ABSTRACT

Background: Haptic simulators have been successfully used in medical education but are relatively new tools in dental education. Aims and Objectives: This study aimed to evaluate the effect of early exposure to haptic feedback (via the MOOG Simodont® Virtual Dental Trainer) on the development of psychomotor skills and on the subsequent performance of a previously unseen manual task. Materials and Methods: Forty second year Dental Science students enrolled at Griffith University (Australia) were randomly divided into two groups. They were then given manual dexterity tasks in a haptic and a non-haptic environment but in a different sequence for each group (early- or late-haptic experience). Pre-experimental, post experimental and flow questionnaires were completed by participants. The Mental Rotation Test –A (MRT-A) was used to control for differences in visual-spatial abilities. Borg's CR-10 scale was used to control for possible differences in mental effort between haptic and non-haptic training sessions. Results: Overall, the students accepted the new dental simulator well. Participants commented both positively and negatively on the fidelity of the preclinical experience. The group that ended with haptic training performed slightly (though not significantly) better than the group that commenced training with haptics (Paired t-test; P = 0.06). Conclusion: Our study showed that haptic simulators could be combined with other methods in preclinical dental skills development but there is no clear evidence in this study that early exposure per se to haptic feedback and the MOOG Simodont® Virtual Dental Trainer could better assist in the development of psychomotor skills in Restorative Dentistry.

Keywords: Dental Education; 3DVR Haptic Device; Haptic Simulators; Psychomotor Skills

Introduction

Like all professional training programs, the process of clinical skills acquisition in dentistry is incremental with core psychomotor skills being developed as early as possible in a preclinical environment. Once mastered, this core skill set is further expanded upon through the provision of patient care prior to graduation and attainment of broad competency. One of the most important skills for dental students to develop early is a fine sense of touch and pressure. Simulators have become a standard in aerospace and aviation and useful in a wide variety of medical fields for procedures such as laparoscopy, sigmoidoscopy, lung biopsy, neurosurgery, vascular access and cardiovascular catheterizations. A number of studies published in the field of medical education indicate that training on simulators significantly improves students’ skills and subsequent performance on patients when compared to those individuals not trained on these devices.

A new technology called Haptic Technology has been introduced and relatively recently applied to dental education. Haptic Technology, or Haptics, is a tactile feedback technology that takes advantage of a user’s sense of touch by applying realistic force feedback to the user. This sensory input is highly important in clinical dentistry to modulate the amount of force to be applied by the operator during patient treatment. Haptic Technology has been used in the fields of medicine and surgery for some years with successful results. Haptic technology enables the operator to feel and manipulate tools and organs in a low-risk virtual environment, as well as performing tasks such as cutting soft and hard tissues with realistic force feedback. Trials to develop a haptic-based Virtual Reality Dental Simulator started in 2006 by developing PerioSim® which allows trainee to practice diagnosing periodontal diseases that does not require deformation of tooth surface. Another simulator allows probing and cutting of a virtual tooth, but the virtual tool implementation is limited to a spherical shape for simplicity. Also a dental training system with a multi-modal workbench was developed and provides visual, audio, and haptic feedback. It allows burring and drilling on the tooth with a spherical tool.

A dental training system was proposed utilizing material stiffness and spring force function. 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. However, these simulators are so new that well-controlled studies of their effectiveness are lacking.

There is also debate amongst dental educators about the urgency and necessity of the inclusion of haptic-based dental simulators for future preclinical teaching and assessment of dental students and whether this could replace, or simply supplement, existing manikin-based systems. This study was conducted to evaluate the students’ perception of the MOOG Simodont® Virtual Dental Trainer, and evaluate the effect of early exposure to haptic feedback via this simulator on the development of psychomotor skills and on the subsequent performance of a previously unseen manual task.
The Simodont® Dental Trainer, the Simodont® Dental Trainer, a brief description about the new system (Figure 3). Technical support was supplied during training sessions if needed. Psychometric tests and evaluations during the study:

Before session 1: All the participants completed a validated psychometric test for visual-spatial ability immediately before the first training session. The revised Vanderburg and Krause Mental Rotation Test, form A (MRT-A) was used to assess visual-spatial ability correlated with general ability. In the MRT-A participants are asked to mentally rotate figures around a vertical axis. The instructions, procedures and scoring were identical to that described by Peter et al., 2000.5 Participants were also asked to complete a pre-experimental questionnaire that was designed by educational advisors from ACTA (Academic Centre for Dentistry Amsterdam). This consisted of a series of eight questions on a 5-point Likert scale detailing their impression, expectations, and attitudes towards the Simodont Dental Trainer.

After Session 1 and session 2: To standardize results, participants were also asked to complete a pre-experimental questionnaire. The majority of participants preferred feedback from Simodont® to be supplemented with the Simodont® haptic training. The majority of participants preferred feedback from Simodont® to be supplemented with the Simodont® haptic training. The majority of participants preferred feedback from Simodont® to be supplemented with the Simodont® haptic training.

Results: Cronbach’s alpha was calculated to test reliability and internal consistency for ratings of the questions of the post and post experimental questionnaires. Both questionnaire showed high reliability (alpha= 0.829 (pre), alpha= 0.902 (post)).

Pre-experimental questionnaire: The students showed enthusiasm about using Simodont® dental trainer. They were less positive about the expected realism of working on the Simodont. They were almost neutral in their expectations to acquire manual dexterity skills with the Simodont® haptic training. Overall, the students’ attitude towards using Simodont® in education was positive. They expected added value in the use of Simodont® in their dental training, and also expected to be able to integrate the dental simulator easily in their learning environment. Table 1 summarizes the results obtained from the pre experimental questionnaire.

Post-experimental questionnaire: The results obtained from the post-experimental questionnaire showed that there was a positive degree of satisfaction with some features of Simodont® dental trainer, while the feedback about other features was less positive. Students rated the realism of the images of anatomical models and instruments in Simodont® higher than the fidelity of the hardness, texture and tactile feedback provided by Simodont®. Overall, only 22.5% of participants agreed that Simodont® approximates of a real preclinical experience.

In relation to educational benefits of the dental simulator, 35-47.5% of the students agreed that using the Simodont®, receiving the educational feedback and the force feedback provided by it assisted their learning, but only 17.5% agreed that it had improved their knowledge. They were equally positive about the importance of using Simodont® in labs in the future to improve their skills and offering Simodont® training to all Dentistry students prior to performing procedures on real patients. Overall, 70% of the students rated the Simodont® dental trainer as a useful educational tool in Dental training programs. There was a clear trend towards keeping it with traditional (manikin-based) simulation methods and supplementing it with the Simodont® haptic training. The majority of participants disagreed that the Simodont® should totally replace Phantom heads in preclinical training. They also agreed that they preferred feedback from Simodont® to be supplemented by feedback from a tutor or a lecturer, as well as showing their appreciation to the presence of the human element in the process of dental education. Table 2 summarizes the results obtained from the post experimental questionnaire.

Table 1. Showing Means, Standard Deviations, and frequency distributions of answers of the pre-experimental questionnaire.
Simodont looked realistic
The images of anatomical models and instruments in preclinical training should totally replace Phantom heads in tool in Dental training programs. Do you think Simodont would be a useful educational mentored by feedback from a tutor or a lecturer as well I would prefer feedback from Simodont to be supplemented prior to performing procedures on real patients
I would prefer feedback from Simodont to be supplemented by feedback from a tutor or a lecturer as well
The force feedback provided by Simodont assisted my learning
The hardness, texture and tactile feedback provided by Simodont felt realistic
The force feedback provided by Simodont assisted my learning
The educational feedback provided by Simodont assisted my learning
The force feedback provided by Simodont assisted my learning

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Simodont® manual dexterity exercises. The results obtained from borg’s CR-10 scale (Non haptic session) 3.80 2.41 4.52 1.75 4.16 2.11 3.95 2.12 4.22 1.81 4.08 1.95

Table 2. Showing Means and Standard Deviations, ranges and frequency distributions of answers of the post-experimental questionnaire

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Psychometric tests:
Statistical analysis showed the absence of significant differences between participants of both groups in terms of visual-spatial abilities, mental effort and responses to the flow questionnaire. The results obtained from all psychometric tests used in the study are summarized in Table 3.

Manual training task: There were no significant differences between students of group A and group B in terms of their performance in the haptic session (Paired t-test; P= 0.549 for the first exercise and Paired t-test; P= 0.942 for the second exercise). There was also a clear trend of obtaining higher scores in the second exercise in both haptic and non-haptic sessions. Statistical analysis of the students’ marks in the final unseen test showed a non-significant difference between the average scores of both groups in this task (Paired t-test; P= 0.066) which indicates that (B) students (late haptics) performed slightly better than group A (students (early haptics) in the final unseen exercise.

Students' evaluation of a 3D VR haptic device (Simodont®) gave a non-haptic learning environment. This was confirmed by the students’ responses to questions in the flow questionnaire. Group (B) who had a later exposure to haptics performed slightly better, though not at a level of significance in the final unseen test. This is in contrast with the findings of a similar study on 38 postgraduate students to investigate the effect of early exposure to haptic feedback in enhancing performance in surgical simulation and found that haptic feedback could be important in the early training phase of skill acquisition in surgical simulation training.23 We believe that the difference in results between both studies can be explained to be due to the difference in age and experience between participants of both studies, as well as the nature of exercises given for evaluation (reality based exercises on training blocks and Phantom heads in our study, compared to the image-guided simulation based tasks in the other study. Both studies show that haptic feedback is an important contributor to success in simulation-based training. Our study does not provide evidence that early exposure to haptic feedback per se enhances psychomotor skills development in Restorative Dentistry.

Our study is limited as the exposure to both haptic and non-haptic learning environments was only for 30 minutes. The performance of our participants improved in the second exercise of every session (haptic or non-haptic), which indicates that even short exposure to a specific training method could help increase the performance curve. Therefore, our results suggest that longer exposure to haptic feedback might affect the performance curve positively and improve skills, speed and accuracy, which is a point for studies in the future. Including two additional groups (One group using haptic feedback in both sessions and one group performing without haptic feedback in both sessions) and investigating the effect of long term exposure to haptics on performance in Restorative Dentistry tasks would have aided in developing a better understanding of the value of haptic feedback, its role in the development of skills and its potential use as a dental education tool in the future. The question of whether students with different levels of visual-spatial ability would perform well on the Simodont® or not requires further investigation.

Conclusion
In conclusion, the Simodont® dental trainer was well accepted by students in our study and they felt it could be easily integrated in their learning environment. Students perceived many educational advantages to the Simodont® dental trainer and noted some technical limitations. Students’ responses indicated that they felt the Simodont® cannot solely replace either traditional educational methods nor a human lecturer or tutor. There is no clear evidence in this study that short-term
and early exposure to haptic 3D VR feedback helps in development of psychomotor skills in Restorative Dentistry ahead of early exposure to haptic feedback enhances performance in surgical simulator training: a prospective randomized crossover study in surgical residents. Surgical endoscopic and other interventional techniques. 2006;20(9):1383-8.


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