© Artificial Intelligence in Vision and Ophthalmology 2025; 7:1-13
Original article
https://doi.org/10.35119/aivo.v1i1.148

Enhancing ophthalmology resident orientation with an experiential simulation lab using virtual reality technology

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Abstract

Purpose: This study explores the efficacy of a virtual reality (VR)-based simulation lab in enhancing foundational knowledge and clinical skills among PGY2 ophthalmology residents. It investigates VR's role in improving anatomical understanding, diagnostic ability, and learner confidence at the beginning of ophthalmology residency.
Methods: A 4-hour experiential simulation lab was conducted at the Loyola University Chicago simulation center using Oculus VR headsets and zSpace stereoscopic displays. PGY2 residents from 5 Chicago-based ophthalmology programs participated in interactive glaucoma and retina modules focusing on ocular anatomy, iridocorneal angle understanding, cranial nerve function, aqueous flow, and pupil examination. Pre- and post-session surveys, knowledge assessments, and anatomical drawings were used to evaluate improvements in understanding and diagnostic skill. Statistical analysis was performed using the exact Wilcoxon signed-rank test.
Results: Fourteen of 18 invited residents (77.8%) participated. Significant improvement was observed in understanding the iridocorneal angle, aqueous

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flow, and pathology diagnosis on virtual patients ($p < 0.05$). Most participants (92.9%) reported enhanced understanding of anatomy and expressed high satisfaction with the training. The majority (85.7%) would recommend the training to peers, and 92.9% supported offering it to future residents.
Conclusion: The VR-based simulation lab significantly enhanced anatomical comprehension and examination skills among ophthalmology residents. The immersive nature of the experience fostered greater learner engagement and confidence. These findings support integrating VR into early ophthalmology education to standardize and improve foundational clinical training.

Keywords: anatomy comprehension, diagnostic skills development, experiential learning in medicine medical education technology, ophthalmology education, PGY2 clinical orientation, simulation-based training, virtual reality simulation

Introduction

Virtual reality (VR) has revolutionized ophthalmic education by providing trainees with immersive, standardized, and reproducible learning environments. Its efficacy in enhancing surgical proficiency, particularly in cataract surgery, is well established, with studies demonstrating improvements in critical steps, such as capsulorhexis and phacoemulsification, while reducing complication rates.[1-6] A recent systematic review further highlighted VR's benefits in enhancing performance, self-efficacy, and non-dominant hand dexterity.[7] However, despite extensive validation in surgical training, its potential for teaching fundamental ophthalmic examination skills remains underexplored, leaving a gap in its application for early-stage resident education. Given that postgraduate year 2 (PGY2) residents enter ophthalmology training with highly variable levels of experience, VR-based training may serve as an effective bridge to standardize early clinical skill acquisition. Our study aims to fill the gap in knowledge by demonstrating how VR can establish essential basic anatomic foundations and further improve diagnostic abilities of residents entering their first year of ophthalmology training (PGY2).

We believe that the incorporation of advanced VR technology, including EyeSim Software (A Nu Reality Inc., Oakbrook, IL, USA), an ophthalmology specific application on Oculus headsets (Reality Labs, Menlo Park, CA, USA), alongside stereoscopic computer screens (zSpaceInc., San Jose, CA, USA), facilitating virtual dissections, will substantially enrich residents' foundational anatomical knowledge and eye examination skills. This innovative approach is expected to deepen their comprehension of complex concepts such as iridocorneal angle anatomy, aqueous flow, and cranial nerve dysfunctions.

This investigation is pivotal in discerning the advantages and challenges of embedding VR-based apps in ophthalmology training, a crucial step in advancing medical education. The anticipated findings from this research are expected to contribute valuable insights into the effectiveness of VR simulations in ophthalmology residency education. By providing evidence-based recommendations for the integration of VR based education resources, this study seeks to advance our understanding of simulation-based methodologies in medical education and inform future developments in ophthalmology residency curricula. As such, it represents a significant contribution to the ongoing discourse on enhancing medical education through innovative technologies and methodologies.

Methods

Problem identification

This study acknowledges the increasing need for educational approaches that are both engaging and immersive, responding to the existing deficit in advanced interactive learning resources for ophthalmology residency programs. This need is particularly pronounced for PGY2 residents who must acquire a thorough understanding of ophthalmic anatomy and examination techniques in a relatively short period of time. Residents have expressed heightened stress during the orientation period due to insufficient time dedicated to learning exam skills in medical school.[8] Therefore, our VR simulation lab is specifically designed to concentrate on ocular anatomy review, bedside eye examination skills, and the identification of pupil and cranial nerve dysfunctions.

Goals and measurable objectives

This study aims to investigate the efficacy of a VR-based stereoscopic and interactive simulation lab in enhancing knowledge, skills, and confidence of ophthalmology residents. Objectives included:

1. Demonstrating anatomical concept clarity through sketching and completing an aqueous humor flowchart.
2. Improving eye exam technique through practice on virtual patients.
3. Enhancing the residents' confidence by means of all the VR tools.

Specific aims included:

1. Increasing learner engagement through an immersive and interactive teaching method.
2. Improving residents' spatial understanding of complex anatomical structures through exploration on stereoscopic and interactive eye models.
3. Enhancing eye examination skills through deliberate practice on a virtual patient.

Educational strategies

The PGY2 ophthalmology curriculum builds upon the foundational knowledge gained during medical school and internship year, emphasizing advanced clinical skills, critical thinking, and immersive learning environments. This curriculum is designed to prepare residents for the practical demands of ophthalmology residency by integrating simulation technology to allow residents to gain confidence in foundational anatomical concepts and basic eye examination skills. The core of the program is a 4-hour experiential simulation lab that takes place within the the Stritch School of Medicine simulation center, utilizing Oculus Quest 1 VR headsets, zSpace holographic displays, and a screen stereo projector with 3D glasses. Residents were first instructed on the use of the technology by Loyola ophthalmology faculty. The sessions were conducted in July, when PGY2 residents began their integration into ophthalmology residency after completing their internship year. Participants were PGY2 residents from Loyola University Chicago, Rush University, University of Chicago, Cook County, and Northwestern University.

Implementation of VR

Provided by Loyola ophthalmology faculty trained in VR simulation, the experiential lab featured the following components:

1. Virtual dissection of the eye and orbital bones to enhance understanding of ocular anatomy.
2. Utilization of Zspace stereo screens to visualize extraocular muscles, their actions, and associated dysfunctions, illustrated through clinical scenarios involving cranial nerve palsies.
3. Practice of pupil examination skills on virtual patients, accompanied by an interactive review of pupillary reflex pathways and related dysfunctions.
4. Immersive VR visualization of the iridocorneal angle and aqueous humor physiology, allowing for correlation of anatomical variations with the diagnosis of open- and closed-angle glaucoma.

Evaluation and feedback for the VR curriculum

To assess the impact of the VR curriculum on residents' understanding, we employed both pre- and post-session surveys (Appendix A) and objective testing, with statistical analysis conducted via exact Wilcoxon signed rank tests. Participation in the surveys was voluntary and anonymous, and this aspect of the study received exemption status from the Institutional Review Board.

In addition to the surveys, 2 independent reviewers graded pre- and post-session student drawings. Participants were asked to draw structures and pathways, including the iridocorneal angle, the aqueous humor pathway, and the retinal layers, before and after the VR session. These reviewers focused on comparing drawings in terms of detail, three-dimensionality, and comprehensiveness. The grading criteria specifically evaluated 3D versus 2D drawings, accurate spatial localization of

structural components, and accurate and thorough labeling of the structures. Participants were also graded on their ability to correctly diagnose ocular pathology, including afferent pupillary defects and cranial nerve palsies on several virtual models using basic diagnostic techniques such as the swinging flashlight test and extraocular muscle testing.

Results

Fourteen of 18 (77.8%) PGY2 residents from 5 Chicago-based ophthalmology programs participated in the study. Participants showed a marked improvement in objective testing demonstrating knowledge of anatomy through illustrations. While there was improvement in all anatomical knowledge, there was significant improvement in demonstrating knowledge of the iridocorneal angle and aqueous flow pathway through illustration ($p < 0.05$) (Fig. 1). Amongst the improvements,

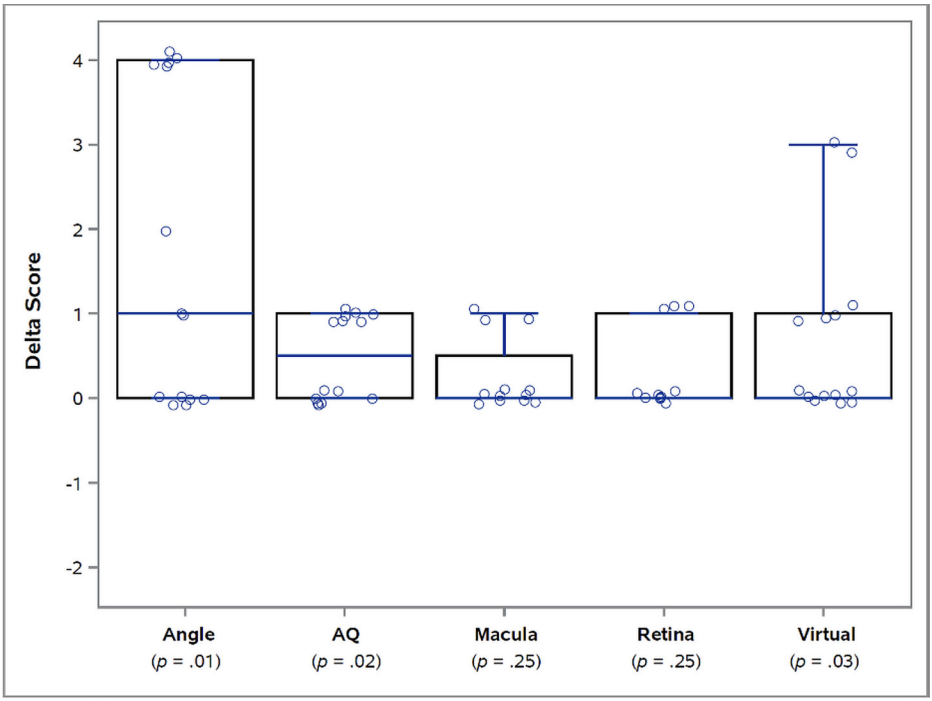

Fig. 1. PGY2's change in response (delta score) after the lab per item, analyzed using the exact Wilcoxon signed-rank test, a non-parametric method assessing whether the median difference in responses significantly differs from zero. Statistically significant differences ($p < 0.05$) are observed in assessments of the angle, aqueous humor flow (AQ), and virtual patient pathology (virtual).

the greatest change was seen with the iridocorneal angle (4 ± 1). Additionally, there was significant improvement in diagnosing pathology on virtual patients ($p < 0.05$) (Fig. 1).

Regarding confidence measures, the majority of participants indicated that the VR simulation session enhanced their understanding in specific areas: 92.8% reported improved understanding of anatomy, while 64% reported enhanced understanding of both the pupil exam and cranial nerve exam skills (Fig. 2). Participants showed a positive inclination towards recommending the training to others, with 85.7% agreeing that they would recommend the session to their peers and 92.9% of participants indicating they would recommend their residency program offer this training for PGY2s next year (Fig. 2). There was also a strong interest in the desire to pursue future learning with this technology, as 92.9% agreed they would

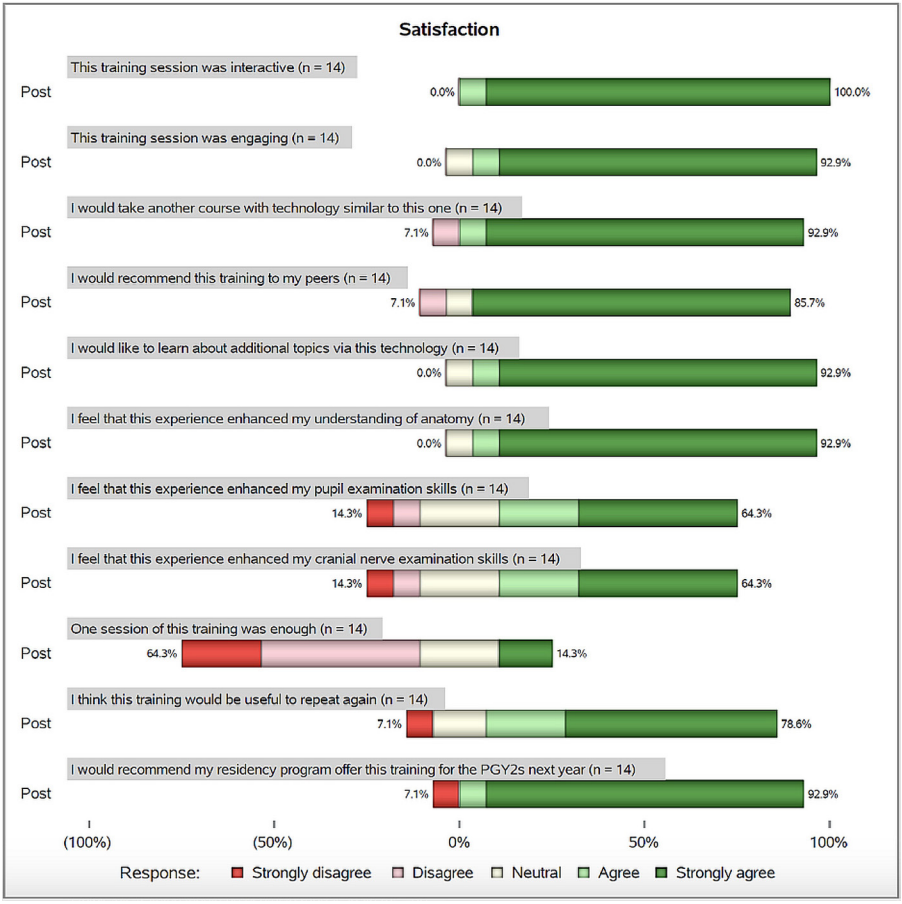

Fig. 2. PGY2's responses to the post-training satisfaction survey.

take another course using this technology and learn additional topics through it (Fig. 2). Additionally, most participants expressed that the sessions were interactive and engaging, with 100% and 92.9% agreement, respectively (Fig. 2). Lastly, 78.6% believed that the training would be useful to repeat and 64.3% strongly disagreed that 1 session was enough, indicating a desire for more extensive training (Fig. 2).

Discussion

VR in medical education, particularly in ophthalmology residency, is an emerging technological application that promises significant enhancements in training and skill acquisition. This study explores the integration of VR-based simulations in the ophthalmology residency didactics, an area that has seen limited scholarly exploration despite the growing prevalence of simulation-based medical education across various medical specialties.[9,10] Our research aims to bridge this gap by evaluating a VR-based experiential lab designed to improve learner engagement, spatial understanding, and eye examination skills. This aligns with the emerging trends in immersive learning technologies.[11–13] The results of our study corroborate these efforts and reveal noteworthy improvements among participants in both anatomical knowledge and diagnostic skills.

Adequate teaching of anatomy in medical education has been declining in recent years to a point that some clinicians describe as below an acceptable level.[14-16] With advancing technology, our goal was to evaluate whether VR can help ameliorate these deficits in teaching anatomy. One of the key findings of this study was that the participants improved anatomical conceptual clarity. The VR sessions were successful in facilitating a more comprehensive understanding of complex structures, such as the iridocorneal angle, demonstrating the potential of VR to enhance spatial and anatomical comprehension. This improvement aligns with the goals of medical education, where a thorough understanding of anatomical structures is foundational to clinical competence.

Moreover, the positive impact of VR training extended beyond anatomical knowledge to practical skills, such as pupil and cranial nerve examination. While computer-aided learning has grown in recent years and shown success in teaching clinical exam skills,[17] the body of literature on using VR to teach diagnostic techniques remains slim. A meta-analysis of VR use in ophthalmology found that the technology can improve ophthalmoscopy techniques in particular.[12] Our study adds to the literature by demonstrating improvements in fundamental diagnostics such as extraocular movement and swinging flashlight testing. Participants expressed that the interactive and engaging nature of the VR sessions contributed significantly to honing these clinical skills. This finding suggests that VR technology not only aids in theoretical understanding but also translates into tangible improvements in the basic practical aspects of ophthalmological practice.

The participants' feedback on the VR training sessions was overwhelmingly positive, with a majority expressing a heightened understanding of anatomy and improved examination skills. In addition, the participants' confidence was profoundly improved from the sessions, which may serve to alleviate the stress that trainees noted during their transition to residency.[8] The enthusiasm expressed by participants, coupled with their willingness to recommend the training to peers and future trainees, underscores the potential for integrating VR technology into mainstream medical education. The desire for additional similar courses and the acknowledgment that a single session was insufficient further emphasize the need for continued exploration and integration of VR based educational resources into ophthalmology residency programs.

It is essential to acknowledge the limitations of this study, such as the relatively small sample size and potential biases associated with self-reported data. While 78% of the total PGY2 residents in the Chicago area participated, future research could focus on larger and more diverse cohorts to ensure the generalizability of findings. This could be achieved through administering this simulation experience to a broader region or by compiling results from new PGY2 participants over several years. Additionally, longitudinal studies could provide insights into the long-term retention and applicability of the skills acquired through VR based training.

In conclusion, this research contributes valuable insights into the efficacy of VR-based simulations in enhancing medical training, particularly in ophthalmology residency programs. The positive outcomes observed in anatomical knowledge, diagnostic skills, and overall participant satisfaction highlight the potential of VR as a transformative experience in medical education. As technology continues to advance, further exploration and integration of VR into medical curricula can contribute to the evolution of training methodologies, ultimately benefiting the competence and proficiency of future ophthalmologists.

Declarations

Ethics approval and consent to participate
This study received exemption status from the Institutional Review Board.

Competing interests
The authors declare that they have no competing interests.

Funding
This work was supported in part by the Perritt Charitable Foundation Grant, which provided funding for the virtual reality software license used in this study.

Acknowledgements
We extend our thanks to the Loyola University Chicago Department of Biostatistics for their invaluable statistical support.

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Appendix

A. PGY2 VR Curriculum PRE test

1. Draw the iridocorneal angle and associated structures.

2. Fill in the typical flow of aqueous humor.

3.

Virtual patient #1 diagnosis: _____

Virtual patient #2 diagnosis: _____

Virtual patient #3 diagnosis: _____

Virtual patient #4 diagnosis: _____

END OF PRETEST! Please don't turn the page yet :)

B. PGY2 VR Curriculum POST Test

Rate your agreement with each statement on a scale of 1 (strongly disagree) to 5 (strongly agree).

A. This training session was interactive.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

B. This training session was engaging.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

C. I would take another course with technology similar to this one.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

D. I would recommend this training to my peers.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

E. I would like to learn about additional topics via this technology.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

F. I feel this experience enhances my understanding of anatomy.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

G. I feel that this experience enhanced my pupil examination skills.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

H. I feel that this experience enhanced my cranial nerve examination skills.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

I. One session of this training was enough.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

J. I think this training would be useful to repeat again.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

K. I would recommend my residency program offer this training for the PGY2's next year.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1. Draw the iridocorneal angle and associated structures.

2. Fill in the typical flow of aqueous humor.

3.

Virtual patient #1 diagnosis: _____

Virtual patient #2 diagnosis: _____

Virtual patient #3 diagnosis: _____

Virtual patient #4 diagnosis: _____