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Haptics – The Science of Touch in Dental Training

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Abstract:-In recent years, technology has been widely used in dental and medical education for both learning and training.The traditional approach to dental skills training has drawbacks in terms of cost, availability, lack ofreal-world cases, with time restraints, clinical supervision, and the funding of raw materials such as real and plastic teeth. The introduction of dental haptics opens the door to a more realistic clinical experience that can be free from the previous constraints and also there is increased effectiveness in comparison with traditional teaching techniques, more efficient learning, objective and reproducible feedback, unlimited training hours, and enhanced cost-effectiveness for teaching establishments.

Keywords:-*Dental education, Haptics, Virtual reality.*

I. INTRODUCTION

Throughout history, education has progressed, and new teaching methods have been devised to improve the quality of learning operations. It has never been a static field; rather, it has always sought to adapt to society's current cultural and technological conditions, as well as its intellectual needs. In recent years, new technology has changed education in a variety of ways. Informatics has supplied a variety of tools and methodologies that have resulted in applications with visual or aural interfaces.[1]

Tactile sense is commonly employed in medical and dentistry procedures to manipulate organs or tissues with specific equipment. To master surgical expertise, hours of supervised, intraoperative instruction are required. Patient safety and procedural efficacy must never be jeopardized for teaching (Leach, 2005).[3]

Virtual Reality (VR) is a popular name for an immersive, interactive, computer-mediated experience in which a person looks around a synthetic (simulated) environment using specialized human-computer interface equipment. Haptic technology, when combined with other virtual reality technologies, allows users to interact with the Virtual Environment via visual, aural, and tactile channels, giving them a better understanding of the VE.[2] Haptic sensibility combines tactile and kinesthetic sensations.[2]

Often we use the sense of touch (haptic) as a modalityin our daily lives, despite its critical relevance. Haptic (or force feedback) gadgets are technological innovation that allows users to feel and interact with objects realistically.[2]

Dentistry is a specialized field in which tactile abilities are essential for giving dental treatment. One of the most challenging fields to study is clinical dentistry[5.] Clinical competency necessitates the integration of a massive amount of data as well as the development of practical skills and the ability to solve a clinical problem.[6]

Practical skills are often learned in dental faculty laboratories throughout both the preclinical and clinical stages. In pre-clinical plase, students work on artificial teeth in a manikin head with dental equipment such as rotary burs and handpieces.[7]

In pre-clinical settings, several technologies are being included in the curriculum to help students develop their fine motor skills and coordination between hand and eye, allowing for a smooth transition to the clinical setting.The simulation equipment comes in a variety of modular, bench, or chair designs, depending on the unit and the type of dentoform utilised, and can be used in operational, prosthodontic, endodontic, pedodontic, and surgical education.

II. WHAT IS HAPTICS?

A haptic interface consists of a real-time display of a virtual or remote environment and a manipulator that serves as the operator-to-simulation interface.By moving the robotic device, the user can move around in the virtual or remote world.

Haptic feedback (HF) allows visually simulated objects to take on real attributes including mass, hardness, and texture. When haptic feedback is employed in virtual or remote situations, users can push, pull, feel, and control items in virtual space rather than just seeing a representation on a video screen.[2]

The most widely used haptic interface is Sensable Inc.'s PHANToM desktop haptic interface(fig 1). It's a haptic interface that uses a pen or stylus. While employing the haptic technology, the operator grabs the stylus at the robot's end. The workspace of the PHANToM desktop device is approximately 160 W 120 H 120 D mm.Oerator receives three-dimensional feedback from the device, with a maximum exertable force of 1.8 foot-pounds (lbf) (7.9 N) and a continuous exertable force of 0.4 lbf (over 24 hours) (1.75 N).

Fig 1: PHANToM haptic interface

Virtual reality simulators can also be utilised to test student competency during dental skill training. Simulators are capable of objective evaluation, providing more information such as the time it takes to complete a task, the efficiency of movements, and the percentage of

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inaccuracy.Various dental simulators have been used globally in the dental preclinical training.

III. DENTAL VIRTUAL SIMULATORS(DVS)

A. *DentSim*

DentSim was one of the earliest virtual reality systems used to teach restorative dentistry. It enables trainees to practice clinical operations on a simulated patient while obtaining real-time feedback and performance evaluation via on-screen visual tracking of the treatment. By far the most developed and well-received systems are the 43 DenX Ltd. modules. The DentSim (Dental Simulator) system was available since 1997. The unit consists of a manikin or simulated patient with a head and dentoform, as well as a dental handpiece and light, an infrared camera, and two computers.

The infrared emitters on the manikin head and handpiece enable the infrared camera to determine their spatial orientation. The computer builds a visual representation of preparing tooth(fig 2) when student is working on manikin head.[9]

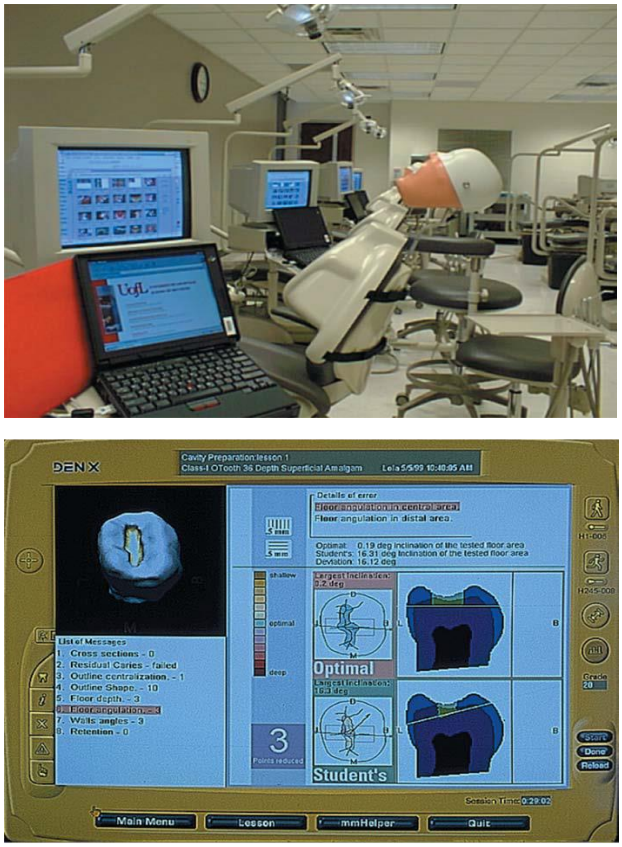


Fig. 2: DentSim virtual simulator

B. *Iowa Dental Surgical Simulator(IDSS)*

The IDSS unit focuses on tactile skill development rather than psychomotor skill development. The IDSS is made up of three hardware components: a computer, a display, and a software-controlled force feedback device.(fig 3) Participants use a joystick or explorer handle attached to the force feedback device to interact with the computer. When the joystickis manipulated over the relevant parts of the tooth, different haptic responses are received.One of the significant extensions to the original software was the creation of force models for distinct dental regions — healthy enamel, healthy dentin, and carious dentin. Between the models, the methodologies for calculating answers differed.[10,11]

- Using the haptics probing system, the prototype can only identify carious lesions (cavities) on the surface of teeth.
- Is more concerned with the development of tactile skills than with the development of psychomotor skills..[13]

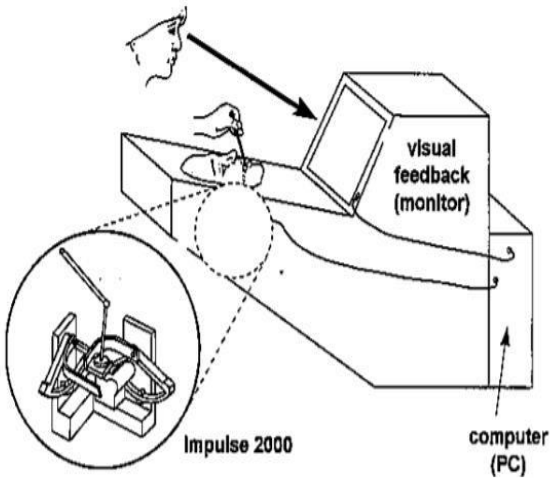


Fig 3:Iowa Dental Surgical Simulator(IDSS)

IV. INDIVIDUAL DENTAL EDUCATION ASSISTANT (IDEA)

The IDEA consists of a six-degree-of-freedom stylus linked to a feedback-giving platform. The learner can practise using tools (Stylus and Phantom Omni) while receiving haptic feedback on this system, which displays a 3D virtual image on the screen.

The simulator calculates and records task time, percentage of desired material removed, and deviation from the allotted drilling task, all of which show accuracy, and then displays a score for each task on the screen.

The unit offers modules for Manual Dexterity™, Caries Detection, Scaling and Root Planing. Currently, available applications has modules for obturation in RCT, radiographs,fixed prosthesis removal, pain management,etc.[16,17]

A. *Simodont® dental trainer*

Thissoftware includes manual dexterity, cariology, crown and bridge exercises, clinical circumstances, and a whole mouth simulation experience. For future release, modules in Dental Hygiene/Periodontics and Endodontics are being developed.

The current systems helps in maintaining ergonomic position with a haptic interface and a 3D projection screen above it, both of which are placed where the patient's head would ordinarily be(fig 4). After that, the operator is immersed in a multi-screen canopy of visual capabilities,

manual skills, and auditory sensations, which is accompanied by an acoustic module with adjustable volume that reproduces the sound of the actual devices and synchronises the guiding hand and foot on the drill's speed control pedal. These tactics are a simulation of the situation he will encounter with the patient later in the clinic.

The simple interface design allows the student to select cases, developing the method using x-rays and photos of the pathology and complete tooth structure, recording the medical history, selecting the instruments and diagnostic tests, and position the tooth and direct or indirect vision with the use of mirror.[12,22]

Fig 4: Simodont® dental trainer

B. Voxel-Man

This simulator is used for surgical training. The operator can use a foot pedal to control the animated high and low speed bursts of various forms and can view teeth in all angles using virtual mirror(dental). The technology can magnify teeth and show cross-sectional images at the same time(fig 5). Real teeth were used to construct models of the tooth in high resolution using microtomography. With the programme, operator can obtain feedback immediately, problem-basedlearning, and evaluation of their performance. [8]

Fig 5 :Voxel-Man simulator

V. VIRTUAL REALITY DENTAL TRAINING SYSTEM (VRDTS)

Virtual cavity preparation can be made using this dental simulator.

A set of dental simulators (low-speed drill, carvers, explorer, a carrier and a packer), amalgam material, and a single molar are simulated in this soft ware. Magnification and cross section modes are included to aid visually. A student holds the PHANTOM interface in the air to use the unit. A virtual simulated image of the dental instrument, tooth, and deterioration is displayed on the monitor. The operator can select the suitable instrument to prepare or restore the juvenile simulated tooth on the monitor by manipulating the interface device. The VRDTS enables for virtual tooth restoration.

Advantages of this unit are:

- Because the teeth in the VRDTS are virtual, there is no need to replace them, which can be costly when utilising other devices like DentSim.
- Another benefit of the VRDTS unit is that it allows forpreparation as well as restoration of the cavity, which is not feasible with DentSim unit.

However, the disadvantage is that it does not enforce or support correct positioning or hand/finger rests because the student holds the interface in the air[6,9,14]

A. HapTEL

Thi system is built around a haptic unit derived from a gaming gadget[4]. It has two screens which allows the operator to look down on a virtual jaw which makes the operator feel like treating a real patient(fig 6). It has specially built software that allows for drilling position flexibility andlight touch sensation, and a foot pedal that controls the bur speed. Users can review and test their skills by replaying the procedure they just completed. They are given a score based on the proportion of caries eliminated and amount of hard tissue removed. The results are saved so that students and teachers can track their development. Starting with mild caries and advancing to more sophisticated caries, a variety of simulations are available.

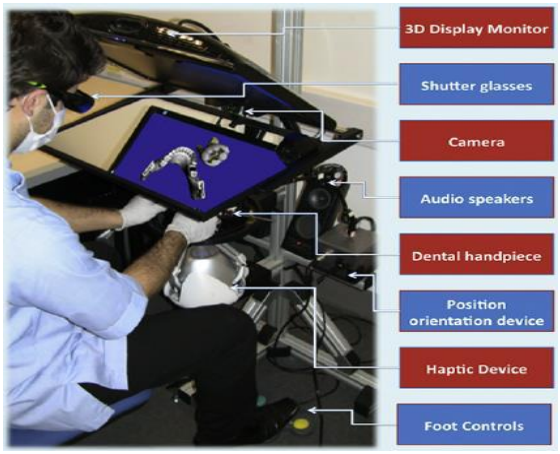


Fig. 6: HapTEL

B. VirDenT system

This system simulates the preparation of permanent dental prostheses using virtual and augmented reality technology (crowns and bridges).

The system contains a virtual teeth, drills, and patient, as well as a haptic interface, allowing the operator to practice restorative procedures in a virtual environment. It enables a student to follow teachers demonstration concurrently and proactively.

Thesimulator graphically and haptically simulates the tooth preparation technique using a video monitor and haptic device.

It is non-invasive and gives pupils feedback, allowing them to recover if they make a mistake. It tracks and analyses students' progress in the same way that hapTEL does. Training with traditional methods is a time-consuming process. This will help in rapid learning and the amount of time they spend doing so will be lowered.[6,15]

C. The Forsslund System

The Forsslund system simulates third molar extraction virtual reality training. Mandibular third molar surgery, like any other type of surgery, necessitates solid clinical reasoning abilities in order to make an accurate diagnosis and arrange therapy.

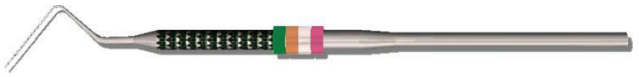
D. Periodontal simulator

In this simulator configuration, A stereoscopic display and a haptic device are used to interact with the simulator.The haptic device is [SensAble] PHANToM Desktop. By grasping a haptic stylus with dimensions similar to those of genuine periodontal instruments, the learner can change the position and orientation of the virtual periodontal instrument in the simulator.

The device maintains a 1:1 movement ratio between the haptic stylus and the virtual instrument, allowing the trainee to develop fine hand dexterity in the same way as it is required when operating on real patients.[18,19]

E. Selection of dental instrument

Each periodontal operation necessitates the use of different diagnostic and surgical instruments.The user can choose the appropriate virtual instrument before beginning the procedure. The virtual periodontal probe, scaler and, explorerimages are shown below.



Virtual periodontal probe

Virtual explorer

Virtual scaler

F. PerioSim

PerioSim is a computerised virtual reality (VR) system that shows a three-dimensional model of a quadrant along with controls for generating a transparent version that shows teeth, gingiva, bone, and all underlying supporting tissue. The system includes 3D graphics, virtual reality (VR) graphics, and tactile sensation (haptics) that allow the user to feel the dental instruments, such as a Shepherd's hook explorer for visualising and detecting the feel of a caries lesion, or a VR periodontal probe for probing and evaluating the disease status of a periodontal pocket..[20,21]

VI. HAPTICS IN IMPLANTOLOGY

Oral implants have now established themselves as an essential therapy option across all medical professions. The procedure necessitates planning, which is frequently based on CBCT scan, in order to identify critical structures and determine the best position for implant placement.[23]

The procedure necessitates sophisticated abilities developed via a particular level of experience. The mandibular canal can be damaged, the maxillary sinus can be pierced, and the Schneiderian membrane can be perforated.[24]

There are several computer programsthat can be used to gather enough data to determine the position of oral implants. They can assist in finding a better implant placement position and even guide the students through drilling operations.However, they do not assist new operators in grasping the sensation of bone drilling during the actual surgery, and surgical bone templates, which are effective guidelines for drilling.

The haptic device incorporates bone drilling simulation and 3-D bone STL data and the operation is conducted with the virtual reality haptic device. (FreeForm and PHANToM, SensAble Technologies, Woburn, USA).

This programme was initially created for cavity preparation training. Later, instead of using a tooth model, they used this programme to create a 3-D jawbone image for inexperienced dentists to practise virtual bone drilling for implant surgery.

A. Image Guided Implantology (IGI)

This system helps in diagnosis, treatment planning, and implant placement. This system uses the same technology as the DentSim, but by entering the patient's CBCT scan data into the device, a virtual reality composite of that patient can be created. The virtual patient can then undergo diagnosis, treatment planning, and virtual trial surgery for implant placement. It has a registration device that can be utilized during the surgery to allow the patient and the virtual patient picture to be coordinated during the actual surgery, which is an interesting and unique feature of this unit. The surgeon can use the computer images for improved implant positioning, and the computer warns if the surgeon deviates from the treatment plan while doing the procedure.

If the computer detects a significant variation in the implant placement during surgery, the handpiece will be stopped, and the surgeon will have to override the computer in order to proceed. This significantly improves patient safety.

Simulators with this level of modern technology will make implant training in dental schools and private practice easier and more complete.[9]

B. Future developments

Current virtual reality dental simulators are mostly used to teach basic or easy dental techniques such as calculus identification and removal, pocket probing, tooth extraction, and cavity preparation. These basic and limited skills, on the other hand, fall far short of meeting all training requirements. As a result, more diverse functions, such as emergency simulation, and communication between the learner and the virtual patientmust be established.[25]

VII. CONCLUSION

Dentistry has seen immense developmentin the past decade with the development of new bio-materials and technological innovations. When compared to traditional educational and learning applications that only provide audio visual information, the Visual-Haptic applications not only provide users with visual and audio information, but also allow them to perceive motion and haptic information while interacting with the haptic device in VE. As a result, haptic technology can improve the authenticity and immersion of engagement in education and learning.

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