Title

RESOLUTION, DEPTH OF FIELD, AND PHYSICIAN SATISFACTION DURING DIGITALLY ASSISTED VITREORETINAL SURGERY

Journal
Retina, Publish Ahead of Print(&NA;)

ISSN
0275-004X

Authors
Freeman, William R
Chen, Kevin C
Ho, Joseph
et al.

Publication Date
2019-09-01

DOI
10.1097/iae.0000000000002236

Peer reviewed

HHS Public Access

Author manuscript

Retina. Author manuscript; available in PMC 2020 September 01.

Published in final edited form as:

Retina. 2019 September ; 39(9): 1768–1771. doi:10.1097/IAE.0000000000002236.

Resolution, Depth of Field, and Physician Satisfaction During Digitally Assisted Vitreoretinal Surgery

William R. Freeman, MD[1,2], **Kevin C. Chen, MD**[1,2], **Joseph Ho, MD**[1,2], **Daniel L. Chao, MD, PhD**[1,2], **Henry A. Ferreyra, MD**[1,2], **A. Burton Tripathi, PhD**[3], **Eric Nudleman, MD, PhD**[1,2], **Dirk-Uwe Bartsch, PhD**[1,2]

[1]Department of Ophthalmology, Shiley Eye Institute, University of California San Diego, La Jolla, CA, USA

[2]Jacobs Retina Center, University of California San Diego, La Jolla, CA, USA

[3]TrueVision 3D Surgical, Santa Barbara, CA, USA

Abstract

Purpose—To evaluate depth of field, lateral resolution, and image quality of a heads-up 3D visualization system for vitreoretinal surgery using physician survey and optical measurement outcomes.

Methods—Depth of field and lateral resolution were compared between the standard ocular viewing system and the digital 3D system at 5×, 13×, and 18× magnification by six retinal surgeons. Optical techniques were used as well as a survey of surgeon impression. Surgeon impression surveys were performed after 6 weeks of surgical use of the device.

Results—Physician questionnaire survey scores for depth of field at high magnification were better for the digital 3D system and equivalent for all other categories. Measured lateral resolution was 36.7 mm and 16.6 mm at 5× magnification ($p<0.001$), 14.3 mm and 6.4 mm at 13× magnification ($p<0.001$), and 9.8 mm and 4.2 mm ($p<0.001$) at 18× magnification for the digital 3D and oculars, respectively. Measured depth of field was 4 mm and 6.8 mm at 5× magnification ($p=0.027$), 0.72 mm and 0.86 mm at 13× ($p=0.311$), and 0.28 mm and 0.40 mm at 18× magnification ($p=0.235$) for the oculars and digital 3D, respectively.

Conclusion—Lateral resolution of the digital 3D system was half that of the ocular viewing system and there was some improvement in depth of field with the digital system. Surgeon impression suggested that the digital system was superior when evaluating depth of field at high magnification.

Keywords

depth of field; digital processing; heads-up imaging; heads-up surgery; resolution; vitreoretinal surgery

Correspondence/reprints should be addressed to: William R. Freeman, MD; Dirk-Uwe Bartsch, PhD – First and Senior Authors, Shiley Eye Institute, 9415 Campus Point Drive, #0946, La Jolla, CA 92093, Phone: (858)534-3513, Fax: (858) 534-7985, wrfreeman@ucsd.edu.

No financial disclosures or proprietary interests exist for any of the authors.

Introduction

Three dimensional digitally assisted imaging is an emerging way of visualizing vitreoretinal surgery. By attaching a camera to the operating microscope in place of the traditional viewing oculars, a stereoscopic video can be recorded and projected to a high-definition 3-dimensional monitor. Wearing passive polarized 3D glasses, users can operate with stereopsis sitting upright and looking across the operating room. Current systems include the Alcon NGENUITY 3D Visualization System (Alcon, Fort Worth, TX) and the Leica M822 and M844 microscopes (Leica Microsystems, Wetzlar, Germany) with TrueVision 3D Visualization (TrueVision 3D Surgical, Santa Barbara, CA).

Benefits of heads-up imaging during surgery have been suggested to include improved ergonomics and lower levels of light exposure.[1,2] As the image is projected on a screen, the entire operating team can see what the surgeon sees and recordings can be played back in 3D for training purposes.[3,4] However, stereoscopic displays presenting binocular images on a single planar surface can decrease depth perception because of conflicting accommodation and vergence stimuli.[5,6] Eckardt et al. subjectively noticed a lower resolution of the first-generation 3D visualization system at lower magnifications that was solved by increasing the magnification in the current second-generation device. Herein, we measure the resolution and depth of field of the TrueVision viewing system compared to the standard viewing oculars as well as describe multiple faculty experience with both systems in the operating room.

Methods

Six retinal specialists at a tertiary retinal referral center were asked to compare a standard ocular viewing setup and the TrueVision 3D system attached to a Leica M844 F40 operating microscope. With the digital 3D system, a medical grade 50-inch 4K OLED TV (TrueVision Systems, Inc., Santa Barbara, CA) was placed at 6 feet and operators wore passive circular-polarizing eyeglasses. The aperture was set at 50%.

Retinal surgeons were asked to subjectively grade depth of field at high and low magnification, resolution at high and low magnification, contrast, color, and ability to operate through media opacities and small pupils from 1 (poor) to 4 (good). The surgeons recorded their answers after using the digital 3D system for six weeks and were asked to repeat the same survey for the standard optical viewing system using the same microscope but with standard oculars.

A 1951 Air Force resolution target (RES-1, Newport, Irvine, CA) was used to measure the minimum lateral discernable resolution at different magnifications of 5×, 13×, and 18× with results recorded as line pairs per millimeter (lp/mm) (Figure 1A). The resolution in lp/mm was converted to millimeter line width according to the definition of the line pair resolution measure (Resolution [mm] = 500 / USAF line pair resolution [lp/mm]).

Measurement of depth of field was performed using a millimeter scale mounted on a 45-degree wedge at magnifications of 5×, 13×, and 18×, with surgeons recording the total distance in focus (Figure 1B). These magnification levels were selected to test low, medium, and high magnification of the operative microscope. The digital 3D system magnification setting was adjusted to account for the intrinsic 30% magnification due to the camera sensor size. Brightness was maintained at a constant level for both viewing systems at 70 percent.

Statistical analyses were performed using Microsoft Excel. Paired t-tests were used to compare lateral resolution and depth of field between the ocular viewing system and digital 3D system per retinal surgeon. The null hypothesis was no difference in the tested measurement between the two viewing systems. Wilcoxon signed rank test was used to compare surgeons' survey results. A p-value <0.05 was deemed statistically significant. Results are expressed as mean ± standard deviation unless otherwise specified. Statistical analysis was performed in SPSS (version 24.0, IBM, Armonk, NY, USA).

Results

Physician questionnaire survey scores (subjective impressions) for depth of field at low magnification was 3.2 ± 0.8 and 3.6 ± 0.9, depth of field at high magnification was 2.8 ± 0.4 and 3.6 ± 0.5, resolution at low magnification was 3.0 ± 0.7 and 3.0 ± 1.0, resolution at high magnification was 3.8 ± 0.4 and 3.4 ± 0.9, contrast was 3.2 ± 0.4 and 3.8 ± 0.5, color was 3.4 ± 0.5 and 3.8 ± 0.4, operating through media opacities was 2.8 ± 0.5 and 2.5 ± 0.6, and operating through small pupils was 2.8 ± 0.5 and 3.0 ± 0.0, for the standard eyepiece and the digital 3D system, respectively. The only significant difference was the depth of field at high magnification in favor of the digital 3D system. The other scores were no significant differences (Table 1).

Lateral resolution using the standard ocular viewing system was 16.62 ± 1.58 mm, 6.43 ± 1.33 mm, and 4.16 ± 0.42 mm at 5×, 13×, and 18× magnification, respectively. Lateral resolution using the digital 3D system was 36.68 ± 4.49 mm, 14.27 ± 5.27 mm, and 9.84 ± 0.00 mm at 5×, 13×, and 18× magnification, respectively. There were significant differences between the two systems at all three magnifications tested (5×: p<0.001, 13×: p=0.002, 18×: p<0.001) (Table 2).

Depth of field with the standard ocular viewing system was 4.00 ± 0.93 mm, 0.72 ± 0.43 mm, and 0.28 ± 0.08 mm at 5×, 13×, and 18× magnification, respectively. Depth of field testing on the digital 3D system yielded 6.78 ± 1.36 mm, 0.86 ± 0.19 mm, and 0.40 ± 0.23 mm at 5×, 13×, and 18× magnification, respectively. These measurements were only significantly different at the lowest magnification (5×: p=0.027, 13×: p=0.311, 18×: p=0.235) where the digital system had a 69% percent improved depth of field. (Table 3).

Discussion

Our surgeons scored the digital 3D system similarly to the standard viewing system at both low and high magnifications. In our conditions, we found that the lateral resolution of the digital 3D system was slightly less than half that of the standard viewing system at all three magnifications tested. While digital 3D system remained at half the resolution of the oculars at higher magnifications, the absolute difference between the two increased as the magnification increased. The disparity between resolution testing but not in survey scores suggests the difference in resolution may not be clinically significant. The lateral resolution of the digital 3D system could be limited by the resolving power of the microscope, the resolution of the viewing screen, and the distance from the operator. Furthermore, the optical resolution in our experiment was higher than the optical resolution that can be expected in intraocular viewing. While our experimental setup allowed us a resolution of about 4 microns, typical resolution when viewing the retina is limited to about 12-15 microns due to the poor numerical aperture of the instrument-eye optical system.

Decreasing the aperture of a camera increases the depth of field of the resulting image. Eckardt and Paulo found that with the TrueVision and Leica M822 microscope, increased depth of field could be perceived when the aperture was set at 25% or smaller.[1] However, the authors felt the image was too dark to operate safely. In our testing, with a constant aperture at 50%, there was an increased depth of field using the digital 3D system at the 5× magnification, but there was not a statistically significant difference at higher magnifications tested. It is a well-known observation in optics that higher magnification lenses will have a shallower depth of field due to the cone angle of light. In our experience, there was no difference in the apparent depth of field at low magnification while operating, but there was a significant difference in depth of field at high magnification.

Still, while we found decreased lateral resolution and slight improvement in depth of field with the digital 3D system, there are other reported benefits of the digitally-assisted system. Murtaza et al. found that digital signal amplification via the 3D digitally-assisted imaging system safely allowed for lower levels of endoillumination in vitreoretinal surgery in 10 cases, theoretically reducing the risk of iatrogenic intraoperative phototoxicity.[2] Authors have also reported on the more natural body positioning allowing for more comfortable operating while using the digital 3D system compared to traditional surgery.[1,3] Furthermore, three-dimensional videos may be more educational for observers learning intraocular ophthalmic surgeries than two-dimensional videos.[4]

Limitations of the current study include the small sample size and recall bias of the survey. In conclusion, we found that resolution of the digital 3D system was half that of the standard oculars while the depth of field was comparable, although resolution was not noticed to be different while operating.

References

1. Eckardt C, Paulo EB. Heads-Up Surgery for Vitreoretinal Procedures: An Experimental and Clinical Study. Retina. 2016; 36(1):137–147. [PubMed: 26200516]
2. Adam MK, Thornton S, Regillo CD, Park C, Ho AC, Hsu J. Minimal Endoillumination Levels and Display Luminous Emittance During Three-Dimensional Heads-Up Vitreoretinal Surgery. Retina. 2017; 37(9):1746–1749. [PubMed: 27902640]
3. Weinstock R. Operate With Your Head Up. Cataract Refract Surg Today. 2011; 8(66):74.
4. Chhaya N, Helmy O, Piri N, Schaal S. Comparison of 2D and 3D video displays for teaching vitreoretinal surgery. Retina. 2017
5. Banks MS, Hoffman DM, Kim J, Wetzstein G. 3D Displays. Annu Rev Vis Sci. 2016 Aug.:1–39. [PubMed: 28532354]
6. Vienne C, Blondé L, Mamassian P. Depth-of-Focus Affects 3D Perception in Stereoscopic Displays. Perception. 2015; 44(6):613–627. [PubMed: 26489206]

Summary statement

The resolution of the digitally assisted imaging system is roughly half that of the standard operating microscope, while the depth of field is similar. Survey scores for depth of field at high magnification were better with the digitally assisted system.

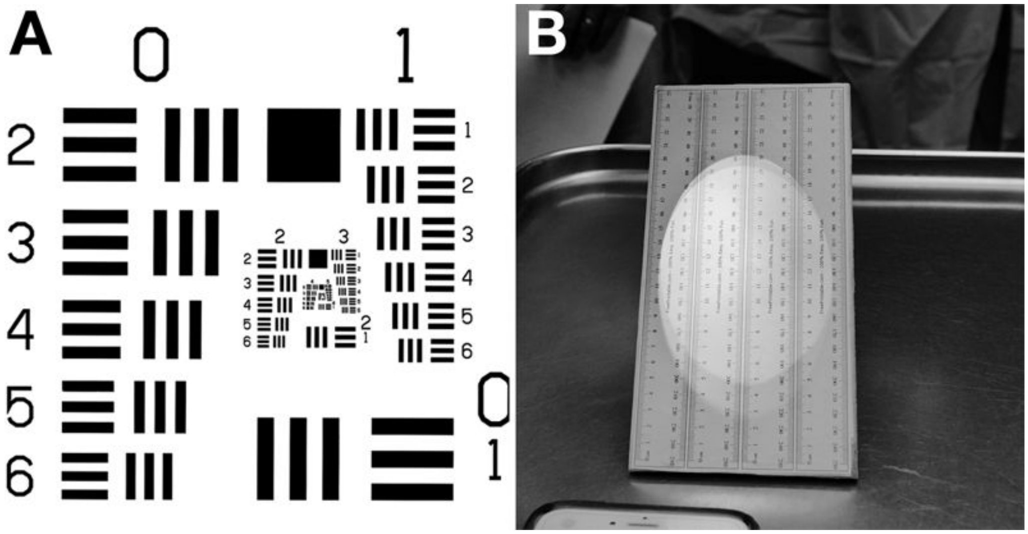

Figure 1.

A. The 1951 Air Force resolution target used to measure the minimum lateral discernable resolution. B. A millimeter scale mounted on a 45-degree wedge used to measure depth of field at different magnifications.

Table 1

Survey complete by retinal surgeons after experience with the digital 3D system. Surgeons were asked to grade from 1 (poor) to 4 (good). (n=6)

	Standard Eyepiece Score	Digital 3D System Score	p-value
Depth of Field at Low Magnification	3.2 ± 0.8	3.6 ± 0.9	0.157
Depth of Field at High Magnification	2.8 ± 0.4	3.6 ± 0.5	0.046*
Resolution at Low Magnification	3.0 ± 0.7	3.0 ± 1.0	1.00
Resolution at High Magnification	3.8 ± 0.4	3.4 ± 0.9	0.414
Contrast	3.2 ± 0.4	3.8 ± 0.5	0.157
Color	3.4 ± 0.5	3.8 ± 0.4	0.157
Operating Through Media Opacities	2.8 ± 0.5	2.5 ± 0.6	0.317
Operating Through Small Pupils	2.8 ± 0.5	3.0 ± 0.0	0.317

Author Manuscript

Author Manuscript

Author Manuscript

Table 2

Lateral resolution of eyepiece and digital 3D system as measured on a 1951 Air Force resolution target by six retinal surgeons at three different magnification settings.

Microscope magnification	Eyepiece lateral resolution (mm)	Digital 3D lateral resolution (mm)	p-value
5×	16.62 ± 1.58	36.68 ± 4.49	<0.001
13×	6.43 ± 1.33	14.27 ± 5.27	0.002
18×	4.16 ± 0.42	9.84 ± 0.00	<0.001

Table 3

Depth of field measurements of eyepiece and digital 3D system on a millimeter scale set at a 45-degree angle from six retinal surgeons at three different magnification settings.

Microscope magnification	Eyepiece depth of field (mm)	Digital 3D depth of field (mm)	p-value
5×	4.00 ± 0.93	6.78 ± 1.36	0.027
13×	0.72 ± 0.43	0.86 ± 0.19	0.311
18×	0.28 ± 0.08	0.40 ± 0.23	0.235