• Review Article •

Non-simulator-based techniques in teaching direct ophthalmoscopy for medical students: a systematic review

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Abstract

● Non-simulator-based examination methods of the fundal examination have shown to be cost-effective. We reviewed different non-simulator-based direct fundoscopy examination methods used in undergraduate curricula and their outcomes. PubMed (MEDLINE) and Cochrane Database of Systematic Reviews were searched using standard Medical Subject Heading (MeSH) terms ophthalmoscopy, medical education, undergraduate medical education, medical student, educational assessment and learning. The search included publications until 28th February 2019. We obtained 34 articles after screening abstracts; of them, 12 articles were included in the qualitative synthesis. The studies were comprised of diverse teaching methods which included fundal photograph matching with corresponding eye, continuous education using community-based eye clinics, formal instructions and demonstrations prior to skills training, ophthalmoscopy skills practice using eye pathologies, teaching versus conventional ophthalmoscopy and group-based teaching. We concluded that non-simulator-based techniques such as use of fundal photograph matching of an eye of a volunteer, introduction to eye pathologies, smaller student groups and formal instructions with video demonstrations prior to skills training were highly effective in teaching direct ophthalmoscopy for undergraduate medical students.

● **KEYWORDS:** education; medical students; ophthalmoscopy skills

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INTRODUCTION

One fifth of patients that visit primary care are due to ophthalmological conditions[1]. Prompt diagnosis of these conditions may depend on the skilfulness of the practicing clinician in direct ophthalmoscopy, since it is one of the primary clinical assessment modalities in the majority of such patients. Since dexterity in direct ophthalmoscopy is a universal need for any medical practitioner, a solid foundation of proper technique has to be laid among the medical students during the undergraduate clinical training. Despite undergraduate ophthalmoscopy teaching, students often fail to recognize fundal abnormalities[2] and confidence in fundal examination using an ophthalmoscope is frequently inadequate[3-4]. Less pathological correlations or insufficient instructions during teaching were the main reasons for inefficiency in performing direct ophthalmoscopy[4-5].

Medical education professionals have identified that early introduction of ophthalmoscopy with formal instructions to students, providing exposure to pathologies in ophthalmology, assessment and feedback on the technique and performance of the students lead to improved achievement of learning outcomes[3]. While some medical curricula predominantly utilize non-simulator methods (volunteers or patients with ophthalmological conditions), several countries have introduced high-tech simulators that mimic the real eye to facilitate teaching ophthalmoscopy. Nevertheless, most of the simulators used for ophthalmology teaching are expensive. Due to economical constrains it may not be feasible to use high-tech simulator techniques in medical schools in developing countries. In most Asian countries, cost effectiveness and availability of abundant patients has made non-simulator based direct ophthalmoscopy popular in undergraduate teaching. Nonetheless, to the best of our knowledge, the effectiveness

of these non-simulator-based teaching techniques in direct ophthalmoscopy has not been reviewed before. Hence, this study systematically reviews the types of non-simulator-based techniques used to teach direct ophthalmoscopy to medical students and their outcomes.

MATERIALS AND METHODS

Current systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[6].

Protocol and Registration PROSPERO registration was obtained before the commencement of the study with inclusion criteria, objectives and method of search specified in advance (protocol registration number CRD42019122427). There were no changes to the original protocol during the study.

Eligibility Criteria The following inclusion criteria were applied: 1) studies that used non-simulator techniques for direct ophthalmoscopy in undergraduate medical teaching; 2) studies that included skill evaluation of students before and after the introduction of the specific teaching method; 3) studies that were written in English language or with detailed summaries in English. Studies that evaluated only the student perceptions on the teaching method rather than a development of ophthalmoscopy examination skills were excluded.

Information Sources The electronic databases PubMed (MEDLINE) and Cochrane Database of Systematic Reviews were used to search literature. Medical Subject Heading (MeSH) subheadings and MeSH terms were identified using available literature and related systematic reviews. Literature review was conducted by searching the online MEDLINE database (Medical Literature Analysis and Retrieval System) using MeSH terms given below: ophthalmoscopy AND teaching OR medical education OR undergraduate medical education OR medical student OR assessment, educational OR learning NOT review NOT simulation training. The search comprised of studies until 28th of February 2019.

Data Collection Process A data extraction sheet was developed and was pilot tested in three randomly selected articles that adhered to the inclusion criteria. The data extraction sheet was then modified accordingly. Two independent reviewers (Samaranayake UMJE and Mathangasinghe Y) extracted the data and disagreements were discussed between the two reviewers. If no agreement could be reached, a third author was included in the review process.

Data Items The data extracted from each study were: 1) study details (country and study setting); 2) methods (type of study, sample size, sampling method, study population); and 3) data on teaching method used, past exposure of the participants to ophthalmoscopic teaching, time allocated for teaching and practice of skills and the outcome of the study was taken into account.

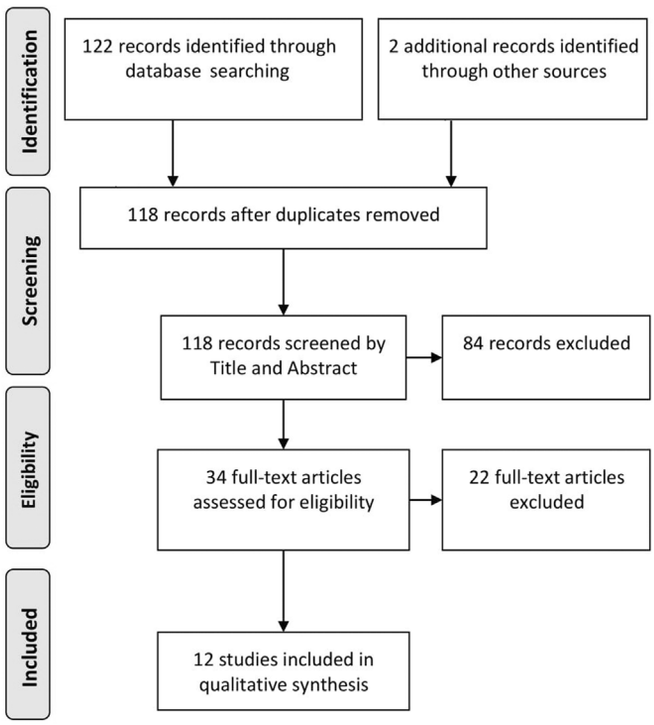

Figure 1 Summary of the search strategy according to PRISMA guidelines.

Risk of Bias in Individual Studies The risk of bias was assessed using a checklist based on inclusion criterion, sampling method, type of study, methodology and data analysis. The checklist was pilot tested on three included articles. The studies to be included were decided after a careful discussion. Disagreements were resolved by consensus.

RESULTS

In the initial search we found 122 hits. We included additional 2 articles after the manual search. We obtained 34 articles after screening abstracts. Of them, 12 articles were included in the qualitative synthesis. The PRISMA flow diagram of the selection of these studies is given in Figure 1.

The studies were based on direct ophthalmoscopy observations matching with corresponding fundal photographs (n=6), application of skills learnt by attending community-based eye clinics (n=1), formal instructions and demonstrations in direct ophthalmoscopy prior to skills training (n=2), ophthalmoscopy skills practice using eye pathologies (n=1), usage of teaching versus conventional ophthalmoscopy (n=1) and number of students in a group attending training (n=1). The studies were conducted in the United States (n=4), Canada (n=2), United Kingdom (n=2), Mexico (n=1), Norway (n=1), Sri Lanka (n=1) and Sweden (n=1).

The non-simulator-based direct ophthalmoscopy teaching methods and their outcomes are summarized in Table 1.

Fundal View Matching with Fundal Photographs Afshar *et al*[7], Asman and Linden[8] and Krohn *et al*[9] conducted cross sectional studies using students who attended their clinical

Table 1 Non-simulator-based techniques used in teaching direct ophthalmoscopy and their outcomes

Author, year, country of the study	Sample size	Study population	Teaching method used	Prior exposure to DO	Time spent on skill training	Outcome of the study
Afshar *et al*[7], 2010, United States	33	4th year students	Students performed DO on a healthy participant and matched the fundal photographs with the examined eye.	Yes	1wk	Improved 67% (22/33), unchanged 27% (9/33), worsened 6% (2/33) in the post-test
Asman and Linden[8], 2010, Sweden	394	Students attending ophthalmology rotation	Students performed DO on a healthy participant and matched the fundal photographs with the examined eye.	Yes	9mo	Successful identification rate of 96.4% in post-test evaluation
Bénard-Séguin *et al*[12], 2018, Canada	15 (IG), 31 (CG)	2nd year students	Students underwent training on fundal photograph matching. Sixteen months following the training, they were assessed according to a standard OSCE checklist.	Yes	35h	IG (78.3%) performed better than the CG (69.4%). Correct matching of optic fundal photographs IG (100%) was better than CG (53.3%).
Brdy *et al*[13], 2014, Mexico	12 (IG), 18 (CG)	2nd year students	IG was given formal teaching and skills training under during clinical rotations by a supervisor. Post training IG examined patients at a community clinic under supervision by a senior in six sessions throughout a year. CG received a single instruction and practical session at the beginning of the course and did not follow up with any training sessions other than clinical rotations.	NA	1y	IG mean assessment score was 48% higher compared to CG. Long-term skill retention was higher in IG than the controls. Therefore, community based free clinics is an ideal setting for training DO skills.
Cordeiro *et al*[14], 1993, United Kingdom	29 (IG), 109 (CG)	1st year students	Initially IG members were assessed using a standard scale for DO examination. Then the formal teaching was conducted by using each other as models. The CG was not given formal instructions. Both groups were tested using a standard scale at two months.	No	NA	Following formal instructions, the performance of IG increased from 53% to 77%. At two months test, IG performed better than the controls.
Cross *et al*[16], 2011, United States	109	1st year students	Small group of 3 to 7 students were taught how to examine undilated pupils followed by fundus photograph matching with observed eye.	No	2h	Students≤5 per group, 93.6% correct matches; students≥6 per group, 85.4% correct matches
Dissanayake *et al*[15], 2017, Sri Lanka	106	2nd year students	A videotape, live demonstration or a combination of the two methods were used in teaching the students followed by an assessment by three examiners using a standard OSCE checklist.	No	20min	Live demonstrations showed a better response than video demonstrations. Combination of two methods was superior to either of the methods alone.
Krohn *et al*[9], 2014, Norway	220	4th year students	Students were given initial instructions on ophthalmoscopy using dilated eye of a volunteer. Students were encouraged to practice on their own for nine weeks and was informed that the students who perform the best at identifying correct fundal photograph with the matching eye will be rewarded at the end of the nine-week appointment.	NA	9wk	Correctly matched fundus view photographs 70%; 30% of the students scored 100%; 19% scored 100% to 75%; 23% scored 75% to 50%; 28% scored lower than 50%.
Kwok *et al*[10], 2017, Canada	32 (IG), 63 (CG)	2nd year students	Students practiced fundus photograph match with a peer's fundus. Confidence in ophthalmoscopy was assessed using 5-point Likert scale.	IG: No; CG: Yes	2wk	Accurately matched the photograph with fundus in IG 93.75% (30/32) compared to 73.02% (46 of 63) in CG. Time and number of attempts needed for a correct match was reduced at the end of the course than at the start in the IG.
Milani *et al*[11], 2013, United States	89 (IG), 42 (CG)	4th year students	Students in the CG were asked to examine the eye of a peer while the IG had the opportunity to match fundus photographs following a peer's eye examination.	Yes	10wk	Pre-test scores for correct identification in intervention/control groups were 41.6%/36%. Post-test scores for intervention/controls were 93.2%/52.4%.
Schulz *et al*[18], 2016, United Kingdom	27 (IG), 28 (CG)	1st and 2nd year pre-clinical students	A "teaching ophthalmoscope" was used in the IG whereas a "conventional ophthalmoscope" was used in the CG. After performing DO of the volunteers the students were given a feedback. Then both groups underwent an OSCE with both teaching and conventional ophthalmoscopes.	Yes	48min	No statistically significant deference in the performance of two groups in teaching ophthalmoscope station. IG performed better at the conventional ophthalmoscopy station. Confidence in DO in IG was higher.
Wile *et al*[17], 1976, United States	18 (IG), 18 (CG)	1st year students	Students were asked to draw, label and identify retinal structures. Then they were divided into two groups, one group was given book A and the other was given book B. Book A had more emphasis on fundal examination findings correlated with systemic illnesses than book B. two weeks later a test was conducted which had theoretical and practical components for both the groups.	NA	2wk	Competency of book A users were higher than the book B users.

CG: Control group; DO: Direct ophthalmoscopy; IG: Intervention group; NA: Not available; OSCE: Objective structured clinical examination.

rotations and concluded, that majority of students correctly matched the fundal photograph with corresponding eye at the end of the programme. In case control studies conducted by Kwok *et al*[10], Milani *et al*[11], and Bénard-Séguin *et al*[12], the correct fundal photograph matching in the intervention groups were higher than the controls. Afshar *et al*[7] reported that of the students who participated, in 27% (9/33) correct fundal identification skills remained unchanged, while in 6% (2/33) the skills deteriorated.

Practice of Learnt Skills in Community-based Eye Clinics A case control study showed community-based clinics aided the students to retain the skills they gathered through the formal training sessions[13]. Intervention group had a 48% higher mean post test score at one month and one year than the controls who received only a single formal training session. They concluded the importance of free eye clinic's access to patients and opportunity to learn from specialists in community clinics was a better way to engage students in learning and to provide continuous education.

Formal Instructions and Video Demonstrations Prior to Practical Use of Skills Cordeiro *et al*[14] conducted a standard ophthalmoscopy test in a group of students prior to and following formal instructions of direct ophthalmoscopy. The performance of the intervention group increased by 23.7% after formal instructions. Intervention group performance in average was 14% higher than the controls at two months post-appointment evaluation. A randomized controlled trial was conducted among pre-clinical medical students where live demonstrations, video tape demonstrations and a combination of both techniques were used to teach ophthalmoscopy in a fixed time duration[15]. The majority of the students in the study population were multimodal learners (61.3%). Three blinded examiners independently assessed the technique of direct ophthalmoscopy using videoclips. In the post-test evaluation of the skills of students, the mean scores were 10.15, 8.27 and 11.71 for live demonstrations, video demonstrations and combination of live and video demonstrations respectively. They concluded that formal instructions using a combination of video and live demonstrations were effective in training direct ophthalmoscopy to medical students[15].

Limitation of Number of Students in a Group A cross sectional study on the performance of students (n=117) following ten sessions of teaching and practical sessions concluded that, ≤5 students per group had 93.6% correct matches, while ≥6 students per group had 85.4% correct matches during post-test[16].

Introduction of Eye Pathologies During Ophthalmoscopy Teaching In a study done in the United States, one group was given a book with pictures demonstrating systemic disease correlations with eye pathologies and the other group was provided with a book that had less systemic disease correlations[17]. There was a statistical difference in the two groups, the former performing better at the post-test evaluation.

Use of Teaching Ophthalmoscope or the Conventional Ophthalmoscope In a randomized control trial, the intervention group (n=27) was trained using a teaching ophthalmoscope, while the controls (n=28) were trained using conventional ophthalmoscope[18]. Subsequently, the participants were subjected to an Objective Structured Clinical Examination (OSCE) at two stations where the students were required to use a conventional and a teaching ophthalmoscopes respectively. At the teaching ophthalmoscopy station intervention group (mean score 19.8) performed better than controls (mean score 17.6). At the conventional ophthalmoscopy station, the performance did not have a statistically significant difference. Intervention group members (mean confidence 6.1) were more confident in performing ophthalmology examination than controls (mean confidence 4.9).

DISCUSSION

Ophthalmoscopy examination skill is a fundamental requirement for any medical practitioner due to the many number of patients that present with ophthalmological pathologies in primary care[2]. Uses of human volunteers or patients with ophthalmological pathologies were proven to be effective over the use of simulators for teaching[2]. To utilize the resources available and time spent in teaching ophthalmology; it is a required that innovative and interactive methods of teaching are adopted to reform the current practice[1]. In this review we summarized the non-simulator methods used worldwide in undergraduate medical curricula to teach direct ophthalmoscopy and the outcomes of the adopted methods.

Differences in the Undergraduate Direct Ophthalmoscopy Curricula Majority of the studies available included pre-clinical students or students attending their ophthalmology clinical rotations. It is agreed by many medical education trainees that ophthalmoscopy teaching should be essentially taught in medical and ophthalmology-related undergraduate curricula[5]. However, there is a vast variation between the medical curricula of different institutions ranging from teaching basic direct ophthalmoscopy examination skills to teachings of ocular pathologies[19-20]. The deficiency in guidelines and definition of objectives in the available undergraduate curricula could have caused this variation[21].

Different Non-simulator Methods Used to Teach Direct Ophthalmoscopy Examination

Direct ophthalmoscopy observations matching with corresponding fundal photographs Majority of the students' skills in direct ophthalmoscopy showed improvement in the post-test evaluation of fundal photograph matching with corresponding eye[7-8]. However, Afshar *et al*[7] reported that

in 6% of the student performance worsened, while 27% did not show any change following the introduction of the said method. The main difference in the above studies was that the in Asman and Linden[8], the skill training continued over a period of nine months, while Afshar *et al*'s[7] study lasted only one week. Furthermore, the time allocation per eye examination was higher in Asman and Linden[8] compared to Afshar *et al*[7], which could have led to the 96.4% accurate matching of fundal eye photographs by the trainees. Therefore, the allocation of time for skills training could yield better results with this method. Nevertheless, artefacts are a common finding with fundal photographs and the peripheral view of the retina cannot be visualized in assessment of the fundal photographs alone.

Continuous application of skills learnt by attending community-based eye clinics The group attended the community-based eye clinics (six times a year) following the formal training, performed better in the post-test evaluation in one month and one year compared to the controls who received the training only during their clinical rotations[13]. These findings suggest that continuous repetition of the skills learnt during formal training could have an impact on short- and long-term skill retention among the students. Ophthalmology teaching is not required to be time constrained; instead it can be practiced throughout the undergraduate years. Additionally, level of comfort and self-confidence is an important aspect in learning[4]. Kwok *et al*[10] reported that confidence in direct ophthalmoscopy improved while the time spent on making an accurate diagnosis reduced following the completion of the training compared to the beginning of the programme. Therefore, increasing the number of opportunities the students get to practice their skills would help them retain the knowledge longer and would boost up their confidence in performing direct ophthalmoscopy.

Formal instructions and demonstrations in direct ophthalmoscopy prior to skill training A successful training is depicted by initial mastering of the motor skills through a detailed stepwise approach[4]. Cordeiro *et al*[14] compared the skills in ophthalmology before and after formal verbal instructions to a group of students and found that the student knowledge in performing direct ophthalmoscopy increased with the formal instructions. In a Sri Lankan randomized control trial, the combination of video and live demonstrations was more effective in student teaching than either of the two methods alone[15]. Bobek and Tversky[22] explained that by providing visual explanations, the students grasp the concepts faster and create coherence in the material. Furthermore, listening is suitable for verbal learners over visual learners[23]. Therefore, the combination of the visual aid with the verbal instructions in Dissanayake's study could have led to enhancement of both visual and auditory learner engagement. Regardless of the learning styles of the students, the overall improvements in acquired ophthalmoscopy skills portray the need of guidance and direction to the students before commencement of practical application of the skills.

Limitation of the Number of Students in a Group A study conducted in the United States demonstrated that 5 or less students per group had better results in the post-test evaluation compared to the groups with larger number of students[16]. In smaller groups, the actions of the students are dependent on the instructor with increased participation by both high and low-achieving students[24]. According to Levine and Moreland[25], in larger groups the student participation is less, and low interactions seen among participants. The opportunity to receive individual instructions for a longer time in smaller groups could be a determinant of better learning outcome. Nevertheless, the interactions in a group can vary depending on the factors such as ethnicity and gender of students[26], which should be considered when forming student groups.

In most of the developing countries, the availability of the trainers as well as ophthalmoscopes may be limiting factors, which would give rise to larger student groups. This issue could have been addressed by integrating blended learning methods to the existing curricula such as flipped classrooms, where the learning material are introduced to a group of students using an interactive learning management system, while the rest of the class practices the technique of direct ophthalmoscopy using the existing resources synchronously. Hence, blended learning methods will help maintain a fixed trainer to student ratio for the allocated time period for direct ophthalmoscopy teaching irrespective of the number of students in the class.

Training Ophthalmoscopy Skills Using Eye Pathologies It was proven by many studies that the clinical integration and problem-based learning strategies is mandatory to sustain the learnt skills[17,27]. The clinical application of the skills makes the student interested in the material taught to them. Nevertheless, it is imperative that the students are skilled in fundal visualization before they acquire skills in diagnosing pathologies[28]. Teaching eye pathologies during the initial introduction to ophthalmoscopy examination could lead to the students being unable to appreciate the difference between the normal from the pathology.

Use of Either Teaching Ophthalmoscope or Conventional Ophthalmoscope A study concluded that the use of either conventional ophthalmoscope or the teaching ophthalmoscope had a similar post-test learning outcome, except the latter showed more self-confidence in handling the ophthalmoscope by students[18]. The main use in teaching ophthalmoscope is that it enables the instructor to picture what is visualized by the student and to give specific instructions; therefore, the

conceptual understanding of the students is superior with teaching ophthalmoscopy. However, with proper instructions it is possible for the students to achieve self-directed goals, hence the equal post-test outcome in the two groups. In this study the students of both groups were given tasks or goals at the end of the programme. This is a significant part in self-guided learning as it keeps the student engaged through teaching[29] which could have contributed to the indifferent outcome in the two groups. Moreover, the advantages of the dexterity of handling a conventional ophthalmoscope versus a teaching ophthalmoscope in a busy clinic by a medical practitioner have to be examined before adopting teaching ophthalmoscopes as the norm in undergraduate medical teaching.

Strengths and Limitations of the Study This review described the studies which used non-simulator-based techniques in medical education. A limited number of studies were available, and the majority were conducted in developed countries. Due to the heterogeneity of the studies, we did not conduct a Meta-analysis to compare effectiveness of each method.

CONCLUSION

Non-simulator-based techniques such as use of fundal photograph matching of an eye of a volunteer, introduction to eye pathologies, smaller student groups and formal instructions with video demonstrations are effective in teaching direct ophthalmoscopy for undergraduate medical students.

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