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THE IMPORTANCE OF VIRTUAL REALITY IN TRAINING SURGEONS IN SIMULATED ENVIRONMENTS: INNOVATIONS AND APPLICATIONS IN MEDICAL PRACTICE

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Abstract: INTRODUCTION: Virtual reality (VR) has emerged as an innovative tool in the training of surgeons, providing a simulated environment that allows for the safe and controlled practice of surgical skills. This systematic review article explores the importance of VR in surgeon training, highlighting its innovations and applications in medical practice. The use of VR simulators has the potential to improve the technical training and confidence of professionals, as well as allowing risk-free repetition of procedures for real patients. **OBJECTIVES:** The main objective of this study is to analyze and synthesize the available evidence on the effectiveness of virtual reality in surgical training. Specifically, it seeks to identify the technological innovations that VR offers, assess its impact on the training of surgeons and discuss its practical applications in different surgical contexts. **METHODOLOGY:** The review was carried out using the PubMed, Lilacs and VHL databases. Articles addressing the use of VR in surgical training were selected, with a focus on studies demonstrating the efficacy and benefits of this technology. The analysis included evaluating different types of simulators, comparing traditional and VR methods, and exploring training scenarios in various surgical specialties. **RESULTS:** The results indicate that VR training results in significant improvements in the surgical skills of professionals. Studies show that surgeons who use VR simulators have a steeper learning curve and a higher success rate in laparoscopic procedures. In addition, VR allows for repetitive practice in a safe environment, increasing surgeons' confidence and reducing the incidence of complications during real surgeries. The technology has also proved effective in adapting training during the COVID-19 pandemic, ensuring continuity of training. **CONCLUSION:** Virtual reality is a significant innovation in the training of surgeons, offering a safe and controlled environment for

practicing technical and interpersonal skills. The benefits of VR are widely recognized, with evidence supporting its effectiveness in improving surgical performance and increasing professional confidence. Continued research and the development of new technologies are essential to maximize the potential of VR in medical education, preparing surgeons for the challenges of modern clinical practice.

Keywords: “virtual reality”, “surgical training”, “simulation” and “surgical skills”.

INTRODUCTION

Virtual reality (VR) has emerged as an innovative and transformative tool in the training of surgeons, providing a safe and controlled environment for practicing surgical skills. This systematic review article seeks to explore the importance of virtual reality in training surgeons in simulated environments, highlighting innovations and applications in medical practice. The use of VR-based simulators allows surgeons to develop and hone their technical skills without the risks associated with procedures on real patients, which is especially relevant in a field where precision and safety are crucial.^{17,18,20,32}

Recent literature indicates that training in simulated environments not only improves surgeons' technical proficiency, but also contributes to reducing errors during real procedures. For example, studies have shown that practicing on minimally invasive surgery simulators results in significantly better performance compared to those who do not use these resources. In addition, simulation allows complex procedures to be repeated, enabling surgeons to practice until they reach a desired level of competence, which is fundamental for training highly qualified professionals.^{10,20,32}

The integration of virtual reality into surgical training is also in line with current trends in medical education, which emphasize

the importance of simulation-based teaching methods. VR simulation not only provides a space for technical practice, but also facilitates the development of non-technical skills, such as communication and teamwork, which are essential for success in surgical environments. The ability to simulate complex and challenging clinical scenarios in a safe environment allows surgeons to learn how to deal with high-pressure situations, better preparing them for real clinical practice.¹⁶

In addition, virtual reality has proved to be a valuable tool for assessing surgical skills. Through simulators, it is possible to carry out objective assessments of surgeons' performance, using metrics that can be analyzed to identify areas for improvement and progress. This approach not only improves the quality of training, but also provides valuable data for research and development of new teaching and assessment methods in the surgical field.^{10,12,13,19,32}

Finally, the adoption of virtual reality technologies in surgical training is not without its challenges. Implementing high-quality simulators can be costly and requires adequate infrastructure, as well as specific training for the instructors who will be using these tools. However, the potential benefits outweigh the difficulties, and the continued evolution of simulation technologies promises to further expand the possibilities for surgical training, making it more accessible and effective.^{2,22}

In short, virtual reality represents a revolution in the training of surgeons, offering an effective and safe means of practicing surgical skills. This systematic review article will explore the innovations and applications of virtual reality in medical practice, highlighting its importance in developing competent surgeons prepared for the challenges of the contemporary clinical environment.

The main objectives of this review are to analyze the effectiveness of virtual reality (VR) as a training tool for surgeons, to explore the technological innovations incorporated into VR in the surgical context, to investigate surgeons' acceptance and perception of the use of VR, to address the practical applications of VR in the continuing education of surgeons, and to discuss the limitations and challenges associated with the implementation of VR in surgical training. These objectives aim to provide a comprehensive overview of the impact of VR on surgical training and practice, contributing to the advancement of medical education and improving the quality of patient care.

METHODOLOGY

This is a systematic review article that was structured in several stages to ensure rigor and transparency in the selection and analysis of relevant studies on the importance of virtual reality (VR) in training surgeons in simulated environments. The stages were designed according to the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The central question guiding the review was: "What is the effectiveness of virtual reality in training surgeons in simulated environments?" This question was formulated to guide the search and selection of relevant articles. Clear criteria were established for the inclusion and exclusion of studies. The inclusion criteria were: (a) studies that addressed the use of VR in surgical training; (b) articles published in English, Portuguese or Spanish; studies that presented empirical data on the effectiveness of VR. Exclusion criteria included: (a) articles that did not present empirical results; (b) literature reviews without original data; studies not related to surgical training. The search was carried out in the PubMed and VHL databases. A combination of keywords

was used, including "virtual reality", "surgical training", "simulation", "surgical skills" and "medical education". The search was carried out in February 2023, and articles published between 2010 and 2023 were considered to ensure the relevance and timeliness of the data. After the initial search, the titles and abstracts of the articles were reviewed by two independent reviewers. The articles that met the inclusion criteria were selected for full reading. In the event of disagreement between the reviewers, a third reviewer was consulted to resolve the disagreement. Relevant data was extracted from the selected articles, including information on the type of study, population, training methods, results and conclusions. The extraction was carried out by two reviewers, and the data was organized in a table to facilitate comparison and analysis. The quality of the included studies was assessed using the Joanna Briggs Institute (JBI) quality assessment tool, which considers criteria such as clarity of objectives, adequacy of study design, validity of results and relevance of conclusions. This assessment was carried out by two independent reviewers. The data extracted was analyzed qualitatively, focusing on the main trends and results related to the use of VR in surgical training. The analysis included the identification of recurring themes, technological innovations and practical applications of VR in the training of surgeons. The results were synthesized in a narrative that highlights the main findings of the review, including the effectiveness of VR, the advantages over traditional training methods and the implications for medical practice. As this is a systematic literature review, no experiments were carried out on humans or animals, so no specific ethical considerations were required. Limitations of the review include the possibility of publication bias, as studies with positive results are more likely to be published. In

addition, the heterogeneity of the included studies may make it difficult to generalize the results. This rigorous methodological approach ensures that the systematic review provides a comprehensive and grounded view of the importance of virtual reality in the training of surgeons, contributing to the advancement of medical education and the improvement of surgical practice.

RESULTS

Virtual reality (VR) has proven to be an innovative and effective tool for training surgeons in simulated environments, providing a series of benefits ranging from improving technical skills to reducing surgical complications. Studies show that the use of VR simulators allows psychomotor skills to be practiced in a controlled environment, where surgeons can repeat procedures without the risk of causing harm to real patients. VR simulation not only improves manual dexterity, but also promotes professional confidence, which is crucial in high-pressure situations such as those that often occur in surgical environments.^{17,20,31,33}

The literature shows that VR training can result in a significant improvement in surgical performance. For example, one study showed that surgeons who trained on VR simulators had a much higher success rate in laparoscopic procedures compared to those who did not use this technology. In addition, simulation allows professionals to experience a variety of clinical scenarios, including unexpected complications, which is fundamental to training a competent surgeon who is prepared for the real world.^{1,34}

Another important aspect of VR in surgical training is the possibility of immediate feedback. Most modern simulators provide detailed analysis of the user's performance, allowing surgeons to identify areas for improvement and adjust their techniques

in real time. This approach not only speeds up the learning process, but also ensures that professionals are better prepared to face challenges during real procedures.^{3,14,15,35}

In addition, VR has proven particularly useful in distance learning contexts, as evidenced during the COVID-19 pandemic. With the need for social distancing, many surgical training programs migrated to virtual platforms, where VR became a viable solution to continue training new surgeons. This adaptation not only ensured the continuity of learning, but also demonstrated that VR can be an effective alternative to traditional teaching methods, especially in times of crisis.^{7,8,30,33}

The integration of VR with other technologies, such as artificial intelligence and machine learning, is also beginning to be explored. These innovations promise to further personalize training by adapting simulation scenarios to the specific needs of each surgeon, which can lead to more efficient and targeted learning. The combination of these technologies could revolutionize surgical training, making it more accessible and effective for professionals around the world.^{9,11}

Finally, VR is not just limited to technical training; it can also be used to develop interpersonal and communication skills, which are essential in medical practice. Simulating interactions with patients and their families in a virtual environment can help surgeons improve their communication, empathy and decision-making skills, which are key to success in clinical practice. Therefore, virtual reality presents itself as a multifaceted tool that not only improves surgical skills, but also prepares professionals for the complex challenges of modern medicine.^{4,24}

In summary, virtual reality represents a significant innovation in the training of surgeons, offering a safe and controlled environment for practicing technical and

interpersonal skills. The benefits of VR are widely recognized in the literature, with evidence supporting its effectiveness in improving surgical performance, increasing professional confidence and adapting to learning needs in times of crisis. As technology continues to evolve, VR is expected to play an even more central role in training competent surgeons who are prepared for the challenges of the future. Photo 1 represents the process of screening and selecting the articles included in the current review.

DISCUSSION

Discussing the importance of virtual reality (VR) in training surgeons in simulated environments is fundamental to understanding the innovations and applications in contemporary medical practice. VR has become an essential tool in medical education, especially in surgical training, where practicing in a safe and controlled environment is crucial for developing the skills needed for clinical practice. The literature reviewed indicates that VR not only improves technical dexterity, but also provides a space for repetitive practice, allowing surgeons to develop their skills without the risk of causing harm to real patients.^{20,21,22,23,24}

One of the main benefits of VR is the ability to simulate complex and varied scenarios that a surgeon may encounter in clinical practice. This includes the possibility of training in emergency situations, where quick and effective decision-making is crucial. Studies show that exposure to these simulations can boost surgeons' confidence and improve their ability to respond in critical situations. In addition, VR allows professionals to practice specific procedures repeatedly, which is fundamental for the acquisition of fine motor skills.^{21,23}

The integration of VR technologies with real-time feedback is another significant in-

novation. Modern simulators offer detailed performance analysis, allowing surgeons to identify areas for improvement and adjust their techniques as necessary. This personalized approach to learning is particularly effective, as it promotes an adaptive learning environment that adjusts to each surgeon's individual needs. The ability to receive immediate feedback during practice is a factor that contributes to the effectiveness of VR training, as it allows professionals to make instant corrections to their approaches.^{23,24,27}

In addition, VR has proven to be a viable solution for medical education in times of crisis, as evidenced during the COVID-19 pandemic. With the restrictions on physical contact, many surgical training programs were forced to adapt and migrate to virtual platforms. VR has not only facilitated the continuity of learning, but has also proven to be an effective alternative to traditional teaching methods, allowing surgeons in training to continue developing their skills in a safe and controlled environment.^{5,6,22}

The literature also highlights the importance of VR in promoting interpersonal and communication skills, which are essential in medical practice. Simulating interactions with patients in a virtual environment can help surgeons improve their communication and empathy skills, which are key to success in clinical practice. This multi-faceted approach to VR, which combines the development of technical skills with the formation of interpersonal competencies, is one of the reasons why this technology is becoming increasingly popular in medical education.^{16,26,27,28,29}

Finally, virtual reality (VR) is not just a training tool, but also a paradigm shift in medical education, promoting personalization and interactivity in learning. With technological evolution, VR plays a central role in the training of competent surgeons, offering a safe environment for practicing technical and interpersonal skills. The literature widely recog-

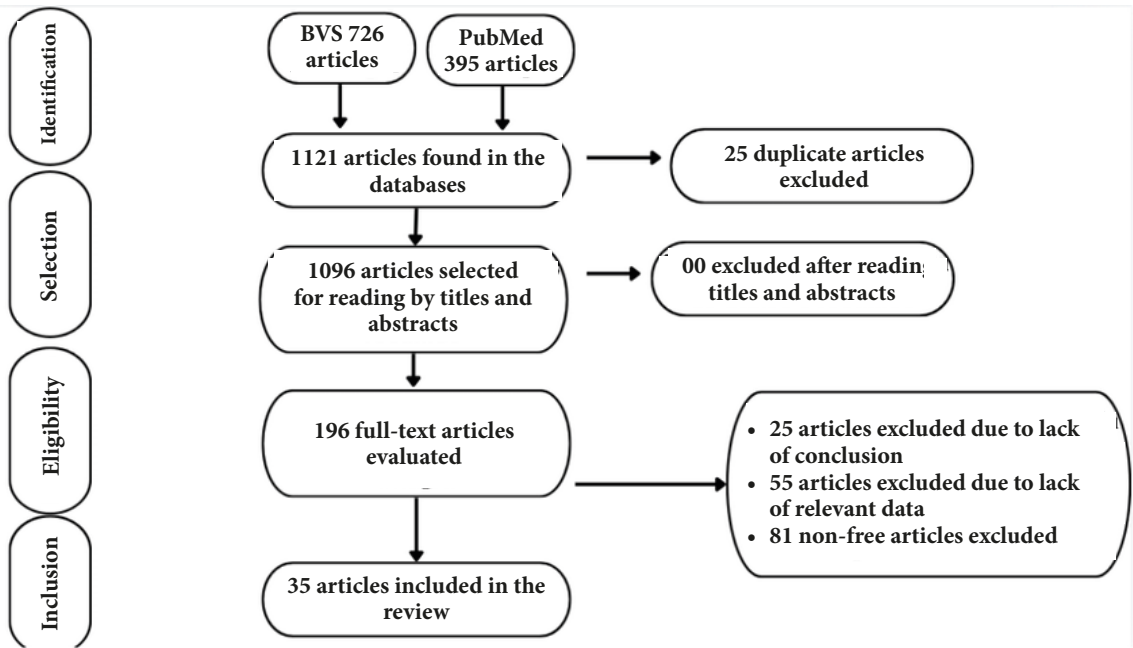


Image 1: Flowchart showing the selection of articles included in the review.

nizes the benefits of VR, highlighting its effectiveness in improving surgical performance, increasing professional confidence and adapting to learning needs, especially in times of crisis. VR promises to further revolutionize the training of surgeons, preparing them for the complex challenges of modern medicine.

CONCLUSION

In short, VR has established itself as an innovative tool that not only improves surgeons' technical skills, but also contributes to the development of interpersonal and decision-making skills in critical situations. The literature reviewed shows that VR simulation provides a safe and controlled environment, allowing professionals to practice complex procedures without the risk of harming real patients.

The results obtained from the studies analyzed show that the use of VR simulators results in significant improvements in surgical performance. Surgeons who underwent VR training showed a steeper learning curve and a higher success rate in laparoscopic procedures and other surgical interventions. In addition,

repetitive practice in simulated environments not only improves technical dexterity, but also boosts professionals' confidence, a crucial factor in high-pressure situations.

Another important aspect addressed in the review is VR's ability to offer real-time feedback, which allows surgeons to identify and correct errors immediately. This feature is fundamental to effective learning, as it promotes a continuous cycle of evaluation and skills improvement. The personalization of training, adapting to the individual needs of each surgeon, is one of the most promising innovations that VR brings to medical education.

In addition, VR proved to be a viable solution during the COVID-19 pandemic, when many training programs were forced to adapt to new realities. The ability to carry out virtual training ensured the continuity of training for new surgeons, demonstrating the flexibility and effectiveness of VR as an alternative to traditional teaching methods. This adaptation not only ensured continuous training, but also highlighted the importance of technology in medical education in times of crisis.

The discussion about integrating VR with other emerging technologies, such as artificial intelligence, suggests that the future of surgical training could be even more promising. The combination of these technologies could lead to more efficient and targeted learning, further personalizing training experiences for each professional. This technological evolution will not only enrich the learning process, but could also transform medical practice, preparing surgeons for the complex challenges of modern medicine.

In conclusion, virtual reality presents itself as a significant innovation in the training of surgeons, offering a safe and controlled environment for practicing technical and interpersonal skills. The benefits of VR are widely recognized in the literature, with evidence supporting its effectiveness in improving surgical performance, increasing professional confidence and adapting to learning needs in times of crisis. Continued research and the development of new technologies will be essential to maximize the potential of VR in medical education, ensuring that the surgeons of the future are well prepared to meet the demands of clinical practice.

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