Preliminary Assessment of Faculty and Student Perception of a Haptic Virtual Reality Simulator for Training Dental Manual Dexterity


Abstract: Virtual reality force feedback simulators provide a haptic (sense of touch) feedback through the device being held by the user. The simulator's goal is to provide a learning experience resembling reality. A newly developed haptic simulator (IDEA Dental, Las Vegas, NV, USA) was assessed in this study. Our objectives were to assess the simulator's ability to serve as a tool for dental instruction, self-practice, and student evaluation, as well as to evaluate the sensation it provides. A total of thirty-three evaluators were divided into two groups. The first group consisted of twenty-one experienced dental educators; the second consisted of twelve fifth-year dental students. Each participant performed drilling tasks using the simulator and filled out a questionnaire regarding the simulator and potential ways of using it in dental education. The results show that experienced dental faculty members as well as advanced dental students found that the simulator could provide significant potential benefits in the teaching and self-learning of manual dental skills. Development of the simulator's tactile sensation is needed to attune it to genuine sensation. Further studies relating to aspects of the simulator's structure and its predictive validity, its scoring system, and the nature of the performed tasks should be conducted.

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IDEA Dental simulators were lent to the authors for the assessment. No company representative was involved in the planning of the experiment or in the analysis of the results.

Keywords: computer simulation, virtual reality simulator, computer-assisted instruction, educational technology, manual dexterity training, psychomotor skills, dental education

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Manual skills and perceptual abilities are essential in dentistry practice. It has been proven that the practice of manual skills improves performance and spatial perception.1 Therefore, dental schools attempt to create a learning environment conducive to the attainment and improvement of these skills. In addition to the traditional apprentice-based training on real patients, dental schools make use of a simulation-based environment and tools that enable practicing and developing these competencies. Simulation creates a safe environment that provides ethical benefits,2 increased precision and relevance of training, and aptitude assessment, as well as teaching error management and safety culture.3

Traditional dental simulators are comprised of a head and jaws containing plastic teeth, which are used for preparation, accompanied by basic dental appliances. The advantages of these traditional educational methods are their relatively low cost, proven experience in use, and long-term credibility. Their major disadvantages include their limited ability to evaluate the work process, as they focus mainly on the outcome, as well as their reliance on instructor evaluation, which lacks reliability owing to human subjectivity.

In recent years, virtual reality simulators (VRS) have been developed and are being increasingly used in various medical fields and utilized for both training and evaluation, especially in surgery, in which manual skills are crucial.4,5 More than a decade ago, VRS also entered the realm of dental education. VRS have major advantages over traditional simulators and exhibit a potential for significant impact on future
The implementation of new technologies calls for their acceptance both by faculty members and the students themselves. Welk et al. surveyed a German dental school’s approach to computer-assisted learning and found that the majority of the respondents considered these tools useful for acquisition of knowledge. Another evaluation of students’ approach to VR simulation and its implementation in the curriculum revealed a controversy with regard to the superiority of the VRS over traditional training. To date, haptic simulators have not been incorporated into a simulated dental operatory, and faculty and student evaluations are not broadly available. This led us to test and attempt to validate a haptic simulator (IDEA Dental, Las Vegas, NV, USA) for training and practicing manual dexterity in dentistry. The purpose of this simulator is to train and improve skills related to the use of the dental drill. Our objective was to provide preliminary evaluation of the simulator on the basis of faculty and student assessment of its ability to serve as a tool for dental instruction, self-practice, and student evaluation.

Materials and Methods

Hardware and Software

The IDEA (Individual Dental Education Assistant) simulator prototype (www.idealidental.com) provides a platform for simulated interaction between dental instruments for cavity preparation. The system (Figure 1) offers a stylus, with six degrees of freedom, attached to a stand (Phantom Omni, Sensable Technologies, Wilmington, MA, USA) that provides the holder with feedback based on a three-dimensional (3D) image viewed on the screen. Phantom Omni technical specifications are described in detail at the company’s website (www.sensable.com/haptic-phantom-omni.htm).

The user is required to perform virtual drilling tasks, the simulation allowing complex contact, such as in the preparation of dental cavities. The interaction between tool and objects produces visual changes in the 3D image viewed on the screen. Phantom Omni hardware and software may be installed on standard computers. The system is multilicent with a central server controlled by an administrator. Tasks can be assigned for each trainee, determining their number, level of difficulty, and submission date. For each task, the simulator measures and records task time, percentage of desired material removed, and deviation from the assigned drilling task, reflecting level of accuracy. These measures are multiplied by predetermined factors, and a score is displayed on the screen. This grading system has not yet been validated.
The system allows a training scenario to be populated with detailed, tangible, unmodifiable and modifiable images. Figure 2 shows a simulated dental handpiece, as well as a green path/trail, describing the virtual drilling required in the simulated region. The red dot simulates the active part/drill of the dental handpiece. With activation, the green trail is correspondingly removed. The software contains a replay mode. Upon completion of a specified task, it can be watched in full by the student or the instructor. The angle of observance can be changed, and the task can be forwarded as desired.

**Evaluation Method**

A total of thirty-three assessors participated in the study, all chosen randomly on a voluntary basis. The participants were divided into two groups. The first group consisted of twenty-one dentists who serve as teachers (dental educators) in the Department of Prosthodontics of the Faculty of Dental Medicine at Hadassah Hebrew University (which operates a six-year dental program). The second group consisted of twelve randomly selected fifth-year dental students. The students were asked to participate in the study for the following two reasons. First, they had recently completed an intensive year of studying and training using traditional simulators, enabling a vivid comparison from the trainee’s point of view. Second, we sought to compare their impression of the simulation with that of veteran dentists.

Each participant received basic uniform instructions, including a brief description of the system’s goals and the objectives of the investigation, prior to his or her acquaintance with the simulator. Other explanations were not given. To maintain standardization, only technical support was supplied if necessary. All participants were instructed to use and explore the simulator, estimating its utility in due course. Each participant performed five drilling tasks with increasing levels of complexity.

The assessors were asked to “drill” in a 3D image that appeared on the screen, characterized by various geometric shapes and depths. Exercises required “drilling” in five different geometric shapes:
Figure 2. Simulation as viewed on the computer screen, straight line task

Figure 3. Circle task
1) straight line (Figure 2); 2) circle (Figure 3); 3) straight line drilling through a virtual mirror, unlike relying on direct vision (Figure 4); 4) deformed heart shape, portraying a wavy pattern; and 5) rectangle shape through a virtual mirror.

The user could control the virtual mirror by pressing a button located on the handpiece, thereby adjusting the mirror to a preferred spot to achieve the desired view. The mirror then becomes set for drilling and can be moved again during the practice session. It is not possible to drill and move the mirror simultaneously. A limited time was allotted for completion of each of the five tasks, varying from two to four minutes per task. Net practice time was fifteen minutes. The level of performance of the participants was not measured in this experiment as the ranking system of the simulator has not yet been validated and since our main goal was to collect preliminary opinions on its future use.

A questionnaire was distributed asking the participants’ opinion of the simulator and their perception of potential ways of using it in dental education.

They were asked to address the following questions:
1. To what extent can the simulator be helpful in teaching manual skills in dentistry?
2. To what extent can the simulator be useful in self-training of manual skills in dentistry?
3. To what extent can the simulator be useful in evaluating manual skills in dentistry?
4. To what extent is the sensation provided by the simulator similar to drilling in a real tooth?
5. To what extent is the sensation provided by the simulator similar to drilling in an acrylic tooth?
6. To what extent is the grip of the simulator similar to a high-speed turbine grip?
7. To what extent is the use of the simulator comfortable?

In addition to these questions, the assessors were asked to provide information regarding their background: age, dental experience, past use of simulators, and confidence in computer use. The opportunity to comment freely was also given. The questions were rated on a scale of 1 to 7, 1 for “least extent,” 4 for “moderate,” and 7 for “very much.” Since 4 is the midpoint value of the scale and was considered a neutral evaluation, we defined 5 as the threshold from which a positive evaluation of the simulator was considered. This value was also adopted by Steinberg et al. in their evaluation of the PerioSim. The questions regarding past use of simulators were also scaled 1 to 7, 1 for “inexperienced,” 4 for “medium
“experienced,” and 7 for “very experienced.” In the question dealing with confidence in using a computer, possible responses ranged from 1 as “not confident at all” to 7 as “very confident.”

The average, standard deviation, and range of ratings for each question were calculated. The data were analyzed for all participants and for each of the two groups. The significance of the differences between the students and the dental educators was tested. Correlations between questions were calculated.

Results

The dental educators who participated in the evaluation had an average professional experience of 11.48 years, ranging from two to thirty-five years. The average age of the dental educators was forty. The average age of the students participating in the study was 27.75 years.

Table 1 shows the results of the questionnaire regarding the estimated benefit of the simulator as a teaching and evaluation tool. All participants rated the expected benefits of using the simulator, practicing, and teaching manual skills with an average score of 5.24. The students rated the expected usefulness with a 5.58 score, higher than the 5.05 score provided by the dental educators. The overall assessment of the anticipated benefits of self-learning of manual skill using the simulator was 5.42. The dental educators evaluated the benefits of self-learning as 5.33, higher than the teaching benefits question, whereas the students rated the benefits of teaching as equal to the benefits of self-learning (5.58). The expected use of the simulator as a tool for assessing manual skills scored a lower average of 4.75 for all participants. A comparison of the two groups showed a score of 4.5 by the dental educators, as opposed to the students, who assessed the benefits closer to the positive side, with an average score of 5.17. The difference in the ratings between the two groups was not statistically significant, but a clear trend toward a higher evaluation by the students was observed.

Table 2 summarizes the reviewers’ perception of the realism of sensation (A) and the convenience in use (B) of the simulator. The participants rated the resemblance to a real tooth or acrylic tooth as lower than midpoint. The discrepancy between the students and the dentists was minor. The similarity of the grip to holding a dental high-speed turbine was estimated at about grade 4, indicating that the participants assessed the grip as moderately similar. The students rated the grip higher than did the dentists. When the participants were asked a general question about the convenience of simulator training, a prominent difference between the groups was observed. The dentists gave a score of 4.82, while the students graded positively with a score of 6. The difference was significant (P<0.05).

Table 3 summarizes the answers relating to past use of simulators and confidence in computer use by the assessors. The results showed that some of the participants had past experience in using virtual reality simulators, but almost none with haptic simulators. Confidence using computers was scored highly by all the participants.

Pearson correlation coefficients between the responses to the various questions were examined. The correlation between the question dealing with the usefulness of the simulator in teaching and the question regarding self-learning was 0.85. The correlation between the questions dealing with the similarity to real teeth or acrylic teeth was 0.79. No significant correlation was found between age and comfort rating of the simulator. There were no significant correlations between confidence in computer use and the other evaluation questions.

Discussion

Implementation of new technologies and educational approaches is generally known to be a long
and gradual process. It certainly applies to the dental education field, which has maintained its traditional teaching for many years. Computerized simulators offer a solution to numerous major problems in operative dentistry courses: reducing dependence on human instruction because of the possibility of performing tasks outside the school’s walls and the ability of the system to judge performance (on condition of there being a well-validated performance measurement). Computerized simulation offers objectivity and standardization of evaluation in general and in particular the ability to evaluate the process in addition to the outcome. To keep the implementation process effective, the faculty must identify the benefits of the system and grasp the possibilities of its use. A dialogue between teachers and developers of the system should be constant in order to improve it and make the necessary adjustments.

In this evaluation, we examined the opinion of faculty members and students regarding perceived benefits, sensation, and convenience of the IDEA dental simulator. All participants in the study ranked the system positively, noting that benefits could be derived from its use in the teaching and learning of manual skills in dentistry. In other words, in their brief experience with the simulator, they recognized its potential use. Several students emphasized that the advantage of the system is based upon there being no limitations on hours of practice and also the lack of additional financial costs. Dental educators noted the perceived qualities: improving spatial perception, game-like training, simulated working with a mirror, and planning cavity preparation. Most evaluators ranked the similarity of the simulator’s force feedback with a realistic sensation as medium and lower, i.e., the sensation it provides does not mimic reality in a convincing manner. The participants rated the similarity between the grip of the stylus and that of the dental high speed turbine as intermediate, attributable to the connection point of the stylus being close to its front edge and not to its end as in a real-life system and drilling operated by pressing a button, requiring the use of a finger. Additionally, several participants noted that a foot pedal for the opera-

### Table 2. Realism of sensation (A) and convenience in use (B) of the simulator as estimated by dental educators and students on a scale of 1 to 7

<table>
<thead>
<tr>
<th>The extent to which:</th>
<th>Students N=12</th>
<th>Dental Educators N=21</th>
<th>Total Participants N=33</th>
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<tr>
<td></td>
<td>Mean  SD</td>
<td>Mean  SD</td>
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<tr>
<td>4. The sensation provided by the simulator is similar to drilling in a real tooth.</td>
<td>A 3.25 1.01</td>
<td>3.14 1.49</td>
<td>3.18 1.34</td>
</tr>
<tr>
<td>5. The sensation provided by the simulator is similar to drilling in an acrylic tooth.</td>
<td>3.42 1.38</td>
<td>3.10 1.27</td>
<td>3.21 1.32</td>
</tr>
<tr>
<td>6. The grip of the simulator is similar to that of a high speed grip.</td>
<td>B 4.50 1.04</td>
<td>3.90 1.34</td>
<td>4.12 1.27</td>
</tr>
<tr>
<td>7. The use of the simulator is comfortable.</td>
<td>6.00 1.00</td>
<td>4.14 1.49</td>
<td>4.82 1.60</td>
</tr>
</tbody>
</table>

### Table 3. Previous experience with virtual reality simulators and confidence in computer use as reported by dental educators and students on a scale of 1 to 7

<table>
<thead>
<tr>
<th>Mean</th>
<th>SD</th>
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<tr>
<td>3.17</td>
<td>2.11</td>
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<tr>
<td>3.81</td>
<td>1.92</td>
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<tr>
<td>3.58</td>
<td>2.02</td>
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<tr>
<td>1.00</td>
<td>0</td>
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<tr>
<td>1.81</td>
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<td>1.52</td>
<td>1.28</td>
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<td>6.25</td>
<td>1.16</td>
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<td>5.86</td>
<td>1.25</td>
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<td>6.00</td>
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tion would contribute to the realism of the system. They also suggested that the lack of a fixed fulcrum for the hand was not realistic. The students rated the convenience of using the simulator with a high score. All the participants had none or scant previous experience using virtual reality simulators, and their experience with a haptic simulator was negligible. All participants reported that they use a computer daily and that they consider themselves very confident in doing so. We did not find any correlation between assessments and the prior use of simulators and/or confidence in computer use.

A notable dissimilarity was observed between students and dentists in their evaluation of the simulator: the students’ assessment of the benefits of simulator use was higher than the dentists’. A possible explanation for the difference might be the twelve-year age difference between the two groups. It is probable that exposure to technology and innovations, which is usually greater in the younger generation, resulted in a participant feeling less intimidation when faced with the simulator system. Furthermore, the assessment by the students is reinforced owing to the considerable time they spent training using conventional old simulators. Therefore, the comparison with the haptic simulator is most relevant. We further claim that the evaluation given by the students is highly important because they are the ones who will be the future users of these systems. An advantage observed by the students was the ability to receive and perform tasks sent to them, performing them in their spare time, rather than in the dental school, a major change compared with traditional training. Dental educators noted the ability to observe the entire work process and not only its result as a major advantage in the learning experience. Our findings correlate with those of Steinberg et al., who evaluated a haptic simulator for periodontal training. They also found a positive approach to its potential as a teaching tool. In both studies, the assessors found that the sensation provided by the simulators was not sufficiently realistic.

Our study is limited because it deals with the assessment of future potential via questionnaires expressing opinions. In order for us to advance in our study of the simulator, face validity had to be established, providing evidence that future users, both teachers and students, considered the haptic simulator to have potential benefits. The positive results obtained so far provide a basis for further exploration of the simulator; the negative aspects should be improved by the manufacturers. We suggest that future research focus on the following aspects of the simulator: validation of its evaluation system, the predictive validity of the simulator, a comparison with conventional training, and a comparison with other VR training. The way in which work is graded and evaluated has a major effect on the simulator’s usefulness in training. As yet there is no valid ranking system regarding this simulator.

Computerized simulation reveals a new world of teaching and learning. However, the system confronts us with new challenges: establishment of the exact parameters by which work shall be rated by the simulator, selection of the appropriate tasks, and determination of the relationship between traditional practice and virtual reality training. It is necessary to further illuminate the contribution of this simulator to manual dexterity training and the acquisition of spatial perception.

Conclusions

Our study resulted in these conclusions. Experienced dental faculty members, as well as advanced dental students, found the simulator to have significant potential benefits in teaching manual skills in dentistry. The participants found the simulator to be useful in self-learning manual skills in dentistry. Development of tactile sensation is needed to attune the stimulator to genuine sensation. A constant dialogue between teachers and developers must be held in order to improve the virtual system. Further studies on the benefits of long-term use of the haptic simulator and its advantages should be conducted.

REFERENCES