

The Utility of Virtual Reality in Ophthalmology: A Review

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Abstract: Virtual reality (VR) has been implemented in multiple facets of healthcare and the study of medicine. In the field of ophthalmology, VR facilitates surgical and non-surgical training while assisting in diagnosis and treatment. Our goal was to explore the applications and feasibility of VR in ophthalmology. We performed a search of the literature on the journal database PubMed using keywords relevant to VR integration in ophthalmological medicine. We included articles published since 2015 in this review of literature. The literature search yielded extensive applications of VR in medical training, as well as techniques for efficient diagnosis and screening using VR models including Eyesi and HelpMeSee. VR training simulators have decreased surgical error rates and improved technique in cataract surgery. In vitreoretinal surgery, a VR vitreoretinal training simulator resulted in improved surgical performance in both training and experienced surgeons. VR is also utilized in non-surgical training through an app to develop funduscopy skills and slit-lamp training for medical students. Additionally, VR is used in diagnosis, screening, and treatment of glaucoma, amblyopia, and strabismus. VR has also improved visual field defects in patients with glaucoma and treated amblyopia in children who did not improve with patching. Barriers to the widespread implementation of VR include high initial capital cost, limited sample sizes for research studies, and discrepancies between VR visual field and real-world clinical practice. Future research in streamlining VR methods to be more accessible and cost-effective has the potential to overcome these challenges. With further investigation into the logistics of VR applications, this technology could improve surgical outcomes and diagnostic accuracy.

Keywords: virtual reality, ophthalmology, cataract surgery, vitreoretinal surgery, amblyopia, glaucoma

Introduction

At its core, virtual reality (VR) is a computer-generated, immersive environment.¹ VR allows a user to perceive and interact with a virtual world, commonly through a head-mounted display.¹ VR has been primarily used for healthcare education via the generation of virtual anatomy models. Interactive VR protocols have been associated with increased healthcare professional knowledge and cognitive skills when compared to traditional forms of education such as textbooks and lectures.¹ VR has been progressively integrated into various medical domains, enhancing both educational and clinical practices. For instance, VR has demonstrated the potential to enhance students' visual-spatial learning and understanding in the anatomy lab.² In surgical training, VR has been shown to improve surgical skill acquisition and confidence while also reducing errors, offering a safer and more effective learning environment.³ In the field of rehabilitation, VR has improved motor function and cognitive outcomes in stroke patients, supporting its use as an adjunct to conventional physical therapy.⁴ These examples underscore VR's transformative impact across multiple facets of healthcare.

In the field of ophthalmology, VR simulators are often being used to aid in surgical training.⁵ Eyesi is one such VR model, which simulates an operating room environment, including surgical instruments and an operating microscope while tracking operating metrics such as efficiency, instrument handling, and surgical complications.⁶ Specifically, this simulator consists of a mannequin that contains a model eye, which can be manipulated with various surgical instruments.⁶ Additionally, the operating microscope can be moved, zoomed, and focused using a foot pedal, thus emulating a real-life surgical experience.⁶ The virtual eye is connected to a computer system, which allows for tracking of surgical instruments, hand pressure, and tremor.⁶ A variety of modules exist within Eyesi which model various cataract and vitreoretinal surgeries for training physicians.⁶ Another VR model being used primarily for cataract surgery is called HelpMeSee.⁷ Much like Eyesi, HelpMeSee provides a simulated eye, which can be manipulated by surgical instruments in a realistic, physics-based model.⁷ This model provides the trainee tactile feedback while performing virtual surgeries, and it is notable for highlighting errors, which may occur in real surgery based on the user's technique.⁷ These simulators represent a broader shift in ophthalmology, where VR is being adopted to enhance not only surgical training but also clinical education and patient care. Recent studies have shown that VR can improve real-life surgical outcomes, reduce complication rates such as posterior capsule rupture and vitreous prolapse, and transfer technical skills across surgical approaches. VR has also demonstrated utility outside the operating room, from slit lamp and funduscopy training to visual field testing and treatment of glaucoma and amblyopia. Herein, we describe current applications of VR technology in ophthalmological training, diagnosis, and treatment while also exploring the challenges that must be addressed for its broader implementation.

Methods

We conducted literature searches on the journal database PubMed (Figure 1). We searched available publications and accessed studies from June 1, 2024, to December 21, 2024. We identified articles to be analyzed for inclusion in this literature review by searching the keywords and phrases “virtual reality in ophthalmology”, “training”, “cataract surgery”, “vitreoretinal surgery”, “phacoemulsification”, “amblyopia”, “treatment”, and “diagnosis”. We identified clinical primary studies as well as reviews, thus our literature review includes discussion of both qualitative and quantitative data. We excluded articles published earlier than 2015, and we included articles published more recently than 2015. Inclusion criteria were as follows: discussion of VR utility in ophthalmological procedures and common eye conditions and relevance to VR applications in ophthalmologic surgery, training, diagnosis, or treatment.

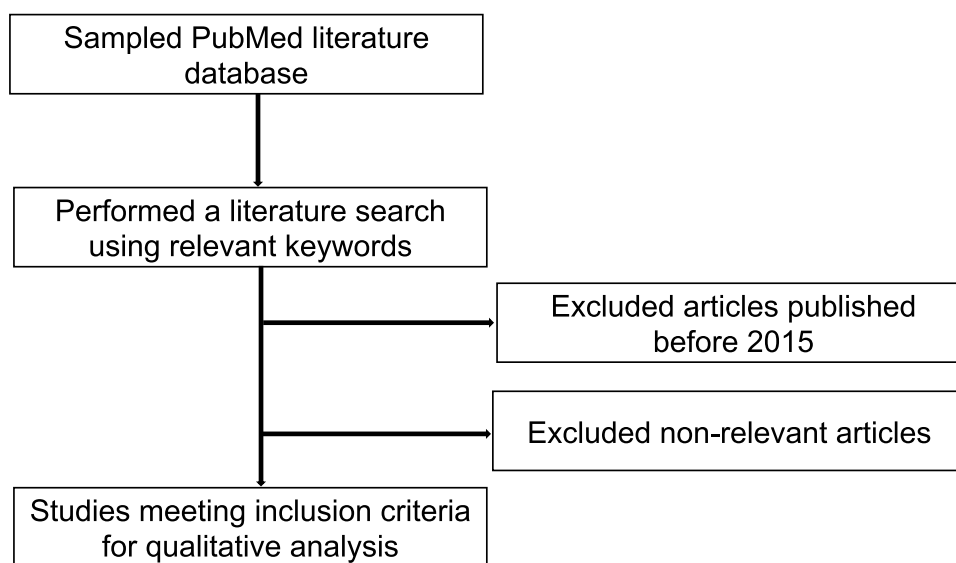


Figure 1 Literature Selection Process. PubMed was queried using virtual reality–related ophthalmology keywords. After filtering by date and manually screening for relevance to ophthalmic clinical or educational applications, studies were included in the final review.

Surgical Training Cataract Surgery

Beginning with cataract surgical training, VR has demonstrated the ability to improve surgical technique and reduce rates of complications in training physicians (Figure 2). First, performance on VR training simulators has been correlated with performance in real-life cataract surgery. In one study, experienced surgeons with limited prior VR exposure completed a validated surgical skills test for cataract surgery on an Eyesi VR simulator that included intracapsular navigation, bimanual training, forceps training, and capsulorhexis training.⁸ The Eyesi system then generated a score based on each participant’s performance.⁸ After performing the simulated cataract surgery, the same surgeons then performed real cataract surgeries.⁸ Recorded videos were collected to estimate surgical skill based on variables such as total path length and number of movements using a validated motion-tracking software.⁸ The authors found a significant association between VR simulation scores and real motion-tracking scores for the surgeons included in this study, indicating that performance on VR models is correlated with real-life cataract surgery prowess.⁸ These findings were corroborated with additional studies showcasing VR’s ability to differentiate between the real-life surgical skill of a resident versus an experienced physician. Thomsen et al (2015) developed a series of Eyesi VR training modules, which could be scored based on proficiency in variables such as tissue treatment, efficiency, and instrument handling.⁹ The authors found that in seven modules, novices had a significantly lower performance compared to both experienced cataract surgeons and experienced vitreoretinal surgeons.⁹ However, when comparing between cataract and vitreoretinal surgeons, no significant differences were found in the calculated score, indicating the ability of Eyesi to assess each surgeon’s underlying microsurgical skills.⁹

However, the applications of VR exceed simply estimating surgical skill. Since establishing the correlation between true surgical skill and skill on VR simulators, various additional studies have highlighted the ability of VR to be used as a training tool to both improve surgical technique and reduce surgical errors in training physicians. For example, Thomsen et al (2017) describe the use of the Eyesi simulator to train novice ophthalmologists, and ophthalmologists with intermediate experience, until reaching a predetermined passing score on a VR simulator.¹⁰ The novice surgeons were then graded based on the Objective Structured Assessment of Cataract Surgical Skill (OSACSS) rating scale while performing real cataract surgeries.¹⁰ After VR training, novices and intermediates achieved a 32% and 38% improvement

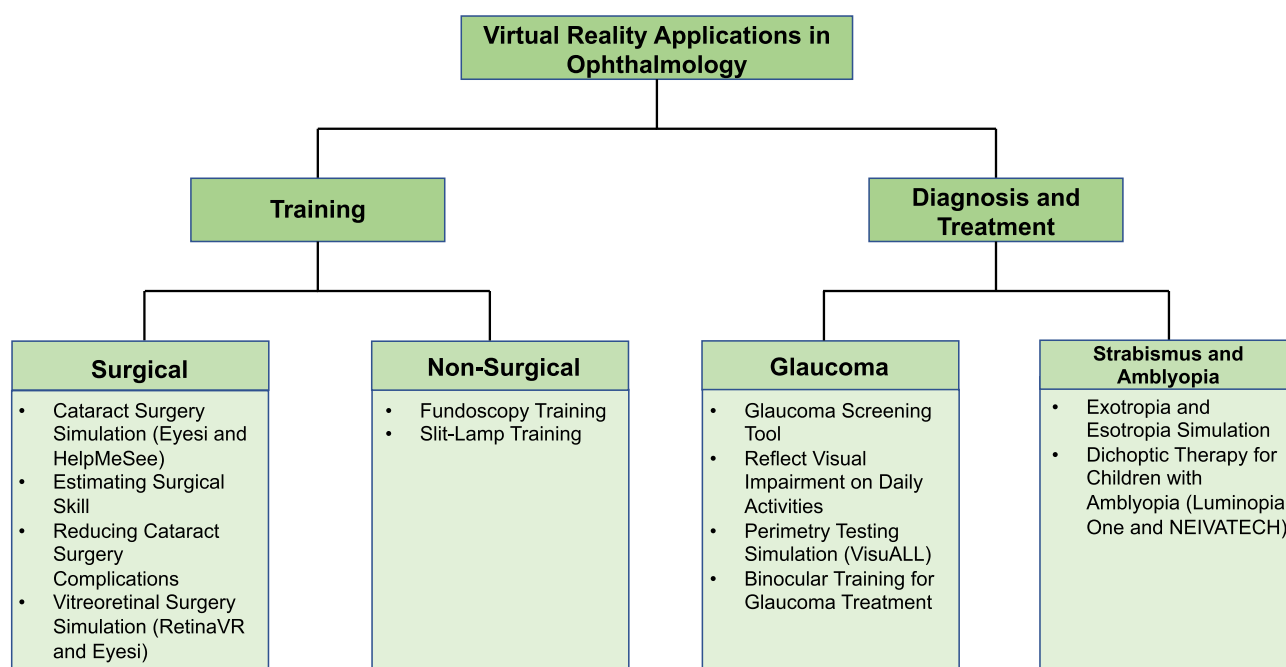


Figure 2 Virtual Reality Applications in Ophthalmology. This diagram summarizes key virtual reality use cases across training, diagnosis, and treatment in ophthalmology.

on the OSACSS rating scale when performing real cataract surgeries compared to their scores on the rating scale before VR training.¹⁰ These findings demonstrate that VR has the potential for use as a standalone tool in improving real cataract surgery proficiency.¹⁰

VR can also be used to reduce rates of surgical errors, or complications. A study by Ferris et al (2020) compared the rates of posterior capsule rupture (PCR), a cataract-surgery complication with the potential to cause vision loss, in training ophthalmologists both with and without VR experience.¹¹ The study compared PCR rates in first- and second-year trainee surgeons in 2009 to PCR rates in the same population in 2015.¹¹ All participants in the 2009 group predated access to Eyesi.¹¹ Within the 2015 cohort, trainee surgeons who used Eyesi training and trainee surgeons who did not use VR training were analyzed.¹¹ The authors found that there was a 38% reduction in PCR rates among trainee surgeons in 2015 who used Eyesi training compared to the 2009 cohort.¹¹ Simultaneously, there was only a three percent reduction in PCR rates in the 2015 cohort surgeons who still did not use Eyesi compared to the 2009 cohort.¹¹ Therefore, the authors postulate that in the United Kingdom, widespread implementation of VR could eliminate roughly 360 cases of PCR annually in cataract surgeries performed by trainee surgeons.¹¹ Furthermore, Staropoli et al (2018) compared cataract surgery error rates between two groups of 11 post-graduate year 3 residents at the Bascom Palmer Eye Institute.¹² One group of residents received mandatory pre-surgical training on the Eyesi surgical simulator prior to their first live cataract surgery, and the other group of residents did not receive Eyesi surgical simulator training prior to the first live cataract surgery.¹² The simulator group had an overall complication rate of 2.4% compared to a 5.1% complication rate in the non-simulator group, a significant difference.¹² Specifically, there was a significant difference in rates of posterior capsule tears and vitreous prolapse with the rates of both complications in the simulator group being 2.2% compared to 4.8% in the non-simulator group.¹² Again, VR simulation training for residents significantly decreased rates of cataract surgery complications in live operations, suggesting the benefit of widespread integration of VR training in residency programs.¹²

Another potential application for VR within cataract surgery is the transfer of surgical skill between different forms of cataract surgery, namely phacoemulsification (PE) and manual small incision cataract surgery (MSICS). In a study by Le et al (2024), the Eyesi VR simulator was used to emulate PE proficiency, while the HelpMeSee VR simulator was used to emulate MSICS proficiency.¹³ Both of these models have previously demonstrated significant correlations between their emulated surgeries and true surgical skill.¹⁴ Resident ophthalmologists and practicing ophthalmologists who had passed an Eyesi simulator proficiency exam within the last 24 hours achieved a significantly higher score and pass rate on their first attempt of HelpMeSee compared to ophthalmologists with no Eyesi experience.¹³ Specifically, ophthalmologists proficient in Eyesi performed better in the capsulorhexis and cortex removal steps of simulated MSICS, steps which are analogous in both types of cataract surgery.¹³ These results indicate that in a simulated environment, proficiency in PE is transferred to other forms of cataract surgery, such as MSICS, potentially easing the real-life transfer of skills simultaneously.

Vitreoretinal Surgery

Alongside cataract surgery, VR has also more recently been implemented into vitreoretinal surgery. Antaki et al (2024) developed a VR simulator designed for vitreoretinal surgical training named RetinaVR.¹⁵ The simulator is accessible via a VR headset and contains training modules that model skills necessary for vitreoretinal surgical procedures, such as simulated peeling of epiretinal membranes and applying endolaser on retinal breaks in the periphery.¹⁵ The authors compared the performance of residents without surgical exposure, considered the novice group, to retinal fellows and attendings, considered the expert group, on RetinaVR.¹⁵ Across all training modules, experts achieved significantly higher safety scores than novices.¹⁵ These results offer preliminary evidence that VR skill can also be correlated with real-world surgical skill in vitreoretinal surgery, much like the previously established correlation in cataract surgical skill, but more studies are needed to examine the skill transfer from VR directly into the operating room.¹⁵

Deuchler et al (2016) describe the use of a VR vitreoretinal training simulator within Eyesi for pars plana vitrectomies capable of improving surgical outcomes in even experienced surgeons.¹⁶ This simulator was capable of generating internal limiting membrane peeling procedures and retinal detachment surgery.¹⁶ After analyzing the simulations, the VR model then generated a score for each participant based on surgical proficiency.¹⁶ The surgeons in this study first used the VR model training session as a warm-up, before being sent to perform real-world pars plana vitrectomies.¹⁶ Recordings

of the real pars plana vitrectomies were graded by expert ophthalmologists with a system similar to that of the VR model.¹⁶ The authors found that when using Eyesi for surgical warm-up, the surgeons included in the study incurred a significant improvement in surgical performance.¹⁶ Notably, all surgeons, ranging from 2 years of experience to 25 years of experience, had an improved surgical performance after warming up.¹⁶ These results indicate that VR could be integrated as a standard portion of vitreoretinal surgical workflow to improve outcomes even among experienced surgeons.

Non-Surgical Training

Outside of surgical training, VR models have recently been implemented for training in the clinical setting, namely for both fundoscopy and slit-lamp training. Fundoscopy is a clinical skill useful for both ophthalmologists, and general practitioners, as a mechanism to diagnose pathology in the posterior segment of the eye. Rao et al (2024) designed an app to allow training physicians to develop fundoscopy skills by utilizing VR before reaching the ophthalmology clinic.¹⁷ The app contains modules designed to teach students how to locate the red reflex, navigate the retina, and recognize common pathologies.¹⁷ Doctors and medical students were recruited to subjectively rate their experience with the application.¹⁷ The authors found that both doctors and medical students agreed that this VR tool would allow others to learn fundoscopy more rapidly.¹⁷ However, more empirical studies are required in the future to gauge VR's ability to definitively help in the fundoscopy training process.

Regarding slit-lamp training, medical students who had previously completed a 1-week ophthalmology internship were tested on their ability to complete an objective structured clinical examination (OSCE) for slit-lamp usage.¹⁸ Half of the students were placed into a VR simulator group, while the other half of students received a traditional slit-lamp course involving an in-person introduction on operation, handling, diagnosis, and abstract structure localization with a slit-lamp.¹⁸ The Eyesi simulator training group completed basic slit-lamp skills training tasks including lateral translation, vertical translation, navigation, and slit width and length.¹⁸ Additionally, the Eyesi training group received diagnostic training for cataracts, infectious diseases, and uveitis.¹⁸ When ultimately tested in the real-world slit-lamp OSCE, the simulator training group performed significantly higher overall compared to the traditional training group.¹⁸ Specific subcategories significantly improved in the VR simulator group include preparation of slit-lamp examinations and finding anterior segment structures with proper illumination techniques.¹⁸ The simulator training group also demonstrated higher, but non-significant scores on diagnosing disease and measuring anatomic structures.¹⁸ These findings indicate that the addition of VR training even outside of the operating room may allow for more efficient training of junior ophthalmologists.

Diagnosis and Treatment

Glaucoma

In addition to resident physician training, VR has also proven to be efficacious for the diagnosis and screening of a variety of neuro-ophthalmologic pathologies, particularly glaucoma, amblyopia, and strabismus. In a study of VR efficacy in glaucoma diagnosis, Lam et al (2020) describe five interactive VR scenarios mimicking daily activities, such as grocery shopping and navigating stairs, used to evaluate the performance of patients with moderate-to-severe glaucoma compared to healthy participants while detecting vision-related impairment.¹⁹ The results indicated that glaucoma patients required significantly more time to finish tasks such as shopping and nighttime navigation and experienced more collisions during these tasks compared to healthy controls.¹⁹ Vision-associated disability was defined as performance falling outside the 95% confidence interval of healthy participants, and 59% of glaucoma patients exhibited vision-associated disability in at least one of the five VR tasks.¹⁹ The study concluded that VR simulations could serve as a screening tool for glaucoma while also offering insight into the impact of visual impairment on daily activities so that clinicians may better understand the functional impact of glaucoma on their patients.¹⁹

Nascimento et al (2024) describe the use of the VisuALL VR headset, which is capable of simulating perimetry testing.²⁰ Standard automated perimetry involves the presentation of static white light across various locations in a patient's visual field.²⁰ By measuring the minimum threshold capable of detection by the patient, standard automated

perimetry can be used to identify loss of light, or contrast, sensitivity in patients with glaucoma.²⁰ VisuALL allows patients to perform perimetry testing with both eyes simultaneously and without the need for a dark room.²⁰ The authors found that the VisuALL VR headset generates reproducible visual fields, indicating the potential for VR to be used as a diagnostic tool for disease monitoring in patients with glaucoma in the future.²⁰

VR's applications also extend to glaucoma treatment. Fan et al (2021) describe the implementation of binocular VR training for glaucoma treatment by improving visual field defects.²¹ The VR training system utilized a variety of techniques including eye movement following, binocular stereopsis training, eye movement fixation training, and eye movement saccade training.²¹ Patients performed these VR trainings twice daily for 20 minutes each session over the course of 3 months.²¹ The authors found that in the VR training group, the visual field index and mean defect values were significantly improved compared to the control group at both 1 month and 3 months.²¹ These findings indicate that VR training has the potential to rehabilitate visual field defects and restore an enlarged visual field in patients with glaucoma.

Strabismus and Amblyopia

VR may also be implemented as a tool to aid in the diagnosis of strabismus and subsequent amblyopia. Moon et al (2021) developed a model, which simulated patients with both exotropia and esotropia to aid residents in future diagnosis.²² In the simulated environment, the model allowed resident ophthalmologists to perform cover-uncover, alternate cover, and prism cover tests to facilitate measurements of a patient's deviation angle.²² After completing a simulated session, resident ophthalmologists then completed examinations on real patients, including an ocular motility exam, cover-uncover test, alternate cover test, and prism cover test.²² Across all of these exams, resident ophthalmologists received a 53% increase in accuracy score and 61% increase in overall performance score on real patients after using the simulator, compared to scores achieved before using the simulator.²²

Regarding treatment, Xiao et al (2022) analyzed the efficacy of Luminopia One, a dichoptic digital therapeutic device for children with amblyopia.²³ Dichoptic therapy aims to promote binocular vision and prevent the visual cortex suppression, which occurs in amblyopia.²³ With the Luminopia One VR headset, children were able to watch TV shows for one hour per day, 6 days per week, with therapeutic full-time refractive correction, over a period of 12 weeks.²³ The VR headset reduced the contrast of images generated to the healthy eye by 15%, compared to the contrast given to the amblyopic eye.²³ Additionally, dichoptic masks were superimposed on images within the VR environment so that both eyes were needed to completely watch video content.²³ When not using the VR headset, patients wore glasses full-time, whereas in the comparison group that did not receive VR training, participants wore glasses full time alone.²³ At 12-week follow-up, participants in the VR headset group achieved an amblyopic eye visual acuity increase of 0.18 logMAR compared to a 0.08 logMAR increase in the glasses only group.²³ Additionally, no serious adverse side effects were reported in the VR group.²³ The 0.1 logMAR difference between both groups was significant, indicating that VR headsets can be implemented into clinical practice for the treatment of amblyopia.²³

Another VR system, NEIVATECH, is designed to treat amblyopia in children older than 7 years who were either noncompliant or nonresponsive to previous attempts at treatment with patching.²⁴ This VR system was composed of multiple games, which stimulated perceptual learning and dichoptic training.²⁴ In this study, the patients with amblyopia received 18, 30-minute sessions over the period of 1 month.²⁴ The authors were able to improve near best-corrected visual acuity (BCVA) by 24% and distance BCVA by 15% after the 1-month administration of therapy, once again indicating that VR systems can be implemented into clinical practice to treat older children refractory to patching.²⁴

Challenges

Although VR presents abundant promise for future utility in the practice of ophthalmology, the logistical implementation of this technology in training, diagnosis, and treatment presents obstacles for its widespread application including initial financial expenses, limited research on translational efficacy, and safety in real-world ophthalmological procedures.

One barrier to the widespread application of VR technology in ophthalmology training and clinical practice is the high initial capital cost. At the time of the randomized-controlled trial by Ng et al (2023), the Eyesi VR simulator and initial setup cost \$249,191.99 with a recurring cost of \$19,690.90 per year per trainee.²⁵ This startup cost of VR implementation into a training program presents a barrier to VR use in facilities that do not have available funding of that

magnitude. However, recent research has demonstrated the effectiveness of low-cost VR devices like the Toronto Portable Perimeter (TPP), which enables reliable home-based glaucoma monitoring.²⁶ Compared to standard clinical follow-up, this VR-based approach significantly reduces both the time and financial burden associated with in-person testing.²⁶ These innovations reflect a broader trend toward affordable, portable VR solutions that could not only reduce the cost of ophthalmologic care but also reduce the financial burden of VR resources for training ophthalmologists, even in the private practice setting.²⁶

Presently available data on VR applications in training for cataract and vitreoretinal surgery, along with diagnosis of amblyopia and glaucoma, suggest high efficacy in decreasing surgical errors and improving diagnostic accuracy. However, these studies are largely limited to single center training programs and smaller sample sizes. Smaller sample sizes limit the ability of academic institutions to generalize findings across diverse trainee populations, making it difficult to confidently integrate VR into curricula. Increased inter-institutional collaboration, which has been associated with greater research productivity and innovation, could help expand sample sizes and improve study design, enabling broader adoption of VR in ophthalmology training.²⁷

Additional discrepancies also exist between the rate of false positives and false negatives across a variety of VR use cases, such as perimetry testing compared to non-VR techniques like standard automated perimetry. One study comparing VR-based perimetry to standard automated perimetry as a gold standard reported a false negative rate of 35.3% and a false positive rate of 20% for the VR-based test.²⁸ However, other studies have cited the potential for VR-based platforms, such as the VisuALL device, to reduce false positive rates and fixation loss, a marker of test reliability that reflects a subject's ability to maintain steady focus throughout the assessment.²⁹ These findings indicate that further research is needed across multiple domains in ophthalmology to reduce diagnostic discrepancies while capitalizing on VR's potential to improve surgical and diagnostic performance.

Yet another challenge to be addressed regarding VR feasibility is smoothing out the visual field for a seamless transition between the VR display and real-life patients in the operating room. In a study by Ho (2019), the implementation of a VR smartphone headset to increase accessibility of VR technology in robot-assisted ophthalmologic operations presented a concern for the headset impairing the surgeon's field of vision.³⁰ Although this study represents a proof-of-concept for smartphone-driven VR technology, it does draw awareness to challenges for hand-eye coordination and visual field continuity.³⁰

Many VR studies in ophthalmology are sponsored by companies developing the technology, raising concerns about potential sponsorship bias and its impact on research integrity. This issue has been well documented in other fields; for example, a systematic review of industry-sponsored studies found such research to be significantly more likely to report positive outcomes.³¹ While direct evidence of this bias in VR research for ophthalmology is limited, its potential underscores the need for independent validation and transparent methodology. Broader ethical issues also remain underexplored, including the collection of sensitive biometric and emotional data, which introduces complex privacy and governance challenges.³² Safety risks such as motion sickness and reduced awareness of real-world surroundings, especially in unsupervised settings, further complicate implementation.³² Additionally, the lack of demographic diversity in VR study populations limits the generalizability of current findings and raises concerns about equitable access.³² Finally, despite growing interest in clinical applications, the absence of clear regulatory frameworks continues to hinder ethical integration of VR in ophthalmology.³²

Future Directions

While the cost of VR implementation in ophthalmology is currently very expensive,²⁵ the cost of VR technology in the medical field as a whole has fallen and projects to continue declining as technology becomes more widespread and efficient.³³ Therefore, future research and development of VR within ophthalmology will likely aid the transition of VR from use in research studies to an affordable form of alternative clinical care. Within other fields of medicine, such as psychiatry, VR is currently being used commonly as a form of exposure therapy for patients with anxiety disorders, such as phobias or PTSD.³⁴ In psychiatry, VR has become a commonly used and affordable tool,³⁴ thanks to significant research and development that have refined its applications. Similarly, if the field of ophthalmology invests in robust

research efforts, VR could follow psychiatry's lead, evolving into a practical and cost-effective solution for visual health care.

As VR becomes more established in ophthalmic education, future research should clarify its potential impact on patient safety and training efficiency. A crucial benefit of VR implementation in surgical training is its ability to provide a risk-free environment where trainees can refine their skills before working with real patients, thereby reducing the potential for preventable harm. Simulation-based education in general has been shown to enhance both technical and non-technical performance without compromising patient safety when integrated into medical training.³⁵ While preliminary findings in ophthalmology indicate reduced complication rates and improved performance, further large-scale studies are needed to quantify the effect of VR training on patient safety when integrated with traditional methods. Simulation-based training has also been shown to reduce the learning curve for complex surgical procedures, enabling trainees to achieve technical proficiency more efficiently.³⁶ In ophthalmology, early findings suggest VR may also accelerate skill transfer between different surgical techniques, but further research is needed to assess how VR could shorten overall training time.¹³

Looking ahead, the integration of artificial intelligence (AI) with VR offers potential to transform ophthalmic education.³⁷ AI-based tools can analyze surgical video footage to assess resident performance, provide intraoperative guidance through stage recognition and complication detection, and power immersive remote training environments that simulate real-time operating room dynamics.³⁷ Future research should focus on developing validated, standardized platforms that combine AI and VR to enhance resident feedback, training outcomes, and cross-institutional implementation.

Conclusion

Our review highlights the implementation of VR into the field of ophthalmology for surgical training, clinical training, and the diagnosis and treatment of glaucoma and amblyopia. Within the field of cataract and vitreoretinal surgery, VR is being used to improve surgical technique and reduce the rates of complications in training physicians. Additionally, VR techniques are helping physicians in training improve their funduscopy and slit-lamp skill within the clinical setting. VR is also being used in glaucoma and amblyopia to improve mean defect values and improve BCVA, respectively. The high initial cost of implementing VR systems and the lack of multi-center, large sample size studies are currently slowing the implementation of VR within the field of ophthalmology. Emerging low-cost platforms have begun to address this barrier, but cost-benefit analyses are still needed to assess whether VR tools offer sufficient long-term value over traditional methods for both training and diagnostics. Furthermore, concerns about inconsistent diagnostic performance, such as high false negative rates in some VR-based perimetry devices, and the absence of unified ethical and regulatory standards continue to limit large-scale clinical adoption. By investing resources into VR and following the example set by other medical specialties to make VR more affordable and accessible, VR could revolutionize the field of ophthalmology, particularly in resident physician training and the diagnosis and treatment of ophthalmologic diseases.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas. All authors took part in drafting, revising or critically reviewing the article. Finally, all authors gave final approval of the version to be published, have agreed on the journal to which the article has been submitted, and agree to be accountable for all aspects of the work.

Disclosure

All authors report no conflicts of interest in this work.

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