European Journal of Plastic Surgery (2019) 42:611–614
https://doi.org/10.1007/s00238-019-01521-1

IDEAS AND INNOVATIONS

Application of a 3D 4K exoscopic system to head and neck reconstruction: a feasibility study

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Received: 3 January 2019 / Accepted: 22 February 2019 / Published online: 16 May 2019

Abstract

Background Technological advancements in surgery provide convenience and new capabilities to surgical practice. A recently developed 3D 4K exoscopic system gives the surgeon a potential alternative to the operating microscope (OM). This paper focuses on the first experience on microsurgical free flap reconstructions performed with a 3D 4K system and evaluates the potentials and pitfalls of this new technology.

Methods Three consecutive cases of head and neck cancers requiring free flap reconstructions were included. Free flap harvesting and anastomosis in 2 and 3 patients, respectively, were performed using the 3D 4K exoscopic system.

Results The 3D 4K exoscope provided a high quality of vision and perception of depth. The setting of the operating theater was ergonomically favorable. No case required a switch to traditional OM.

Conclusions This initial experience shows that harvesting free flaps and performing microanastomoses with the 3D 4K exoscopic system are feasible. Further studies on larger series are warranted to explore if the applicability of this technology to other fields of head and neck surgery can compensate for its costs.

Level of Evidence: Level V, therapeutic study

Keywords Microsurgery · Free tissue flap · Reconstructive surgical procedures · 3D · Exoscope · Surgical technology

Introduction

Since its introduction in the middle of the twentieth century, the operative microscope (OM) has been considered as an essential tool in reconstructive surgery. More recently, endoscopes have gained popularity in various surgical fields, proving advantages in terms of image sharpness, magnification, and brightness, thus paving the way to a new surgical concept [1–4].

Recently, digital 3-dimension (3D) vision coupled to HD video has been widely used in computer games, the commercial film industry, printing manufacturing, and finally in surgery applied to endoscopic and exoscopic devices. The exoscope is a novel surgical tool consisting in an external optical body that serves for observing and illuminating a surgical field from a position set apart from the patient's body [5].

In the last 2 years, some studies in the neurosurgical literature have highlighted the emerging role of exoscopes with 3D technology mainly using the Video Telescope Operating Microscopy (VITOM®—Karl Storz GmbH, Tuttlingen, Germany), a novel telescope held in position by a mechanical system holder equipped by a full HD camera and fiber optic light cable [6–9]. The use of the same system for microsurgical free flap reconstruction in one patient has also been recently reported [10].

In this article, we present our initial experience on the application of a new 3D 4K video exoscope (Orbeye®, Sony Olympus Medical Solutions, Inc., Tokyo, Japan) in three consecutive head and neck microsurgical free flap reconstructions and discuss its potential and limits. To the best of our

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00238-019-01521-1) contains supplementary material, which is available to authorized users.

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knowledge, this is the first report on the use of this system and the first using a 4K processor in head and neck reconstruction.

Methods

A single surgeon (A.G.) performed three consecutive cases of microsurgical free flap reconstruction for head and neck defects at the Department of Otorhinolaryngology and Head and Neck Surgery, University of Brescia, Italy. The surgical setting for microsurgical procedures is shown in Fig. 1: a 55-in monitor was set opposite to the first surgeon, while a 35-in 3D HD monitor was used by a second surgeon; the exoscope was positioned behind the first surgeon with the arm coming over the head on the surgical bed. 3D polarized glasses were worn during the procedures (Fig. 2). The system was used for harvesting the flap, pedicle dissection, and vascular anastomoses. Two latissimus dorsi non-perforator and one anterolateral thigh (ALT) perforator flaps were raised (Video 1). The diameter of the perforator pedicle dissected was less than 1 mm in one case and more than 2.5 mm in the others (Fig. 3). Anastomoses were performed with 8–0 Ethilon (Ethicon Inc., Somerville, New Jersey, USA) sutures for artery, 9–0 for vein, and 10–0 in one case of facial nerve reconstruction with a great auricular nerve cable graft (Videos 2 and 3). At the end of each procedure, a second check of the anastomoses with OM was done. Flap dissection, vascular anastomoses, and nerve reconstruction were feasible, and no cases required switching to OM to complete the procedure. Ethical approval was obtained (protocol n. SIC70601-602).

Fig. 2 Intraoperative picture of the surgical procedure showing the 3D monitor, the arm of the exoscope located over the surgical field, and assistant surgeon position during vascular anastomoses

Representative cases (Table 1)

Case 1

A 52-year-old man underwent auriculectomy, total petrosectomy with dural resection, radical parotidectomy, and selective neck dissection for ceruminous adenocarcinoma of external auditory canal staged cT4bN0M0. Reconstruction of dura and soft tissues defects were accomplished by multilayer plasty and myocutaneous latissimus dorsi free flap, respectively. Arterial and venous microanastomoses were performed in an end-to-end fashion. On the 12th postoperative day, revision duraplasty for

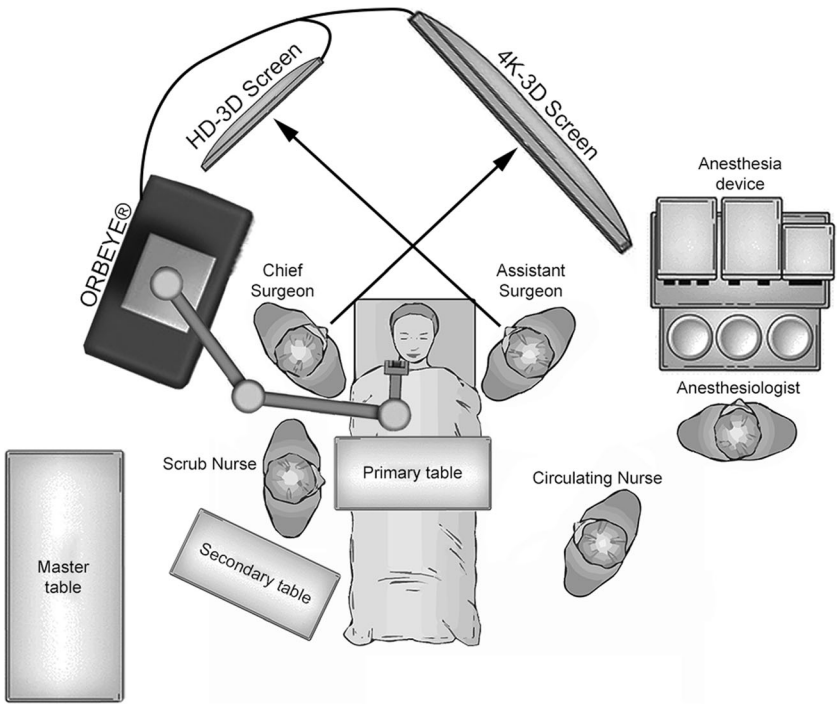

Fig. 1 Surgical set-up for microsurgical procedures using the 3D 4K exoscopic system

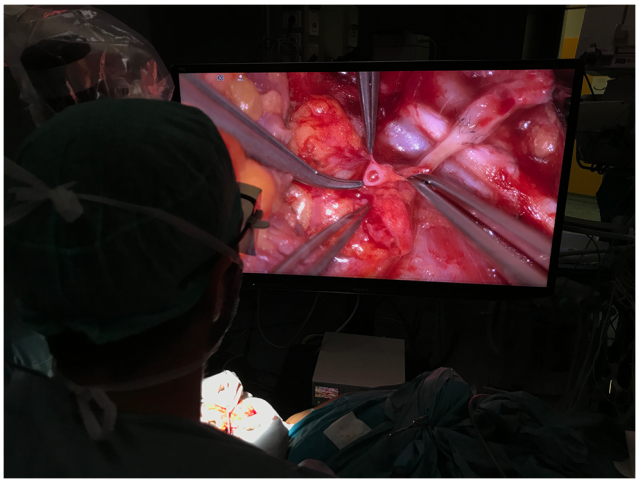

Fig. 3 Intraoperative picture of the surgical procedure showing image definition and brightness of colors prior to vein anastomoses. The vein lumen in the center and the arterial anastomoses on the upper right angle of the monitor are clearly visible

cerebro-spinal fluid leak was required. No flap complications occurred. The patient was discharged at 22 days after surgery.

Case 2

A 54-year-old man received segmental mandibulectomy and selective neck dissection for squamous cell carcinoma of the alveolar ridge, staged cT4aN0M0. Oral rehabilitation with bone reconstruction and osteo-integrated dental implants were preoperatively excluded, so that reconstruction was obtained with a perforated fasciocutaneous anterolateral thigh free flap and plate positioning. Arterial and vein anastomoses were performed in an end-to-end and end-to-side fashion, respectively. In the 14th postoperative day, as a consequence of cervical infection with skin dehiscence, the patient underwent revision surgery with a pectoralis major pedicled flap. No free flap complications occurred. Hospital stay was 45 days.

Case 3

A 75-year-old man underwent a combined endoscopic and transcranial resection (including total maxillectomy, orbital exenteratio, nasopharyngectomy type III, and dural resection) for naso-ethmoidal intestinal-type adenocarcinoma, staged cT4bN0M0. Dural reconstruction was achieved by multilayer plasty and maxillo-orbital defect reconstruction was performed by myocutaneous latissimus dorsi free flap. Arterial and venous microanastomoses were performed in an end-to-end fashion. No complications occurred. Hospital stay was 21 days.

Discussion

The use of a 3D 4K exoscopic system for microvascular procedures might be beneficial in reconstructive surgery. In our limited experience, this system can provide an alternative to the traditional OM for microsurgery. Three consecutive cases were performed and subjective technical improvements, although not supported by statistical analysis, were observed. Even during the phase of flap harvesting, the width of the field, quality and brightness of images, and maneuverability of the 3D 4K exoscopic system gave the surgeon a better perception of spaces compared to surgical loupes.

In our opinion, the strength that differentiates this system compared to other exoscopes is the overall improvement in viewing small details of the surgical field, with satisfactory definition and depth perception. The initial feedback of the first author was the higher image definition, since the 4K processor maintains brightness of colors and clearness of details at both optical and digital high magnifications [8]. These advantages are even more evident when comparing the 3D 4K exoscopic system with OM. However, some authors who reported their experience with 3D HD exoscopes (not equipped with a 4K processor) found differences regarding comfort and resolution in favor of OM [9].

Another advantage of the 3D 4K exoscopic system is the wide view of the surgical field, which enables ideal visualization of surgical gestures that are not through an area that is as narrow as with OM. As reported by Krishnan et al. [6], 3D 4K systems offer an augmented reality with immediate 3D perception that leads the surgeon to adapt surgical movements in a short period of time.

Although the 4K camera provides a focal length ranging from 220 to 550 mm, comparable to OM, the wider and deeper visual field makes this device more suitable for performing microanastomoses in deep and narrow surgical corridors (i.e., submandibular spaces, deep lateral neck) and better understand

Table 1 Type of resection, free flap performed, and duration of anastomoses

Patient	Age	Gender	Site of tumor	Type of resection	Histology	Free flap	Duration of flap harvesting (min)	Duration of arterial anastomosis (min)	Duration of venous anostomosis (min)
1	52	F	Temporal bone	Auriculectomy, petrosectomy, radical parotidectomy, selective neck dissection	Adenocarcinoma	Latissimus dorsi free flap (left)	54	23	46
2	54	M	Oral cavity	Tumor resection, segmental mandibulectomy, selective neck dissection	Squamous cell carcinoma	Anterolateral thigh free flap (left)	67	19	40
3	75	M	Naso-ethmoid	Craniofacial resection, orbital exenteration	Intestinal-type adenocarcinoma	Latissimus dorsi free flap (left)	72	25	42

pedicle geometry, thus avoiding twisting or kinking of vessels in end-to-side anastomoses. Another advantage of the 4K processor is the absence of image latency observed with 3D-HD exoscopic systems [11], which is especially evident for hand-to-eye movements at high magnifications.

The overall encumbrance of the 3D 4K exoscopic system is significantly lower compared to OM. Whereas both systems are equipped with a counterbalanced arm coupled to a dead man switch providing fluid movements, the streamlined and compact optical head mounted on the exoscopic system allows the surgeon to move in a more comfortable working space. Surgical comfort is further enhanced by the possibility of positioning the camera up to 1 m over the surgical field. The camera head is the only portion of the device that needs to be tilted if angle changes are needed, while the OM requires more extensive modular movements of the whole structure and sometimes forces the surgeon to assume unpleasant anti-ergonomic postures. Some authors found other 3D devices cumbersome to use due to the presence of a mechanical holding arm equipped with locking screws which, once released, completely relax all the joints, thus rendering the system unstable and time-consuming to reposition [6, 12]. Similar to other 3D equipment, this system has the advantage to ensure involvement of all the members of the team in the operating theater. This feature is also important for educational purposes, especially in the academic setting for training of students, residents, and fellows.

The main criticism with exoscopic systems is visualization of the surgical field on a screen instead of having direct vision as with OM. Indeed, microsurgeons, who are acquainted to the use of OM, may complain of some discomfort in hand-eye coordination and be visually distracted by the operative room environment. In our experience, this limit was quickly overcome with surgical practice and by optimizing the position of screens for both the first and assistant surgeons. The ideal setting should include two wide 4K, 55-in. monitors, angled at 45°, and placed at the head of the surgical bed in front of each surgeon. A limitation of the present report, which should be addressed by future studies, is the lack of an objective comparison between the 3D 4K exoscopic system with other 3D HD exoscopes and OM. Finally, a non-negligible disadvantage for the 3D 4K exoscope is the cost of the system, which is substantially higher compared with traditional OM, especially when two monitors are required.

Conclusions

We report the first use of the 3D 4K exoscopic system for microsurgical reconstruction. Harvesting of free flaps and microanastomosis with the 3D 4K exoscopic system is feasible. The easy maneuverability of the system together with satisfactory performance in terms of definition and perception of depth can pave the way to extend its indications in head and neck surgery. The issue of cost, however, deserves careful analysis.

Compliance with ethical standards

Conflict of interest statement Author A and Author B declare that they have no conflict of interest.

Ethical approval Ethical committee approval was obtained (SIC70601-602).

Informed consent Informed consent was obtained from all individual participants included in the study.

Funding The system used in the surgeries was for a trial period. No financial or commercial relations are present between the authors and any of the companies mentioned in the text. No funding was received for the study.

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