

Simulation in Dentistry

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Abstract

All healthcare professions rely not only on textbooks and lectures but also on the amount of skill and training beforehand to be better prepared for real clinical procedures. The increased emphasis on the principles of safety in dental and medical offices has augmented the use of healthcare simulations. Along with traditional pre-clinical simulation laboratories, advanced technologies like virtual reality with haptics and the use of life-like mannequins have been introduced to ensure that dental students do not suffer the transition from theory to practice without enough skills to accomplish their tasks.

This review article discusses the various simulation technologies that have recently become available or are in the developmental stage, along with their abilities and impact on dental education.

Keywords: Dental Education; Haptics; Preclinical Training; Simulation; Virtual Reality

Introduction

Simulation is the imitation of the operation of a real-world process or system over time [1]. The reliance on simulation for dental education is quite mature and may actually exceed other healthcare specialties. Dental students must achieve an acceptable level of competence prior to actual patient care since most procedures on teeth, such as root canal therapy, oral and periodontal surgeries are irreversible, and learning these skills solely on patients is not an acceptable practice [2].

Being subject to unique risks in real settings too, from things such as infected needles, knife blades and other sharps as well as electrical equipment, they are also protected during simulations that allow them to perfect their craft [3]. Simulation allows students to repeat procedures till they demonstrate acceptable levels of skill, without putting actual patients at risk and yet acquiring procedural competence. Hence, most psychomotor skills are first learned in a simulated manner before the students progress to direct patient care [2].

The use of simulation for pre-clinical dental education has been around for quite some time. Back in the 18th century, when formal dental education started at the Baltimore College of Dental Surgery, Ohio [4], restorative techniques were practised using extracted teeth and bench-top simulations [5]. Due to the limited availability of extracted teeth and less realism of the clinical environment, phantom head simulators were developed in the early 1900s. These were cast-bronze receptacles with upper and lower dental casts mounted on a metal pole, which were made to hold either extracted or plastic teeth in occlusion, to represent a human jaw [6]. In order to make pre-clinical simulation more realistic, mannequins with wooden heads and torsos and masticatory systems were developed. The current simulation laboratories in different dental colleges make use of these simulated mannequins or patients for pre-clinical training. Students are shown informative diagrams, pictures and models of the procedures to be performed, and are asked to repeat them on plastic or extracted teeth. The final product is then evaluated by an instructor who usually gives verbal feedback as well [7].

With recent developments in virtual-reality technology, haptics and robotics, dental simulation is providing more optimal practice conditions to smoothen the transition from the traditional model-based simulation laboratory to the clinic. Using these technologies, dental simulators are now able to create an environment in which users can practise clinical procedures, such as restorative dentistry, endodontics, periodontal assessment, implant placement and even dental extractions [8].

With increased effectiveness, more efficient learning, unlimited training hours, provision of real-time feedback leading to a reduction in supervision, and the students being able to practise in their free time without laboratory supervisors, educationalists are becoming more aware of the additional benefits of VR simulation. Negative aspects have been indicated as initial setup costs, faculty training, and the lack of a variety of content and current educational simulation programs [5].

Simulation is becoming very beneficial in the area of health care education. This article reviews the development of simulation in dental education and its impact on the current pre-clinical training, along with the advanced technology simulation that will expand opportunities and enable students in their pre-clinics to have a successful clinical exposure.

Virtual Reality

Virtual reality (VR) typically refers to computer technologies that use a software to generate the realistic images, sounds and other sensations that replicate a real environment (or create an imaginary setting), and simulate a user's physical presence in this environment. A person using virtual reality equipment is typically able to "look around" the artificial world, move about in it and interact with features or items that are depicted on a screen or in goggles [5]. Virtual reality based technology (VRBT) has been used in many areas of healthcare training to improve the safety, effectiveness, and efficiency of healthcare services. It provides identical clinical simulations for all students, allowing standardization for grading if used for assessment purposes. Students are able to replicate procedures they may find difficult, allowing more individualized learning. It offers a great potential for significant impact on dental education.

The DentSim simulator manufactured by DenX Ltd. [9] of Israel; the VRDTS (Virtual Reality Dental Training System) prototype [10] developed by Novint Technologies of New Mexico; the MOOG Simodont Dental Trainer [11] developed in cooperation between MOOG Nieuw-Vennep, the Netherlands and the Academic Centre for Dentistry Amsterdam (ACTA), the Netherlands; and the IDSS (Iowa Dental Surgical Simulator) [12,13], a product of collaboration between the Colleges of Dentistry and Engineering at the University of Iowa, are all products using VRBT. Apart from student training, these simulators can also be used for the evaluation of the students' performances or the quality control of various teaching methods.

DentSim

DentSim is an augmented reality advanced dental training simulator. While seated at a mannequin and preparing a preparation, movement of the student's handpiece and the typhodont-tooth are optically tracked and analysed in real-time [9]. The unit consists of low speed and high-speed dental handpieces that operate with water, an air/water syringe, suction, foot pedal, overhead lighting, a desk, simulated patient/mannequin with head and dentoform, infrared camera, and a computer (Figure 1a). The mannequin head and handpiece of the simulator unit contain infrared emitters that allow the infrared camera to detect their orientation in space. Once the student begins preparing a cavity in a tooth of the mannequin head, the computer formulates a virtual image of the tooth being worked on, in the computer. The virtual tooth can then be compared to the ideal preparation approved by the faculty, and abundant, detailed visual feedback can be given, including a grade. The unit can evaluate the process of the preparation and not just the end product.7 It provides instantaneous visual and digital feedback in regards to floor depth, outline shape, outline centralization, hand-piece positioning, wall angles, retention, floor smoothness, and wall smoothness, etc. The student can compare his/her plastic tooth to the on screen (augmented reality) feedback (Figure 1b), think about his/her next steps, execute the steps and subsequently check feedback again to see if he/she has accomplished their goals [9]. A study was conducted of 50 pre-dental students [9], where 25 students were made to work with the traditional equipment and the other 25 with DentSim technology. Students were taught how to prepare a Class I cavity on tooth 36 and how to operate the equipment. Each student was given 5 teeth to prepare. Students not using DentSim saw approximately a 2 point average increase in their score

between their first and fifth attempts at their preparation, while those using DentSim improved their scores on an average from 78.26 to 90.47 between their first and fifth attempts. Thus, with access to unlimited feedback whenever needed reduced the amount of clinically unacceptable errors and improve their overall score. Twenty-one restorative procedures are currently programmed into the DentSim, but the major disadvantage is that the restorations (amalgam, composite or crown) cannot be recorded and faculty must continue to evaluate this part of the procedure. At the present time, DentSim units can be found in twenty dental schools worldwide (nine U.S. schools) [7].

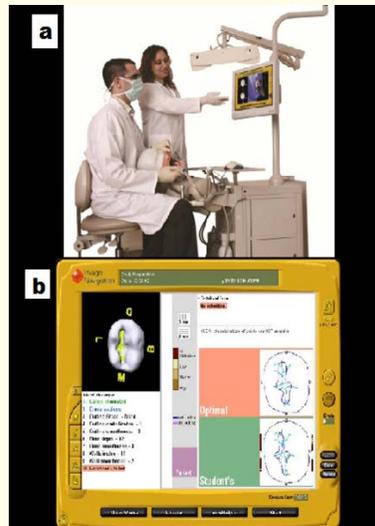


Figure 1: (a) Virtual reality-based simulator (adopted from www.dentsimlab.com); (b) View of evaluation screen on DentSim unit. Upper left is the virtual image of student's preparation. Right side of screen is cross-section of optimal preparation (right middle) and student's preparation (lower right).

Haptic Technology

Haptics is the science of applying touch (tactile) sensation and control to interaction with computer applications. The word derives from the Greek word *haptēin* meaning “to fasten” [14]. Haptics offers an additional dimension to a virtual reality or 3-D environment. In combination with a visual display, haptics technology can be used to train people for tasks requiring hand-eye coordination, such as surgeries in medicine and dentistry. It creates the illusion of substances (teeth, alveolar bone, instruments, handpieces, burs, implants) and force within a simulated virtual world of the mouth [15].

The haptic devices provide force-feedback of the virtual dental operative instruments as they come in contact with the virtual teeth and alveolar bone giving the operator a perception of manipulation of objects using the senses of touch and proprioception [15].

The MOOG Simodont Dental Trainer [16,17] (Figure 2) was developed in cooperation between MOOG Nieuw-Vennep, the Netherlands and the Academic Centre for Dentistry Amsterdam (ACTA), the Netherlands. This Dental Trainer allows dental students to be trained in operative dental procedures in a dedicated immersive virtual reality environment while receiving haptic, visual, and audio sensory information. Hand instruments as well as dental burs are simulated for training on hand skills including removing tooth decay and preparing crowns [11]. By incorporating pathological dental conditions within the system, it offers the opportunity to train from a problem-based perspective [17]. The cases can be customized and created by teachers, and students' work can be traced and evaluated by the software and staff [11,17].

The technology helps in providing an additional learning & teaching opportunity for the acquisition of skills in various fields of dentistry, where students can learn, develop and improve their operative skills in a novel and fun virtual simulation environment.

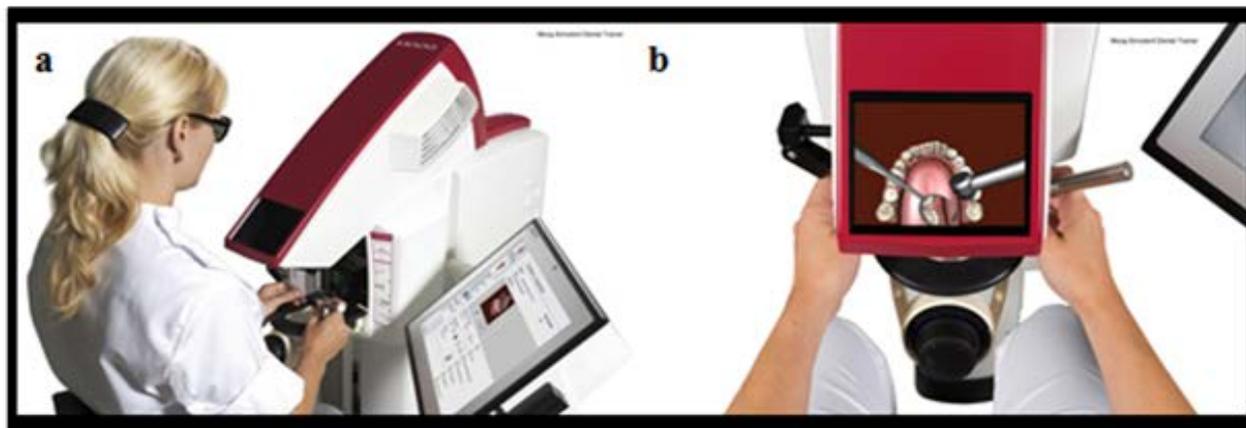


Figure 2: (a) MOOG Simodont Dental Trainer (adopted from www.moog.com); (b) A haptic tooth preparation exercise.

Robotic Patients for Simulation

The use of virtual patients in dental education is gaining acceptance as an adjunctive method to live patient interactions for training dental students [18]. Following the developments in industrial robot technology, robotics has found its way into the medical field. A technological breakthrough, opening a new era in dental simulation training, is a robotic patient or DENTAROID [19] (Figure 3a) introduced in Japan by Nissin Dental Products. A clinically more realistic training with this robot cultivates students' medical accident avoidance capability and communication competency with patients. The robot knows over 20 patterns of automatic dialogues, thus allowing communication just like with an actual patient. Also, its various lifelike body movement functions such as eye blinks create a realistic training environment. It is also equipped with different reaction movements that simulate accidents that can occur during treatment, such as reaction to pain, cough reflex, vomiting reflex and irregular pulse. It makes irregular movements under various situations which allow students to gain experience under a clinically realistic environment [19].

The robot is controlled by a surgeon sitting in a control box away from the patient, from where he or she is able to control any action of the robot (Figure 3b) [20]. An easy to use control panel allows intuitive operation of the robot [19]. This new level of simulation, unlike our previous models for simulation labs, has the real potential to influence and modify how we learn. It could offer dentistry improved accuracy, predictability, safety and quality of care.

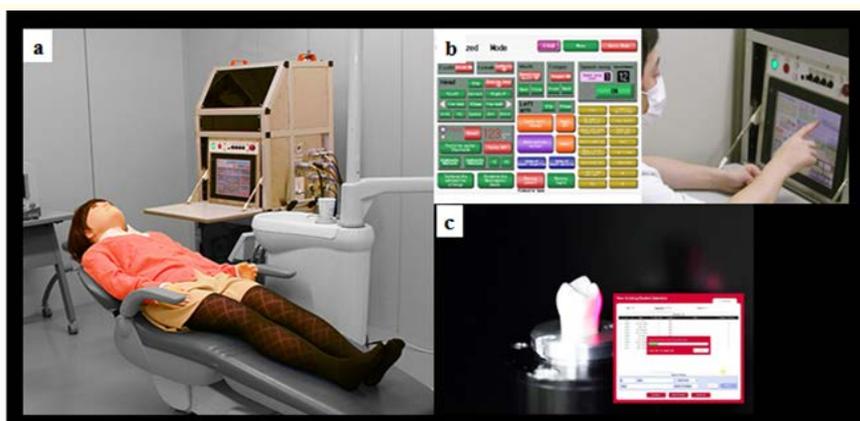
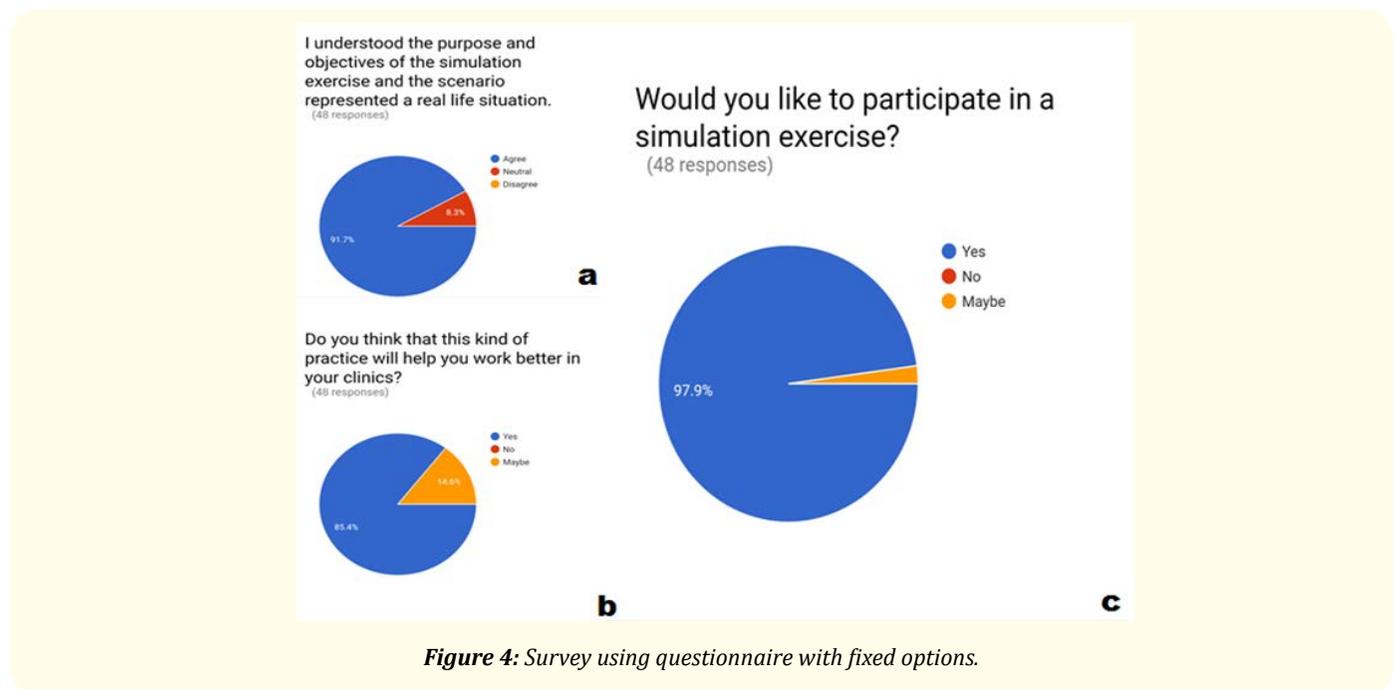


Figure 3: (a) Robotic patient or Dentaroid; (b) Easy to use control panel with custom made instructions for intuitive operation of the robot; (c) The Dentaroid grading system (adopted from www.nissin-dental.net).

Survey

To check if the inclusion and use of various technologies listed above aided in better understanding and preparation for future practice, a survey was conducted among a target population (pre-clinical students of the parent institution). The target population was 48 students traditionally practising preclinical tooth preparation on mounted teeth and mannequins. The various technologies and techniques of learning were explained to them and the survey was conducted using a questionnaire with fixed options.

The questions were based in their understanding of the purpose and objectives of the simulation exercise (Figure 4a), whether they felt the use of this technology would help them work better clinically (Figure 4b), and if they wished to participate in a simulation exercise (Figure 4c). The results were all resoundingly positive. About 91% students said that they agreed with the representation of the simulation as a real life scenario. 85.4% students agreed that this technology would definitely bring about an improvement in their clinical acumen and work, and 97.9 % were willing to participate in a simulation exercise.



Such positive results led to a search for availability of and access to any of these technologies in hospitals or dental schools in the vicinity. The Department of Conservative Dentistry and Endodontics at the Government Dental College, Mumbai, has a preclinical teaching unit simulator (Figure 5) that works on the principles of virtual reality as explained earlier. The unit consisted of the dentoform, infrared camera, handpiece and head with infrared emitters, and the computer screen showing evaluation of the product with detailed visual feedback at the end of preparation.



Figure 5: Pre-clinical teaching unit simulator at the Department of Conservative Dentistry and Endodontics, Government Dental College, Mumbai.

Conclusion

Advanced simulation technology shows potential to improve the methods and quality of dental education. Skill and confidence, on part of the dentist, to use various instruments in the oral cavity is essential for the patient's protection. With the wide acceptance and integration of these technologies into the dental curricula, students can achieve a higher level of competency before they begin clinical practice. If coupled with case-based scenario programs, they will be encouraged to handle various difficult situations with precision and proficiency. Advanced simulation emphasizes on ergonomics, expands the students' knowledge of clinical experiences and helps them perform better in the clinics, and hence, their incorporation into dental schools and syllabi can make a huge impact on dentistry.

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