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Original Article

Stereoscopic Three-Dimensional Images of an Anatomical Dissection of the Eyeball and Orbit for Educational Purposes

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The purpose of this study was to develop a series of stereoscopic anatomical images of the eye and orbit for use in the curricula of medical schools and residency programs in ophthalmology and other specialties. Layer-by-layer dissection of the eyelid, eyeball, and orbit of a cadaver was performed by an ophthalmologist. A stereoscopic camera system was used to capture a series of anatomical views that were scanned in a panoramic three-dimensional manner around the center of the lid fissure. The images could be rotated 360 degrees in the frontal plane and the angle of views could be tilted up to 90 degrees along the anteroposterior axis perpendicular to the frontal plane around the 360 degrees. The skin, orbicularis oculi muscle, and upper and lower tarsus were sequentially observed. The upper and lower eyelids were removed to expose the bulbar conjunctiva and to insert three 25-gauge trocars for vitrectomy at the location of the pars plana. The cornea was cut at the limbus, and the lens with mature cataract was dislocated. The sclera was cut to observe the trocars from inside the eyeball. The sclera was further cut to visualize the superior oblique muscle with the trochlea and the inferior oblique muscle. The eyeball was dissected completely to observe the optic nerve and the ophthalmic artery. The thin bones of the medial and inferior orbital wall were cracked with a forceps to expose the ethmoid and maxillary sinus, respectively. In conclusion, the serial dissection images visualized aspects of the local anatomy specific to various procedures, including the levator muscle and tarsus for blepharoptosis surgery, 25-gauge trocars as viewed from inside the eye globe for vitrectomy, the oblique muscles for strabismus surgery, and the thin medial and inferior orbital bony walls for orbital bone fractures.

Key words: stereoscopic camera-captured images, education, local anatomical dissection, orbit, eye

Human anatomy has been a major part of the basic science requirements in medical schools since the nineteenth century. Recent advances in molecular biology and biochemistry have led to an understanding of the human body and human diseases from a molecular point of view. In addition, information technology has allowed the production of stereoscopic anatomical images that visualize organs in three dimensions. These advances in knowledge and technology have led to questions about the necessity of manual anatomical dissection as an educational process in medical schools [1].

Recently, there has been growing demand for anatomical information that will enhance the safety and efficacy of surgeries and other medical interventions [2, 3]. The educational curriculum for human ana-

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tomical dissection has usually been organized as courses of systematic dissections of the vascular system, muscle system, and nervous system. In contrast, local anatomical dissection places an emphasis on the interrelationship of vessels, muscles, and nerves for vascular interventions or surgical procedures which are performed on the basis of clinical imaging modalities such as computed tomography and magnetic resonance imaging [4, 5]. Under the circumstances, it has increasingly been considered that more elements of local anatomical dissection should be taught to medical students in the course of human anatomy to prepare for their future careers. In this study, we provide an example of a local anatomical dissection in stereoscopic images from the viewpoint of ophthalmic surgery.

Methods

Layer-by-layer anatomical dissection was performed by an ophthalmologist (Toshihiko Matsuo) using the head from the cadaver of an elderly Japanese male who had no apparent head diseases. The cadaver was donated by living will to Okayama University Medical School for educational and research purposes. Before the eye globe dissection, 25-gauge trocars were inserted from the conjunctiva into the pars plana of the eye and an infusion cannula was attached to one trocar for purposes of education for transconjunctival 25-gauge trocar system vitrectomy. Panoramic three-dimensional images, their centers positioned at the center of the lid fissure, were captured by a stereoscopic camera system with viewing angles of 360 degrees in the horizontal plane and angles of up to 90 degrees in the vertical plane along the anteroposterior axis perpendicular to the frontal plane around the 360 degrees. The images were captured at 5-degree intervals on each of the 5-degree-apart meridians of the virtual sphere. The horizontal plane was set to be parallel with the frontal plane of the head, while the vertical plane was defined as perpendicular to the horizontal plane, nearly equal to the anterior-posterior axis of the eye globe. The high-definition images could be presented to viewers stereoscopically using the frame sequential technology developed by Panasonic Corporation (Kadoma City, Osaka, Japan). This study was the part of a collaborative project titled "3D Anatomy," which is being conducted by Yoshimasa Takeda and Aiji Ohtsuka at Okayama University (e-mail correspondence to 3D@okayama-u.ac.jp), together with a technical team led by Keisuke Suetsugi and Takuma Chiba at Panasonic Corporation.

Results

The planes of the anatomical dissection are summarized in Table 1. In brief, the skin (Fig. 1A) was removed to reveal the orbicularis oculi muscle (Fig. 1B), which was then removed to reveal the levator muscle and the tarsus (Fig. 1C). After the upper and lower eyelids were completely removed, the bulbar conjunctiva was visualized (Fig. 1D), and three 25-gauge trocars were placed as at vitrectomy (Fig. 1E). The cornea was removed by incision with a razor blade at the limbus, and the iris plane was shown (Fig. 1E). The lens with mature cataract was dislocated into the vitreous cavity (Fig. 1F). The eye globe was opened by scleral incision between the pars plicata and the pars plana to observe the trocars from inside the eye globe (Fig. 2A). The sclera was cut at the equator of the eye globe to observe the retina in the posterior pole of the fundus (Fig. 2B and Fig. 2C). The superior oblique muscle, passing through the trochlea, and the inferior oblique muscle, arising from the periosteum of the inferior orbital bony wall were exposed (Fig. 2B, Fig. 2C, and Fig. 2D). Their attachment sites to the eye globe were observed (Fig. 2D).

The eye globe was cut posterior to the optic disc to observe the 4 rectus muscles at the muscle cone around the optic nerve. The ophthalmic artery was also visualized (Fig. 2E). The optic nerve, together with the 4 rectus muscles, was cut at the outlet of the optic nerve canal (Fig. 2F). The thin portions of the medial orbital bone and the inferior orbital bone were easily cracked with a forceps to expose the ethmoid sinus and the maxillary sinus, respectively (Fig. 2F).

Each dissection image was viewed from the oblique angles, which were tilted up to 90 degrees along the anteroposterior axis, perpendicular to the frontal plane, which was rotated 360 degrees (Fig. 3).

Discussion

The goal of this study was to present anatomical pictures from the viewpoint of clinical ophthalmology. In general, details of the local anatomy are highly

Table 1 Step-by-step anatomical dissection

Step	View	Procedure
1	Eyelid skin (Fig. 1A)	Drape-covering around the eyelids
2	Orbicularis oculi muscle **(Fig. 1B)**	Skin removal
3	Levator muscle with Whitnall ligament, upper and lower tarsus **(Fig. 1C)**	Removal of orbicularis oculi muscle
4	Cornea and bulbar conjunctiva, lacrimal gland at superotemporal orbital bone edge **(Fig. 1D)**	Removal of upper and lower eyelids
5	Transconjunctival 25G-vitrectomy-system trocars with an infusion cannula (Fig. 1E)	Three 25G-trocars insertion
6	Iris surface with the lens with mature cataract **(Fig. 1E)**	Corneal removal by circumferential limbal incision
7	Lens dislocation into vitreous cavity **(Fig. 1F)**	Rupture of the ciliary zonules
8	Vitreous cavity, retina, and pars plana with three 25G-trocars **(Fig. 2A)**	Scleral cut at the junction between the pars plana and pars plicata, and removal of the dislocated cataractous lens
9	Vitreous cavity, retina, and pars plana with two 25G-trocars on the nasal side **(Fig. 2B)**	Scleral cut at the equator of the eyeball on the temporal side
10	Posterior pole retina with optic disc Superior oblique muscle with trochlea at the superonasal orbital bone edge and inferior oblique muscle **(Fig. 2C)**	Scleral cut at the equator of the eyeball along the entire circumference
11	Posterior pole retina with optic disc Superior oblique muscle with trochlea and inferior oblique muscle **(Fig. 2D)**	Scleral cut at the posterior pole of the eyeball
12	Four (medial, inferior, lateral, and superior) rectus muscles, and superior and inferior oblique muscles	Scleral cut around the optic disc
13	Optic nerve with sheath and ophthalmic artery **(Fig. 2E)**	Removal of 4 rectus muscles and 2 oblique muscles Further cutting of the optic nerve posterior to the exit from the eyeball
14	Periosteum of the orbital bony wall **(Fig. 2E)**	Cutting of the optic nerve and ophthalmic artery at the orbital apex
15	Ethmoid sinus and maxillary sinus **(Fig. 2F)**	Cracking of thin portions of the medial and inferior orbital bones with a forceps

important for surgery and other clinical interventions. To teach local anatomy in a more efficient way in medical schools as well as in residency programs, we recorded a layer-by-layer dissection in the form of three-dimensional stereoscopic images. The basic assumption underlying this effort was that images from real dissections would better train medical students and residents for their encounters with the actual anatomies of patients, compared with the computer graphics that are frequently used in modern anatomical education.

In the field of ophthalmology, knowledge of the local anatomy of the upper eyelid is required for levator muscle surgery for congenital and age-related blepharoptosis. Local anatomy of the extraocular muscles, especially the superior oblique muscle and inferior oblique muscle, is difficult to understand from the viewpoint of their muscle courses and attachment sites on the eyeball. The superior oblique muscle originates from the muscle cone at the apex of the orbit and has a unique structure, called the trochlea, that changes the path of the muscle in the anterior-to-posterior direction in the orbit and allows it to attach to the eyeball. The inferior oblique muscle originates from the periosteum of the lower orbital wall and attaches to the posterior part of the eyeball. These oblique muscles are surgically manipulated in patients with congenital and acquired superior oblique muscle palsy. From the viewpoint of muscle surgeries, the dissection views, approached from the eye surface with the eyeball in place inside the orbit, as demonstrated in this study, would be superior to the observation of

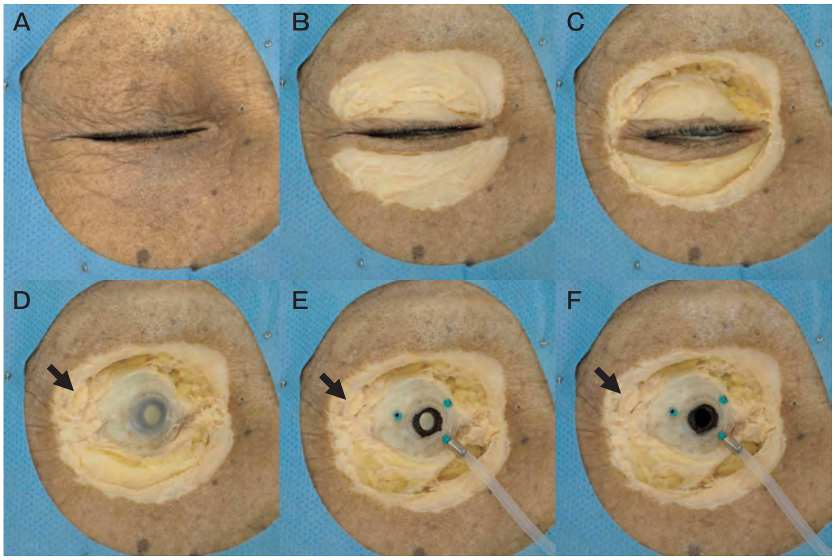

Fig. 1 Layer-by-layer dissection in the right eye. A, Eyelid skin; B, Orbicularis oculi muscle; C, Upper tarsus with levator muscle and lower tarsus; D, Bulbar conjunctiva after total removal of the upper and lower eyelids; E, Transconjunctival insertion of three 25-gauge trocars and corneal removal by incision at the limbus to observe the lens with mature cataract. An infusion cannula is attached to one trocar placed in the inferonasal quadrant; F, Dislocation of the lens into the vitreous. Note the lacrimal gland at superotemporal orbital bone edge (arrows in D, E, and F). The top sides are the upper sides in all plates.

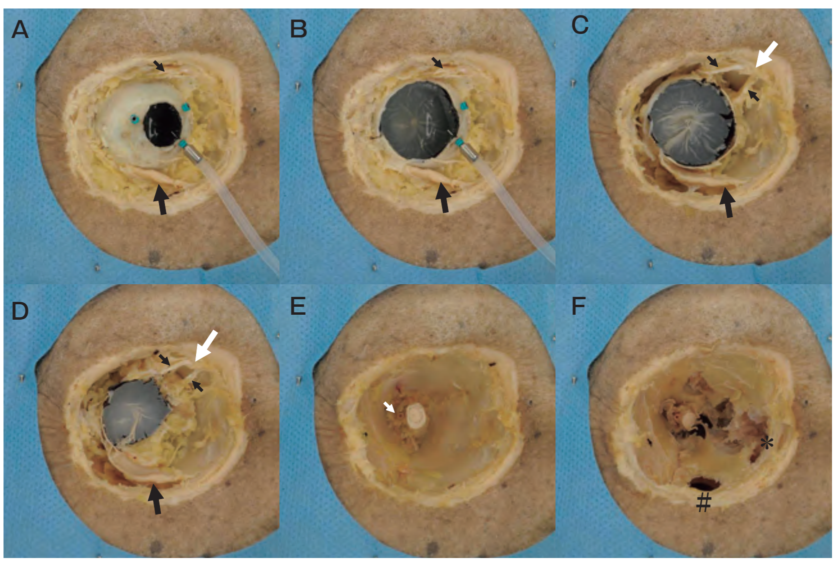

Fig. 2 Layer-by-layer dissection in the right eye, following the plates in Fig. 1. A, The sclera is cut shortly posterior from the limbus to observe the 25-gauge trocar with the infusion cannula from the inside; B to D, The sclera is further cut to observe the retina. Note the inferior oblique muscle (large black arrows) and the superior oblique muscle (small black arrows) with the trochlea (white arrow) in plates A to D; E, The optic nerve is cut posterior to the eyeball to observe the ophthalmic artery (small white arrow); F, The orbital bony walls are cracked with a forceps on the medial wall and inferior wall to observe the ethmoid sinus (asterisk) and the maxillary sinus (#). The top sides are the upper sides in all plates.

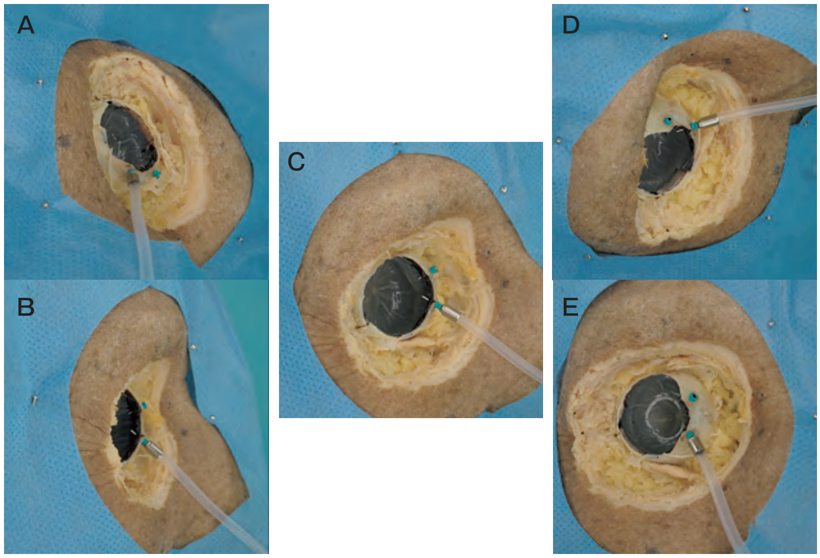

Fig. 3 Central image (**C**) of the dissection shown in Fig. 2B, viewed from oblique angles tilted up to 90 degrees along the anteroposterior axis perpendicular to the frontal plane, which can be rotated 360 degrees (**A**, **B**, **D**, **E**).

extraocular muscles of the isolated eyeball and also superior to the view from the upper side after removal of the bony orbital roof in the area of the anterior cranial fossa, as reported in the previous study [3].

In transconjunctival microincision vitrectomy surgery, it is important to understand the sites of insertion of the 25-gauge trocars from the viewpoint of the anatomical structure inside the eye globe. The sclera was therefore cut at several levels in the anterior-posterior axis of the eyeball to visualize the location of 25-gauge trocars from inside the eyeball.

In the field of otolaryngology, endoscopic surgeries in the ethmoid sinuses risk complications that can damage the medial rectus muscle [6]. In addition, accidental blunt trauma can cause an orbital bone fracture, involving the inferior orbital wall and the medial orbital wall. These clinical settings would be understandable to medical students and residents, based on the fact that the medial and inferior orbital bony walls are thin enough to crack easily with a forceps.

In conclusion, rotatable three-dimensional panoramic views of local dissection of the eyelids, eyeball, and orbital structures were developed for educational purposes. Medical students and ophthalmology residents as well as other specialty residents could use these anatomical images to clarify surgical procedures such as vitrectomy and oblique muscle surgeries, and to gain insight into the reasons why orbital bone fractures take place in the medial and inferior walls as sequelae to blunt trauma or complications of endoscopic sinus surgery. Even in the present era of three-dimensional computed tomography and magnetic resonance imaging, students and residents could learn local anatomy more thoroughly by performing actual manual dissections and reviewing cadaver-based dissection views such as those developed in this study.

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