EVALUATION OF SIMODONT® HAPTIC 3D VIRTUAL REALITY DENTAL TRAINING SIMULATOR

Mahmoud M Bakr, Ward L Massey, Heather Alexander

ABSTRACT

Background: Haptic dental simulators are relatively new tools with a promising future in dental education. The majority of these devices are in the early stages of development with no extended evaluations of their usage, benefits and limitations. Aims and Objectives: To assess the perception of academic staff members of the realism of the Simodont® haptic 3D-VR dental trainer. Materials and Method: Eleven full-time academic staff from the School of Dentistry and Oral Health - Griffith University (Australia) participated in this study through completion of psychomotor exercises available on the Simodont® dental trainer and pre- and post-evaluation questionnaires. Results: Academic staff members were neutral with regards to their expectations about the Simodont® pre-evaluation. Post-evaluation, they noted the educational benefits of the E-lessons loaded on the Simodont® but also raised concerns regarding perceived technical limitations of the hardware and software at this time. The majority agreed that automated feedback provided by Simodont® dental trainer could not totally replace traditional preclinical training methods but could be used as a valuable supplementary tool for student self-evaluation. Conclusion: The benefits of the Simodont® dental trainer were noted by academic staff members but further research was deemed necessary to compare the benefits of its Haptic 3D-VR technology against other dental simulators in the market.

Keywords: Dental simulators; Dental education; Preclinical training.

Introduction

Visual, acuity and sensory motor skills are essential for performing different procedures in Dentistry. The importance of repetitive training and practice of fine manual skills in improving performance and spatial perception of dental students has been proven.1,2 Visual skills are more easily taught as instructors can verbally describe and explain the shape characteristics, while the tactile sensation is not easily described. The use of a haptic device would allow the user to capture tactile sense with minimal intervention from the instructor.3

Haptic technology, or Haptics, is tactile feedback technology, which takes advantage of a user’s sense of touch by applying forces, vibrations, and/or motions upon the user. The literal meaning of haptics is “I fasten onto, I touch”.4 Haptics technology has been used widely in the fields of aviation, telecommunication and medicine.5,6 In Dentistry, early studies investigated the use of virtual reality technology in different fields such as orthodontics5,7 restorative dentistry,8 orthognathic surgery,9 implantology10,11 and endodontics.12

In the past decade, attempts were made to develop a dental simulator by different manufacturers13–17 Most of these dental simulators are still in the early, or even experimental phase of development.1,2,18 Advantages of simulation-based environment include safety, ethical benefits,19 increased precision and relevance of training as well as teaching error management.20 The disadvantages include high costs, need for a long process of assimilation, and the lack of validity of the grading and evaluation systems in use.20 More advanced features are now being included in this rapidly developing technology, such as development of a tutoring mode in their study on a virtual reality dental simulator, where dental students can observe a recorded procedure carried out by an expert, and feel the actual movement of the tools through haptic feedback provided, so that they can learn the amount of forces to applied as well as angulations of tools in an interactive manner.21 Recently in Japan, a robot patient capable of performing unexpected real life situation reactions such coughing, shaking neck, tongue thrusting and salivary secretion was introduced to be used in dental education as well as medical emergency education in a dental setting, and showed effectiveness in those fields,22,23 and there will be more to come in the near future with expectations of having a fully virtual teaching environment.24

With the apparent advantages of haptics 3D VR technology and the lack of literature related to evaluation of using haptics in preclinical dental education, we considered that an evaluation of the Simodont® 3D VR dental trainer would be a step forward in understanding the benefits of this technology. The goal of this study was to assess the perception of academic staff members of the School of Dentistry and Oral Health, (Griffith University, Australia) of the realism of the Simodont® dental trainer.

Materials and Method

Subjects: All academic staff members from the School of Dentistry and Oral Health – Griffith University (Australia) were invited to participate in this study. Eleven academic staff members volunteered to participate. The mean time used for training on the dental simulator, evaluation and completion of the questionnaires was 60 minutes.

The Simodont Dental Trainer: The Simodont® Dental Trainer (Figure 1) was used in the present study. Moog Industrial Group, Amsterdam, manufactures this unit. The Simodont® courseware has been developed by ACTA (Academic Centre for Dentistry in Amsterdam) and is currently being trialled in a variety of curricula. The courseware allows a variety of operative dental procedures to be practiced in a virtual oral and dental environment with force feedback.
Evaluation methods: Evaluation was conducted through the use of a pre-experimental and a post-experimental questionnaire for all participants. Before using the Simodont®, all participants were asked to complete a pre-experimental questionnaire that included questions about their impression, expectations, and attitudes towards the Simodont® Dental Trainer. Responses were captured on a five point Lickert scale where one was considered to show strong negative disagreement, three being neutral and five showed strong positive agreement. All tasks given to the participants during the evaluation session, were identical and included manual dexterity exercises, clinical exercises on a single tooth as well as a simulated full arch experience with teeth present in contact (Figure 2).

Participants were then asked to complete a post-experimental questionnaire after using the simulator. This questionnaire contained a set of sixteen questions detailing their experience using the Simodont® dental trainer, the realism of 3D images and force feedback and the usefulness of this haptic simulator as a tool in preclinical dental education (improving students' knowledge, preclinical skills, manual dexterity skills and visual-motor skills) on a five point Lickert scale. Using SPSS® statistical modules (version 21/2013), statistical comparisons for all ratings were determined. Following completion of the post-experimental questionnaire, participants were invited to comment about the advantages, limitations and missing elements in the Simodont dental simulator through open-ended questions.

Results
Reliability: Cronbach’s alpha was calculated to test reliability and internal consistency for ratings of the questions of the pre and post experimental questionnaires. Both questionnaires showed high reliability [alpha= 0.910 (pre), alpha= 0.949 (post)].

Pre-experimental questionnaire: The results obtained from our pre-experimental questionnaire showed that the academic staff members of the School of Dentistry and Oral Health (Griffith University) were mostly neutral in regards to their expectations of the value of Simodont® dental trainer in assisting students’ learning. The Mean values for the answers of all eight questions presented in the pre-experimental questionnaire are shown in Table 1.
### Table 2: Showing Means and Standard Deviations, and frequency distributions of answers of the post-experimental questionnaire

<table>
<thead>
<tr>
<th>Questions</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The images of anatomical models and instruments in Simodont looked realistic</td>
<td>4.09</td>
<td>1.13</td>
<td>0</td>
<td>1(9.1%)</td>
<td>3(27.3%)</td>
<td>1(9.1%)</td>
<td>6(54.6%)</td>
</tr>
<tr>
<td>The hardness, texture and tactile feedback provided by Simodont felt realistic</td>
<td>2.63</td>
<td>1.28</td>
<td>2(18.2%)</td>
<td>4(36.4%)</td>
<td>2(18.2%)</td>
<td>2(18.2%)</td>
<td>1(9.1%)</td>
</tr>
<tr>
<td>The instructions given by Simodont was clear and provided in an easy format</td>
<td>3.90</td>
<td>.833</td>
<td>0(0%)</td>
<td>0(0%)</td>
<td>4(36.4%)</td>
<td>4(36.4%)</td>
<td>3(27.3%)</td>
</tr>
<tr>
<td>I felt comfortable using Simodont</td>
<td>3.27</td>
<td>.646</td>
<td>0(0%)</td>
<td>1(9.1%)</td>
<td>6(54.6%)</td>
<td>4(36.4%)</td>
<td>0(0%)</td>
</tr>
<tr>
<td>Using Simodont assisted my students’ learning</td>
<td>3.45</td>
<td>1.12</td>
<td>0(0%)</td>
<td>3(27.3%)</td>
<td>2(18.2%)</td>
<td>4(36.4%)</td>
<td>2(18.2%)</td>
</tr>
<tr>
<td>The educational feedback provided by Simodont assisted my students’ learning</td>
<td>3.54</td>
<td>1.29</td>
<td>0(0%)</td>
<td>3(27.3%)</td>
<td>3(27.3%)</td>
<td>1(9.1%)</td>
<td>4(36.4%)</td>
</tr>
<tr>
<td>The force feedback provided by Simodont assisted my students’ learning</td>
<td>3.36</td>
<td>1.02</td>
<td>0(0%)</td>
<td>3(27.3%)</td>
<td>2(18.2%)</td>
<td>5(45.5%)</td>
<td>1(9.1%)</td>
</tr>
<tr>
<td>Using Simodont improved my Visual-motor skills</td>
<td>3.63</td>
<td>1.12</td>
<td>0(0%)</td>
<td>2(18.2%)</td>
<td>3(27.3%)</td>
<td>3(27.3%)</td>
<td>3(27.3%)</td>
</tr>
<tr>
<td>Using Simodont improved my knowledge</td>
<td>3.54</td>
<td>1.12</td>
<td>1(9.1%)</td>
<td>0(0%)</td>
<td>4(36.4%)</td>
<td>4(36.4%)</td>
<td>2(18.2%)</td>
</tr>
<tr>
<td>I think my students will feel more confident about their skills after using Simodont</td>
<td>3.36</td>
<td>1.12</td>
<td>0(0%)</td>
<td>3(27.3%)</td>
<td>3(27.3%)</td>
<td>3(27.3%)</td>
<td>2(18.2%)</td>
</tr>
<tr>
<td>Using Simodont in labs in the future will help my students improve their preclinical/clinical skills</td>
<td>3.63</td>
<td>1.20</td>
<td>0(0%)</td>
<td>3(27.3%)</td>
<td>1(9.1%)</td>
<td>4(36.4%)</td>
<td>3(27.3%)</td>
</tr>
<tr>
<td>Simodont should be offered to all Dentistry students prior to performing procedures on real patients</td>
<td>3.27</td>
<td>.904</td>
<td>0(0%)</td>
<td>2(18.2%)</td>
<td>5(45.5%)</td>
<td>3(27.3%)</td>
<td>1(9.1%)</td>
</tr>
<tr>
<td>I would prefer feedback from Simodont to be supplemented by feedback from a tutor or a lecturer as well</td>
<td>4.18</td>
<td>1.07</td>
<td>0(0%)</td>
<td>1(9.1%)</td>
<td>2(18.2%)</td>
<td>2(18.2%)</td>
<td>6(54.6%)</td>
</tr>
<tr>
<td>Do you think Simodont would be a useful educational tool in Dental training programs</td>
<td>3.45</td>
<td>1.29</td>
<td>1(9.1%)</td>
<td>2(18.2%)</td>
<td>1(9.1%)</td>
<td>5(45.5%)</td>
<td>2(18.2%)</td>
</tr>
<tr>
<td>Simodont should totally replace Phantom heads in preclinical training</td>
<td>1.45</td>
<td>.934</td>
<td>8(72.7%)</td>
<td>2(18.2%)</td>
<td>0(0%)</td>
<td>1(9.1%)</td>
<td>0(0%)</td>
</tr>
<tr>
<td>How closely does Simodont approximate a real preclinical experience to you</td>
<td>2.63</td>
<td>.924</td>
<td>1(9.1%)</td>
<td>4(36.4%)</td>
<td>4(36.4%)</td>
<td>2(18.2%)</td>
<td>0(0%)</td>
</tr>
</tbody>
</table>

**Score:** 1.Strongly Disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly Agree

*a* Not realistic at all,  
*b* Not realistic,  
*c* Neutral,  
*d* Realistic,  
*e* Very realistic

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Range between 3.3 – 3.8. Table 1 summarizes the results obtained from the pre-experimental questionnaire.

**Post-experimental questionnaire:** Comparing the statistical results obtained from the post-experimental questionnaire to the ones obtained from the pre-experimental showed that there were some points of technical disappointment after using the Simodont® dental trainer such as the hardness, texture of different tissues and the force (haptic) feedback. In other educational aspects the academic staff members seemed positive about continuing using the Simodont® dental trainer such as the hardness, texture of different tissues and the force (haptic) feedback. In other educational aspects the academic staff members seemed positive about continuing using the Simodont® dental trainer such as the hardness, texture of different tissues and the force (haptic) feedback.

Eighty per cent (80%) of academic staff members commented about technical issues such as the simulated texture of the different dental hard tissues, the positioning of finger rests, cutting efficiency of tools and the size and weight of the virtual hand piece. They stated: “The handpiece was too large obstructing the view”, “No adequate finger rests along
supporting teeth", "Slight delay between hand movement and simulation is present", "Amalgam feels too hard to be removed by bur". However, seventy per cent (70%) of academic staff members liked the educational feedback and assessment methods provided by the Simodont®. They stated: "Overall it is a useful addition to the learning armamentarium".

Fifty percent (50%) of academic staff members also liked the game-like situation the Simodont® provides and thought it would encourage students use as well as being a good tool for promoting dental education. Also forty percent (40%) of academic staff members felt the use of the Simodont® would increase the confidence of students before entering the clinical environment and provide opportunities for additional remediation and practice for weaker preclinical and clinical students to strengthen their clinical skills.

Thirty percent (30%) of academic staff members felt it was difficult to create a smooth floor and remove caries with the current cutting instruments and software. They stated: "It was difficult to create a smooth floor, and remove small edges". Also twenty percent (20%) of the academic staff members did not feel the colour depictions of the caries detection dyes and of restorative materials in the simulated tooth/oral cavity were appropriate and facilitated psychomotor development. The most important missing features mentioned by the participants were a wider selection of rotary and hand instruments. Within the E-lessons loaded onto the simulator and provides educational feedback, customizations of the clinical cases available and variable strategies for treatment planning were considered a priority.

Discussion

One of the most important points of agreement between participants in this study was that the preclinical teaching methods could be fully replaced with the Simodont®. A majority of the academic staff members preferred the educational feedback provided by the Simodont® to be supplemented by feedback from a staff member as they felt the human element is crucial in any educational process and should not be eliminated. The authors believe this is due to the fact that a preclinical experience using manikins in a simulation lab is usually a richer educational experience that involves more visual and tactile input. It also includes communication with staff, clinical problem solving and decision making, which is more difficult to be provided by an automated system.

One of the perceived advantages of the Simodont® is that it combines visual, auditory and haptic feedback. This combination was found to be more efficient in improving performance in medical training tasks such as suture tension23 as well as in tele-operation tasks24 than using a single sensory input (i.e haptics only). Another advantage of this new dental trainer is the ability to connect online through a network database. This has the ability to create a more interactive situation between students and staff in the same institution as well as offering a chance to work across a network with students from other institutions. In the future it is hoped that this would provide a motive for students to practise and perform at their best levels. In the tutoring mode, students could also view across a local or area network pre-recorded procedures performed by experts using the Simodont® and feel the actual movement of instruments by those experts in real-time.

Participants commented about the texture of different tissues provided by the Simodont® and that it was difficult for even experienced dentists to create a smooth surface and fine features within preparations. The current Simodont® instrument has three degrees of freedom in force feedback. This means that only the tip of an instrument provides force feedback and the lateral aspects of the instruments do not. This results in a lack of collision detection with the lateral aspect of the instrument. In the future, with the use of a haptic system with six degrees of freedom this would be improved, as both the tip and lateral aspects of the instrument would be providing force feedback. However, in spite of these drawbacks three evaluators were positive about the hardness and texture of tissues and were positive about the value of the force feedback provided by the Simodont® in helping their students' learning.

The comments that the tactile feedback provided by the Simodont® is not realistic is in agreement with other studies3 on PerioSim® the haptic 3-D virtual reality dental training simulator and another study that evaluated the IDEA (Individual Dental Education Assistant) prototype and found out that the sensation it provided did not mimic reality in a convincing manner.25 Our results confirmed the findings of both studies in regards to the potential benefits of uses of haptic simulators in teaching manual skills, as well as the suggestions that the evidence of concept of use of these haptic devices was successful.

The reported limitations and missing elements in the Simodont® dental trainer were technical (e.g: the positioning of finger rests and selection of hand and rotary instruments), while the educational benefits of this dental trainer were appreciated by our participants. This indicates that a multidisciplinary cooperation between dental practitioners, psychologists, educational experts, engineers and software programmers is needed to achieve a common language between all of them in order to address any issues or problems with the current simulator, understand the needs of dental education and put them into virtual reality. This is in agreement with a similar study that suggested that further research collaboration is needed to increase knowledge of the human factors influencing the design and use of simulators.26 An earlier study in 2001 emphasized the importance of sharing knowledge between different disciplines, as the research outcome of one discipline might be beneficial to other discipline.27

Although the majority of participants valued the Simodont® dental trainer as a new educational tool, further studies are needed to investigate the optimal use of the technology in dentistry programs. Whether it should be used in early learning to acquire new skills or to speed the learning curve of an already learned skill remains a key question. Development of
a universally agreed evaluation system for dental simulators and finding a relationship between computerized simulation and traditional manikin based methods of teaching may assist in students’ learning and exploring the new horizons of dental education offered by haptics technology.

Conclusion
In conclusion, the Simodont® dental trainer was accepted by academic staff members in our study as a new educational tool. However, they hold the view that dental simulation cannot replace traditional educational methods and cannot replace a human lecturer or tutor. Most of the advantages of the Simodont® are seen to be educational while the reported limitations and missing element were technical. More studies are required to investigate the value of short and long term use of Simodont® in dentistry programs for early learners and senior students, as well as comparing the effect of using Simodont® versus traditional training methods in development of new skills. A detailed comparison between Simodont® and other available dental simulators using a universal valid ranking system is needed.

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Ethical approval
This study was approved by The Human Ethics office for research (Griffith University), Australia (DOH/08/11/HREC).

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