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ORIGINAL RESEARCH

Efficacy of Simulator-Based Slit Lamp Training for Medical Students: A Prospective, Randomized Trial

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ABSTRACT

Introduction: Simulation training has an important role in medical education. In ophthalmology, simulation-based training has been shown to be significantly effective for surgical and diagnostic training in direct and indirect ophthalmoscopy. In this study, we analysed the effects of simulator-based slit lamp training.

Methods: In this prospective controlled trial, medical students in their eighth semester at Saarland University Medical Center ($n = 24$) who had attended a 1-week ophthalmological internship were randomized into two groups: The traditional group ($n = 12$) was examined directly after the 1-week internship; the simulator group ($n = 12$) was trained with the slit lamp simulator before passing an objective structured clinical examination (OSCE). A masked ophthalmological faculty trainer assessed the students' slit lamp skills (maximum total score 42 points [pts]): preparation (5 pts), clinical examination (9.5 pts), assessment of findings (9.5 pts), diagnosis (3 pts), commentary on the examination approach (8 pts), measurement of structures (2 pts) and recognition of five diagnoses (5 pts). All students completed post-assessment surveys. Examination grades and survey responses were compared between the groups.

Results: The overall performance of the slit lamp OSCE was significantly better ($p < 0.001$) in the simulator group than in the traditional group (29.75 [7.88] vs. 17.00 [4.75]) with significantly higher scores for the preparation and assessment of slit lamp controls (5.0 [0.0] vs. 3.0 [3.5]; $p = 0.008$) and localization of relevant structures (6.75 [3.13] vs. 4.0 [1.5]; $p = 0.008$). Consistently higher scores, but not significant, were assigned for the description of structures found (4.5 [3.38] vs. 3.25 [2.13]; $p = 0.09$) and the correct diagnosis (3.0 [0.0] vs. 3.0 [0.0]; $p = 0.48$). Surveys reflected the students' subjectively perceived knowledge gain during the simulator training for slit lamp illumination techniques ($p = 0.002$), recognition ($p < 0.001$), and assessment of the correct localization of pathologies ($p < 0.001$).

Conclusion: Slit lamp examination is an important diagnostic method in ophthalmology. Simulator-based training improved

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students' examination techniques for localizing anatomical structures and pathological lesions. The transfer of theoretical knowledge into practice can be achieved in a stress-free atmosphere.

Keywords: Education; Ophthalmology; Simulation; Slit lamp; Virtual reality

Key Summary Points

Why carry out this study?

A slit lamp is considered one of the most essential eye-examination instruments in ophthalmology.

Past studies have shown that medical students, and consequently practising physicians, lack confidence in their ophthalmoscopy skills due to insufficient training during medical school.

After clinical introduction, the effectiveness of simulator-based slit lamp training was analysed for the first time.

What was learned from the study?

Simulator-based training improved students' examination techniques for localizing anatomical structures and pathological lesions significantly.

The long-term effect of slit lamp simulation vs. peer physical examination training on diagnosing diseases has to be evaluated in further studies.

INTRODUCTION

A slit lamp is considered one of the most essential eye-examination instruments in ophthalmology [1, 2]. With the help of complex optical–mechanical components coupled to a stereomicroscope at different magnification steps, a slit lamp allows visualization of the anterior segment of the eye, including corneal foreign bodies [3], cells [4], and lens opacifications [5]. The variable slit adjustment using different settings, such as rotation, three-axis position of illumination and observation system, slit width and length, and inclination and rotation of the slit beam, offers—when applied correctly—a three-dimensional view with a high depth of field [6, 7]. Additional optical tools such as gonioscopy or funduscopy lenses enable viewing of the anterior chamber angle or the patient's vitreous and retina [8, 9].

Despite the establishment of these important examination techniques, past studies have shown that medical students, and consequently practising physicians, lack confidence in their ophthalmoscopy skills due to insufficient training during medical school [10–13].

Traditionally, teaching slit lamp examination skills comprises student-on-student or student-on-patient practice, but this leads to several challenges: Examination of "healthy" students' eyes rarely provides the chance to recognize diseases, the students are dependent on patient volunteers, the educator's clinical routine is time-limited; and students often receive inadequate feedback.

As McGaghie et al. stated in their review article [14], the impact and educational utility of simulation-based medical education are likely to increase in the future. Therefore, more thematic research programs are required. Simulation-based education must be adapted to organizational contexts, and a well-defined curriculum is a prerequisite for meeting student needs.

In recent publications, simulation has been shown to significantly improve both surgical [15–17] and diagnostic skills in direct and indirect ophthalmoscopy [18–21]. Ferris et al. [15] described a 38% reduction in complication rates after introduction of Eyesi simulator training for cataract surgery. Regarding diagnostic training, Boden [18] and Howell [20] reported students reached significantly higher scores in examinations after direct ophthalmoscopy simulator training.

In 2003, Romanchuk first described a model for teaching slit lamp skills [22]. A mannequin was used to simulate the position of a patient at the slit lamp. Due to the mannequin and pre-

arranged limited pathologies, the student could not obtain an independent evaluation of their examination. In 2022, the Eyesi slit lamp simulator (Haag-Streit Simulation, Mannheim, Germany) was clinically introduced after several years of development. It is a virtual reality simulator used to practice the slit lamp technique itself and recognize relevant pathologies. The simulator was integrated into a BQ 900 slit lamp model from Haag-Streit Diagnostics and supplied all functions of a real slit lamp (Fig. 1).

This is combined with a didactically structured curriculum for self-guided learning. The courseware consists of four educational tiers that range from basic device-handling tasks to abstract tasks with virtual patients to simulated pathologies to complex clinical case studies. The software indicates how the slit lamp settings should be adjusted to fulfil a given task and provides feedback on the user's performance. Currently, there are no studies of simulator-based slit lamp training and its effect on practical and theoretical slit lamp skills.

The objective of this study was to evaluate the efficacy of simulator-based slit lamp training by evaluating the students' slit lamp examination performance of the traditional vs. simulator-trained group using OSCE examination.

Fig. 1 The Eyesi slit lamp simulator equipped with original BQ 900 hardware. Physically accurate real-time simulation helps students transfer learned techniques to the clinical setting

METHODS

The study was conducted in accordance with the Declaration of Helsinki. It was evaluated by the Ethics Committee of Landesärztekammer Hessen (number 2022–3167-AF), and it was deemed that ethical approval was not required. The prospective randomized controlled trial was conducted in three phases: study recruitment that ensures an equal training level of all participants, practising on the slit lamp simulator and skills assessment. The study duration took 3 months. Twenty-four students could be included and randomized into a traditional ($n = 12$) and a simulator-trained group ($n = 12$), both passing an OSCE examination to evaluate the performance of these two groups.

For the study recruitment, medical student volunteers of the Saarland University Medical Center in their eighth semester were asked to participate in the study via email. They were only eligible if they had previously attended a complete 1-week ophthalmology internship at Saarland University Medical Center, which consisted of courses about ophthalmologic examination methods including the traditional slit lamp course, imaging methods, ophthalmologic diseases and emergencies. During the traditional slit lamp course they received an introduction to slit lamp operation and handling, and performed abstract tasks such as finding illustrations on a sheet of paper with the slit lamp and the presentation of clinical images of pathologies.

Twenty-four students met the inclusion criteria and were included in the study. Written informed consent was obtained from all participants before they were randomized 1:1 into two groups using block randomization. The traditional group ($n = 12$), who did not receive simulator training, was examined right after the 1-week internship; the simulator group ($n = 12$) was trained with the slit lamp simulator before taking an objective structured clinical examination (OSCE). The traditional group was given an opportunity for simulator-based slit lamp training after the OSCE examination in which all participated.

For practicing at the slit lamp simulator, five 90-min courses for four to six students were established:

To enable active application of the slit lamp technique, further subgroups of one to two students were formed so that one subgroup and the instructor could observe and support the examination on the monitor, meanwhile the other subgroup practiced surgical steps of relevant anterior segment diseases using the Eyesi Surgical simulator. Both simulators were guided respectively by one ophthalmology-certified faculty instructor.

With the slit lamp simulator, students were first presented with abstract tasks (Fig. 2i, ii) to learn different examination techniques. Each separate slit lamp function is individualized as a single task using a gamified teaching approach which incorporates a user having to find and identify common items found in a virtual ophthalmologist's office. For the study, we selected five subsequent tasks—lateral translation, vertical translation, navigation exercise, slit width, and slit length—out of the basic device handling tier of the Eyesi slit lamp courseware. Therefore, after each level has been achieved it remains for the following task, so that with this step-by-step approach the students became familiar with more and more settings as they progressed through the course. Students had to become proficient in performing each task to pass and to proceed to the next task. Once students passed all selected abstract tasks for device handling, they were asked to examine and diagnose a set of virtual patients chosen from the simulator database and adapted to the curriculum of medical students: nuclear vs. cortical cataract (Fig. 3i, ii); trichiasis with and without corneal erosions, staphylococcal vs. seborrheic anterior blepharitis, herpes zoster vs. herpes simplex keratitis, arcus senilis, corneal neovascularization, iris naevus vs. iris melanoma, anterior uveitis (with cells and flare), and pterygium (Fig. 4i, ii).

For the skills assessment, an OSCE examination for slit lamp microscopy was developed. As a basis, we used the OSCE form for direct ophthalmoscopy developed by Boden et al. [18] and adapted it for slit lamp examination (Table 1).
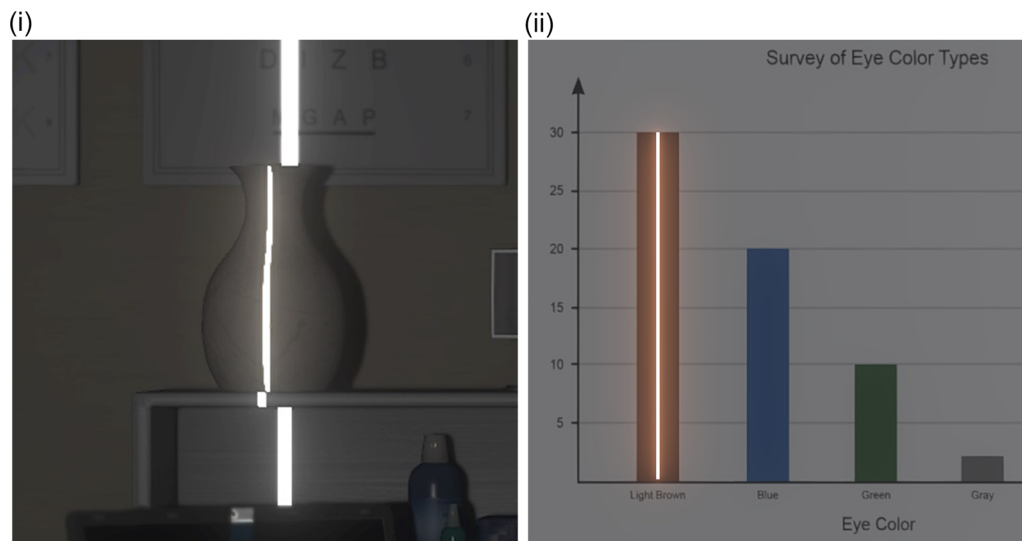
(i) (ii)

Fig. 2 i. At left, the slit width is adjusted on a three-dimensional object (a vase). ii. At right, the slit length is set to defined values on a flat surface. Trainees set the slit length to different heights displayed on a diagram
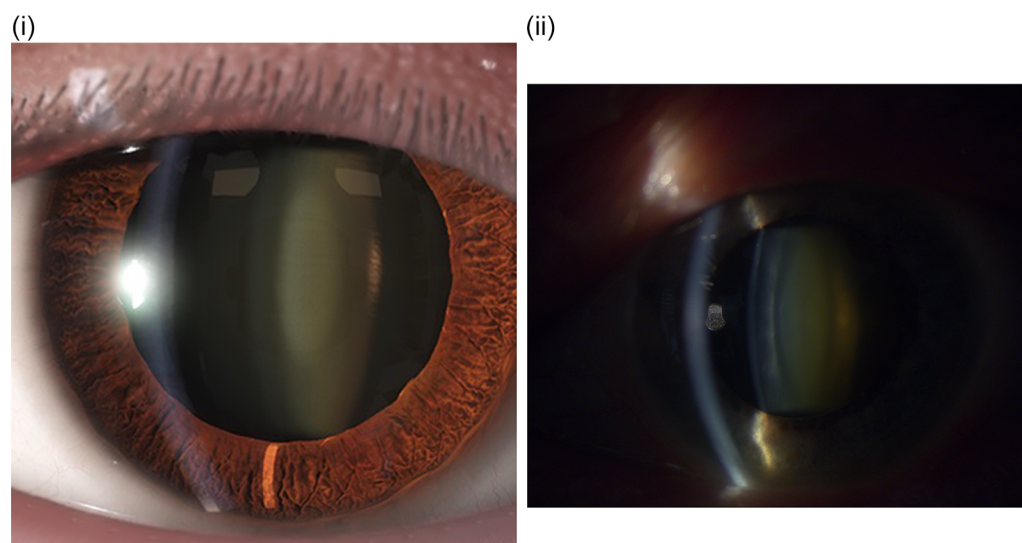
(i) (ii)

Fig. 3 i, ii. An image of a nuclear cataract (left) taken during a slit lamp simulator course, compared to a real slit lamp image (right)

The following rubrics were prospectively created to guide the evaluator in assigning scores for student slit lamp skills: preparation of the slit lamp examination (max 5 pts), finding relevant anatomical structures of the anterior segment with the correct illumination techniques (max 9.5 pts), describing the appearance of the found structures (max 9.5 pts), correct diagnosis of the patient volunteer's disease (max 3 pts), explanation of ophthalmological procedures such as inverting the eyelids or staining the cornea (max 8 pts), measurement of anatomical structures (max 2 pts), and the correct diagnosis of five clinical images randomly chosen from 11 (max 5 pts). Scores per task were assigned depending on the difficulty level and importance for the slit lamp examination (Table 1). All the rubrics were tabulated
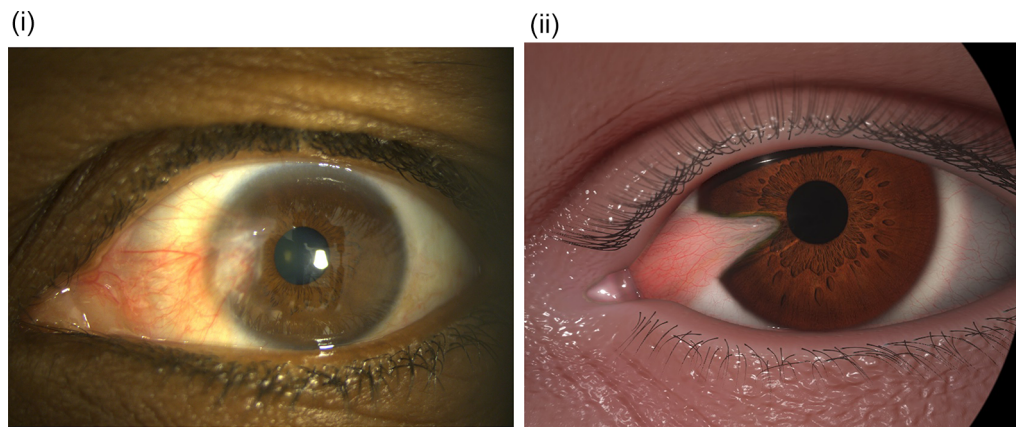
Fig. 4 i, ii. An image of a pterygium (left) taken during a slit lamp simulator course, compared to a real slit lamp image (right)

to calculate the total score (max 42 pts) for the overall performance.

One masked ophthalmologist, a professor of ophthalmology with over 20 years of experience in medical student training, volunteered to assess the OSCE by rating students' performance. The examination room was on another floor to ensure he had no contact with students during the study.

Eight patient volunteers were recruited from among inpatients for the OSCE. Each student subgroup examined a different patient to guarantee there was no exchange of information regarding the diagnosis among the students.

Survey Tool

After both the slit lamp simulator course and the OSCE, each student completed a post-assessment survey. The survey was developed based on the principles of survey tool development (Medical Didactics course, Goethe University, Frankfurt). The course supervisor assured each student responded only once. The following rubrics were collected and evaluated: usefulness of the slit lamp simulator course, increase in knowledge, effectiveness of abstract tasks, training of slit lamp illumination techniques, training of illumination techniques in pathologies, three-dimensional localization of pathologies, efficacy of multimedia learning of pathologies, efficacy of independent

examination training, preparation for a real slit lamp examination, and recognition of disease patterns. The students were asked to assign point values to each question. The questionnaire responses were scored on a scale of 1–7. A score of 1 represented low importance, and 7 represented very high importance.

Furthermore, the students were asked to compare the two course types (simulator vs. traditional course) and determine which course contributed more to the achievement of curriculum-relevant skills acquisition: application of slit lamp illumination techniques, examination of a healthy eye, recognition of pathologies, and assessment of the correct location of pathologies. Open-field questions addressed the advantages of slit lamp simulator training vs. traditional training and improvement suggestions.

Data and Statistical Analysis

The medical student volunteers were provided written and oral information about the study and were informed that they could withdraw at any time. Confidentiality was assured by keeping the materials pseudonymized in the examination and survey sheets, and data in this study were only accessible to the authors.

All data were evaluated using Excel, IBM SPSS Statistics v.28, and BiAS for Windows v. 11.12.

Table 1 Prospective rubrics to guide the masked assessor in assigning scores to the medical students' OSCE performance

Rubrics	Score Max	Factors related to student performance	Score
Task 1:	5	Setting refraction at the eyepieces and distance between the pupils	1
Preparation of the slit lamp examination		Correct positioning of the patient at the slit lamp	1
		Correct adjustment of the slit	2
		Vertical and horizontal translation	1
Task 2:	9.5	Lid edges upper and lower eyelid	1
Finding relevant structures of the anterior segment		Inverting the eyelid [a]	0.5
		Conjunctiva	1
		Transition cornea/limbus	1
		Cornea	1
		Staining the cornea with fluorescein [a]	0.5
		Anterior chamber	1
		Iris	1
		Movement of the pupils	1
		Mydriasis [a]	0.5
		Lens	1
Task 3: Describing the structures found	9.5	Lid edges (regular/seborrhoeic/inflamed/position of the eyelashes)	1
		Inverting the lid (foreign bodies, papillae)	0.5
		Conjunctiva (regular/hyperaemic/conjunctival tumor)	1
		Transition to cornea/limbus (regular/neovascularizations/opacities)	1
		Cornea (clear/reflective/opacities/keratitis)	1
		Fluorescein: staining epithelial damages	0.5
		Anterior chamber (clear/Tyndall/cells)	1
		Iris (regular/distorted/iris tumor)	1
		Movement of the pupils (directly/retarded/incomplete)	1
		Mydriasis (for a better presentation of the lens)	0.5
		Lens (clear/opacity of the nucleus or the cortex)	1
Task 4: Correct diagnosis	3	Correct diagnosis found	3
		Diagnosis of the student:	
		Correct diagnosis:	

Table 1 continued

Rubrics	Score Max	Factors related to student performance	Score
Task 5: Please comment on your examination approach	8	Inverting (when/why)	2
		Staining the cornea (when/why)	2
		Mydriasis (when/why)	2
		What are contraindications for using pupil-dilating eyedrops (narrow-angle glaucoma, Contusio bulbi …)	2
Task 6: Measurement of structures	2	Diameter of the cornea	2
Task 7: Recognition of five diagnoses using clinical pictures	5	(Choose five clinical pictures at random: 1 Cataract nuclearis; 2 Cataract corticalis; 3 Blepharitis; 4 Pterygium; 5 Keratitis dendritica; 6 Arcus senilis; 7 Corneal vascularization; 8 Trichiasis; 9 Cell and flare; 10 Iris nevus; 11 Iris melanoma)	0 to 5
		Picture: Number: Diagnosis:	
		Picture: Number: Diagnosis:	
		Picture: Number: Diagnosis:	
		Picture: Number: Diagnosis:	
		Picture: Number: Diagnosis:	
Total Score	42		

[a]To relieve the patient volunteer this task should only be mentioned by the student but not performed

OSCE objective structured clinical examination

The primary outcome measures were the examination grades of the simulator and traditional groups. The scores were first examined for normal distribution using the Shapiro–Wilk test. As these scores were not normally distributed, the statistical analysis was based on the Wilcoxon-Mann–Whitney U-exact test to analyse differences between the objective OSCE results of the simulator and traditional groups [23, [24]. Data were described using the median (interquartile range [IQR]). Additionally, the effect size (Rosenthal) was calculated (0,1 small effect, 0,3 medium, 0,5 large) [25]. Secondary outcomes included subjective evaluation of the students, and binomial tests were applied to compare the achievement of skill acquisition conveyed in the two courses (traditional slit lamp vs. slit lamp simulator course). For the survey tools, a descriptive analysis was conducted with a presentation of the frequencies in contingency tables. A significance level of $p < 0.05$ was assumed for all tests.

RESULTS

A total of 24 medical students in their eighth semester who had passed the ophthalmology internship volunteered to participate and were randomized into the simulator ($n = 12$) or traditional ($n = 12$) training groups.

The overall performance (total score) of medical students in the slit lamp OSCE was significantly higher ($p < 0.001$) in the simulator group than in the traditional group (29.75 [7.88] vs. 17.00 [4.75]). The highest overall performance score, 37.50 of 42, was reached by a student in the simulator group. Table 2

Table 2 Statistical analysis of grades assigned by the masked ophthalmologist during the slit lamp OSCE, comparing the simulator and traditional groups

Task	Group[a]	Median	IQR[b]	Minimum score	Maximum score	p value[c]	Effect size[d]
Task 1:	Simulator group	5.0	0.0	4.0	5.0	**p = 0.008**	0.61
Preparation of the slit lamp examination	Traditional group	3.0	3.5	0.0	5.0		
Task 2:	Simulator group	6.75	3.13	3.0	9.5	**p = 0.008**	0.54
Finding of relevant structures of the anterior segment	Traditional group	4.0	1.5	1.0	8.0		
Task 3: Describing the structures found	Simulator group	4.5	3.38	2.0	8.5	p = 0.09	0.36
	Traditional group	3.25	2.13	1.0	7.0		
Task 4: Correct diagnosis	Simulator group	3.0	0.0	2.0	3.0	p = 0.48	0.25
	Traditional group	3.0	0.0	0.0	3.0		
Task 5: Please comment on your examination approach	Simulator group	6.0	2.0	4.0	8.0	**p < 0.001**	0.80
	Traditional group	2.0	1.25	0.0	4.0		
Task 6: Measurement of structures	Simulator group	0.0	0.0	0.0	2.0	p = 0.51	0.30
	Traditional group	0.0	0.0	0.0	0.0		
Task 7: Recognition of 5 diagnoses from clinical pictures	Simulator group	5.0	1.0	3.5	5.0	p = 0.07	0.40
	Traditional group	4.0	1.63	2.0	5.0		
Total score	Simulator group	29.75	7.88	21.00	37.50		
	Traditional group	17.00	4.75	9.00	30.00	**p < 0.001**	0.70

[a] Simulator group n = 12, traditional group n = 12
[b] IQR = Q3-Q1 (interquartile range)
[c] Wilcoxon–Mann–Whitney-U Exact test
[d] Effect size R by Rosenthal [19]

summarizes the grades assigned to the students in each group.

The scores assigned to simulator-trained students were consistently higher than those assigned to traditionally trained students. A significant difference was found in the preparation of the slit lamp examination (5.0 [0.0] vs. 3.0 [3.5]; $p = 0.008$), finding relevant structures of the anterior segment (6.75 [3.13] vs. 4.0 [1.5]; $p = 0.008$) and commentary on the examination approach (6.0 [2.0] vs. 2.0 [1.25]; $p < 0.001$). Consistently higher scores, but with no statistically significant improvement, were found for describing the structures found (4.5 [3.38] vs. 3.25 [2.13]; $p = 0,09$), the correct diagnosis (3.0 [0.0] vs. 3.0 [0.0]; $p = 0.48$), measurement of structures (0.0 [0.0] vs. 0.0 [0.0]; $p = 0,51$), or recognition of five diagnoses from clinical pictures (5.0 [1.0] vs. 4.0 [1.63]; $p = 0.07$).

Survey Tool

All students returned their survey forms. Students in the simulator group, who were trained using the slit lamp simulator before taking the OSCE, and in the traditional group, who attended simulator-based slit lamp training after the examination, reported predominantly positive experiences in the slit lamp simulator course and would recommend it to others (7.0 [0.25]) (Table 3).

The results show that most students noticed an increase in knowledge over the course (7.0 [1.0]), rated the abstract courses as useful tasks (7.0 [0.0]), and felt able to learn the slit lamp simulator techniques (7.0 [1.0]) and to apply the techniques for localizing pathologies (6.0 [1.0]). In their estimation, the multimodal imaging helped them to memorize different diseases (7.0 [0.0]) and to identify them in real patients after the slit lamp simulator training (7.0 [1.0]).

Based on open-field responses, major themes among perceived advantages of simulator training included access to unlimited training without burden on patients or fellow students (16 [72.72%] of 22 answers). Mistakes can be made in a stress-free atmosphere, and educators

are available for questions. Another major advantage mentioned (9 [40.91%] of 22 answers) was the possibility of diagnosing autonomous curriculum-relevant pathologies.

The major advantage of using real patients for slit lamp training (20 [90.91%] of 22 answers) was the ability to interact with patients, which helped dissipate inhibitions and fears regarding real patient contact.

Nine out of 22 students had no suggestions for improving the slit lamp simulator course. Eight out of 15 students (53.33%) wished to spend more time with the slit lamp simulator.

Comparing skill acquisition in the two course types (simulator vs. traditional), 20 out of 24 students reported application of the slit lamp illumination techniques could be better understood with the simulation slit lamp training ($p = 0.002$).

Eight students preferred to learn the process of examining a healthy eye using each other, and 16 preferred the simulator slit lamp ($p = 0.15$). The recognition of pathologies ($p < 0.001$) and assessment of the correct location of these pathologies ($p < 0.001$) were significantly better in the simulator group.

DISCUSSION

The slit lamp is a challenging examination tool, not only for medical students but also for residents of ophthalmology or optometrists in their first years, due to its various device settings: degrees of freedom, magnifications, slit widths and lengths, filters, and inclination and rotation of the slit beam [4, 6, 7]. Often, in a clinical setting, there is not enough time to introduce medical students or residents to all these functions [26]. It is a burden for the patient who is exposed to increased light exposure, and patients are increasingly concerned that students or residents are practising on them [27]. However, for more specialized examinations, students must be well trained in all these functions to independently recognize the pathology in a later stage of education.

The alternative of students examining each other is limited, as most colleagues are healthy, preventing students from learning to localize

Table 3 Results of the post-assessment survey of 24 medical students regarding the efficacy of the slit lamp simulator course[a]

Survey responses	1 (does not apply at all) [b]	2	3	4	5	6	7 (fully applies)
I found this course useful and would recommend it to others.	0	1	1	0	1	3	18
Simulator group:	0	1	1	0	0	2	8
Traditional group:	0	0	0	0	1	1	10
I noticed an increase in knowledge over the period of training.	0	1	0	0	1	7	15
Simulator group:	0	1	0	0	0	4	7
Traditional group:	0	0	0	0	1	3	8
The abstract tasks on the slit lamp helped me to get a feeling for the slit lamp.	0	0	0	0	1	0	8
Simulator group:	0	0	0	0	1	0	4
Traditional group:	0	0	0	0	0	0	4
I have been able to understand the slit lamp illumination techniques in general.	1	0	0	0	1	7	15
Simulator group:	1	0	0	0	0	3	8
Traditional group:	0	0	0	0	1	4	7
I have been able to apply the slit lamp illumination techniques in the context of the corresponding pathologies.	0	0	1	0	2	12	9
Simulator group:	0	0	1	0	1	5	5
Traditional group:	0	0	0	0	1	7	4
During the course, I gained a better sense of the location of pathologies (cornea, anterior chamber...).	0	1	0	0	0	7	16
Simulator group:	0	1	0	0	0	2	9
Traditional group:	0	0	0	0	0	5	7
The interactive multi-media learning approach to recognition of pathologies helps me to memorise them better.	0	1	0	0	0	4	19
Simulator group:	0	1	0	0	0	1	10
Traditional group:	0	0	0	0	0	3	9
Being able to independently diagnose the disease patterns on the simulation slit lamp has improved my understanding of the manifestation of individual disease patterns.	0	0	1	0	2	4	17
Simulator group:	0	0	1	0	1	1	9
Traditional group:	0	0	0	0	1	3	8

Table 3 continued

Survey responses	1 (does not apply at all) [b]	2	3	4	5	6	7 (fully applies)
I feel adequately prepared for performing the examination on real patients after training with the simulator slit lamp.	0	0	1	3	7	8	5
	0	0	1	2	2	4	3
Simulator group:	0	0	0	1	5	4	2
Traditional group:							
I now feel better prepared to identify diseases with the slit lamp after training with the simulator slit lamp.	0	0	1	0	0	9	14
	0	0	1	0	0	3	8
Simulator group:	0	0	0	0	0	6	6
Traditional group:							

abnormalities. Furthermore, the willingness to be physically examined is low depending on religiousness, gender and examiner [28].

The connection of a co-observer tube or a video connection of the slit lamp can improve this situation by co-observing a patient [29], but it is not an alternative for learning one's own application and practice of specific hand movements to obtain certain images and insights.

Simulation training offers the student the possibility to train systematically in a self-guided manner: the tiers are designed to build on one another methodically, and they can be flexibly geared to each student's requirements [30]. The student can develop a cognitive link between the appropriate slit lamp settings for the different pathologies by obtaining a direct objective performance assessment using the simulator. The increased confidence instilled with this training also helps reduce students' inhibitions and fears regarding the first real examination of a patient. Yu et al. [31] found that medical students need to be repeatedly exposed to simulation education experiences to develop a sense of psychological stability and competently deliver medical treatment in a clinical setting.

The increase in clinical competency by simulation training of general clinical skills, such as wound bandaging or vacuum blood collection, was revealed by Zhang et al. [32], who analysed

student performance afterward using an OSCE with 16 stations in 2015.

The effects of direct ophthalmoscope simulation training were investigated by Boden et al. [18]. They randomized 34 medical students during their ophthalmological internship to classical and simulator training for 45 min after a 5-min introduction. The students in the classical group achieved an OSCE score of 78%, whereas those in the simulator group achieved a higher score of 91%, with a lower scatter in all subdisciplines. Significantly higher scores in the subdisciplines "Locating essential structures" ($p = 0.04$) and "Description of recognized structures" ($p = 0.001$) were obtained in the simulator group. These results are consistent with those of Howell et al. [20]. In their study, 33 first-year medical student volunteers were provided with a longer training period. After a 1-h didactic instruction course, they were randomized to an additional hour of training on a direct ophthalmoscope simulator or traditional training. After a 1-week independent student practice using the assigned training methods, masked ophthalmologist observers assessed the students' ophthalmoscopy skills. The simulator group reported significantly longer practice times ($p = 0.002$) and higher technique scores ($p = 0.03$) than the traditional group. Higher grades for efficacy, global performance, and patient-volunteer scores were found for the simulator group, but without statistical

significance. Since the clinical development and launch of the Eyesi slit lamp simulator, there are currently no studies which deal with its effect on practical and theoretical slit lamp skills.

We identified that students trained with the slit lamp simulator showed significantly better overall performance ($p < 0.001$) in the OSCE. Consistently higher scores were assigned to the simulator group for all tasks, but not all tasks reached a statistically significant difference. The simulator group had a significantly better approach in using the correct device settings, such as adjustment of refraction and pupil distance at the eyepieces, positioning of the patient, adjustment of slit length and width and application of vertical and horizontal translation. Thus, they were also significantly better at adjusting the anatomical structures of the anterior segment ($p < 0.001$). No significant differences were found for determining the correct diagnosis of a patient volunteer. This could be attributed to the time limit of the course. A longer training period, probably for weeks with the chance to train and repeat different pathologies, could lead both groups not only to better practical skills as a fundamental prerequisite, but also to better performance in identifying the correct and differential diagnoses. In this respect, the advantage of simulator training is its availability. Students can train independently—regardless of time and whether or not a teacher and other students or patient volunteers are available due to its self-guidance. The post-assessment survey also showed a significant knowledge gain subjectively perceived by the students regarding the application of the slit lamp illumination techniques ($p = 0.002$), the recognition of pathologies ($p < 0.001$), and the ability to assess the correct locations of pathologies ($p < 0.001$). This gain of clinical knowledge and skill proficiency better prepares students for the clinical setting. These results confirm those of Yu et al. [31], who showed a lower level of anxiety and a significantly higher level of confidence after simulation training in a safe environment.

The strengths of our study include the randomized design, the masked objective assessment of acquired skills by an experienced faculty instructor, and evaluation of the students' subjective assessment of the effectiveness of slit lamp training. Furthermore, the OSCE was taken using patient volunteers so that the transferability from the simulator to real patients could be verified. The limitations of this study include the relatively small number of student volunteers (all had attended a 1-week ophthalmology internship to create equal prerequisites) and the limited training time. Furthermore, the simulator group received more training time (90 min) than the traditional group. So, only the effective results of simulator training can be shown with that study. What cannot be shown is that this training is more efficient than continued traditional training. To solve this, two groups with equal training time have to be formed and should be evaluated. The OSCE performance should be assessed by two independent masked observers to ensure inter-rater reliability. Another issue is that the scoring system, though adapted from the direct ophthalmoscopy OSCE template of Boden et al. [18], still uses a non-validated scoring system. The same applies to the survey tool, which was based on the principles of survey tool development but is not representative of a validated questionnaire.

The long-term effect of slit lamp simulation training over weeks—using the complete Eyesi courseware with four educational tiers from basic device-handling tasks to complex clinical case studies—on diagnosing diseases, as well as the effect of training with additional optical tools such as gonioscopy or funduscopy lens to examine the anterior chamber or the fundus should be also aspects for further research [33]. Even though the students had considered the abstract slit lamp training tasks as useful in the post-assessment survey, this should be objectively verified in the future, as the study by Petersen et al. [34] did not show positive skill transfer from basic skills training to the procedure-specific modules in time, starting score or amplitude of plateau. Finally, the validity evidence for the slit lamp simulator has to be evaluated carefully along existing formal validation frameworks [35].

CONCLUSIONS

In summary, our findings show that the Eyesi slit lamp simulator as a complement to traditional training methods is a useful tool that improves practical skills, such as the application of illumination techniques. Students become familiar with the device settings in a structured way and can acquire a routine in a patient- and instructor-independent way. In the future, further studies are necessary that compare the same amount of traditional vs. simulator training time to evaluate if one training method is more efficient than the other for the acquisition of slit lamp skills.

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