2016

VIRTUAL REALITY SYSTEMS FOR THE TRAINING OF OPHTHALMIC SURGERY

HEALTH TECHNOLOGY ASSESSMENT SECTION (MaHTAS)

MEDICAL DEVELOPMENT DIVISION

MINISTRY OF HEALTH MALAYSIA

004/2016

DISCLAIMER

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DISCLOSURE

The author of this report has no competing interest in this subject and the preparation of this report is totally funded by the Ministry of Health, Malaysia

EXECUTIVE SUMMARY

Background

Patient safety is becoming increasingly important in the medical field and can be achieved by improving psychomotor skills. Standard surgical training has traditionally been one of apprenticeship, where the trainees learn to perform the surgery under the supervision of a trained and experienced surgeon. Mastery of performance, especially of highly technical tasks such as microsurgery in ophthalmology field takes years of repeated practice to achieve. Thus, this is costly, time-consuming, and is of variable effectiveness.

Laparoscopic surgery involves the use of instruments using keyhole and is generally considered more difficult than open surgery. Training using a virtual reality simulator or a computer simulation is an option to supplement standard laparoscopic surgical training. It is becoming an important part of training in ophthalmology field. A shift from counting cases to competence-based curricula for learning surgery is on its way, and the implementation of structured surgical curricula has also been shown to have a favourable impact on complication rates.

In many ophthalmology departments, simulation training is a required part of the training curriculum. Surgical simulators represent an important step in narrowing the gap between clinical practice and simulator practice. Often, the simulator is also used for assessment, and surgical trainees are quantitatively evaluated on the surgical simulator as a form of diagnostic tool for ophthalmic surgical skills.

This technology review was requested by Consultant Ophthalmologist and Head of Ophthalmology Department Hospital Shah Alam to review the evidence on virtual reality systems for the ophthalmic surgery.

Objective/aim

To assess the effectiveness/efficiency such as increased surgical proficiency and improves operating times, safety, cost-effectiveness and organizational issues of virtual reality systems for training of ophthalmic surgery.

Results and conclusions

A total of 351 titles were identified through the OVID interface and PubMed. There were seven studies included which consists of one systematic review (SR), two randomised controlled trials (RCTs), three observational studies and one pre- and post- intervention study.

Effectiveness

There was fair to good level of retrievable evidence to suggest that the VR systems for ophthalmology training were able to improve surgeon operating performance and

skills. Studies also reported that inexperienced residents or surgeons were more likely to benefit from the training curriculum using VR systems. The evidence related to trainees' satisfaction was inconclusive. One study reported that VR programme seemed to improve the surgeons satisfaction as the programme was reported as "more fun" to use (24.1% versus 4.2%) and they were more likely to use this type of programme again compared with the likelihood of using the traditional tools (58.6% versus 4.2%). However, another study reported no significant difference in satisfaction between residents trained by traditional wet-lab versus surgical simulation.

Safety

There was limited fair level of retrievable evidence to suggest that VR systems for training of ophthalmic surgery were safe with fewer complications such as posterior capsule tear or perforation.

Cost-effectiveness

There was no retrieval evidence on the cost-effectiveness of the VR systems for the training of ophthalmic surgery.

Organizational issues

Training and learning curve for trainee

There was fair to good level of retrievable evidence to suggest that VR systems were associated with learning curves.

Methods

Literature search was done to search for published articles to assess the effectiveness, safety and cost-effectiveness of virtual reality training of surgical trainees in ophthalmic surgery. The following electronic databases were searched via OVID Interface: MEDLINE (1946 to present), EBM Reviews-Cochrane Database of Systematic Reviews (2005 to February 15 2016), EBM Reviews-Cochrane Central Register of Controlled Trials (February 2016), EBM Reviews–Database of Abstracts of Review of Effects (1st Quarter 2016), EBM Reviews-Health Technology Assessment (1st Quarter 2016) NHS economic evaluation database (1st Quarter 2016), PubMed and Embase database. The last search was run on 13 March 2016. Relevant articles were critically appraised using Critical Appraisal Skills Programme (CASP). Evidence was graded according to the US / Canadian Preventive Services TaskForce.

VIRTUAL REALITY SYSTEMS FOR THE TRAINING OF OPHTHALMIC SURGERY

1. INTRODUCTION

The traditional way for producing an expert practitioner in a medicine field is through apprenticeship. Years ago, clinical apprenticeship has been the centre for medical education. Particularly in surgery field, all residents observed, assisted and then begun to perform their standard surgical procedures under the supervision of a trained senior surgeons. This is time-consuming, costly and consists of variable effectiveness.[1, 2]

The concept of simulation was born in 1929 when Edward Link developed a mechanical flight simulator to reduce the incidence of catastrophic accidents in flight. Computer-generated simulation was first introduced in 1963 in a landmark doctoral thesis by Sutherland on man-machine graphical communications systems which galvanised the research community and set the tone for future technological breakthroughs. A growing interest in the potential for simulation to affect patient safety and improve the quality of medical education and training surfaced in the 1990s, and research teams throughout the United States of America (USA) initiated the concept of surgeons rehearsing procedures via computer simulation.[3,4]

Training using a simulator claimed that this VR systems is an option to supplement standard training. It is claimed that VR systems training improves the technical skills of surgical trainees such as decreased time for suturing and improved accuracy.[5] Virtual reality systems simulation training improves resident performance as measured by the simulator itself and wet-lab performance.[6] It also offers an ethical way of assessing the competency of a surgeon in performing a procedure without risk to the patient.[5, 6]

Laparoscopic surgery is different from conventional open method surgery because it increased the need for hand-eye-co-ordination to perform tasks looking at a screen to compensate for not being able to operate under direct vision. Traditionally, surgical residents develop their techniques and master the art of their practice in the surgical theatre on live patients and under supervision, but pressure is mounting for a more formally structured, more financially manageable, and a more time efficient curriculum.[3,4]

This technology review was requested by Consultant Ophthalmologist and Head of Ophthalmology Department Hospital Shah Alam to review the evidence on virtual reality systems for the ophthalmic surgery.

2. OBJECTIVE/AIM

To assess the effectiveness/efficiency such as increased surgical proficiency and improves operating times, safety, cost-effectiveness and organizational issues of virtual reality systems for training of ophthalmic surgery.

3. TECHNICAL FEATURES

Virtual reality or virtual realities can be broadly defined as the use of computational methods to propel users into a multimedia environment that simulates reality through software programming. Virtual reality is also known as immersive multimedia. There are many types of VR namely:[1,3]

- Window on world system
- Hands on Virtual Worlds
- Head Tracking Systems
- Immersive Systems
- Tele-presence
- Mixed or Augmented Reality

VR simulator has four essential components:

- a virtual world
- immersion
- sensory feedback and
- interactivity

Immersion is the sensation or experience of physically and, hopefully, mentally being in the virtual world through synthetic visual, haptic, and/ or auditory stimuli. Immersive VR requires sensory input and output incorporated through haptic instruments. Artificial intelligence capabilities provide cognitive interaction and assessment. With current VR technology, the user will be actively modifying a 3-D virtual world, not only as a passive observer.

Through the combination of human; computer interfaces, graphics, artificial intelligence, haptic (touch and pressure feedback) technology, high-end computing, and networking, current VR systems allow the user to become immersed in and interact with an artificial environment. The most widely used medical example of simplified VR is anatomic atlases. Advanced virtual reality involves visual and haptic computer-user interface, most often derived from the use of external props. Early surgical simulation is a mixture of advanced VR systems in which haptic feedback is lacking.

Sensory feedback is an essential ingredient of any virtual-reality simulation. Visual feedback is considered standard, but haptic feedback is an integral component of surgical simulation.
Lastly, interactivity means that the actions of the user should have a direct effect on the virtual world in which the user is engaged. VR simulation can be divided into three levels of complexity. Simplified VR is limited to a computer-user interface that does not use real-world props, artificial intelligence, or supporting systems.[3]

Figure 1: Virtual reality simulator enables the user to experience real life time situations by various training module

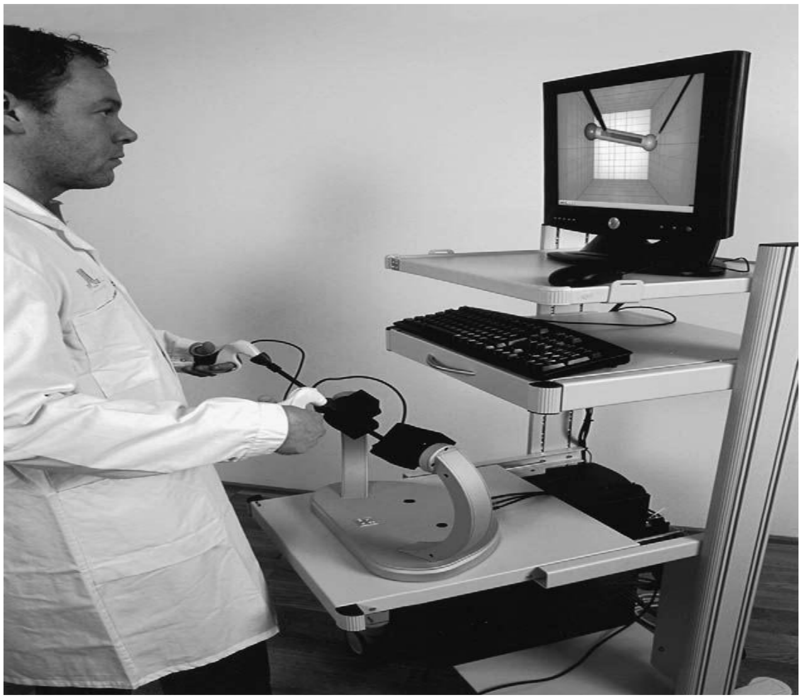
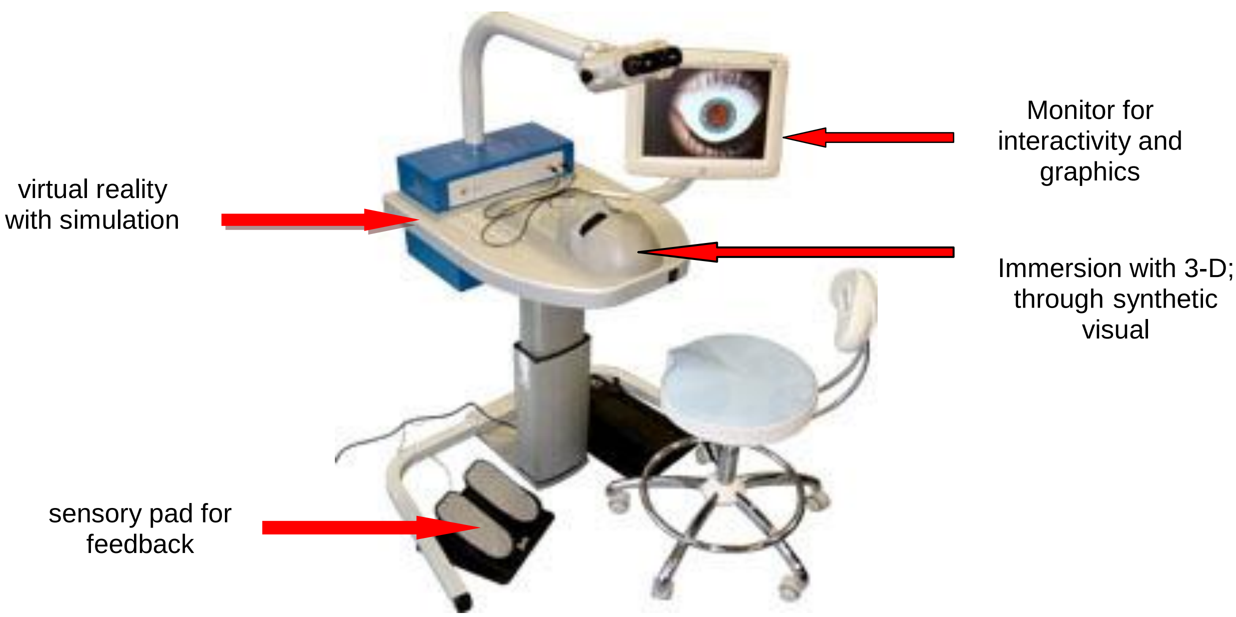


Figure 2: Surgical simulator essential components



4. METHODS

4.1. Searching

Electronic databases searched through the Ovid interface;

- OVID MEDLINE (R) In process & Other Non-Indexed Citations and OVID MEDLINE (R) 1946 to present
- EBM Reviews - Cochrane Central Register of Controlled Trials - Feb 2016
- EBM Reviews – Database of Abstracts of Review of Effects 1st Quarter 2016
- EBM Reviews - Cochrane database of systematic reviews – 2005 to Feb 15 2016
- EBM Reviews - Health Technology Assessment – 1st Quarter 2016
- NHS economic evaluation database – 1st Quarter 2016
- EBM Reviews- ACP Journal Club 1991 to Feb 2016
- EBM Reviews- Cochrane Methodology Register 1st Quarter 2016
- Embase

Other databases

- PubMed

In addition, other search engine such as Google was used to search for additional web based-materials and information. Last search was done on 13 March 2016 and limitation to English articles and human only during the search.

4.2. Selection

A reviewer screened the titles and abstracts against the inclusion and exclusion criteria and then evaluated the selected full-text articles for final article selection. The inclusion and exclusion criteria were:

Inclusion criteria

Population	• Resident medical officers/Trainees/ Students/surgeons in ophthalmic surgery field • Eye surgery (includes anterior and posterior)
Interventions	• Virtual reality system • Simulator
Comparators	• Conventional method/no training/traditional way of learning • Box-training • Wet-lab training
Outcomes	• Efficacy and effectiveness such as: improved operating performance/surgeon skills • Safety such as: reduced medical errors and help on patients' safety • Cost and economic evaluation • organizational issue such as training / usage of space
Study design	Health Technology Assessment (HTA) reports, Systematic review (SR) and Meta-analyses, SR, Randomised Controlled Trials (RCT), observational studies
	Full text English language articles

Exclusion criteria:

i) Animal study / laboratory study, other study design
ii) Narrative review
iii) Non English full text articles

Relevant articles were critically appraised using Critical Appraisal Skills Programme and graded according to US/Canadian preventive services task force (Appendix 2). Data were extracted, analyse and summarised in evidence table as in Appendix 3. Evidence was graded according to the US / Canadian Preventive Services Task Force2001.

5. RESULTS AND DISCUSSION

5.1 EFFECTIVENESS / EFFICACY

There were six studies included in this review that reported on the effectiveness/efficacy. The studies consist of one systematic review, two RCTs, two cross sectional studies and one pre- and post- intervention study. Most studies originated from United Kingdom and USA.

5.1.1 Surgeon operating skills/performance

Saleh GM et al. conducted a prospective cross sectional study in 2013 to evaluate the variability of performance among the novice ophthalmic trainees in a range of repeated tasks using the VR systems simulator at Moorfields Eye Hospital. Eighteen trainees took three attempts of five cataracts specific and generic three-dimensional tasks which every task were score on a maximum of 100 points. The VR consists of five selected tasks which include one cataract-specific task (known as capsulorhexis level 1) and another four generic 3-dimensional tasks (i.e. cracking and chopping level 2, cataract navigation level 3, cataract bimanual training level 1 & anti-tremor level).

The study observed that there was no significant differences in the scores between the juniors using different tasks; $p = 0.1104$ (Table 1). Trainees' overall performance differed significantly between first and second attempt ($p < 0.0001$) and between the first and third attempt ($p < 0.0001$), but not between the second and third attempt ($p = 0.65$). The study also showed that highly significant differences among the results achieved by module ($p < 0.0001$). There was a significant difference between the highest and lowest score by task ($p = 0.003$). It showed that the performance varies significantly with the complexity of the task (for example it is more challenging to perform a capsulorhexis).

Table 1: Scores across individuals (inter-novice performance)

Scores in all tasks by trainee				*Difference between highest and lowest score in a single task*			
Trainee	*Lower limit*	*Median*	*Upper limit*	*Trainee*	*Lower limit*	*Median*	*Upper limit*
1	0	32	76	1	35	51	57
2	0	69	70	2	10	18	22
3	0	78	94	3	4	6	61
4	6	64	85	4	21	23	32
5	0	19.5	81	5	0	4	21.5
6	0	72	84	6	6	12	24
7	17	59	90	7	30	46	59
8	11	65	93	8	37	39	65
9	0	34	76	9	8	24	39
10	0	57	86	10	21	28	29
11	0	53.5	75	11	16	47.5	78
12	37	74	88	12	28	36	36
13	0	53	69	13	3	24	42
14	49	77	95	14	30	39	66
15	0	35	73	15	0	21	42
16	0	79	92	16	4	5	6
17	0	62	79				
18	0	0	58				
P-value		0.1104		*P*-value		0.3878	

The study concluded that there was a clear upward trend of performance with repeated attempts. Even though there was poor reproducibility when comparing the first attempt with second ($p < 0.0001$) and the third ($p < 0.0001$), novice trainees seemed to achieve a certain level of competency and consistency on their scores between the second and the third attempt ($p = 0.65$) in Table 2. Therefore, the simulator would be more useful to monitor performance (formative assessment) rather than to evaluate and quantify overall skills (summative assessment).[2, level II-3]

Table 2: Scores across attempts (intra-novice performance)

2-Scores of all tasks by attempt			
Attempt	*Lower limit*	*Median*	*Upper limit*
1st	0	36.5	
2nd	0	68	83.5
3rd	13	69	83
1st *vs* 2nd attempt		*P*-value <0.0001	
1st *vs* 3rd attempt		*P*-value <0.0001	
2nd *vs* 3rd attempt		*P*-value 0.65	

Spiteri AV et al. (2014) conducted in a cross sectional study to develop evidence based and stepwise VR training curriculum for technical skills for phacoemulsification surgery. The study reported two primary outcomes in term of abstract tasks (which include anti-tremor and forceps) and procedural tasks (included lens cracking, phaco of quadrants and capsulorhexis).

All subjects (N=30) were divided into three group; Group I – novice (n=10), Group II – intermediate (n=10) and Group III – experienced (n=10). All subjects in this study must completed two sessions on the four abstract skills and two sessions on the five procedural tasks.

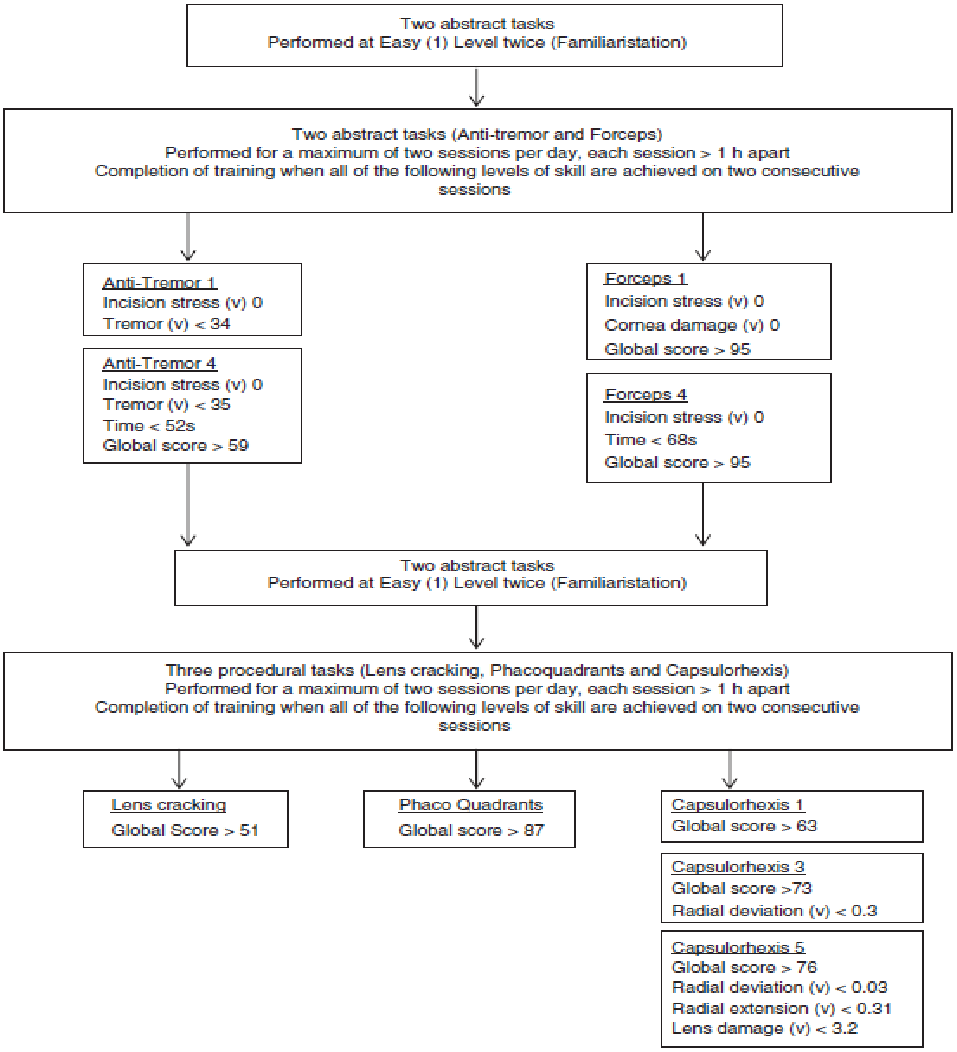
A large different in end-results or "ceiling effect" were established between the novice group and intermediate group and between novice and experienced groups but not between the intermediate and experienced groups. Significance results were achieved primarily on global score (Anti-Tremor1) only in the first repetition.

Another procedure in abstracts task (Forceps 1) showed significant difference between novice, intermediate and experienced groups; 46, 87, and 95 respectively; $p < 0.001$.

Procedural tasks were found to be a construct validity (i.e. the ability to reliably distinguish between novice groups and expert) such as:[8, level II-3]

i. Global score metrics in lens cracking: (0, 22, and 51; $p < 0.017$)
ii. Phaco of quadrants: (16, 53, and 87; $p < 0.017$)
iii. Capsulorhexis 1, the global scores demonstrated a similar trend (0, 19, and 63; $p < 0.017$).
iv. Capsulorhexis 3 and 5 (the difficulty of the task increased), global score performance in the novice and intermediate group decreased but improved in the experience: 0, 55, and 73; $p < 0.017$) and (0, 48, and 76; $p < 0.017$).

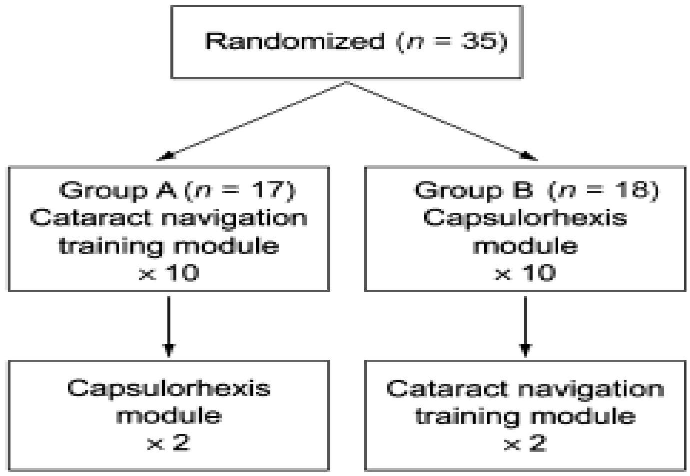
Figure 3: Evidence-based virtual reality training curriculum for PS
(v)= value; (s)= seconds



The authors concluded that this study was the first evidence based training curriculum for novice phacoemulsification surgeons using the VR simulators, with benchmark levels set by the intermediate and experienced surgeons. It also concluded that inexperienced residents or surgeons are thus most likely to benefit from the VR training curriculum.[8, level II-3]

A RCT of small sample size conducted by Selvander M et al. in 2012 which studied the initial learning curves of the medical students attending to the ophthalmology rotation by using the VR eye surgery simulator for anterior segment modules/procedures. The medical students (N=35) were randomised into a cataract navigations training module; (n=17) and a capsulorhexis module; (n=18) in Figure 4. Within three months of learning courses using the VR, both groups demonstrated significant improvements in performance over the ten iterations modules.

Figure 4: Study set-up. Training on one module (10 iterations) was immediately followed by two iterations on the other module at the same time.



The saved videos from the second capsulorhexis were then evaluated by a cataract surgeon according to the cataract performance rating tool Objective Structured Assessment of Cataract Surgical Skill (OSACSS). The simulator videos were also evaluated using the video-based modified Objective Structured Assessment of Technical Surgical Skills (OSATS) scoring system. The simulator overall score on the capsulorhexis module had a significant positive correlation with the modified OSATS score (r = 0.77, $p < 0.0001$) and with the OSACSS score r = 0.84, $p < 0.0001$). From the study, it concluded that the trainees quickly learned how to more efficiently and cautiously handle instruments inside the model eye. Therefore, the simulator has the potential to be part of the initial training of new cataract surgeons.[9, level II-1]

A RCT was conducted by Daly MK et al. (2013) which aims to compare the operating-room performance of ophthalmology residents trained by traditional wet-lab versus surgical simulation on the continuous curvilinear capsulorhexis (CCC) portion of cataract surgery in an academic tertiary referral centre. Residents were randomised to preoperative CCC training in wet lab or on a simulator. Two groups of second-year ophthalmology trainees from Boston University and the Massachusetts were divided into a simulator group (n=11) and a wet lab group (n=10). The simulator group completed four capsulorhexis training modules of increasing difficulty, whereas the wet lab group performed CCC in silicone eyes. After completion of their preoperative training (wet lab versus simulator), residents performed their first CCC of the clinical rotation under the direct supervision of an attending physician as part of their training at the facility. Residents then completed satisfaction questionnaires regarding their preoperative training. Two attending surgeons reviewed and graded each video of operating room performance. The mean score between the two attending physicians was used as the individual performance score for each of the 12 performance criteria. The overall score was calculated as the sum of these 12 individual performance scores (standardized).

They reported there was no significant difference in overall score between the two groups (p= 0.608). There was no significant difference in any individual score except time (wet-lab group faster than simulator group); p= 0.038) as showed in Table 3.

Table 3: Operating room performance scores

Question	Score Type	Mean Score		P Value
		Simulator	Wet Lab	
1. Time to complete CCC	Continuous, in minutes	9.48	4.70	.038†
2. Attending help	0 = yes, 1 = no	55%*	20%*	.183‡
3. Economy of movement	3 = clear economy, 1 = unnecessary movements	1.55	1.75	.512§
4. Confidence of movement	3 = fluent, 1 = awkwardness	1.55	1.75	.557§
5. Errors	3 = fewest, 1 = frequent	2.00	2.10	.705§
6. Total entries into chamber	7 = fewest entries, 1 = highest entries	3.55	4.50	.512§
7. Incisional stress	4 = no stress, 1 = severe stress	2.64	2.40	.918§
8. CCC size	3 = excellent, 1 = causes difficulties	2.18	2.35	.251§
9. Continuity of CCC	2 = continuous, 1 = not continuous	1.82	1.80	.809§
10. Shape	3 = very round, 1 = irregular	2.23	2.30	.557§
11. Centering	3 = excellent, 1 = poorly centered	2.50	2.50	.314§
12. Movement of microscope	3 = clear economy, 1 = unnecessary movements	2.18	2.05	.973§
Overall score	Sum of scores 1–12 above¶ (standardized z scores)	−1.046	1.152	.608

CCC = capsulorhexis
*Percentage who needed help
†Student t test, independent samples, 2 tailed
‡Fisher exact test
§Exact significant, Mann-Whitney U test
¶For determination of overall score, time was assessed using a predefined scoring system of 7 points, where time was binned into 1.5-minute intervals (eg, 0–1.5 minutes = 7; 1.5–3 minutes = 6) up to >9 minutes, which was given a score of 1. Time, otherwise, was assessed as a continuous measure.

The operating room performance showed that there was high correlation between the scores of both attending surgeons (r= 0.91). This study suggested that surgical-simulator training is a safe non-risk method when compared with traditional wet-lab training of preparing trainees to perform CCC during their initial surgical experiences on real patients in the operating room at our institution.[10, level II-1]

A systematic review by Sikder S et al. (2014); they conducted a search through PubMed database which included 10 studies that provide adequate results to prove the validity of the simulator and the effect of the simulator on training and education especially in ophthalmology field. Five stud
ies were from Banerjee E., Privett N., Selvander A., Asman N. and Feudner V focused on proving that the simulator objectively differentiated between experienced and novice surgeons in terms of surgical proficiency.

All studies showed a significant result in term of:

- concurrent validity of the circularity of the capsulorhexis metric; (p< 0.05)
- cataract navigation training module
- better scores on both easy and medium levels of the module

- lower rate of complications in the cases performed during the second half of the year compared to those performed in the first half of the year.
- shorter median operating time in cases 11–50 (34 min for the simulator group versus 38 min in the non-simulator group).

The authors concluded that VR simulator was effective tool in measuring the performance of trainees and differentiating their skill level.[11, level I]

5.1.2 Surgeon satisfactions

Henderson BA et al. (2010) performed a pre- and post-test intervention study at seven academic departments of ophthalmology in USA to evaluate the effectiveness of an interactive cognitive computer simulation for teaching the hydro-dissection portion of cataract surgery compared with standard teaching. The study also assessed the attitudes of surgical residents about the teaching tools and their perceived confidence in the knowledge gained after using the simulator. The surgical resident were divided into two groups; Group A (n=30) received traditional teaching materials and Group B (n=38) received a digital video discs of the Virtual Mentor programme which is an interactive cognitive simulation. Both groups took online pre-test and post-tests on knowledge acquisition and also answered satisfaction questionnaires in one hour for each tests.

They reported that there was no difference in the pre-test scores between the two groups (p= 0.62). However, group B (VR) scored significantly higher on the post-test (p= 0.01). Mean difference between pre-test and post-test scores were significantly better in the VR group than in the traditional learning group (p= 0.04) as shown as Table 4, 5 and 6.

Table 4: Mean overall pre- test scores by assignment and training level

Year 1, n (%)		Year 2, n (%)		Year 3, n (%)		Overall, n (%)	
Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
13 (64.1)	15 (68.8)	11 (75.1)	12 (71.1)	6 (84.4)	10 (77.3)	30 (72.3)	38 (72.2)
P = 0.47		P = 0.23		P = 0.24		P = 0.62	

Table 5: Mean overall post-test scores

Year 1, n (%)		Year 2, n (%)		Year 3, n (%)		Overall, n (%)	
Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
13 (68.7)	13 (76.9)	10 (75.3)	10 (85.3)	6 (83.3)	6 (87.8)	29 (74.0)	29 (82.1)
P = 0.12		P = 0.03		P = 0.46		P = 0.01	

Table 6: Mean difference on overall pre-test and post-test Scores: Total point

Group	n	Training Level (Year) 1	2	3	P-Value
A	29	0.69	0.10	−0.17	.04
B	28	1.62	2.0	1.17	

From the questionnaire, it reported that the VR program was "more fun" to use (24.1% versus 4.2%) and surgical residents were more likely to use this type of program again compared with the likelihood of using the traditional tools (58.6% versus 4.2%). Hence, the study demonstrated that VR was an effective supplement to traditional teaching in the overall groups besides was more enjoyable and more likely to be used repetitively by the surgical ophthalmology residents.[1, level II-2]

Daly MK et al. (2013) reported that satisfaction questionnaires were completed by the residents in both groups after they performed their CCC in the operating room. Both wet-lab and simulator trainees were likely to judge their preoperative training to be helpful. All trainees reported enjoying their preoperative training regardless of to which group they were randomised. Although the results were not statistically significant; p= 0.81, all residents in the wet-lab group reported some frustration with their preoperative training versus the simulator group, which reported less frustration.[10, level II-1]

Table 7: Resident satisfaction survey

Question	Score Type	Mean Score: Simulator	Mean Score: Wet Lab	P Value*	Relation to Surgical Performance†: F	P	η^2
How helpful did you find preop training?	5 = Extremely helpful, 1 = useless	4.4	4.5	.71	3.18	.05	0.36
How realistic did you feel training was?	5 = extremely realistic, 1 = hurtful	3.6	4.5	.97	1.96	.16	0.26
How helpful was the preop training experience for microscope?	5 = Extremely helpful, 1 = harmful	3.9	4.6	.06	0.85	.48	0.13
How helpful was preop training for instruments?	5 = Extremely helpful, 1 = harmful	3.5	5.0	.00	0.74	.54	0.12
What was your level of frustration with preop training?	5 = no frustration, 1 = extremely frustrated	3.1	2.9	.81	0.80	.51	0.12
Did you enjoy the preop training experience?	5 = very enjoyable, 1 = very negative	4.5	4.8	.31	4.18	.03	0.32
Did you find having an attending present helpful?	5 = Extremely helpful, 1 = harmful	4.6	5.0	.28	0.98	.40	0.10
How strongly would you recommend preop training to peers?	5 = Extremely recommended, 1 = avoid at all cost	4.5	4.9	.31	0.56	.58	0.06
What was your level of disappointment at being randomized?	5 = happy to be in group, 1 = extremely disappointed	4.0	4.7	.17	0.19	.90	0.03

*Exact significant, Mann-Whitney U test
†One-way analysis of variance against overall scores

5.2 SAFETY

Pokroy et al. (2013) accessed the impact of virtual reality (VR) surgical training to a well-structured surgical training programme at a single centre of Henry Ford Hospital. The study used the first 50 phacoemulsification cases from 20 residents' cataract surgery from the year 2007 until 2010. The residents were divided to a simulator group (n=11) and non-simulator group (n=10). Results showed that the difference in surgical time between the two groups was most significant for the number of cases longer than 40 min, which is a measure of overall surgical proficiency {62 cases (66%) versus 51 cases (52%)}; *p*= 0.07. Even though surgical time improvement for cases 10 through 50 was significantly better for the simulator group; the complication rate was not significantly different. The non-simulator group actually performed better when a comparison between the first cases where shorter operating times for first ten cases with statistically non-significant lower incidence of complications (median: 41 minutes versus 46.5 minutes).

However further along the learning curve, the simulator residents outperformed the non-simulator group with regard to the operating time, and showed a trend towards fewer posterior capsule ruptures or complications. The non-simulator and simulator groups each comprised 500 cases with 40 and 35 posterior capsule tears respectively. Capsular tear rates for the non-simulator and simulator groups were 8.8% and 10% respectively for cases 26 through 50. The percentage of long cases (defined as >40 min) for cases 10 through 50 was 42.3% and 32.4%; *p*= 0.005 for the non-simulator and simulator groups respectively.[12, level II-2]

With regards to safety, VR systems has been registered and received 510 (K) by United States Food and Drug Administration (US FDA).

5.3 COST/COST-EFFECTIVENESS

No articles retrieved about the cost-effectiveness of the VR training compared to traditional methods or wet-lab training or box-lab training or no training. Price per unit of the VR systems is between USD100, 000 and USD200, 000, depending on optional features and the date of purchase.

5.4 ORGANIZATIONAL ISSUES

5.4.1 Learning curve/training

Most of the studies reported that VR systems used for training of the ophthalmic surgery showed a learning curve in their initial training.[2, level II-3, 9, level II-1, 11, level I, 12, Level II-2] Studies demonstrated that initial learning curves for the different modules on VR simulator and rapid learning were common results seen among the trainees. Less instructor intervention may partly explain the shorter learning curve of the simulator group. It showed that shorter learning curve, improved eye-hand coordination, and improved techniques were agreed by most of the trainees.[11, level II-2]

5.5 LIMITATIONS

This technology review has several limitations. The selection of studies was done by one reviewer. Although there was no restriction in language during the search but only English full text articles were included in this report.

6. CONCLUSION

6.1 Effectiveness/Efficacy

There was fair to good level of retrievable evidence to suggest that the VR systems for ophthalmology training were able to improve surgeon operating performance and skills. Studies also reported that inexperienced residents or surgeons were more likely to benefit from the training curriculum using VR systems. The evidence related to trainees' satisfaction was inconclusive. One study reported that VR programme seemed to improve the surgeons satisfaction as the programme was reported as "more fun" to use (24.1% versus 4.2%) and they were more likely to use this type of programme again compared with the likelihood of using the traditional tools (58.6% versus 4.2%). However, another study reported no significant difference in satisfaction between residents trained by traditional wet-lab versus surgical simulation.

6.2 Safety

There was limited fair level of retrievable evidence to suggest that VR systems for training of ophthalmic surgery were safe with fewer complications such as posterior capsule tear or perforation.

6.3 Cost-effectiveness

There was no retrieval evidence on the cost-effectiveness of the VR systems for the training of ophthalmic surgery.

6.4 Organizational issues

6.1 Training and learning curve for trainee

There was fair to good level of retrievable evidence to suggest that VR systems were associated with learning curves.

8. REFERENCES

1. Henderson BA, Kim JY, Golnik KC et al. Evaluation of the virtual mentor cataract training program. Ophthalmology. 2010;117(2):253-8
2. Saleh GM, Theodoraki K, Gillan S et al. The development of a virtual reality training programme for ophthalmology: repeatability and reproducibility (part of the International Forum for Ophthalmic Simulation Studies). Eye (Lond). 2013; 27(11):1269-1274
3. Khalifa YM, Bogorad D, Gibson V, et al. Virtual reality in ophthalmology training. Surv Ophthalmol. 2006;51(3):259-273
4. Nagendran M, Gurusamy KS, Aggarwal R et al. Virtual reality training for surgical trainees in laparoscopic surgery. Cochrane Database Syst Rev. 2013 Aug 27;8:CD006575
5. Hassan I, Maschuw K, Rothmund M et al. Novices in surgery are the target group of a virtual reality training laboratory. Eur Surg Res. 2006;38(2):109-13
6. Nagendran M, Gurusamy KS, Aggarwal R et al. Virtual reality training for surgical trainees in laparoscopic surgery. Cochrane Database Syst Rev. 2013 Aug 27;8:CD006575
7. Selvander M, Asman P. Ready for OR or not? Human reader supplements Eyesi scoring in cataract surgical skills assessment. Clin Ophthalmol. 2013;7:1973-1977
8. Spiteri AV, Aggarwal R, Kersey TL, et al. Development of a virtual reality training curriculum for phacoemulsification surgery. Eye (Lond). 2014;28(1):78-84
9. Selvander M, Åsman P. Virtual reality cataract surgery training: learning curves and concurrent validity. Acta Ophthalmol. 2012;90(5):412-417
10. Daly MK, Gonzalez E, Siracuse-Lee D et al. 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(11):1734-1741
11. Sikder S, Tuwairqi K, Al-Kahtani E et al. Surgical simulators in cataract surgery training. Br J Ophthalmol. 2014;98(2):154-158
12. Pokroy R, Du E, Alzaga A et al. Impact of simulator training on resident cataract surgery. Graefes Arch Clin Exp Ophthalmol. 2013;251(3):777-781

9. APPENDIX

9.1. Appendix 1: LITERATURE SEARCH STRATEGY

Ovid MEDLINE® In-process & other Non-Indexed citations and Ovid MEDLINE® 1946 to present

Search Strategy: Re-run search 13032016
----
1 OPHTHALMOLOGIC SURGICAL PROCEDURES/ (10015)
2 (procedure* adj ophthalmologic* surgical).tw. (0)
3 (surgical procedure* adj ophthalmologic*).tw. (0)
4 (surger* adj1 (computer aided or computer-aided or image guided or image-guided or computer-assisted or computer assisted)).tw. (1645)
5 OPHTHALMOLOGY/ (20445)
6 ophthalmology.tw. (16295)
7 opthalmic surgery.mp. (12)
8 (chamber* adj1 anterior).tw. (14265)
9 ANTERIOR CHAMBER/ (8916)
10 10 LENS IMPLANTATION, INTRAOCULAR/ (0)
11 LENS IMPLANTATION, INTRAOCULAR/ (9168)
12 (intraocular lens adj1 implantation*).tw. (3432)
13 (intraocular adj1 len* implantation*).tw. (3444)
14 CATARACT EXTRACTION/ (22050)
15 (extraction* adj1 cataract).tw. (7045)
16 phakectom*.tw. (6)
17 (enzymatic adj1 zonulolys*).tw. (93)
18 CORNEA/ (41235)
19 cornea*.tw. (75822)
20 PHACOEMULSIFICATION/ (7947)
21 phacoemulsification*.tw. (6681)
22 CATARACT/ (25347)
23 (cataract* adj1 membranous).tw. (22)
24 pseudoaphakia*.tw. (7)
25 (len* adj1 opacit*).tw. (1914)
26 cataract*.tw. (45781)
27 USER-COMPUTER INTERFACE/ (30829)
28 (system* adj1 virtual).tw. (108)
29 (interface* adj1 (user-computer or user computer)).tw. (7)
30 COMPUTER SIMULATION/ (154778)
31 (computer* adj1 model*).tw. (8434)
32 Virtual reality.mp. (5542)
33 VIRTUAL REALITY EXPOSURE THERAPY/ (227)
34 (reality adj therap* virtual).tw. (0)
35 (virtual reality adj1 (therap* or immersion theraphy or exposure therapy)).tw. (56)
36 eye simulator.mp. (4)
37 eyesi.tw. (31)
38 eye surgery simulator.tw. (4)
39 virtual-reality simulation*.tw. (246)
40 capsulorhexis.tw. (1060)

41 VRMagic.tw. (11)
42 ophthalmic virtual reality surgical simulator.tw. (1)
43 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 (182960)
44 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 (188233)
45 43 and 44 (1879)
46 limit 45 to (english language and humans and last 15 years) **(351)**

OTHER DATABASES		
EBM Reviews - Cochrane Central Register of Controlled Trials		Same MeSH, keywords, limits used as per MEDLINE search
EBM Reviews - Database of Abstracts of Review of Effects		
EBM Reviews - Cochrane database of systematic reviews		
EBM Reviews - Health Technology Assessment		
NHS economic evaluation database		
Embase		

8.2. Appendix 2

HIERARCHY OF EVIDENCE FOR EFFECTIVENESS STUDIES
DESIGNATION OF LEVELS OF EVIDENCE

I	**Evidence obtained from at least one properly designed randomized controlled trial.**
II-1	Evidence obtained from well-designed controlled trials without randomization.
II-2	Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one centre or research group
II-3	Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence.
III	Opinions or respected authorities, based on clinical experience; descriptive studies and case reports; or reports of expert committees.

SOURCE: US/CANADIAN PREVENTIVE SERVICES TASK FORCE (Harris 2001)

Evidence Table : Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery
Question : Is Virtual reality systems is effective and safe for training of ophthalmic surgery?

<table>
<tr><th>Bibliographic citation</th><th>Study Type / Methods</th><th>LE</th><th>Number of patients & patient characteristics</th><th>Intervention</th><th>Comparator</th><th>Length of follow up</th><th>Outcome measures/ Effect size</th><th>GC</th></tr>
<tr>
<td>1. Saleh GM, Theodoraki K, Gillan S et al. The development of a virtual reality training programme for ophthalmology: repeatability and reproducibility (part of the International Forum for Ophthalmic Simulation Studies)

Eye (2013) 27, 1269–1274

24/7/2015</td>
<td>Cross sectional

Aim:
To evaluate the variability of performance among <u>novice ophthalmic trainees</u> in a range of repeated tasks using the virtual reality (VR) simulator (EYESI)

Methods:
At Moorfields Eye Hospital with SteLi (simulation and Technology-enhanced Learning Initiative) & IFOS (International Forum of Ophthalmology Simulation)
Used mannequin head with a Virtual eye an operating microscope and a touch screen and connected to a PC.

Statistical analysis
using non-parametric tests because of evidence of non-normality
The Kruskal–Wallis test used to assess whether the overall and the range of (highest–lowest) scores differed between individuals and/or between tasks.</td>
<td>II-3</td>
<td>N= 18

18 subjects took 3 attempts of 5 cataract specific and generic three-dimensional tasks:

Scores each attempts were out of a maximum of 100 points

Inclusion criteria:
All eligible novice ophthalmic trainees with 2 h/ less of simulation & intraocular surgical experience

Exclusion criteria:
Novice trainees who did not wish to participate in the study & those with > 2h of simulation & intraocular surgical experience

VR tasks:
5 selected,:
-1 cataract-specific task (capsulorhexis level 1)
-4 generic 3-D tasks (cracking & chopping level 2, cataract navigation level 3, cataract bimanual training level 1 & anti-tremor level</td>
<td>virtual reality (VR) simulator</td>
<td>nil</td>
<td></td>
<td><u>A: Surgeon skills</u>

--No significant differences in the scores were demonstrated between the juniors using different tasks (p= 0.1104).

Table 1 Scores across individuals (inter-novice performance)
<table>
<tr><th colspan="4">Scores in all tasks by trainee</th><th colspan="4">Difference between highest and lowest score in a single task</th></tr>
<tr><th>Trainee</th><th>Lower limit</th><th>Median</th><th>Upper limit</th><th>Trainee</th><th>Lower limit</th><th>Median</th><th>Upper limit</th></tr>
<tr><td>1</td><td>0</td><td>32</td><td>76</td><td>1</td><td>35</td><td>51</td><td>57</td></tr>
<tr><td>2</td><td>0</td><td>69</td><td>70</td><td>2</td><td>10</td><td>18</td><td>22</td></tr>
<tr><td>3</td><td>0</td><td>78</td><td>94</td><td>3</td><td>4</td><td>6</td><td>61</td></tr>
<tr><td>4</td><td>6</td><td>64</td><td>85</td><td>4</td><td>21</td><td>23</td><td>32</td></tr>
<tr><td>5</td><td>0</td><td>19.5</td><td>81</td><td>5</td><td>0</td><td>4</td><td>21.5</td></tr>
<tr><td>6</td><td>0</td><td>72</td><td>84</td><td>6</td><td>6</td><td>12</td><td>24</td></tr>
<tr><td>7</td><td>17</td><td>59</td><td>90</td><td>7</td><td>30</td><td>46</td><td>59</td></tr>
<tr><td>8</td><td>11</td><td>65</td><td>93</td><td>8</td><td>37</td><td>39</td><td>65</td></tr>
<tr><td>9</td><td>0</td><td>34</td><td>76</td><td>9</td><td>8</td><td>24</td><td>39</td></tr>
<tr><td>10</td><td>0</td><td>57</td><td>86</td><td>10</td><td>21</td><td>28</td><td>29</td></tr>
<tr><td>11</td><td>0</td><td>53.5</td><td>75</td><td>11</td><td>16</td><td>47.5</td><td>78</td></tr>
<tr><td>12</td><td>37</td><td>74</td><td>88</td><td>12</td><td>28</td><td>36</td><td>36</td></tr>
<tr><td>13</td><td>0</td><td>53</td><td>69</td><td>13</td><td>3</td><td>24</td><td>42</td></tr>
<tr><td>14</td><td>49</td><td>77</td><td>95</td><td>14</td><td>30</td><td>39</td><td>66</td></tr>
<tr><td>15</td><td>0</td><td>35</td><td>73</td><td>15</td><td>0</td><td>21</td><td>42</td></tr>
<tr><td>16</td><td>0</td><td>79</td><td>92</td><td>16</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>17</td><td>0</td><td>62</td><td>79</td><td></td><td></td><td></td><td></td></tr>
<tr><td>18</td><td>0</td><td>0</td><td>58</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">P-value</td><td colspan="2">0.1104</td><td colspan="2">P-value</td><td colspan="2">0.3878</td></tr>
</table>

Trainees' overall performance differed significantly between 1^{st} and 2^{nd} attempt (P< 0.0001) and

between the 1^{st} and 3^{rd} (P< 0.0001), but not between the 2^{nd} and 3rd attempt (P= 0.65)

Table 2: Scores across attempts (intra-</td>
<td></td>
</tr>
</table>

<table>
<tr><th>Bibliographic citation</th><th>Study Type / Methods</th><th>LE</th><th>Number of patients & patient characteristics</th><th>Intervention</th><th>Comparator</th><th>Length of follow up</th><th>Outcome measures/ Effect size</th><th>GC</th></tr>
<tr><td></td><td>P-value < 0.05 was considered significant</td><td></td><td></td><td></td><td></td><td></td><td>novice performance)
Table 2 Scores across attempts (intra-novice performance)
<table>
<tr><th colspan="4">2-Scores of all tasks by attempt</th></tr>
<tr><th>Attempt</th><th>Lower limit</th><th>Median</th><th>Upper limit</th></tr>
<tr><td>1st</td><td>0</td><td>36.5</td><td></td></tr>
<tr><td>2nd</td><td>0</td><td>68</td><td>83.5</td></tr>
<tr><td>3rd</td><td>13</td><td>69</td><td>83</td></tr>
<tr><td colspan="2">1st vs 2nd attempt</td><td colspan="2">P-value <0.0001</td></tr>
<tr><td colspan="2">1st vs 3rd attempt</td><td colspan="2">P-value <0.0001</td></tr>
<tr><td colspan="2">2nd vs 3rd attempt</td><td colspan="2">P-value 0.65</td></tr>
</table>
This indicates an initial poor reproducibility for the high-fidelity tasks by this group of novice trainees, while a certain level of consistency in scores is achieved between the 2nd and the 3rd attempt (p= 0.65).

<u>Table 3: summarises the trainees' scores for each task</u>

Table 3 Scores across tasks
<table>
<tr><th colspan="4">Overall performance by task</th><th colspan="4">Difference in highest and lowest score in a single task</th></tr>
<tr><th>Task</th><th>Lower limit</th><th>Median</th><th>Upper limit</th><th>Task</th><th>Lower limit</th><th>Median</th><th>Upper Limit</th></tr>
<tr><td>Capsulorhexis 1</td><td>0</td><td>0</td><td>45</td><td>Capsulorhexis 1</td><td>21</td><td>51</td><td>61.5</td></tr>
<tr><td>Cracking and Chopping 2</td><td>65</td><td>89.5</td><td>94</td><td>Cracking and chopping 2</td><td>7</td><td>23</td><td>38</td></tr>
<tr><td>Cataract navigation 3</td><td>42</td><td>73.5</td><td>78</td><td>Cataract navigation 3</td><td>23</td><td>40.5</td><td>47.5</td></tr>
<tr><td>Bimanual training 1</td><td>68.5</td><td>81</td><td>91</td><td>Bimanual training 1</td><td>6</td><td>19.5</td><td>28</td></tr>
<tr><td>Anti-tremor 2</td><td>0</td><td>0</td><td>0</td><td>Anti-tremor 2</td><td>0</td><td>1</td><td>34</td></tr>
<tr><td>P-value</td><td colspan="3">0.0001</td><td>P-value</td><td colspan="3">0.0030</td></tr>
</table>
Highly significant differences among the results achieved by module (p< 0.0001).

There was a significant difference between the highest and lowest score by task (p= 0.003). It showed that the performance varies significantly with the complexity</td><td></td></tr>
</table>

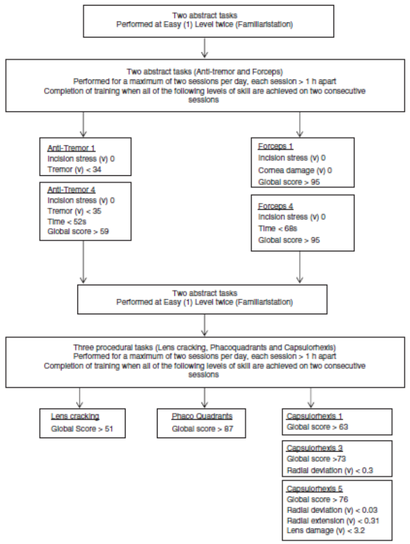
Bibliographic citation	Study Type / Methods	LE	Number of patients & patient characteristics	Intervention	Comparator	Length of follow up	Outcome measures/ Effect size	GC
							of the task (more challenging to perform a capsulorhexis). **Conclusion:** --Clear upward trend of performance with **repeated attempts** (as shown by the median scores achieved in each of the three repeats, Table 2). Even though there is poor reproducibility when comparing the 1st attempt with 2nd (P< 0.0001) and the 3rd (P< 0.0001), **novice trainees seem to achieve a certain level of competency and consistency on their scores between the 2nd and the 3rd attempt** (P= 0.65). **--**Simulator would be **more useful to monitor performance** (formative assessment) rather than to evaluate and quantify overall skills (summative assessment).	

Evidence Table : Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery
Question : Is Virtual reality systems is effective and safe for training of ophthalmic surgery?

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow-up	Outcome measures/ Effect size	GC
2. Spiteri AV, Aggarwal R, Kersey TL, Sira M, Benjamin L, Darzi AW, Bloom PA. **Development of a virtual reality training curriculum for phacoemulsification surgery.** Eye (Lond). 2014 Jan;28(1):78-84	**Cross sectional** **phacoemulsification surgery (PS)** **Aims:** to develop an evidence based and stepwise VR training curriculum for acquisition of technical skills for PS.	II-3	N= 30 Group I n= 10 (novice group) Group II n= 10 (intermediate) Group III n= 10 (experienced) All subjects completed 2 sessions on the 4 abstract skills, and 2 sessions on the 5 procedural tasks. Abstract skills: --Anti-tremor No statistically significant difference between the first and second repetition. The second session scores were used for analysis to further reduce the effect of participant familiarization with the simulator during the first session. Construct validity was initially established overall for the total global scores of the nine selected tasks (Figure 2).	VR	nil	-	**OUTCOME:** A. Abstract tasks: (anti-tremor and forceps) - a 'ceiling effect' with construct validity established between (novice) and (intermediate) and between (novice) and experienced (experience) groups, but not between (intermediate) and (experience) groups. II. Statistical significance was achieved primarily on global score — Anti-tremor 1 revealed a significant difference only in the first repetition and is excluded. Forceps 1 was significantly different between (novice) and (intermediate) and (experience) = 46, 87, and 95 respectively; P<0.001 between (n) and (i)). Increasing difficulty of task showed a significantly reduced performance in global score in (novice) but minimal difference between (intermediate) and (experience) Anti-tremor 1 and 4 showed similar results for average tremor value (47.1, 34.4, 34.3, and 45.6, 35.9, and 35.3; P< 0.017 between (novice) and (intermediate)). Incision stress value in both tasks at both	-

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow-up	Outcome measures/ Effect size	GC
							levels of difficulty also exhibited statistically significant differences between (novice) and (intermediate) but not between (intermediate) and (experience). Time Taken In Seconds showed significant differences between (novice) and (intermediate) only for the more difficult tasks Anti-tremor 4 and Forceps 4; but not the easier Anti-tremor 1 and Forceps 1. B. Procedural tasks (Lens cracking, Phaco of quadrants and Capsulorhexis) Procedural modules were found to be construct valid between groups (novice) and (intermediate) and between groups (intermediate) and (experience). e.g: i. Global score metrics in Lens cracking: (0, 22, and 51; Po0.017) ii. Phaco of quadrants: (16, 53, and 87; Po0.017). iii. Capsulorhexis 1, the global scores demonstrated a similar trend (0, 19, and 63; P< 0.017). As the difficulty of the task increased (capsulorhexis 3 and 5), the global score performance in the (novice) and (intermediate) group decreased but improved in the (experience): 0, 55, and 73; P< 0.017) and	

<table>
<tr><th>Bibliographic citation</th><th>Study Type / Methods</th><th>LE</th><th>Number of patients and patient characteristics</th><th>Intervention</th><th>Comparator</th><th>Length of follow-up</th><th>Outcome measures/
Effect size</th><th>GC</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>(0, 48, and 76; P< 0.017).

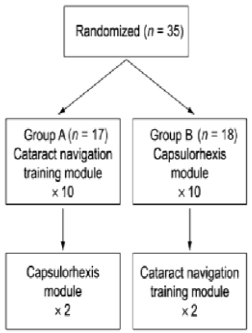


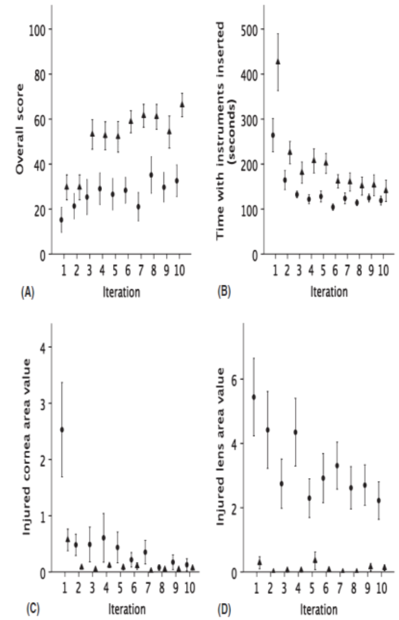
3 Evidence-based virtual reality training curriculum for PS (v) = value; (s) = seconds.

Conclusion:

- 1st evidence based training curriculum for novice phacoemulsification surgeons using the VR simulator, with benchmark levels set by intermediate and experienced surgeons
- No difference between the performance of intermediate and experienced groups on all the abstract tasks.

--Inexperienced subjects are thus most likely to benefit from this training curriculum.</td><td></td></tr>
</table>

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow-up	Outcome measures/ Effect size	GC
Evidence Table : Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery **Clinical Question : Is Virtual reality systems is effective and safe for training of ophthalmic surgery?**								
Bibliographic citation	**Study Type / Methods**	**LE**	**Number of patients and patient characteristics**	**Intervention**	**Comparator**	**Length of follow up**	**Outcome measures/ Effect size**	**GC**
3. Selvander M, Åsman P. **Virtual reality cataract surgery training: learning curves and concurrent validity**. Acta Ophthalmol. 2012 Aug;90(5):412-7	**RCT** **Aims;** The aim of this study was to examine learning curves on the EYESi simulator anterior segment modules and whether achieved skills are transferable between tasks.  All of them **underwent simulator training.** They **received standard oral instructions** by one test leader who also supervised	II-1	**N= 35 medical students** attending the ophthalmology rotation Group 1: n=17 cataract navigation training module X10 Group B: n= 18 Capsulorhexis module X10	VR Cataract navigation training module	VR Capsulorhexis training module	3 months	Both group A (Cataract navigation training module) and group B (Capsulorhexis module) demonstrated significant improvements in performance over the ten iterations Improvement for capsulorhexis overall score was not significant ; p = 0.752	no itt small sample size

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow-up	Outcome measures/ Effect size	GC
	all tasks. **Shown a short instructional film incorporated in the simulator system, before performing each task on the simulator**. The simulator comes with several different modules for cataract surgery, including both cataract-specific tasks such as capsulorhexis and phacoemulsification, as well as manipulation exercises.						 **Fig. 3.** Initial learning curves for Capsulorhexis module (*circles*) and Cataract navigation training module (*triangles*). (A) Improvement over the ten iterations for capsulorhexis overall score was not significant $p = 0.752$ but score at the 10th iteration was significantly higher than at the 1st iteration ($p = 0.047$). For Cataract navigation, training improvement over the 10 iterations was significant $p = 0.004$ reaching a plateau at third iteration. (B) Time with instruments inserted decreased significantly for both modules $p < 0.0001$, plateau reached at third iteration. (C) Injured cornea area value decreased for Capsulorhexis module $p < 0.0001$ reaching a plateau at sixth iteration and for Cataract navigation training ($p = 0.0003$) reaching a plateau at seventh iteration. (D) Injured lens area value for capsulorhexis did not decrease significantly over the 10 iterations ($p = 0.336$) but was significantly lower at the 10th iteration when compared with the 1st $p = 0.022$. Injured lens area value for cataract navigation decreased significantly $p = 0.0033$ but did not reach a plateau.	

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow-up	Outcome measures/ Effect size	GC
							No significant improvement was observed for the specific capsulorhexis parameters centring and roundness ($p = 0.091$ and $p = 0.873$). The simulator overall score on the Capsulorhexis module had a significant positive correlation with the modified OSATS score **(r2 = 0.59, p < 0.0001) and with the OSACSS score (r2 = 0.704, p < 0.0001).** **Conclusions:** ■ On both our studied modules, the students learned how to more efficiently and cautiously handle instrument inside the model eye. By training with the simulator, trainees quickly learned how to more efficiently and cautiously handle instruments inside the model eye. Therefore, the **simulator has the potential to be part of the initial training of new cataract surgeons**. ■ The **capsulorhexis procedure** is considered to be one of the most difficult steps in a cataract operation, the trainees reached a plateau regarding time but not regarding overall score. ■ The overall score parameter includes quality parameters of the final rhexis and is a better representative of capsulorhexis skill acquisition than time.	

Evidence Table : **Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery**
Question : **Is Virtual reality systems is effective and safe for training of ophthalmic surgery?**

Bibliographic citation	**Study Type / Methods**	**LE**	**Number of patients and patient characteristics**	**Intervention**	**Comparator**	**Length of follow up**	**Outcome measures/ Effect size**	**GC**
4. Sikder S, Tuwairqi K, Al-Kahtani E, Myers WG, Banerjee P. **Surgical simulators in cataract surgery training.** Br J Ophthalmol. 2014 Feb;98(2):154-8	**Systematic Review** PubMed search **Total articles = 38** and a total of 10 articles were reviewed. **keywords:** Search was conducted using the following keywords: **virtual simulator, virtual reality, cataract, phacoemulsification, education, training, and assessment.**	I	3 cataract surgery simulators have been studied: *1. Eyesi (VR Magic)* *2. PhacoVision (Melerit Medical)* *3. Microvis Touch (Immersive Touch)* At this time, *Eyesi* simulator is the only device that have been validated in peer reviewed publications and is available in the market for cataract and vitreoretinal surgery training where Microvis Touch and Phaco Vision are limited. **Inclusion criteria:** Only papers that provided adequate results to prove the validity of the simulator and the effect of the simulator on training and education were included.				<u>**Construct And Concurrent Validity Studies**</u> 5 studies focused on proving that the simulator Objectively differentiated between experienced and novice surgeons in terms of surgical proficiency. **a. Banerjee** et al investigated the concurrent validity of capsulorhexis performance metrics (duration, number of capsular grabs per completed capsulorhexis, and circularity of the capsulorhexis) between the MicrovisTouch simulator (ImmersiveTouch) and live surgeries. The study did not provide a statistically significant result to correlate between the simulator and live surgeries in the duration and number of capsular grabs metric during capsulorhexis. It showed a significant concurrent validity of the circularity of the capsulorhexis metric ($p<0.05$). Capsulorhexis: **b. Privett et al** evaluated the construct validity of capsulorhexis training modules of the simulator EYESi. 23 participants were divided into 2 groups: 16 medical students and residents; 7 experienced surgeons. The experienced surgeons showed statistically significant better scores on both	-

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow up	Outcome measures/ Effect size	GC
							the easy and medium levels of the module. The study demonstrated significant construct validity for the capsulorhexis module. **c. Selvander and Asman** evaluated construct validity of the capsulorhexis, hydro-manoeuvres, phacoemulsification, navigation, forceps, cracking and chopping training modules of the EYESi simulator. 24 participants were divided into 2 groups: 17 medical students and residents; 7 experienced surgeons. 3 trials were performed by each participant, with a video recording of the second trial evaluated for capsulorhexis, hydro-manoeuvres, and phacoemulsification modules by the modified Objective Structured Assessment of Surgical Skills (OSATS) and OSA of Cataract Surgical Skill (OSACSS) tools. The experienced surgeons showed a statistically significant better score on the simulator for the capsulorhexis, navigation and forceps modules, with less obvious score differences noted in the phacoemulsification, cracking and chopping modules. No difference in overall score on the simulator was found on hydro-manoeuvres. However, by using alternative tools for assessment, OSATS and OSACSS, significant difference between the two groups in the capsulorhexis, hydro-manoeuvres and phacoemulsification was demonstrated.	

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow up	Outcome measures/ Effect size	GC
							The study showed significant construct validity for the previously mentioned modules with the hydro-manoeuvres requiring the video evaluation tool. **<u>Training curriculum and surgical outcomes studies</u>** 6 studies were performed using the EYESi simulator to examine the outcomes of implementing the simulator in ophthalmology training programmes and its effect on the acquisition of the skill. i. **Selvander and Asman** studied the learning curve of the capsulorhexis and cataract navigation modules of the EYESi surgical simulator. The study showed a significant improvement ($p<0.05$) and plateau for the cataract navigation training module (plateau at third iteration), time with instrument insertion (plateau at third iteration for both modules), and injured cornea area (plateau at sixth iteration on capsulorhexis and seventh iteration for the cataract navigation training module). ii. **Feudner et al** demonstrated that the use of the EYESi virtual simulator helped improve the capsulorhexis wet-lab score in a study of 63 participants (31 medical students and 32 residents) Inter-rater reliability assessment was determined by correlating the assessment of randomly selected videos with the assessment of the observers.	

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow up	Outcome measures/ Effect size	GC
							iii. **Belyea et al** retrospectively compared the performance of the non-simulator experienced residents trained by a single attending ophthalmologist with a newer group of residents who had been trained by the same attending ophthalmologist with the EYESi simulator. The study also showed that the simulator group had a **significantly lower rate of complications** in the cases performed during the second half of the year compared to those performed in the first half of the year. iv. Pokroy et al also investigated retrospectively the incidence of posterior capsule rupture and operation time for the first 50 phacoemulsification procedures of the non-simulator trainees (before 2007–2008) and simulator trainees (after 2009–2010). The Simulator group showed a **significantly shorter median operating time in cases** 11–50 (34 min for the simulator group vs 38 min in the non-simulator group). v. **Baxter et al** evaluated the outcomes of implementing a 2 year intensive cataract surgery training programme on a total of 3 residents. The study showed that the average complication rate for cataract surgery in the first 6 months of the training (after about 150 cases for each trainee) was 1%, and after 1 year (>250 cases) the average was 0.66%, significantly lower than the complication rates previously published in the literature	

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparator	Length of follow up	Outcome measures/ Effect size	GC
							(3.77–7.17%; $p<0.05$). vi. **Saleh et al** conducted a study that aimed to investigate the efficiency of implementing a training programme that had been established by the International Forum of Ophthalmic Simulation (IFOS) using the EYESi simulator. The comparison between the entry and exit scores showed a significant improvement of the median scores for all tasks in addition to the overall score ($p<0.05$). **Discussion:** Improving the scoring system of the non-validated modules, incorporation of the tactile (haptic) feedback in the tactile-deficient simulator, and adding suturing of the incision may prove to be helpful additions in surgical simulation technology. **Conclusion:** **Virtual simulator use is a safe and effective tool in measuring the performance of trainees and differentiating their skill level.** Additionally, it is useful in improving the learning of techniques by trainees and will ultimately lead to better patient outcomes in cataract surgery.	

Evidence Table : **Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery**
Question : **Is Virtual reality systems is effective and safe for training of ophthalmic surgery?**

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC
5. Henderson BA, Kim JY, Golnik KC, Oetting TA, Lee AG, Volpe NJ, Aaron M, Uhler TA, Arnold A, Dunn JP, Prajna NV, Lane AM, Loewenstein JI. **Evaluation of the virtual mentor cataract training program.** Ophthalmology. 2010 Feb;117(2):253-8	Pre- and post- test intervention study **Obj:** i. to **evaluate the effectiveness** of an interactive cognitive computer simulation for teaching the hydro-dissection portion of cataract surgery compared with standard teaching ii. **to assess the attitudes of Residents about the teaching tools and their perceived confidence** in the knowledge gained after using the tools. **Study at:** 7 academic departments of ophthalmology **Method:** 2 groups: **Group A (n=30) as control** and received traditional teaching materials; **Group B (n=38) received a digital video disc of the Virtual Mentor program;**	**II-2**	2 groups: Group A (n=30) - control and received traditional teaching materials; Group B (n=38) received a digital video disc of the Virtual Mentor program; interactive cognitive simulation, Both groups took online anonymous pre-tests (n = 68) and post-tests (n = 58), and answered satisfaction questionnaires (n = 53). Wilcoxon tests were completed to compare pretest and posttest scores between groups. Analysis **of variance** **Part I:** Each resident completed a closed-book, multiple choice pretest. **Part II:** After post-test, they were asked to complete a subjective questionnaires using a modified 5-points Likert scale, designed to access their attitude about the teaching tool that they had used and their	VR	-		**Main Outcome Measures:** ▪ Scores on pre-tests, post-tests, and satisfaction questionnaires. **<u>Surgeon satisfactions:</u>** Results: ▪ There was no difference in the pre-test scores between the 2 groups (*p*= 0.62). However, group B ((VR) scored significantly higher on the post-test (*p* = 0.01). Mean difference between pre-test and post-test scores were significantly better in the VM group than in the traditional learning group (*p*= 0.04). ▪ Questionnaire revealed that the VM program was “more fun” to use (24.1% vs 4.2%) and residents were more likely to use this type of program again compared with the likelihood of using the traditional tools 58.6% vs 4.2%). ▪ The mean difference in pre-test and post-test scores was significantly better in the VR groups; **(mean increase: 1.64 points)** than the tradisional learning group **(mean increase: 0.31points)**	-

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC
	interactive cognitive simulation, Both group obviously participated in the standard education in cataract surgery provided by their residency programme. Both groups took online anonymous pre-tests (n=68) and post-tests (n= 58), answered questionnaires (n=53). Wilcoxon tests were completed to compare pretest and posttest scores between groups. Analysis of variance was performed to assess differences in mean scores between groups.		confidence in their knowledge .				(Tables 4, 1, 2 and 3 below) **Conclusion:**	

Table 4. Questionnaire Results: Percent with Highest Rating

Question	Group A (n = 24)	Group B (n = 29)
Understanding of cataract surgery before training	16.7%	10.3%
Understanding of cataract surgery after training	12.5%	17.2%
Understanding of hydrodissection before training	20.8%	17.2%
Understanding of hydrodissection after training	12.5%	20.7%
Material easy to use	33.3%	27.6%
Material fun to use	4.2%	24.1%
Would like to use materials again	4.2%	58.6%

Year 1, n (%)		Year 2, n (%)		Year 3, n (%)		Overall, n (%)	
Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
13 (64.1)	15 (68.8)	11 (75.1)	12 (71.1)	6 (84.4)	10 (77.3)	30 (72.3)	28 (72.2)
P = 0.47		P = 0.23		P = 0.24		P = 0.62	

Table 2. Mean Overall Posttest Scores

Year 1, n (%)		Year 2, n (%)		Year 3, n (%)		Overall, n (%)	
Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
13 (68.7)	13 (76.9)	10 (75.3)	10 (85.3)	6 (83.3)	6 (87.8)	29 (74.0)	29 (82.1)
P = 0.12		P = 0.03		P = 0.46		P = 0.01	

Table 3. Mean Difference in Overall Pretest and Posttest Scores: Total Points

		Training Level (Year)			
Group	n	*1*	*2*	*3*	P-Value
A	29	0.69	0.10	−0.17	.04
B	28	1.62	2.0	1.17	

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC
							1. The study demonstrated that the Virtual Mentor (Fig 2) was an **effective supplement to traditional teaching** in the overall group of residents from 7 training programs. 2. --The VM, a cognitive computer simulation, augmented teaching of the hydro-dissection step of phaco-emulsification surgery compared with traditional teaching alone. --The program was more enjoyable and more likely to be used repetitively by ophthalmology residents.	

Evidence Table : **Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery**
Question : **Is Virtual reality systems is effective and safe for training of ophthalmic surgery?**

<table>
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<tr>
<td>6. Pokroy R, Du E, Alzaga A et al.

Impact of simulator training on resident cataract surgery.

Graefes Arch Clin Exp

Ophthalmol. 2013 Mar;251(3):777-81</td>
<td>Retrospective study

Method:

Single centre (Henry Ford Hospital) the first 50 phacoemulsification cases from 20 residents (year 2007 until 2010)

Exclusion criteria:

i. cataract cases using other procedures or

ii. other procedures combined with others

iii. the resident was not the primary surgeon

Objective:

- This study aims to determine whether virtual surgery simulator training improves actual resident cataract surgery performance.

- to access the impact virtual reality surgical training (Eyesi) to a well-structured surgical training</td>
<td>II-2</td>
<td>Characteristics:

2 groups

a. Non-simulator group (n=10) trained without access to virtual reality simulation

b. Simulator group (n=10) trained with Eyesi, spends at least 6 h training within the first 18 months of residency</td>
<td>trained with VR /EYESI</td>
<td>not trained with VR</td>
<td></td>
<td>Outcomes measures:

1. Incidence of posterior capsule tear with/without vitreous loss

2. operating time

Results:

Table 1 . Main outcomes for 2 groups

Table 1 Outcome measures of nonsimulator and simulator groups
<table>
<tr><th></th><th>Nonsimulator group</th><th>Simulator group</th><th>P value</th></tr>
<tr><td>No. of phacoemulsification cases</td><td>500</td><td>500</td><td></td></tr>
<tr><td>No. of residents</td><td>10</td><td>10</td><td></td></tr>
<tr><td>Male/female</td><td>4/6</td><td>5/5</td><td></td></tr>
<tr><td>Mean±SD operating time, min</td><td>41.8+15.8</td><td>40.6+16.5</td><td>.24</td></tr>
<tr><td>Median operating time, min (range)</td><td>38.0 (13–109)</td><td>37.0 (13–107)</td><td></td></tr>
<tr><td>No. of posterior capsule ruptures (%)</td><td></td><td></td><td></td></tr>
<tr><td>Resident cases 1–50</td><td>40 (8.0)</td><td>35 (7.0)</td><td>.63</td></tr>
<tr><td>Resident cases 1–25</td><td>22 (8.8)</td><td>26 (10.4)</td><td>.65</td></tr>
<tr><td>Resident cases 26–50</td><td>18 (7.2)</td><td>9 (3.6)</td><td>.11</td></tr>
<tr><td>No. of anterior vitrectomies (%)</td><td>30 (6.0)</td><td>29 (5.8)</td><td>1.0</td></tr>
</table>

Table 2. Compares surgical time</td>
<td></td>
</tr>
</table>

<table>
<tr><th>Bibliographic citation</th><th>Study
Type / Methods</th><th>LE</th><th>Number of patients and
patient characteristics</th><th>Intervention</th><th>Comparison</th><th>Length of follow up</th><th>Outcome measures/
Effect size</th><th>GC</th></tr>
<tr><td></td><td>program.

Method:

First 50 phaco emulsification cases of 20 residents, at a single residency program (Henry Ford Hospital), were retrospectively compared as two groups: before (2007–8) and after (2009–10) introduction of the Eyesi virtual surgery simulator to the surgical training program.</td><td></td><td></td><td></td><td></td><td></td><td>Table 2 Cataract surgery time comparison
<table>
<tr><th>Surgical cases</th><th colspan="2">Nonsimulator group (n=498)</th><th colspan="2">Simulator group (n=492)</th><th>P value*</th></tr>
<tr><th></th><th>Median (min)</th><th>No. of cases >40 min n (%)</th><th>Median (min)</th><th>No. of cases >40 min n (%)</th><th></th></tr>
<tr><td>First 50</td><td>38.0</td><td>220 (44.2)</td><td>37.0</td><td>191 (38.8)</td><td>.1</td></tr>
<tr><td>11 to 50</td><td>38.0</td><td>196 (42.3)</td><td>34.0</td><td>129 (32.4)</td><td>.005</td></tr>
<tr><td>21 to 50</td><td>36.5</td><td>112 (37.3)</td><td>33.0</td><td>83 (27.9)</td><td>.017</td></tr>
<tr><td>31 to 50</td><td>36.0</td><td>64 (32.0)</td><td>31.0</td><td>43 (21.7)</td><td>.028</td></tr>
<tr><td>41 to 50</td><td>35.0</td><td>25 (25.0)</td><td>29.5</td><td>17 (17.3)</td><td>.253</td></tr>
<tr><td>First 10</td><td>41.0</td><td>51 (52.0)</td><td>46.5</td><td>62 (66.0)</td><td>.07</td></tr>
<tr><td>11 to 20</td><td>43.0</td><td>57 (57.0)</td><td>39.0</td><td>46 (46.0)</td><td>.157</td></tr>
<tr><td>21 to 30</td><td>40.0</td><td>48 (48.0)</td><td>37.0</td><td>40 (40.0)</td><td>.319</td></tr>
<tr><td>31 to 40</td><td>36.0</td><td>39 (39.0)</td><td>32.5</td><td>26 (26.0)</td><td>.07</td></tr>
<tr><td>41 to 50</td><td>35.0</td><td>25 (25.0)</td><td>29.5</td><td>17 (17.3)</td><td>.253</td></tr>
<tr><td>First 25</td><td>42.0</td><td>137 (55.2)</td><td>42.0</td><td>131 (53.7)</td><td>.8</td></tr>
<tr><td>26 to 50</td><td>36.0</td><td>83 (33.2)</td><td>31.5</td><td>60 (24.2)</td><td>.034</td></tr>
</table>
* Comparison of number of cases >40 min, two-tailed chi-squared

Results:

For main outcomes, no significantly differences, however when stratified longitudinal noted that a lower trend complications in the simulator group.

1. Capsular tear rates for the non-simulator vs simulator groups
■ the first 25 cases: 8.8 % vs 10 %
and
■ cases 26 through 50: 7.2 % and 3.6 %
(P= 0.11) respectively

2. Operating/surgical time:
There were differences between the 2 groups.
Beyond the 1st 10 cases, the simulator group had shorter surgical times than non-simulator group.</td><td></td></tr>
</table>

Bibliographic citation	Study Type / Methods	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC

Table 3 Supervising surgeons' opinions regarding improved resident surgical performance

Supervising surgeon	Improved hand–eye coordination	Improved learning curve	Quicker surgery	Less attending intervention	Less complications	Improved capsulorrhexis	Improved phaco
A	4	4	4	5	4	4	4
B	5	5	5	5	4	5	4
C	4	4	3	4	3	4	3
D	4	5	3	5	3	5	4
E	5	4	3	5	3	5	4
Mean	4.4	4.4	3.6	4.8	3.4	4.6	3.8
Median	4	4	3	5	3	5	4

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

Conclusion:

- Simulation training decreased the need for instructor intervention during resident phacoemulsification and improved capsulorhexis performance. The addition of a modern VR surgery stimulator alongside an organised surgery training program appears to **slightly improve resident real surgery performance,** with less adept resident benefitting most.
- Adding module that stimulates intraoperative complications may **further improve the simulator's impact as a surgery training tool.**
- The simulator is useful to practice the surgical techniques and cognitively concentrate on the weak points of the past surgical cases.

Evidence Table : Effectiveness/Efficiency (TR: Virtual Reality (VR) systems for the training of ophthalmic surgery
Clinical question : Is Virtual reality systems is effective and safe for training of ophthalmic surgery?

Bibliographic citation	Study Type / Methods	LE	Number of patients & patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC
7. Daly MK, Gonzalez E, Siracuse-Lee D, et al. **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 Nov;39(11):1734-41	**RCT** **Aims:** to compare rhe operating room performance of ophthalmology residents trained by tradisional wet-lab versus surgical simulation on the continuous curvilinear capsulorhexis (CCC) portion of cataract surgery **Methods:** Residents who chose to participate and provided informed consent **were randomized** to preoperative CCC training in the wet lab or on a simulator	II-1	2 group: Simulator (n= 11) wet lab (n=10) Patients: Second-year ophthalmology residents from Boston University and the Massachusetts. **wet lab group:** performed continuous curvilinear capsulorhexis (CCC) in silicone eyes. **Simulator group:** Completed 4 capsulorhexis training modules of increasing difficulty. They could not proceed to the next module until they passed the previous module. Residents filled out a **questionnaire regarding their satisfaction** with preoperative wet-lab versus simulator training. Each video of operating room performance was reviewed and graded by the **same 2 attending surgeons.** **The mean score** between the 2 attending physyicians was used as the individual	simulator VR	wet lab	-	Results: **1. Operating Room Performance** -The correlation between the scores of both attending surgeons who reviewed the videos was high **(r^2 = 0.826).** **-No significant difference in overall score** between the wet-lab group and the simulator group (P= 0.608). -Group wet lab took less time to complete the CCC in the operating room than group simulator **(P= 0.038). (→ operating time)** -Residents who took more time to pass the simulator course also had a significantly lower overall performance score on their first human case (**P= 0.034; r^2 = 0.410)**	small sample size n=21

<table>
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<tr><td></td><td></td><td></td><td>performance score for each of the 12 performance criteria. The overall score was calculated as the sum of these 12 individual performance scores (standardized).</td><td></td><td></td><td></td><td>
<table>
<tr><th colspan="5">Table 1. Operating room performance scores.</th></tr>
<tr><th></th><th></th><th colspan="2">Mean Score</th><th></th></tr>
<tr><th>Question</th><th>Score Type</th><th>Simulator</th><th>Wet Lab</th><th>P Value</th></tr>
<tr><td>1. Time to complete CCC</td><td>Continuous, in minutes</td><td>9.48</td><td>4.70</td><td>.038[†]</td></tr>
<tr><td>2. Attending help</td><td>0 = yes, 1 = no</td><td>55%*</td><td>20%*</td><td>.183[‡]</td></tr>
<tr><td>3. Economy of movement</td><td>3 = clear economy, 1 = unnecessary movements</td><td>1.55</td><td>1.75</td><td>.512[§]</td></tr>
<tr><td>4. Confidence of movement</td><td>3 = fluent, 1 = awkwardness</td><td>1.55</td><td>1.75</td><td>.557[§]</td></tr>
<tr><td>5. Errors</td><td>3 = fewest, 1 = frequent</td><td>2.00</td><td>2.10</td><td>.705[§]</td></tr>
<tr><td>6. Total entries into chamber</td><td>7 = fewest entries, 1 = highest entries</td><td>3.55</td><td>4.50</td><td>.512[§]</td></tr>
<tr><td>7. Incisional stress</td><td>4 = no stress, 1 = severe stress</td><td>2.64</td><td>2.40</td><td>.918[§]</td></tr>
<tr><td>8. CCC size</td><td>3 = excellent, 1 = causes difficulties</td><td>2.18</td><td>2.35</td><td>.251[§]</td></tr>
<tr><td>9. Continuity of CCC</td><td>2 = continuous, 1 = not continuous</td><td>1.82</td><td>1.80</td><td>.809[§]</td></tr>
<tr><td>10. Shape</td><td>3 = very round, 1 = irregular</td><td>2.23</td><td>2.30</td><td>.557[§]</td></tr>
<tr><td>11. Centering</td><td>3 = excellent, 1 = poorly centered</td><td>2.50</td><td>2.50</td><td>.314[§]</td></tr>
<tr><td>12. Movement of microscope</td><td>3 = clear economy, 1 = unnecessary movements</td><td>2.18</td><td>2.05</td><td>.973[§]</td></tr>
<tr><td>Overall score</td><td>Sum of scores 1-12 above[¶] (standardized z scores)</td><td>−1.046</td><td>1.152</td><td>.608</td></tr>
<tr><td colspan="5">CCC = capsulorhexis
*Percentage who needed help
[†]Student t test, independent samples, 2 tailed
[‡]Fisher exact test
[§]Exact significant, Mann-Whitney U test
[¶]For determination of overall score, time was assessed using a predefined scoring system of 7 points, where time was binned into 1.5-minute intervals (eg, 0-1.5 minutes = 7; 1.5-3 minutes = 6) up to >9 minutes, which was given a score of 1. Time, otherwise, was assessed as a continuous measure.</td></tr>
</table>

2. Surgeon satisfaction
-Both groups (simulator and wet lab) said their training was equally realistic
= (mean score in both groups 3.6)
- Although the results were not statistically significant (P= 0.81), all residents in the wet-lab group reported some frustration with their preoperative training versus the simulator group, which reported less frustration.

<u>Conclusion:</u>
This study suggests that surgical-simulator training, when compared with traditional wet-lab training, is a safe non-risk method of preparing trainees to perform CCC during their</td><td></td></tr>
</table>

Bibliographic citation	Study Type / Methods	LE	Number of patients & patient characteristics	Intervention	Comparison	Length of follow up	Outcome measures/ Effect size	GC
							initial surgical experiences on real patients in the operating room at our institution.	