Augmented Reality and Virtual Reality in Dentistry

Subjects: Dentistry, Oral Surgery & Medicine

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Augmented reality (AR) and virtual reality (VR) have been found to be beneficial tools for clinical practice and for enhancing the learning experiences of students during their pre-clinical education and training sessions. Clinicians can use VR technology to show their patients the expected outcomes before the undergo dental procedures. Additionally, AR and VR can be implemented to overcome dental phobia, which is commonly experienced by pediatric patients. Future studies should focus on forming technological standards with high-quality data and developing scientifically-proven AR/VR gadgets for dental practice.

augmented reality virtual reality dentistry education health

1. AR and VR in Dental Specialties

Augmented reality (AR) and virtual reality (VR) have their use in a variety of specialties of dentistry, as presented in **Figure 1**. AR and VR technologies have a promising role in the field of dentistry. The details of its application in oral health are described below.

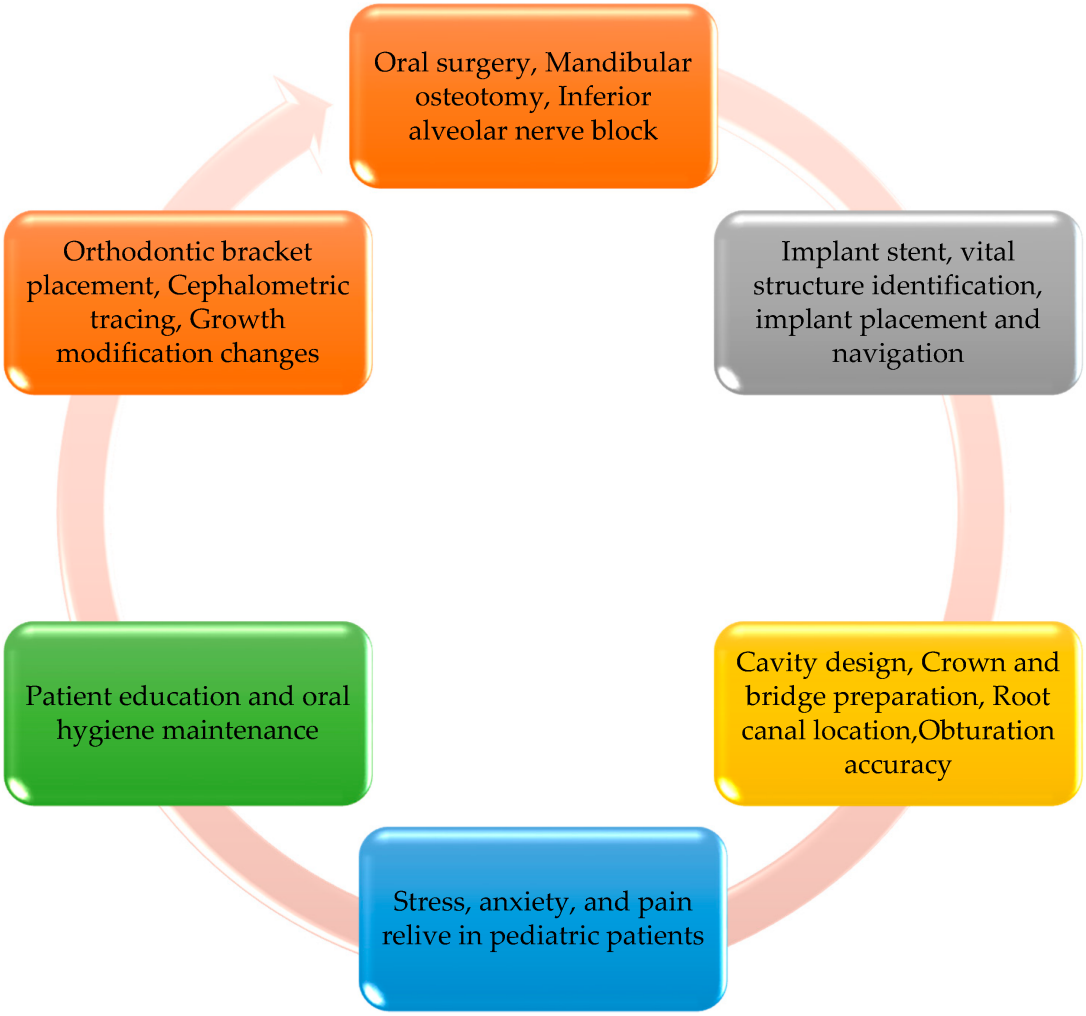

Figure 1. Use of virtual /augmented reality in dentistry.

2. AR and VR in Dental Education/Training

Traditionally, the training of dental students has been conducted on phantom heads and teeth to practice and improve their clinical skills before performing treatments on patients. These simulators allow teachers to demonstrate the treatment techniques and aim to enhance the manual dexterity of the students. The use of such simulators makes it mandatory for the students to give their teachers constant feedback about their progress before moving to different treatment techniques.

In the delivery of dental education and training, instructors can help students and PG residents to achieve precision in pre-clinical/clinical skills, respectively, with 3D real-time digital simulations as well [1][2]. Learning and retaining the anatomy of the head and neck is a crucial part of dental education. Lectures and 2D images from textbooks of anatomy have been used for teaching this subject to students [3]. In this traditional mode of teaching, cadaveric skulls are commonly employed, and students are instructed through these. However, the visualization of all associated muscular, neural, vascular, and other structures is quite challenging for students and it is not fully effective either [4].

In the midst of the COVID-19 pandemic, students suffered due to limited learning opportunities and the ability to enhance their pre-clinical skills as students could not train at their universities without the instructor's direct supervision. Therefore, helping these students to learn while controlling the spread of COVID-19 has been the most challenging aspect for the universities. Amidst the quest for better teaching methodologies, one group described an innovative technique to teach clinically relevant anatomy to students of dentistry that replaces cadavers with dissected and sliced plastinated specimens [5]. However, one recent study incorporated digital tools and a 3D augmented curriculum, which is an interactive 3D experience that combines the view of the actual world with elements generated by computers along with traditional teaching methods (lectures and cadavers). The study demonstrated improved understanding and a positive influence on the retention of anatomical knowledge in students as compared to the control group (taught via textbooks/2D images) [6].

To further increase the knowledge of dental students, virtual reality allows the students to watch oral treatments as a direct participant. Moreover, students can also try to reproduce the oral treatment scenario under the guidance of professionals.

3. AR and VR in Oral and Maxillofacial Surgery

Oral pathologies such as oral squamous cell carcinoma, cleft lip and palate, and congenital abnormalities are common findings that are treated by oral and maxillofacial surgeons. Many of these pathologies are treated by surgeons using their manual dexterity along with their years of experience. In recent years, many technological advancements have taken place in the field of surgery such as the introduction of augmented and virtual reality [7].

The application of AR and VR technology has been explored in many surgical fields of medical science, such as laparoscopic surgery, neurosurgery, and plastic surgery. In dentistry, the use of AR in oral and maxillofacial surgery has focused on the placement of dental implants, craniofacial surgery, and orthognathic surgery. The use of AR technology allows the users to combine information and images to bring them to reality.

The training period of surgical residents is a crucial phase where the residents learn and practice their surgical skills on different simulators before actually performing on patients. Pulijala et al. [8] evaluated the effectiveness of virtual reality in surgical training and found that many of the surgeons were not confident about performing the surgeries. With the introduction and implementation of VR technologies, this has resulted in surgical residents improving their knowledge and confidence whilst performing the surgeries. VR is an additional tool that has immense importance in further enhancing the skills already possessed by surgeons to achieve optimal outcomes that boost confidence amongst surgeons.

Inferior alveolar block anesthesia is one of the most fundamental anesthesia used in dentistry to operate on the mandibular teeth for procedures such as root canal treatment, extractions, dental fillings, and complex surgeries. Many factors have been associated with the failure of inferior alveolar block anesthesia such as poor technique, and anatomical variations. In a study by Won et al. [9], AR was used for inferior alveolar block anesthesia and it was concluded the use of AR in this block anesthesia can improve the effectiveness when block anesthesia is used

alone. AR helps in improving the precision and accuracy of using block anesthesia as the images that are directly generated from the patient help in converting those images to reality.

One of the most widely studied applications of AR and VR in dentistry is orthognathic surgery. The prime advantage of using AR-guided navigation tools is that it provides real surgical images and virtual surgical plans to guide through the treatment plan. One of the important surgical procedures in orthognathic surgery is mandibular angle split osteotomy. Mandibular angle split osteotomy is a cosmetic surgical procedure that aims to improve the prominent mandibular angle, thereby improving the aesthetics of the patient.

In their study, Zhu et al. [10] used AR for mandibular angle split osteotomy and found that the use of AR enhances the translocation of the maxilla in orthognathic surgery. The use of such AR systems allows surgeons to operate real-time streaming video images that allow them to plan the surgery and study the anatomical structures of the patient, thus enhancing the accuracy of such orthognathic surgical procedures.

The use of AR has also been studied in distraction osteogenesis. In a study by Qu et al. [11], patients suffering from hemifacial microsomia were treated with an intraoral distractor using AR and it was found that AR was more accurate in proper positioning of the osteotomy planes as compared to the conventional methods. Additionally, one study explored the use of AR systems where images were overlaid, which allowed surgeons to observe and follow the virtual surgical plans to reposition the bones of the patient after performing maxillary osteotomies [12]. Additionally, to further enhance the surgical skills, VR technology replicated different functions such as drilling, place fixation, and bone sawing with the help of hepatic force feedback [13][14].

So, the importance of VR and AR in oral and maxillofacial surgery can be appreciated given the improved accuracy of the surgery performed, the decrease in the chance of errors by the surgeons, and the unlimited number of training sessions available to surgeons. Therefore, VR and AR as an adjunct can prove to be useful tools for surgeons.

4. AR and VR in Paediatric Dentistry

Pediatric dentistry is one of the most challenging specialties of dentistry as the commonest factor determining the treatment outcomes in such patients is their compliance. To improve patient cooperation and compliance, different tools have been used ranging from the armamentarium of the dentist, such as behavior modification, and pharmacological interventions. Pediatric patients who are visiting the dental practice often present with tremendous amounts of anxiety as most of the time it is their first interaction with dentists [15]. So, managing the anxieties and behavior of children is one of the crucial factors in patient management.

To decrease the levels of anxiety and stress of such patients, virtual reality is one of the innovative tools that have been discussed in the literature, although to a limited extent. Different techniques to manage anxiety include in vivo exposure therapy (IVET) and virtual reality exposure therapy (VRET). IVET consists of the direct confrontation of patient's fear to reduce their anxiety levels and this method has been categorized as a gold standard method.

VRET is a recent technique that consists of computer-generated images for patients where the simulation makes the patient experience their fears without facing them in reality, thereby helping them to reduce their anxiety [16]. In a study by Ran et al. [2], the effect of virtual reality on the behavioral management of children was studied, where it was concluded that the average anxiety and behavioral scores of the patients with virtual reality was significantly reduced as compared to the control group. Since virtual reality makes use of interactive and creative audiovisual representations of information that is attractive to children, such a method of anxiety reduction can be beneficial.

Another study by Osama et al. [3] assessed the effect of virtual reality on the pain and anxiety of pediatric patients during infiltration anesthesia, where it was found that virtual reality was effective in reducing the anxiety and stress of these patients. Since the patients experience the entire scenario virtually before the actual procedure commences, this helps patients to understand the treatment and face their fears. So, one of the most important factors that determine the treatment outcomes in patients in this age group is the anxiety and stress associated with visiting the dental practice. Virtual reality can help to provide an artificial environment that is more relaxing for the patients, which can help them forget their fears.

5. AR and VR in Dental Implantology

Many advances have been made in dentistry in regard to the replacement of missing teeth or teeth in the mandibular and maxillary arches of patients such as removable dentures, fixed dental prostheses, and dental implants. Dental implants have emerged as a suitable and preferable choice for many patients because of their high success rate and the long-term benefits associated with them [17][18]. The introduction of AR technology in dental implants has significantly improved many procedures associated with the placement of implants. Initially, the AR surgical navigation technology was used to place implants using the retinal imaging display as the surgeon keeps his visual on the operative area, avoiding the need for the surgeon to turn away [19].

In a study by Jiang et al. [20], it was found that the use of augmented reality resulted in higher accuracy and applicability for guided placement of dental implants as compared to the traditional two-dimensional navigational method. Such AR navigation systems help the surgeon to concentrate only on the site of the implant placement, thereby providing only useful information to the surgeon, which eventually reduces the cost and time of the procedure [21]. It is of prime importance that the location of the implants should be as accurate as possible because negligence in this step of implant placement could be one of the factors responsible for future implant failure.

Moreover, one study used augmented reality-based dental implant placement to evaluate the virtual placement of the implant as compared to the actual prepared implant site created [17]. In this research, it was found that the use of augmented reality resulted in a significantly decreased deviation in implant placement from the actual planned site. Since AR navigation-based systems help the surgeon to accurately locate and place the dental implants, the accuracy of such procedures thereby increases as compared to the traditional methods.

The placement of the dental implant is a surgical procedure, so with the help of VR technology, patients have an opportunity to get a detailed explanation of the treatment and what they will experience while the treatment is being

performed. Complete information given to the patients with the help of VR makes them better prepared mentally.

6. AR and VR in Restorative Dentistry and Endodontics

Restorative dentistry and endodontics are some of the most challenging and exhausting fields of dentistry. In order to treat diseases such as dental caries, pulpitis, and dental abscess, knowledge and clinical skills are required to become a proficient clinician [22]. A high caries rate is prevalent throughout the globe, which mandates a visit the dentist and may require dental fillings or even root canal treatment as well. These treatments are performed to save a tooth that might require extraction if not managed in a timely fashion. Many factors are associated with failed dental fillings and endodontic treatments such as isolation, poor technique, smoking, underfilled canals, and missed canals [23].

Conventionally, students are first trained in the laboratory on a phantom head where the mannequin mimics the patient, which allows the students to work as if they are working on an actual patient as in a clinical setup [24]. Procedures such as cavity preparation are practiced on these mannequins by the students. In a study by Llena et al. [25], cavity preparation using AR technology was studied. In this research, it was found that the participants that used AR technology showed an improvement in their knowledge and skills. With the help of AR, realistic simulations can be delivered to the students in order to practice and improve their clinical skills without the need for live test subjects.

To overcome the chances of failure in endodontic treatments in patients, augmented reality has been used in endodontics for the reliable detection of root canals. In a study by Bruellmann et al. [23], augmented reality was used to detect root canals where it was found that overall higher sensitivity was noted in detecting root canals in molars and premolars. The success rate of root canal treatment directly depends on identifying all of the root canals as any missed canal has pulp remnants that might trigger pain for the patient [26][27].

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