Perspectives in vitreoretinal surgery: profound and continuous transformation

Perspectivas na cirurgia vitreorretiniana: transformação profunda e contínua

Lucas Zago Ribeiro[1], Mauricio Maia[1]

[1]Department of Ophthalmology and Visual Sciences, Federal University of São Paulo, São Paulo, SP, Brazil

How to cite:
Ribeiro LZ, Maia M. Perspectives in vitreoretinal surgery: profound and continuous transformation. Rev Bras Oftalmol. 2025;84 (Supl. 3):ex0001.

doi:
https://doi.org/10.37039.1982.8551.2025S3ex0001

Received on:
June 6, 2025

Accepted on:
June 11, 2025

Corresponding author:
Mauricio Maia, MD, PhD, Department of Ophthalmology and Visual Sciences, Federal University of São Paulo, CEP 04021-001, São Paulo, Brazil (Phone: +55-11-557-64981; mmaia@unifesp.br)

Institution:
Department of Ophthalmology and Visual Sciences, Federal University of São Paulo, São Paulo, SP, Brazil

Conflict of interest:
no conflict of interest.

Vitreoretinal surgery, which is dedicated to the management of complex disorders of the retina and vitreous, has undergone remarkable changes in the last 5 decades.[1,2] What began as a high-risk intervention with unpredictable outcomes has improved into a safe and effective approach, offering innovative therapies for previously untreatable diseases. This editorial highlights the current state of vitreoretinal surgery and explores future directions.

The journey of vitreoretinal surgery started with Machemer and Parel's pioneering introduction of pars plana vitrectomy (PPV) in 1970. As with any disruptive technology, each successive advance over the past decades has had to demonstrate superiority while overcoming practical barriers such as high cost, learning curves, and surgeons' preference for established techniques.

For more than three decades, 20-gauge PPV remained the surgical mainstay. Early in the 21st century, the advent of transconjunctival 23-gauge systems reduced surgery-related trauma, shortened operating time, lowered the risk of iatrogenic retinal breaks, and promoted faster wound healing without sacrificing efficiency.[3]

Subsequent 25- and 27-gauge systems were introduced, but early probes were compromised by slower cut rates and reduced flow. Progressive increases in cut rates – now reaching 30,000 cuts per minute – have positioned the 25-gauge system as the platform preferred by most surgeons.[4-6]

Vital dyes have become indispensable in modern chromovitrectomy because they turn transparent tissues into visible surgical targets. Brilliant blue G (BBG) remains the first-line dye used for internal limiting membrane (ILM) peeling thanks to its high affinity and favorable safety record,[7] whereas preservative-free triamcinolone acetonide is still the workhorse for highlighting the posterior hyaloid.[8] Combination preparations containing BBG and trypan blue also have improved staining of the ILM and epiretinal membranes.[9]

Two recent Brazilian contributions deserve to be mentioned: the addition of soluble lutein–zeaxanthin crystals to BBG,[10] now commercially available in Brazil, and the dye extracted from açaí (*Euterpe oleracea*), which remains under experimental investigation.[11]

The advent of three-dimensional (3D) heads-up surgery and real-time intraoperative optical coherence tomography (OCT) has set new standards for surgical precision. These systems provide unparalleled visualization, enabling surgeons to make real-time decisions based on live data.[12,13] In Brazil, two heads-up platforms are currently marketed: Alcon Ngenuity® and Carl Zeiss Artevo 800.

Emerging platforms include the Bausch & Lomb SeeLuma™ heads-up system, which integrates the Heidelberg OCT technology. The Beyeonics One exoscope from Israel goes a step further, replacing the traditional tower and monitor with a lightweight augmented-reality headset and eliminating the need for external 3D monitors.[14]

Gene therapy represents a major milestone in the treatment of inherited retinal diseases. Voretigene neparvovec-rzyl (Luxturna®, Novartis), targeting *RPE65*-mutated retinal dystrophies, is the first ocular gene therapy approved by the US Food and Drug Administration (FDA).[15] Brazilian groups have already treated patients with this therapy, demonstrating both its feasibility and associated challenges.[16] Numerous clinical trials are currently underway for a variety of retinal conditions, including degenerative macular diseases such as wet age-related macular degeneration, which have a promising therapeutic frontier, although high costs and complex technical-logistical demands remain major barriers.

In addition, therapies using embryonic stem-cell–derived retinal pigment epithelium cells show encouraging potential for visual improvement in dystrophic and degenerative diseases.[17]

Although current anti-vascular endothelial growth factors agents and corticosteroids have greatly improved the management of many retinal disorders, the substantial treatment burden underscores the need for longer lasting, more efficient therapies. Multiple studies are investigating implants and/or sustained-release systems, such as the Port Delivery System (Susvimo, Genentech), a refillable ranibizumab reservoir, to reduce injection frequency and enhance adherence and efficacy. The remaining challenges include the implant size, leakage rates, infection risk, and refill difficulties; however, phase 3 results have been encouraging.[18,19] This approach is likely to gain prominence in the coming years and may be incorporated into routine clinical practice.

Surgical simulators have advanced significantly in recent years, allowing for frequent use in training and enabling a better understanding of surgical techniques. Platforms, such as EYESi (VRmagic, Mannheim, Germany), allow residents and fellows to practice complex maneuvers in a controlled, repeatable, and risk-free setting, improving both dexterity and decision-making.[20] Beyond technical skill acquisition, these simulators enable researchers to evaluate how external factors – such as caffeine intake, alcohol consumption, tremor, sleep deprivation, and even pharmacologic modulation – affect surgical performance.[21-23] Such insights would be ethically and logistically unfeasible to obtain in real-life operating rooms. As a result, virtual reality simulators not only enhance the preparation of new surgeons but also serve as valuable tools for studying human performance and optimizing intraoperative behavior in ways that directly impact patient outcomes. Their practicality and relevance continue to grow, and they are expected to become an increasingly integral part of surgical training and research.

Despite noteworthy progress, several challenges persist. High equipment costs still restrict access to state-of-the-art care, especially in resource-limited environments. Clinically, proliferative vitreoretinopathy and the absence of an ideal vitreous substitute continue to challenge surgeons, while each new generation of instruments lengthens the learning curve and demands ongoing investment in training.

Looking into the future, the field's trajectory will be shaped by the convergence of artificial intelligence, surgical robotics, personalized gene-based therapies, and next-generation imaging and vitrectomy platforms. These technologies promise unprecedented precision and efficiency.

Vitreoretinal surgery now exists in a transformative era. Recent advances have expanded the range of treatable diseases and elevated both anatomic and functional outcomes, ultimately improving patients' quality of life. As the field continues to evolve, ensuring the accessibility of these innovations is essential so that patients worldwide can benefit from the remarkable progress achieved. Through sustained research, cross-disciplinary collaboration, and a commitment to global equity, the future of vitreoretinal surgery can be as inclusive as it is extraordinary.

REFERENCES

1. Abrams GW, Topping T, Machemer R. An improved method for practice vitrectomy. Arch Ophthalmol. 1978;96(3):521-5.
2. Machemer R, Buettner H, Norton EW, Parel JM. Vitrectomy: a pars plana approach. Trans Am Acad Ophthalmol Otolaryngol. 1971;75(4):813-20.
3. Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. Retina. 2005;25(2):208-11.
4. Chow SC, Lo JM, Quddus M, Li Q, Lam WC, Fung NS. Performance, safety and efficiency comparison between a 25G 20,000 and a 10,000 cuts per minute vitrectomy: a prospective randomized control study. Int J Retina Vitreous. 2025;11(1):45.
5. Mitsui K, Kogo J, Takeda H, Shiono A, Sasaki H, Munemasa Y, et al. Comparative study of 27-gauge vs 25-gauge vitrectomy for epiretinal membrane. Eye (Lond). 2016;30(4):538-44.
6. Stone T. 17th Annual Preferences and Trends Survey. Poster presented at: American Society of Retina Specialists 33rd Annual Meeting. Vienna, Austria; 2015.

7. Enaida H, Hisatomi T, Hata Y, Ueno A, Goto Y, Yamada T, et al. Brilliant blue g selectively stains the internal limiting membrane/brilliant blue g-assisted membrane peeling. Retina. 2006;26(6):631-6.
8. Bergamo VC, Caiado RR, Maia A, Magalhães O Jr, Moraes NS, Rodrigues EB, et al. Role of vital dyes in chromovitrectomy. Asia Pac J Ophthalmol (Phila). 2020;10(1):26-38.
9. Iuliano L, Kacerik E, Corbelli E, Bandello F, Codenotti M. Intraoperative efficacy and clinical outcomes of two commercial staining solutions used in idiopathic epiretinal membrane surgery. Int Ophthalmol. 2021;41(3):1033-41.
10. Maia M, Furlani BA, Souza-Lima AA, Martins DS, Navarro RM, Belfort R Jr. Lutein: a new dye for chromovitrectomy. Retina. 2014;34(2):262-72.
11. Caiado RR, Peris CS, Lima-Filho AA, Urushima JG, Novais E, Badaró E, et al. Retinal toxicity of acai fruit (Euterpe Oleracea) dye concentrations in rabbits: basic principles of a new dye for chromovitrectomy in Humans. Curr Eye Res. 2017;42(8):1185-93.
12. Kantor P, Matonti F, Varenne F, Sentis V, Pagot-Mathis V, Fournié P, et al. Use of the heads-up NGENUITY 3D Visualization System for vitreoretinal surgery: a retrospective evaluation of outcomes in a French tertiary center. Sci Rep. 2021;11(1):10031.
13. Palácios RM, Maia A, Farah ME, Maia M. Learning curve of three-dimensional heads-up vitreoretinal surgery for treating macular holes: a prospective study. Int Ophthalmol. 2019;39(10):2353-9.
14. Schwartz S, Gomel N, Loewenstein A, Barak A. Use of a novel Beyeonics One three-dimensional head-mounted digital visualization platform in vitreoretinal surgeries. Eur J Ophthalmol. 2024;34(3):880-3.
15. Russell S, Bennett J, Wellman JA, Chung DC, Yu ZF, Tillman A, et al. Efficacy and safety of voretigene neparvovec (AAV2-hRPE65v2) in patients with RPE65-mediated inherited retinal dystrophy: a randomised, controlled, open-label, phase 3 trial. Lancet. 2017;390(10097):849-60.
16. Ferraz Sallum JM, Godoy J, Kondo A, Kutner JM, Vasconcelos H, Maia A. The first gene therapy for RPE65 biallelic dystrophy with voretigene neparvovec-rzyl in Brazil. Ophthalmic Genet. 2022;43(4):550-54.
17. Brant Fernandes RA, Lojudice FH, Zago Ribeiro L, Santos da Cruz NF, Polizelli MU, Cristovam PC, et al. Transplantation of subretinal stem cell-derived retinal pigment epithelium for stargardt disease: A Phase I Clinical Trial. Retina. 2023;43(2):263-74.
18. Holekamp NM, Campochiaro PA, Chang MA, Miller D, Pieramici D, Adamis AP, et al. Archway randomized phase 3 trial of the Port Delivery System with ranibizumab for neovascular age-related macular degeneration. Ophthalmology. 2022;129(3):295-307.
19. Sun Y, Miller DC, Akpandak I, Chen EM, Arnold BF, Acharya NR. Association between immunosuppressive drugs and Coronavirus disease 2019 outcomes in patients with noninfectious uveitis in a large US claims database. Ophthalmology. 2022;129(10):1096-106.
20. Roizenblatt M, Jiramongkolchai K, Gehlbach PL, Dias Gomes Barrios Marin V, Treiger Grupenmacher A, Muralha F, et al. A multifactorial approach for improving the surgical performance of novice vitreoretinal surgeons. Retina. 2021;41(10):2163-71.
21. Roizenblatt M, Gehlbach PL, da Silveira Saraiva V, Nakanami MH, da Cruz Noia L, Watanabe SE, et al. Weight-adjusted caffeine and β-blocker use in novice versus senior retina surgeons: a self-controlled study of simulated performance. EYE. 2023;37(14):2909-14.
22. Roizenblatt M, Fidalgo TM, Polizelli M, Cruz NF, Roizenblatt A, Jiramongkolchai K, et al. Effect of chronic cocaine use on fine motor coordination tested during ophthalmic vitreoretinal simulated performance. J Psychiatr Res. 2021;132:7-12.
23. Roizenblatt M, Dias Gomes Barrios Marin V, Grupenmacher AT, Muralha F, Faber J, Jiramongkolchai K, et al. Association of weight-adjusted caffeine and β-blocker use with ophthalmology fellow performance during simulated vitreoretinal microsurgery. JAMA Ophthalmol. 2020;138(8):819-25.