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REVIEW

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# Virtual and Augmented Reality in Oral and Maxillofacial Surgery: A Narrative Review

**Shobha Eshwar Singh**[1] | **Prashanth N Tavane**[2] | **Vinod Rangan**[3] | **Anagha M. D.**[4]

[1]Professor and HOD, Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Bengaluru, India

[2]Private Practitioner, Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Bengaluru, India

[3]Professor, Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Bengaluru, India

[4]Intern, Department of Oral and Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Bengaluru, India

**Correspondence**
Shobha E S, Department of Oral & Maxillofacial Surgery, Dayananda Sagar College of Dental Sciences, Karnataka, India. 560011.
Email: shobhaes@dscds.edu.in

## Abstract

In recent years, there has been a growing interest in virtual reality (VR) and augmented reality (AR) technologies. This has led to the creation of various VR/AR devices such as head-mounted displays, other haptic devices, and AR headsets. In the field of oral and cranio-maxillofacial surgery, AR applications are becoming increasingly popular and widely adopted. The availability of surgery-specific head-mounted devices that ensure the accuracy required for surgical tasks and optimal ergonomics may encourage the widespread use of AR systems in the operating room.

**KEYWORDS**
Virtual reality, augmented reality, head-mounted displays, surgery-specific

## 1 | INTRODUCTION

Oral and craniomaxillofacial surgery is a specialised field that deals with treating conditions affecting the mouth, jaws, face, head, and neck. Patients often need a CT scan done before surgery because of the intricate nature of these disorders and the delicate structure of the affected areas. With the help of this scan, the surgeon can accurately replicate the surgical plan throughout treatment and plan a suitable surgical strategy [1]. In the field of dentistry, technological advancement has culminated in several developments, such as Augmented Reality (AR) and Virtual Reality (VR). Augmented reality is a technology that blends computer-generated images, audio, and videos with real-life surroundings. In contrast, VR is a simulated environment built from computer-generated graphics, sound, and images where users are fully immersed and cannot see the real world. [2,3,4]. The advancements in computer graphics and sensor technologies have created new possibilities for diagnostic and surgical techniques by leveraging VR and AR technologies. [5].

## 2 | HISTORY

Jaron Lanier is widely acknowledged as having coined the term virtual reality (VR) in 1986. This term encompasses a combination of technological components, including a computer capable of interactive 3D visualization, head-mounted displays (HMDs), and controllers equipped with one or more position trackers. [6]. In the early 1990s, the healthcare industry pioneered the adoption of virtual reality (VR) technology to aid in visualization of complex medical data during surgical procedures and to assist the pre-planning for surgeries. [7].

## 3 | SURGICAL PLANNING

Virtual and Augmented Reality devices were employed in orthopedic surgical procedures to address complex bone-related conditions, specifically those involving cranio-maxillofacial bones and the hip bone. [5]. In maxillofacial surgery, a combined reality-based system plays a crucial role. This innovative system integrates a dental stone cast model with a 3D computerized maxillofacial model in meshed structure. Its primary objective is to coordinate the movement of the real-world dental cast model with the virtual 3D patient model. This synchronization is designed to facilitate precise movement of the 3D model in sync with the transformation of the dental stone model.[8]. In the realm of facial contouring surgery, a haptic device is employed to realistically simulate the reduction of a protruded zygoma and the precise insertion of a chin implant[9]. Furthermore, virtual reality-based systems have replicated mandibular angle reduction procedures, showcasing their potential in advancing surgical techniques[10]. With the integration of 3D virtual planning and computer simulation, the field of mandibular reconstructive surgery has witnessed substantial progress, paving the way for enhanced precision and effectiveness[11]. Moreover, the incorporation of a specialized cranio-maxillofacial reconstructive surgery setup, complete with 3D eyewear, promises to greatly facilitate these complex procedures. The inclusion of a partially transparent and a specifically-designed haptic device in the workbench serves to elevate the operators' involvement during surgical planning process, providing a truly immersive experience. Furthermore, this innovative system, developed based on authentic surgical procedures, empowers surgeons to simulate intricate processes such as mandibulectomy and fibular transplant through the use of a 3D patient meshed model. It further grants surgeons the ability to experiment and pinpoint the optimal location of blood vessels and skin paddles, thereby contributing to more effective reconstructive surgeries[12].

## 4 | SURGICAL NAVIGATION

AR-based technologies have been employed across a range of surgical procedures, including orthognathic surgery, aesthetic facial surgery, bone tumor resection, and neurosurgery[5]. In orthognathic surgery, AR-based navigation systems now provide visual guidance and virtual surgical plans[1,13,14]. Additionally, head-mounted devices (HMDs) have been utilized to display virtual surgical plans, aiding in the repositioning of patient bones during maxillofacial osteotomies[1]. A head-mounted display (HMD) is used in a system that combines a virtual surgical guide model and a 3D model of the patient's mandible in real-time to perform mandibular angle osteotomy surgery using augmented reality technology. With the aid of this device, surgeons can precisely execute cutting procedures and adhere to a surgical guide indicating the intended position.[15]. The implementation of markerless AR-based technology has contributed significantly to the advancement of support in oral and maxillofacial surgery. This cutting-edge technology facilitates the precise alignment of a patient's 3D teeth model with their real-time video image, thus enabling accurate tracking of their position. Furthermore, it allows for the seamless overlay of additional 3D anatomical models such as the bone, vital nerves, and blood vessels, resulting in comprehensive and enhanced surgical guidance[16].

## 5 | SURGICAL TRAINING

Haptic devices have a well-established role in medical training, particularly for refining specific skills such as those of bone drilling and cutting. These sophisticated tools are essential for procedures in maxillofacial and neurosurgery, as well as orthopaedic fracture reduction[5]. An advanced workbench system, incorporating a haptic device, has been developed to facilitate training for orthognathic surgery procedures[17,18]. Specifically designed for LeFort 1 procedures, the system encompasses functionalities for sawing the bone, drilling, and plate fixing while providing haptic force feedback[5]. OssoVR offers a cutting-edge virtual reality simulation platform designed for immersive surgical procedure training. It utilizes an HMD with trackable hand-held controllers, allowing surgeons to interact naturally with the virtual world using their hands.[19].

## 6 | ADVANTAGES AND DISADVANTAGES OF HEAD MOUNTED DEVICES

Incorporating augmented reality (AR) into surgical procedures can greatly enhance treatment effectiveness and precision by providing surgeons with seamless virtual navigation integrated within the physical surgical field[20]. Utilizing AR guidance enables surgeons to enhance their spatial awareness and perception of the patient's 3D anatomical structures, akin to an X-ray view. Through AR technology, surgeons can project task-specific geometrical shapes, such as tumor contour margins, skin incision lines, and craniotomy/osteotomy lines, based on preoperative planning data. This functionality significantly improves the efficiency and precision of intricate surgical tasks, leading to time savings in the operating room[1]. The integration of head-mounted displays (HMDs) in AR surgical applications offers improved ergonomics and a more personalized viewpoint for the surgeon, in contrast to traditional computer-assisted surgical systems[21,22]. However, it's important to address the challenge of achieving precise alignment between virtual content and the real surgical field for accurate guidance. Furthermore, it is essential to consider strategies to mitigate potential eye strain and visual discomfort associated with prolonged use of HMDs[1].

## 7 | ACCURACY

Assessing the accuracy of AR systems—defined as the precise superimposition of the virtual scene onto the real surgical field—remains challenging. A reliable benchmark is difficult to establish as definitions and measurement methodologies vary significantly across studies[1]. However, sub-millimeter accuracy is generally required for safe surgical navigation.

## 8 | CONCLUSION

AR applications are becoming increasingly popular and are gaining traction in the field of oral and maxillofacial surgery. The quality of the AR experience and the ability to seamlessly integrate the surgeon's perception and efficiency are the key factors that contribute to a successful outcome. The availability of ergonomic head-mounted devices that can ensure the accuracy required for surgical tasks can promote the widespread use of AR guidance in the operating room.

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