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Three-Dimensional Video Microscopy: Potential for Improved Ergonomics without Increased Operative Time?

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Abstract

Three-dimensional (3D) video exoscopes are high-magnification stereo cameras that project onto monitors mounted in the operating room, viewable from different angles. Outside of plastic surgery, exoscopes have been shown to successfully improve the ergonomics of microsurgery, though sometimes with prolonged operating times. We compare a single surgeon's early experience performing free flap procedures from 2020 to 2021 using either a binocular microscope or a 3D video exoscope. Ten procedures were performed with the standard operating microscope and 8 procedures with the 3D exoscope. The microsurgeon, having minimal prior experience using an exoscope, reported less neck discomfort following the free flap procedures performed with the exoscope compared with the binocular surgical microscope. Total average operating time was comparable between the standard surgical microscope and the 3D exoscope (13.7 vs. 13.4 hours, $p = 0.34$). Our early experience using a 3D exoscope in place of a standard optical microscope demonstrated that the exoscope shows promise, offering an ergonomic alternative during microvascular reconstruction without increasing overall operating times. Future studies will compare free flap ischemia time between cases performed using the exoscope and the conventional binocular microscope. Medical Subject Headings authorized following words: free tissue flaps; operating rooms; ergonomics; microsurgery.

Keywords
- free tissue flaps
- operating room
- ergonomics
- microsurgery
- microscopes

Since the birth of microvascular surgery in the early 1960s, many improvements have emerged to aid microvascular anastomosis. Typically, an operating microscope or surgical loupes are used to establish a magnified view of the surgical field.[1] However, the use of surgical microscopes aggravates the ergonomic stress that microsurgeons frequently experience due to sustained static postures and hyperflexion of the cervical spine for prolonged periods of time.[2–4] The use of binocular surgical microscopes for 3 hours or more per week has been associated with an increased incidence of musculoskeletal complaints due, in part, to prolonged neck flexion.[5] A survey of plastic surgeons in North America reported that almost 80% of plastic surgeons experience musculoskeletal symptoms, most commonly neck and lower back pain.[6]

Newer biomedical devices such as three-dimensional (3D) video microscopes (also known as "exoscopes") have

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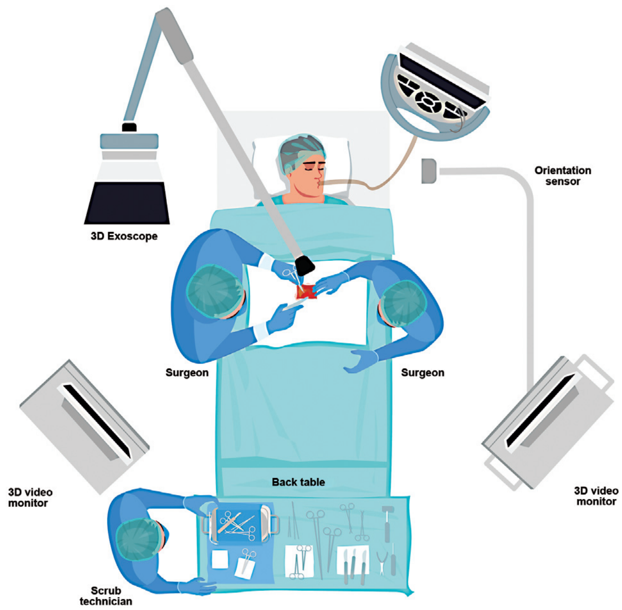

Fig. 1 Operating room setup using the three-dimensional (3D) exoscope in reconstructive microsurgery.

emerged as an alternative to the classic operating microscope. These devices substitute the optics of a standard microscope with a stereo video camera. The resulting image is projected onto a high-resolution monitor that can be viewed using polarized glasses to provide depth perception. The 3D exoscope was first introduced in the field of neurosurgery as an alternative to the standard operating microscope. Oertel and Burkhardt described the application of the VITOM-3D exoscope in cranial and spinal procedures in 2017. The authors noted comparable image quality to the standard operating microscope and an excellent comfort level for all procedures performed with the exoscope.[7] Several other studies have demonstrated that the 3D-exoscope may prove superior to the operating microscope in terms of depth of focus, image quality, and ergonomics.[1,8–11]

Despite the benefits associated with the use of the 3D exoscope, prolonged operative times have been described in the literature.[9,10,12,13] We aimed to compare the benefits, techniques, and operating (ischemia) times for each type of microscope in performing microvascular reconstructive procedures. We report on a single surgeon's experience performing free flap procedures from 2020 to 2021 using both a

Fig. 2 The principal surgeon and assistant surgeon are each standing in a position of comfort, facing a three-dimensional monitor that is behind the other surgeon. The video monitors are mirrored and positioned to provide an unobstructed view, enabling all participants wearing special polarized eyewear to experience a magnified view of the surgical field.

Fig. 3 Scrub technician's view. The monitor and motion sensor are both adjustable to promote neutral posture, limit neck flexion, and optimize surgical ergonomics.

binocular microscope and the Modus V (Synaptive Medical Inc. 2017, 555 Richmond Street West, Suite 800, Toronto, ON, M5V 3B1) 3D exoscope. This exoscope offers a field of view of 6.5 to 207.9 mm and can be configured in a way that optimizes the operating room layout (►**Figs. 1** and **2**).

We describe the first 9 free flap procedures performed with the exoscope and 11 consecutive free flap procedures performed with the standard binocular surgical microscope during the same time frame. Ischemia times and differences in technique were compared between similar procedures performed with each type of microscope (►**Fig. 3**).

Twenty patients underwent free flap reconstructions between 2020 and 2021, including the first 9 performed with a 3D exoscope. The total ischemia time was comparable for free flaps performed with the exoscope and the standard binocular microscope (152 minutes vs. 110 minutes, respectively; $p = 0.054$). The type of microscope was not a significant predictor of ischemia time for radial forearm free flap phalloplasty (exoscope: 195 minutes vs. standard microscope: 154 minutes; $p = 0.117$). Similarly, ischemia time was comparable for both unilateral and bilateral deep inferior epigastric artery perforator (DIEP) breast reconstruction (exoscope: 83 minutes per breast vs. standard microscope: 94 minutes; $p = 0.29$; ►**Tables 1** and **2**).

Our experience using a 3D exoscope in place of a standard optical microscope demonstrates that the exoscope shows promise, offering an ergonomic alternative during microvascular reconstruction without significantly increasing ischemia times. 3D exoscopes have recently been adopted as an alternative to the traditional operating microscope and surgical loupes due to several advantages. The emergence of a 3D imaging system with 4K-resolution has been reported as a notable benefit, as it allows for enhanced visualization of the surgical field with adequate depth perception.[14,15] Another reported advantage is the notable reduction in thermal injury to tissues during surgery as the LED light source of the 3D exoscope radiates much less heat than the light source of standard microscopes.[16,17] Improved posture and decreased musculoskeletal strain have also been described by surgeons using the 3D exoscope.[10,14] This is particularly important in microsurgery, which requires a sustained downward gaze and static posture in the neck and shoulders.[18] Additionally, the 3D exoscope offers all participants in the operating room a 3D view of the operation, as long as they have the appropriate eyewear. Though standard operating microscopes may also project a view of the surgical field on monitors mounted in the operating room, the image is flat and does not provide the viewer perception of depth.[19] This 3D view of the surgical field is helpful from a teaching

Table 1 Cases performed with the 3D exoscope

Case	Procedure	Nerve coaptations	Arterial anastomoses	Venous anastomoses	Ischemia time (min)
1	RFFF PUP	2	1	2	225
2	RFFF PUP	2	1	2	169
3	RFFF PUP	2	1	2	221
4	ALT PUP	1	1	1	143
5	RFFF PUP	2	1	2	218
6	Unilateral DIEP		2	2	98
7	Unilateral DIEP		2	2	99
8	Unilateral DIEP		2	2	52
9	RFFF PUP	2	1	2	143

Abbreviations: 3D, three dimensional; ALT PUP, anterolateral thigh flap phallourethroplasty; DIEP, deep inferior epigastric perforator flap; RFFF PUP, radial forearm free flap phallourethroplasty.

Table 2 Cases performed with a standard operating microscope

Case	Procedure	Nerve coaptations	Arterial anastomoses	Venous anastomoses	Ischemia time (min)
1	RFFF PUP	2	1	2	106
2	Unilateral DIEP	2	1	2	84
3	Unilateral DIEP		2	2	157
4	Unilateral DIEP		2	2	75
5	Unilateral DIEP		2	2	105
6	Unilateral DIEP		2	2	57
7	Unilateral DIEP		2	2	93
8	Unilateral DIEP		2	2	112
9	Unilateral DIEP		2	2	69
10	RFFF PUP	2	1	2	171
11	RFFF PUP	2	1	2	185

Abbreviations: ALT PUP, anterolateral thigh flap phallourethroplasty; DIEP, deep inferior epigastric perforator flap; RFFF PUP, radial forearm free flap phallourethroplasty.

standpoint, as all viewers, including trainees and observers, experience the same image.

Although the exoscope offers excellent 3D vision and stereopsis, there have been reports of surgeons developing headaches and dizziness from use of the 3D glasses during the surgical procedures.[19] 3D exoscopes have also been linked to prolonged operative times in comparison to the standard microscope.[10,13–15] This may be attributed to a learning curve since most surgeons are not familiar with this new tool and the need to develop indirect vision skills to maneuver.[16] Piatkowski et al describe their experience using a 3D exoscope and a standard operating microscope for autologous breast reconstruction. Though complication profiles were comparable between the two types of microscopes, microvascular anastomoses took longer to complete with the 3D exoscope.[20] This contrasts with our experience using the exoscope for DIEP flaps where ischemia times averaged 10 minutes less (this did not reach significance). Additionally, the cost of a 3D exoscope typically ranges between $250,000 and $1,500,000, which is similar to the cost of a high-end conventional microscope but may be a limiting factor for some healthcare systems.[16]

There appears to be a growing awareness and urgency surrounding musculoskeletal injury in surgery. Our preliminary experience using an exoscope sheds light on an important recently introduced technology that may be adopted into clinical practice to improve the ergonomics of microsurgery. Microvascular plastic surgeons have yet to widely adopt the 3D exoscope, but we demonstrate its potential utility while allaying fears that it is difficult to learn and adapt to microsurgical practice.

Ultimately, adoption of this technology, along with other ergonomic improvements, may better protect the health and career longevity of the physician workforce.

Authors' Contributions

Y.S. and E.R. made substantial contributions to conception and design of the study, drafting and revisions, as well as performed data acquisition, analysis, and interpretation.

Patient Consent

Patients provided written informed consent for the publication and the use of their images.

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Conflict of Interest

None declared.

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References

1 Ahmad FI, Mericli AF, DeFazio MV, et al. Application of the ORBEYE three-dimensional exoscope for microsurgical procedures. Microsurgery 2020;40(04):468–472

2 Epstein S, Sparer EH, Tran BN, et al. Prevalence of work-related musculoskeletal disorders among surgeons and interventionalists: a systematic review and meta-analysis. JAMA Surg 2018;153 (02):e174947. Doi: 10.1001/jamasurg.2017.4947

3 Ohlsson K, Attewell RG, Pålsson B, et al. Repetitive industrial work and neck and upper limb disorders in females. Am J Ind Med 1995; 27(05):731–747

4 Godwin Y, Macdonald CR, Kaur S, Zhelin L, Baber C. The impact of cervical musculoskeletal disorders on UK consultant plastic surgeons: can we reduce morbidity with applied ergonomics? Ann Plast Surg 2017;78(06):602–610

5 Capone AC, Parikh PM, Gatti ME, Davidson BJ, Davison SP. Occupational injury in plastic surgeons. Plast Reconstr Surg 2010;125 (05):1555–1561

6 Khansa I, Khansa L, Westvik TS, Ahmad J, Lista F, Janis JE. Work-related musculoskeletal injuries in plastic surgeons in the United

States, Canada, and Norway. Plast Reconstr Surg 2018;141(01):165e–175e
7 Oertel JM, Burkhardt BW. Vitom-3D for exoscopic neurosurgery: initial experience in cranial and spinal procedures. World Neurosurg 2017;105:153–162
8 Krishnan KG, Schöller K, Uhl E. Application of a compact high-definition exoscope for illumination and magnification in high-precision surgical procedures. World Neurosurg 2017;97:652–660
9 Mamelak AN, Danielpour M, Black KL, Hagike M, Berci G. A high-definition exoscope system for neurosurgery and other microsurgical disciplines: preliminary report. Surg Innov 2008;15(01):38–46
10 Sack J, Steinberg JA, Rennert RC, et al. Initial experience using a high-definition 3-dimensional exoscope system for microneurosurgery. Oper Neurosurg (Hagerstown) 2018;14(04):395–401
11 Takahashi S, Toda M, Nishimoto M, et al. Pros and cons of using ORBEYE™ for microneurosurgery. Clin Neurol Neurosurg 2018; 174:57–62
12 Yu D, Green C, Kasten SJ, Sackllah ME, Armstrong TJ. Effect of alternative video displays on postures, perceived effort, and performance during microsurgery skill tasks. Appl Ergon 2016; 53(Pt A):281–289
13 Rossini Z, Cardia A, Milani D, Lasio GB, Fornari M, D'Angelo V. VITOM 3D: preliminary experience in cranial surgery. World Neurosurg 2017;107:663–668
14 Kwan K, Schneider JR, Du V, et al. Lessons Learned Using a High-Definition 3-Dimensional Exoscope for Spinal Surgery. Vol 16.; 2019 Doi: 10.1093/ons/opy196
15 Mamelak AN, Nobuto T, Berci G. Initial clinical experience with a high-definition exoscope system for microneurosurgery. Neurosurgery 2010;67(02):476–483
16 Fiani B, Jarrah R, Griepp DW, Adukuzhiyil J. The role of 3D exoscope systems in neurosurgery: an optical innovation. Cureus 2021;13(06):e15878. Doi: 10.7759/cureus.15878
17 Muhammad S, Lehecka M, Niemelä M Preliminary experience with a digital robotic exoscope in cranial and spinal surgery: a review of the Synaptive Modus V system. Acta Neurochir (Wien) 2019;161(10):2175–2180
18 Kokosis G, Dellon LA, Lidsky ME, Hollenbeck ST, Lee BT, Coon D. Prevalence of musculoskeletal symptoms and ergonomics among plastic surgery residents: results of a national survey and analysis of contributing factors. Ann Plast Surg 2020;85(03):310–315
19 Wanibuchi M, Komatsu K, Akiyama Y, Mikami T, Mikuni N. Effectiveness of the 3D monitor system for medical education during neurosurgical operation. World Neurosurg 2018;109:e105–e109
20 Piatkowski AA, Keuter XHA, Schols RM, van der Hulst RRWJ. Potential of performing a microvascular free flap reconstruction using solely a 3D exoscope instead of a conventional microscope. J Plast Reconstr Aesthet Surg 2018;71(11):1664–1678

