Evaluation of 3D Heads up ophthalmic surgery from the perspective of surgeons and postgraduate trainees

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Research article

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Abstract

Background The purpose of this study is to evaluate the satisfaction of surgeons and postgraduate trainees on 3D heads up ophthalmic surgery compared to traditional microscopic surgery in terms of working and educational aspect.

Methods This was a validated questionnaire-based study. This study was conducted at a tertiary referral and postgraduate teaching hospital in Kuala Lumpur, Malaysia over a one-month period during which the Ngenuity viewing system was demonstrated in the Ophthalmology operating theatre. All surgeons and trainees exposed to the viewing system were recruited for the study which involved answering an online questionnaire comprising the components of visualization, physical, ease of use, teaching and learning components and a question on satisfaction. This questionnaire is designed to evaluate the perception of the students and surgeons regarding learning-teaching methodology and benefits gained by them comparing between 3D heads up system and traditional microscopic surgery.

Results All seven surgeons and 33 postgraduate students responded to the survey. A total of 32 cases were operated with the 3D system, which consisted of phacoemulsification, pterygium surgery, glaucoma procedures, cornea and vitreoretinal operations. There was no significant difference reported by the surgeons in all specific components ($p>0.05$, paired t-test). Postgraduate trainees reported better experience with 3D heads up surgery compared to traditional microscopic operation in terms of the illumination ($p=0.008$) and manoeuvrability ($p=0.01$), physical factors such as glare ($p=0.037$), eye strain ($p=0.008$), neck and upper back pain ($p=0.000$), lower back pain ($p=0.019$) and for all subcomponents of teaching and learning. Both surgeons and postgraduate trainees were more satisfied with 3D heads up system in general than traditional microscopic surgery ($p=0.047$ and $p=0.009$ respectively).

Conclusions 3D heads up surgery and viewing is preferred to traditional microscopic surgery viewing particularly by postgraduate trainees. The overall satisfaction with this viewing system is also higher among surgeons and trainees than traditional microscope viewing.

Trial Registration: Reference number: UKM PPI/111/8/JEP-2019-724 (UKM Research Ethics Committee)
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Background

The eye is a complex 3 Dimension (3D) structure in which its anatomy is difficult to be appreciated in regular 2 Dimension (2D) settings, especially for learning purposes. Optical microscopes have entered new innovations in the 1990s, and modern microscopes tend to come with an attached computer [1, 2, 3]. Moreover, digital entertainment has implemented 3D technology to augment virtual reality for the last ten years. This advancement enables 3D head up surgery to be conducted in current settings.

With traditional operating microscopes, the surgeons need to perform ophthalmic surgery while looking through the binoculars and 2D images will be displayed in another monitor for the observers to learn [4,

5]. In a 3D visualization system, the observers will be able to watch 3D images with the same resolution as seen live by the surgeon using 3D glasses [4]. The surgeon is also able to position their head in the up position, also known as “heads up” surgery rather than gazing down the oculars of the microscope. Bhayani et al. demonstrated positive responses to 3D surgery used in urology and gastrointestinal surgical procedures [6].

Regarding new ophthalmic technology, work done by Mario et al. illustrated that 3D surgery has been implemented in vitreoretinal operations such as rhegmatogenous retinal detachment (RRD), tractional retinal detachment (TRD), full-thickness macular hole (FTMH), epiretinal membrane (ERM), vitreous haemorrhage and dropped nucleus [4]. Despite an excellent response to heads up 3D surgery in term of ease of use, the teaching aspect of its utilization has not been adequately explored. It was reported that 3D videos play an essential role for the observers to achieve better understanding and knowledge as visualization and surgical depth perception are the critical steps to learn different surgical skills and procedures [7].

The 3D heads up display system has been used in anterior and posterior ophthalmic surgeries as described by Martinez et al. [8] The new technology is found to be useful in anterior segment surgeries following the introduction of True Vision 3D surgical system (Alcon Laboratories, Texas, United State America USA) [9]. Its first use in cataract surgery was reported by Weinstock in 2008, while Riemann stated that 3D system was introduced in vitrectomy world starting from 2010. 3D heads up surgery not only display a better image with manipulation of colour and brightness of images, but it also enables access to multiple images at the same time such as images of the optical coherence tomography (OCT) and endoscopic view [10]. 3D visualization in OCT and its implementation in vitreoretinal surgeries resulted in higher success rate [11, 12, 13].

In traditional ophthalmic surgery, some data such as corneal topography, keratometry and lens implantation information are separately in a disintegrated manner. Additionally, axis markings for astigmatism correction procedures such as limbal relaxing incision, astigmatic keratectomy or toric lens implantation are done manually. However, the innovation of the True Vision 3D system enables the digital overlay of data and markings on the surgeon’s view during procedures [14].

In a retrospective surgical case series involving 113 of vitrectomies and 90 phacoemulsifications revealed that none of these cases converted from the 3D surgery to the traditional ophthalmic surgery [10]. Additionally, the 3D system was reported to provide better visualization and help to reduce the risk of reoperations [15, 16, 17, 18]. There were no complications shown attributable to the 3D heads up method in the anterior and posterior segment procedure [19, 20].

It is vital to highlight that traditional microsurgery may cause work-related injuries to the surgeons contributed by failure to remain ergonomic while performing the surgeries. Chronic poor postures and musculoskeletal fatigue can increase the rate of disability, physical and mental distress in microsurgeons [21, 22, 23, 24]. This condition is more notable among vitreoretinal surgeons who perform longer than routine cataract surgeries which are often more than one hour in duration. In 3D microsurgery, the

surgeons can choose a more ergonomic position while operating and looking at a monitor. The 3D surgery also may help the surgical assistant to be more comfortable and efficient in passing the instruments and anticipate the surgeons' needs. The heads-up surgery is shown to be more ergonomic and offers a better educational environment for most if not all members of the team who are simultaneously able to perceive what the surgeon can see [25, 26, 27].

Methods

This validated questionnaire-based study was carried out at Universiti Kebangsaan Malaysia Medical Centre (UKMMC), a tertiary referral and postgraduate teaching hospital in Kuala Lumpur, Malaysia over a one month period during which the Ngenuity™ viewing system (Alcon Laboratories, Texas, USA) was demonstrated in the Ophthalmology operating theatre number 16 from 7 August– 6 September 2019. This study obtained ethical approval with the reference number UKM PPI/111/8/JEP-2019-724 from the UKMMC Research Ethics Committee. A total number of cases operated with the 3D system recorded were 32 surgeries which consist of phacoemulsification, pterygium surgery, glaucoma procedure, cornea procedure and vitreoretinal surgery. All 7 surgeons and 33 trainees exposed to the viewing system were recruited for the study which involved answering an online questionnaire comprising the components of visualization, physical, ease of use, teaching and learning components and a question on satisfaction. All participants gave written informed consent.

The questionnaire was designed to evaluate the perception of the students and surgeons regarding the learning-teaching methodology and benefits gained by them. It was adapted from pre-existing questionnaires found in the literature review of similar studies [28-31]. The questionnaire underwent content validation and face validation before being used. Validation was done with 5 surgeons of at least 2 years' experience: 3 of whom performed traditional ophthalmic surgery at UKMMC but not 3D heads up surgery while the other 2 surgeons performed both traditional and 3D surgery in another institution. Validation for trainees was done with 5 trainees who had experienced viewing surgery using a traditional viewing screen but had not experienced 3D viewing. The validated questionnaire was distributed to study participants using Google form format, which was paperless and environment friendly.

The questionnaire also collected demographical data which included age, gender, years of experience (for the surgeon) or years in the ophthalmology postgraduate training programme (for trainees) and refractive error of the surgeon. The subjects were required to complete the questionnaire using a Likert scale ranging from scale 1 to 5 (1=poor, 2= below average, 3= average, 4= above average, 5= excellent). Some questions were open-ended. The participants would score individually traditional surgery and the 3D head up surgery in the general aspects of:

1) Visualization components: Specifically

- i. Perception of depth
- ii. Image resolution

- iii. Fine details of ocular structures
- iv. Width of field
- v. Illumination

2) Physical components: Specifically

- i. Neck and upper back strain
- ii. Lower back pain
- iii. Eye strain
- iv. Headache
- v. Double vision

3) Ease of use: Specifically

- i. Simplicity
- ii. Technical feasibility
- iii. Manoeuvrability

4) Teaching and learning components: Specifically

- i. Communication among surgeon and students
- ii. Comfortable learning environment
- iii. Acquisition of knowledge of the surgery

All ophthalmic surgeons from UKMMC who had performed at least one ophthalmic surgery with 3D heads up viewer and all trainees who had observed at least one ophthalmic surgery with 3D heads up display in UKMMC were invited to be included in the study. We excluded doctors who had not experienced traditional or 3D surgery, surgeons from other institutions and doctors who did not return their completed forms.

A total of 40 questionnaires was collected from two major subgroups of 33 postgraduate trainees and 7 surgeons. All data were tabulated in a raw data table using Microsoft Excel Worksheet. Responses for all questions were then entered into separate tables to compare the satisfaction of each component between traditional microscopic surgery and 3D heads up surgery. All the data were analyzed using Statistical Package for Social Sciences (SPSS) software version 21 via the paired T-test samples test. The results obtained from trainees and surgeons were illustrated in a bar chart.

Results

All 7 surgeons and 33 postgraduate students who experienced both traditional microscopic surgery and 3D heads up digitally assisted surgery responded to the study invitation and returned their questionnaires

completed. Total of 40 questionnaires were therefore collected for analysis. Table 1 shows the demographic data of the surgeons and trainees in the study.

Table 1.1: Demographic data of the surgeons

Demographic data	No of surgeons
Gender	
Female	6
Male	1
Years of experience	
<5 years	2
5-10 years	1
>10 years	4
Refractive errors	
Myopia	6
Hyperopia	-
Presbyopia	-
None	1
Total No of 3D cases	
<5 cases	4
5-10 cases	2
>10 cases	1
No of each 3D cases	
Phacoemulsification	7 (total)
1. <5 cases	1. 6
2. >5 cases	2. 1
Pterygium	1 (1 case)
Glaucoma needling/procedure	1 (6 cases)
Cornea procedure	1(2 cases)
Vitreoretinal procedure	2 (1 & 6 cases each)
Using own specs during 2D operation	
Yes	
No	4
	3
Use in 3D surgery	
3D spectacles	2
3D clips on	4

Table 1.2 Demographic data of postgraduate trainee

Demographic data	No of postgraduate trainees
Gender	
Female	24
Male	9
Year of the postgraduate program	
Year 1	4
Year 2	10
Year 3	13
Year 4	6

The total number of cases operated with the 3D system was recorded to be 32 surgeries, which consisted of phacoemulsification, pterygium surgery, glaucoma procedure, cornea and vitreoretinal operation. The number of each type of surgery performed is shown in Fig. 1.

The responses of the surgeons are shown in Figs. 2 to Fig. 5 shows the mean Likert score for each subcomponent. In all the subcomponents, the mean Likert score for the subcomponent was higher for 3D than traditional viewing except for eye strain in which the mean score was equivalent and for the depth of focus in which the mean score was lower. However, the difference was found to be not statistically significant with $p > 0.05$.

When general satisfaction was enquired, surgeons still gave a significantly higher report of satisfaction with 3D at 4.71 than traditional viewing with a p-value of 0.047 (Fig. 6).

As for the trainee group, mean scores for each type of viewing is shown in Table 2 with 3D surgery having higher scores in every category. In terms of visualization components, 3D surgery was shown to offer greater illumination with p-value of 0.008 as compared to the traditional microscopic surgery (Fig. 7). The postgraduate trainees also found that 3D surgery showed a significant reduction in glaring, eye strain, lower back pain, neck and upper back pain (Fig. 8). Besides that, maneuverability aspect seems to favour 3D surgery technically compared to traditional microscopic surgery with a p-value of 0.01 despite surgical time and ease of instruments usage during operations not being statistically different (Fig. 9).

Table 2: Comparison of each component in postgraduate trainees between 2D traditional microscopic surgery and 3D heads up surgery

Components	Mean score		p-value
	2D surgery	3D surgery	
Visualization			
Depth of focus	3.94	4.06	0.458
Image resolution	4.09	4.33	0.073
Width of focus	3.88	4.15	0.095
Illumination	4.00	4.36	0.008
Physical			
Neck and upper back strain	2.97	3.79	0.000
Lower back pain	3.33	3.85	0.019
Eye strain	3.12	3.82	0.008
Glaring	3.48	3.91	0.037
Headache	3.39	3.61	0.386
Diplopia	3.76	4.03	0.163
Technical			
Ease of use	3.82	3.91	0.609
Operative time	3.58	3.70	0.488
Maneuverability	3.52	3.91	0.001
Teaching and learning			
Communication	3.82	4.33	0.002
Comfortable environment	3.70	4.27	0.001
Sharing of knowledge	3.76	4.30	0.000
General satisfaction	3.79	4.12	0.009

3D heads up surgery was reported to be more beneficial to the trainees from the aspect of learning and teaching components. It offered a more comfortable learning environment to postgraduate trainees with p-value of 0.001. Based on the evaluation done, most trainees reported that sharing of knowledge between surgeon and master students was more convenient and easier to understand. It also helped to improve the communication between the surgeon and postgraduate trainees (Fig. 10). Concerning the general satisfaction, the trainees rated the 3D heads up surgery to be superior to traditional technique with an average rating of 4.12 for 3D heads up surgery as compared to 3.79 in traditional analogue microscopic surgery which was statistically significant (Fig. 11).

Discussion

In general, implementation of the 3D system in ophthalmic surgery seems to provide greater satisfaction to the surgeons and postgraduate trainees. In traditional microscopic technique, surgeons found it challenging to obtain the best angle for operative view, especially those involving the posterior segments as the fundus visualization through the lens is indirect [4]. Visualization and perception of depth are important steps in learning-teaching process for a surgical technique. However, in traditional microscopic surgery, the images were limited to the surgeon and a single assistant only [7]. The 3D viewing system has been incorporated into ophthalmic microsurgery so that the entire team has an opportunity to appreciate what exactly the surgeon sees during the live surgery. The 3D technique can be a new and innovative tool for learning-teaching purpose [3].

Surgeon's comfort is one of the important factors in any surgery and this ensures the safety and speed of operation. In traditional microscopic surgery, the surgeon has restricted motion of the head, shoulder and back throughout the operation [1,2]. This will affect the physical condition over the years due to chronic poor posture, back pain, musculoskeletal fatigue and mental stress, subsequently contributing to increased rate of disability [21–24]. This favors 3D heads up technology as it allows a greater degree of movement during operation. However, majority of the operations required short operative time and so this issue becomes less of a problem when compared to traditional surgery. On the other hand, vitreoretinal and orbital surgeries tend to have longer operating time. The study involved only 7 cases of posterior segment surgery. This could explain why the response to these advantages were not seen in the surgeon group overall.

We need to acknowledge the differences between surgeon and trainee response to this technology. The learning curve has been said to be not steep (4,19,32). However, the technology was introduced during a demonstration period. Therefore, the surgeons involved in this study were still in their learning curve using the technology [33]. This may have contributed to their hesitation and reluctance to ranking 3D higher than traditional viewing methods. Surgeries were also more likely to have been done slowly with 3D so as not to compromise patient comfort and safety. Finally, surgeons were also cautious and critical during the evaluation period. However, there was a preference for 3D as shown in the overall satisfaction.

Trainees on the other hand, were very optimistic and accepting of the new viewing system. As shown in the result, the 3D viewing offered many advantages over traditional viewing. 3D system provides a more excellent illumination which allows the microsurgery to be done with excellent precision. The colour balance, brightness and contrast parameters used in the 3D technology enable the use of minimal illumination without affecting the image quality [5, 19, 34]. The great reduction in the illumination than is generally used in traditional technique resulted in lower phototoxicity to the retinal cells [34, 35]. The electronic amplification of signal from the 3D camera allowed excellent visualization of delicate ocular structures.

Besides that, postgraduate trainees found that 3D heads up surgery is more ergonomic than traditional viewing. Iwakiri et al. demonstrated that workers using visual display terminals in-office experienced eye strain (72.1%), followed by neck pain or stiffness (59.3%), low back pain and stiffness (32%) and hand strain (13.9%) [36]. A study done by EC Lee et al. showed that watching a 3D display will cause more eyestrain to the viewers than the 2D viewing [37]. However, the surgeon experienced visual fatigue only at the beginning of the operation before the eyes were able to adapt to the visual field [38]. Yamauchi et al. evaluated the severity of visual fatigue between 2D and 3D endoscopic surgeries conducted about one hour, which showed no difference [39]. Our study concluded that 3D viewing caused less eyestrain and glaring as described by the postgraduate trainees.

Neck and back postures of the surgeon and surgical assistant during operation can lead to occupational-related injuries, thus resulting in higher chance of disability to perform long surgeries [40]. 3D viewing allows microsurgery to be done in a more physiologic and neutral by providing flexible movement in the neck, upper and lower back pain intraoperatively. 3D viewing provides not only a more ergonomic working experience but also a better educational tool.

All the observers will have a chance to experience the perception of depth and anatomical structures as perceived by the main surgeon [5]. The camera technology in 3D heads up display has a higher resolution of image and focus than the traditional microscope [4]. Thus, it allows our human eyes to view more dynamic surgical images which are superior to the traditional microscopic display. The engagement of the entire team in visualizing the same depth of focus will improve the communication during the teaching-learning process in live surgeries.

This study was conducted in the first postgraduate teaching hospital in Malaysia, involving both surgeons and postgraduate trainees. The 3D system was introduced during a demonstration period to give exposure to the microsurgeons and trainees to evaluate its usage and benefits. In view of the positive feedback gained from this study, we reckon that the usage of this technology beyond its trial period will open new opportunity and diversity in ophthalmic microsurgery. On top of that, the 3D system can be practised across the nation, not just in ophthalmic surgery but in another field as well.

Nevertheless, this study has its limitations. Out of the participants recruited, there were only 7 surgeons involved as compared to 33 trainees. From the total number of ophthalmic surgeries involving anterior and posterior segments, 50% of the cases done were phacoemulsification while other types of surgery

only had an average of 4 cases each. Furthermore, only one surgeon had diverse experience in using 3D surgery compared to the other surgeons with total of 13 surgeries. Most of the surgeon respondents only did an average of 4 surgeries with 3D viewing. Therefore, the results cannot be extrapolated to experience different types of ophthalmic surgeries.

Calibrating the visualization aspect from the 3D surgery seems to be the biggest challenge to the remaining surgeons. Other than better colour adjustment settings, it is essential to have a distance check tool between the television (TV) screen and surgeon in order to achieve the maximum potential of focus and view in the future. The placement of TV screen is very important for the surgeons to get the best angle of view during operations.

In this study, we included 33 postgraduate trainees across the four years of master program. Even though we had many trainees, the years of postgraduate training varied from one trainee to another. This might have affected their perception and understanding of the surgeries. The more senior trainee might be able to relate and understand better regarding the surgeon's steps and thought during the operation, thus reflecting more significant result in each arm. However, only 18% of the trainees were in the fourth year of master program (Fig. 12). In future, recruiting more senior trainees in the study might result in a more significant outcome as they can fully appreciate the appreciation towards the surgery with 3D method.

Despite the development of 3D heads up viewing technology, it is still in the early phase of the development and trial, where it has not been fully utilized to its full potential yet. It cannot be denied that most of the surgeons are more used to performing operations via traditional microscopic technique. They may find it quite tricky initially to incorporate the 3D system into their practice as they need to change their visual focus from the binocular of the microscope to the 3D images on heads up display [2].

As 3D heads up system is an innovation, outcomes of the patients in 3D surgeries are essential for evaluation of its pros and cons. The post-operation status and complications should be compared between 3D surgery and traditional microscopic surgery for any significant improvement in the outcomes. The difference in time taken for each type of surgery should be evaluated. The sample size was limited to surgeons and postgraduate trainees in UKMMC, which had been exposed to the two technologies. UKMMC was the first postgraduate teaching centre in Malaysia to have the 3D system demonstrated. It will be beneficial to future studies to recruit more postgraduate trainees and experienced surgeons from other teaching institutions.

Nevertheless, this technology immediately came to mind during the current worldwide novel coronavirus-19 (COVID-19) pandemic. This is because this technology allows the surgeon to work at a further distance from the patient. It also obviates the assistant from needing to peer down the ocular for a 3D view. Hence it allows learning to proceed at a safer distance. Given that high speed devices such as high-speed vitrectomy cutters are known to generate aerosols [41], this technology could increase the safety profile for ophthalmologists performing these procedures and trainees learning about surgery.

Conclusions

In traditional microscopic surgery, the images were limited to the surgeon and surgical assistant. Other observers in the team will be only able to see the images in 2D display with low resolution. Incorporation of 3D heads up viewing into the surgical procedures allows the whole team to appreciate images with excellent depth perception and focus as perceived by the surgeon. This study was conducted using a validated questionnaire comparing the visualization, physical, ease of use, teaching and learning aspects of the two surgical technologies. 3D heads up surgery showed that both surgeons and postgraduate trainees had a better experience in viewing the surgical images. It is also more favourable to the trainees for teaching-learning session as it provides excellent illumination with less glare, eye strain, neck and back pain.

Abbreviations

2D	2 Dimension
3D	3 Dimension
ERM	Epiretinal Membrane
FTMH	Full Thickness Macular Hole
OCT	Optical Coherence Tomography
RRD	Rhegmatogenous Retinal Detachment
TRD	Tractional Retinal Detachment
TV	Television
UKMMC	Universiti Kebangsaan Malaysia
USA	United State America

Declarations

(i) Ethics approval and consent to participate

This study was approved by the Board of Ethics, Universiti Kebangsaan Malaysia Medical Centre with the reference number UKM PPI/111/8/JEP-2019-724. Written consent to participate in the study was obtained from all subjects.

(ii) Consent for publication

Written consent was obtained from all participants.

(iii) Availability of data and materials

The raw data can be obtained from the google forms with the links below

<https://docs.google.com/forms/d/1nlmdnnAhwYkxC0ZpNyYq9TSMk9R2hIQqaAZK4p8-Zto/edit?ts=5dc02709>

<https://docs.google.com/forms/d/1pfRgqWlxHpvadsQ59wx-8J1tsc1UTJXpRFCksw2W-kc/edit?ts=5dbbf2b9>

(iv) Competing interests

The authors declare no financial interest in the above described product

(v) Funding

There is no funding body in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript should be declared.

(vi) Authors' contributions

CTC, MFNY, MCB generalized the idea of the research, analyzed and interpreted the data on satisfaction of surgeons and postgraduate trainees towards 3D heads up surgery and were the major contributors in writing the manuscript. The rest of the authors helped in term of idea contribution and manuscript writing. All authors read and approved the final manuscript.

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(viii) Authors' information (optional)

Not applicable

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Figures

Figure 1

Number of specific cases operated using Ngenuity™ viewing system

Figure 2

Comparison on visualisation components from surgeons' perspective

Figure 3

Comparison on physical components from surgeons' perspective

Figure 4

Comparison on technical components from surgeons' perspective

Figure 5

Comparison on teaching and learning component from surgeons' perspective

Figure 6

Comparison on general satisfaction from surgeons' perspective

Figure 7

Comparison on visualisation components from trainees' perspective

Figure 8

Comparison on physical components from trainees' perspective

Figure 9

Comparison on technical components from trainees' perspective

Figure 10

Comparison on learning and teaching component from trainees' perspective

Figure 11

Comparison on general satisfaction from trainees' perspective

Figure 12

Number of postgraduate trainees in each year