

The role of simulators in improving vitreoretinal surgery training — A systematic review

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Abstract

Objective: To conduct an appraisal of current evidence regarding the effectiveness of EyeSi®-based training of vitreoretinal surgery.

Methods: The systematic review was conducted in July 2020, and comprised literature search on Cochrane Library, PubMed and Embase for articles regarding simulation training in vitreoretinal surgery. The shortlisted articles were subjected to qualitative analysis. Existing evidence was assessed, and predictions on how outcomes may be applied to improve vitreoretinal surgery training were made. The risk of bias of each study was calculated in line with the guidelines of the Cochrane Handbook.

Results: Of the 124 articles identified, 7(5.6%) were shortlisted; 5(71.4%) established construct validity; 1(14.3%) discriminate validity and 1(14.3%) concurrent validity. Analysis disclosed minimal bias in the selected studies.

Conclusion: Current evidence on simulation training in vitreoretinal surgery suggests it is a thoroughly validated training tool with minimal risk of bias. Vitreoretinal surgery training programmes should adopt and gauge the impact simulation training has on patient-related outcomes.

Keywords: Vitreoretinal surgery, Virtual reality, Training, Eyesi, Ophthalmic simulators, Surgical simulation.

Introduction

For centuries, surgical training has been conducted under the master-apprentice model of "see one, do one, teach one".¹ The limitation of this model, however, has been its dependence on patients.² This is a drawback that the use of simulators during training may entirely resolve. In the past 20 years, many specialities, including cardiothoracic,³ laparoscopic,⁴ and ophthalmic surgeries,⁵ have widely

begun to embrace the singular role of simulation training in bridging this gap. When it comes to ophthalmology, the literature on simulator training is ample, with the existing articles on simulated vitreoretinal surgeries principally aiming to establish if there is any validity to the scoring metrics of the EyeSi®, and if skills acquired on the simulator transfer to real-life vitreoretinal surgery (VRS).⁶ A systematic review of existing literature is necessary to assess the extent to which simulation training can achieve these metrics and if there is a benefit to augmenting vitreoretinal training programmes with simulation training. The current systematic review was planned to assess available studies evaluating the use of simulators in VRS training.

Materials and Methods

The systematic review was conducted in July 2020, and comprised literature search on Cochrane Library, PubMed and Embase for articles regarding simulation training in vitreoretinal surgery. The keywords used were: "vitreoretinal surgery", "virtual reality", "EyeSi" and "training". Only studies providing qualitative results evaluating the impact of the EyeSi® simulator on training were included, while the rest were excluded.

The abstracts of all the included studies were evaluated by two authors. The entire texts were subsequently reviewed by both the authors. Articles mutually found to be appropriate were included.

All relevant data from the included studies was exported onto a worksheet. The date of publication, number and designation of participants, skills trained, and outcomes of each study were noted. Classification of the skills trained on the EyeSi® simulator was done according to inbuilt vitreoretinal EyeSi® modules consisting of navigation training, bimanual training, forceps training, laser photocoagulation, internal limiting membrane peeling (ILM-peel), vitrectomy, posterior hyaloid and retinal detachment. Outcomes were classified as operating time, skill assessment and skill acquisition. The risk of bias of each study was calculated using the guidelines of the Cochrane Handbook.⁷ The included studies were independently reviewed by both the authors

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and were categorised as unclear, low risk or high risk of bias.

Results

Of the 124 articles identified, 7(5.6%) were shortlisted (Figure-1). None of the included studies had all bias items assessed as carrying low risk. The bias item that ranked poorest overall was blinding of outcome assessment. Of the studies, only Vergmann et al. included a protocol which allowed for assessment of reporting bias.⁸ Allocation bias and performance bias was unappreciable for 2(18.6%) studies as they were single-group studies (Figure-2).

The included studies were all published between 2004 and 2019. Collective attributes of the studies were summarised (Table-1).

Of the 7 studies, 5(71.4%) established construct validity,⁸⁻¹² 1(14.3%) established discriminate validity¹³ and 1(14.3%) established concurrent validity.¹⁴

Attributes of each individual study were also noted separately (Table-2). Rossi et al.¹⁰ explored how simulated performance on the EyeSi® correlates with real-life VRS performance. It comprised 3 groups of students, residents and surgeons who were required to perform 3 separate intraocular navigation and ILM-peel tasks. The participants' completion times and scores on the EyeSi® performance curve were recorded. A statistically significant difference between the graded performance of students and surgeons ($p=0.003$) and between residents and students ($p=0.05$) in all 3 groups was found.

Vergmann et al.⁸ carried out a study evaluating if more real-life surgical experience was associated with better scores on the EyeSi® VRS simulator. A total of 35 participants were allocated into 3 experience-based

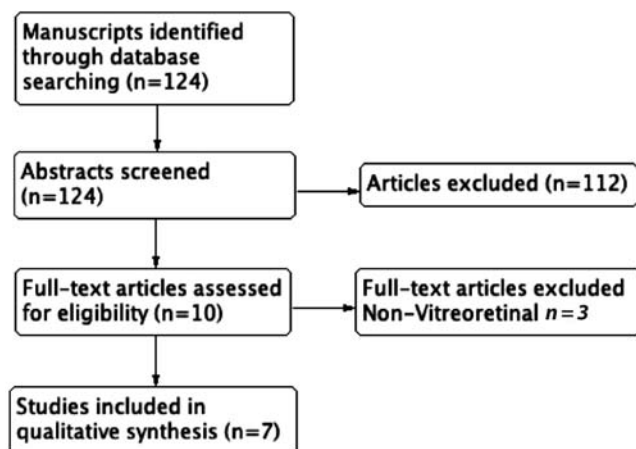


Figure-1: The study flowchart.

Table-1: Collective attributes of the included studies.

Study Attributes	Studies (Number)	Participants (Number)
All studies	7	157
Participants*		
Medical students	3	45
Residents	5	73
Surgeons	6	39
Skills trained		
Navigation training	6	157
Bimanual training	4	73
Forceps training	3	71
Laser photocoagulation	2	50
Posterior hyaloid	3	69
Vitrectomy	2	36
Internal limiting membrane peel	4	73
Retinal detachment	2	19
Years of publication		
2004-2009	2	69
2009-2019	5	88

*Some studies included medical students, residents, and surgeons leading to some overlap in participant numbers.

cohorts of students, residents and surgeons. Each group then performed and was graded on 6 simulated VRS modules on the EyeSi®. The participants then received feedback and repeated all 6 modules. Measures of association between their simulator scores and the experience-group they fell under were determined. Results showed the surgeons' group had the highest overall scores, followed by the residents and then the students ($p<0.01$). Of note was the fact that the cohorts of surgeons with less experience showed greater improvement during the second attempt, while the more experienced surgeons did not.

Thomsen et al.¹¹ correlated past cataract surgery training experience to scores on the VRS module of on the EyeSi®. The study recruited 12 residents; 6 with no past ophthalmic surgical experience, and 6 with past cataract VRS experience, alongside 3 surgeons. All participants completed the procedure and were graded on 11 VRS modules on the EyeSi®. There were significant differences in the mean test scores between the surgeons and the novice residents ($p=0.023$) and between the surgeons and experienced residents ($p=0.003$).

Solverson et al.¹² evaluated the ability of the EyeSi® simulator to differentiate between novices and experienced vitreoretinal surgeons. The novice group consisted of 12 participants comprising residents, interns and ophthalmic staff. The expert group consisted of 7 experienced vitreoretinal surgeons. Both groups completed the procedure and were graded on the same navigational microdexterity module on the EyeSi®

Table-2: Attributes of the included studies.

Article	Year	Skills Trained	Study Type	Participants	Measured Outcomes	Summary of Effect
Cissé et al. ⁹	2019	Navigation training Forceps training Vitreotomy	Nonrandomised group comparison	15 residents 6 surgeons	Skill assessment	Surgeons > Residents (P=0.001)
Vergmann et al. ⁸	2017	Navigation training Forceps training Bimanual training Laser coagulation Posterior hyaloid ILM peel	Nonrandomised group comparison	20 medical students 10 residents 5 surgeons	Skill assessment	Surgeons > Residents (P < 0.01)
Solverson et al. ¹²	2009	Navigation training,	Nonrandomised group comparison	18 residents 7 surgeons	Error score	Residents > Surgeons (P<0.05)
Deuchler et al. ¹⁴	2016	Bimanual training ILM peel Retinal detachment	Single group	4 surgeons	1) Skill assessment 2) Surgical Performance	1) Years of surgical experience positively correlated with improved scores on the EyeSi® simulator (P=0.000342). 2) Warm up on the simulator was associated with improved subsequent real surgical performance (P=0.0302)
Rossi et al. ¹⁰	2004	Navigational	Nonrandomised group comparison	6 medical students 24 residents 14 surgeons	Skill assessment	Surgeons > Students (P=0.003) Residents > Students (P=0.05)
Mellum et al. ¹³	2020	Navigation training, Bimanual training Posterior hyaloid ILM peel	Single group	19 surgeons	Surgical Performance	Distracting factors led to poorer performance as compared to baseline on the EyeSi® (P=0.0007)
Thomsen et al. ¹¹	2017	Navigation training, Forceps training, Bimanual training Vitreotomy Laser coagulation Posterior hyaloid ILM peel Retinal detachment	Nonrandomised group comparison	12 residents 3 surgeons	Skill assessment	Surgeons > Novice residents (P=0.023) Surgeons > Experienced residents (P=0.003)

simulator. The total error score between the experienced and novice groups showed a statistically significant difference with it being 24.1 for the novices and 11.3 for the experts ($p < 0.05$).

Cissé et al.¹⁹ conducted a study comparing the scores of 6 experienced vitreoretinal surgeons with >100 procedures per year, and 15 residents with no past VRS experience. Both groups completed the procedure and were graded on the same four modules on EyeSi®. Results showed that the surgeons achieved significantly better scores than residents on navigation ($p = 0.01$), forceps ($p < 0.01$), epiretinal membrane peeling-1 ($p = 0.02$) and epiretinal peeling-2 modules ($p = 0.04$). No difference was noted between the groups on the 2 vitrectomy modules ($p = 0.17$ and $p = 0.26$).

Deuchler et al.¹⁴ evaluated the efficacy of EyeSi® simulator in preparing surgeons for performing VRS and the potential to predict the given surgeon's performance during the upcoming procedure. Four participating cataract surgeons performed 9 vitrectomies immediately following warmup on the EyeSi® vitreoretinal module. The same group of surgeons also performed 12 vitrectomies without any EyeSi® warmup. The warmups were graded on the simulator and the vitrectomies were recorded and graded according to the Global Rating Assessment of Skills in Intraocular Surgery (GRASIS) score by two masked observers. Results showed that a warmup period on the EyeSi® prior to surgery was associated with significantly improved subsequent surgical performance ($p = 0.0302$). Furthermore, the surgical experience of each surgeon in years was found to be positively correlated with the surgeon's scores on EyeSi® ($p = 0.0003$).

	Sequence Generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Cissé et al. ⁹	+	+	+	+	+		+
Deuchler et al. ¹⁴	+			+	+		-
Mellum et al. ¹³	+			+	+		-
Rossi et al. ¹⁰	-	+	+	-	+		+
Solverson et al. ¹²	+	+	+	-	+		+
Thomsen et al. ¹¹	+	+	+	+	+		+
Vergman et al. ⁸	+	+	+	-	+	+	+

Green: Minimal risk, Blank: Inapplicable to the study design, Red: High risk.

Figure-2: The risk of bias in the selected studies.

Mellum et al.¹³ examined if distracting factors had any impact on the surgical performance of 19 novice surgeons who completed a basic training programme on EyeSi® until a minimum eligibility score was reached. Once familiarised, the surgeons completed four vitreoretinal modules on the simulator without any distracting factors to determine a reference score. Next, the surgeons completed the same four modules under the influence of each of the four distracting factors: auditory distraction, fasting, interrupted sleep and 24-hour sleep deprivation. All distracting factors resulted in lower performance compared to the reference scores ($p=0.0007$).

Discussion

Prior to the widespread adoption of a new technology, its validity must be verified. Gallagher et al.¹⁵ defined a set of measures to gauge validity. These included face validity which is a subjective validation primarily aimed at determining if an instrument is capable of measuring

what it is intended to measure. The next is content validity, which is also a subjective but more rigorous validation done by methodically examining test contents. Content and face validity do not carry significant weight.¹⁵ Then comes construct validity, which is the ability of an instrument to identify and discriminate between variables it measures. This is judged on the basis of the instrument to differentiate novices from experts. The concurrent validity judges how closely on-the-instrument scores correlate with scores on well-established gold standard instruments. The discriminate validity is the degree to which the scores generated by a instrument correlate with any and all factors with which they are expected to correlate. Finally, predictive validity assesses on the basis of evaluations made by the instrument being accurately predictive of actual performance.

One study has shown EyeSi® to have concurrent validity.¹⁴ Deuchler et al.¹⁴ found that GRASIS scores, the current gold standard for scoring ophthalmic surgeries, were strongly correlated with EyeSi® proficiency scores for the ILM-peel and retinal detachment modules. Deuchler et al.¹⁴ also discovered that EyeSi® proficiency scores across these modules were also strongly linked with the total number of years of VRS experience. Through these two metrics, the concurrent validity of the EyeSi® vitreoretinal simulator was established.

The majority of existing literature validating EyeSi® does so by establishing the construct validity of VRS simulator. Of the included studies, Cissé et al.,⁹ Vergmann et al.,⁸ Rossi et al.,¹⁰ Thomsen et al.¹¹ and Solverson et al.,¹² established construct validity of the simulator. The navigation training module was validated by all 5 studies. Navigation training is the most basic and central module of EyeSi® and is thought to underpin the validity of other modules. The validation of this module serves as a benchmark for how EyeSi® can accurately differentiate between novices and experts at the most fundamental level.

Deuchler et al.¹⁴ also established the predictive validity of the simulator by looking at how EyeSi® scores before surgery correlated with GRASIS performance during subsequent real surgeries.

Mellum et al.¹³ established the discriminate validity of EyeSi® by looking at how distracting factors that are well known to result in a poor surgical performance led to decrease in performance scores on the simulator. In essence, variables that are known to adversely affect surgical performance also negatively affected scores on the EyeSi®, indicating that the simulator has discriminate

validity.

Through these studies, EyeSi® has effectively stand validated at all levels of Gallagher's 6 criteria for instrument validation.¹⁵ However, further studies on discriminate and predictive validity are necessary given the small sample sizes of the current studies investigating those outcomes. Moreover, while evidence regarding basic modules on the EyeSi®, such as navigational training, is robust, more evidence is needed regarding advanced procedural modules, such as retinal detachment and membrane peeling.

There exists an extensive body of evidence supporting the validity of this instrument in realistically simulating VRS scenarios. The next step in assessing the effectiveness of the EyeSi® would be integration into ophthalmic training programmes and comparing resident training programmes with access to EyeSi® against those without access. Notably, numerous cataract surgical training programmes have done this with EyeSi® and have reported positive outcomes with supplementing training programmes with EyeSi®.¹⁶ The most noteworthy finding made by these programmes has been the decreased complication rates of EyeSi®-augmented residents compared to EyeSi®-naïve residents.¹⁷ It would be interesting to see if similar benefits of EyeSi®-augmented cataract surgery training carry over to EyeSi®-augmented VRS.

The risk of bias evaluation indicated that of all the included studies, only 1 was fully bias-free. Bias primarily arose due to a lack of blinding of participants and outcome assessment. The automated nature of EyeSi® grading, however, diminishes the importance of potentially-biased outcome assessment. Consequently, on holistic examination, all studies generally ranked low in bias risk and adhered to acceptable reporting standards.

The obstacle that remains in the path to broader implementation of the EyeSi® simulator is the significant purchasing cost of ~£100,000 to £150,000, along with recurrent yearly maintenance costs of £5000 up to £10,000. These costs, however, may be diluted by sharing the cost amongst several hospitals in a region and designating one regional training centre where trainees may share access to EyeSi®. This is of particular benefit in countries with limited resources where the quality of healthcare training systems may vary vastly between different training centres. Having a designated training centre where trainees from different training programmes could jointly practice surgical skills may help bridge this gap. Standardisation improves process

reliability and may aid in more consistent training across the region. Doing so may also encourage discourse and collaboration between regional training programmes and may lead to the development of a standardised curriculum to better align training programmes in developing countries with international standards. Furthermore, grading and assessment of trainees may also be conducted on the simulator in a more objective manner, free from the innate human error associated with current observational grading metrics, such as GRASIS.¹⁵ Current assessment methods are also limited in their dependence on the availability of a senior surgeon to manually assess each trainee, which is another human limitation that simulators may reduce.

These costs also need to be balanced against patient-safety benefit associated with current training models where novice surgeons partly develop their skills by operating on real patient's eyes. Literature shows that VRS performed by trainee surgeons is associated with greater complication rates.¹⁸ EyeSi® shifts this necessary yet dangerous period of a trainee's learning curve away from the eyes of vulnerable patients. The trainee gets the authentic training necessary and the patients do not get exposed to what, with the advent of EyeSi®, may be considered unnecessary operating risks.

Strengths and limitations

The strength of the current review is that it used well-established metrics of gauging simulator effectiveness, such as Gallagher's criteria,¹⁵ to standardise and allow for a level of stratification and generalisability between the findings of the various studies. Another strength is that it was conducted as per Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.¹⁹ A limitation of the review is that articles that were unpublished were not searched for. This might have contributed to publication bias.

Conclusion

EyeSi® simulator was found to have the ability to assess and predict VRS proficiency at all levels. A risk-of-bias analysis of the included studies showed no significant bias in study design or execution. As the vitreoretinal module of EyeSi® becomes more widely adopted in training programmes, further studies are needed to compare the effect of augmenting training with EyeSi® on patient outcomes as it will gauge the impact of EyeSi® on VRS training.

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