Original Article

An objective evaluation of simulated surgical outcomes among surgical trainees using manual small-incision cataract surgery virtual reality simulator

Sankarananthan R, Senthil Prasad R, Tony Alex Koshy, Padam Dharani, Ashish Bacchav, Van Charles Lansingh, Chetan Ahiwalay, Balagiri K, Madhu Shekhar

Purpose: The purpose of this study was to evaluate trainee performance across six modules of a virtual reality (VR) simulator. **Methods:** A retrospective observational study was conducted on 10 manual small-incision cataract surgery (MSICS) trainees who practiced cataract surgery on an MSICS VR simulator for one month. They were assessed in six major steps which included scleral groove, tunnel dissection, keratome entry, capsulorhexis, nucleus delivery, and intraocular lens (IOL) insertion under a trainer's supervision. The information included in their score metrics was collected, and their overall performance was evaluated. **Results:** Thirty attempts were evaluated for scleral groove, tunnel dissection, and capsulorhexis and 15 attempts for keratome entry. Candidates had varied results in the dimensional aspects and their rates of complications with a mean satisfactory score of 3.1 ± 4.17, 6.8 ± 5.75, 5.8 ± 7.74, and 1.8 ± 2.57, respectively. Nucleus delivery (n = 5) had more of iris pull and IOL insertion (n = 5) had more of lost IOL as complications but both had a higher satisfactory outcome. **Conclusion:** A VR simulator is a useful tool for training surgeons before their entry into live surgery. It is an effective method for evaluating objectively the structural characteristics of each phase in MSICS and their associated complications, helping them anticipate it earlier during live surgery by giving them a near real world experience.

Access this article online

Website: www.ijo.in

DOI: 10.4103/ijo.IJO_1600_22

Quick Response Code:

Key words: HelpMeSee simulator, MSICS, trainee surgeons, VR simulator

There are an estimated 31.7 ophthalmologists per million population globally, of whom only less than half perform cataract surgery (mean number, 14.1 ophthalmologists per million population).[1] Taking into consideration the fact that cataract has become one of the leading causes of blindness worldwide, there is an imminent need to train and equip ophthalmologists worldwide to be competent in the field of cataract surgery.

Different training models have been developed and are being used for this very reason which include animal eyeballs, cadaver eyeballs, and inanimate and virtual-reality (VR) models.[2]

Simulation-based training has been in use in various other industries—including the aviation industry—and have now crossed borders into surgical sub-specialties.

Foreign body injuries to the cornea, deep anterior lamellar keratoplasty, goniotomy, various laser procedures, nasolacrimal duct surgery, oculoplastic, retrobulbar injection, scleral indentation, scleral suturing, strabismus surgery, trabecular meshwork surgery, and vitreoretinal procedures are among the many other surgeries in ophthalmology for which simulator models exist.[2]

Retrospective studies have shown that ophthalmologists who have been trained with a virtual reality simulator for cataract surgery have had reduced complication rates during surgery.[3,4]

There have been several VR simulators that have been developed for phacoemulsification,[5] including the Eyesi Surgical, Phaco Trainer/MicroVisTouch, PhacoVision, and the Phantom Phaco simulator, among others.[6–10]

A VR simulator is an invaluable training tool found to have significantly reduced complication rates among novice surgeons when compared to surgeons trained as per the conventional training curriculum.[4,11]

The HelpMeSee™ Eye Surgery Simulator (HelpMeSee, Inc., New York, USA) is an advanced, virtual reality–based surgical simulator designed for manual small-incision cataract surgery (MSICS) which incorporates the physics model of surgical activities with movements in 3 degrees of freedom and tactile feedback, giving the user a near real world experience [Fig. 1a and b].[11]

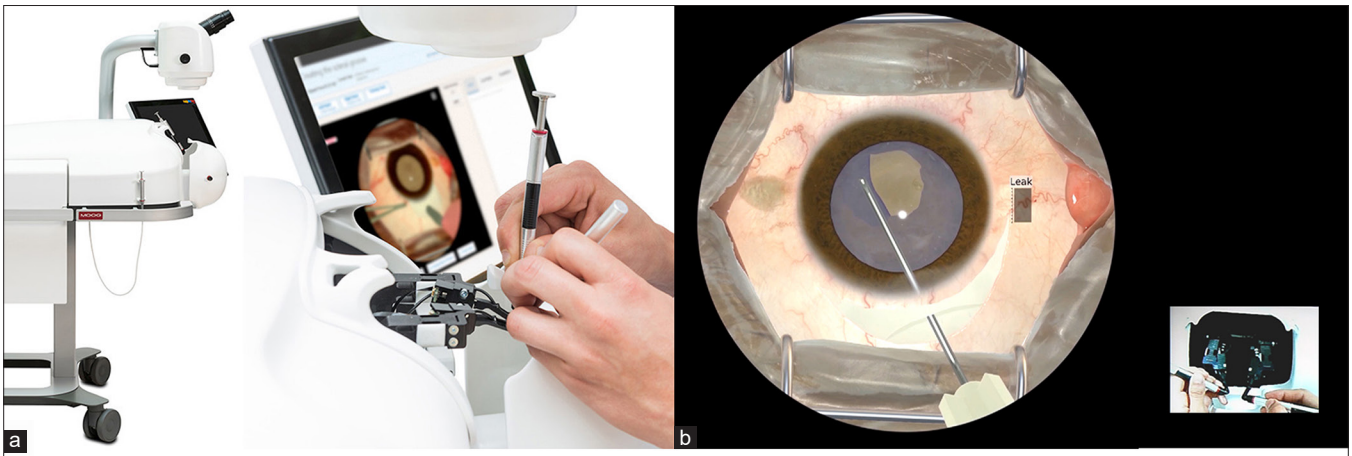
These are necessary for surgeons to effectively acquire skills mandatory during live surgery.[11]

Department of Cataract and IOL Services, Aravind Eye Hospital, Madurai, Tamil Nadu, India

Correspondence to: Dr. Madhu Shekhar, Chief, Cataract and IOL Services, Aravind Eye Hospital, Madurai, Tamil Nadu, India. E-mail: Madhushekhar93@gmail.com

Received: 04-Jul-2022 Revision: 02-Sep-2022
Accepted: 15-Sep-2022 Published: 25-Oct-2022

Cite this article as: Sankarananthan R, Prasad RS, Koshy TA, Dharani P, Bacchav A, Lansingh VC, *et al*. An objective evaluation of simulated surgical outcomes among surgical trainees using manual small-incision cataract surgery virtual reality simulator. Indian J Ophthalmol 2022;70:4018-25.



Performance Parameter	Condition Matched	Actual Recorded	Outcome	Score	Feedback
Maximum length of the tunnel into the cornea (mm)	x >= 0	1.84		NA	No records found
Length of the inner tunnel limit (mm)	x >= 7.5	8.57		1/1	No records found
Length of the tunnel (mm)	3.0 <= x <= 5.0	3.28		1/1	No records found
Maximum depth of the tunnel (mm)	x >= 0	0.43		NA	No records found
Minimum depth of the tunnel (mm)	x >= 0	0.02		NA	No records found
Uveal prolapse	-	False	Limit not evaluated	0/0	No records found
Perforation of the outer wall (button holes)	-	False	Limit not evaluated	0/0	No records found
Laceration of the outer wall	-	False	Limit not evaluated	0/0	No records found
Premature entry	-	False	Limit not evaluated	0/0	No records found
Task Review >			Satisfactory	2/2	Comment

c

Figure 1: (a) The HelpMeSee Eye Surgery Simulator with the handpieces which transmit the forces and sensation of touch to the fingertips of the operating surgeon**.** (b) The eyepiece view of the three-dimensional visuals when a trainee is performing capsulorhexis. (c) A screenshot of the sclero-corneal tunnel performance data that the simulator provides after every attempt. Note the scoring system based on the errors and performance data; the simulator can also assess if the attempt was satisfactory or not

Trainers' evaluations and assessments of trainees' progress will be subjective and contextual, changing based on factors such as the trainers' own experience, the trainees' prior surgical background, and the types of patients on whom the trainees perform surgery.

Data from surgical simulators provide a more objective, standardized basis for assessing a surgeon's performance.

The purpose of this observational study is to objectively evaluate the MSICS performance of trainees using the HelpMeSee™ simulator in accordance with the simulator's modules.

Methods

This was a retrospective observational study conducted between December 2021 and May 2022 in a tertiary teaching hospital in Madurai, Tamil Nadu. The study protocol conformed to the Declaration of Helsinki and was approved by the institutional ethics committee.

Participants in the study were various specialty fellows who were posted in microsurgical training for a period of 1 month and who fulfilled the inclusion and exclusion criteria.

The inclusion criteria included trainees who reported performing less than 30 cataract surgeries and those trainees who had completed the minimum number of attempts decided for each step.

The exclusion criteria were those participants with prior experience in the HelpMeSee™ simulation-based training program.

Training in MSICS was standardized according to a well-defined curriculum. This program featured practical oriented theory classes led by a trainer and an independent study through the use of an eBook created by HelpMeSee™.

Trainees would get a detailed description of their live surgery errors which were done daily and which would in turn help them focus on practicing those steps repeatedly on the simulator.

The curriculum included didactic lectures, lab activities, and simulation practice sessions in addition to the simulation training sessions.

During the live surgery, the wet lab, and the simulator practice, each of the trainees were directly supervised by the same trainer.

The simulator had four basic modules in its MSICS simulation-based training course (MSTC): a sclero-corneal tunnel course (SCTC), capsulorhexis and nucleus delivery course (CNDC), cortex removal and intraocular lens (IOL) implantation course (CRIC), and restoration of physical condition course (RPCC).

Trainees were assessed in six major steps in the simulator which included scleral groove, tunnel dissection, keratome entry, capsulorhexis, nucleus delivery, and IOL insertion.

Trainees were designated by the letters A through J.

Each step was assessed as explained below.

Scleral groove

The simulated scleral groove should be between 6.5 and 8.5 mm in length and will get a score of 1. A score of 0 is given if the dimensions lie outside that limit.

The depth of the groove is evaluated by the simulator as true (score of 1) or false (score of 0). Any value that deviates from these will lead to a bad tunnel architecture and an unsatisfactory result.

Uveal prolapse, if present while making a scleral groove, is noted under complication and will receive a score of −3.

The maximum score in this task is 2 and the minimum attainable score is −3.

Tunnel dissection

Length of the tunnel inner lip of 5–7.5 mm and length of tunnel of 3–5 mm are tunnel dimensions necessary for a suitable result with a score of 1 for each. Perforation of outer wall, laceration of outer wall, premature entry, and uveal prolapse are included under complications, each with a score of −3. The maximum attainable score in this task is 2 and minimum score is −12 [Fig. 1c].

Keratome entry

Dimensions of keratome entry should be as follows: length of inner tunnel opening ≥7.5 mm and length of cornea dissected from limbus at 1.7–2.7 mm with a score of 1 each if the candidate performs it satisfactorily. Complications include premature entry, contact with the iris, endothelial contact, contact with the lens, lateral tunnel laceration, and button hole. Nil contact with iris, endothelium, or lens and absence of a premature entry will be awarded a score of 1 while lateral tunnel lacerations and button hole will be given a score of −7 each. The maximum score attainable is 6 and minimum score is −14

Capsulorhexis

Capsulorhexis should have a maximum dimension of at least 6 mm and a minimum dimension of at least 4.5 mm and are awarded a score of 1 if the suitable dimensions are achieved. Contact with iris, endothelial touch, zonular dialysis (ZD), and rhexis runout are included under complications. An absence of iris or endothelial touch and a ZD of less than 10% is awarded a score of 1. ZD of 10%–50% gets a score of 0. ZD of >50% and capsulorhexis runout gets a score of −6. The maximum score in this task is 5 and minimum score is −12.

Nucleus delivery

The nucleus is delivered with wire Vectis. Iris pull and endothelial touch are included under its complications which, if absent during the procedure, will be given a score of 1 each, giving a maximum score of 2 and minimum of 0.

IOL insertion and dialing

IOL insertion is done using a pair of McPherson forceps and dialing by the Sinskey hook. Here, ZD and lost IOL are included in its complications. Occurrence of ZD will be given a score of −2, and if there is no IOL lost during the procedure a score of 1 will be awarded giving a maximum score of 1 and minimum of −2 in this task.

Results

A total of thirty scleral groove attempts were assessed for each candidate. The maximum number of adequate scleral groove length was 23 (B) and minimum was 7 (E, J, and I) [Tables 1-3].

Nine out of ten candidates had inadequate tunnel depths in more than 20 cases.

Table 1: Data of total number of successful attempts in scleral groove, capsulorhexis, nucleus delivery, and IOL implantation in candidates A-D

	Candidate A	Candidate B	Candidate C	Candidate D
Scleral groove length	20	23	11	13
Scleral groove depth	2	10	6	13
Uveal prolapse during scleral groove	4	3	0	1
Satisfactory scleral groove	1	8	2	13
Maximum rhexis size	7	12	17	22
Minimum rhexis size	10	12	19	27
Iris contact during rhexis	6	14	5	4
Endothelial touch during rhexis	1	8	1	0
Zonular dialysis during rhexis	3	23	5	5
Rhexis runout	1	0	2	1
Satisfactory rhexis	2	1	13	24
iris pull during nucleus delivery	3	2	0	0
Endothelial touch during nucleus delivery	0	0	0	0
Satisfactory nucleus delivery	2	3	5	5
Zonular dialysis during IOL insertion	0	0	0	0
Lost IOL during IOL insertion	2	1	1	0
Satisfactory IOL insertion	3	4	4	5

Table 2: Data of total number of successful attempts in scleral groove, capsulorhexis, nucleus delivery, and IOL implantation in candidates E-G

	Candidate E	Candidate F	Candidate G
Scleral groove length	7	13	13
Scleral groove depth	1	6	2
Uveal prolapse during scleral groove	1	0	11
Satisfactory scleral groove	0	3	0
Maximum rhexis size	15	25	9
Minimum rhexis size	12	20	12
Iris contact during rhexis	10	7	4
Endothelial touch during rhexis	3	3	3
Zonular dialysis during rhexis	12	15	15
Rhexis runout	0	1	0
Satisfactory rhexis	6	9	0
Iris pull during nucleus delivery	0	1	3
Endothelial touch during nucleus delivery	0	0	3
Satisfactory nucleus delivery	5	4	0
Zonular dialysis during IOL insertion	0	0	0
Lost IOL during IOL insertion	1	1	2
Satisfactory IOL insertion	4	4	3

Table 3: Data of total number of successful attempts in scleral groove, capsulorhexis, nucleus delivery, and IOL implantation in candidates H-J

	Candidate H	Candidate I	Candidate J
Scleral groove length	14	7	7
Scleral groove depth	3	8	4
Uveal prolapse during scleral groove	1	1	3
Satisfactory scleral groove	1	2	1
Maximum rhexis size	16	8	9
Minimum rhexis size	15	5	5
Iris contact during rhexis	11	3	11
Endothelial touch during rhexis	9	22	8
Zonular dialysis during rhexis	3	5	24
Rhexis run out	0	0	3
Satisfactory rhexis	3	0	0
Iris pull during nucleus delivery	0	0	3
Endothelial touch during nucleus delivery	0	0	2
Satisfactory nucleus delivery	5	5	1
Zonular dialysis during IOL insertion	0	0	0
Lost IOL during IOL insertion	0	0	0
Satisfactory IOL insertion	5	5	5

Complications during scleral groove with uveal prolapse was 11 times by candidate F while others had it occurring less than five times.

Candidate D reached the best satisfactory score in the scleral groove with 13, while the other nine candidates received scores below 10, for a mean satisfactory score of 3.1 ± 4.17 (0–13) across all candidates.

Even though candidate B had satisfactory scleral groove lengths in 23 cases, there were 20 inadequate scleral groove depth attempts, hence reducing the satisfactory score to only eight.

Thirty tunnel dissections were evaluated in all. The length of the inner tunnel limit had variable results with the maximum correct attempts being 21 (A) and minimum being no satisfactory result (I) [Tables 4-6]. It was satisfactory in less than 10 cases in five candidates (B, C, D, I, J) and more than 20 cases by A, whereas length of the tunnel was satisfactory in more than 10 cases by seven candidates (A, E, F, G, H, I, J).

Perforation and laceration of the outer wall were the more common complications during tunnel dissection, with five candidates having 10 or more perforation of the tunnel outer wall (B, C, F, I, J) and 5 had 10 or more tunnel laceration (B, C, E, G, I). Only two candidates had a total satisfactory tunnel

Table 4: Data of total number of successful attempts in tunnel dissection and keratome entry into AC in candidates A–D

	Candidate A	Candidate B	Candidate C	Candidate D
Length of inner tunnel limit	21	2	2	8
Length of tunnel	28	5	5	8
Uveal prolapse during tunneling	0	0	0	0
Perforation of outer wall	7	19	19	6
Laceration of outer wall	4	16	16	3
Premature entry	0	0	0	1
Satisfactory tunnel	17	0	0	6
Length of inner tunnel opening after keratome entry	13	8	2	11
Laceration after keratome entry	0	0	0	0
Premature entry	1	2	0	4
Contact with iris	0	4	1	3
Contact with lens	1	3	0	5
Length of corneal distance from limbus	12	9	12	11
Endothelial touch	14	11	13	2
Button hole	0	0	0	0
Satisfactory keratome entry	2	0	0	8

Table 5: Data of total number of successful attempts in tunnel dissection and keratome entry into AC in candidates E-G

	Candidate E	Candidate F	Candidate G
Length of inner tunnel limit	14	15	19
Length of tunnel	15	22	15
Uveal prolapse during tunneling	1	1	0
Perforation of outer wall	5	12	9
Laceration of outer wall	11	2	10
Premature entry	6	1	0
Satisfactory tunnel	9	13	7
Length of inner tunnel opening after keratome entry	4	7	3
Laceration after keratome entry	0	0	0
Premature entry	2	1	2
Contact with iris	1	0	0
Contact with lens	0	5	3
Length of corneal distance from limbus	14	13	4
Endothelial touch	6	5	6
Button hole	0	1	0
Satisfactory keratome entry	2	2	0

dissection of more than 10 cases (A, F). The mean satisfactory score was 6.8 ± 5.75 (0–17).

Complication like uveal prolapse was seen only in three candidates (E, F, J) and premature entry in four (D, E F, J) in their 30 attempts.

A total of 15 keratome entry were assessed for each candidate [Tables 4-6]. The maximum number of correct lengths of inner tunnel opening after keratome entry was in 13 attempts (A) and 11 attempts (D) and minimum was 1 attempt (J). Only four candidates had a satisfactory attempt in only less than 5 cases and 2 in more than 10 attempts.

The maximum number of correct lengths of corneal distance from limbus was in 21 attempts by candidate A. There were six candidates who had a satisfactory attempt in more than ten cases, three candidates who had a satisfactory attempt between five and ten cases (B, I, J), and one candidate who had a satisfactory attempt in fewer than five cases (G).

In the complications, laceration after keratome entry and button hole occurred only once (J and F, respectively). Premature entry and contact with iris were seen in less than five cases in all candidates with maximum occurrence of four times (D and B, respectively). Contact with lens was observed in fewer than 5% of nine candidates. Endothelial touch was seen a maximum of 14 times (A and J) of which 8 candidates had an endothelial touch in more than 5 attempts. Less than five candidates out of nine had an AC entry that was satisfactory, with a mean value of 1.8 ± 2.57 (0–8).

In the 30 capsulorhexis attempts by each candidate, the maximum capsulorhexis size was satisfactory in less than 10 attempts in three candidates, 11–20 attempts in five candidates,

Table 6: Data of total number of successful attempts in tunnel dissection and keratome entry into AC in candidates H-J

	Candidate H	Candidate I	Candidate J
Length of inner tunnel limit	15	0	7
Length of tunnel	16	13	13
Uveal prolapse during tunneling	0	0	2
Perforation of outer wall	8	22	10
Laceration of outer wall	3	14	4
Premature entry	0	0	1
Satisfactory tunnel	10	0	6
Length of inner tunnel opening after keratome entry	8	8	1
Laceration after keratome entry	0	0	1
Premature entry	1	1	0
Contact with iris	2	2	1
Contact with lens	1	11	1
Length of corneal distance from limbus	16	7	9
Endothelial touch	7	12	14
Button hole	0	0	0
Satisfactory keratome entry	4	0	0

and more than 20 in two candidates. The maximum number of correct attempts was 25 (F) and minimum was 7 (A) [Tables 1-3].

The minimum capsulorhexis size was satisfactory in less than ten attempts in three candidates, 11-20 attempts in six candidates and more than 20 in one candidate, with the maximum number of correct attempts being 27 (D) and minimum being 5 (I, J).

Complications like iris contact, endothelial touch, and capsulorhexis runout occurred in less than or equal to 10 cases in 7, 9, and 10 candidates, respectively.

ZD occurred in less than 10 attempts in five candidates, 11–20 attempts in three candidates, and more than 20 in two candidates.

The mean satisfactory score for capsulorhexis amongst all the candidates was 5.8 ± 7.74 (0–24).

Five attempts of nucleus delivery were assessed [Tables 1-3]. There were no complications noted in five candidates whereas five candidates had iris pull (A, B, F, G, J) and two candidates had endothelial touch (G, J) during nucleus delivery. Five candidates had 100% satisfactory nucleus delivery (C, D, E, H, I) and 1 candidate had no satisfactory nucleus delivery (G).

Five attempts of IOL insertion were assessed for each candidate [Tables 1-3]. None of the trainee surgeons had ZD while 1 instance of lost IOL was seen in candidates B, C, E, F and two by candidates A and G. Four candidates had 100% satisfactory outcomes (D, H, I, J).

On a sub-analysis of the current data, when comparing the candidates' first half of their attempts to their subsequent second half of their attempts in scleral groove, sclero-corneal tunnel, keratome entry, and capsulorhexis, it was observed that the candidates had an overall improvement in the number of satisfactory attempts.

The mean number of satisfactory attempts in scleral groove was 0.8 ± 1.48 (0–4) in the first 15 attempts and 2.1 ± 2.38 (0–8) in the second half of their attempts with a p value of 0.0016. For sclero-corneal tunnel, it improved from 2.3 ± 2.16 (0–7) to 4.5 ± 3.75 (0–10) with a p value of 0.017. For keratome entry, it improved from 0.6 ± 1.07 (0–3) in the first 8 attempts to 1.4 ± 1.58 (0–5) for cases 9–15 with a p value of 0.045. In Capsulorhexis the improvement was from 1.7 ± 2.50 (0-7) to 4.1 ± 5.34 (0-17) with a p value of 0.011. It was statistically significant in all the four steps.

The mean scores in the second half of the attempts also improved when compared with the first half of the attempts in each of the four aforementioned steps Viz. scleral groove, sclero-corneal tunnel, keratome entry and capsulorhexis with a p value 0.413, 0.024, 0.032, and 0.025, respectively, with all steps reaching reaching statistical significance except scleral groove.

Discussion

Only after adequate deliberate practice with feedback, reflective learning, and a competency outcome assessment benchmarked to appropriate standards should supervised live surgical training on patients begin. There are many examples of a standardized curriculum for residency graduates like the comprehensive residency curriculum and standards established by The International Council of Ophthalmology and The Accreditation Council for Graduate Medical Education and the American Board of Ophthalmology before performing cataract surgery.[12,13]

Our study did an objective analysis of the surgical performances of 10 trainees in a simulator and their complications while doing so.

There are several lacunae and untapped potential in the area of research in a VR simulator-based studies.

This study is one of the few or if any which has objectively analyzed the results of the performances by trainee surgeons from the metrics provided by the simulator during their MSICS training course alone.

A direct comparison to their live surgical performances during this training period has not been assessed, as we believe

the results could be biased owing to certain confounding factors that the subjects get like added information from textbooks, training videos, meetings, wet lab training, and a surgical instructor who explains the intricacies of surgical technique, whose values would be hard to quantify as evidenced in the study by Naseri and Chang[14] that may contribute to the improvement in trainees' performance.

The ideal ophthalmic surgery simulator would give learners a virtual eye world that looks and feels like a living eye along with a uniform, complete curriculum. Metrics used during training would be reflective of students' actual abilities and predictive of their actual performance during surgery on real patients.

Evidence indicates that operative performance improves when introducing VR simulation into the cataract surgery curriculum.[15–17]

Capsulorhexis and phaco divide and conquer were previously rated the two most difficult steps in phacoemulsification by trainee surgeons, thus strengthening the usefulness of a simulator-based practice.[18]

VR simulator-based training enhanced performance of capsulorhexis in the wet lab, according to Feudner *et al*.,[6] although direct transfer to real-world surgeries has yet to be demonstrated.

In our study, the dimensions of capsulorhexis in the simulator were adequate more often than the complication rates resulting in lower satisfactory score. This information had enabled the trainees to perform adequately sized capsulorhexis while mitigating those anticipated complications better during live surgeries.

Similarly, the proportions of the sclero-corneal tunnel and keratome entry into AC were generally superior in their dimensional aspects, but were fraught with complexities and architectural issues, with endothelial touch during AC entry being more common.

Hence a better understanding of the complications that are more prone to occur during surgery are identified and rectified earlier by repeated practice and discussions.

According to retrospective research, access to a VR simulator for cataract surgery training (Eyesi; VR Magic) resulted in a 38.1% reduction in posterior capsular rent (PCR) rates for cataract surgical procedures conducted by junior trainees in the United Kingdom, from 4.2% to 2.6%.[3]

Mandatory simulator training for new US residents resulted in a drop of PCR rates from 4.8% to 2.2% in a retrospective comparison.[4]

According to one study, VR training is more effective than using an animal model,[19] and another study showed only an insignificant difference by training on a VR simulator compared to an inanimate model (silicone eye).[20]

When comparing subsequent performance on an animal or cadaver model, two trials found that training on a VR simulator was superior to no training.[6,21]

Training surgery students in the operating room increases costs because of increased surgery duration.[22–24] Lowry *et al*.[25] performed a cost analysis that suggested that introduction of a VR simulator in a residency program is associated with cost reductions owing to reduction in surgery time. Operating room time was estimated to cost $10 per minute, without including the price of disposable instruments, anesthetics, and other supplies.

Simulator metrics are a good indicator of general microsurgical skills, as demonstrated by the similar performance by experienced cataract surgeons and vitreoretinal surgeons on the simulator.[2]

Simulation-based learning is unavoidable due to the growing ethical concerns, as traditional patient-based practice is no longer acceptable when there are alternatives.

Overall, candidates who practiced on the HelpMeSee™ MSICS Surgical Simulator found it to be beneficial during their training period, with improved performance after additional practice and timely feedback.

Our study has certain limitations, one being the small sample size as only few subjects had completed the set number of attempts in each step and another being the retrospective design of the study.

Only the last set of the defined number of attempts for each module were included from the trainees and not their entire attempts as there were varied number of total attempts in each module by the different trainees, hence the total number of satisfactory attempts have not been included.

Also, a direct comparison between the outcomes from the simulator with the surgical outcomes has not been assessed in this study and will require further studies to elaborate on those findings.

It is possible that a more thorough knowledge of the correlation between simulator performance and actual surgical outcomes could be attained by the use of a larger, more comprehensive, multi-centric, double-blinded prospective trial.

Conclusion

In conclusion, an ophthalmic VR simulator is one of the many options for training ophthalmic surgeons during the early stages of their surgical careers, along with other training modalities such as wet lab, cadaveric eyes, and inanimate objects, but is likely the best tool to objectively evaluate a surgeon's performance to date. Practicing on the simulator might also minimize the complication rates and improve the dimensional accuracy of each MSICS phase, which can be validated only by additional research in this field.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Resnikoff S, Lansingh VC, Washburn L, Felch W, Gauthier TM, Taylor HR, *et al*. Estimated number of ophthalmologists worldwide (International Council of Ophthalmology update): Will we meet the needs? Br J Ophthalmol 2020;104:588-92.
2. Thomsen AS, Subhi Y, Kiilgaard JF, la Cour M, Konge L.

Update on simulation-based surgical training and assessment in ophthalmology: A systematic review. Ophthalmology 2015;122:1111-30.e1.

3. 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.
4. 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.
5. McCannel CA. Continuous curvilinear capsulorhexis training and non-rhexis related vitreous loss: The specificity of virtual reality simulator surgical training (An American Ophthalmological Society Thesis). Trans Am Ophthalmol Soc 2017;115:T2.
6. Feudner EM, Engel C, Neuhann IM, Petermeier K, Bartz-Schmidt KU, Szurman P. Virtual reality training improves wet-lab performance of capsulorhexis: Results of a randomized, controlled study. Graefes Arch Clin Exp Ophthalmol 2009;247:955-63.
7. Banerjee PP, Edward DP, Liang S, Bouchard CS, Bryar PJ, Ahuja R, *et al*. Concurrent and face validity of a capsulorhexis simulation with respect to human patients. Stud Health Technol Inform 2012;173:35-41.
8. Agus M, Gobbetti E, Pintore G, Zanetti G, Zorcolo A. Real Time Simulation of Phaco-Emulsification for Cataract Surgery Training. The Third Workshop on Virtual Reality Interactions and Physical Simulations (VRIPHYS 2006) 10. Madrid: The Eurographics Association; 2006.
9. Choi KS, Soo S, Chung FL. A virtual training simulator for learning cataract surgery with phacoemulsification. Comput Biol Med 2009;39:1020-31.
10. Laurell CG, Söderberg P, Nordh L, Skarman E, Nordqvist P. Computer-simulated phacoemulsification. Ophthalmology 2004;111:693-8.
11. Nair AG, Ahiwalay C, Bacchav AE, Sheth T, Lansingh VC, Vedula SS, *et al*. Effectiveness of simulation-based training for manual small incision cataract surgery among novice surgeons: A randomized controlled trial. Sci Rep 2021;11:10945.
12. International Council of Ophthalmology. ICO residency curriculum. Available from: http://www.icoph.org/refocusing_education/curricula.html. [Last accessed on 2020 Aug 20].
13. Mishra D, Bhatia K, Verma L. Essentials of setting up a wet lab for ophthalmic surgical training in COVID-19 pandemic. Indian J Ophthalmol 2021;69:410-6.
14. Naseri A, Chang DF. Assessing the value of simulator training on residency performance. J Cataract Refract Surg 2012;38:188-9.
15. Belyea DA, Brown SE, Rajjoub LZ. Influence of surgery simulator training on ophthalmology resident phacoemulsification performance. J Cataract Refract Surg 2011;37:1756-61.
16. McCannel CA, Reed DC, Goldman DR. Ophthalmic surgery simulator training improves resident performance of capsulorhexis in the operating room. Ophthalmology 2013;120:2456-61.
17. Pokroy R, Du E, Alzaga A, Khodadadeh S, Steen D, Bachynski B, *et al*. Impact of simulator training on resident cataract surgery. Graefes Arch Clin Exp Ophthalmol 2013;251:777-81.
18. Dooley IJ, O'Brien PD. Subjective difficulty of each stage of phacoemulsification cataract surgery performed by basic surgical trainees. J Cataract Refract Surg 2006;32:604-8.
19. Alwadani F, Morsi MS. PixEye virtual reality training has the potential of enhancing proficiency of laser trabeculoplasty performed by medical students: A pilot study. Middle East Afr J Ophthalmol 2012;19:120-2.
20. Daly MK, Gonzalez E, Siracuse-Lee D, Legutko PA. Efficacy of surgical simulator training versus traditional wet-lab training on operating room performance of ophthalmology residents during the capsulorhexis in cataract surgery. J Cataract Refract Surg 2013;39:1734-41.
21. Weiss M, Lauer SA, Fried MP, Uribe J, Sadoughi B. Endoscopic endonasal surgery simulator as a training tool for ophthalmology residents. Ophthalmic Plast Reconstr Surg 2008;24:460-4.
22. Hosler MR, Scott IU, Kunselman AR, Wolford KR, Oltra EZ, Murray WB. Impact of resident participation in cataract surgery on operative time and cost. Ophthalmology 2012;119:95-8.
23. Taravella MJ, Davidson R, Erlanger M, Guiton G, Gregory D. Time and cost of teaching cataract surgery. J Cataract Refract Surg 2014;40:212-6.
24. Winter TW, Olson RJ, Larson SA, Oetting TA, Longmuir SQ. Resident and fellow participation in strabismus surgery: Effect of level of training and number of assistants on operative time and cost. Ophthalmology 2014;121:797-801.
25. Lowry EA, Porco TC, Naseri A. Cost analysis of virtual-reality phacoemulsification simulation in ophthalmology training programs. J Cataract Refract Surg 2013;39:1616-7.