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Ophthalmic Education: The Top 100 Cited Articles in Ophthalmology Journals

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Abstract

Purpose To identify the top 100 (T100) cited articles on ophthalmic education and examine trends and areas of focus in ophthalmic education.

Methods A literature search was conducted for articles published between 2011 and 2021 related to ophthalmic education within ophthalmology journals using the ISI Web of Science Core Collection database. The search was performed in June 2022 and was conducted using the search phrase ([educat* OR teach* OR instruct* OR train* OR "medical student*" OR residen* OR fellow* OR undergrad* OR postgrad* OR "faculty" OR "attending"] AND *ophthalm*). Results were analyzed using VOSviewer v.1.6.18 and statistical analysis was performed using Microsoft Excel.

Results The majority of articles were published in the *Journal of Cataract & Refractive Surgery* (19%), followed by *Ophthalmology* (12%), and *Eye* (12%). Articles were most often published in the year 2013 (15%), followed by 2014 (12%) and 2012 (12%). Articles most commonly originated from English-speaking countries, including the United States (43%), England (14%), Canada (8%), and India (8%). Topics most often examined in ophthalmic education were resident education (51%), medical school education (21%), and surgical training (21%). The most common study types were cohort studies (22%), case series (21%), and prospective trials (16%). There were 16 institutions that produced more than one article in the T100 articles list.

Conclusion The T100 articles on ophthalmic education were primarily U.S. based and focused on resident education, surgical training, and medical school ophthalmic curriculum. Further research into ophthalmic education is warranted to establish evidence-based curricula guidelines.

Keywords
- ophthalmic education
- bibliometrics
- scientometrics
- curricula guidelines

Ophthalmic education has witnessed notable advancements over the past 50 years.[1] As diagnosis and treatment strategies, both clinical and surgical, are rapidly evolving, it is increasingly evident that ophthalmic education does not end with current training programs.[2] Additionally, through the internet and other technological advances, both ophthalmology educators and trainees have gained access to increasingly sophisticated educational tools.[3] Ongoing research in

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ophthalmic education is vital amidst an ever-changing environment, as the coronavirus disease 2019 (COVID-19) pandemic has compelled ophthalmologists to incorporate digital technology, artificial intelligence, and telemedicine for virtual instruction, clinical care, and research.[2] As ophthalmic education directly shapes the future of ophthalmology and impacts the quality of patient care, research regarding ophthalmology education, including methods and curricula, is of paramount importance for clinical educators to ensure evidence-based guidelines are implemented. However, a recent review found that research in this field is limited, and there is a significant need for multicenter and well-designed studies in the field of ophthalmic education.[4] Examining the most influential studies on ophthalmic education may provide insight into the progress achieved thus far, unveil additional grounds for discovery, and provide educators with evidence by which they can improve their respective training programs.

Bibliometric analysis is a statistical method used for quantitatively analyzing written publications and obtaining information regarding the origin, format, type, and citation count of published journal articles.[5] It generates data on the scholarly impact of research within a particular field.[5] This method has significantly benefited from computerized data, and in recent years, there has been an increase in the number of bibliometric publications.[6] This current bibliometric study aims to identify the top 100 (T100) cited research articles on ophthalmic education. Analyzing the history of ophthalmic education research leading up to its current state can help researchers find potential collaborators, reveal areas for future contributions, and positively impact patient care.

Materials and Methods

Search Strategy

We utilized the ISI Web of Science (WoS) Core Collection (Institute for Scientific Information, Thomson Scientific, Philadelphia, PA) database to identify the T100 cited research articles on ophthalmic education. WoS, currently owned by Clarivate Analytics, was launched in 1997 and has made possible the widespread use of citation analysis.[7]

We conducted one search within the WoS "ophthalmology" category, which consisted of 114 ophthalmology-related journals at the time of our investigation (June 2022). Only journals indexed in PubMed and searchable on WoS were included. Our search goal was to capture all articles related to ophthalmic education related to medical school, undergraduate, and postgraduate ophthalmology training. We used Boolean search operators, including "OR", and truncation marks (i.e., "educat*") to ensure all forms of the word were searched. Our search phrase was (educat* OR teach* OR instruct* OR train* OR "medical student*" OR residen* OR fellow* OR undergrad* OR postgrad* OR "faculty" OR "attending"). All research articles discovered through our search were reviewed and evaluated for inclusion in the study by two authors (C.T., N.R.).

We organized our initial search results by the number of citations in descending order. Articles were further categorized by title, journal, authorship (first author, last author, number of authors), institution and country of first and last authors, total number of citations, year of publication, citations per year, topic, and study type. Study type was assigned from one of the following categories: clinical experience (observational), randomized clinical trial (interventional), epidemiological, review, and other. Clinical experiences were further categorized as either descriptive studies (case reports/case series) or analytic studies (retrospective cohort, prospective cohort, cross-sectional, and case–control).[8]

Inclusion and Exclusion Criteria

Our inclusion criteria for articles were as follows: (1) original reports, (2) case series, (3) published between 2011 and 2021, (4) indexed in PubMed, (5) searchable by WoS. Our exclusion criteria for articles were as follows: (1) editorials, (2) reviews, (3) letters, (4) meeting abstracts, (5) proceedings papers, (6) non-English articles.

Statistical Analysis

Data were extracted from WoS and results were analyzed using VOSviewer v.1.6.18 to create a knowledge map, a scientometric method of organizing data to provide a holistic view and analysis of a particular field. Statistical analysis was performed using Microsoft Excel (v. 16.64, Redmond, WA). Associations between continuous variables were depicted using Pearson's correlation coefficients and *p*-values were calculated. Alpha was set at 0.05 for all analyses. The total number of citations per article was portrayed using median and interquartile range. Articles were assigned the same list ranking if more than two shared the same total citation number.

Results

►**Table 1** presents the T100 most frequently cited articles in ophthalmologic education. The final two ranked articles, articles 99 and 100, were included in the search as the result of being the most recent articles published at the time of the search with nine citations. Articles were published in a total of 19 journals, as displayed in ►**Fig. 1**, with the most common journals being the *Journal of Cataract & Refractive Surgery* (19%), followed by *Ophthalmology* (12%), and *Eye* (12%).

A total of 15 countries were represented by the corresponding authors of the T100 ophthalmologic education articles. The most common locations of corresponding authors were the United States (43%), followed by England (14%), Canada (8%), India (8%), Australia (6%), Denmark (6%), Iran (3%), Sweden (3%), Greece (2%), New Zealand (2%), Brazil (1%), Germany (1%), Israel (1%), Portugal (1%), and Singapore (1%). The distribution of year published, as displayed in ►**Fig. 2**, are as follows: 2013 (15%), 2014 (12%), 2012 (12%), 2016 (11%), 2018 (11%), 2011 (10%), 2017 (9%), 2019 (7%), 2015 (6%), 2020 (6%), and 2021 (1%).

The mean number of citations was 23.77 ± 17.29, with a median of 18 and a range of 9 to 96. No correlation was found between the number of years since publication and the number of citations (Pearson's correlation coefficient $= -0.14$, $p = 0.16$). The mean number of citations per year was 6.06 ± 10.30, with a

Table 1 Top 100 ophthalmic education articles

Ranked articles		Number of citations
1.	Thomsen AS, Bach-Holm D, Kjærbo H, et al. Operating room performance improves after proficiency-based virtual reality cataract surgery training. *Ophthalmology*. 2017;124(4):524–531	96
2.	Belyea DA, Brown SE, Rajjoub LZ. Influence of surgery simulator training on ophthalmology resident phacoemulsification performance. *J Cataract Refract Surg*. 2011;37(10):1756–1761	87
3.	Mishra D, Nair AG, Gandhi RA, et al. The impact of COVID-19 related lockdown on ophthalmology training programs in India - outcomes of a survey. *Indian J Ophthalmol*. 2020;68(6):999–1004	74
4.	McCannel CA, Reed DC, Goldman DR. Ophthalmic surgery simulator training improves resident performance of capsulorhexis in the operating room. *Ophthalmology*. 2013;120(12):2456–2461	74
5.	Ferrara M, Romano V, Steel DH, et al. Reshaping ophthalmology training after COVID-19 pandemic. *Eye (Lond)*. 2020;34(11):2089–2097	59
6.	Pokroy R, Du E, Alzaga A, et al. Impact of simulator training on resident cataract surgery. *Graefes Arch Clin Exp Ophthalmol*. 2013;251(3):777–781	59
7.	Kelly LP, Garza PS, Bruce BB, Graubart EB, Newman NJ, Biousse V. Teaching ophthalmoscopy to medical students (the TOTeMS study). *Am J Ophthalmol*. 2013;156(5):1056–1061.e10	59
8.	Ti SE, Yang YN, Lang SS, Chee SP. A 5-year audit of cataract surgery outcomes after posterior capsule rupture and risk factors affecting visual acuity. *Am J Ophthalmol*. 2014;157(1):180–185.e1	57
9.	Shah M, Knoch D, Waxman E. The state of ophthalmology medical student education in the United States and Canada, 2012 through 2013. *Ophthalmology*. 2014;121(6):1160–1163	54
10.	Woodfield AS, Gower EW, Cassard SD, Ramanthan S. Intraoperative phacoemulsification complication rates of second- and third-year ophthalmology residents a 5-year comparison. *Ophthalmology*. 2011;118(5):954–958	48
11.	Ferris JD, Donachie PH, Johnston RL, Barnes B, Olaitan M, Sparrow JM. Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 6. The impact of EyeSi virtual reality training on complications rates of cataract surgery performed by first and second year trainees. *Br J Ophthalmol*. 2020;104(3):324–329	44
12.	Selvander M, Åsman P. Virtual reality cataract surgery training: learning curves and concurrent validity. *Acta Ophthalmol*. 2012;90(5):412–417	43
13.	Taravella MJ, Davidson R, Erlanger M, Guiton G, Gregory D. Characterizing the learning curve in phacoemulsification. *J Cataract Refract Surg*. 2011;37(6):1069–1075	42
14.	Adams JW, Paxton L, Dawes K, Burlak K, Quayle M, McMenamin PG. 3D printed reproductions of orbital dissections: a novel mode of visualising anatomy for trainees in ophthalmology or optometry. *Br J Ophthalmol*. 2015;99(9):1162–1167	41
15.	Seider MI, Rofagha S, Lin SC, Stamper RL. Resident-performed Ex-PRESS shunt implantation versus trabeculectomy. *J Glaucoma*. 2012;21(7):469–474	41
16.	Saleh GM, Lamparter J, Sullivan PM, et al. The international forum of ophthalmic simulation: developing a virtual reality training curriculum for ophthalmology. *Br J Ophthalmol*. 2013;97 (6):789–792	34
17.	Selvander M, Asman P. Cataract surgeons outperform medical students in Eyesi virtual reality cataract surgery: evidence for construct validity. *Acta Ophthalmol*. 2013;91(5):469–474	34
18.	Daly MK, Gonzalez E, Siracuse-Lee D, Legutko PA. Efficacy of surgical simulator training versus traditional wet-lab training on operating room performance of ophthalmology residents during the capsulorhexis in cataract surgery. *J Cataract Refract Surg*. 2013;39(11):1734–1741	34
19.	Thomsen AS, Smith P, Subhi Y, et al. High correlation between performance on a virtual-reality simulator and real-life cataract surgery. *Acta Ophthalmol*. 2017;95(3):307–311	33
20.	Hashemi H, Mohammadpour M, Jabbarvand M, Nezamdoost Z, Ghadimi H. Incidence of and risk factors for vitreous loss in resident-performed phacoemulsification surgery. *J Cataract Refract Surg*. 2013;39(9):1377–1382	33
21.	Myung JS, Paul Chan RV, Espiritu MJ, et al. Accuracy of retinopathy of prematurity image-based diagnosis by pediatric ophthalmology fellows: implications for training. *J AAPOS*. 2011;15(6):573–578	33
22.	Blomquist PH, Morales ME, Tong L, Ahn C. Risk factors for vitreous complications in resident-performed phacoemulsification surgery. *J Cataract Refract Surg*. 2012;38(2):208–214	32

Table 1 (*Continued*)

Ranked articles		Number of citations
23.	Le TD, Adatia FA, Lam WC. Virtual reality ophthalmic surgical simulation as a feasible training and assessment tool: results of a multicentre study. *Can J Ophthalmol*. 2011;46(1):56–60	30
24.	Wong RK, Ventura CV, Espiritu MJ, et al. Training fellows for retinopathy of prematurity care: a Web-based survey. *J AAPOS*. 2012;16(2):177–181	30
25.	Yousuf SJ, Kwagyan J, Jones LS. Applicants' choice of an ophthalmology residency program. *Ophthalmology*. 2013;120(2):423–427	27
26.	Succar T, Zebington G, Billson F, et al. The impact of the Virtual Ophthalmology Clinic on medical students' learning: a randomised controlled trial. *Eye (Lond)*. 2013;27(10):1151–1157	26
27.	Chatziralli I, Ventura CV, Touhami S, et al. Transforming ophthalmic education into virtual learning during COVID-19 pandemic: a global perspective. *Eye (Lond)*. 2021;35(5):1459–1466	25
28.	Kwong A, Law SK, Kule RR, et al. Long-term outcomes of resident- versus attending-performed primary trabeculectomy with mitomycin C in a United States residency program. *Am J Ophthalmol*. 2014;157(6):1190–1201	25
29.	Taravella MJ, Davidson R, Erlanger M, Guiton G, Gregory D. Time and cost of teaching cataract surgery. *J Cataract Refract Surg*. 2014;40(2):212–216	25
30.	Bergqvist J, Person A, Vestergaard A, Grauslund J. Establishment of a validated training programme on the Eyesi cataract simulator. A prospective randomized study. *Acta Ophthalmol*. 2014;92(7):629–634	24
31.	Leitritz MA, Ziemssen F, Suesskind D, et al. Critical evaluation of the usability of augmented reality ophthalmoscopy for the training of inexperienced examiners. *Retina*. 2014;34(4):785–791	24
32.	Mamtora S, Sandinha MT, Ajith A, Song A, Steel DHW. Smart phone ophthalmoscopy: a potential replacement for the direct ophthalmoscope. *Eye (Lond)*. 2018;32(11):1766–1771	23
33.	Saleh GM, Theodoraki K, Gillan S, et al. The development of a virtual reality training programme for ophthalmology: repeatability and reproducibility (part of the International Forum for Ophthalmic Simulation Studies). *Eye (Lond)*. 2013;27(11):1269–1274	23
34.	Baxter JM, Lee R, Sharp JA, Foss AJ; Intensive Cataract Training Study Group. Intensive cataract training: a novel approach. *Eye (Lond)*. 2013;27(6):742–746	23
35.	Steedman M, Abouammoh M, Sharma S. Multimedia learning tools for teaching undergraduate ophthalmology: results of a randomized clinical study. *Can J Ophthalmol*. 2012;47(1):66–71	22
36.	Spiteri AV, Aggarwal R, Kersey TL, et al. Development of a virtual reality training curriculum for phacoemulsification surgery. *Eye (Lond)*. 2014;28(1):78–84	22
37.	Chhaya N, Helmy O, Piri N, Palacio A, Schaal S. Comparison of 2D and 3D video displays for teaching vitreoretinal surgery. *Retina*. 2018;38(8):1556–1561	21
38.	Gurwin J, Revere KE, Niepold S, et al. A randomized controlled study of art observation training to improve medical student ophthalmology skills. *Ophthalmology*. 2018;125(1):8–14	21
39.	Narayanan R, Tyagi M, Hussein A, Chhablani J, Apte RS. Scleral buckling with wide-angled endoillumination as a surgical educational tool. *Retina*. 2016;36(4):830–833	21
40.	Gong D, Winn BJ, Beal CJ, et al. Gender differences in case volume among ophthalmology residents. *JAMA Ophthalmol*. 2019;137(9):1015–1020	20
41.	Payal AR, Gonzalez-Gonzalez LA, Chen X, et al. Outcomes of cataract surgery with residents as primary surgeons in the Veterans Affairs Healthcare System. *J Cataract Refract Surg*. 2016;42 (3):370–384	20
42.	Mehta VJ, Perry JD. Blepharoptosis repair outcomes from trainee versus experienced staff as the primary surgeon. *Am J Ophthalmol*. 2013;155(2):397–403.e1	20
43.	Vergmann AS, Vestergaard AH, Grauslund J. Virtual vitreoretinal surgery: validation of a training programme. *Acta Ophthalmol*. 2017;95(1):60–65	19
44.	Turnbull AM, Lash SC. Confidence of ophthalmology specialist trainees in the management of posterior capsule rupture and vitreous loss. *Eye (Lond)*. 2016;30(7):943–948	19
45.	Mohammadi SF, Mazouri A, Jabbarvand M, Rahman-A N, Mohammadi A. Sheep practice eye for ophthalmic surgery training in skills laboratory. *J Cataract Refract Surg*. 2011;37(6):987–991	19
46.	O'Neill EC, Kong YX, Connell PP, et al. Gaze behavior among experts and trainees during optic disc examination: does how we look affect what we see? *Invest Ophthalmol Vis Sci*. 2011;52 (7):3976–3983	18

(*Continued*)

Table 1 (*Continued*)

Ranked articles		Number of citations
47.	Ramani S, Pradeep TG, Sundaresh DD. Effect of wet-laboratory training on resident performed manual small-incision cataract surgery. *Indian J Ophthalmol*. 2018;66(6):793–797	18
48.	Falavarjani KG, Aghamirsalim M, Modarres M, et al. Endophthalmitis after resident-performed intravitreal bevacizumab injection. *Can J Ophthalmol*. 2015;50(1):33–36	18
49.	Kim Y, Chao DL. Comparison of smartphone ophthalmoscopy vs conventional direct ophthalmoscopy as a teaching tool for medical students: the COSMOS study. *Clin Ophthalmol*. 2019; 13:391–401	18
50.	Wu AR, Fouzdar-Jain S, Suh DW. Comparison study of funduscopic examination using a smartphone-based digital ophthalmoscope and the direct ophthalmoscope. *J Pediatr Ophthalmol Strabismus*. 2018;55(3):201–206	18
51.	Yeu E, Reeves SW, Wang L, Randleman JB; ASCRS Young Physicians and Residents Clinical Committee. Resident surgical experience with lens and corneal refractive surgery: survey of the ASCRS Young Physicians and Residents Membership. *J Cataract Refract Surg*. 2013;39(2):279–284	18
52.	Saleh GM, Wawrzynski JR, Saha K, et al. Feasibility of Human Factors Immersive Simulation Training in Ophthalmology: The London Pilot. *JAMA Ophthalmol*. 2016;134(8):905–911	17
53.	Ajay K, Krishnaprasad R, Divya DS. Ophthalmic surgical training in Karnataka and Southern India: present status and future interests from a survey of final-year residents. *Indian J Ophthalmol*. 2015;63(4):306–311	17
54.	Ludwig CA, Newsom MR, Jais A, Myung DJ, Murthy SI, Chang RT. Training time and quality of smartphone-based anterior segment screening in rural India. *Clin Ophthalmol*. 2017; 11:1301–1307	17
55.	Patel SN, Martinez-Castellanos MA, Berrones-Medina D, et al. Assessment of a tele-education system to enhance retinopathy of prematurity training by international ophthalmologists-in-training in Mexico. *Ophthalmology*. 2017;124(7):953–961	17
56.	Byrd JM, Longmire MR, Syme NP, Murray-Krezan C, Rose L. A pilot study on providing ophthalmic training to medical students while initiating a sustainable eye care effort for the underserved. *JAMA Ophthalmol*. 2014;132(3):304–309	17
57.	Milani BY, Majdi M, Green W, et al. The use of peer optic nerve photographs for teaching direct ophthalmoscopy. *Ophthalmology*. 2013;120(4):761–765	17
58.	Androwiki JE, Scravoni IA, Ricci LH, Fagundes DJ, Ferraz CA. Evaluation of a simulation tool in ophthalmology: application in teaching funduscopy. *Arq Bras Oftalmol*. 2015;78(1):36–39	16
59.	Jacobsen MF, Konge L, Bach-Holm D, et al. Correlation of virtual reality performance with real-life cataract surgery performance. *J Cataract Refract Surg*. 2019;45(9):1246–1251	16
60.	Schulz C, Moore J, Hassan D, Tamsett E, Smith CF. Addressing the 'forgotten art of fundoscopy': evaluation of a novel teaching ophthalmoscope. *Eye (Lond)*. 2016;30(3):375–384	16
61.	Winter TW, Olson RJ, Larson SA, Oetting TA, Longmuir SQ. Resident and fellow participation in strabismus surgery: effect of level of training and number of assistants on operative time and cost. *Ophthalmology*. 2014;121(3):797–801	16
62.	Roensch MA, Charton JW, Blomquist PH, Aggarwal NK, McCulley JP. Resident experience with toric and multifocal intraocular lenses in a public county hospital system. *J Cataract Refract Surg*. 2012;38(5):793–798	16
63.	Fong CS, Mitchell P, de Loryn T, et al. Long-term outcomes of phacoemulsification cataract surgery performed by trainees and consultants in an Australian cohort. *Clin Exp Ophthalmol*. 2012;40 (6):597–603	15
64.	Campbell RJ, El-Defrawy SR, Gill SS, et al. New surgeon outcomes and the effectiveness of surgical training: a population-based cohort study [published correction appears in Ophthalmology. 2017;124(12):1879]. *Ophthalmology*. 2017;124(4):532–538.	15
65.	Ajay K, Krishnaprasad R. Feedback of final year ophthalmology postgraduates about their residency ophthalmology training in South India. *Indian J Ophthalmol*. 2014;62(7):814–817	15
66.	Lotfipour M, Rolius R, Lehman EB, Pantanelli SM, Scott IU. Trends in cataract surgery training curricula. *J Cataract Refract Surg*. 2017;43(1):49–53	15
67.	White CA, Wrzosek JA, Chesnutt DA, Enyedi LB, Cabrera MT. A novel method for teaching key steps of strabismus surgery in the wet lab. *J AAPOS*. 2015;19(5):468–70.e1	15

Table 1 (*Continued*)

Ranked articles		Number of citations
68.	Pouyeh B, Galor A, Junk AK, et al. Surgical and refractive outcomes of cataract surgery with toric intraocular lens implantation at a resident-teaching institution. *J Cataract Refract Surg*. 2011;37 (9):1623–1628	15
69.	Wagoner MD, Wickard JC, Wandling GR Jr, et al. Initial resident refractive surgical experience: outcomes of PRK and LASIK for myopia. *J Refract Surg*. 2011;27(3):181–188	15
70.	Grover AK, Honavar SG, Azad R, Verma L. A national curriculum for ophthalmology residency training. *Indian J Ophthalmol*. 2018;66(6):752–783	14
71.	Welch S, Eckstein M. Ophthalmology teaching in medical schools: a survey in the UK. *Br J Ophthalmol*. 2011;95(5):748–749	14
72.	Zhang HH, Hepschke JL, Shulruf B, et al. Sharpening the focus on ophthalmology teaching: perceptions of medical students and junior medical officers. *Clin Exp Ophthalmol*. 2018;46(9):984–993	13
73.	Hussain R, Singh B, Shah N, Jain S. Impact of COVID-19 on ophthalmic specialist training in the United Kingdom-the trainees' perspective [published correction appears in Eye (Lond). *Eye (Lond)*. 2020;34(12):2157–2160	13
74.	Dean WH, Grant S, McHugh J, Bowes O, Spencer F. Ophthalmology specialist trainee survey in the United Kingdom. *Eye (Lond)*. 2019;33(6):917–924	13
75.	Petrarca CA, Warner J, Simpson A, et al. Evaluation of eLearning for the teaching of undergraduate ophthalmology at medical school: a randomised controlled crossover study. *Eye (Lond)*. 2018;32 (9):1498–1503	13
76.	Selvander M, Åsman P. Stereoacuity and intraocular surgical skill: effect of stereoacuity level on virtual reality intraocular surgical performance. *J Cataract Refract Surg*. 2011;37(12):2188–2193	13
77.	Low SAW, Braga-Mele R, Yan DB, El-Defrawy S. Intraoperative complication rates in cataract surgery performed by ophthalmology resident trainees compared to staff surgeons in a Canadian academic center. *J Cataract Refract Surg*. 2018;44(11):1344–1349	12
78.	Rai AS, Rai AS, Mavrikakis E, Lam WC. Teaching binocular indirect ophthalmoscopy to novice residents using an augmented reality simulator. *Can J Ophthalmol*. 2017;52(5):430–434	12
79.	Tran EM, Scott IU, Clark MA, Greenberg PB. Resident wellness in US ophthalmic graduate medical education: the resident perspective. *JAMA Ophthalmol*. 2018;136(6):695–701	12
80.	Smith RJ, McCannel CA, Gordon LK, et al. Evaluating teaching methods of cataract surgery: validation of an evaluation tool for assessing surgical technique of capsulorhexis. *J Cataract Refract Surg*. 2012;38(5):799–806	12
81.	Sharda RK, Sher JH, Chan BJ, Kobetz LE, Mann KD. A comparison of techniques: informed consent for resident involvement in cataract surgery. *Can J Ophthalmol*. 2012;47(2):113–117	11
82.	Pasricha ND, Haq Z, Ahmad TR, et al. Remote corneal suturing wet lab: microsurgical education during the COVID-19 pandemic. *J Cataract Refract Surg*. 2020;46(12):1667–1673	11
83.	Bakri SJ, Alniemi ST, Chan RV. Experiences of vitreoretinal surgery fellows in the United States. *Retina*. 2013;33(2):392–396	11
84.	Succar T, McCluskey P, Grigg J. Enhancing medical student education by implementing a competency-based ophthalmology curriculum. *Asia Pac J Ophthalmol (Phila)*. 2017;6(1):59–63	10
85.	Le K, Bursztyn L, Rootman D, Harissi-Dagher M. National survey of Canadian ophthalmology residency education. *Can J Ophthalmol*. 2016;51(3):219–225	10
86.	Bellan L. Recent Canadian ophthalmology graduates: experiences in finding jobs and assessment of their training. *Can J Ophthalmol*. 2012;47(3):236–239	10
87.	Thomsen ASS, la Cour M, Paltved C, et al. Consensus on procedures to include in a simulation-based curriculum in ophthalmology: a national Delphi study. *Acta Ophthalmol*. 2018;96(5):519–527	10
88.	Nderitu P, Ursell P. Factors affecting cataract surgery operating time among trainees and consultants. *J Cataract Refract Surg*. 2019;45(6):816–822	10
89.	Tzamalis A, Lamprogiannis L, Chalvatzis N, Symeonidis C, Dimitrakos S, Tsinopoulos I. Training of resident ophthalmologists in cataract surgery: a comparative study of two approaches. *J Ophthalmol*. 2015; 2015:932043	10
90.	Ramakrishnan S, Baskaran P, Fazal R, Sulaiman SM, Krishnan T, Venkatesh R. Spring-action apparatus for fixation of eyeball (SAFE): a novel, cost-effective yet simple device for ophthalmic wet-lab training. *Br J Ophthalmol*. 2016;100(10):1317–1321	10

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Table 1 (*Continued*)

Ranked articles		Number of citations
91.	Kamal S, Ali MJ, Nair AG. Outcomes of endoscopic dacryocystorhinostomy: experience of a fellowship trainee at a tertiary care center. *Indian J Ophthalmol*. 2016;64(9):648–653	10
92.	Bandhu SD, Raje S. Experiences with E-learning in ophthalmology. *Indian J Ophthalmol*. 2014;62 (7):792–794	10
93.	Schmidt CM, Sundararajan M, Biggerstaff KS, Orengo-Nania S, Coffee RE, Khandelwal SS. Indications and outcomes of resident-performed cataract surgery requiring return to the operating room. *J Cataract Refract Surg*. 2016;42(3):385–391	10
94.	Todorich B, Shieh C, DeSouza PJ, et al. Impact of microscope-integrated OCT on ophthalmology resident performance of anterior segment surgical maneuvers in model eyes. *Invest Ophthalmol Vis Sci*. 2016;57(9):146–153	10
95.	Elfersy AJ, Prinzi RA, Peracha ZH, et al. IOP elevation after cataract surgery: results for residents and senior staff at Henry Ford Health System. *J Glaucoma*. 2016;25(10):802–806	10
96.	Greninger DA, Lowry EA, Porco TC, Naseri A, Stamper RL, Han Y. Resident-performed selective laser trabeculoplasty in patients with open-angle glaucoma. *JAMA Ophthalmol*. 2014;132(4):403–408	10
97.	Yousuf SJ, Jones LS. Ophthalmology residency match outcomes for 2011. *Ophthalmology*. 2012;119(3):642–646	10
98.	Lee AG, Oetting TA, Blomquist PH, et al. A multicenter analysis of the ophthalmic knowledge assessment program and American Board of Ophthalmology written qualifying examination performance. *Ophthalmology*. 2012;119(10):1949–1953	10
99.	Marques RE, Ferreira NP, Sousa DC, et al. Glaucoma gel implant learning curve in a teaching tertiary hospital. *J Glaucoma*. 2019;28(1):56–60	9
100.	Oh DJ, Kanu LN, Chen JL, Aref AA, Mieler WF, MacIntosh PW. Inpatient and emergency room ophthalmology consultations at a tertiary care center. *J Ophthalmol*. 2019; 2019:7807391	9

Note: The orders of articles with the same number of citations were determined from the orders displayed on the ISI Web of Knowledge database when the search was conducted.

range of 1.11 to 25.00. There was a statistically significant correlation between the number of years since publication and the number of citations per year (Pearson's correlation coefficient $= -0.45$, $p < 0.001$).

►**Table 2** presents the topics of the T100 articles in ophthalmic education. The most common topics were resident and fellow education (51%), medical student education (21%), and surgical training (21%). The distribution of types of study is displayed in ►**Fig. 3**.

Discussion

Establishing and maintaining research in ophthalmic education is crucial to providing evidence-based guidelines to direct educational interventions. Ultimately, higher standards of ophthalmic education translate to increased quality of care and treatment of ocular diseases.[1] Recent evaluations of the state of ophthalmic education suggest that not all medical trainees are receiving necessary educational experiences, highlighting the need to use an evidence-based methodology in an ophthalmic education curriculum.[4] This study aimed to examine the most impactful articles on ophthalmic education to reveal trends and themes that could impact future ophthalmic training and education.

Nearly 50% of the T100 articles cited in ophthalmic education were published in the *Journal of Cataract & Refractive Surgery*, *Ophthalmology*, and *Eye* (►**Fig. 1**). All three journals are ranked in the top 15 of the SCImago Journal Rank indicator (14, 2, and 12, respectively) as well as have an impact factor greater than 3.5 (3.528, 14.28, and 4.46, respectively). Previous studies have suggested an association between the impact factor of a journal and the number of T100 articles.[8,9] This finding suggests ophthalmic education articles are of significance to the ophthalmologic community despite the more clinical focus of these journals. Additionally, the *Indian Journal of Ophthalmology* and *Canadian Journal of Ophthalmology* had a greater portion of T100 articles published than other national society journals. This result suggests a regional or national interest for specific topics within ophthalmology education regardless of journal impact factor.[10]

With nearly half of the articles (43%), the United States was the most represented country of origin among the T100 articles in ophthalmic education, a trend also seen in other ophthalmology bibliometric analyses.[8,9,11] Several studies have attributed this trend to the relatively large number of U.S.-based journals and the potential bias of U.S.-based reviewers to more favorably review papers from U.S. authors and institutions.[11–13] Additionally, the United States has the highest impact factor journals, which may explain the higher tendency for authors to submit to these journals.[5] It is also important to note some of the T100 articles published in U.S.-based journals were by international authors, including the #1 ranked article published in *Ophthalmology* and written by authors from Denmark

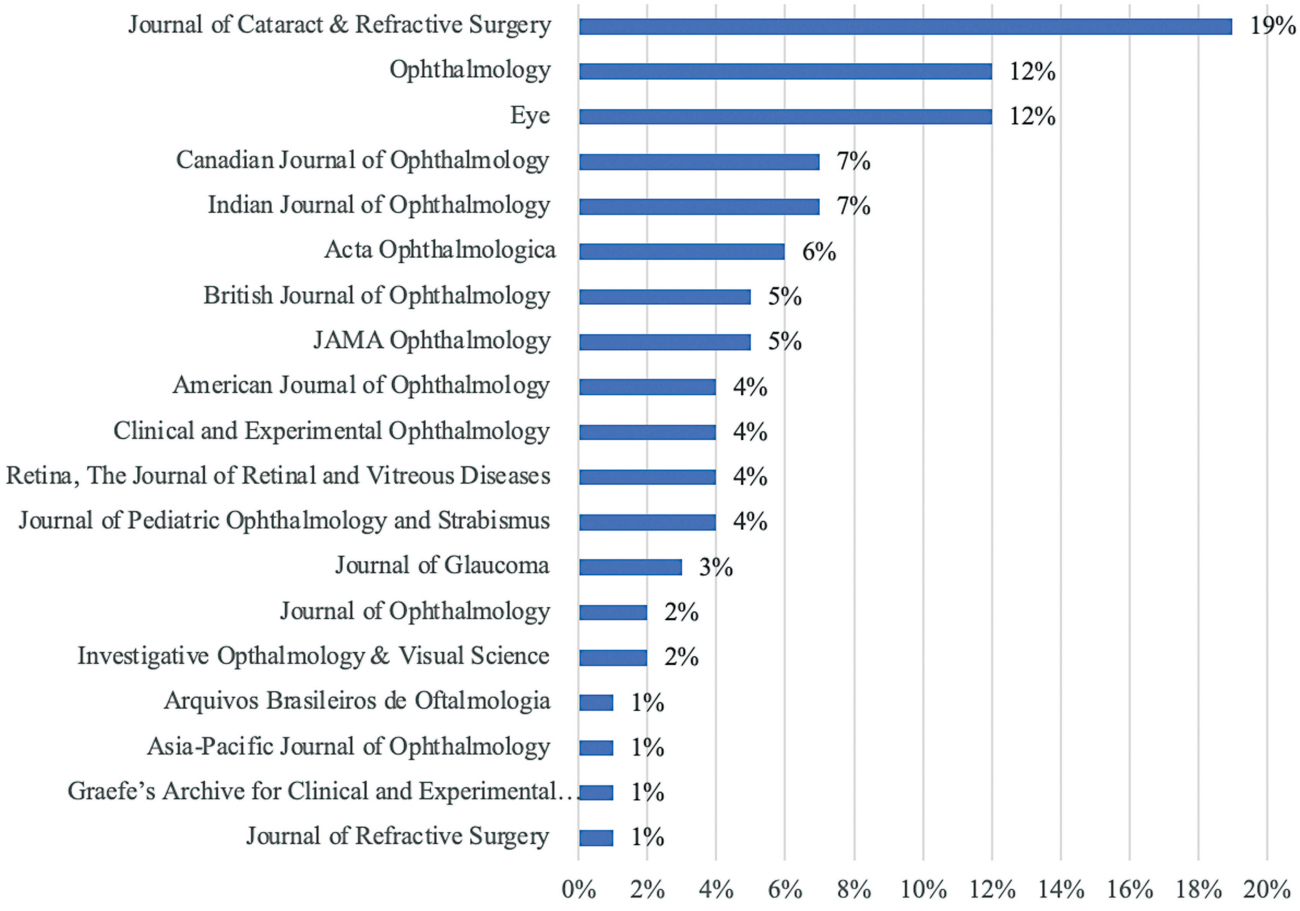

Fig. 1 Top 100 ophthalmic articles journal distribution.

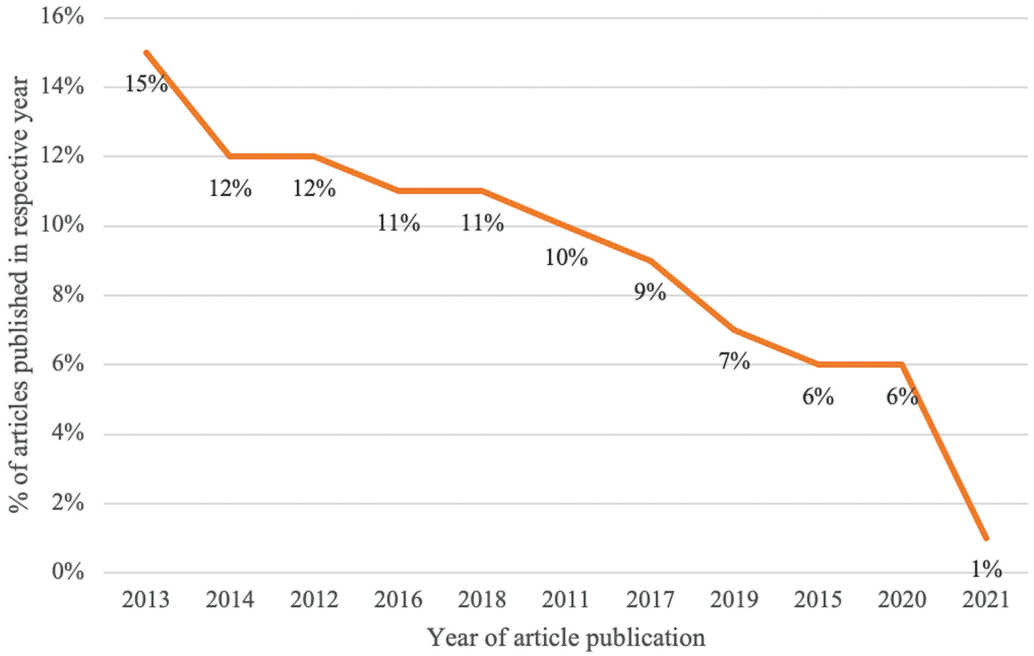

Fig. 2 Distribution of year of article publication.

(►**Table 1**). Following the United States, England, Canada, India, and Australia were among the next highest countries of origin. Each country has English as the official or one of its official languages, which follows previous studies positing a publication bias toward English-speaking countries.[14] This finding may also be augmented by our search criteria excluding non-English articles. However, there have been some suggestions that this trend of predominately U.S.-produced

Table 2 Topics of the 100 most cited articles in ophthalmic education

Topic	Number of articles	Article ranks from Table 1
Resident and fellow education	51	
Residency curriculum	18	13, 20, 29, 34, 35, 40,52, 62, 66, 70, 80, 81, 85, 87, 89, 94, 99, 100
Cataract surgical outcomes	11	8, 10, 22, 41, 44, 63, 68, 77, 88, 93, 95
Glaucoma surgical outcomes	3	15, 28, 96
Clinical management of retinopathy of prematurity	2	21, 24
Residency application	2	25, 97
Blepharoptosis	1	42
Intravitreal Bevacizumab (IVB) injections	1	48
Lens and corneal refractive surgery	1	51
Tele-education	1	55
Strabismus	1	61
Evaluation of residency and its effectiveness	4	53, 65, 74, 86
Photorefractive keratectomy (PRK) and LASIK	1	69
Residency wellness	1	79
Binocular indirect ophthalmoscopy (BIO)	1	78
Vitreoretinal surgery	1	83
Endoscopic endonasal dacryocystorhinostomy (En-DCR)	1	91
Board examination performance	1	98
Surgical training	21	
Virtual reality	11	1, 11, 12, 16, 17, 19, 23, 33, 36, 43, 59
Surgery simulator	5	2, 4, 6, 18, 30
Wide angle endoillumination	1	39
Evaluation of surgical training	1	57
Wet lab	3	47, 67, 82
Medical school education	21	
Ocular fundus examination and direct ophthalmoscope	8	7, 32, 49, 50, 56, 57, 58, 60
Ophthalmology in medical school curriculum	5	9, 38, 71, 72, 84
Virtual Ophthalmology Clinic (VOC)	1	26
BIO	1	31
Vitreoretinal surgeries	3	51, 92, 98
E-learning	2	75, 92
Stereoacuity	1	76
Other	7	
Coronavirus disease and ophthalmologic education	4	3, 5, 27, 73
Educational devices	2	14, 90
Gaze behavior	1	46

ophthalmic articles is changing.[15] For example, the *American Journal of Ophthalmology* has seen an increase in manuscript submissions from outside the United States, specifically from countries such as South Korea and India.[16] Interestingly, this shift toward greater international research output is seen among the top five authors with the highest number of first or last authorships, who are all from institutions outside the United States. Of note, authors from a Nordic country, either Denmark (Ann Sofia Skou Thomsen and Lars Konge) or Sweden (Madeleine Selvander and Peter Åsman) contributed to 14 of the T100 articles (►**Table 1**). Significant Nordic contributions to ophthalmology research in various subfields have been noted in the past and may explain the larger output of research in the field of ophthalmic education.[17,18]

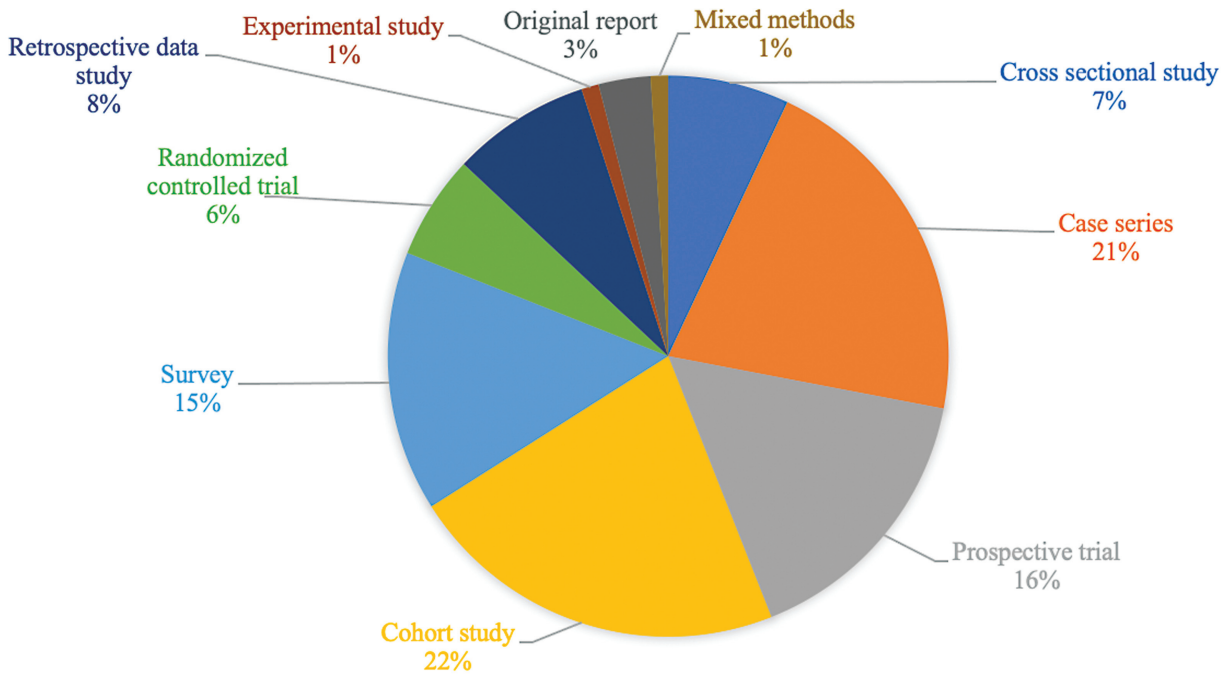

Fig. 3 Pie chart of study types.

The topics of the T100 ophthalmic education articles show a wide range of focus over our search time frame (►**Table 2**). Most of the articles (51%) focus on resident education, with a notable interest in improving existing residency curricula. Previous authors have reported that the quality of a residency program and its curriculum can affect ophthalmology residents' confidence and competency posttraining.[19,20] In addition, within the realm of resident education, we observed several T100 articles reporting outcomes of resident-performed cataract and glaucoma surgeries. Previous studies have highlighted the varying microinvasive glaucoma surgeries surgical experiences of ophthalmology residents.[21] Furthermore, a study by Liebman et al suggested performing a more significant number of cataract cases improves operative time and is an "educational benefit."[22] Notably, among the subsections of resident education was the singular article focused on resident wellness. The importance of residency wellness has become more prominent in recent years; however, a discrepancy between resident wellness and its priority has been noted among residents and program directors.[23] Overall, there is a clear variety of topics of focus within resident education.

There were 21 articles on medical school education in the T100 list, with most focusing on teaching direct ophthalmoscopy/fundoscopy. Direct ophthalmoscopy has a steep learning curve and also has significant utility to medical practitioners outside of ophthalmology to properly examine the posterior segment.[24] Ophthalmic educators are highly motivated to teach this critical skill, and this is reflected in the number of T100 articles that discuss methods to improve existing curricula in this area. Another area highlighted in ophthalmic medical school education was E-learning. Due to advancements in technology and the constraints of the COVID-19 pandemic, there has been an interest in nontraditional teaching methods, including E-learning.[25] With more articles being published examining the effect of COVID-19 on ophthalmic education, including four articles in the T100 list, the growth of ophthalmic education articles focused on E-learning may encourage research in the area and more articles in the T100 list.

Surgical training received considerable attention among the T100 articles. As mentioned previously, a residency's ability to provide adequate surgical training can affect surgical outcomes and trainees' confidence after graduation.[19,20,26] The articles in the T100 reflect the various methods of teaching surgical training, from wet labs to surgical simulators. More than one-half of articles on this topic examined virtual reality, highlighting its present and future relevance in surgical training. Significantly, the implementation of virtual reality curricula has been shown to improve outcomes and reduce residents' rate of complications during cataract surgery, such as s posterior capsular rupture and poor curvilinear capsulorrhexis.[27,28] As surgical simulators are increasingly utilized by residency programs, future work exploring the use of virtual reality simulators by postophthalmology match medical students and early-year ophthalmology residents may be an area of interest to educators.

The distribution of the year articles in the T100 were published shows that 55% of the articles were published in the first half of the decade (2011–2015) of our study period (►**Fig. 2**). While there was no correlation between the number of citations and the number of years since publication, older articles may have more citations due to their longevity compared with more recent publications. However, this may not always be true as older knowledge can

present information outdated to newer studies, thus leading to fewer citations.[29] A statistically significant correlation was found between the number of citations per year and the number of years since publication ($p < 0.001$). A possible explanation is that more recent publications have a shorter time to be cited enough to be included in the T100 articles. Examples can be seen in articles #3 and #5 from ►**Table 1**, which were both COVID-related ophthalmic education articles published in 2020. These articles have, respectively, 37 and 29 to 30 citations per year, which is much higher than the average of 6.06 article citations per year. This finding may also suggest articles on COVID-related education papers are of particular interest to readers and researchers, which would explain their higher citations despite their relatively short publication time.

Common study types utilized in the T100 articles were cohort studies, case series, and prospective trials (►**Fig. 3**). Overall, observational studies represented the majority of studies compared with randomized controlled trials (RCT), often considered the gold standard in evidence-based medicine.[30] However, some have suggested that observational studies and RCTs do not differ in effectiveness.[31,32] Additionally, the nature of ophthalmic education offers challenges in reducing confounding variables, obtaining adequate study population numbers, and implementing an RCT study design. Factors such as a constantly changing trainee population, varying teaching methods, availability of resources, and other modalities may influence study designs toward observational studies.

This study has several limitations. First, variations in databases could offer different search results based on additional or different search phrases; thus, a bibliometric study utilizing another database or additional search terms may be warranted. Second, articles were limited to ophthalmological journals that may have excluded noteworthy ophthalmology education articles published in nonophthalmology journals. Third, our search led to over 26,000 WoS results that had to be manually trimmed to the T100 relevant articles according to the number of citations. This high search result presents opportunities for human error in the selection of the T100 articles. However, this limitation was mitigated by having two authors perform the search and evaluate article inclusion according to the study's inclusion and exclusion criteria. Fourth, is the linear association between the time articles have been published and the number of citations of an article (►**Fig. 2**). This finding only suggests articles that were cited more often and not necessarily which articles are most "important." An analysis considering the year of publication and article citations to identify articles with the potential for greater citations is warranted in future studies. Finally, it is important to mention the exclusion of the *Journal of Academic Ophthalmology*. While the journal does focus on ophthalmology academia, it is not indexed in PubMed and did not appear in our WoS search, which included 114 ophthalmology-focused journals. It is not possible to ascertain whether articles from the *Journal of Academic Ophthalmology* would meet at least nine article citations to be included in the T100 list, and thus, future studies utilizing other databases should consider PubMed index status to include the journal.

In summary, this bibliometric study examines general trends and areas of focus among the T100 articles in ophthalmic education in recent years. Our study showed that articles tend to be from U.S.-based authors with a focus on high-impact journals; however, there has been a greater contribution from non-U.S. authors and countries recently. Resident education, medical school education, and surgical training are the most studied topics in the T100. Researchers interested in ophthalmology education may use these findings to plan meaningful and relevant studies in the future.

Conflict of interest
None declared.

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