A Singular View: The Ocularist's Role in Eye Loss Restoration and Rehabilitation

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1 The Fourth "O" in Eye Care: Ocularists

The successful rehabilitation of an individual who has lost an eye requires the attention of several eye care specialists: ophthalmologists, optometrists, opticians, and ocularists. Ocularists are eye care professionals whose task is to restore the appearance of a patient who has lost an eye to disease, trauma, or congenital malformation. Of course, eye removal is considered only after all vision-saving procedures are exhausted. Patients are generally referred by the surgeon who operated on the affected eye; they can tell the patients what to expect from the ocularist's art.

While the ocularist's work has long been considered an art form, the eye-maker's role in health care has rarely been clearly defined. An artificial eye maker creates custom ocular prostheses, or prosthetic eyes, but what we give patients can be much more: improved self-image and the confidence necessary to return to independent, productive living.

2 Introduction

The injury or surgery is the first of many challenges for a patient who loses an eye. The newly monocular may stumble when walking, have difficulty doing other everyday activities, and feel disoriented. These difficulties can last up to a year or more. Coday notes the challenges of eye loss as follows:

> Loss of a sighted eye results in loss of depth perception and a decrease in peripheral visual field. The sudden loss of vision in one eye can also result in psychological trauma and cosmetic deformity. The annual incidence of enucleation is 4.3 per 100,000. Although it has been estimated that 50,000 patients lose a sighted eye each year, the annual incidence of acquired monocular vision is probably much higher since any patient who has no light perception vision in one eye is monocularly blind. Patients who become blind in one eye as the result of glaucoma, optic neuropathies, proliferative diabetic retinopathy, intraocular tumors, expulsive choroidal hemorrhage, endophthalmitis, and chronic uveitis could all be considered to have acquired monocular vision if their other eye functions relatively well [1]. AU2

Ocularists are dedicated to caring mainly for monocular patients (Fig. 1). Members of the profession spend many hours with each patient in the course of designing, fitting, and maintaining prosthetic eyes. Patients often visit the ocularist just 4–6 weeks after eye removal surgery, when they are just beginning to adjust to the eye loss. Newly monocular patients and even many health care providers are unaware of the specific challenges of losing an eye.

3 The Main Visual Challenges of Monocularity

The sense of proprioception (knowing where one's limbs are) is unchanged after eye loss. However, monocular patients have lost an important source of spatial cues that those with binocular vision use constantly: stereopsis (depth perception). People who have never had stereopsis are adept at judging distance from monocular clues, according to neuro-ophthalmologist Steven A. Newman, M.D. He notes "Playing squash with a 1-eyed patient was not a problem, as he never had stereopsis and could easily judge the ball's distance. I also took care of one [individual] of the centers of UVA [University of Virginia] basketball who had no stereopsis, and it did not keep him from putting the ball through the hoop" [Personal communication, April 4, 2014].

Newly monocular patients, however, notice the loss of stereopsis the first time they reach for an object and miss it. Newman observes, "There is no question that patients who have become acutely monocular or have been used to stereopsis will have difficulties at the length of their arms, particularly with reaching for objects, pouring objects, etc., although, over time, this will gradually improve" [Personal communication, April 4, 2014]. It takes practice to reconcile objects' physical locations with monocular perception.

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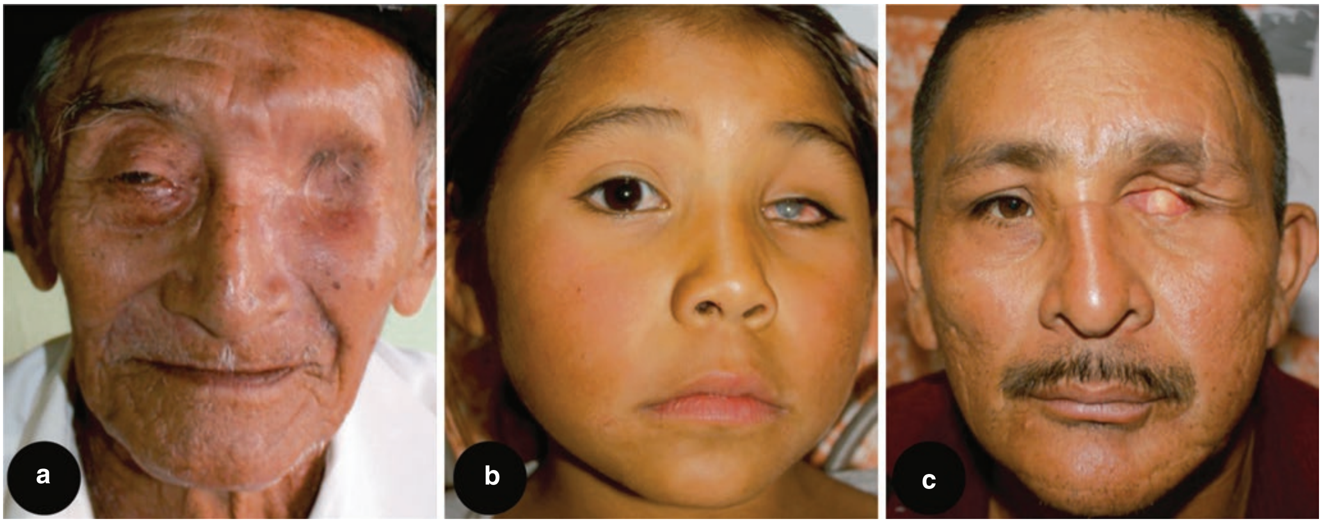


Fig. 1 Typical causes of eye loss include: (**a**) exenteration, (**b**) blindness, and (**c**) enucleation. Patients with all these conditions require prosthetic restoration. Of course, the cause of eye loss is not always as obvious as shown here

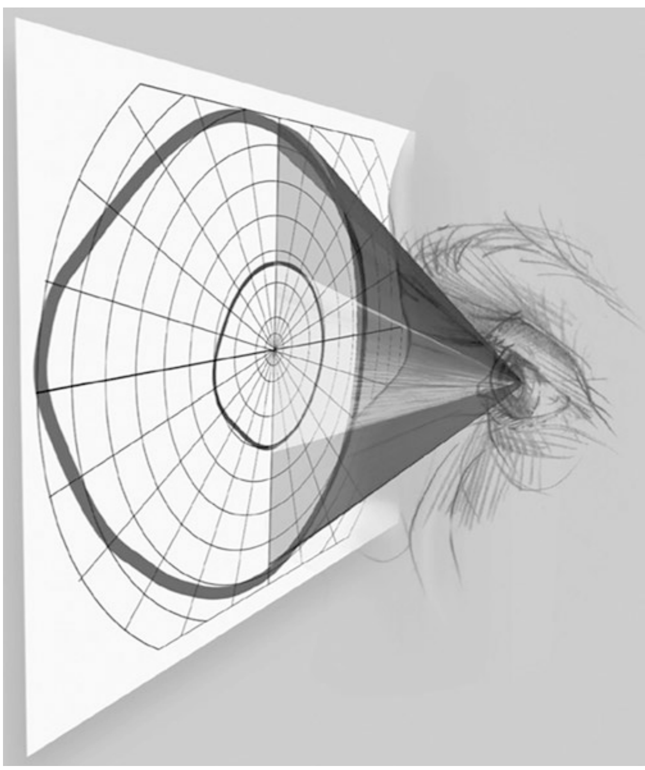


Fig. 2 The central and peripheral visual fields may be different shapes

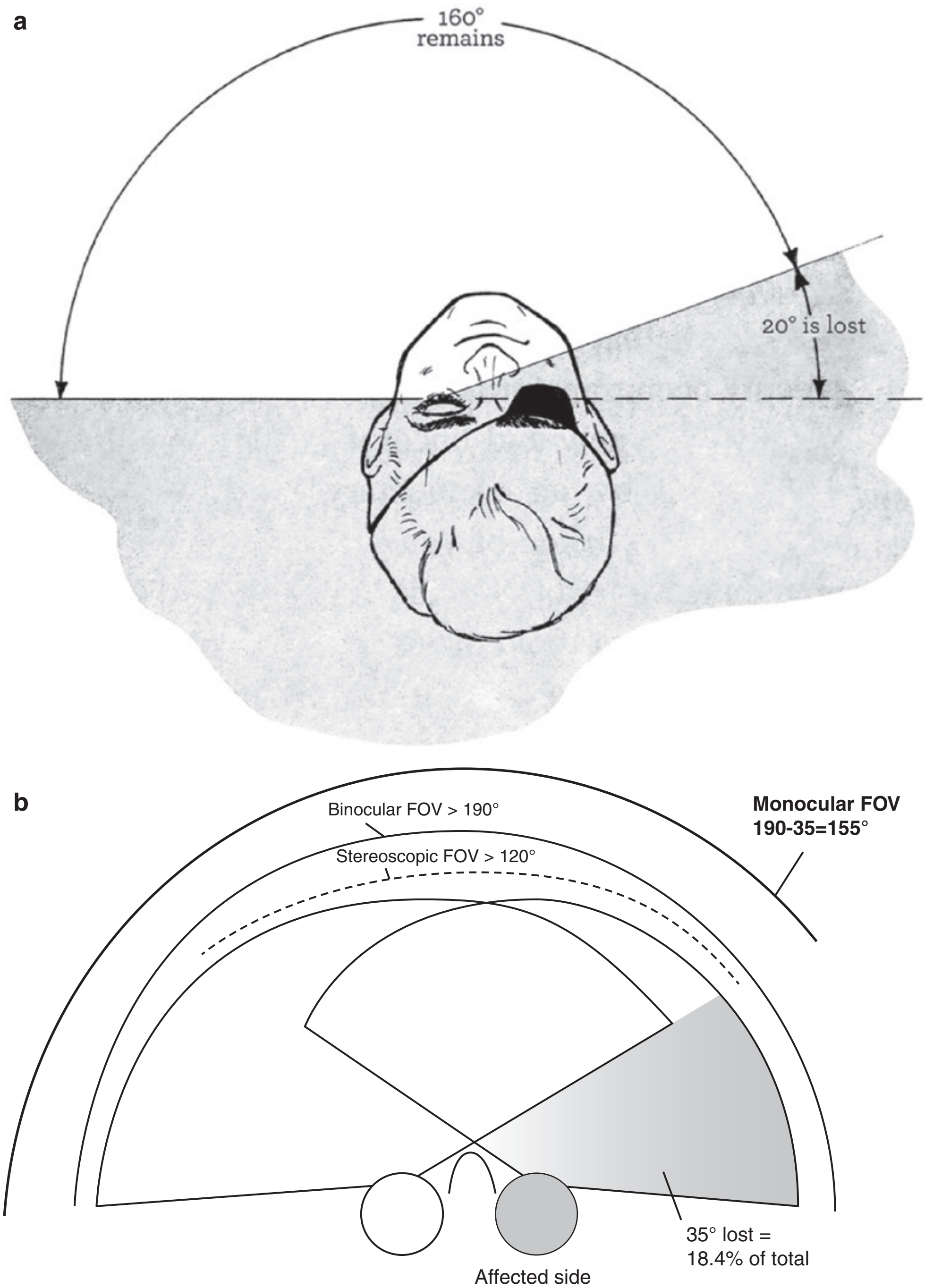
In his book A Singular View, written long after his own adjustment to monocularity, Frank B. Brady includes tips and advice on compensating for these losses. Brady found he could engage in most of the activities he had done with both eyes once he compensated for depth of field. He coped so well that, using modern instruments, he was able to pursue his passion for aviation and even fly solo again [2]. Brady was not alone; aviator Wiley Post adjusted to eye loss so well that he made the first solo flight around the world and set many other aviation records [3].

4 Visual Field Loss

A binocular field of vision includes information from the area where the eyes' visual fields overlap. As all eye care providers know, the brain assembles images from signals sent by the eye. When 2 synchronized fields are presented to the visual pathways, the brain will construct a 3-dimensional experience from the combined fields (Fig. 2) [4]. As Brady points out, the normal horizontal visual field is 180°, but a monocular person has only up to 160° because the nose gets in the way of the single working eye (Fig. 3) [4]. With these deficits, the patient with one eye sees as if they are looking through a window at a 2-dimensional picture, rather than experiencing it in 3 dimensions.

A newly monocular person may experience the world as if surrounded by optical illusions. They do not receive all the visual cues that a binocular person does because the eyes normally work together. (Some 15%–18% of binocular people do have limited depth perception) [5]. For example, the brain usually processes the difference in field signals from both retinas to alert a person that something is approaching [6]. For monocular people, although the functional eye sends a signal to the brain, there is no longer any difference to pick up [5]. Thus, monocular people are at risk of injuries that people with both eyes can easily avoid.

The monocular patient must learn to identify risks by training and experiment. Moving the remaining eye can also help the brain adapt by sending it more than one image of the



AU3 **Fig. 3** The field of view (FOV) is the area visible to the eye. Binocular humans have an FOV of about 190° and can see about 120° in stereo using both eyes. Each eye sees about 60° toward the nose and 95° to the side. Monocular FOV is 35° less than binocular FOV (95–60 = 35). This means that 35°, or 18.4% of total binocular FOV, is lost on the side of the eye loss. While the FOV is sometimes simplified to 180°, it is reasonable to conclude that maximum FOV of 190° is only available at the straight lateral, not at cheek or brow

surrounding environment [2]. This can be done by moving the head. Movement in any direction will help, but because this movement can be hard to do subtly, a vertical movement may be less obvious and appear more positive (Fig. 4).

5 Areas of Visual Field Limitation

The normal monocular visual field (VF) can be imagined as a cone extending beyond potential barriers, such as the bridge of the nose. The central visual field (what is viewed directly in the macula) accounts for only 15° of total vision [6]. Peripheral vision (normally 160–180°) (Fig. 5a) is most affected in monocular patients. It is impinged by the surrounding anatomical structures of the nose, brow, and cheek (Fig. 5b). The most central occlusion is the eyelids and lashes, which present a blurred outline. While the lower eyelid can flatten the inferior VF in down-gaze, both the upper and lower eyelids and lashes are usually seen; they also function to dispel reflected glare. As visual fields are usually tested, the area of the face that is visible defines the outer extent of the VF. In our practice, we refer to this as the facial

Fig. 4 Moving the eyes is the best way to gather subjective information about the environment. Monocular people can add movement by moving their heads. This figure shows a monocular person raising her chin slightly as she approaches a step. Depending on cultural norms, vertical head movement may be more socially acceptable and more subtle than moving the head back and forth horizontally

visual field deficit (FVFD) (Fig. 5c). It may be a different shape from the tested visual fields because it is determined by a dynamic, moving eye rather than a fixed central position, as in static perimetry. Figure 5d shows an example of the FVFD, which varies according to the shape and size of individual facial features.

In the FVFD, the nose is the largest problem area, as the sole barrier to the VF on the opposite side. The extreme example of dealing with this obstacle is from Frederico, Duke of Urbino, who directed his surgeon to remove the glabellar region of his nose after the loss of his right eye (Fig. 6). Newman notes that while VF loss has more to do with the location of retinal receptors in the remaining eye than with facial anatomy, it is possible that anatomical features, such as the nose, prominent brows, or sunken eyes, can reduce the visual field if the lids or the brow impinges close to the visual axis [Personal communication, April 4, 2014]. How much anatomical features impinge on VF depends on individual anatomy, and it is rare that patients are aware of this impingement.

6 Solutions to Visual Field Limitations

While anatomical visual field barriers are unavoidable, ocularists can avoid adding to the monocular patient's burden by helping patients find appliances that avoid further obstruction. Eyeglasses or facial prostheses that impinge on the visual fields are simply a new obstacle to monocular patients.

Some monocular patients may also wear facial prostheses. Patients may wear eyeglasses with these prostheses to disguise the seams of the appliance or help to hold it in place. Figure 7 shows both standard ocular prostheses in various materials [a–c] and oculofacial prostheses [d–f]. For monocular patients, eyeglasses also help protect the remaining natural eye. However, both the glasses and any facial prostheses are also VF barriers, so it is important to select frames for minimal interference with the patient's VF.

Unfortunately, most eyeglass frames are designed primarily for fashion or fit (Fig. 8), not to minimize VF limitations. Tips for choosing eyeglasses include limiting frame elements that fall within the FVFD (usually in the nasal inferior area). Though some elements of the eyeglass frames will be within the FVFD (usually nasal-inferior), those elements in the VF should be limited. (Figure 7e shows bulky eyeglass frames that help hide the margins of the prosthesis but may also limit the VF). The brain unconsciously fills in most of the details from the blocked area, just as it does in the blind spot over the optic disk.

Most tests of vision and VFs are done to reveal changes in the visual fields over time, rather than to demarcate the FVFD. It may be necessary to refer the patient to an ophthalmologist or optometrist to delineate the full VF. Perimetry (the demarcation of VFs) can now be performed by an automated instrument in less than 3 min, though full VF testing takes much longer. Alternatively, the patient's FVFD may be evaluated and drawn directly on the face with a temporary water-soluble marker, as shown in Fig. 5d.

Ocularists and other eye care professionals may also share practical guidance to help monocular patients compensate for visual field deficits, as shown in Fig. 9. Monocular patients and those with other visual impairments may find digital media more challenging than audio or large print instructions. This is not necessarily caused by monocularity itself. In our practice, we have observed that patients with eye loss often belong to older age groups that may use digital media less frequently than the young or working-age populations.

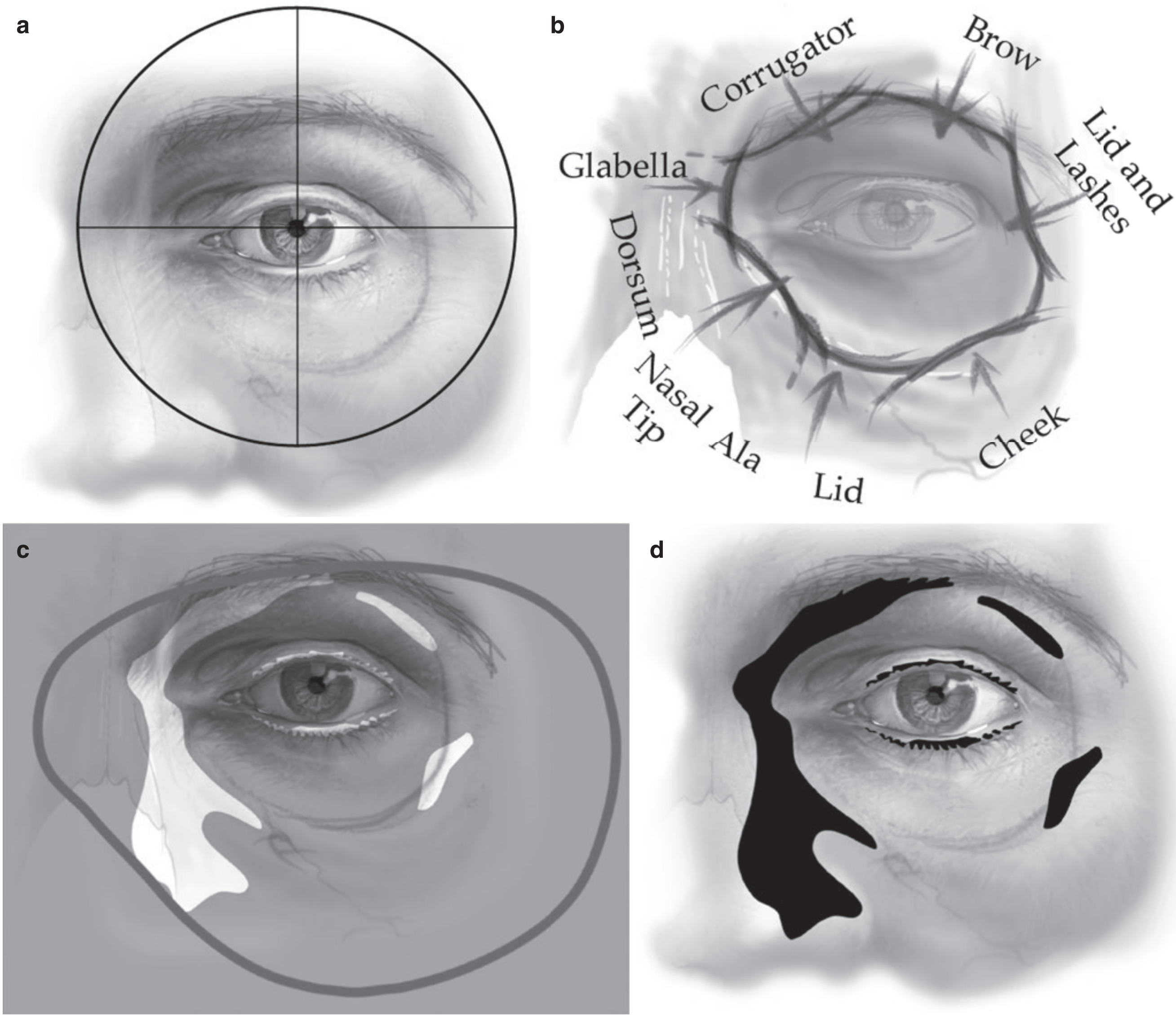


Fig. 5 The visual field (VF) and facial visual field deficits (FVFD). (**a**) The theoretical cone of the VF as centered on the pupil. (**b**) The anatomical structures shown impinge on the VF of a single eye. (**c**) Facial visual field deficits (FVFD) are caused by anatomical barriers inside the visual field. (**d**) FVFD mapped on the skin. The deficits are different for each patient. Ocularists, anaplastologists, and optometrists should avoid prosthetics or appliances that enlarge these deficits, if possible. The area of the eyeglass frame is subtracted from the FVFD shown

A surprising observation is that quite often, even surrounding a difficult diagnosis and treatment, many individuals are more concerned with their appearance following eye loss (evisceration, enucleation, exenteration) surgery than their medical condition.

7 Reconstruction Following Eye Loss

While evisceration, enucleation, and exenteration all entail the removal of eye tissue, enucleation, the removal of the eyeball from the orbit, remains the most common procedure. Evisceration and enucleation are generally followed by insertion of an ocular implant. To be effective, the implant must reasonably reproduce the volume, position, and motility of the natural eye; it must retain a covering suitable for lubrication, and it must neither migrate nor extrude.

The size, material, and placement of the implant depend on the surgeon's work and the patient's needs. Generally, a smaller implant is used when it is placed within the eyeball or its fascial capsule (Tenon's capsule) or when it is wrapped in another material. To increase covering tissue thickness, the implant is often placed behind the posterior Tenon's capsule (see Fig. 10).

Proper sizing of the implant is crucial: too small an implant will cause possible migration, enophthalmos, or a

Fig. 6 Frederic, Duke of Urbino, had the glabellar portion of his nose removed to reduce the visual field deficit caused by his eye loss. We cannot recommend this elective procedure. (Illustration by C.A. Luce based on four known portraits)

deep sulcus. If too large an implant is used, pressure on the front of the implant may increase the risk of wound dehiscence, erosion, or implant exposure and infection. It is ideal for the ocular implant to provide 65–70% of the volume of the lost eye, with the remaining volume taken up by the ocular prosthesis.

In evisceration, the sclera remains, while in enucleation, the extraocular eye muscles are either attached to the implant or cross-sutured and the anterior tissues (Tenon's and conjunctiva) closed without tension. Two of the more difficult challenges for ophthalmologists and ocularists are superior sulcus deformities from inadequate orbital volume and eyelid ptosis or laxity.

8 The Ocularist's Work

Prosthetic eyes are often called "glass eyes" because, before the development of polymethyl-methacrylate plastics in the 1940s, prosthetic eyes and ocular implants were generally made of hand-blown glass, a technique that dates to the mid-1800s. (Cryolite glass is still used in parts of Eastern Europe).

The initial visit to the ocularist usually takes place 6 weeks after surgery. Most ocularists begin by obtaining an alginate (gel) impression of the eye socket, the sensitive tissue which will house the prosthetic eye. (Although this is a painless procedure, some younger patients may find the one-minute setting time uncomfortably long.) While careful post-surgery observation by other professional "Os" in eye care is often assumed to provide adequate evaluation of the socket,

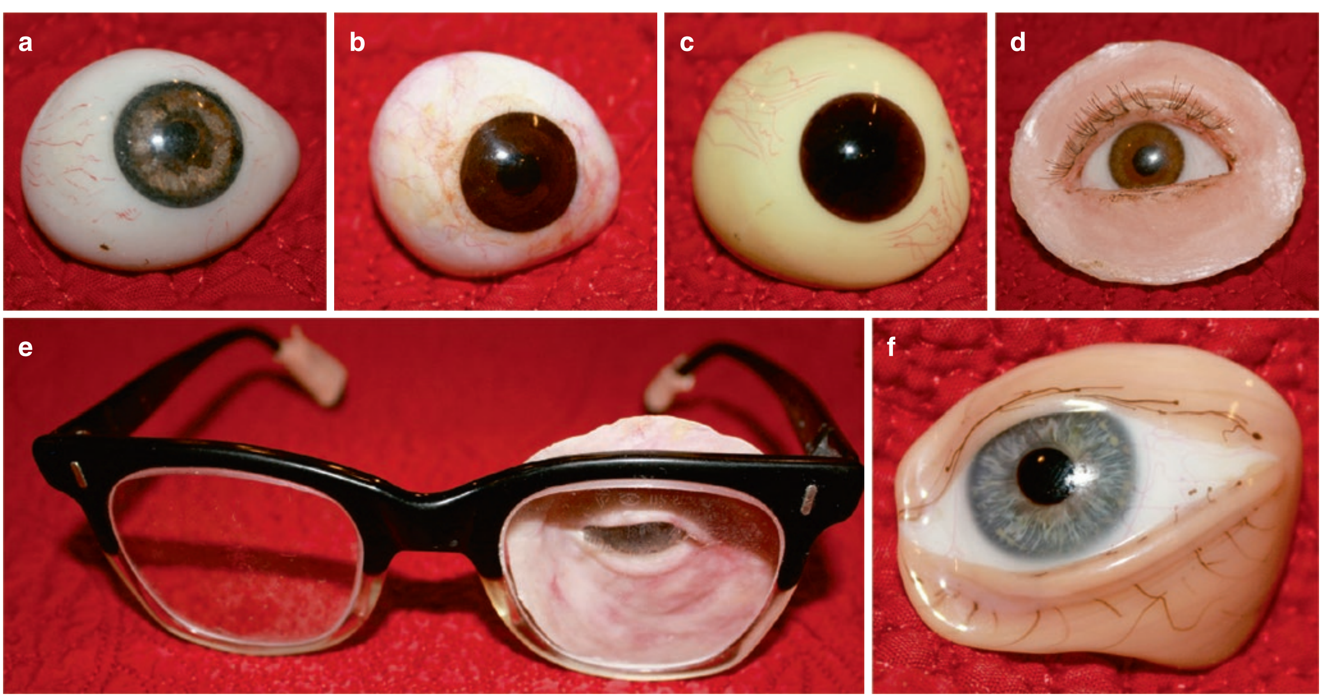


Fig. 7 Common prostheses and materials, including: (**a**) silicone ocular prosthesis, (**b**) acrylic (PMMA) ocular prosthesis, (**c**) glass (cryolite) prosthesis, (**d**) silicone orbital prosthesis, (**e**) acrylic orbital prosthesis attached to eyeglasses, and (**f**) glass orbital prosthesis

Fig. 8 This collage shows a patient with a prosthetic right eye wearing some of the many eyeglass styles available. As the photos show, eyeglasses can complement a patient's appearance and camouflage eye conditions, including ptosis and superior sulcus problems, but frames can also obstruct peripheral vision. Style may take priority over function, especially for younger patients. The ocularist and optometrist can help the patient balance these priorities

many irregularities are only discovered when the alginate mold (or "impression") of the healed socket made in the ocularist's office is examined. Though most swelling has usually subsided by this time, only after 3 or 4 months is the healed socket's shape stabilized.

Duplicating the socket shape precisely reduces irritation of the conjunctiva and maximizes the movement of the finished eye. When the proper fit is achieved, the lubricating tear system often operates normally. After the impression and fitting of a wax pattern, the resulting shape is cast in plastic.

Several factors are important in successfully fitting a patient with a prosthetic eye. For the most natural appearance, it is essential to simulate the iris of the companion eye.

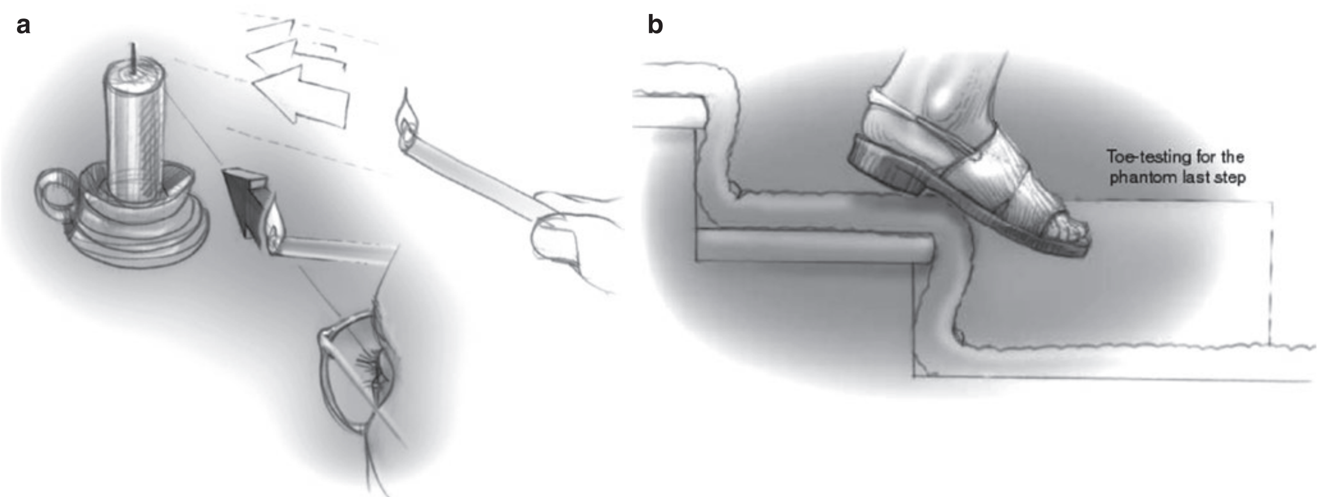


Fig. 9 The ocularist is a source of practical guidance on learning to live with one eye. For example, (**a**) Lining up the working eye with a target like the candle shown here can help a monocular person reach that target correctly. (**b**) Monocular people must learn new ways to navigate even familiar spaces, such as using the feet to feel for the end of a staircase

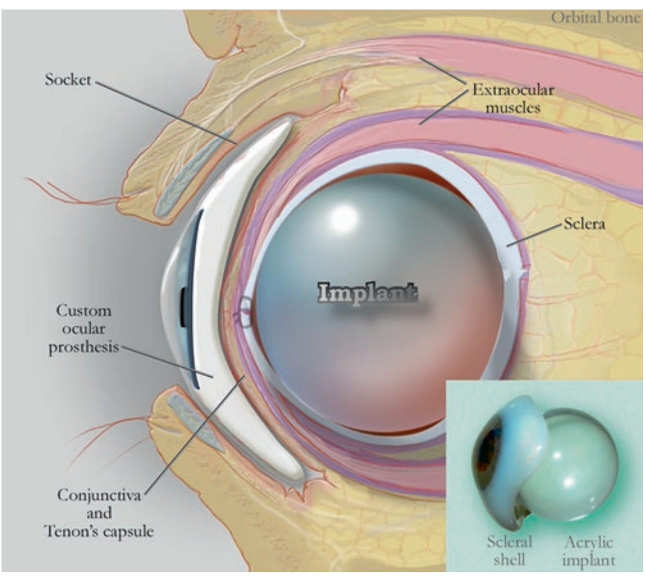


Fig. 10 Illustration depicts a left post-evisceration eye socket in the parasagittal section. The implant replacing the volume of the eye is placed inside the sclera. In front of the repositioned conjunctiva, the custom-made prosthesis is placed under the eyelids

This requires a 3-dimensional effect. Because the human iris is living tissue, bathed with ocular fluids and moving naturally, the ocularist can only aim to simulate its appearance, not duplicate it completely. Hand painting both the iris and sclera using a combination of pigments and liquid plastics is the most common practice in replicating the eye with a prosthesis.

After fitting the eye, the ocularist hand-paints the iris and sclera using direct observation of the patient's unaffected eye, mixing a variety of pigments, lacquers, or oils onto the acrylic shape bonded with liquid acrylic (see Fig. 11). The painting is sealed with acrylic, and a cornea of clear plastic is cast and cured under heat and pressure. Polishing the eye to a flawless surface ensures there will be smooth eyelid movement and no recesses to accommodate flora.

Mass-produced, digitally printed eyes with painted or digitally printed irises have become increasingly popular in recent years. While digital printing is not new, the quality has improved greatly from its earliest days. While it is virtually impossible to create a mirror image of the companion eye due to the infinite array of iris colors and textures, digital irises provide excellent approximate matches. Minimal touch-up and overpainting allow an even closer match while saving time for the practitioner. Digital iris buttons may be most appreciated in cases where patients need bilateral ocular prostheses and 2 matched irises are needed.

When the finished eye is inserted, the patient is given a mirror to see the restored image (see Fig. 12). Care of the prosthetic eye is simple; new patients are often surprised to learn that they need not remove it for routine washing. A cleaning and polishing by the ocularist during each annual examination are sufficient.

Refinements in surgical procedures, ocular implants (including materials) and custom hand-painted prostheses have made great improvements in the cosmesis and comfort of prosthetic eye wearers.

9 Conclusion

Patients with acquired monocular vision often experience a lengthy process of adjustment to monocularity and prosthetic restoration. Health care professionals must accom-

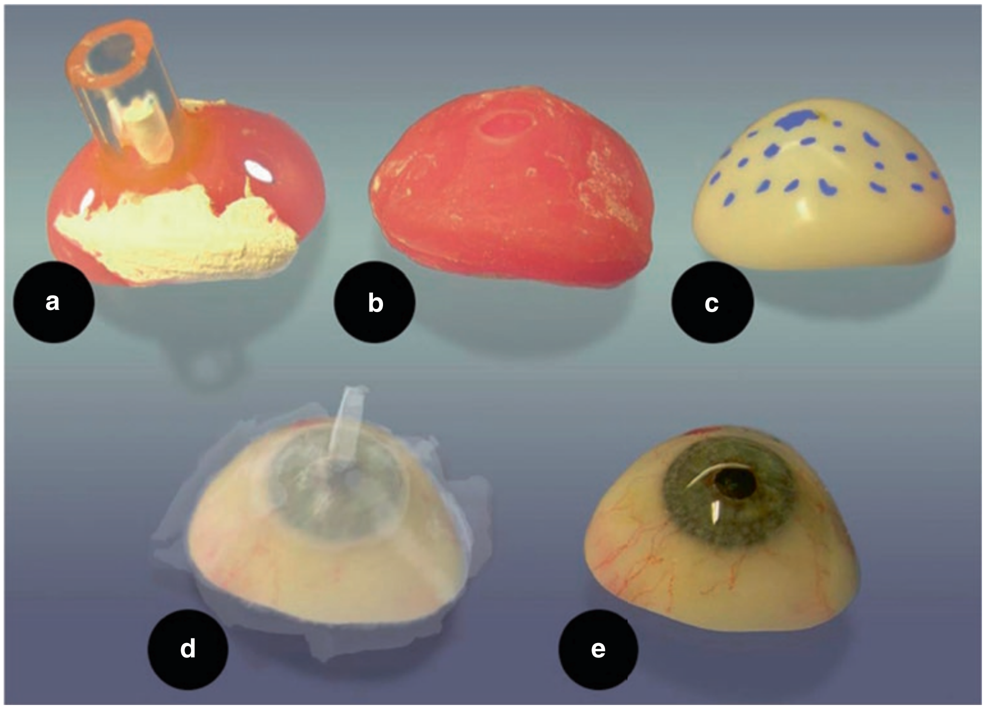


Fig. 11 The process of fabricating an artificial eye in acrylic, as seen in stages: (**a**) The gel impression (negative) of the socket. (**b**) The wax pattern cast from the impression and fitted further. (**c**) An acrylic shape sized to the socket and refined as to gaze. (**d**) The painted prosthesis just out of the mold and before polishing. (**e**) The final prosthesis ready to insert

Fig. 12 Monocular patient with a successful OS prosthesis

modate these patients' needs as they prescribe and create appliances for functional and cosmetic rehabilitation, including ocular and maxillofacial prostheses and eyeglasses. Anything applied to the face must limit the visual field as little as possible, whether it is an appliance or a necessary eyeglass frame. As formal studies may never be published, it is suggested that any appliance that might impinge on a monocular patient's visual field should be tested, possibly in consultation with an eye care provider, documented directly on the face, or both. With time, attention to detail, and awareness of educational resources, anaplastologists and ocularists can serve patients' needs for as complete a functional and cosmetic recovery as possible.

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References

1. Coday MP, Warner MA, Jahrling KV, Rubin PAD. Acquired monocular vision: functional consequences from the patient's perspective. Ophth Plast Reconstr Surg. 2002;18:56–63.
2. Newman SA. Wiley post and visual standards for pilots. Surv Ophthalmol. 2014;59(3):373–4. https://doi.org/10.1016/j.survophthal.2013.08.004. Epub 2013 Dec 22.
3. Brady F. A singular view: the art of seeing with one eye. 1st ed. Oradell, NJ: Medical Economics Co.; 1972.
4. Montés-Micó R. Prevalence of general dysfunctions in binocular vision. Ann Ophthalmol. 2001;33:205–8.
5. Kandel E, Schwartz J, Jessell T. Principles of neural science. 4th ed. New York: McGraw-Hill; 2000. p. 515–20.
6. Journal of Ocular Prosthetics. American Society of Ocularists. http://www.ocularist.org/resources_journal.asp. Accessed 9 November 2010.
7. Bosniak SL, Smith BC, editors. Advances in ophthalmic, plastic and reconstructive surgery. Vol 8: The anophthalmic socket. New York: Pergamon Press; 1990.
8. Brady F. A singular view: the art of seeing with one eye. 8th ed. Vienna, VA: Michael O. Hughes, Neill Hughes; 2020.
9. Erph SF, Wirtz MS, Dietz VH. Plastic-artificial-eye program, U.S. army. Am J Ophthalmol. 1946;29:984–92.