Hariharan, J Oral Hyg Health 2021, 9:8

Journal of Oral Hygiene and Health

Review Article Open Access

Virtual Reality and Augmented Reality in Oral Implantology

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Received date: December 03, 2021; **Accepted date:** December 17, 2021; **Published date:** December 24, 2021

Citation: Hariharan AS (2021) Virtual Reality and Augmented Reality in Oral Implantology. J Oral Hyg Health 9: 295.

Abstract

To provide insight into virtual reality/augmented reality in oral implant ology. Oral Implants are currently an established treatment modality in fixed prosthodontics. It requires a certain amount of advanced skill gained from theoretical and extensive clinical experience. With the recent introduction of three-dimensional (3D) diagnostic and treatment planning technologies in implant dentistry, a team approach to the planning and placement of dental implants, according to a restoratively driven treatment plan, has become the norm in quality patient care. Incorporation of virtual reality in the education and treatment planning in implant ology could revolutionize the practical patient management in clinical scenario. This study hence aims to spread awareness on the methods and equipment required for virtual/augmented which could change the way we learn and teach. With computer assisted procedures becoming more and more part of dentistry, the introduction of virtual reality and augmented reality based teaching, treatment planning and simulation software's has opened avenues to better understanding, diagnosis and treatment and created an interdisciplinary environment in which communication leads to better patient care and outcomes. Combining virtual and augmented reality aided software in implant dentistry provides trainees and dentists a holistic learning experience on anatomical knowledge, spatial visualization, judgment and inter-professional teamwork. Dentistry has got practically little attention from VR research, yet it is rapidly becoming an often used therapeutic aid in orthopedics and neurophysiologic procedures. This review can hence become a source of reference on virtual and augmented reality in oral implantology.

Keywords: Oral implants; Prosthodontics; Implantology; Neurophysiologic; Oral implantology

Introduction

Computer assisted planning and teaching software has been widely used in fields of neurosurgery, orthopedics, and oral and maxillofacial surgery. The use of virtual and augmented reality aided programs in implant dentistry is a relatively new concept [1]. Safe and correct positioning of implants in the maxillofacial region is a precise procedure and is quite challenging. Virtual reality describes a 3D computer generated environment which can be readily explored and interacted with by a person. Augmented reality combines virtual reality with 3D real environment to provide real time feedback. Use of teaching and planning software augmented with AR/VR improves professional training for trainees with simultaneous evaluation of their skills and also provides an innovative approach to learning by simulating the clinical situation with very high accuracy and reliability. The introduction of these softwares enables the surgeon to perform accurate positioning of dental implants from a prosthetic as well as an anatomical point of view. The three dimensional guidance also helps the surgeon to avoid injury of anatomically important structures and to rule out surgical mistakes. Studies performed by Lin YK and Pellegrino G show the cases where implants were placed using the assistance of augmented reality. There is a lack of attention from researchers in terms of the scope of VR/AR in dentistry as a whole and implantology in particular [2-5]. This review hence is a compilation of literature on the use of these technologies in implant ology which could act as a reference for future research.

Literature Review

What is the difference between virtual augmented and mixed realities?

Virtual reality: Virtual Reality involves a computer-generated simulation of a three-dimensional image or environment that provides a standardized, safe, and flexible platform that can be interacted with in a seemingly real or physical way by a person using special electronic equipment consisting of sensors. To achieve this, the user of this technology should be exposed to a realistic multidimensional visual stimulus that allows complete integration of cognitive, motor and mental functions.

Augmented reality: Augmented reality combines virtual reality with 3D environment specific to an operator to achieve an image that augments the virtual scene with the real one. It fulfills three basic features: A combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects (7) implant surgery it enables overlapping the CBCT on the surgical field enabling better understanding of the bone morphology [5].

Mixed reality: Mixed reality merges real and virtual worlds such that they coexist and interact in real time. It does not exclusively take place in the physical or virtual world but is a hybrid that encompasses augmented reality and augmented vitality by immersive technology.

Haptics

The word 'haptic' means something that relates to or precedes the sense of touch. A haptic interface is a device that allows a user to interact with a three-dimensional (3D) image on a computer by receiving tactile feedback. This perception relies on the degree of opposing force applied to the user *via* the operation of a manipulator. In implant dentistry, the inclusion of haptic incorporated software enables learning operators to grasp the feeling of bone drilling similar to an actual surgery, and to better understand the tactile sensation of different bone types. Training systems in dental implantology require precise haptic feedback and hence require six degrees of freedom, which includes three translational forces and three rotational torques to render all forces applied to a drilling tool [6-8].

Haptic devices and simulation of bone drilling: Virtual bone drilling can be categorised into two techniques the voxel based approaches and the implicit surface based approaches. The voxel based approach uses volume data as the collision model, the advantage of this being that the drilling simulation is not limited to the shape of the tool, but voxelization leads to loss of surface information of the tool. On the other hand, when implicit surface based approach can render accurate collision detection, it can only represent simple geometry such as sphere, cone and cylinder. As dental implant surgery involves removal of some portion of alveolar bone it is represented as volume data, typically a 3D discrete regular grid of voxels. Each voxel has density property similar to that of the remaining bone and when the drill collides with the bone its value decreases according to the bone removal rate. The bone removal rate is logarithmically proportional to the thrust force, such that in a controlled haptic cycle greater the thrust force greater the bone removed which is then tuned to the implantologist for real time feedback. Vibrations are generated when a sinusoidal force is combined with the force feedback which is controlled for realistic haptic feedback.

Categories of virtual reality

Immersive virtual reality: Combines virtual reality with the characteristics of the captured environment to provide the operator the sense of being in the scene, able to visualize the recorded image in 3D, and to interact using a sophisticated wearable device that detects eye movements and track leap motions of the hands.

Non-Immersive virtual reality: Involves computer generated experiences on a desktop, while the user interacts with a mouse, in a virtual environment. Conventional surgical procedures usually fall under this category [9-13].

Benefits

- **Endless scenarios:** Unlimited capacity to create a broad range and deep experience of patient scenarios and treatment required by creating different disease states. Enables enhanced learning, and helps evaluate the errors that could possibly occur in real clinical scenarios better preparing the learning dentists.
- **Evaluation:** Learning and planning through virtual and augmented reality aids provides overwhelming amounts of data, tracking the hand movements of the operator enabling sub-millimeter level accuracy for evaluation. The learning scenarios could be programmed with a feedback loop to give students an immediate signal while making a mistake [14].

Limitations

- **Expensive infrastructure:** To set up a station that is VR/AR enabled comes at the expense of precious time and money to build and support the ever changing technology.
- **Content creation:** Building content for a VR/AR platform is a complex process and requires the assistance of an engineer which could again add on to the cost of setting up.
- **Bugs:** As with any digital platform, AR/VR softwares are not immune to bugs which could lead to interruption in the transmission of information [15].

Types of implantology simulators

- The Anatomical Simulator (AS)
- The Virtual Simulator (VS)
- Anatomical Virtual Simulator (AVS)
- The Virtual Simulator with Force Feedback (VSFF)

The first two types of simulators are passive simulators providing no interaction with the operator whereas the second two are active. The anatomical simulator is the conventional phantom head used in pre-clinical training in dentistry. The virtual simulator consists of computer generated 3D image for better visualisation and planning, but does not permit interaction. This drawback is compensated for in the anatomical virtual simulator by the incorporation of haptic interface, graphics and acoustics making it an active simulator allowing interaction with the operator. The virtual simulator with force feedback possesses the same features as its predecessor but with the incorporation of force feedback [16].

Virtual reality based simulators used in implantology

Image Guided Implant ology (IGI): It uses technology similar to its predecessor DentSim which consists of a dental mannequin dental handpiece, lights, infrared cameras and two computers. This system is based on optical input, the hand piece being equipped with an optical sensor and a camera detector that accurately tracks its movements. The patient's jaw positions are initially registered using fiducial markers which were incorporated into the acrylic splint. This splint was placed in the patient's mouth during the registry of CT scan and also during the surgery enabling the overlapping of the planned treatment with that of real case scenario [17]. This acts like a feedback preventing the operator from making errors and hence creates minimal to nil deviation from the planned treatment. Simulators with such advanced technology encourage easier and more thorough practice in dental schools and for dentists in private practice.

Virtual scope: Developed by Areal, Neuilly-sur-Seine, France. This simulation device allows elimination of position markers during CT scan as it was thought to create mismatch in the orientation of the planned position and actual point of entry. This system instead uses an ultrasound probe for a real time 3D capture. Mapping of the clinical image is matched to the CT-scanned data and updated continuously thus creating a registration independent of the guide [18].

Rodent: Developed by Rodent GmbH, Berlin, Germany. It consists of a 3D planning system guided by sensor data for inserting dental implants and for treatment planning. This system uses optical passive sensors such as Polaris or Ronal, both NDI, Ontario, Canada, to measure the location of the patient and the instrument. . Since most measurement and calibrations are automated, the user interaction is intuitive and simple. The system has the medical approval for the

European market and has been proven its practicability in more than 100 successfully navigated implantations [19].

Impala System: Developed by Premedical, Sydney in 2015. Based on optical live tracking technology, Impala provides an environment for implant surgery planning and a dual solution for improving the accuracy and safety of surgical procedures in combination with automatic drill guide generation and live tracking of surgical instruments. This system provides full volume interactive intra-surgery navigation and finds application in flapless surgeries, for angled implants, for use in atrophic sites and even for zygotic implant planning and placement.

VirtEasy System: Developed by DIDHAPTIC1. This system consists of two subsets; VirtEasy Scan Implant, VirtEasy Implant Pro. The objective of this system being two parts was to orient the students in planning using the VirtEasy Scan Implant without 3D interface based on a set of case reports and then allow the students to perform virtual surgeries in the VirtEasy Implant Pro that were planned in the scan implant programme. The VirtEasy Implant Pro is programmed with a force feedback mechanism allowing realistic training. VirtEasy implant pro allows force feedback with 6Degrees of freedom and the arm can work in a spherical volume of ten centimeters of diameter.The two systems together create a learning loop which allows preparation-perform-review own activity- regulation [20].

Dynamic navigation in implant surgery

Technological advancements in virtual and augmented realities has led to its successful application in dental implantology. In dental implantology accurate positioning of the implant is essential for esthetics and functions [21]. With the incorporation of virtual or augmented reality, the preoperative CBCT is used to determine the implant size, position, direction and proximity to vital structures. For this 3D planning is done and this information is transferred using static and dynamic guides to the surgical site. Numerous static guiding systems are available based on CAD CAM which includes Easy Guide, GPIS, Impla 3D, *In vivo* Dental, Implant 3D, Nobel Bioguide and VIP (Implant Logic System). On the flip side the other method for computer assisted surgery is dynamic navigation that allows real time feedback during the placement of the implant. Such surgery has been extensively used in orthopedics, neurosurgery and maxillofacial surgery and is quickly becoming popular in the field of dental implantology. Studies done by Ruppin, and Kang show comparable accuracy between static and dynamic surgeries. Dynamic surgery overcomes certain drawbacks associated with a static guide such as the time associated with impressions and lab procedures required for a static guide and also allows a direct view of the surgical field. Dynamic surgery allows standard drills to be used for surgery which comes handy during cases with limited mouth opening [22].

Discussion

Dynamic surgery provides room for greater flexibility by allowing alteration of the surgical plan during the time of the surgery in accordance to the surgical site and conditions which would not have been possible with a static guide. A dynamic guide is not restricted by the implant size or the drill tube size and allows planning in a single day. It allows the operator to perform minimally invasive surgery [23]. The possible disadvantage of using dynamic guided surgery in implantology comes with the need to pay attention to the patient as well as the navigation system. The integration of augmented reality through an integrated screen allows the surgeon to visualize, in real-time, patient parameters, relevant x-rays, 3D reconstruction or a navigation system screen [24,25]. This could significantly increase the use of dynamic navigation. Dynamic navigation hence proves to be the future of implant surgery, necessitating the need for further extensive studies.

Conclusion

New technologies based on 3D evaluation of the patient and computer guided surgeries are expanding the avenues of implantology. It has enabled better understanding, enhanced teaching and learning potential, predictable diagnosis and multi-disciplinary approach to patient management. There is a steep learning curve associated before the successful incorporation of VR/AR guided surgeries hence encouraging the dentists to pursue continued education and training. Digitally augmented learning has also the potential to bring about a paradigm shift in dental education bringing about enhanced psychomotor skills, critical and innovative thinking and evidence-based decision making.

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