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Review Article

Application of Augmented Reality and Virtual Reality in Dentistry: A Comprehensive Review

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ABSTRACT:
Augmented Reality (AR) and Virtual Reality (VR) technologies are revolutionizing the field of dentistry by enhancing educational, diagnostic, and therapeutic practices. This review explores the diverse applications of AR and VR within dental environments, focusing on their role in education and training, preoperative planning, patient treatment, and postoperative care. The integration of these technologies improves the visualization of complex dental structures, facilitates immersive learning experiences for dental students, and enhances patient engagement and understanding. Furthermore, AR and VR can assist in precise surgical simulations, reducing procedural errors and improving outcomes. This comprehensive review synthesizes current findings, highlighting the benefits, challenges, and future implications of AR and VR in dentistry, aiming to inform practitioners and researchers about the transformative potential these technologies hold for the dental profession.
Keywords: Augmented Reality, Virtual Reality, Dentistry

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INTRODUCTION

Numerous technical developments in dentistry have altered the scope of numerous subspecialties in the profession in recent years. New improvements have been made to further strengthen and enhance dental education and the clinical application of dentistry. Among these are virtual reality and augmented reality, which have been developed and researched with the intention of enhancing dentistry. In computing and technology, the term "virtual" describes something that seems to exist even when it isn't physically there. Real-time dentofacial structural simulation is done in dentistry using software. For a complex yet comprehensive virtual experience, the operation of these anatomical structures is also replicated. The widely used traditional digital technologies work by first obtaining a digital image through a digital scanner, then using that image to make changes to the patient's various dental features. Lastly, the changes are then transmitted to the digital wax-up.[1,2]

In contrast, virtual reality uses laser scans of the patient's teeth and other extraoral and oral structures as needed. These scans are then fed into a computer, which creates a three-dimensional (3D) model of the patient's teeth, which is then loaded into a simulator. In a variety of dental specialties, including oral and maxillofacial surgery, orthodontics, implantology, restorative dentistry, dental public health, and dental education, dental surgeons and students can use this simulator to practice and conduct assessments prior to the procedure being carried out on a real patient. This system incorporates automated data recording, enabling users to conduct self-evaluation and post-operative analysis.[2-4]

By fusing the actual and virtual worlds, augmented reality primarily seeks to enhance clinical practice in the dental sector by enabling the direct visualization of clinical information on the patient. The main application of augmented reality in dentistry involves enhancing reality with digital data, enabling efficient

patient-dentist communication via images, videos, and three-dimensional models.

Background[1-3]

- The first stereoscope, which projected an image using a set of mirrors to give the user a sense of depth and immersion, was created in the 1830s, which is when the idea of virtual reality first emerged.
- A flight simulator designed to educate US air force pilots later added VR-like haptic capabilities in 1929; this system could replicate plane movements and air turbulence.
- Ivan Sutherland invented the first head-mounted display in the early 1960s, which launched "virtual reality" as we know it today.
- NASA and military training requirements, which were met by the development of several vehicle simulators, were the main drivers of VR development in the 1970s.
- VR systems were integrated with haptic gloves and computer systems by the late 1980s and early 1990s. They were also utilized in NASA's astronaut training programs and, more recently, to assist in operating the Mars rovers. VR systems that are accessible to the general public, like Virtuality, Sega VR, and Nintendo's Virtual Boy, have become extremely popular as video games in arcade machines.
- New VR systems, including headgear, such as Oculus, Project Morpheus, and HTC VIVE, have been commercially available since 2012. A fresh wave of interest in virtual reality and augmented reality (VR/AR) was sparked by these systems, and their applications have now spread beyond gaming to include social networking, education, and skill development, to mention a few. VR is currently utilized in a wide range of fields, including education, military simulations, and pilot training. Through mobile applications, augmented reality is also becoming more prevalent in daily life.[1-4]

Definitions: VR is "a computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way," according to the Oxford English Dictionary and AR as "the use of any of a variety of electronic devices to add computer-generated output, like sound or images, to a person's view or experience of his or her physical surroundings." Immersion in a computer-generated environment is a general definition of virtual reality. AR, on the other hand, might be viewed as the superimposition of a computer-generated environment onto the real world.[1,2]

Parts of VR/AR: With or without tactile controllers, VR/AR technology systems are typically head-mounted devices with OLED panels that let users interact with virtual models or application functions. Professionally oriented systems, such the Simodont dental trainer (VR system) and the Virteasy dental trainer, typically feature a "handpiece-replica" device that delivers haptic feel in addition to 3D screens that show a virtual tooth, jaw models, and instruments. The design features of alternative systems, including the DentSim dental trainer (AR), differ slightly. These include a real computer-tracked handpiece and real plastic teeth models that can enhance realism by displaying a virtual 3D model of the real-time preparation and providing immediate on-screen feedback, even in the absence of haptic feel. [1,2]

Benefits of VR/AR: The many advantages of AR and VR in dentistry practice and education can be divided into three categories: patient education, collaborative learning, and individualized learning.[5-8]

- **Patient education:** Dental practitioners can better explain procedures to patients by using AR and VR technology, which help patients understand complicated dental procedures. Patients can gain a better understanding of their anatomical problems and the planned surgical procedures by using immersive images. This is essential for reducing patient anxiety before to surgery and obtaining informed consent.
- **Collaborative learning:** Students' engagement and retention of information are greatly enhanced by the dynamic and captivating learning environment that AR and VR's immersive qualities produce. With the help of these tools, students can practice difficult procedures in a risk-free environment and learn from their mistakes without worrying about endangering real patients. AR and VR's real-time feedback makes it easier to fix mistakes and improve methods right away, which improves learning results and increases psychological readiness. AR and VR lessen fear and promote a deeper comprehension of dental anatomy and procedures by exposing students to realistic clinical scenarios. Additionally, they facilitate interaction in virtual environments, which improves collaborative learning. This approach improves learning's efficacy, appeal, and accessibility while better preparing students for clinical practice in the real world.
- **Individualized learning:** This includes training that is risk-free, economical, provides real-time feedback, improves experience, offers a variety of scenarios, and is easily available. Through the improvement of individualized and cooperative learning experiences, AR and VR are revolutionizing dental education. Because of the risk-free teaching environment provided by these technologies, students can rehearse intricate procedures without worrying about endangering patients. By reducing the need for tangible models and materials, this method lowers expenses while facilitating a dynamic learning

process with real-time feedback. By exposing students to real-world clinical situations, the prompt correction of errors and the improvement of methods greatly improve learning results, increase psychological readiness, and increase student confidence. These immersive resources significantly enhance learning and memory retention.

Additionally, by encouraging cooperation, knowledge exchange, and decision-making among dental professionals, AR and VR technology facilitate collaborative learning. These technologies are very accessible and efficient, and they help improve personalized learning by offering affordable training settings with varied situations and real-time feedback. Consequently, this facilitates the advancement of federated learning models in the dentistry field. When it comes to patient education, AR and VR provide visual explanations that facilitate patient comprehension and involvement in collaborative decision-making. These technologies also improve clinical outcomes, team resource management, and dental surgery safety, all of which contribute to healthcare resilience.

Scope of AR/VR: In-depth knowledge of head and neck anatomy and physiology, sophisticated technical skills (restorative, endodontic, periodontic, prosthodontic, and surgical therapy), nuanced clinical skills (from communication to clinical judgment), strong academic comprehension, and leadership abilities are just a few of the diverse range of abilities required for dentistry practice. Because dentistry education covers such a wide range of topics, there are numerous ways that VR and AR might be used to enhance instruction. In order to illustrate the present trends in VR/AR use in dental education and to determine the future course of VR/AR technology development in this area, we have compiled recent data in this review. Applications in medical and dental education are rapidly developing in addition to the widely used VR/AR in gaming, the military, and business. VR/AR systems that increase the learning of restorative and operative skills, supplement general anatomy instruction, and enable the practice of sophisticated oral, orthognathic, and maxilla-facial surgery are just a few examples of recent advancements in dental and medical education.[1,5,6]

APPLICATIONS OF AR AND VR IN DENTISTRY[1-3,8-11]

AR/VR in Dental Education/Training: Before administering treatments to patients, dental students are traditionally trained on phantom heads and teeth to hone their clinical capabilities. With the help of these simulators, educators may show pupils how to receive therapy and work to improve their manual dexterity. Before switching to new treatment methods, students using these simulators are required to provide their lecturers with ongoing input regarding their development. With the use of 3D real-time digital simulations, dental educators may assist students and postgraduate residents in achieving accuracy in pre-clinical and clinical skills, respectively. An essential component of dentistry education is learning and remembering the anatomy of the head and neck.

For instance: a. Moog Simodont dental trainer: Using a haptic virtual reality simulation (Moog Simodont dental trainer) with cavity preparation practice led to more satisfactory results. b. Virteasy dental trainer: Practicing caries removal with a virtual reality simulator (Virteasy dental trainer) produced drilling abilities comparable to those learned through traditional means. c. SensAble OMNI and SensAble PHANToM OMNI haptic devices: Haptic AR simulation (SensAble Omni haptic device), which can be linked to a typical PC and monitor, taught students how to identify visuo-tactile caries and remove it using minimally invasive methods just as well as training on extracted teeth. Additionally, it reduced the amount of time that inexperienced users needed to finish endodontic access opening.

Students have been taught this subject through lectures and two-dimensional illustrations from anatomy textbooks. Cadaveric skulls are frequently used in this traditional teaching method, and students are taught using them. However, students find it difficult and ineffective to visualize all of the related vascular, neurological, muscular, and other structures.

AR/VR in Oral and Maxillofacial Surgery: Oral and maxillofacial surgeons treat common oral diseases, including congenital anomalies, cleft lip and palate, and oral squamous cell carcinoma. Surgeons use their years of knowledge and hand dexterity to address many of these diseases. Numerous technological developments, including the introduction of augmented and virtual reality, have occurred in the field of surgery in recent years. Numerous surgical specialties, including plastic surgery, neurology, and laparoscopic surgery, have investigated the use of AR and VR technology. Dental implant implantation, craniofacial surgery, and orthognathic surgery have been the main areas of focus for AR's application in oral and maxillofacial surgery. Users can bring photos and information to life by combining them using augmented reality technology. Before operating on patients, surgical residents must study and hone their surgical skills on various simulators during their training period, which is an essential stage.

One of the most basic types of anesthesia used in dentistry to operate on mandibular teeth for treatments like extractions, dental fillings, root canal therapy, and intricate surgeries is inferior alveolar block anesthesia. The failure of inferior alveolar block anesthesia has been linked to a number of reasons, including anatomical differences and inadequate technique. Because AR converts visuals directly generated by the patient into reality, it helps to increase the precision

and accuracy of block anesthesia. Orthognathic surgery is one of the most extensively researched uses of AR and VR in dentistry.Real surgical images and virtual surgical plans are provided to guide patients through the treatment plan, which is the main benefit of utilizing AR-guided navigation tools. The mandibular angle split osteotomy is a crucial surgical technique in orthognathic surgery. A cosmetic surgical technique called mandibular angle split osteotomy seeks to enhance the patient's appearance by correcting the significant mandibular angle.
For instance, systems based on mobile applications: Students performed faster and more successful anesthesia as a result of an AR simulation for Inferior Alveolar Nerve Block (IANB) training that used a mobile device in a headset and specifically made patterned models.

AR/VR in Paediatric Dentistry: Since compliance is the most common element influencing treatment outcomes for these individuals, pediatric dentistry is one of the most difficult dental specialties. A variety dental techniques, including pharmaceutical interventions and the dentist's arsenal of behavior modification techniques, have been employed to increase patient cooperation and compliance. Since it is frequently their first time interacting with a dentist, children who are visiting the dental office frequently exhibit extreme nervousness. Therefore, one of the most important aspects of patient care is controlling children's anxiety and conduct. Virtual reality is one of the cutting-edge methods that have been somewhat mentioned in the literature to help these individuals feel less stressed and anxious.
Virtual reality exposure treatment (VRET) and in vivo exposure therapy (IVET) are two methods for managing anxiety. IVET, which has been regarded as a gold standard therapy, involves confronting the patient's fear directly in order to lower their anxiety levels. VRET is a relatively new approach that uses computer-generated visuals to assist patients experience their anxieties without really encountering them. This helps patients feel less anxious.

AR/VR in Dental Implantology: Dental implants, fixed dental prostheses, and removable dentures are just a few of the advancements in dentistry that have been made to replace missing teeth or teeth in patients' mandibular and maxillary arches. Because of their excellent success rate and related long-term benefits, dental implants have become a viable and preferred option for many individuals. The implementation of augmented reality technology in dental implants has greatly enhanced numerous implants placing processes. In order to avoid turning away, the surgeon initially used AR surgical navigation technology to insert implants using the retinal imaging display while maintaining eye contact with the surgical site. These AR navigation systems assist the surgeon in focusing solely on the implant placement site, giving them only pertinent information. This ultimately lowers the procedure's time and expense as well as implant deviation.

AR/VR in Restorative Dentistry and Endodontics: Among the most difficult and draining areas of dentistry are restorative dentistry and endodontics. A competent clinician must possess the information and clinical abilities necessary to treat conditions like dental caries, pulpitis, and tooth abscess. Globally, there is a high occurrence of dental caries, which necessitates a trip to the dentist and may even call for root canal therapy or tooth fillings. These procedures are carried out to save a tooth that, if left untreated, may need to be extracted. Failed dental fillings and endodontic treatments can be caused by a variety of causes, including smoking, isolation, inadequate technique, underfilled canals, and missed canals. Usually students receive their initial training on a phantom head in the lab, where the mannequin replicates the patient. This allows the students to practice treating a real patient, just like in a clinical setting. The students use these mannequins to practice procedures like cavity preparation. Students can practice and enhance their clinical skills without using live test subjects by using augmented reality (AR) to create realistic simulations. Augmented reality has been utilized in endodontics to reliably detect root canals, reducing the likelihood that patients would experience treatment failure.

Clinical Implications of Haptic Feedback in AR/VR: When using a handheld virtual reality instrument to manipulate oral structures, tactile/ haptic feedback is the sensation of physical resistance or vibration. Haptic feedback in conjunction with augmented or virtual reality creates a realistic setting for dental procedures. In the oral cavity, dental operations typically call for a bi-manual instrumentation technique. It can be difficult for software developers working in the healthcare sector to simulate this using haptic feedback. Accurate haptic interactions with a virtual world require simulating the contact of rigid and deformable structures as well as the force response of oral structures. Although several studies have highlighted significant limits for users working with haptics, dental surgeons or students can practice on virtual patients with real-time haptic input, enabling them to complete regular and sophisticated treatments swiftly and effectively.

ADVANTAGES[1-3]

1. Enhanced visualization of dental anatomy.
2. Improved educational experiences for students.
3. Increased patient engagement and understanding.
4. Facilitated preoperative planning and simulations.
5. Reduced procedural errors during treatments.
6. Accelerated learning curves for dental professionals.

7. Safe practice environments for surgical techniques.
8. Customizable treatment plans based on 3D models.
9. Better communication between dentist and patient.
10. Increased accessibility to complex procedures through remote consultations.

DISADVANTAGES[1-3]

1. When dental clinics experience equipment failures, it may take a long time for the technician to show there and fix the problem.
2. Technical issues that could result in mistakes in procedure.
3. AR and VR technologies are expensive.
4. The learning curve for AR and VR is high, and it takes a lot of effort and continuous education to train dental professionals to become proficient with these advanced technologies.
5. Given the sensitive nature of the patient data used in these systems, data security and privacy are also crucial concerns.

Prospects: With a continuous feedback system, virtual reality offers dental surgeons a learning opportunity to perform safe and effective dentistry. The continuing epidemic has shown how crucial infection control is now more than ever in all healthcare settings. In light of this, dentistry based on augmented and virtual reality might be even more useful after the epidemic. It is imperative that educators and physicians weigh the advantages and disadvantages of purchasing the necessary equipment for AR/VR applications. Future research is actively focused on collaborating with physicians and specialists in the domains of medical informatics and public health informatics to integrate AR and VR-based treatment plans and processes into standard clinical practice. Additionally, more research is required to assess the value of AR and VR in dental education so that various dentists can independently practice various treatments.

CONCLUSIONS

A dentist may profit from new technologies being created in this industry, which is developing at a quick pace. These technologies offer improved visualization capabilities, shorter operating times, improved patient consultation, and promising treatment results. In addition to changing how dentistry students are taught, these technologies are improving the caliber and effectiveness of clinical procedures. Dental practitioners will be more equipped to handle clinical issues as they advance and become more widely accepted, which will ultimately result in better patient care and increased professional knowledge. Additionally, dental phobia, which is frequently encountered by young patients, can be overcome with AR and VR. Future research should concentrate on creating scientifically validated AR/VR devices for dental practices and establishing technological standards using high-quality data.

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