, and professionalism. The students were exposed to such situations as a patient with a hypoglycemic episode, which required them to assess the patient’s condition and quickly come up with a plan of action. Content was delivered in various modes including written narratives, patient interviews, photographs, and radiographs. Additional information came from sources such as journal articles and videos. Each section of the case was accompanied by guided questions to be answered either independently or in pairs and then discussed in a small group with a faculty facilitator. The role of the faculty facilitator was simply to guide the discussion and encourage the students to explore all aspects relevant to the case. Facilitators were encouraged to create a safe and positive environment conducive to learning, exploration, discussion, and feedback. The students participated in virtual patient sessions one afternoon a month during the fall and spring semesters.

The faculty members participated in calibration sessions before each virtual patient session. A debriefing session was held at the end of each session to help the students assimilate the material and to encourage reflective thinking. Debriefing was guided by faculty members with the goal of reinforcing the learning objectives and evaluating the outcomes of the simulation session.

The quantitative portion of this study utilized a pretest-posttest design using the Health Science Reasoning Test (HSRT). In the first month of their senior year, students were invited to participate in the 45-minute pretest to measure their critical thinking skills. Students were given a written invitation to participate, and consent was implied by completion of the instrument. Participants were randomly assigned a nine-digit identifying number to protect their anonymity. Students were informed that participation would have no bearing on their grades and that test scores would remain anonymous.

The HSRT is a 33-item multiple-choice test designed to measure critical thinking skills with a total possible score of 33.28-31 A score of 25 or above indicates strong core critical thinking skills, typical of an individual capable of complex problem-solving. Scores between 15 and 24 are associated with demonstrated competence in critical thinking. These individuals should be capable of meeting the demands of problem-based learning. Scores of 14 or lower suggest fundamental weaknesses in core critical thinking skills and are classified as “not manifested.” A score of 10 or lower is extremely weak and not consistent with minimal entry-level college performance.

The HSRT is part of the California Critical Thinking Test family of instruments that assesses critical thinking skills with questions in contexts suited to health care professionals although no health science knowledge is presumed. The HSRT provides five measures of critical thinking domains in addition to a total score that is an overall measure of critical thinking skill level. The five scale scores are analysis and interpretation, inference, evaluation and explanation, deductive reasoning, and inductive reasoning. The HSRT is based on the consensus statement of the American Philosophical Association (APA) and has undergone extensive testing and validation.28,29,31 Validation studies with the HSRT have shown internal consistency (Kuder Richardson-20) ranging from 0.77 to 0.84 with an overall internal consistency of 0.81.29,31 A KR-20 above 0.70 indicates an acceptable level of internal consistency. The 0.81 overall reliability coefficient of the HSRT is more than sufficient for researchers to have confidence in the internal consistency of its items to measure the desired construct of critical thinking.

Content and construct validity of the HSRT have also been established by correlating test items with the cognitive skills identified by the Delphi Report from the APA.28,29,31 Construct validity of the HSRT refers to the degree to which it measures the Delphi conceptualization of critical thinking. Content validity on the HSRT refers to its ability to represent the various aspects of the specific construct in question, specifically the domain of critical thinking.29,31 Further, evidence for the construct validity of the HSRT is apparent by the improvement in students’ scores after they had taken a course in critical thinking. The same validation studies have also established that there is no evidence of threats to validity due to prior experience with the instrument (test effects).

In this study, the HSRT pretest was administered at the beginning of the fall semester before the students had any exposure to virtual patient simulation. Instructions were given by the principal investigator using a standardized script provided by Insight Assessment, the company that developed the HSRT.29,31 After the investigator left the room, an independent administrator proctored the test and collected the score sheets. The HSRT was again
administered as a posttest toward the end of the spring semester. Score sheets for both pretest and posttest were sent to Insight Assessment for scoring and analysis.

In an effort to further evaluate the use of virtual patients in this dental hygiene curriculum, a survey was administered to explore the students’ perceptions of whether virtual patient simulation helped develop their critical thinking skills and improved their ability to provide competent patient care. This survey instrument was designed by the author. Survey items (on a five-point Likert scale) sought to define the effect virtual patients had on students’ critical thinking, clinical decision making, and confidence.

Results

A convenience sample of 34 senior dental hygiene students initially agreed to participate in the study, but only 31 completed both the HSRT pretest and posttest. That was 81.5% of the total students in that class. In the second part of the study, a convenience sample of 30 senior dental hygiene students completed the survey on their perceptions of the simulation (78.9% response rate).

Demographic data on the participants were not obtained as information regarding gender, age, or ethnicity could have enabled the investigator to match individuals to their scores. Data collected included composite scores as well as five subscale scores for analysis, inference, evaluation, inductive reasoning, and deductive reasoning for each of the test groups (pretest and posttest). The paired t-test of comparisons of the mean overall scores did not demonstrate a statistically significant gain from pretest ($M=19.219$, $SD=5.116$) to posttest ($M=20.188$, $SD=3.685$; $t[30]=1.84$, $p=-0.075$) (Table 2, Table 3).

Examining mean score differences in small samples can result in an incomplete analysis of pretest-posttest data when the tests are for the same test-takers. A more informative way to examine scores, particularly in small samples, would be to examine the difference in scores for each individual from pretest to posttest. The analysis in this study included the difference in scores from each individual from pretest to posttest. While the mean difference score was only 0.77, some students improved their scores as much as six points. However, a few students’ scores dropped from pretest to posttest. Figure 1 shows the scores of the 31 students who submitted both a pretest and a posttest.

When compared to national norms of undergraduate health sciences students, the average of the national percentile rankings for the pretest group was in the 48th percentile. The average of the posttest sample rankings was the 53rd percentile. The comparison of the individual and group scores to

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*Note: Total highest possible score was 33.*

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<th>Table 3. Posttest descriptive statistics</th>
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*Note: Total highest possible score was 33.*
a similar national sample of test-takers provides a way to judge the relative strength of the test-takers.

In addition to the total score, five HSRT subscale scores were compared from pretest to posttest (Figure 2 and Figure 3). The subscale scores represent the major core skills identified in the APA’s Delphi Report. Analysis and interpretation skills are used to closely examine ideas, to recognize assumptions, reasons, and claims, and to be able to assimilate detailed information from paragraphs, charts, diagrams, and graphs. The inference scale measures the ability to draw conclusions based on reasons and evidence. Evaluation and explanation skills are used to identify the credibility of claims as well as the strength and weakness of arguments. The deductive reasoning scale measures the ability to move from the assumed truth of a premise to a logical conclusion. Inductive reasoning involves the ability to draw probable conclusions based on evidence, data, testimony, or relevant cases. Evaluation of these subscales is helpful in identifying any individual area weaknesses.

As well as measuring changes in the students’ critical thinking, this study sought to determine how they would characterize the effect of virtual patient simulation on their critical thinking ability and confidence in their ability to provide patient care. This survey found that the students perceived virtual patient simulation to be a favorable learning experience that helped them utilize critical thinking in making clinical decisions regarding their virtual patients. The responding students’ perceptions were largely favorable: 86.7% agreed or strongly agreed that the use of virtual patients improved their critical thinking skills, and 93.3% agreed or strongly agreed that the use of virtual patients improved their ability to make good clinical decisions. Likewise, 73.4% agreed or strongly agreed that they felt more confident treating patients because of their experience with virtual patient simulation. A forced completion question asked the students to make additional comments regarding their perceptions of virtual patients. One student reported that the virtual patient session was “helpful in reinforcing information that we learn but may not have the chance to practice in the clinical setting.” Another commented that “virtual patient simulation was great by helping us with clinical decision making.” Other comments pointed to students’ feeling that the sessions should have been more challenging and that they wished they had had the opportunity to experience the sessions earlier in the curriculum.

Figure 1. Students’ difference scores on Health Science Reasoning Test (HSRT) from pretest to posttest

Note: Blue bars indicate educationally meaningful gains. Orange bars are unexplained losses.
Figure 2. Students’ Health Science Reasoning Test scale area scores at pretest

Note: Blue bars are strong scores; white bars are moderate scores; and orange bars are “not manifested.”

Figure 3. Students’ Health Science Reasoning Test scale area scores at posttest

Note: Blue bars are strong scores; white bars are moderate scores; and orange bars are “not manifested.”
Discussion

Although there was not a significant gain in the mean score, more than one-third of the participating students scored at least two points higher on the posttest HSRT than the pretest. Test-retest reliability for the HSRT meets or exceeds 0.88 in samples in which administration conditions are adequately controlled at pretest and posttest.\(^{31}\) Correlation levels of 0.80 are generally considered acceptable. With no intervention aimed at improving critical thinking skills, test-takers will likely score within one point of their pretest score.\(^{31}\) As each question on the HSRT contains distractor choices that invite common human reasoning errors, an overall improvement suggests that, on average, the participants made fewer reasoning errors and used their critical thinking skills to accurately identify the one correct answer at posttest.

Although most students improved their scores, a few had scores that dropped from pretest to posttest. One such participant completed less than 60% of the items at posttest after completing the entire test at pretest (scoring 18 at pretest and 15 at posttest). A difference of -1 or -2 is possible as test-takers are challenged by the items and choose the wrong response, while a large decrease would indicate a false test, as critical thinking skills do not deteriorate over short periods of time unless there is an intervening cognitive injury.\(^{30}\) Reasons for the decrease in scores at posttest could be attributed to diminished effort. Some individuals lack sufficient intrinsic motivation to put forth the effort necessary for a cognitively challenging test when they do not see any personal benefit. Instead of refusing to take the test, they may rush through it or leave a number of questions unanswered.\(^{31}\) The posttest was given near the end of the senior year, so it is also possible that motivation was reduced, a phenomenon reported in a previous study.\(^{32}\) It is possible that motivation to complete the test and deliver necessary effort was diminished due to “senioritis” or burnout. Student burnout with resulting lack of motivation toward the end of the senior year has been identified by researchers.\(^{33}\)

One interesting result was the consistent gains in total scores overall, except in the group that scored the highest at pretest. The number of scores in the 25-30 range (indicating strong core critical thinking skills) was less at posttest, with six participants scoring in this range at pretest vs. only two at posttest. This phenomenon may be due to regression to the mean in this non-random sample. The regression to the mean of some of the highest pretest scores could account for the relatively low overall change in mean scores. This phenomenon can occur when relatively high (or relatively low) scores are followed by less extreme ones nearer the subject’s true mean, as an individual’s score is determined in part by skill and in part by chance.

The results of the survey following the HSRT posttest suggested that students found the virtual patient sessions to be a positive educational experience. Responses indicated that the students perceived virtual patient simulation to be an effective teaching method to promote critical thinking, problem-solving, and confidence in the clinical realm.

There were several limitations to this pilot study, beginning with the fact that it featured a very small convenience sample, which limits the generalizability of the findings. Demographic data were not obtained, but specific demographic information might have explained some of the lower scores, particularly if English was not the primary language of the test-taker. Although my research found little in the medical or dental education literature addressing the design of virtual patient cases to maximize the use of critical thinking, the virtual patient cases may not have been designed with adequate complexity to require the students to adequately exercise critical thinking skills. Additionally, utilizing more sophisticated simulations, such as high-fidelity manikins used in medical education that can interact with the student clinician, may further foster critical thinking. Study design would have been strengthened with the addition of a control group, which was not a practical option as all students were required to participate in the virtual patient sessions. Finally, there is no way to definitively conclude that improvements in students’ critical thinking scores were attributed to the use of the virtual patient simulations. Improved overall scores could have resulted from the effects of history and maturation; also, students in this study were likely to have been exposed to other educational strategies throughout the curriculum that were designed to promote critical thinking.

Conclusion

The results of this pilot study indicated that the virtual patient simulations did not have a direct effect on the critical thinking scores of these senior dental hygiene students, measured with the HSRT. The students did, however, report that the use of virtual
patients contributed to building their critical thinking skills and confidence in making good clinical decisions. Quantitative evaluation of computer-simulated patients in dental and dental hygiene education is limited particularly for outcome measures of simulation in the area of critical thinking. This study contributes to the literature supporting educational strategies that promote critical thinking in dental hygiene students. There is a need for additional randomized controlled studies with larger sample sizes. It is also important to evaluate the instructional design of virtual patient cases to ensure that cases challenge the students to use their critical thinking skills. Further research is necessary to evaluate the effectiveness of strategies such as virtual patient simulation that are intended to increase students’ critical thinking skills and the application and transfer of knowledge to clinical care.

Acknowledgments
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