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Review Article

Robotics and laser applications in ophthalmic surgery: Current advances, challenges, and future prospects

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Abstract

Robotics and laser technology integration into ophthalmic surgery has represented a paradigm shift in the precision, security, and effectiveness of ocular interventions. Robotic systems have been shown to have considerable potential in the management of physiological tremors, facilitation of complex microsurgical manoeuvres, and extending the frontiers of intraocular and orbital surgeries. In parallel, femtosecond lasers and excimer lasers have transformed refractive, cataract, and oculoplastic surgeries by improving accuracy and reducing collateral tissue damage. Despite these advances, challenges remain, including high costs, steep learning curves, ergonomic concerns, and limited global accessibility. Recent developments in artificial intelligence (AI) and robotic integration further highlight the transformative potential of these technologies in ophthalmology, especially in vitreoretinal and cataract surgeries. This review synthesizes existing evidence regarding robotic and laser technology use in ophthalmic surgery, examines their safety, feasibility, and drawbacks, and delves into future directions such as AI-based platforms, telesurgery, and implementation in resource-limited environments.

Keywords: Robotic surgery, Ophthalmology, Laser applications, Vitreoretinal surgery, Cataract surgery, Artificial intelligence, Femtosecond laser, Surgical ergonomics, Telesurgery.

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1. Introduction

Ophthalmic surgery has witnessed a revolutionary change in the last few decades with the quest for higher precision, safety, and reproducibility. The anatomy of the human eye offers special surgical challenges because of its complexity, fine tissues, and micron-level precision needed for successful interventions. Traditional microsurgical techniques, although efficacious, are frequently hampered by physiological tremors, limited manoeuvrability, and the inherent nature of human variability.[4] These constraints have driven the implementation of sophisticated technologies like robotics and lasers into ophthalmological practice. Robotic systems offer increased dexterity, tremor filtering, and enhanced visualization, enabling surgeons to conduct extremely complicated intraocular and orbital procedures with more precision.[1,2] In vitreoretinal surgery, robotic technology has provided unrivaled precision in retinal vein cannulation and subretinal injection, tasks that are still very daunting with manual methods.[10,23] Robotic systems have also been tried in strabismus, orbital oncology, and cataracts with promising initial outcomes.[6,11,13] **Table 1** presents a comparison of traditional vs. laser- and robotic-assisted ophthalmic surgery techniques

Concurrently with robotics, laser technology has transformed the ophthalmic surgical environment. Femtosecond and excimer lasers have revolutionized cataract and refractive surgery with bladeless, accurate corneal and lens cuts, minimizing complications and enhancing visual results.[9,27] Laser technology has also become increasingly important in oculoplastic and orbital surgery, with tissue-selective ablation and minimal destruction of surrounding structures.[24,31] The last few years have also seen the advent of artificial intelligence (AI) in conjunction with robotic platforms, with an aim to improve decision-making, surgical planning, and intraoperative navigation.[5,13] Not only do these developments unveil the disruptive potential of robotics and

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lasers in ophthalmology, but they also reflect an increasing requirement for diligent assessment of their clinical efficacy, availability, and cost-effectivenes.[28,32]

This review gives a general overview of the state of robotic and laser technology in ophthalmic surgery today. It assesses how they affect precision in surgery and outcomes, considers drawbacks such as ergonomics and training issues, and maps out the future possibilities, including AI, telesurgery, and extended use in developing healthcare systems.

2. Robot-Assisted Surgery in Ophthalmology

2.1. Historical background and evolution

Ophthalmic surgery has also evolved dramatically by embracing robotic technologies, laser devices, and artificial intelligence to improve surgical accuracy, safety, and reproducibility.[1-3] Robotic systems were first introduced to improve microsurgical accuracy and decrease the risk of human error.[16-20] Early systems were mainly experimental, with attention being given to ergonomics and training of the surgeon.[18,19,21] With the passage of time, these systems transformed to clinical viability in retinal, cataract, and orbital surgeries.[3,12,15] **Table 2** illustrates the chronology of significant milestones of robotic and laser ophthalmic surgery. Robotic-assisted ophthalmic surgery confers great advantages by minimizing physiological tremors, facilitating high-precision micro-manipulations, and enhancing surgical outcomes, especially in vitreoretinal and orbital surgery.[4,6,11,15,23,34] Multiple robotic platforms, such as the Da Vinci system, RAOS, and ophthalmic specialty robots, are shown to be effective in enhancing instrument stability, dexterity, and reproducibility, with decreased surgical errors and improved patient safety noted in studies.[1-3,7,15]

Laser technology, specifically femtosecond and excimer lasers, has transformed refractive and corneal surgery by offering accurate incision depth, repeatable ablation profiles, and minimal collateral damage to the surrounding tissues.[8,9,24,29] Femtosecond laser surgery enables precise lamellar dissection, flap creation, and capsulotomy, whereas excimer lasers enhance LASIK and PRK outcomes.[24,25] In addition to corneal use, lasers enable oculoplastic and anterior segment operations, where CO2 and Er:YAG lasers minimize postoperative morbidity and induce accelerated healing.[30] Moreover, AI interfacing with robots further improves surgical accuracy through real-time feedback, monitoring instrument trajectories, anticipating tissue behaviour, and allowing semi-autonomous manoeuvres.[5,13,31,32] This combination enables adaptive control in sophisticated procedures and minimizes intraoperative errors. Ergonomics and surgeon fatigue also continue to be major concerns in robotic ophthalmology. Although robotic systems minimize musculoskeletal fatigue and tremor-induced errors, lengthy procedures can exact cognitive tolls, making training methods more structured and simulation-based learning more important.[18,40,41] Standardized curriculum, virtual reality modules, and competency-based programs are vital for maximizing performance and patient safety.[18,32,40] **Table 3** presents the subspecialty-by-subspecialty comparison of traditional vs. laser- and robotic-assisted methods in eye surgery.

Although clinical value, challenges to adoption include initial cost, low availability in resource-poor areas, and the requirement for extensive training.[7,28,32] Worldwide trends towards adoption are seen with advanced robotic centers highly localized in North America, Europe, and some parts of Asia, while developing regions have nascent programs in development.[7,32] Regulatory barriers, system consistency, and cost-benefit analysis are still essential for wider implementation.[28,35] In conclusion, the marriage of robotics, laser technologies, and AI embodies a new paradigm in ophthalmic surgery that presents safer, more accurate, and reproducible results. Ongoing technological optimization combined with formal training and evidence-based assessment is needed to unlock the entire clinical potential of these advancements.[1,2,5,7,13,23,24]

3. Discussion

Robot-assisted ophthalmic surgery is a paradigm change in eye care that combines microsurgical accuracy with high-technology robotics and AI to achieve beyond human limitations of tremor, fatigue, and limited dexterity.[1,3,4] The findings of this review underscore major advances in anterior segment and posterior segment surgeries and increasing use of AI-assisted guidance in optimizing surgical results.[2,5,32] the benefits and limitations of lasers and robotics in ophthalmology are summarized in **Table 4**.

3.1. Technological impact and clinical significance

Robotic technology provides unmatched precision with microsurgical movements. As a case in point, robotic retinal vein cannulation and vitreoretinal surgery illustrate sub-millimetres accuracy that is superior to traditional manual intervention.[10,34] This is particularly important in sensitive ocular structures where even slight variations can cause irreversible damage.[4,34] Femtosecond lasers and robotic systems have synergistically enhanced the outcomes of refractive surgery, minimizing complications such as irregularities in the flap, capsulotomy that is not complete, and damage to endothelial cells.[8,9,24] Robotic orbital and strabismus surgery have also shown to be feasible and may increase the role of minimally invasive techniques in complex ocular conditions.[6,11] Integration of AI into robotic surgery can optimize intraoperative decision-making, predict surgical challenges, and minimize human error. Algorithms may aid in tissue identification, path planning, and instrument manipulation, enabling a semi-autonomous surgical process.[5,13,32]

3.2. Research gaps and future directions

The literature on robotic ophthalmic surgery also identifies areas for additional research:

1. Long-term Clinical Outcomes: Short-term feasibility and safety are reported by most; longitudinal studies of robotic vs. manual surgery are warranted.[2,10,22]
2. AI Optimization: Improvement of adaptive learning algorithms that can make decisions in real time and prevent errors is still in the early stages.[5,13,32]
3. Cost-Effectiveness Analyses: Thorough economic analysis must support robotic investment compared with conventional surgery, taking into account direct healthcare costs as well as indirect costs.[12,29,33]
4. Ergonomics and Surgeon Wellbeing: Future research should measure the extent to which robotic systems alleviate fatigue, musculoskeletal stress, and cognitive burden for long procedures.[41]
5. Integration with Telemedicine: Remote robotic interventions may enhance access to specialist care in rural and underserved areas.[19,20]

3.3. Implications for clinical practice

Robotic platforms are slowly revolutionizing ophthalmology, especially for advanced vitreoretinal procedures, paediatric operations, and high-accuracy anterior segment interventions.[10,34] With decreased human error and improved ergonomics, robotic-assisted surgery holds promise for enhancing patient safety, surgical efficiency, and reproducibility. Nonetheless, due attention needs to be paid to cost, training, infrastructure, and ethical issues prior to widespread adoption.[7,12,28,35] Surgeons, administrators, and policymakers need to work together to promote equitable access and suitable regulatory policies.

Ophthalmic surgery has been revolutionized considerably by robotic and laser technologies with unprecedented accuracy and safety of microsurgical procedures. In the past two decades, several studies have shown robotic systems can alleviate physiologic tremors, enhance surgical precision, and enable subtle maneuvers in vitreoretinal and anterior segment surgery that would be very difficult to achieve manually.[4,6,10,23,24] The literature today emphasizes that these systems are not adjuncts but transforming tools that broaden the boundaries of human surgical capability.[1-3,7,12] Robotic-assisted surgery has been found to improve outcomes in strabismus correction, vitreoretinal manipulations, orbital tumour excisions, and cataract surgery. For example, Bourcier et al. (2019) showed the effectiveness of robot-assisted simulated strabismus surgery with high accuracy and low tissue trauma.[6] Likewise, Mi et al. (2025) emphasized the application of robotic systems in vitreoretinal surgery in terms of enhanced dexterity, decreased procedural variability, and micro-incisional precision beyond physiological limits.[23,24]

The integration of laser technologies, such as femtosecond and excimer lasers, has also further widened the scope of surgery by allowing precise corneal incisions, capsulotomies, and refractive corrections.[8,9,24,30] **Table 5** also gave the specifications of major robotic and laser platforms for ophthalmic surgery. Laser procedures reduce collateral tissue damage, decrease postoperative inflammation, and enhance visual recovery more quickly, supplementing robotic systems by offering predictable, reproducible tissue manipulation. This combination of laser precision with robotic stability is a synergistic development in ophthalmic surgery.[25,29] An important addition to this evolution is the inclusion of artificial intelligence (AI). AI-based platforms provide intraoperative advice, recognition of tissues, and predictive modelling to assist surgeons with decision-making and risk reduction.[5,13,32] AI algorithms are able to track minor intraoperative parameters, identify discrepancies in real time, and make recommendations reducing human error, hence improving both patient safety and procedural effectiveness.

Table 1: Comparison of conventional vs. laser- and robotic-assisted techniques in ophthalmic surgery

Parameter	Conventional (Manual) Techniques	Laser- and Robotic-Assisted Techniques
Precision	Dependent on surgeon's manual dexterity; limited by physiologic tremor and fatigue	Micron-level accuracy with robotic stabilization and femtosecond/excimer laser precision; eliminates tremor effects
Reproducibility	Variable outcomes due to inter-surgeon differences	High reproducibility due to automation and standardized laser algorithms
Intraoperative Safety	Higher risk of iatrogenic trauma in delicate tissues (e.g., retina, cornea)	Enhanced safety with stabilized robotic platforms and controlled laser energy delivery
Learning Curve	Skills acquired through prolonged training and surgical experience	Robotic interfaces, haptic feedback, and simulators shorten learning curve; structured training platforms available
Ergonomics	High musculoskeletal strain and fatigue during long procedures	Improved ergonomics; robotic systems reduce strain and allow comfortable surgeon posture
Invasiveness	Larger incisions and greater tissue disruption in some procedures (e.g., cataract surgery)	Minimally invasive laser-assisted incisions and precise capsulotomies reduce collateral damage

Procedure Time	Often longer due to manual steps and complexity	Reduced time in standardized steps (e.g., femtosecond laser capsulotomy); but robotic setup may initially prolong total time
Patient Recovery	Variable; often longer due to greater tissue trauma	Faster recovery, reduced inflammation, and improved visual outcomes
Cost	Lower initial setup; widely available	High acquisition and maintenance costs; limited accessibility in low-resource settings
Clinical Applications	Widely applied in cataract, corneal, retinal, and orbital surgeries using manual tools	Increasingly applied in vitreoretinal surgery, refractive surgery, cataract surgery, and orbital oncology with ongoing expansion

Table 2: Timeline of key milestones in robotic and laser ophthalmic surgery

Year/Decade	Milestone
1980s	Introduction of excimer laser for corneal refractive surgery (keratomileusis)
1990s	Widespread adoption of excimer laser in LASIK and PRK
Early 2000s	Emergence of femtosecond lasers for corneal flap creation in LASIK
Mid 2000s	Application of femtosecond lasers in cataract surgery (capsulotomy, lens fragmentation)
2010s	Introduction of robotic platforms (e.g., Preceyes) for vitreoretinal microsurgery
2016	First human trials of robot-assisted retinal vein cannulation and subretinal injection
Late 2010s	Expansion of femtosecond laser applications in keratoplasty and complex cataracts
2020s	Integration of AI with robotic and laser systems; exploration of telesurgery in ophthalmology
Future	Personalized robotic-laser-AI hybrid platforms; global expansion of tele surgical ophthalmology

Table 3: Subspecialty-wise comparison of conventional vs. laser- and robotic-assisted techniques in ophthalmic surgery

Subspecialty	Conventional (Manual) Techniques	Laser- and Robotic-Assisted Techniques
Cataract Surgery	Manual capsulorhexis and phacoemulsification; variable incision sizes	Femtosecond laser-assisted capsulotomy, corneal incisions, and lens fragmentation with reproducible precision
Refractive Surgery	Mechanical microkeratome for corneal flap creation (LASIK); PRK with manual excimer ablation	Femtosecond laser for flap creation; excimer laser with image-guided platforms for highly customized ablations
Vitreoretinal Surgery	Manual membrane peeling, subretinal injections, and vein cannulation; higher risk of retinal damage	Robotic platforms stabilize instruments for microscale manoeuvres; precise subretinal injections and vascular cannulations
Corneal Surgery	Manual trephination and sutured grafts in keratoplasty	Femtosecond laser-assisted corneal incisions, lamellar dissections, and sutureless graft placement
Glaucoma Surgery	Manual trabeculectomy and tube shunt implantation	Emerging use of femtosecond lasers for precise sclerostomy; robotic assistance under exploration
Orbital and Oculoplastic Surgery	Manual dissection and tumour excision; limited by access and visibility	Robotic-assisted minimally invasive resections with enhanced visualization and dexterity; potential applications in orbital oncology
Strabismus Surgery	Manual recession and resection of extraocular muscles	Early development of robotic systems to enhance precision and reduce variability

Table 4: Advantages and limitations of robotics and lasers in ophthalmology

Aspect	Advantages	Limitations
Precision	Micron-level accuracy; tremor elimination; consistent outcomes	Dependent on calibration, imaging resolution, and system integration
Reproducibility	Standardized and automated procedures; reduced inter-surgeon variability	Limited adoption and validation in large multicentred studies
Safety	Reduced iatrogenic trauma; controlled energy delivery (lasers)	System errors or failures could introduce new risks

Ergonomics	Minimizes surgeon fatigue and musculoskeletal strain	Requires adaptation to new interfaces and workflows
Learning & Training	Simulation, haptic feedback, and AI-assisted learning reduce training risks	Steep learning curve; extensive training required for mastery
Patient Outcomes	Faster recovery, fewer complications, improved visual outcomes	Long-term outcomes not yet fully validated
Access & Cost	Potential to expand advanced care with telesurgery and automation	High acquisition and maintenance costs; limited availability in resource-poor settings

Table 5: Key robotic and laser platforms in ophthalmic surgery

Platform/System	Type	Key Features	Applications	Current Clinical Status
Preceyes Surgical System	Ophthalmic robotic platform	Micron-level precision, tremor elimination, telemanipulation	Vitreoretinal surgery (membrane peeling, subretinal injections)	Early clinical trials, CE-marked in Europe
Da Vinci Surgical Robot	General robotic system	Multi-arm robotic control, 3D visions, tremor filtration	Orbital and oculoplastic surgery (tumour resection, reconstructive surgery)	Widely used in general surgery; adapted experimentally in ophthalmology
Micron Handheld Microrobot	Handheld robotic tool	Active tremor cancellation, enhanced instrument stability	Retinal microsurgery	Prototype stage, experimental
LenSx Laser	Femtosecond laser	Precise corneal incisions, capsulotomy, lens fragmentation	Cataract surgery	Widely adopted; FDA-approved
Catalys Precision Laser System	Femtosecond laser	Image-guided planning, customizable parameters	Cataract surgery	Clinically established
Victus Femtosecond Laser	Femtosecond laser	Multi-application platform (cataract + corneal surgery)	Cataract and refractive surgery	Clinically established
Excimer Laser Platforms (e.g., VISX, WaveLight)	Excimer laser	UV laser ablation with wavefront/ topography-guided modes	Refractive surgery (LASIK, PRK)	Globally adopted, gold standard

Although these benefits have been reported, practical limitations remain with the application of laser and robotic systems. High costs, deep learning curves, and issues of accessibility are important barriers, especially where low-resource settings are involved.[7,28,32] Ergonomic factors also take priority; robotic systems minimize surgeon fatigue and error due to tremor, but lengthy procedures continue to necessitate optimal training programs and cognitive ability development.[18,40,41] Solutions to these limitations are necessary for broad-scale applicability and sustainability of these technologies. From a global health point of view, robotic and laser-based systems can potentially democratize sophisticated ophthalmic treatment. Remote telesurgery and AI-based platforms can enable specialist surgeons to remotely direct operations in under-resourced areas, reducing inequality in access to quality eye treatment.[19,20] This is especially important in areas with high rates of vision-debilitating disorders such as uncorrected refractive disorders, diabetic retinopathy, and intricate cataracts.[26,27] In short, the robotic and laser-based ophthalmic surgery is not an incremental advance but a paradigm shift. With the integration of precision, AI-based decision support, and ergonomic advantages, these technologies hold the potential for safer, more effective, and more accessible surgical care. Yet to realize their full transformative value requires consistent research, cost optimization, regulatory monitoring, and formal training.

4. Conclusion

Robotic and laser-assisted eye surgery constitute a revolution in contemporary eye care with unparalleled precision, tremor-free operations, and compatibility with state-of-the-art imaging and AI systems. The last decade has seen a plethora of studies establishing the safety, effectiveness, and practicability of robotic systems in vitreoretinal, cataract, strabismus, and orbital surgeries.[1-7,10,11,23,33] Femtosecond lasers and other laser technologies continue to improve accuracy and safety in refractive, corneal, and oculoplastic surgeries.[8,9,14,24,30]

4.1. Key takeaways

1. Improved Surgical Precision and Outcomes: Robotic systems diminish physiologic tremor, facilitate microscale manipulations, and permit complex procedures with greater reproducibility.[4,6,10,34]
2. Integration of AI: Artificial intelligence provides real-time guidance, tissue recognition, and predictive analytics, which can improve intraoperative decision-making and postoperative outcomes.[5,13,32]
3. Training and Ergonomics: Robotic platforms enhance surgeon ergonomics and alleviate fatigue, while simulation-based training mitigates the steep learning curve.[18,40,41]
4. Limitations: Technical issues (e.g., absence of haptic feedback), infrastructure needs, and high costs continue to hinder universal adoption.[7,12,29,33,38]
5. Future Directions: Miniaturization advancements, tele-robotic surgery, modular platforms, and AI-supported autonomous systems hold the promise to improve accessibility and minimize ophthalmic care disparities.[5,19,20,32]

4.2. Recommendations for Clinical Practice and Research

1. Investment in Training Programs: Develop uniform, simulation-based training programs for robotic eye surgery to hasten skill development while ensuring patient safety.[18,40]
2. Cost-Effective Alternatives: Promote the development of modular or reusable robotic devices to lower economic barriers.[29,33]
3. Regulatory and Ethical Readiness: Establish definitive guidelines for AI-enabled and semi-autonomous interventions, encompassing data protection, patient consent, and accountability systems.[28]
4. Multidisciplinary Research: Encourage multidisciplinary collaborations among engineers, ophthalmologists, AI experts, and policymakers to ensure optimal system design, performance, and clinical integration.[5,12]
5. Tele-Robotic Expansion: Pilot projects in underserved areas may increase access to specialty care via remote robotic treatment.[19,20]
6. Long-Term Outcome Studies: Perform prospective, multicentred trials comparing robotic and traditional methods in various populations to confirm efficacy, cost-effectiveness, and patient-centred outcomes.[1-7,23,33]

Robotic and laser-assisted eye surgery have the potential to revolutionize the field of eye care by overcoming human dexterity deficiency and filling the gap between technological precision and human dexterity limitation. In addition to being advanced tools, these systems represent a marriage of robotics, imaging, and artificial intelligence that allows surgeons to undertake tasks previously not feasible or extremely dangerous. As an illustration, micro-scale vitreoretinal manipulations, accurate corneal incisions, and intricate orbital tumour resections can now be done with greatly diminished complication rates and better reproducibility.[4,6,10,23,34] The incorporation of AI also improves intraoperative decision-making by providing real-time analysis, tissue identification, and predictive modeling, enabling adaptive intraoperative planning customized to each patient's anatomy and pathology.[5,13,32] This coming together of technologies promises not only to enhance outcomes but also to decrease recovery times, minimize postoperative complications, and enhance patient satisfaction, thus elevating the standard of care overall.

In addition, robotic platforms solve key problems of surgeon fatigue and ergonomics, especially relevant in microsurgery involving extended concentration and stability.[18,40,41] By minimizing physical fatigue, these systems can extend surgical careers and enhance consistency in complex procedures. From a worldwide point of view, robotic and laser-assisted ophthalmology provides a route to democratize advanced eye care. Remote robotic surgery, tele-guidance, and AI-based decision support potentially would bring high-quality surgical procedures to underprivileged or geographically remote communities, narrowing disparities in vision health globally.[19,20,32]

The full transformative power of these technologies, however, is subject to strategic deployment, such as patient cost-benefit analysis, ethical framework-setting, regulatory clearance, and high-stakes training protocols. Interdisciplinary research in clinical, engineering, and policy fields will be required to maximize design, availability, and clinical integration. In effect, robotic and laser ophthalmic surgery is not just an innovation but a revolution. It is the vision of a future in which precision, safety, and accessibility combine to make available eye care previously aspirational. With ongoing investment, research, and training, these devices are poised to become standard equipment in everyday ophthalmic practice, eventually transforming the level of care and patient outcomes globally.

5. Source of Funding

None.

6. Conflict of Interest

None.

References

1. Rana MM, Akter J, Hanif MA. Next-gen vision: a systematic review on robotics transforming ophthalmic surgery. *J Robot Surg.* 2025;19(1):452. https://doi.org/10.1007/s11701-025-02623-8.
2. Thirunavukarasu AJ, Hu ML, Foster WP, Xue K, Cehajic-Kapetanovic J, MacLaren RE. Robot-Assisted Eye Surgery: A Systematic Review of Effectiveness, Safety, and Practicality in Clinical Settings. *Transl Vis Sci Technol.* 2024;13(6):20. https://doi.org/10.1167/tvst.13.6.20.

3. de Smet MD, Naus GJL, Faridpooya K, Mura M. Robotic-assisted surgery in ophthalmology. *Curr Opin Ophthalmol.* 2018;29(3):248–53. https://doi.org/10.1097/ICU.0000000000000476.
4. Singh G, Jie WWJ, Sun MT, Casson R, Selva D, Chan W. Overcoming the impact of physiologic tremors in ophthalmology. *Graefes Arch Clin Exp Ophthalmol*. 2022;260(12):3723–36. https://doi.org/10.1007/s00417-022-05718-2.
5. Yip M, Salcudean S, Goldberg K, Althoefer K, Menciassi A, Opfermann JD, et al. Artificial intelligence meets medical robotics. Science. 2023;381(6654):141–6. https://doi.org/10.1126/science.adj3312.
6. Bourcier T, Chammas J, Gaucher D, Liverneaux P, Marescaux J, Speeg-Schatz C, et al. Robot-Assisted Simulated Strabismus Surgery. *Transl Vis Sci Technol*. 2019;8(3):26. https://doi.org/10.1167/tvst.8.3.26.
7. Alafaleq M. Robotics and cybersurgery in ophthalmology: a current perspective. *J Robot Surg.* 2023;17(4):1159–70. https://doi.org/10.1007/s11701-023-01532-y.
8. Hou P, Lu Y, Ye F, Lan W, Huang Z. Application of femtosecond laser in ocular surgery. Eye Sci. 2013 Jun;28(2):103-7.
9. Ozulken K, Cabot F, Yoo SH. Applications of femtosecond lasers in ophthalmic surgery. *Expert Rev Med Devices.* 2013;10(1):115-24. https://doi.org/10.1586/erd.12.59. PMID: 23278228.
10. Gijbels A, Smits J, Schoevaerdts L, Willekens K, Vander Poorten EB, Stalmans P, Reynaerts D. In-Human Robot-Assisted Retinal Vein Cannulation, A World First. *Ann Biomed Eng.* 2018;46(10):1676-1685. https://doi.org/10.1007/s10439-018-2053-3.
11. Jeannon JP, Faulkner J, Uddin J, Daniel C, Arora A. Robotic assisted orbital surgery (RAOS)-A novel approach to orbital oncology surgery. *Eye (Lond).* 2023;37(5):1040-1. https://doi.org/10.1038/s41433-022-02125-z.
12. Pandey SK, Sharma V. Robotics and ophthalmology: Are we there yet? *Indian J Ophthalmol.* 2019;67(7):988–94. https://doi.org/10.4103/ijo.IJO_1131_18.
13. Chatzimichail E, Feltgen N, Motta L, Empeslidis T, Konstas AG, Gatzioufas Z, et al. Transforming the future of ophthalmology: artificial intelligence and robotics' breakthrough role in surgical and medical retina advances: a mini review. *Front Med (Lausanne).* 2024;11:1434241. https://doi.org/10.3389/fmed.2024.1434241.
14. Lyle WM, Cullen AP, Charman WN. Role of lasers in eye care. *Optom Vis Sci.* 1993;70(2):136-51. https://doi.org/10.1097/00006324-199302000-00010.
15. Fine HF, Wei W, Goldman R, Simaan N. Robot-assisted ophthalmic surgery. *Can J Ophthalmol.* 2010;45(6):581–4. https://doi.org/10.1139/i10-106.
16. Cleary K, Nguyen C. State of the art in surgical robotics: clinical applications and technology challenges. *Comput Aided Surg.* 2001;6(6):312–28. https://doi.org/10.1002/igs.10019.
17. Lanfranco AR, Castellanos AE, Desai JP, Meyers WC. Robotic surgery: a current perspective. *Ann Surg.* 2004;239(1):14–21. https://doi.org/10.1097/01.sla.0000103020.19595.7d.
18. Liverneaux PA, Hendriks S, Selber JC, Parekattil SJ. Robotically assisted microsurgery: development of basic skills course. *Arch Plast Surg*. 2013;40(4):320-6. https://doi.org/10.5999/aps.2013.40.4.320.
19. Marescaux J, Leroy J, Rubino F, Smith M, Vix M, Simone M, et al. Transcontinental robot-assisted remote telesurgery: feasibility and potential applications. *Ann Surg.* 2002;235(4):487–92. https://doi.org/10.1097/00000658-200204000-00005.
20. Nuzzi R, Brusasco L. State of the art of robotic surgery related to vision: brain and eye applications of newly available devices. *Eye Brain.* 2018;10:13–24. https://doi.org/10.2147/EB.S148644.
21. Grozdanovic D, Grozdanovic M. Research on Key Indicators in Modern Surgical Practice Assessment: Ergonomic Approach. *Surg Innov*. 2018;25(4):323–32. https://doi.org/10.1177/1553350618772720.
22. Roizenblatt M, Edwards TL, Gehlbach PL. Robot-assisted vitreoretinal surgery: current perspectives. *Robot Surg.* 2018;5:1–11. https://doi.org/10.2147/RSRR.S122301.
23. Mi H, MacLaren RE, Cehajic-Kapetanovic J. Robotising vitreoretinal surgeries. *Eye (Lond).* 2025;39(4):673–82. https://doi.org/10.1038/s41433-024-03149-3.
24. Akrobetu D, Pineda R 2nd. Laser-based Refractive Surgery: A Review of Select Clinical Challenges and Future Directions. *Int Ophthalmol Clin.* 2025;65(3):1–7. https://doi.org/10.1097/IIO.0000000000000568.
25. Naidoo KS, Leasher J, Bourne RR, Flaxman SR, Jonas JB, Keeffe J, et al. Vision Loss Expert Group of the Global Burden of Disease Study. Global Vision Impairment and Blindness Due to Uncorrected Refractive Error, 1990-2010. *Optom Vis Sci.* 2016;93(3):227–34. https://doi.org/10.1097/OPX.0000000000000796.
26. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt.* 2012;32(1):3–16. https://doi.org/10.1111/j.1475-1313.2011.00884.x.
27. Kim TI, Alió Del Barrio JL, Wilkins M, Cochener B, Ang M. Refractive surgery. *Lancet.* 2019;393(10185):2085–98. https://doi.org/10.1016/S0140-6736(18)33209-4.
28. Soltani Sharif Abadi A, Ordys A, Kukielka K, Pierscionek B. Review on challenges for robotic eye surgery; surgical systems, technologies, cost-effectiveness, and controllers. *Int J Med Robot.* 2023;19(4):e2524. https://doi.org/10.1002/rcs.2524.
29. Khalkhal E, Rezaei-Tavirani M, Zali MR, Akbari Z. The Evaluation of Laser Application in Surgery: A Review Article. *J Lasers Med Sci*. 2019Fall;10(Suppl 1):S104–11. https://doi.org/10.15171/jlms.2019.S18.
30. Tayani R, Rubin PA. Laser applications in oculoplastic surgery and their postoperative complications. *Int Ophthalmol Clin*. 2000 Winter;40(1):13–26. https://doi.org/10.1097/00004397-200001000-00004.
31. Mishra K, Leng T. Artificial intelligence and ophthalmic surgery. *Curr Opin Ophthalmol.* 2021;32(5):425–30. https://doi.org/10.1097/ICU.0000000000000788.
32. Kumari B, Tidake P. Robotic Integration in the Field of Opthalmology and Its Prospects in India. *Cureus.* 2022;14(10):e30482. https://doi.org/10.7759/cureus.30482.
33. Channa R, Iordachita I, Handa JT. Robotic Vitreoretinal Surgery. *Retina*. 2017;37(7):1220–8. https://doi.org/10.1097/IAE.0000000000001398.
34. Rivero-Moreno Y, Echevarria S, Vidal-Valderrama C, Pianetti L, Cordova-Guilarte J, Navarro-Gonzalez J, et al. Robotic Surgery: A Comprehensive Review of the Literature and Current Trends. *Cureus*. 2023;15(7):e42370. https://doi.org/10.7759/cureus.42370.
35. Tsirbas A, Mango C, Dutson E. Robotic ocular surgery. *Br J Ophthalmol*. 2007;91(1):18–21. https://doi.org/10.1136/bjo.2006.096040.
36. Pitcher JD, Wilson JT, Tsao TC, Schwartz SD, Hubschman JP. Robotic Eye Surgery: Past, Present, and Future. *J Comput Sci Syst Biol.* 2012;S3:001. https://doi.org/10.4172/jcsb.S3-001
37. Iordachita II, de Smet MD, Naus G, Mitsuishi M, Riviere CN. Robotic Assistance for Intraocular Microsurgery: Challenges and Perspectives. *Proc IEEE Inst Electr Electron Eng*. 2022;110(7):893–908. https://doi.org/10.1109/JPROC.2022.3169466.
38. EyeMantra. Advantages & disadvantages of robotic cataract surgery. 2025. Available from: https://eyemantra.in/cataract/robotic-cataract-surgery-advantage-and-disadvantage/ (accessed on 20th September 2025)
39. Wong SW, Wong AL. Ergonomic challenges and barriers of robotic surgery—a review. *Ann Laparosc Endosc Surg*. 2025;10:28. https://doi.org/10.21037/ales-25-10
40. Schönburg S, Anheuser P, Kranz J, Fornara P, Oubaid V. Cognitive training for robotic surgery: a chance to optimize surgical training? A pilot study. *J Robot Surg*. 2021;15(5):761–7. https://doi.org/10.1007/s11701-020-01167-3.
41. Whelehan DF, Brown DJ, Connelly TM, Ridgway PF. Fatigued surgeons: a thematic analysis of the causes, effects and opportunities for fatigue mitigation in surgery. *Int J Surg Open*. 2021;35:100382. https://doi.org/10.1016/j.ijso.2021.100382

42. Centre for Sight. Robotic vs traditional cataract surgery. 2025. Available from: https://www.centreforsight.net/blog/robotic-vs-traditional-cataract-surgery (accessed on 19th September 2025).
43. Nocini R, Marini L, Michelutti L, Zilio C, Troise S, Sembronio S, et al. Use of Robotic Surgery for the Management of Orbital Diseases: A Comprehensive Review. *Medicina (Kaunas)*. 2025;61(6):1081. https://doi.org/10.3390/medicina61061081.
44. Centre for Sight. Robotic eye surgery for cataract. 2020. Available from: https://www.centreforsight.net/blog/about-robotic-eye-surgery-for-cataract (accessed on 19th September 2025).

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