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Evaluation of a Cost-Effective Virtual Reality Training System in Oral Maxillofacial Surgery: A Pilot Study



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INTRODUCTION: Virtual reality (VR) is increasingly being explored in surgical education for its potential to create immersive training environments. However, many VR systems are expensive and require complex setups, limiting their accessibility. This survey study assesses the feasibility of cost-effective VR training on the education of oral maxillofacial surgical trainees and practitioners. Given the limited opportunities for hands-on practice in performing major surgical procedures, cost-effective VR training can provide an essential and accessible platform for developing surgical skills.

MATERIALS AND METHODS: Cadaver surgery videos of complex maxillofacial procedures were created in 360° VR and 2D formats and published on YouTube. Trainees enrolled in a cadaver course were surveyed after viewing both formats. Fifteen trainees completed questionnaires comparing their learning experiences, with responses analyzed using Fisher's exact test.

RESULTS: About 73.3% of participants found the VR video improved their understanding of the procedure, and over 75% reported enhanced spatial awareness. However, 86.6% experienced discomfort or motion sickness. In comparison, 66.6% felt the 2D video helped their understanding, and only 40% found it improved spatial awareness. No statistically significant difference was found between the VR and 2D formats for procedural understanding or spatial awareness. Notably,

participants rated the VR video as more intuitive and user-friendly compared to the standard 2D video, with the difference achieving statistical significance. Overall, 66.6% preferred the VR format, while 33.3% favored 2D.

CONCLUSION: This feasibility study highlights the utility of a cost-effective VR solution for enhancing maxillofacial surgery training, providing a practical option for preparing trainees for real-life scenarios. (J Surg Ed 82:103505. © 2025 The Author(s). Published by Elsevier Inc. on behalf of Association of Program Directors in Surgery. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>))

KEY WORDS: Virtual Reality, 360 video, VR training, Surgical education, Virtual learning

ACGME COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning and Improvement

INTRODUCTION

Virtual reality (VR) technology is emerging as an important tool in medical education providing immersive and interactive learning experiences that complement traditional training methods.¹ Specifically, 360° VR videos offer an interactive, panoramic field of view, which conventional 2D videos lack. Effective educational tools are required to convey the complex, detailed and dynamic nature of surgical procedures, which can be challenging for students to comprehend via traditional educational methods. VR learning addresses this need by allowing

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trainees to explore the surgical field interactively, providing an immersive experience that bridges the gap left by traditional methods.²

Studies have demonstrated that VR training can have tangible benefits and improve performance in real-life surgical procedures. For example, Aggarwal et al. found that VR training improved performance in laparoscopic and endoscopic procedures by enhancing spatial understanding and procedural skills.³ In addition, Lamb reported that participants who trained using VR platforms for a mock tibia intramedullary nail (IMN) surgery completed the training in 9.2 min, compared to 12.2 min for those who underwent traditional training methods.⁴ Additionally, studies have noted that VR training can significantly enhance surgical skills by providing a safe and controlled environment outside the operating room, thereby eliminating possible risks to patients.^{5,6}

Despite the advantages of VR, many current VR educational methods are hindered by high costs and logistical challenges. Most VR systems require expensive headsets, wired connections, and the installation of specialized software. The use of VR in medical education is limited primarily due to the significant costs associated with its implementation.⁷ Therefore, the need for affordable and accessible VR solutions is critical for broader implementation in surgical education. This indicates that further investigation of a cost-effective, simple form of VR system is warranted.

To address this gap in the use of VR for maxillofacial surgery training, this paper focuses on the integration and evaluation of cost-effective VR solutions in surgical education. One such promising solution is Google VR Cardboard. Although VR devices such as the Google VR Cardboard have been sparingly used in medical education, their affordability and accessibility indicate significant potential. For instance, surgeons at Nicklaus Children's Hospital in Florida used Google Cardboard to plan complex heart surgical procedures, demonstrating its potential for presurgical planning.⁸ Additionally, Google Cardboard has been utilized in pilot programs to improve informed consent processes for medical procedures by creating immersive and interactive experiences.⁹ These examples highlight the potential of cost-effective VR solutions in enhancing surgical education.

By leveraging widely available and affordable devices such as the Google VR Cardboard and video platforms like YouTube, this study aims to provide an accessible and immersive training experience without the financial and technical barriers typically associated with VR technology. The 360° VR training videos created for this study are designed to be easily viewable via smartphones, eliminating the need for costly equipment and complex setups. This approach not only enhances accessibility but also ensures that trainees can benefit from

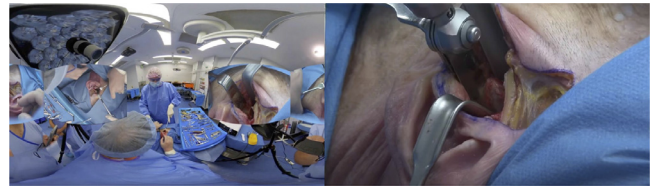


FIGURE 1. (A) 360° VR video view with 3 standard 2D video angle shots overlaid. (B) Standard 2D video illustration from an overhead camera angle (TMJ replacement).

advanced educational tools without significant financial investment.

The aim of this study is to evaluate the effectiveness of 360° VR training videos compared to conventional 2D videos in the context of maxillofacial surgery education. Specifically, the research examines fibula free flap harvest and temporomandibular joint (TMJ) replacement access surgical procedures, performed on cadavers to simulate real-life surgical conditions (Figs 1A and 1B). By providing a detailed, immersive view of these procedures, we aim to determine whether the enhanced spatial understanding and interactive nature of VR can improve learning outcomes for oral maxillofacial trainees and practitioners.

METHODOLOGY

The collection of survey data evaluating the VR training system was deemed exempt from Human Research Ethics Committee review by the Royal Brisbane & Women's Hospital Human Research Ethics Committee (LNR/2021/QRW/74330). The study involved the completion of postactivity questionnaires by oral maxillofacial surgeons from a variety of levels of practice. All clinicians enrolled in the cadaver course were invited to participate in the study by providing them with a Participant Information and Consent Form (PICF) prior to participating. Those who consented participated in the study.

Objectives and Outcomes

The primary objective of this study is to evaluate the feasibility and educational value of using a cost-effective virtual reality (VR) training system in the education of oral maxillofacial surgical trainees and practitioners. The study aims to determine whether these affordable VR solutions can effectively enhance the learning experience by providing a more immersive and interactive environment compared to conventional 2D videos.

Outcome Measure: Participant feedback on ease of use, accessibility, and understanding of surgical procedures.

Another key objective is to assess the immersive experience provided by the VR training system and its impact

on user engagement, as well as to identify any discomfort or motion sickness associated with the use of VR technology. The study seeks to determine if the 360° VR videos offer a superior sense of presence and involvement in the surgical environment, which is hypothesized to enhance the educational value of the training. This combined assessment helps to identify the potential benefits of VR in creating a more engaging and effective learning tool for surgical education, while also informing future improvements in VR technology to mitigate any adverse effects.

Outcome Measure: Participant ratings on immersion, engagement, and reports of discomfort or motion sickness.

Finally, the study seeks to determine the overall preference of participants between the VR and 2D training formats. By surveying participants on their preferred method of learning, the study aims to gather insights into the acceptance and potential adoption of VR technology in surgical education. This preference data, combined with the other outcome measures, provides a comprehensive understanding of the effectiveness and practicality of cost-effective VR solutions in enhancing the training of oral maxillofacial surgeons.

Outcome Measure: Survey results indicating the preferred training format (VR vs. 2D).

Production of Oral Maxillofacial Surgery Training Videos

The production of the surgery training videos involved capturing 2 major maxillofacial surgical procedures: fibula free-flap harvest and TMJ replacement access surgical procedures. These procedures were performed on a cadaver in an operating room, simulating real-life surgery conditions, with live commentaries by a lead consultant oral maxillofacial surgeon with >20 years surgical experience. Three high-definition cameras (1080p) were used to film the surgical procedures: left and right angles were captured with standard mirrorless cameras, while the overhead shot was obtained from a camera mounted in the overhead surgical light. Additionally, a 360° VR video was recorded in 4K using an InstaOne X2 camera in panoramic format (.insv). Audio was recorded directly from the recording cameras to ensure clarity and synchronization with the visual content. The filming process was synchronized across all cameras, and a film team managed the equipment to ensure clear and focused views of the key surgical aspects, providing comprehensive footage of the procedures.

Once the filming process was complete, the standard 2D shots and the 360° video were exported for processing and editing. The 360° VR video was processed and edited using the Insta 360 Studio software. To enhance

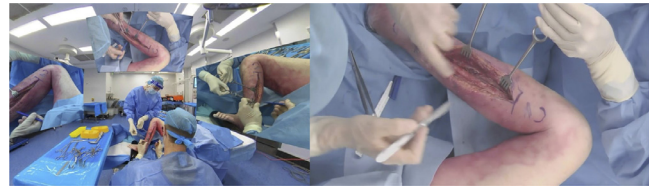


FIGURE 2. (A) 360° VR video view with 3 standard 2D video angle shots overlaid. (B) Standard 2D video illustration from an overhead camera angle (Fibula Free-Flap Harvest).

the contextual understanding for the trainees, the 2D videos shot from 3 different angles (left, right, overhead) were overlaid in the 360° VR video at corresponding angles and synchronized using the Final Cut Pro X software (Fig. 2A). This provided additional visual cues and a comprehensive view of the surgical procedures.

For the standard 2D videos, only the overhead camera shot was utilized to maintain a conventional and straightforward viewing experience (Fig. 2B). After the editing process, both the 2D and 360° VR videos were exported and subsequently uploaded to YouTube. These videos were made accessible via mobile apps on smartphones. The 360° VR videos could be viewed using a Google VR Cardboard for an immersive experience, while the 2D videos were directly viewable on the YouTube platform without additional equipment.

The links to the playlist of the videos are available here: https://www.youtube.com/playlist?list=PLywDS_KcRbKQjhcYm1cCrzEmc3SHAfPzE.

Study Workflow

Participants were shown both the 2D and 360° VR videos of the surgical procedures in a randomized order to minimize order effects. The training videos for both videos were accessed via YouTube. For the 360° VR videos, participants used the VR setting in YouTube and inserted their phone into a Google Cardboard. This setup ensured that all participants had straightforward access to the videos, with the VR videos providing an interactive experience while the 2D videos offered a conventional viewing format.

Questionnaire

Following the viewing of both the 2D and 360° VR videos, participants completed a postexposure questionnaire to gauge their learning and overall experiences with the videos (see Appendix 1). The questionnaire, completed anonymously to ensure confidentiality, collected data such as level of training, as well as information on prior exposure to the surgical procedures and VR technology. Participants rated their experiences using a forced Likert-scale. Questions focused on ease of use, engagement, immersion, and educational value for

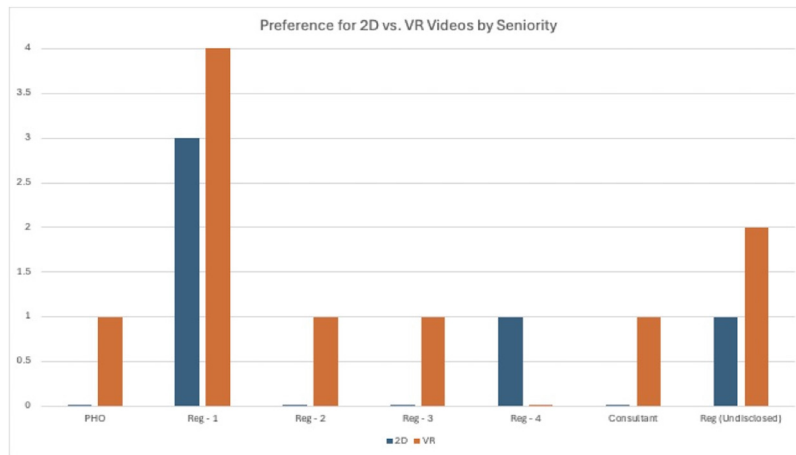


FIGURE 3. Preference for 2D versus VR videos by participant seniority.

both video formats. For example, they assessed statements like “The video provided me with a better understanding of the surgical procedure” with responses ranging from “Strongly Disagree” to “Strongly Agree.” Additionally, a section for subjective comments allowed for further feedback.

Statistical Analysis

The data was tabulated on Microsoft Excel spreadsheet for database development and then imported into GraphPad PRISM 8.0 software (GraphPad software, San Diego, Calif., USA) for statistical analysis. Responses were summarized, and comparisons were made. The output of data was presented in a table format as well as a graphical format. For all ordinal and dichotomous survey data, given the small sample size, a Fisher’s exact test with the Freeman-Halton extension was used to assess associations for larger contingency tables. Statistical significance was set at $p < 0.05$.

RESULTS

Fifteen participants completed and participated in the survey. A summary of the results and analysis can be seen in [Figure 3](#). All participants practiced in the maxillofacial area with varying levels of training, registrars (a doctor accepted into the college of oral and maxillofacial surgery 4-year training program) consultant, principal house officer, and undisclosed. According to the survey, 3 participants (20%) had not seen the procedure before, 7 participants (46.7%) had seen it 1 to 5 times, 1 participant (6.7%) had seen it 11 to 19 times, and 1 participant (6.7%) had seen it more than 20 times.

The results of the survey after the use of the VR video showed that the majority of the participants (73.3%) agreed that the VR video helped them understand the surgical procedure. Over 3-quarters of the participants agreed that the VR video enhanced their spatial understanding of the surgical environment. Similarly, results showed that the majority agreed that the video felt immersive. It was also found that 33.3% strongly agreed and 53.3% agreed that they would like to have greater access to VR videos like these to improve their skill in the future. However, 20% strongly agreed and 66.6% agreed that the VR videos made them experience discomfort and motion sickness ([Fig. 4](#)).

The results of the survey after the use of the standard 2D video showed that 66.6% agreed that the video helped them understand the surgical procedure. However, only 40% agreed that the video enhanced their spatial understanding of the surgical environment. Similarly, only 26.6% of participants found the standard 2D video to be immersive, while 40% disagreed. Of the participants, 93.33% stated they did not feel any discomfort from the video ([Fig. 5](#)).

When participants compared the VR video and the standard 2D video in terms of immersion, a p-value of 0.0056 was calculated in which there was a statistically significant difference observed ([Table 1](#)).

A statistically significant difference ($p = 0.0005$) was also found when participants were surveyed about whether the VR or standard 2D video caused them discomfort or motion sickness. Notably, participants rated the VR video as more intuitive and user-friendly compared to the standard 2D video, with the difference achieving statistical significance ($p = 0.038$). However, no statistically significant difference was observed when comparing the VR or standard 2D video for other

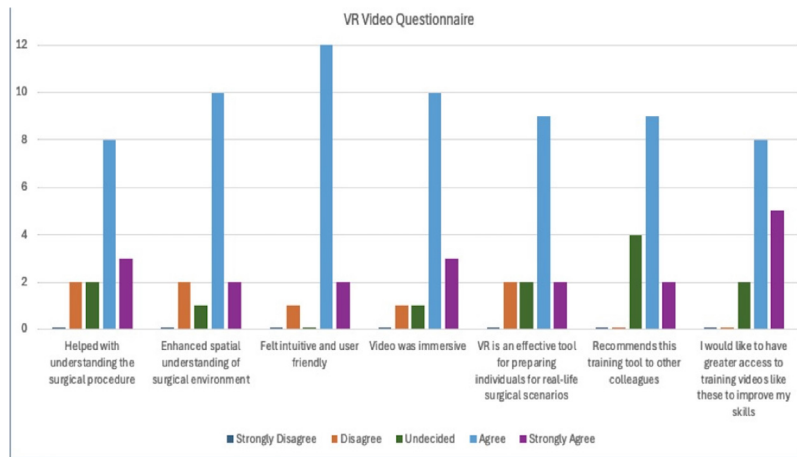


FIGURE 4. VR video questionnaire responses.

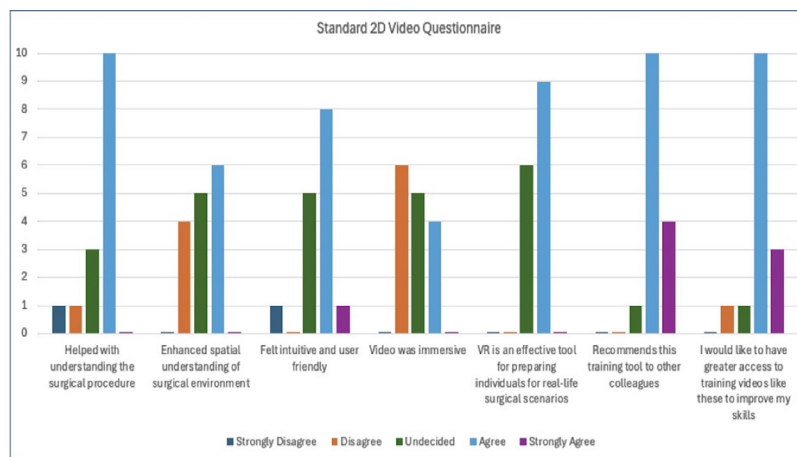


FIGURE 5. Standard 2D video questionnaire response.

questions as shown in Table 1. Ultimately, at the end of the questionnaires, 66.66% preferred the VR video, while the remaining 33.33% preferred the standard 2D video.

DISCUSSION

The findings from this study demonstrate the potential and limitations of using cost-effective VR technology, in the context of oral and maxillofacial surgery training. Overall, the results indicate that the 360° VR videos provide a more immersive and engaging learning experience compared to conventional 2D videos, although certain challenges and areas for improvement were identified.

The significant difference in participants' ratings of immersion between the VR and 2D videos underscores the enhanced engagement that VR technology offers.

With 80% of participants agreeing that the VR video felt immersive, compared to only 26.6% for the 2D video, indicating that the 360° VR format provides a superior sense of presence and involvement in the surgical environment. This aligns with existing literature suggesting that VR can create a more realistic and interactive training experience, thereby improving spatial understanding and facilitating a deeper understanding of the procedural context.^{2,10} Interestingly, more senior clinicians (i.e. those who have seen the procedure more and have attended the operating theatre more) did not find that VR enhanced their spatial understanding of the surgical environment. This could be due to their already strong expertise in the field, requiring less visual assistance for the procedures. One of the significant benefits of this study is the simplicity and cost-effectiveness of using Google VR Cardboard headsets compared to more expensive and complex VR equipment. In our survey, 60% of participants indicated that a budget range of

TABLE 1. Results of Fisher’s Exact Test for Participant Responses to the Questionnaire

Statement	Fisher’s Exact Test p-value
The video helped with understanding the surgical procedure	0.3933
The video enhanced spatial understanding of the surgical environment	0.1026
The video felt intuitive and user-friendly	0.03815*
The video was immersive	0.005623*
I experienced discomfort or motion sickness while watching the video	0.0004998*
The video is an effective tool for preparing individuals for real-life surgical scenarios	0.119
I would recommend this training tool to other colleagues	0.3395
I would like to have greater access to training videos like these to improve my skills	0.6446

Significant p-values ($p < 0.05$) are marked with an asterisk (*), indicating statistically significant results.

\$50-200 AUD would be ideal for a VR headset, and the Google VR Cardboard meets this criterion. This affordability would ensure that trainees could access the VR technology without significant financial barriers. Another notable finding was the statistically significant difference for the “felt intuitive and user friendly” question, with participants favoring the VR video over the 2D video. This suggests that VR may provide a more user-friendly interface and an immersive environment similar to the real world.

A notable drawback of the VR video-training is the discomfort associated with VR usage. Although the VR videos were well-received in terms of educational value, 86.6% of participants reported experiencing some level of discomfort or motion sickness. This issue has been documented in prior research and highlights the need for further refinement of VR technology to mitigate such adverse effects. For instance, a similar study involving medical students using VR simulators for robotic-assisted surgery reported significant instances of nausea and disorientation.¹¹ Other studies have corroborated these findings, further emphasizing the need to address motion sickness due to VR simulation to enhance the effectiveness and comfort of VR-based medical training.¹² However, of the participants that preferred 2D video over the VR video (33.3%), 50% had no discomfort or motion sickness. For the other 50%, the discomfort or motion sickness ranged from very mild to moderate discomfort, with one of these participants also stating

moderate discomfort watching the 2D video. Indeed, this was the only participant who mentioned motion sickness when providing short answer feedback on VR improvements. The other primary negative feedback for the VR from these participants was poor video quality, lack of controls to pause and zoom and the fact they had to tilt their head to look around.

Potential solutions could include improving the resolution and stability of VR content and exploring the use of higher-quality VR recording devices and headsets. In a similar study by Pulijala et al., a higher-end VR system was reported as robust and comfortable to use by participants, indicating that the quality and design of VR equipment may play a crucial role in user experience.¹³ This discrepancy underscores the importance of balancing cost-effectiveness with the quality of the VR experience. This is further corroborated by participants’ answers to short questions at the end of the survey on how the VR video could be improved. Answers included “The optics need to be improved,” “Resolution could be improved,” and “Higher quality [needed].” “Lack of clarity/focus.” “Motion sickness.” This could potentially limit the depth of the VR experience and its impact on learning outcomes. In contrast, the 2D format videos had certain advantages, as some participants noted an improved view of the surgical area and better lighting. This could be overcome with higher-end VR systems, however, these come with a different set of problems primarily cost barriers, with most surgical training in Australia and New Zealand being conducted in public hospitals where funding is tight, the widespread adoption of high-end VR systems could be problematic.

The study’s reliance on self-reported data through questionnaires may introduce subjective biases. The anonymous nature of the surveys, while ensuring confidentiality, also prevents tracking individual progress over time. Another notable limitation of the study methodology is the removal of the VR feature from YouTube for iPhone users. Accessing VR videos via YouTube offered a familiar platform for participants which reduced the learning curve of training using VR videos. However, YouTube has since ceased the support for Google Cardboard for iPhone users, which reduces availability and accessibility of the training videos, as many trainees will have to access such videos using either an alternative, less familiar platform, or gain access to a fully-fledged VR device.

The relatively small sample size of 15 participants also limits the generalizability of the findings. Future research should aim to include larger and more diverse cohorts to validate and extend the results of this study. Additionally, including participants from a variety of surgical fields and various institutions could provide a more comprehensive understanding of the effectiveness of

VR training across different contexts. The study was also conducted in a controlled environment, with surgical procedures done on cadavers, which may not fully replicate the complexities and variability of real-life surgical settings. Future studies could include larger sample sizes and a more diverse range of surgical procedures to validate the findings further. Filming the 360° VR video in a real working operating theater may also be considered for a more life-like experience, although it is important to note that this may pose significant challenges in terms of logistics, patient consent, proper illumination and clarity of the surgical field(s) being captured.

Addressing the reported discomfort and enhancing the visual and audio quality of the VR content are critical for improving user experience. Although the 360° VR video was filmed in 4K, the resolution perceived by users is lower than what is typically expected from 4K traditional 2D footage. The limitation here is likely also the sensor size, lens limitations, and focus quality of the VR device. The high resolution diminished by these limited components being squeezed into a small device. A specific VR lens attachment to a higher end camera would be more ideal for future studies. Some of the feedback received for the VR video included “Increase resolution of [VR] video, increase zoom.” This highlights the need for increased resolution of the VR video and incorporating interactive functions so that trainees can better visualize the details of the surgery. Future studies could explore the impact of higher-resolution (e.g., 8K 360°) VR videos, which would provide a more detailed and immersive visual experience. Additionally, incorporating spatial audio through high-quality headphones could enhance the auditory experience, making the learning environment more immersive and comfortable.

A suggested direction for future studies is evaluating the efficacy of the use of VR videos accessed using an interactive 2D screen instead of viewing them in “VR Mode.” The use of an interactive 2D touchscreen will enable trainees to appreciate the smaller details of the procedures. Some feedback from participants indicated that a 2D version of the VR training would be more advantageous, as this format allows users to access the content anytime and anywhere. The 2D VR format offers the advantage of camera movement, zooming, and the ability to view multiple screens. This functionality addresses some of the issues highlighted in feedback about 2D videos, such as the need for different viewing angles and avoids the need for a VR headset, or for a viewing application that facilitates a VR headset. Additionally, it avoids the vestibular side effects of using a VR headset.

Another important direction for future research is the integration of VR training into routine surgical education

curricula and assessing its impact on trainee performance in real clinical settings. There is still a strong need for the validation of VR simulators to ensure their full integration into medical training.¹⁴ Longitudinal studies tracking the progress of trainees over time would be valuable in assessing the long-term impact of VR training on skill retention and clinical performance. Such studies could help determine whether the initial benefits of VR training translate into improved outcomes in real-life surgical scenarios.¹⁵ Furthermore, VR has seen applications in various medical training areas apart from surgical training which includes but not limited to emergency and pediatric emergency medicine, medical radiation and imaging, catheterization training and interprofessional medical training.¹⁶

CONCLUSION

The evaluation and trial of the new cost-effective VR training tool, and the survey data presented here demonstrate the utility of a new process to assist surgical trainees and practitioners in learning complex maxillofacial surgical procedures. The study’s outcome measures revealed that 73.3% of participants reported improved understanding of surgical procedures with VR, compared to 66.6% with 2D videos. In terms of immersion and engagement, 80% found the VR video immersive, while only 26.6% felt the same about the 2D video. However, 86.6% of participants experienced discomfort or motion sickness with VR, whereas 93.33% did not experience any discomfort with 2D videos. Ultimately, 66.66% of participants preferred the VR format, while 33.33% preferred the 2D format. Notably, participants rated the VR video as more intuitive and user-friendly compared to the standard 2D video, with the difference achieving a statistically significant difference with Fisher’s exact test. These results underscore VR’s potential as an effective learning tool in surgery. While the study highlights the feasibility and benefits of using cost-effective VR solutions in surgical training, ongoing research and innovation are essential to maximize the potential of VR in medical education. By addressing current limitations and exploring new avenues, VR technology can become an integral part of effective and accessible surgical training programs.

The survey distributed to participants is available as [Appendix 1](#).

This study aligns with ACGME Competencies 1 (Patient Care), 2 (Medical Knowledge), 3 (Practice-Based Learning and Improvement) through the use of VR-based surgical training.

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SUPPLEMENTARY INFORMATION

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