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ORIGINAL ARTICLE

Low-cost fundoscopy simulation for everyone? Evaluation of knowledge gain and student satisfaction with the Kyoto Kagaku model

Simulation de rétinoscopie à faible coût pour tous ? Évaluation des connaissances acquises et de la satisfaction des étudiants avec le modèle Kyoto Kagaku

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Direct ophthalmoscopy ;
Education ;
Kyoto Kagaku

Summary
Purpose. — To evaluate the influence of a relatively low-cost fundoscopy simulator, the Kyoto Kagaku model for direct ophthalmoscopy (DO), on the subjective learning experience and objective knowledge gain of medical students at Saarland University Medical Centre, Homburg, Germany.
Methods. — Medical students were enrolled in a physical examination course on ophthalmoscopy and ophthalmoscopically visible pathologies. The course consisted of a theoretical part, an introduction to the practical basics of DO using the Kyoto Kagaku fundoscopy simulator, and a mutual examination of real eyes (the classical DO course). They filled out two questionnaires — one on their subjective learning experience immediately after the course and another on objective clinical knowledge in direct ophthalmoscopy (DO), completed before the start of DO training and one week later.

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Results. — The medical students showed a significant gain in knowledge after the course with the Kyoto Kagaku fundoscopy simulator ($P < 0.001$). Specific anatomical structures in the fundus were significantly more often identified during the simulator training compared to the classical DO course ($P < 0.001$). Forty-seven percent of the medical students preferred a simulator-based course only, 23% a classical DO course and 30% a combination of both.
Conclusion. — Simulator-based training is a valuable tool for teaching DO skills to medical students (and aspiring resident physicians). Hands-on courses using the Kyoto Kagaku fundoscopy simulator have been successful in increasing medical students' interest in medical simulation and ophthalmology. This model, known for its relatively low cost, is a good immersive tool for teaching the basics of direct fundoscopic examination and various retinal pathologies.

MOTS CLÉS
Formation médicale assistée par simulateur ;
Fundoscopie ;
Ophtalmoscopie directe ;
Éducation ;
Kyoto Kagaku

Résumé
Objectif. — Évaluer l'influence d'un simulateur de rétinoscopie relativement peu coûteux, le modèle Kyoto Kagaku pour l'ophtalmoscopie directe (DO), sur l'expérience d'apprentissage subjective et l'acquisition objective de connaissances des étudiants en médecine du centre médical universitaire de la Sarre, à Homburg, en Allemagne.
Méthodes. — Les étudiants en médecine ont suivi un cours d'examen physique sur l'ophtalmoscopie et les pathologies visibles à l'ophtalmoscope. Le cours comprenait une partie théorique, une introduction aux bases pratiques de la DO à l'aide du simulateur de fundoscopie Kyoto Kagaku et un examen mutuel d'yeux réels (cours classique de DO). Ils ont rempli deux questionnaires : l'un sur leur expérience d'apprentissage subjective immédiatement après le cours et l'autre sur leurs connaissances cliniques objectives en ophtalmoscopie directe (DO), avant le début de la formation en DO et une semaine plus tard.
Résultats. — Les étudiants en médecine ont montré un gain significatif de connaissances après le cours avec le simulateur de fundoscopie Kyoto Kagaku ($p < 0{,}001$). Les structures anatomiques spécifiques du fond de l'œil ont été identifiées significativement plus souvent pendant la formation sur simulateur que pendant le cours classique sur l'DO ($p < 0{,}001$). Quarante-sept pour cent des étudiants en médecine ont préféré un cours basé uniquement sur le simulateur, 23 % un cours classique sur la DO et 30 % une combinaison des deux.
Conclusion. — La formation sur simulateur est un outil précieux pour enseigner les compétences en DO aux étudiants en médecine (et aux futurs médecins résidents). Les cours pratiques utilisant le simulateur de fundoscopie Kyoto Kagaku ont permis d'accroître l'intérêt des étudiants en médecine pour la simulation médicale et l'ophtalmologie. Ce modèle, connu pour son coût relativement faible, est un bon outil immersif pour enseigner les bases de l'examen fundoscopique direct et diverses pathologies rétiniennes.

Introduction

Simulator-based training has been a teaching tool for over a decade in aviation and aerospace industries and is now widely used in a variety of high-risk professions and disciplines, such as medicine [1]. Simulator-based medical education (SBME) has been shown to be a useful adjunct to surgical training in ophthalmology [2—6]. Multiple studies have demonstrated the effectiveness of simulation in the teaching of basic science and clinical knowledge, procedural skills, teamwork, and communication as well as assessment at the undergraduate and graduate medical education levels [7].

Several key roles of SBME are feedback, skill acquisition and maintenance, and transfer to practice. Feedback is often seen as the primary role of SBME, as its purpose is to improve the trainee's clinical performance and skill acquisition [8]. Depending on the complexity of the device used for SBME, the feedback comes from the device itself (autonomous, independent learning) or from an instructor (heteronomous, dependent learning). The primary role of the instructor is facilitating, guiding and motivating learners during the SBME. This role can be performed by a trained instructor or by a complementary web-based progress monitoring service for networked simulators, e.g. VRmNet (Haag-Streit Simulation, Mannheim, Germany) [9].

Figure 1. A frontal view of the s, showing the cogwheel at the top of the head for adjusting the pupil size in three steps (2.0, 3.5 and 5.0 mm) to increase or decrease the level of difficulty (www.kyotokagaku.com/en/products_data/m82m82a).

Wu et al. [10] reported that medical students, residents and faculty internists, collectively and by training level, had the lowest self-confidence in the non-dilated direct fundoscopic examination using an ophthalmoscope to assess retinal vasculature. They suggested that the low self-confidence was due to a combination of two factors: difficulty to master the examination technique and that the examination should be performed by a trained professional if necessary, in this case, an ophthalmologist. Meanwhile, this skill is difficult to teach effectively in the early stages and to guide students during the examination as tutors, due to the lack of a screen attached to the direct ophthalmoscope.

The Kyoto Kagaku EYE Examination Simulator (Kyoto Kagaku Co. Ltd., Kyoto, Japan) (Fig. 1) is a simulator designed to train medical students in DO. It uses two-dimensional visualizations of fundoscopic images (both normal and pathological) combined with an adjustable pupil in three steps (2.0, 3.5 and 5.0 mm) to increase or decrease the level of difficulty. The unit has one display for each eye, which can be monitored separately. It has an initial set of normal and pathological fundus photographs. It is possible to add new fundus images from external sources (e.g. own clinical environment) to the device via a USB connection. The aim of this study is to evaluate the influence of a relatively low-cost fundoscopy simulator, the Kyoto Kagaku model, on the subjective learning experience and objective knowledge gain of medical students.

Materials and methods

This study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Ethics Committee of the Saarland Medical Association, Germany (registration number 94/22).

Participants

A total of 117 undergraduate medical students from the Saarland University Medical Centre (Homburg, Saarland, Germany) were recruited for this study. The students were divided into small groups, with each group consisting of 6-8 individuals, to enhance teacher and student interaction. All participants were enrolled in the same direct ophthalmoscopy (DO) training course and were novice learners in this area. The DO training course consisted of a theoretical part, an introduction to the practical basics of DO using the Kyoto Kagaku fundoscopy simulator, and an examination of real eyes on each other with dilated pupils (the classical DO course).

Theoretical training

The training began with theoretical education provided by the same instructors. During this session, the instructors discussed the anatomy of the posterior chamber of the eye, focusing on important structures visible through fundoscopy. Additionally, the students were instructed in the systematic assessment of the fundus and were introduced to several important pathologies with their typical characteristics and pathogenesis, which can be observed during funduscopic examination.

Practical training with Kyoto Kagaku fundoscopy simulator

After the theoretical training, the students engaged in practical training using the Kyoto Kagaku fundoscopy simulator. During this part, two Kyoto Kagaku fundoscopy simulators were available to the small group of students. In combination with a direct handheld ophthalmoscope (Heine Beta 200, HEINE Optotechnik GmbH & Co. KG, Gilching, Germany), this simulator allowed the students to practice the fundamental techniques of DO and to gain hands-on experience to develop their skills in DO. They were required to identify different anatomical structures, including the papilla, macula, and the four main vessel arcades (superior/inferior, nasal/temporal).

Classic direct ophthalmoscopy course

Subsequently, the students participated in a classic DO class. In this session, two students from each group underwent mydriasis on one eye, with one student having their right eye dilated and the other having their left eye dilated. This arrangement allowed the students to practice DO on each other with a single dilated pupil, and also gave each student the same amount of time during the classic direct ophthalmoscopy course as on the simulator. The primary objective of this course was to enable the students to recognize the same anatomical structures they had learned about theoretically and by using the Kyoto Kagaku model, on real-life ''patients''.

Questionnaires

After the completion of the DO training, the students were asked to complete two questionnaires. The first ques-

Table 1 Objective clinical gain of knowledge.

	Before training, correct (%)	After training, correct (%)	Mc Nemar
Questions about theory			
1. Difference in direct/indirect ophthalmoscopy	50.4%	88.5%	$P < 0.001$
2. Direct ophthalmoscopy perceived fundoscopic image	35.4%	82.8%	$P < 0.001$
3. Contraindication to mydriatic eye drops	22.8%	85.2%	$P < 0.001$
4. Relevance of ophthalmoscopy to other disciplines	92.9%	95.9%	$P = 1.00$
Questions about pathology with fundus photographs			
5. Central toxoplasmosis pigmented chorioretinal scar	40.9%	87.7%	$P < 0.001$
6. Glaucomatous optic nerve atrophy	28.3%	74.6%	$P < 0.001$
7. Branch retinal vein occlusion	34.6%	60.7%	$P = 0.004$
8. Dry age-related macular degeneration	47.2%	84.4%	$P < 0.001$
9. Severe non-proliferative diabetic retinopathy	32.3%	73.8%	$P < 0.001$
10. Papilledema	51.2%	89.3%	$P < 0.001$
Mean	4.4	8.2	Wilcoxon
Median	4	9	$P < 0.001$
Minimum	1	4	
Maximum	9	10	
Standard deviation (SD)	1.7	1.7	
Lower quartile (Q1)	3	7	
Upper quartile (Q3)	5	10	
Interquartile range (IQR)	2	3	

Two questionnaires about the objective clinical knowledge gained in ophthalmoscopy were filled out before the start of direct ophthalmoscopy training and 1 week thereafter. Mc Nemar test was used to compare the results from both tests for each of the 10 questions in the knowledge test individually. A Wilcoxon signed-rank test as a non-parametric test was performed to compare general results from both tests.

tionnaire was designed to assess their subjective learning experience (five-point Likert scale), as well as the subjective identification of the anatomical structures during fundoscopy during the simulator training and the classic DO course, and was filled out shortly after the course. The second questionnaire aimed to evaluate the objective clinical knowledge gained in DO. This questionnaire, consisting of ten multiple-choice questions with four to five answer possibilities, was completed by the students both before the start of the DO training and one week after its completion.

Statistical analysis

Statistical analysis was performed using Excel 2021 (Microsoft 365, Microsoft Corp., Redmond, WA), and a significance level of $P < 0.05$ was adopted to determine statistical significance. To assess the overall knowledge gain, a Wilcoxon signed-rank test as a non-parametric test was performed to compare results from both questionnaires. The Mc Nemar Test was utilized to individually calculate the p-values for each of the 10 questions in the knowledge test. In addition, the Chi-Square test was used to determine if there was a significant difference in the recognition of anatomical structures within the fundus.

Results

The medical students showed a significant ($P < 0.001$, Wilcoxon signed-rank test) gain in knowledge of the fundoscopic examination and pathologies after the completion of the entire course (Table 1). Based on our results, theoretical question number 4 about the relevance of ophthalmoscopy for different medical disciplines, did not require in-depth prior knowledge to be answered correctly. The specific anatomical structures in the fundus were significantly more often subjectively identified ($P < 0.001$, chi-square test) during the simulator training compared to the classical DO course (Table 2). Students seem to have the most difficulties with recognizing the macula compared to the optic disc and the vessel arcades. Overall, the students were satisfied with the combination of both the simulator and classical DO course (Table 3). A lot of students mentioned having an interest in simulator-based training as a part of their medical training and in technology as a whole. Although not many students showed affection for ophthalmology priorly, the DO training was able to awaken more enthusiasm towards the discipline of ophthalmology (five-point Likert scale). Additionally, the students did not only objectively gain more insight into (direct) ophthalmoscopy and its pathologies, but they also subjectively acknowledged a growth in knowledge after the course (Table 3). To conclude our results, 47% of the medical students preferred a simulator-based course only, 23% a classical DO course and 30% a combination of both (Fig. 2).

Discussion

The implementation of SBME has shown promising results and offers several significant advantages [11,12]. One of the most crucial factors in the widespread adoption of

Table 2 Subjective recognition of anatomical structures simulator versus classic direct ophthalmology training.

Identification of	Simulator	Classic	*P*-value
Optic disc	112	67	< 0.001
Macula	104	32	< 0.001
Nasal superior vessel arcade	102	61	< 0.001
Temporal superior vessel arcade	106	64	< 0.001
Nasal inferior vessel arcade	100	44	< 0.001
Temporal inferior vessel arcade	102	55	< 0.001
Total	**116**	**116**	

The chi-square test was used to determine if there was a significant difference in the subjective recognition of anatomical structures within the fundus comparing the simulator and the classic direct ophthalmoscopy training. One student did not complete the form, so the total number of responses was 116 instead of 117. Bold characters: A total of 116 students responded to the questions.

Table 3 Subjective rating of the direct ophthalmology course.

	Totally agree	Agree	Partially (dis)agree	Disagree	Totally disagree	Total
I am satisfied with the direct ophthalmoscopy training	67	49	1	0	0	117
I am interested in technology	23	42	40	12	0	117
I would prefer more simulator training	42	47	24	4	0	117
I was already particularly interested in ophthalmology prior to opthalmoscopy training	3	2	24	67	21	117
I was not interested in ophthalmology prior to training, but i am now.	5	30	54	22	4	115
I developed an understanding of the principle of direct ophthalmoscopy	49	61	7	0	0	117
I have improved my understanding of individual ophthalmologic disease patterns	42	63	12	0	0	117

Rating:	Very good	Good	Satisfactory	Sufficient	Inadequate	Unsatisfactory	Total
Training	**73**	42	1	0	0	0	116
Supervision	**103**	14	0	0	0	0	117

A questionnaire on the subjective learning experience (five-point Likert scale) and the subjective rating of the direct ophthalmoscopy course (combination of simulator and classic) was filled out shortly after the course had ended. Two students did not respond to the fifth question, and one did not rate the training itself.

simulator-based training is the cost of simulator material. To ensure accessibility to a broader range of universities and clinical institutions, it is imperative to develop cost-effective simulators without compromising their quality and effectiveness. By addressing the cost issue, medical educators can facilitate the integration of simulator-based training into the standard medical curriculum, giving the students more standardized training opportunities.

In view of the current demographic trends and the relative shortage of young doctors and specialists, the quality of teaching is of great importance, as only good, high-quality teaching can attract students and trainees to ophthalmology and ensure the training of our future ophthalmologists [13]. Particularly in a technique that is difficult and time-consuming to master such as direct ophthalmoscopy, an autonomous simulator (independent learning) could greatly enhance the efficiency of training medical students and residents, as well as their confidence in performing physical examinations [14—16]. Repeated exposure of medical students to SBME experiences can not only develop a sense of psychological stability and confidence, but also improve their clinical performance [16,17].

The modern generation of medical students has grown up surrounded by technology and is naturally more inclined towards utilizing technological tools in their learning process. As such, this presents an opportune moment to incorporate simulator-based training into the standard medical training curriculum. By leveraging students' fami-

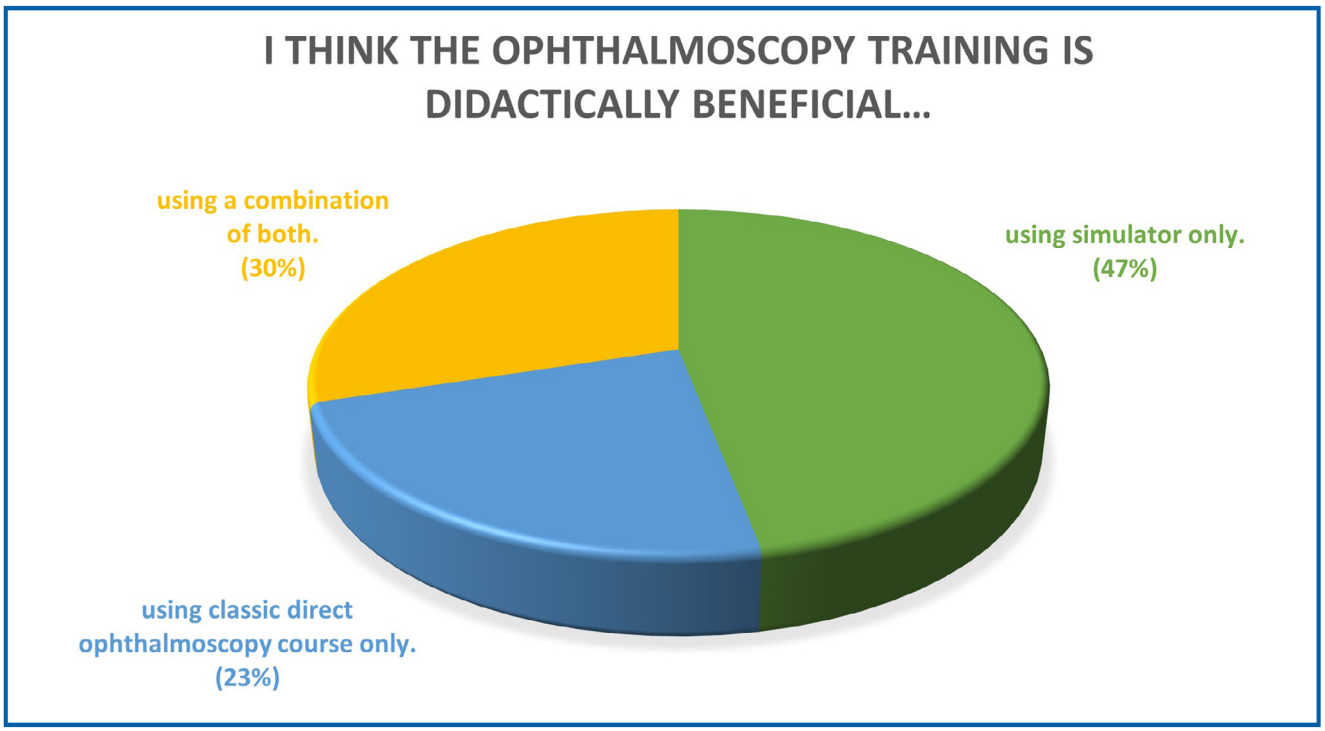

Figure 2. A questionnaire on the subjective learning experience and on how the future direct ophthalmoscopy course should look was completed shortly after the course.

liarity with technology, educators can enhance engagement and foster more effective learning experiences.

Simulator-based training has already demonstrated its value in various industries, such as pilot training, and has also shown promising results in the surgical and diagnostic field of ophthalmology [1—6,18,19]. Our results have indicated that SBME with the Kyoto Kagaku model led to significant knowledge gain and greater satisfaction compared to the standard DO course. This emphasizes the potential of SBME to improve medical education outcomes and enhance clinical skills.

One of the key advantages of SBME is the elimination of the need for real patients to demonstrate specific pathologies. This aspect is particularly valuable for rare cases, where real patients may be scarce or inaccessible. By utilizing simulators, students can be exposed to a wide range of medical scenarios, preparing them for the challenges they might encounter in their future medical practice.

Additionally, SBME in ophthalmology offers several practical benefits. Patients and/or students who play patient, no longer need to be exposed to a stressful intense light during fundoscopy. In a climate where patients increasingly worry about students and residents ''practicing'' on them, SBME can help to mitigate this trend [7]. While the motivation to participate and acceptance of the physical examination course generally appears to be high among medical students, willingness to be examined on certain parts of the body varies, depending on religion, gender and examiner [20]. Furthermore, the use of mydriatic agents, which can cause temporary vision impairment and restricts patients from driving, becomes unnecessary when using simulators.

Howell et al. [14] reported advantages of SBME for direct ophthalmoscopy (DO) using Eyesi direct (Haag-Streit Simulation, Mannheim, Germany), including improved technique, ability to localize fundus lesions, and increased training time during SBME. Furthermore, Flockerzi et al. [21] observed that medical students' skills in ophthalmoscopy increased and their professional interest in ophthalmology was aroused due to SBME with Eyesi direct. Rai et al. [15] also reported similar benefits of SBME for binocular indirect ophthalmoscopy using Eyesi indirect (Haag-Streit Simulations, Mannheim, Germany) compared to conventional teaching of first-year residents. SBME reduces the need for the patient to be present, without causing them any discomfort (e.g. exposure to light) [7,22]. Both simulators have a screen attached, facilitating tutors' guidance. The use of simulators can provide a cost-effective and safe way to train individuals in certain medical skills without time pressure [22].

Incorporating virtual reality (VR, three-dimensional visualization) simulations into medical education holds even greater promise as it offers a more immersive and interactive learning experience. VR can overcome the limitations of two-dimensional visualization and provide a more realistic simulation of medical procedures, further enhancing the benefits of simulator-based training. In addition, more recent simulators have built-in feedback systems (autonomous, independent learning), reducing the need for an instructor to be present during training sessions. However, it is essential to acknowledge that the integration of VR simulators and more autonomous simulators comes at a higher cost. This higher price also correlates with a greater variety of training applications compared to the Kyoto Kagaku fundoscopy simulator, e.g. Eyesi direct offers a standardized curriculum from training in instrument handling, recognition of anatomical structures and documentation of ophthalmoscopic findings to a wide variety of clinical

cases supported by theoretical background guidance. These advanced simulators could provide a great teaching platform for ophthalmology residents, but may provide too much detail for non-ophthalmology medical disciplines that also use direct ophthalmoscopy as a screening tool. Therefore, the Kyoto Kagaku simulator could provide a low-cost training in the basics of first-line screening to non-ophthalmology specialists as well as to beginning ophthalmology residents. Balancing the potential benefits and cost considerations will be crucial in determining the feasibility of incorporating (autonomous VR) simulators into medical education, depending on the medical specialty.

Conclusion

Hands-on DO courses using the Kyoto Kagaku fundoscopy simulator have been successful in increasing medical students' interest in SBME and ophthalmology, as well as achieving a significant gain in knowledge of fundoscopic skills and recognition of anatomical structures of the posterior chamber of the eye, and its pathologies. This model, known for its relatively low cost, is a good immersive tool for teaching the basics of direct fundoscopic examination and various ophthalmoscopically visible pathologies (two-dimensional visualization). Therefore, the Kyoto Kagaku simulator could provide a low-cost training in the basics of first-line screening to non-ophthalmology specialists as well as to beginning ophthalmology residents. SBME has the potential to revolutionize medical education by offering cost-effective and engaging alternatives to traditional methods. Addressing cost concerns and exploring the possibilities of virtual reality simulations will be pivotal in maximizing the benefits of simulator-based training in the medical field. Although there are still challenges to overcome, such as accessibility and cost of advanced simulators, the future of simulator-based training in ophthalmology looks promising.

Lessons for practice

1. Kyoto Kagaku fundoscopy simulator success: the Kyoto Kagaku EYE Examination Simulator, a cost-effective tool, significantly improves students' subjective learning and objective clinical knowledge in direct ophthalmoscopy. Incorporating virtual reality (VR, three-dimensional visualization) simulations into medical education holds even greater potential as it offers a more immersive and interactive learning experience.

2. SMBE's essential role: simulator-based training is crucial in medical education, offering feedback, skill acquisition, and knowledge transfer to enhance clinical performance and self-confidence.

Disclosure of interest

The authors declare that they have no competing interest.

Références

[1] Issenberg SB, Gordon MS, Gordon DL, Safford RE, Hart IR. Simulation and new learning technologies. Med Teach 2001;23:16—23.

[2] Staropoli PC, Gregori NZ, Junk AK, Galor A, Goldhardt R, Goldhagen BE, et al. Surgical simulation training reduces intraoperative cataract surgery complications among residents. Simul Healthc 2018;13:11—5.

[3] Roohipoor R, Yaseri M, Teymourpour A, Kloek C, Miller JB, Loewenstein JI. Early performance on an eye surgery simulator predicts subsequent resident surgical performance. J Surg Educ 2017;74:1105—15.

[4] 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;104:324—9.

[5] Lucas L, Schellini SA, Lottelli AC. Complications in the first 10 phacoemulsification cataract surgeries with and without prior simulator training. Arq Bras Oftalmol 2019;82:289—94.

[6] Thomsen ASS, Smith P, Subhi Y, la Cour M, Tang L, Saleh GM, et al. High correlation between performance on a virtual-reality simulator and real-life cataract surgery. Acta Ophthalmol 2017;95:307—11.

[7] Okuda Y, Bryson EO, DeMaria S, Jacobson L, Quinones J, Shen B, et al. The utility of simulation in medical education: what is the evidence? Mt Sinai J Med 2009;76:330—43.

[8] McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003—2009. Med Educ 2010;44:50—63.

[9] Deuchler S, Sebode C, Ackermann H, Schmack I, Singh P, Kohnen T, et al. [Combination of simulation-based and online learning in ophthalmology: efficiency of simulation in combination with independent online learning within the framework of EyesiNet in student education]. Ophthalmologe 2022;119:20—9.

[10] Wu EH, Fagan MJ, Reinert SE, Diaz JA. Self-confidence in and perceived utility of the physical examination: a comparison of medical students, residents, and faculty internists. J Gen Intern Med 2007;22:1725—30.

[11] Boden KT, Rickmann A, Fries FN, Xanthopoulou K, Alnaggar D, Januschowski K, et al. [Evaluation of a virtual reality simulator for learning direct ophthalmoscopy in student teaching]. Ophthalmologe 2020;117:44—9.

[12] Deuchler S, Dail YA, Koch F, Buedel C, Ackermann H, Flockerzi E, et al. Efficacy of simulator-based slit lamp training for medical students: a prospective, randomized trial. Ophthalmol Ther 2023;12:2171—86.

[13] Van Way CW. Thoughts on medical education. Mo Med 2017;114:417—8.

[14] Howell GL, Chávez G, McCannel CA, Quiros PA, Al-Hashimi S, Yu F, et al. Prospective, randomized trial comparing simulator-based versus traditional teaching of direct ophthalmoscopy for medical students. Am J Ophthalmol 2022;238:187—96.

[15] Rai AS, Rai AS, Mavrikakis E, Lam WC. Teaching binocular indirect ophthalmoscopy to novice residents using an augmented reality simulator. Can J Ophthalmol 2017;52:430—4.

[16] Yu JH, Chang HJ, Kim SS, Park JE, Chung WY, Lee SK, et al. Effects of high-fidelity simulation education on medical students' anxiety and confidence. PLoS One 2021;16:e0251078.

[17] Zhang M, Cheng X, Xu A, Luo L, Yang X. Clinical simulation training improves the clinical performance of Chinese medical students. Med Educ Online 2015;20:28796.

[18] Deuchler S, Scholtz J, Ackermann H, Seitz B, Koch F. Implementation of microsurgery simulation in an ophthalmology clerkship in Germany: a prospective, exploratory study. BMC Med Educ 2022;22:599.
[19] Deuchler S, Dail YA, Berger T, Sneyers A, Koch F, Buedel C, et al. Simulator-based versus traditional training of fundus biomicroscopy for medical students: a prospective randomized trial. Ophthalmol Ther 2024;13:1601—17.
[20] Burggraf M, Kristin J, Wegner A, Beck S, Herbstreit S, Dudda M, et al. Willingness of medical students to be examined in a physical examination course. BMC Med Educ 2018;18:246.
[21] Flockerzi E, Deuchler S, Abdin A, Flockerzi V, Flockerzi F, Koch F, et al. Direct ophthalmoscopy teaching of medical students based on a standardised simulator-based procedure versus the classic ophthalmoscope. Klin Monbl Augenheilkd 2026, http://dx.doi.org/10.1055/a-2751-3142.
[22] Al-Elq AH. Simulation-based medical teaching and learning. J Family Community Med 2010;17:35—40.