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Haptics: The virtual reality in periodontics

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Abstract

The simulation of clinical situations along with the acquisition of fine motor skills comprise an essential aspect of student's learning experience. However conventional approach to dental training poses certain drawbacks in terms of cost, availability, lack of real clinical cases, shortage of time, clinical supervision, and the funding of raw materials. The introduction of the concept of haptics opens the door to a more realistic clinical experience which is free from the previous limitations. Also, haptics offers the possibility of unlimited training hours by which students can gain skills without demands on manpower and resources. For the improvement of tactile sensation, the sense of touch and force-feedback might offer greater improvements to the existing learning techniques, thus enhancing the quality of education procedures. This paper provides a comprehensive insight into the domain of haptics for enhancing motor skills during clinical training of periodontal procedures.

Keywords: Technology based learning, virtual simulators, haptics, virtual reality

Introduction

Over the past decade utilization of technology based learning as well as training in both the fields of dental and medical education has increased. Medical simulation has become a valuable tool for learning and acquiring skills. In order to gain surgical expertise it takes more than merely observing patients, diagnosing and managing the disease, but needs a practical experience of the tactile information as well. Conventional clinical training is conducted in two stages. Firstly, dental students are trained on artificial teeth, placed within a manikin head, using real dental instruments, like burs, etc. Practicing on manikins reduces the risk to some extent but is less effective considering the cost, availability, and lack of rare real-world cases (cannot provide the level of detail and material properties of real life teeth and procedures). In the second stage, the students perform dental procedures on real patients under the close supervision of their professors. So, the students/clinicians go through a trial and error process by working on real patients before achieving better and more consistent experience and safe performance of dental procedures.

Despite conventional techniques have their own importance in training, students/clinicians must have a firm knowledge about the use of tools and the material properties of the organs before practicing on live patients. Hence, a system, which simulates real dental procedures graphically and haptically, might serve as a better option to increase student's knowledge/experience level and to perform mock surgeries before practicing on live patients. Introduction of haptic technology can bring about better outcomes with less error^[1].

"Haptics" refers to the area of robotics and Virtual Reality (VR) and deals with simulation devices used for sensing pressure, vibration and other senses related to touch. Dental simulator along with haptic devices allows users to touch, feel the objects and perform operations on soft and hard tissues with tactile sense^[2]. Haptic device is a mechanical device which allows two-way communication or exchange of information between user and the virtual environment (Fig.1)^[3].

Desktop haptic devices with simulation software can offer the operator, a safe and an inexpensive method for improving manual dexterity or psychomotor skills in preclinical training.^[4] 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.

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Fig 1: Simulator setup and handling the real instrument and the haptic stylus

Haptics-based simulators comprises a haptic device and a platform to facilitate dental practicing (virtual models of a human tooth or mouth). The trainee needs to hold the stylus of haptic device instead of real dental instruments and can manipulate the instruments, shown on the screen, which in turn reproduces clinical sensations in the hand of the operator through tactile feedback. The advantage of using such Virtual Reality (VR) simulators is that, they provide an opportunity for surgeons to practice surgical or operative procedures repeatedly, with no additional cost [3].

Historical Background and Principles

- Wang *et al.* [5] worked on a simulator that allows probing and cutting a virtual tooth, but the virtual tool implementation was limited to a spherical shape for simplicity.
- Kim *et al.* [6] developed a dental training system with a multi-modal workbench providing visual, audio, and haptic feedback. It allows burring and drilling on the tooth with a spherical tool.
- Yau *et al.* [7] proposed a dental training system utilizing material stiffness and spring force function.
- Luciano [8] developed periosim, which allows trainee to practice diagnosing periodontal diseases that does not require deformation of tooth surface.
 - Haptics works on the principles of creating virtual environment, which replaces the reality, and user can interact to perform various motor and perceptual tasks. It can help one to be mentally transported and immersed in virtual worlds through various computer softwares.

Hardware for the haptic system comprises

- Monitor and speakers
- Haptic interface device (stylus)
- Glasses and helmets for visualizing 2D video

- display as 3D
- Gloves to feel the sensations.[1]

Application in Periodontics

Differentiating between pathological and normal conditions, diagnosing and treating periodontal diseases requires skill which can be achieved by employing one of the two visuo-haptic systems: periosim and a periodontal simulator [9, 10]. Periosim and periodontal simulator were developed by university of Illinois at Chicago. The application simulates three dental instruments: A periodontal probe, a scaler, and an explorer, which can be used for training students in various aspects of Periodontology.

Diagnosis: Diagnosing the periodontal disease mainly depends on probing and measuring the clinical attachment loss. Probing depth measurement vary from examiner to examiner because of variation in angulation, pressure, force etc., and thus virtual periodontal probe could be used to teach the correct probing technique, which will help in determining the health and severity of disease of periodontal tissue and thus the correct diagnosis.

Treatment: Encompasses complete elimination of etiological factors like supragingival calculus which is easily seen can be removed effectively using scalers, but the problem arises in completely removing the sub-gingival calculus, which mainly depends on tactile sensation, which can be mastered using a haptic technology while learning [1].

In the evaluation phase, a virtual periodontal explorer may be used to determine whether the calculus has been completely removed. This evaluation could be performed with both a transparent and an opaque gingiva to contrast the results obtained by the trainee.

Haptics and Bone Surgery

In the Stanford Bio Robotics Laboratory, a visuohaptic simulation of bone surgery for training and evaluation has been devised. A hybrid data structure is used to represent the bone: A volumetric array stores the density values and attributes of the data, whereas a surface triangulation is used to render the bone graphically. The volume data and surface triangles are obtained from computer tomography or magnetic resonance data after a preprocessing procedure. The system also simulates bone dust, provides drilling sounds, and can incorporate a second haptic device as a suction and irrigation tool [11].

Bone Navi, another computer- aided support system for implant surgery, has been developed in Japan to simulate implant placement and surgical guide fabrication for dental implant surgery

Table 1: Comparison of some of the haptic simulators available worldwide is shown in [12]

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
Perio Sim	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.	-

Operating a Periodontal Simulator

- **Instrument selection:** Using the control panel, one of three periodontal instruments can be selected for onscreen use: a periodontal probe, explorer, or scaler [fig. 2].



Fig 2: Virtual periodontal probe, explorer, or scaler

- **Graphics Control:** In the main window of the simulator, the user can see the full-screen 3d model of area of interest in a dental arch along with the main control

panel. The main control panel contains a variety of controls for navigation which include options to select and manipulate gingiva.

- **Haptics control:** Includes the basic ability to turn haptics on or off for each selected object. Also parameters such as stiffness, viscosity, static friction, dynamic friction can be controlled and altered separately for each object. By moving the haptic stylus, a trainee can move the virtual instrument on the tooth surface and feel the crevice or pocket area within the margin of the gingiva along the root surface of the tooth [figure 3, 4]. The 3D virtual periodontal probe can be used to determine and measure crevice or pocket depths around the gingival margins of the teeth. The textural feel of pocket areas can be differentiated and regions of sub- gingival calculus can be located. This situation corresponds to conditions encountered clinically [13].

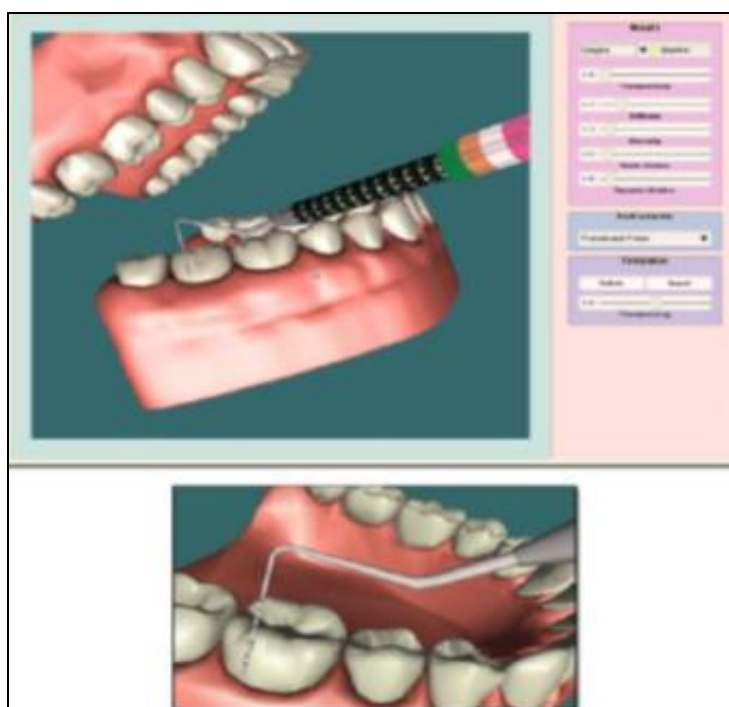


Fig. 3: Measuring pocket depth with



Fig 4: Calculi being removed with probe scaler

Advantages

- Reinforcement of learned dental concepts
- Correct use of dental instruments
- Correct ergonomic positioning
- Good psychomotor skills.
- Standardized evaluation
- Faster acquisition of skills
- Positive student perception.

Disadvantages

- Dental simulators are at an early or experimental stage
- Tactile perception for gingiva is not very real
- The initial cost can be substantial.
- Difficulty in maintenance and repair ^[1]

Conclusion

Virtual reality might establish the next level in dental education. The technology of virtual reality innovates how clinical training takes place. Unlike existing systems for clinical courses, they overcome the limitations of phantom head systems and provide standardized cases, objective assessment, and interactivity. Also, this methodology, which improves the level of perception, sense of touch and feel and reduces the distance between the virtual and the real world and at the same time encourages a self-assessment process to identify self-directed learning. Haptics holds a promising future which might serve an excellent complementary means of training and could replace the existing ones.

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