The Technology of Haptics in Dental Education

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Abstract

As dentistry is a skilled profession, tactile skills of a dentist play an obvious role in delivering dental treatment to the patients. One of the current trends in dental education is to empower dental students on a global platform using advanced technology. The technology of haptic is known to provide a unique experience of a sense of touch either as tactile or kinesthetic to the user. The force feedback system in a haptic device can offer "a clinician in training" to feel the "tissues" during pre-clinical procedures before working on real patients. This paper focuses on how virtual simulators with haptic technology can play a role in bridging the gap in dental education.

Keywords: *Haptic Technology, Dental Education, Force Feedback, Virtual Simulators. Virtual Reality*

1. INTRODUCTION

Why Virtual Simulators in DentalEducation?

Dentistry is a skilled profession where tactile skills play a major role in delivering dental treatment. Procurement of psychomotor skills at the earlier phases of training, can help in producing competent clinicians On a global scale, technology is increasingly being utilized in medical education for clinical training.[1–3] Contextually, medical simulation can become a valuable tool for developing manual dexterity or psychomotor skills, required for clinical competency. [4,5] Manual dexterity is the ability to effortlessly accomplish activities related to hand-eye coordination. An interesting analogy can be related to the flight simulators where it is crucial for pilots to be preciseand well trained as lives of hundreds of people are at risk. Practical skills are usually obtained in the laboratories of the dental faculties in both pre-clinical and clinical phases. A typical pre-clinical phase consists of a dental student working on artificial teeth in a manikin head, with dental instruments such as rotary burs and hand-pieces. Such laboratory training happens on many interactions between the faculty and the student, and are relatively less effective in simulating the real-world cases. However, the

Traditional training have been popular, as the required infrastructure is less expensive to incorporate in a dental institution. Clinical phase consists of students performing dentalprocedures on real patients under the close supervision of their professors before achieving independence in performing dental procedures.[4,6]

The current dental program in India accommodates the progression of psychomotor skill development in dental education from instrument control to the phantomhead simulator followed by clinical performance on patients. Such traditional approach may not permit a gradual learning curve, for trial and errors before working on patients. Simulators can play an important role in boosting student confidence and improving their psychomotor skills. Pre-clinical teaching environments can be typically classified into traditional laboratory with mounted mannequin heads, the simulation clinics and the virtual reality or computer-assisted simulation clinics.[7]A number of technological developments such as use of accelerometer devices including games to improve hand-eye coordination and fine motor skills, training devices with haptic feedback have been proposed to develop and refine manual dexterity. The advantage of using such Virtual Reality (VR) simulators for medical

and dental skills is that, they provide an opportunity for surgeons to practice surgical or operative procedures repeatedly, with no additional cost.[8]

What is Haptic and What is its Relevance to Dental Education?

The term "haptics" refers to the area of robotics and Virtual Reality (VR) deals with simulation devices used for sensing pressure, vibration and other senses related to touch. Dental simulator with haptic devices allows users to touch, feel the objects and perform operations on soft and hard tissues with tactile sense.[9] Haptic device is a mechanical device which facilitates the two-way

communication or exchange of information between user and the virtual environment as shown in Fig.1 and Fig.2[8] Desktop hapticdevices with simulation software can offer the operator, a safe and an inexpensive method for improving his or her manual dexterity skills in preclinical training.[10] In the course of dental skill training, virtual reality simulators can also be used to assess student's competency. Simulators are capable of objective assessment offering greater level of detail such as time taken to finish the procedure, efficiency of movements and percentage of error.[9] Haptic virtual reality technology were able to differentiate skill performances of novice and expert students during crown preparation.[11]

Fig. 1 Typical haptic interface device

Fig. 2 Haptic device at dental stations

How Does Haptics Work?

The rich receptor nerve endings of hands and the dexterity of human joints has always inspired technology to imitate nature. Machines and robots were soon designed to mimic touch sensations, evolving from the crude mechanical instruments to the more recent computer programmed machines with artificial intelligence. Haptic systems consist of a software that calculates the forces required to feel the object by the user and a hardware device through which such forces can be transmitted to the user to feel. The hardware device interface that offers the user to feel the touch sensation is commonly a joystick with certain degrees of freedom[12]

Haptic based devices involves an interdisciplinary science that integrates computer graphics, medical imaging with health sciences.

Visual rendering technology has been one of the most popular means of involving users to the simulated world. Visual rendering is usually accommodated through a basic hardware consisting of a CPU, GPU and a screen or head mounted virtual reality displays. Haptic rendering, on the other hand, consists of force feedback, collision detection and object modelling. The device set-up consists of electromechanical transducers driven by computational system with varying degrees of freedom of the interface. The virtual collision

between the tool and the object, which brings in the sense of feel, is detected through algorithms.[13]

Status of Dental Simulators Globally

The Individual Dental Education Assistant is designed as a device equipped with a contemporary gaming approach with haptic interfaces. It consists of a handheld stylus device (SensAble Technologies, Inc., Woburn, MA, USA) which can be held by the student as a dental

hand piece equipped with force feedback, displayed on the screen. The system provides an interactive haptic software to teach and assess the student performance, in the process of developing the required manual dexterity skills.[10] Phantom Desktop of SensAble Technologies were applied for virtual drilling on three dimensional tooth models, in endodontic cavity preparation program and proficiency of such simulations in skill enhancement in endodontics has also been validated and contradicted.[14–16]

Table 1. Comparison of Dental Simulators available world wide

Type of Simulators	Field	Principle	Advantage	Gap
Dent Sim Simulator	Tooth/ cavity preparation	Infra-red emitters on handpiece and manikin head	✓ Visual feedback compared to the ideal preparation. ✓ Faster evaluation though similar skill	Restoration cannot be recorded.
Image Guided Implantology	Implant	CT scan of patient (Bone)	✓ Patient safety :Computer guides the surgery	-
Virtual Reality Dental Training System (VRDTS)	Tooth/cavity preparation	Virtual images of dental instruments and tooth	✓ Less costly	Interface is in the air.
Iowa Dental Surgical Simulator			✓ Sense of touch through joystick	More of haptic and less of psychomotor skills
PerioSim	Periodontics	Periodontal probe	✓ Evaluates caries lesion and periodontal pockets ✓ Small robot like arm with force feedback system	-
Haptic Training Simulation for the Administration of Dental Anaesthesia based upon Accurate Anatomical Data			✓ 3D laser scanning, 2D data capture, data processing and optimisation, 3D reconstruction of objects and environments, photo-realistic rendering, user interface. ✓ As with the anatomical model displayed by the Head and Neck Application, manipulation of the virtual patient head and navigation in the virtual environment are supported by conventional input methods.	-

PerioSim is a haptic enabled reality dental simulator that helps in diagnosing periodontal diseases with a periodontal probe. The system offers 3 dimensional, virtual reality graphics and tactile sensation allowing the user to feel a variety of dental instruments, such as a Shepherd's hook explorer for training in visualizing and detecting the feel of an caries active white spot lesion and evaluate the disease status of a periodontal pocket. On a realistic 3-D human mouth, the student can adjust a control panel consisting of parameters such as degree of model transparency, navigation, haptic tissue fidelity and tremor modulation. The haptic device allows the student to feel the sensations in the virtual mouth with the instrument pressure in grams of force while being applied to the gingival area.[4,17] Dent Sim is a computer assisted device that provides a multi-media learning environment for students in tooth preparation. It consists of a hardware, software with a mannequin and dentiform tooth model.[18] Simulation of dental implant surgical insertion, with virtual bone drilling for surgical guide accuracy was developed using haptic technology.[19] A haptic learning system for self paced learning in local anesthesia delivery was developed on anatomic models.[20]

Different simulators for probing and cutting a virtual tooth were developed using 3D model of tooth or bone, use of different shapes of cutting tools. At Thammasat University, Thailand, Faculty of Dental Sciences developed virtual reality based dental training system with a haptic force feedback device. A 3D surface model of patients teeth and dental hand piece with a cylindrical bur was created to which collision detection, haptic rendering were computed through algorithms. A haptic rendering with six degrees of freedom for dental implantology simulation was developed focusing on the simulation of drilling by Cedric and Christian.[9] Comparison of some of the haptic simulators available worldwide is shown in Table 1.

2. CONCLUSION

Quality of a doctor's skills and quality of health care delivery are interlinked. Dentistry is a skilled profession where tactile skills play a major role in delivering quality dental treatment. Use of haptic devices during training can help empower dental students in skill development for competency based education.

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