PERSPECTIVE

Three-dimensional digital heads-up microscope for ophthalmic microsurgery

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Abstract

The use of the three-dimensional (3D) digital heads-up microscope is increasingly popular in ophthalmology. Its advantages include improved depth of field, excellent visualization, lower illumination requirements, better ergonomics, and more effective teaching. A pilot study involving 18 ophthalmologists was conducted to compare the 3D microscope with the traditional optical microscope in performing microsurgical steps. Although the mean total operating time to complete five tasks was longer using the 3D microscope than the optical microscope (545 vs 410 seconds, p=0.0009), a downward trend was observed for the mean duration for each task using the 3D microscope. The rapid learning curve reflects the ease of learning and fast adaptation to the new instrument. Operating times may improve with more practice.

Key words: Imaging, Three-Dimensional; Microscopy; Microsurgery; Ophthalmologists

Background

Use of the three-dimensional (3D) digital heads-up microscope is increasingly popular in the field of ophthalmic microsurgery. It allows surgeons to view stereoscopic 3D images on a large high-definition monitor in a heads-up position rather than peering through the oculars of a microscope.[1]

3D display systems can be classified as active or passive systems.[2] An active system shows alternating consecutive images for the right and left eyes rapidly; special electronic glasses are required to actively suppress the image in the contralateral eye. It is mostly used for head-mounted systems. In a passive system, two images are mixed horizontally and then split and viewed by polarized glasses.[2] The passive system is used in commercially available display systems including the ZEISS ARTEVO 800 (Carl Zeiss Meditec, Jena, Germany) and the NGENUITY 3D Visualization System (Alcon, Fort Worth [TX], USA)

The use of 3D heads-up display systems in cataract surgery was first reported by Weinstock et al.[3] Other applications include Descemet's membrane endothelial keratoplasty,[4] strabismus surgery,[5] glaucoma surgery,[6] and vitrectomy.[1]

The ZEISS ARTEVO 800 microscope was introduced in 2019 and launched in North America, Germany, and the United Kingdom over the course of 2020. In March 2020, The University of Hong Kong was among the first places in Asia to use the microscope. Unlike the NGENUITY 3D Visualization System in which a video system is adapted to optical microscopes, the ZEISS ARTEVO 800 has a built-in digital and optical system. This enables a higher resolution sensor, integrated optical coherence tomography, simultaneous optical and digital viewing, and a much shorter lag time. Additionally, the absence of an external camera enables an unobstructed view of the screen.

With regard to optics, it offers a digital view that enables the full performance of cameras, enhanced depth perception, and higher resolution. It reduces the illumination level requirements and the associated risk of phototoxicity.[7] The

ZEISS ARTEVO 800 comes with two integrated three-chip 4K cameras and a 4K monitor. The 3D system can show multiple displays simultaneously such as real-time optical coherence tomography scans and the digital overlay of data, providing live feedback to aid intraoperative decision-making.[8] Moreover, the ZEISS ARTEVO 800 has an auto-adjust function and a contact-free fundus viewing system, which helps improve surgeons' workflow. It can switch to traditional optical viewing if the surgeon chooses, providing a simultaneous 3D heads-up perspective as well.

Heads-up surgery allows for greater freedom of posture and better ergonomics while manipulating surgical instruments, compared with traditional methods, as surgeons view the microscope's images on a panel display in a more natural stance (**Figure**).[9] It minimizes neck and lower-back fatigue and musculoskeletal injuries related to unnatural postures. For educational purposes, 3D animated ophthalmic surgery teaching effectively improved students' practical and theoretical understanding. Medical students and ophthalmologist trainees are more accepting of learning this way than via traditional surgical videos.[10]

Methods

A pilot study involving 18 ophthalmologists (ranging from second-year trainees to consultants) was conducted to compare the 3D digital heads-up microscope with the traditional optical microscope. Ophthalmologists with prior experience with 3D viewing systems were excluded. A standardized introductory course on video-assisted 3D technology was given. A maximum of five doctors were tested in each session to maximize exposure and minimize variations. Pedal use, 3D set-up, and microscope functions were also taught.

Figure. Surgeons viewing the microscope images on a panel display in a more natural stance.

Participants were asked to suture and tie knots with 10-0 nylon and graft with 7-0 Vicryl five times using either the 3D microscope or the optical microscope. They then performed the same tasks another five times using the alternate microscope. All attempts were timed and recorded. Their performances were independently assessed by two blinded consultant surgeons via recorded videos using the Objective Structured Assessment of Technical Skills rating scale. Parameters assessed included respect for tissue, time and motion, instrument handling, flow of operation, knot quality, suture placement, and comfort rating of the surgeon.

Participants were asked to rate their satisfaction of the illumination, size of the television screen, and screen distance. They were also asked to compare viewing, ergonomics, ease of task, and ease of microscope operation for the two systems. The learning curve of the 3D microscope and the performance of the microsurgical task were assessed. Student's *t* test was used to compare the participants' ratings of the two systems.

Results

The mean total operating time to complete five tasks was longer using the 3D microscope than the optical microscope (545 vs 410 seconds, $p=0.0009$), regardless of which microscope was used first. This is because doctors are trained and have more experience using the optical microscope. Nonetheless, a downward trend was observed for the mean duration for each task using the 3D microscope. The first task took 117 seconds on average; the time decreased to 95 seconds for the fifth task. Tasks were performed consecutively; the rapid learning curve reflects the ease of learning and fast adaptation to the new instrument. Operating times may improve with more practice.

The overall Objective Structured Assessment of Technical Skills scores for the 3D microscope and the optical microscope were comparable in all aspects. Surgeons with >10 years post-fellow experience displayed better surgical performance when using the 3D microscope in terms of knot quality, suture placement, and comfort rating. Similarly, surgeons with 2 to 10 years post-fellow experience displayed better surgical performance when using the 3D microscope in terms of respect for tissue, instrument handling, and comfort rating. However, surgeons with <2 years post-fellow experience received lower performance scores in all categories when using the 3D microscope. More training should be provided to younger surgeons to facilitate their transition from the optical microscope to the 3D microscope.

Participants were satisfied with the television screen size and screen distance, with a mean score of 4.50 and 4.39 out of 5, respectively. Surgeons with >10 years post-fellow experience reported better ergonomics when using the 3D microscope (p=0.025). Most participants reported the 3D microscope to be equivalent or superior to the optical microscope in terms of viewing (61%) and ease of microscope operation (78%). Yet, more than half of participants gave the optical microscope a higher rating in ease of task. This could be biased by their previous training and surgical experiences with optical microscopes.

Conclusion

The 3D heads-up microscope has improved depth of field, excellent visualization, lower illumination requirements, and ergonomic advantages. Although there is an initial learning curve, the ease of manipulation and the speed with which people adapt to the new instrument suggest that ophthalmologists can be accustomed to using the 3D microscope quickly even when they were first trained on an optical microscope.

Contributors

All authors designed the study, acquired the data, analyzed the data, drafted the manuscript, and critically revised the manuscript for important intellectual content. All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

All authors have disclosed no conflicts of interest.

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Data availability

All data generated or analyzed during the present study are available from the corresponding author on reasonable request.

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