The journal of
PROSTHETIC AND IMPLANT DENTISTRY
Official Publication of Indian Prosthodontic Society Kerala State Branch

# AN INSIGHT INTO AUGMENTED REALITY INTEGRATED IMPLANT PLACEMENTS

*Sahla P, **Kavitha Janardanan, ***Harshakumar K, ****R Ravichandran

*Postgraduate Student, **Associate Professor, ***Professor & Head of the Department, ****Professor, Department of Prosthodontics, Government Dental College, Thiruvananthapuram - 695 011 | Corresponding Author: Dr. Sahla P, E Mail: sahlamuhammed94@gmail.com

https://doi.org/10.55231/jpid.2024.v07.i02.09

## Abstract

*Dental implant is an extensively used treatment approach to replace a missing or extracted tooth. Implant placement procedure is a delicate procedure which requires extensive skills and theoretical knowledge. Augmented reality is a computer-based simulation which creates a three-dimensional image or environment. The integration of augmented reality in planning and placing of dental implants revolutionize the patient care in a clinical scenario. The introduction of augmented and virtual reality in treatment planning, teaching and simulation software's has opened avenues for better understanding, diagnosis and treatment which leads to better patient care and outcomes. This article provides an insight into the available virtual reality tools for dental implant placements, effectiveness, challenges and the future of these tools in oral implantology.*

***Keywords: Augmented reality, Virtual reality, Digital navigation system, Oral implantology simulators***

## Introduction

Modern prosthodontic practice has witnessed a revolution from traditional methods to what is practiced today, from conventional impressions to a completely digitalized workflow. Digital advancements like Computer aided designing and Computer aided manufacturing have set new horizons in simplifying the treatment procedures in Prosthodontics. Replacement of missing tooth with implants is a widely used treatment option in fixed prosthodontics. Implant placement is a delicate procedure which requires precise planning and positioning. And the precise three-dimensional positioning of implants in maxillofacial region is quite challenging due to the proximity to vital structures and complex anatomy. But with the advent of 3D technologies and advancements this has become lesser challenging now. The most recent of them is the reality–virtuality continuum augmented reality and virtual reality. The integration of reality-virtuality improves the clinical practice by compiling real data with the digital data obtained from the patient.

Virtual Reality (VR) is a computer-generated simulation of a three-dimensional image or environment which provides a standardized, safe, and flexible platform that can be interacted with in a seemingly real or physical way by a person with special electronic equipment consisting of sensors[1]. Augmented reality (AR) involves an interactive technology which is distinct from virtual reality in that the user interacts with an integral image of the patient's teeth/anatomical structures and works on them in a 3D environment registered using fundamental imaging techniques, and thus AR enhances the physical elements with virtual elements[1]. AR and VR systems require real and virtual data sources, tracking, registration, visualization processing, perception locations, display types, and feedback methods. Virtual reality forms a virtual world where Augmented Reality builds a link between the real and virtual worlds which allows users to interact with both worlds simultaneously.

Head-mounted displays (HMD), monocular systems, monitor- based interfaces and other combined technologies are the devices commonly used in augmented reality systems. The main application of AR system in dentistry is that it overlays the digital data on to the real world data like photos, videos and 3D models and forms a live communication mode between clinician and patient through photos, videos, and 3D models[2]. AR guiding devices show real-time intraoperative data right on the operating site, in contrast to image-guided surgery where the doctor has to focus away from the surgical field thereby minimizing the surgical risk. A 3D model is created right in the patient's mouth by the augmented reality device. This allows for 3D Aesthetic planning of the prosthesis. An AR system can also share the operators data with the technician or with a specialist[3].

But there is a steep learning curve associated with the successful integration of VR/AR guided surgeries and the high cost of setting up may limit the use for most clinics[4] and the further benefits of this technology has yet to be explored. This article reviews various aspects of augmented reality integrated implant placements which may aid in future research and references.

## Evolvement of AR and VR into Dentistry

The evolvement of Augmented Reality into dentistry and oral implantology comes through the development of various aspects of digital technologies. The development of Digital dentistry can be traced back to 1970s when computerized tomography (CT) was introduced. With CT scans a detailed and accurate imaging of teeth and jaws is possible which provided an improved diagnosis and treatment planning. The actual digitalization came into dentistry in the form of Computer aided Designing/ Computer Aided Manufacturing (CAD/CAM). It was introduced in 1980s for dental restorations. It was through the CAD/CAM designing and milling of restoration was made possible and with the advent of 3D printers in 1990s digitalization advanced rapidly. CEREC system can be considered as the pioneers in the world of digital dentistry through which digital imaging and CAD/CAM made it possible to deliver prosthesis in single visit. In the next few years digital technology advanced rapidly. Various companies like 3Shape, Dentsply Sirona, developed software, advanced digital imaging and scanning technologies and 3D printers for virtual treatment planning and simulation. Computer assisted procedures were slowly integrated into various fields of dentistry. Oral implantology witnessed a dramatic progress from free handed surgeries to static guided surgeries to navigated system controlled surgeries.

The parallel advancements in radiographic imaging such as CBCT scans provided 3D images of the teeth and jaw, which can be used to plan the placement and positioning of the implant and with the help of 3D printing and CAD/CAM surgical templates were easily manufactured for static guided surgeries. Computerized navigation surgery evolved from neurosurgical procedures into the field of oral implantology. This technique allows the clinician to precisely transfer a detailed presurgical implant plan to the patient. The clinician uses computerized navigation to adjust the position and angulation of the surgical drill according to the presurgical digital implant plan. The real time imaging of the surgical drill allows for continuous updates on the positioning of the drill to avoid critical anatomic structures. Dynamic navigation (DN) aids the surgeons by providing a real-time navigation tool to improve the accuracy of implant placement.

Although the navigation tool assists in better implant positioning and drilling operations, they do not provide the operator to grasp the feel of bone drilling and surgeon has to frequently look away from the surgical site on to the screen. It was then virtual reality which enables us to feel the sense of sight and touch integrated to the oral implantology[5]. The advent of virtual reality in oral implantology could bridge the short comings and enables the surgeon to feel the sense of sight and touch of implant placement

## Different AR systems in Oral Implantology Simulators

The Anatomical Simulator (AS) and The Virtual Simulator (VS) are passive simulators which do not have any interaction with the operator. Anatomical Virtual Simulator (AVS) and the Virtual Simulator with Force Feedback (VSFF) are active type of simulators. The phantom head used in preclinical labs in dental training is a type of anatomical simulator. The computer generated 3D images constitute the virtual simulator which helps in better visualization and planning and do not permit any interaction.

The anatomical virtual simulator includes 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 but it involves incorporation of force feedback.

## Dynamic Navigation in Implant Surgery

Recent advancements in 3D technologies like augmented reality and virtual reality has led to successful applications in oral implantology. An accurate positioning of dental implants is inevitable for aesthetics and functions. The integration of virtual and augmented reality with preoperative CBCT is done to determine the implant dimension, direction of implant placement, position and proximity to vital structures. 3D planning is done and the data is transferred to the surgical site with the help of static and dynamic guides. Various static guiding systems based on CAD/CAM is available including Easy Guide, GPIS, Impla 3D, *In vivo* Dental, Implant 3D, Nobel Bioguide and VIP (Implant Logic System). The dynamic system on the other side allows real time feedback while placing an implant.

Dynamic surgery has added advantages over static guide as the laboratory procedures can be eliminated and there is a live view of the surgical field. Dynamic navigation provides real-time monitoring of implant site preparation during surgery. Recording of the dentition and the reconstruction of the cone beam computed tomography (CBCT) or computed tomography (CT) data is carried out and the surgeon can monitor the position of the surgical drills on the CT reconstruction with the help of the specialized software and tracking methods to follow the movement of the surgical instruments in surgical site.

Marton Kivovics et al concluded from an invitro study that implant positioning accuracy of AR-based dynamic CAIS was comparable to that provided by static CAIS and superior to that obtained using the free-hand approach[6].

## Implant placement procedures through AR system

The first step in placing an implant with the help of AR tool is to make a CBCT scan with the markers plate from the navigation system. These markers must be positioned in situ as per protocol by using the navigation system and for which the plates should be fixed with a hard impression material[7]. After the scan, the markers plate has to be removed and replaced in the same position on the day of the surgery.

The CBCT data has to be analysed through the navigation system planning software and the position of implant has to be virtually planned. At the time of the surgery the patient reference tool for the navigation system has to be fixed on the same support of the markers plate. Another reference tool has to be positioned and rigidly fixed on the implant drill handle. Then the calibration tool is connected to the handle and the drill axis is identified by the navigation system. The first lance drill is successively used to touch the fiducial markers on the markers plate to verify the patient position.

AR systems can be of four types. TYPE I - Involving the use of glasses or head-sets, TYPE II - Digital data being projected on a half-silvered mirror, TYPE III - Images are shown directly onto the patients, TYPE IV - With the use of an external monitor[1].

In systems using glasses after the calibration procedures, the navigation system has to be directly interfaced with the virtual reality glasses through a WIFI connection using a dedicated software [8]. In systems using glasses, the surgeon can contemporarily visualize the surgical field and the output of the navigation system screen. The virtual position and the trajectory of the drill into the bone, the implant planned position and the bone anatomy around the implant site can be checked in real-time throughout the whole surgical procedure.

The advantages of AR systems can be out listed as in Preoperative planning[1] : It helps to provide realistic outcome predictions based on a precise pre-operative planning. Intraoperative navigation helps surgeon with improved results and for avoiding potential risks. With the help of AR system a number of clinical scenarios and treatment requirements can be created which will help to evaluate the possible errors that occur in clinical conditions and enables the surgeon prepare for it better. During implant surgery AR systems combine real and virtual worlds and the real time interaction and a precise 3D registration of real and virtual objects with superimposing of CBCT on the surgical site enables the clinician to understand the bone morphology better[7].

In implant placement procedures AR systems can filter out the information and display only the relevant data to clinician thereby helping them to concentrate on the implant placement procedures reducing the risk and improving the outcomes[9]. Integrating the surgical template with the AR system in implant procedures significantly reduced placement deviation[6]. Learning and planning through virtual and augmented reality aids lay out prodigious data, tracking of the hand movements of the operator and finest level of accuracy for evaluation[10]. The learning systems can be programmed with a feedback loops to warn the students against any minute mistakes. As an educational tool, AR simulators provide enhanced opportunities to students and medical residents[11].

Various challenges involved in AR system includes:

There is often a discrepancy between the real image and the virtual image due to an overlay or positional error[12]. As with any technology a steep learning curve exists for using AR/VR system. Setting up a clinic with AR/VR system which is an ever changing technology can be expensive in terms of money and time. Building up the content for a VR/AR system can be difficult and may necessitate the help of an engineer or technical expert. As with all digital system digital platform, AR/VR software are also prone to bugs which can lead to interruption in the transmission of data[13].

## Future

Other technologies can be integrated to enhance the current AR systems like Photon emission tomography, near infra-red spectroscopy and the use of dyes, such as indocyanine to identify complex anatomy and vital structures[14]. Haptic force feedback and robotics are also promising avenues to combine with AR technology[7]. However further in vivo clinical trials has to be conducted to investigate the clinical accuracy and treatment quality of the proposed system in the future. Future studies should be based on virtual variation simulation of CAD/CAM template combined with AR-based guided surgeries on actual patients to reveal surgical system limitations and errors as well as to gain more experience to minimize the geometric variation.

## Conclusion

The integration of advanced technologies based on 3D evaluation of the patient and computer guided surgeries in oral implantology provides better understanding, precise diagnosis and successful prosthodontic rehabilitation of patients. The giant leaps in the technological advancements may soon give rise to computer and robotics assisted surgeries which may become a routine in planning and positioning implants. Thorough pre-operative planning and surgical simulation with the help of AR system provides a new learning experience and a paradigm shift in enhancing psychomotor skills.

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