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Dentistry in Metaverse: Virtual Aspect of Practical World

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Abstract
Modern advancements in dentistry have provided great ease in the dental practice. Dentophobia is a major concern especially during the time of invasive dental procedures. Virtual Reality (VR) and Augmented Reality (AR) have proven beneficial in changing the patient's experience as well as in providing a thorough exposure of the clinical application of dentistry to the dental professionals hence improving their skills and quality of education. VR and AR have set their foot in almost every single branch of dentistry, ranging from maxillofacial surgery, implantology, endodontics to pediatric dentistry. AR and VR are the perfect example of amalgamation of the virtual world and the real world. There are three types of VR systems- immersive, semi-immersive and non-immersive. With the AR system a surgeon is able to map the entire surgery along with the necessary modifications to be incorporated during the procedure to increase its efficacy. VR and AR systems are the modern non pharmacological methods used in the behaviour management in pediatric dentistry with significant positive results. These systems are also used in detecting the pulp canals which increases the quality of an RCT. The use of AR and VR has improved the diagnosis leading to the formulation of an effective and upgraded treatment plan. However certain disadvantages like visual fatigue, expenditure and equipment failure cannot be overlooked while utilising these revolutionised systems.

Keywords: Virtual Reality, Augmented Reality, Immersive, Semi-Immersive, Non-Immersive, Visual Fatigue, Expenditure, Equipment Failure

INTRODUCTION

Virtual reality technology is a means of simulating or replicating an environment in three dimensions, providing the user with the impression that they are inside it, have control over it, and can interact with it directly[(1)]. Such environments are computer generated. In the field of medicine, VR is used in formulating a mind-map of surgical procedures, patient education and student training. It is helpful in the treatment of psychological disorders because it offers a legitimate, regulated virtual environment that makes behaviour access and cognitive and functional ability rehabilitation easier [(1)]. In dentistry, simulation of dentofacial structures and their functionality is done via software in real-time providing a sophisticated, improved and complete virtual experience [(2)]. The digital scanner is used to retrieve a digital image, the digital image is modified according to the dental aspects of the patients, ultimately the modifications in the digital image are transferred to the digital wax-up. The required teeth, oral, and extraoral structures are laser scanned in virtual reality, and the resulting 3D model is then loaded into a simulator. [(2)]

FEATURES OF VR SYSTEMS

1. **IMMERSION –** It is the sense of being present in a computer generated (virtual) environment. This environment is created by synthesizing 3D images, sound and other stimuli, making the user feel being physically present in the virtual world when they are surrounded by it [1]. The degree of immersion varies according to the capabilities of the virtual reality system.
2. **INTERACTION-**. The ability to alter the virtual environment belongs to the user [1]. In these systems, the user interacts with the this computer generated world the user has a control over the virtual environment. He/she can move around it, visualise it from different angles, reach it, grab it and reshape it. Interaction is achieved by use of head mounted video goggles, wired clothing and fibre-optic data gloves [1]. Position-tracking devices and real time update of visual, systems with auditory display are also important elements of interaction.

TYPES OF VR SYSTEMS

1. **Immersive VR simulation** - It is greatest level of immersion. A psychophysical experience of entirely being surrounded by a virtual computer-generated environment is provided to the user with the aid of interaction devices, software, and hardware. It is generated via head mounted devices that display 3D images through a process called stereoscopy [1]. Two images -one per eye- are seen by the user which are then combined into one 3D image by the brain. The other components like data gloves permit the person to interact with the objects like pulling, twisting or gripping them. The user may receive force feedback, called a haptic [1].
2. **Semi-immersive VR simulation** – - The user is placed in a room with rear projection walls, a floor projection, speakers positioned at different angles, walls equipped with tracking sensors, and sound and music equipment in this simulation. [1] Everything is seen three dimensionally by the user through goggles [1]. This system is not an entirely immersive simulator because the user is still able to still see himself/herself. For example, Cave Automatic Virtual Environment.
3. **Non-immersive VR simulation** – it permits least immersion and has the least expense as compared to the other two stimulations [1]. Monitors with stereo display and glasses are incorporated to allow the involvement of the user in the 3D environment. They can be operated on a standard desktop computer with the help of mouse and joystick [1].

ARTIFICIAL INTELLIGENCE (AI) AND ROBOTICS

The ability of a machine to perform human tasks and imitate human cognitive skills based on a set of data is called AI [2]. The aim of the AI is to increase the intelligence components of machines to perform tasks with speed, low resources, accuracy, and precision via machine learning. Machine learning is part of AI, dependent upon artificial neural networks, algorithms, to predict outcomes based on a dataset [2]. The medical AI are active in the area of diagnostics and prediction of prognoses. This is usually done by generating modelling tools for caries to aid in the calculation of the chance of developing dental caries in an individual based on clinical findings or demographic and lifestyle factors [2].

Robotics is an adjunct to AI, redefining the frontiers of modern dentistry. Introduced to medicine in 1992 but put to use in 200, a successful dental caries removal, an endodontic treatment and executed a crown and bridge preparation, all were performed by a human-controlled robot.[2]

AR AND VR IN DENTAL TRAINING

Dental training has conventionally been given on phantom heads and teeth models. this aimed at improving the clinical skills of dental students and enhancing the manual dexterity prior to performing treatments on patients. However, this method did not allow the liberty of working in a challenging environment like the one encountered in the dental clinics. The ideal ambience provided by the phantom heads refrained the students getting the exposure of the complex morphology and pathology experienced in the clinics, thereby decreases their ability and effectiveness in emergency situations and in patient handling.

The AR and VR systems provide as 3D real-time digital stimulations especially of the head and neck anatomy, which can be difficult to imagine and understand when studied via books in 2 dimension [3]. The use of artificially formulated stimulations eliminates the need of use of the cadavers, making learning convenient.

Dental simulation systems consist of PerioSim, the Simodont dental trainer and DentSim [4]. By using computer-assisted stimulation, the simulator and computer learning software are connected. The dental handpieces that students use to operate the simulator produce three-dimensional images. For the further evaluation and feedback, the results are sent back to the computer [4].

Dissimilar cutting resistances are possessed by different dental tissues. Hence, the experience of the tactile sensation by the user is important when these tissues are drilled. In the areas of inaccessibility dentists, count on their tactile sensation for navigation., the Simodont dental trainer reciprocates the touch sensation during drilling, cavity preparation, caries removal and other restorative procedures delivery with the help of a force feedback [4]. The tactile feeling depending to each tooth tissue's level of hardness is transmitted through the gimbal[5]. The cutting resistance resemblance of enamel, dentine and pulp is improved in comparison to typhodonts. Simodont can emulate the caries's softness making students familiar with the sensation of drilling into these carious lesions and developing a sense of confidence in performing the procedure on real patients.

APPLICATIONS OF AR AND VR IN DENTISTRY

1. ORAL AND MAXILLOFACIAL SURGERY-

Artificial intelligence (AR) has been applied primarily to craniofacial, orthognathic, and dental implant placement in oral and maxillofacial surgery. Numerous surgeons were found to be lacking confidence when performing the surgeries in a study by Pulijala et al [6] that assessed the usefulness of virtual reality in surgical training. Oral surgeons now possess greater knowledge as a result of the development and application of virtual reality technology.

A novel tool that has significantly enhanced surgeons' existing skills to produce the best outcomes is virtual reality[3]

One of the most fundamental aesthetic techniques used in dentistry is the inferior alveolar nerve block. Dental fillings, extractions, root canal therapy, and complex surgeries involving the mandible teeth are among the procedures for which it is employed. Technique errors and anatomical differences have been identified as contributing factors to inferior alveolar block anaesthesia failure. Studies by Won et al. [7] found that when AR was used in place of inferior alveolar block anaesthesia, the anaesthesia's efficacy was increased.

With AR, the patient directly generates the images, which aids in turning them into reality and increases the accuracy and precision of applying the nerve block.

Orthognathic surgery makes extensive use of AR and VR [3].
Zhu et al.'s study [8] found that using AR enhances maxilla translocation during orthognathic surgery and was beneficial for mandibular angle split osteotomy. Surgeons use real-time streaming video images for surgical planning, anatomical study of the patient, and an improvement in the accuracy of orthognathic surgical procedures.
Distraction osteogenesis has also been studied with AR. In a study, Qu et al.[9] used augmented reality (AR) to treat patients with hemifacial microsomia who were receiving intraoral distractors. They discovered that this method improved the accuracy of osteotomy plane placement when compared to traditional techniques.

2. ENDODONTICS

The Simodont Dental Trainer [10] has the ability to stimulate dental drilling, cavity fillings, crown and bridge preparation, removal of tooth decay, and mirror reflection. The HapTEL simplified the learning and practice of several dental procedures, including dental drilling, caries removal, and cavity preparation for tooth restoration.
Dental drilling and wisdom tooth extraction can be practiced virtually with the help of the Forsslund system [10]. .The Virtual Reality Dental Training System (VRDTS) was created by Novint Technologies in association with the Harvard School of Dental Medicine to use virtual reality technology for cavity preparation and virtual tooth restoration. With the VirDentT system prototype [10], teeth can be prepared for ceramic crowns. to teach users about the functioning of drilling instruments, the challenges faced in clinics, and the composition of teeth.
Prognosis prediction, treatment planning, and diagnosis are all improved by AI-based approaches. When data from radiological exams are analysed by an algorithm, oral pathology and disease can be automatically diagnosed and treated more effectively [3]. Furthermore, exceptional outcomes have been noted in the identification of dental caries and assessment of the appropriate working length in endodontics through the application of AI.

3. ORTHODONTICS

The accuracy of robots' tooth preparation abilities, such as those for laminate veneers and crowns, was shown by Yuan et al. [11], in 2017. In just four minutes, a newly developed mobile wire-bending machine using intraoral scan data could create a fixed orthodontic retainer wire [3]. Robotics-assisted computer-assisted surgery allows for real-time tracking of the position of a surgical instrument.
The dentist can receive guidance by projecting the position of the device onto a digital image of the anatomic area of interest, following the expected pathways and identifying potential interference with nearby tissues [3].
The optical tracking systems that are most widely used to track the location of several light-emitting diodes that are mounted on. [1]
The Invisalign Production Process, orthodontic diagnosis, treatment planning, and appliance fabrication all involve the use of CAD/CAM technology. This includes sending the scan, imprints, and photos to the business in accordance with the physician's orders. [1] A precise 3D digital model is created for every dental arch using the intraoral scans or impressions, and a stereolithographic is then produced for every stage. Finally, each model has a clear plastic aligner made for it, and the set of aligners is sent straight to

the physician.(2) [1] AI is also used in the fabrication of occlusal splints and in determining the position of maxillary canines that are impacted. [1]

4. IMPLANTS

Using AI, tooth replacement techniques such as fixed dental prostheses, removable dentures, and dental implants have become exceedingly sophisticated. For many patients, dental implants are now a suitable and preferred option as a result of their high success rate and long-term advantages [3]. The principal use of AR surgical navigation technology was placement of implants while the surgeons maintained their gaze fixed on the surgical site, thereby eliminating the need for the them to turn away [3].
A study published by Jiang et al. [12] discovered that using augmented reality increased accuracy and applicability when compared to the conventional two-dimensional navigational method used for guided placement of dental implants. These AR navigation systems reduce procedure time and cost by providing the surgeon with only relevant information, enabling them to focus exclusively on the implant placement site [13]
Another study compared the prepared implant site made with augmented reality-based dental implant placement to the virtual placement of the implant [14]. This study discovered that the introduction of augmented reality led to a significantly lower implant placement deviation from the actual planned site and a more effective implant placement. Patients can get a thorough explanation of the treatment and what to expect during the procedure thanks to virtual reality technology. This helps patients get mentally ready for the surgery.

5. PEDIATRIC DENTISTRY

Dentophobia can be quite challenging to deal with especially amongst the children. AR and VR are used in the paediatric to clinics to reduce the stress and anxiety caused due to dentophobia. Different methods like the in vivo exposure therapy (IVET) and virtual reality exposure therapy (VRET) are used to manage the anxiety levels in such patients [3].
As part of IVET, patients' fears are directly confronted in an effort to lower their anxiety levels. We refer to this as the gold standard. With the utilisation of computer-generated imagery, a new technique called VRET allows patients to experience their fears virtually without actually having to face them [3].
In contrast to the control group, patients who used virtual reality showed lower average anxiety and behavioural scores, according to a study by Ran et al. [15].
In comparison to participants who did not have any form of distraction, a clinical study found that dental patients undergoing subgingival scaling experienced a significant reduction in pain when VR was incorporated into their treatment [16].
VR eyewear was shown to successfully reduce pain perception and anxiety during dental treatment in children aged 4-6, according to Aminabadi et al. [17]. Virtual reality (VR) decreased the patient's perception of physical pain by refocusing attention from an unpleasant environment to a calm and engaging virtual world. As a result, the patient cooperated more during treatments, such as root canal therapy and caries treatment [18].

WHETHER TO EMBRACE ARTIFICIAL INTELLIGENCE OR NOT?

The use of AR and VR technology in dentistry is quite widespread since it allows for the stimulation of all the natural events that take place during a procedure on a real patient, such as bleeding upon pulpal floor perforation during training for a root canal procedure [19]. A strong emphasis on teaching dental students to use cutting-edge technology to improve clinical skills is necessary in the pandemic era. Research in dentistry uses AR/VR systems to look into study participants remotely in a 4D environment (hologram); this reduces study-related costs and easily takes care of the ethical sensitivity issue that some studies raise [20].The use of virtual reality simulators minimizes material waste.

LIMITATIONS

Adults and children experiencing visual fatigue from using stereoscopic views is a cause for concern [3]. In dental care settings, paediatric and geriatric patients may experience negative effects from frequent and repeated exposure to AR/VR environments. Repeated randomized control trials (RCTs) of dental procedure-based simulations involving patients in various age groups are required to assess this. According to cognitive load theory (CLT), in order to validate reports of cybersickness and sensory overload resulting from the use of AR/VR-based training and treatments, exploratory studies should be carried out using appropriate and validated questionnaires distributed to a great number of participants [3]. Artificial intelligence can now be accessed in practically every area of dentistry due to equipment failure and high equipment costs.

Dental surgeons can now practice safe, effective dentistry with a continuous feedback mechanism thanks to a virtual reality learning platform. Since the number of COVID-19 cases is increasing, AR and VR-based dentistry may be used even more after the pandemic than it was before. The rationale behind this is that infection control has become increasingly crucial in all healthcare settings [3].

Nonetheless, the advantages and disadvantages shouldn't be ignored by clinicians before making the necessary equipment purchases for AR/VR apps. Research on how to integrate AR and VR-based treatment planning and procedures into standard clinical work is still ongoing. This entails cooperation between the medical informatics and public health informatics experts, clinicians, and the operator team of these setups.

CONCLUSION

The goal of future VR, AR, and robotics is to treat "presence and realism," and there is much room for improvement [16]. By utilizing the flexibility of virtual reality, newly created custom virtual worlds can be enhanced in terms of immersion, leading to even more significant pain reductions. Numerous research projects are still in progress to enhance and adjust VR and AR systems.

Healthcare in the coming decades will be greatly impacted by virtual reality and robotics, which are the future of diagnosis and treatment planning [1]. For patients who pose technical challenges, dynamic association of imaging data with an actual organ allows for the creation of new treatment and diagnosis modalities [1]. While less experienced surgeons may at least benefit from better access, visualization and orientation of critical anatomical landmarks providing a better sense of comprehension and idea of these anatomical landmarks, the experienced surgeons will benefit from the extension of the safe limit for the operations, which will increase procedure efficiency. By doing this, the possibility of failure or any other incident occurring when they operate on a real patient will be eliminated.

CONFLICT OF INTEREST

There are no potential conflicts of interest to declare.

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