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Virtual Reality In Oral Surgical Procedures: A Review

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Abstract

Virtual reality (VR) has emerged as a transformative innovation in oral and maxillofacial surgery, revolutionizing surgical planning, education, intraoperative guidance, and postoperative rehabilitation. By integrating advanced imaging modalities such as CT, CBCT, and MRI, VR enables realistic 3D visualization of patient-specific anatomy for precise virtual surgical planning and simulation. Immersive training platforms enhance surgical skills, accuracy, and confidence through repetitive, feedback-driven practice in risk-free environments. Intraoperatively, VR and mixed reality (MR) systems facilitate real-time navigation, reducing errors and improving outcomes, while VR-based patient education and distraction therapy significantly decrease anxiety and enhance satisfaction. Postoperatively, VR-guided rehabilitation and AI-driven adaptive physiotherapy promote faster and more effective recovery. Overall, VR serves as a powerful complementary tool that enhances precision, safety, and patient-centered care across the entire surgical continuum in oral and maxillofacial practice.

Keywords: Virtual reality, Oral and maxillofacial surgery, Surgical simulation, Patient rehabilitation, Intraoperative navigation

Introduction

Technological innovations have profoundly transformed oral and maxillofacial surgery, advancing from basic digital imaging to sophisticated simulation technologies, immersive environments, and intelligent surgical planning systems that enable more precise, efficient, and patient-centered care.[1] The integration of advanced imaging modalities, artificial intelligence (AI), robotics, and 3D printing has revolutionized diagnostics and therapeutic approaches, facilitating patient-specific implant design, customized prostheses, and virtual surgical planning (VSP) for accurate treatment simulations.[2] These developments have improved surgical accuracy, reduced operative times, and enhanced outcomes by allowing detailed anatomical visualization and procedural rehearsal before actual surgery. The evolution from traditional two-dimensional (2D) radiographs to three-dimensional (3D) imaging through cone beam computed tomography (CBCT) marked a significant leap, providing volumetric insights that refined diagnosis and surgical planning.[3] Building on this, virtual reality (VR), augmented reality (AR), and mixed reality (MR) have emerged as transformative tools: VR creates fully immersive environments for realistic surgical simulations and training; AR overlays digital data onto the real world for guided procedures; and MR integrates both realms, enabling interaction between physical and virtual elements for enhanced planning and intraoperative navigation.[4] Among these, VR has gained prominence in oral surgical procedures for its ability to simulate complex operations such as osteotomies, implant placements, and soft tissue surgeries in a risk-free, realistic setting that enhances skill acquisition and clinical confidence. VR-based training platforms provide repetitive practice with real-time feedback, significantly improving precision, reducing errors, and accelerating the learning curve for both students and residents.[5] Beyond technical competence, VR serves as an effective adjunct for patient care by reducing anxiety, fear, and pain through immersive distraction therapies that lower physiological stress responses, thus improving cooperation and comfort during procedures. Furthermore, VR supports detailed surgical planning by allowing surgeons to explore 3D reconstructions of patient anatomy, optimize implant positioning, and anticipate intraoperative challenges, while emerging MR systems extend this functionality into real-time navigation.[6] In education, VR facilitates remote learning and global collaboration, allowing learners to virtually observe or participate in surgical procedures, while also fostering empathy by enabling clinicians to experience scenarios from the patient's perspective.[5]

Review of literature

Casap et al. (2011) demonstrated that the use of VR navigation systems in dental implantation training improved the accuracy of implant site marking, although the overall value compared to traditional freehand methods remained modest, emphasizing the importance of a balanced integration of both approaches.[6] Similarly, Suebnukarn et al. (2012) integrated VR with cone-beam computed tomography (CBCT) data for endodontic microsurgery training, reporting significantly improved surgical competency and precision, suggesting that VR-assisted practice could enhance safety and efficiency in dental education.[7] Pulijala et al. (2018) evaluated immersive virtual reality (iVR) using Oculus Rift and Leap Motion for orthognathic surgery training and found that participants exposed to iVR demonstrated greater self-confidence and cognitive skill enhancement compared to conventional learning methods.[8] Sytek et al. (2021) compared 2D, 3D, and VR simulation modalities for orthodontic and orthognathic surgery planning among graduate residents, finding that VR and 3D simulations allowed better visualization and engagement, though they required longer completion times and had an associated learning curve.[9] Vincent et al. (2022) further validated the educational potential of VR by using the Virteasy® haptic simulator for dental implantation training, revealing that virtual aids significantly improved procedural accuracy, safety, and learning efficiency through tactile feedback and repeated practice.[10] Wan et al. (2024) extended these findings to surgical education, showing that fifth-year medical students trained with iVR systems achieved higher assessment scores, greater accuracy, and faster completion times compared to those trained with traditional manuals and videos, reinforcing VR's capacity to enhance surgical proficiency.[11] In parallel, Yari et al. (2024) explored AR-based learning using augmented reality books for teaching local anesthesia, demonstrating improved concentration, practical skill acquisition, and reduced procedural times, underscoring AR's potential to enhance engagement and retention in dental education.[12] Complementing these empirical studies, Andrade et al. (2024) and Dhane et al. (2024) highlighted the clinical applications of immersive technologies, noting that VR-based virtual planning using CT and 3D models optimizes preoperative strategy, while AR-assisted intraoperative navigation enhances visualization of critical structures and tumor margins.[13,14] Moon (2022) emphasized the broader educational and interdisciplinary benefits, including improved communication, decision-making, and teamwork among surgical teams. Despite these advances, challenges remain particularly concerning cost, accessibility, standardization of training protocols, and the limited tactile realism of current systems. Moreover, while VR has shown promise in reducing patient anxiety and enhancing the preoperative experience through immersive distraction techniques, its full therapeutic potential in patient care requires further validation.[15]

Technological Evolution and Integration of Virtual Reality in Oral and Surgical Simulation

The integration of Virtual Reality (VR) technology into oral and maxillofacial surgical simulation has revolutionized both education and clinical practice by merging advanced hardware, haptic systems, and intelligent software for immersive, precise, and interactive experiences. Modern VR systems typically comprise high-resolution headsets such as the Oculus (Meta Quest) and HTC Vive, which provide stereoscopic displays and motion tracking for full immersion, while haptic feedback devices simulate tactile sensations like tissue resistance or bone density, enabling users to “feel” surgical procedures virtually.[16] These systems are complemented by sophisticated tracking technologies optical sensors, cameras, and base stations that ensure real-time synchronization between user movement and the virtual environment. Software platforms such as SimX, Romexis VR, and VirtaMed, along with CAD/CAM-integrated tools like Nobel Bioguide and Implant 3D, utilize CBCT and DICOM data to create patient-specific simulations for treatment planning, surgical rehearsal, and education.[17] The level of immersion varies from non-immersive desktop-based environments to semi-immersive simulator rooms and fully immersive headset-based experiences that allow users to operate entirely within a digital 3D anatomical space. Integration with advanced imaging modalities such as CT, CBCT, and MRI facilitates the import and manipulation of volumetric patient data, enhancing spatial awareness and surgical accuracy during preoperative planning, implant placement, and intraoperative navigation.[18] Historically, the conceptual foundation of VR was laid by Ivan Sutherland’s “Ultimate Display” in 1965, but it was not until the late 1990s that AR and VR began gaining momentum in dental education with the advent of powerful computing and 3D modeling capabilities. Early applications focused on anatomy visualization and basic procedural training, evolving into highly realistic, interactive surgical simulations that now form an essential part of modern dental curricula.[19] Over the past two decades, major technological advancements particularly in haptic feedback and real-time augmented visualization have elevated VR from a learning aid to a critical clinical tool. Augmented reality, too, has advanced concurrently, projecting real-time anatomical data and implant positioning directly into the surgeon’s field of view, thereby increasing accuracy and reducing procedural errors. As AR and VR technologies continue to evolve, their integration promises to further refine surgical precision, enhance training outcomes, and promote safer, individualized patient care in a risk-free virtual setting.[20]

Virtual Reality in Enhancing Precision, Training, and Patient-Centered Outcomes

Virtual reality (VR) and virtual surgical planning have revolutionized preoperative preparation, education, and training in oral and maxillofacial surgery, enabling patient-specific, precise, and reproducible outcomes. Through volumetric integration of CT, CBCT, and MRI datasets, VR platforms generate highly detailed, interactive 3D reconstructions of craniofacial anatomy and pathology, allowing surgeons to manipulate, segment, and analyze structures for optimal surgical mapping and evaluation.[21] These immersive simulations facilitate precise planning of dental implant placement, orthognathic procedures, and tumor resections by virtually performing osteotomies, aligning jaws, and delineating resection margins before the actual surgery. Advanced planning software such as ProPlan CMF, Dolphin, Romexis, SimPlant, and Maxilim seamlessly integrates with CAD/CAM systems, enabling the export of customized digital models for 3D printing of surgical guides, splints, and patient-specific implants that translate preoperative simulations into intraoperative precision, reducing operative time and potential complications.[22] In the realm of education and training, VR-based modules offer an immersive, risk-free environment for dental students and surgical residents to repeatedly practice complex procedures such as osteotomies and implant placements while receiving real-time feedback on performance metrics like accuracy, time, and error rates.[23] Compared to cadaveric or mannequin-based training, VR provides repeatable, standardized, and interactive learning experiences that significantly enhance hand-eye coordination, spatial reasoning, and confidence. Systems such as Touch Surgery and Voxel-Man exemplify validated platforms used to simulate oral and maxillofacial procedures with high anatomical fidelity and integrated performance tracking.[24]

Intraoperative Assistance Applications of Virtual Reality in Oral and Maxillofacial Surgery

Virtual and mixed reality (VR/MR) technologies are redefining intraoperative precision and patient management in oral and maxillofacial surgery by seamlessly integrating digital surgical planning with real-time operative execution and immersive patient engagement. Intraoperatively, VR and MR interfaces enable surgeons to visualize complex craniofacial anatomy through real-time overlays of preoperative 3D virtual models directly onto the operative field, enhancing spatial awareness and accuracy during procedures such as dental implant placement, orthognathic corrections, and tumor resections.[25] Advanced optical tracking and dynamic navigation systems provide continuous, high-precision feedback, allowing surgeons to align intraoperative movements with preplanned trajectories and anatomical references, thereby minimizing deviations and improving surgical control. Mixed reality headsets project essential anatomical landmarks, resection planes, and spatial orientation cues into the surgeon's field of vision, effectively merging digital and real-world views to guide precise localization and safeguard critical structures.[26] Studies demonstrate that such technologies achieve sub-2 mm accuracy in craniofacial and implant navigation, significantly reducing intraoperative errors, operative time, and the risk of iatrogenic injury while enhancing intraoperative decision-making. Beyond the operating room, VR is also transforming patient care through immersive preoperative education and anxiety management. VR-based consultation tools allow patients to explore personalized 3D visualizations of their anatomy and planned surgical interventions, improving comprehension, trust, and informed consent while setting realistic expectations. Additionally, VR distraction therapy using calming virtual environments or interactive games has proven effective in reducing anxiety, perceived pain, and physiological stress during minor oral surgical procedures, particularly benefiting pediatric and phobic patients.[27]

Rehabilitation and Postoperative Care Using Virtual Reality in Oral and Maxillofacial Surgery

Virtual reality (VR) technologies are redefining postoperative rehabilitation and recovery in oral and maxillofacial surgery, particularly after temporomandibular joint (TMJ) and orthognathic procedures, by delivering interactive, adaptive, and accessible physiotherapy solutions. Immersive VR systems guide patients through controlled jaw movements and muscle exercises in engaging virtual environments, helping to reduce stiffness, restore mobility, and promote functional recovery.[28] Real-time visual and auditory feedback reinforces correct motion patterns and improves patient adherence to prescribed regimens, while VR-assisted educational modules allow both clinicians and patients to better understand surgical outcomes and rehabilitation goals. Gamified VR exercises further enhance motivation and participation, transforming often monotonous physiotherapy into an interactive and rewarding experience that accelerates healing and strengthens patient commitment to recovery.[29] The integration of artificial intelligence (AI) within VR systems enables adaptive rehabilitation by dynamically adjusting exercise difficulty and intensity based on individual performance metrics, while also tracking progress, predicting complications, and personalizing therapy for optimal safety and effectiveness. Expanding beyond standalone use, hybrid environments that combine VR with augmented reality (AR) and mixed reality (MR) extend support across the entire surgical continuum from preoperative simulations and intraoperative guidance to postoperative recovery by overlaying real-time anatomical and movement cues to ensure accurate exercise execution. Additionally, cloud-based VR platforms facilitate tele-rehabilitation and remote monitoring, empowering clinicians to deliver personalized therapy and collaborate on postoperative management from any location.[30]

Conclusion

In conclusion, virtual reality has emerged as a transformative adjunct in oral and maxillofacial surgery, enhancing precision, anatomical visualization, and long-term efficiency. It provides safer, reproducible training and significantly reduces patient anxiety through immersive education and engagement. By improving both clinical accuracy and learning outcomes, VR bridges the gap between simulation and surgery. Ultimately, it should be viewed as a powerful complementary tool that augments, rather than replaces, conventional surgical practice.

References

1. Alfayez E. Current Trends and Innovations in Oral and Maxillofacial Reconstruction. Med Sci Monit. 2025 Mar 28;31:e947152. doi: 10.12659/MSM.947152. PMID: 40150813; PMCID: PMC11963826.
2. Stucki J, Dastgir R, Baur DA, Quereshy FA. The use of virtual reality and augmented reality in oral and maxillofacial surgery: A narrative review. Oral Surg Oral Med Oral Pathol Oral Radiol. 2024 Jan;137(1):12-18. doi: 10.1016/j.oooo.2023.07.001. Epub 2023 Jul 13. PMID: 37723007.
3. Klaire SJ. The integration of digital technology and AI in oral surgery: Transforming patient care and surgical outcomes [Internet]. ***J Orofac Health Sci***. 2024 [cited 2025 Oct 08];11(3):89-92. Available from: https://doi.org/10.18231/j.johs.2024.020
4. Mehrabanian, M. Emerging technologies in oral and maxillofacial surgery. *Br Dent J* **235**, 856 (2023). https://doi.org/10.1038/s41415-023-6611-1
5. Lin PY, Chen TC, Lin CJ, Huang CC, Tsai YH, Tsai YL, Wang CY. The use of augmented reality (AR) and virtual reality (VR) in dental surgery education and practice: A narrative review. J Dent Sci. 2024 Dec;19(Suppl 2):S91-S101. doi: 10.1016/j.jds.2024.10.011. Epub 2024 Oct 28. PMID: 39807259; PMCID: PMC11725085.
6. N. Casap, S. Nadel, E. Tarazi, E.I. Weiss Evaluation of a navigation system for dental implantation as a tool to train novice dental practitioners, J Oral Maxillofac Surg, 69 (2011), pp. 2548-2556
7. S. Suebnukarn, P. Rhienmora, P. Haddawy; The use of cone-beam computed tomography and virtual reality simulation for pre-surgical practice in endodontic microsurgery; Int Endod J, 45 (2012), pp. 627-632
8. Y. Pulijala, M. Ma, M. Pears, D. Peebles, A. Ayoub; Effectiveness of immersive virtual reality in surgical training-A randomized control trial; J Oral Maxillofac Surg, 76 (2018), pp. 1065-1072
9. L. Sytek, M.R. Inglehart, V. Ramaswamy, S. Aronovich, S. Edwards, H. Kim-Berman; Comparisons of orthodontic residents' performance and attitudes using 2D, 3D, and virtual reality surgical simulation methods ;J Dent Educ, 85 (2021), pp. 1415-1426
10. M. Vincent, R. Giess, R. Balthazard, N. Tran, É. Mortier, D. Joseph; Virtual aids and students' performance with haptic simulation in implantology; J Dent Educ, 86 (2022), pp. 1015-1022
11. T. Wan, K. Liu, B. Li, X. Wang; Effectiveness of immersive virtual reality in orthognathic surgical education: a randomized controlled trial; J Dent Educ, 88 (2024), pp. 109-117
12. A. Yari, P. Fasih, A. Goodarzi, A. Nouralishahi, D. Nikeghbal; The effect of augmented reality book on the proficiency of local anesthesia administration of the inferior alveolar nerve; J Dent Educ, 88 (2024), pp. 1000-1008
13. de Andrade, T. V., da Silva, K. G., Oliveira, N. B., Polizel, A. M., Andrade, J. vitor D., Fonseca, J. V., de Moura, L. F. C., Faria, L. S., de Castro, M. F., de Martin, V., Oliveira, I. da S., Silva, M. A., & Silveira, A. K. G. (2024). Virtual planning in oral and maxillofacial surgery. *Contribuciones a Las Ciencias Sociales*. https://doi.org/10.55905/revconv.17n.9-334
14. Dhane, A. S., Sarode, S. C., & Sarode, G. S. (2024). Augmented reality and virtual reality: Transforming the landscape of oral cancer surgical management. *Oral Oncology*, *9*, 100192. https://doi.org/10.1016/j.oor.2024.100192
15. Moon, S. (2022). Virtual Reality(VR) simulation for Oral and Maxillofacial Surgery. *Taehan Ch'ikkwa Uisa Hyŏphoe Chi*, *60*(10), 648–654. https://doi.org/10.22974/jkda.2022.60.10.005
16. Virtual reality and dentistry. (2023). *International Journal of Current Pharmaceutical Research*, 6–8. https://doi.org/10.22159/ijcpr.2023v15i3.3005
17. Wehrkamp K, Miksch RC, Polzer H, Gilbert F, Bühner M, Holzapfel BM, Böcker W, Neudeck R. The Impact of Virtual-, Augmented- and Mixed Reality during Preoperative Informed Consent: A Systematic Review of the Literature. J Med Syst. 2025 Jun 24;49(1):89. doi: 10.1007/s10916-025-02217-9. PMID: 40555846; PMCID: PMC12187789.
18. Frajhof L, Borges J, Hoffmann E, Lopes J, Haddad R. Virtual reality, mixed reality and augmented reality in surgical planning for video or robotically assisted thoracoscopic anatomic resections for treatment of lung cancer. J Vis Surg 2018;4:143.

19. Bjelovucic R, Wolff J, Nørholt SE, Pauwels R, Taneja P. Effectiveness of Mixed Reality in Oral Surgery Training: A Systematic Review. Sensors (Basel). 2025 Jun 25;25(13):3945. doi: 10.3390/s25133945. PMID: 40648202; PMCID: PMC12251658.

20. Kröplin J, Friedrich C, Harms L, Lenz JH, Frerich B. A virtual reality training program to enhance surgical skills in dental education: Prospective comparative analysis of students and residents. J Craniomaxillofac Surg. 2025 Sep;53(9):1548-1555. doi: 10.1016/j.jcms.2025.06.011. Epub 2025 Jul 1. PMID: 40603148.

21. Martinez-Bernal D, Vidovich C, Keenan C, Correll L, Laserna A, Hasselberg M, Cross WF, Kolokythas A. The Use of Virtual Reality to Reduce Pain and Anxiety in Surgical Procedures of the Oral Cavity: A Scoping Review. J Oral Maxillofac Surg. 2023 Apr;81(4):467-482. doi: 10.1016/j.joms.2022.11.011. Epub 2022 Dec 24. PMID: 36572388.

22. Ayoub A, Pulijala Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. BMC Oral Health. 2019 Nov 8;19(1):238. doi: 10.1186/s12903-019-0937-8. PMID: 31703708; PMCID: PMC6839223.

23. Haq, J. (2023). 19. Revolutionizing Oral and Maxillofacial Surgery: Insights from Virtual Reality Technology. *British Journal of Oral & Maxillofacial Surgery*. https://doi.org/10.1016/j.bjoms.2023.08.020

24. Bhatt, M., Kemmu, A., Choudhary, A., Baghel, A. S., Parthasarathy, B., & Aishwarrya, P. (2025). Use of Virtual Surgical Planning in Oral Surgery: A Systematic Review. *Cureus*. https://doi.org/10.7759/cureus.81051

25. Dastgir, R., Stucki, J., & Quereshy, F. A. (2023). Use of Virtual Reality and Augmented reality in Oral and Maxillofacial Surgery. *Journal of Oral and Maxillofacial Surgery*. https://doi.org/10.1016/j.joms.2023.08.108

26. Ougradar, A., & Ahmed, B. (2019). Patients' perceptions of the benefits of virtual reality during dental extractions. *British Dental Journal*, *227*(9), 813–816. https://doi.org/10.1038/S41415-019-0939-6

27. Falguière A, LeGruiec C, Herry H, Genest-Beucher S, Dessus JM, Boisramé S. Contribution of virtual reality in oral surgery: A literature review. *J Stomatol Oral Maxillofac Surg*. 2021;122(4):405–410.

28. Towers A, Field J, Stokes C, Maddock S, Martin N. A review of the use and application of virtual reality in pre-clinical dental education. Br Dent J. 2019;226(5):358–366. doi: 10.1038/s41415-019-0041-0.

29. Huang TK, Yang CH, Hsieh YH, Wang JC, Hung CC. Augmented reality (AR) and virtual reality (VR) applied in dentistry. Kaohsiung J Med Sci. 2018 Apr;34(4):243-248. doi: 10.1016/j.kjms.2018.01.009. PMID: 29655414; PMCID: PMC11915632.

30. Chen X, Hu J. A review of haptic simulator for oral and maxillofacial surgery based on virtual reality. Expert Rev Med devices. 2018;15(6):435–444. doi: 10.1080/17434440.2018.1484727.