1 Introduction to Approaches and Modalities in Postoperative Orbital Imaging

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1.1 Overview

Determining if and when diagnostic imaging is required following ophthalmic and orbital surgery is very much an art. The primary radiological imaging modalities include radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound. Each of these modalities has certain advantages and disadvantages as described below. Often the different imaging modalities serve complementary roles, and familiarity with each of these is important for optimal management. In many cases, the indications and suitable modalities are similar to those for preoperative imaging, and the *ACR Appropriateness Criteria® orbits, vision and visual loss* offers general guidelines. More detailed information is also provided in the subsequent chapters in this text. Ultimately, familiarity with the basic anatomy of the eye and orbit and the alterations that may result after treatment is critical for interpreting the imaging studies.

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1.2 Radiography

Radiographs of the orbits may be helpful in the postoperative setting in particular situations, such as confirming the position of certain punctal plugs and evaluation of eyelid spring function and integrity. Radiographs may be used to screen patients with suspected metal implants from surgery prior to undergoing an MRI (Fig. 1.1). Typically, at least 2 orthogonal views are obtained in order to localize structures, including the occipitomental view (Waters view), which helps to separate the orbits from the maxillary sinuses. Radiographs may also be obtained during dacryocystography procedures, in which contrast material is injected into a canaliculus to assess the lacrimal drainage system patency (Fig. 1.2). Dacryocystography can also be performed in conjunction with CT or MRI to further delineate surrounding anatomy (Fig. 1.3).

D.T. Ginat, S.K. Freitag (eds.), *Post-treatment Imaging of the Orbit*,
DOI 10.1007/978-3-662-44023-0_1, © Springer-Verlag Berlin Heidelberg 2015

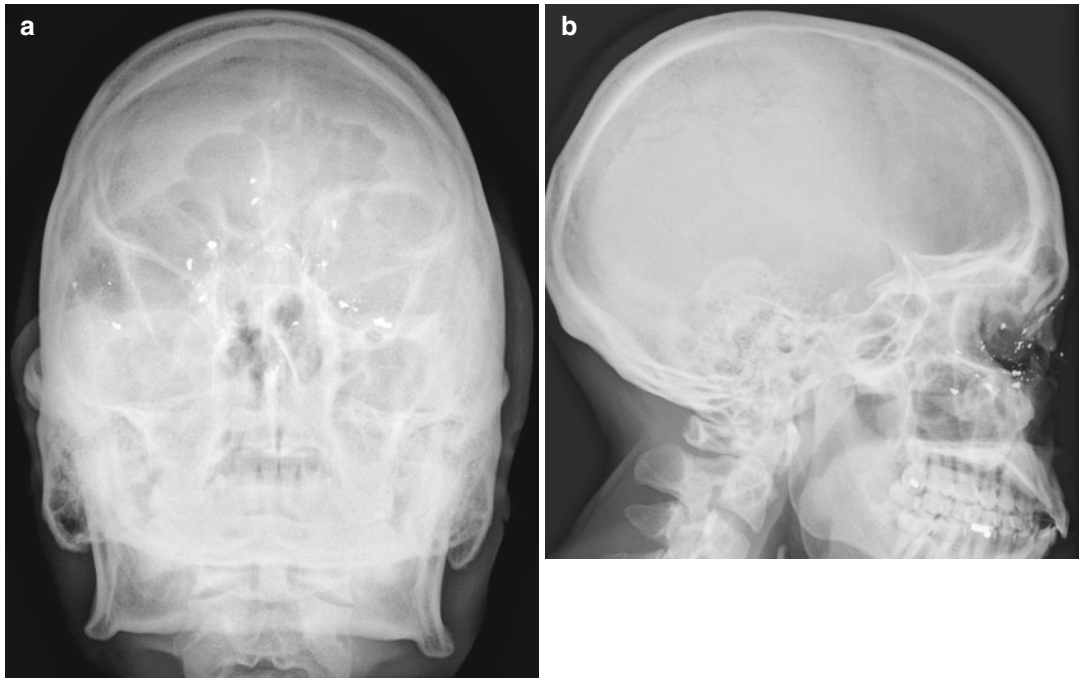

Fig. 1.1 Face radiographs. Waters (**a**) and lateral (**b**) projection radiographs show multiple radiopaque metallic bullet fragments in the bilateral periorbital soft tissues, which remained after orbital and facial reconstructive surgery

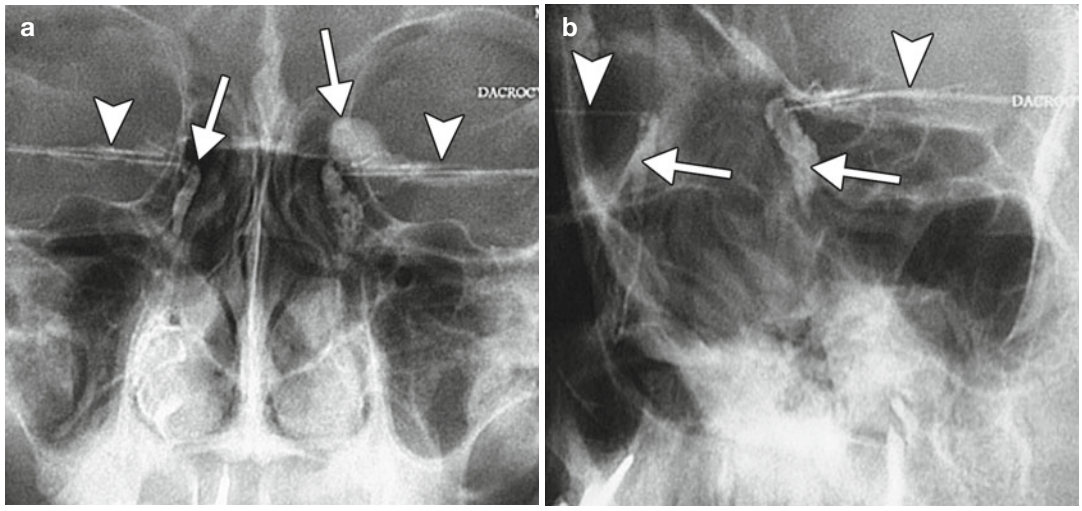

Fig. 1.2 Fluoroscopic dacryocystography. Frontal (**a**) and oblique (**b**) radiographic images show bilateral canalicular catheters (*arrowheads*) and contrast material within the bilateral nasolacrimal system (*arrows*), but no free spillage into the nasal cavity, suggestive of obstruction

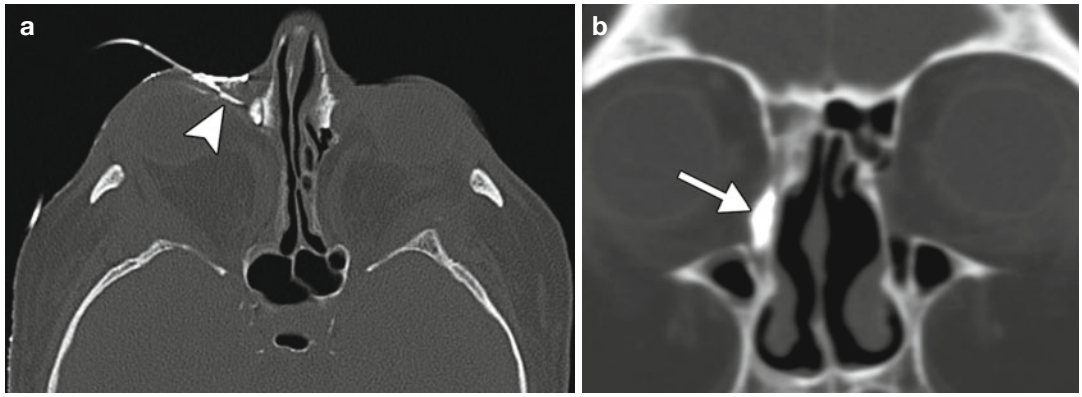

Fig. 1.3 CT dacryocystography. Axial CT image (**a**) shows the catheter and contrast material within the right inferior canaliculus (*arrowhead*). Coronal CT image (**b**) shows contrast within the right lacrimal sac (*arrow*)

1.3 Computed Tomography

Orbital CT is typically acquired with thin axial sections (0.6–1.0 mm) from which coronal and sagittal reformatted images are generated and displayed in both soft tissue and bone algorithms (Fig. 1.4). Thus, CT is well suited for delineating the osseous structures and the positioning of many types of orbital implants in fine detail. 3D surface renderings can be a useful adjunct for visualization of the implants. Except for stainless steel, tantalum, and certain embolization materials, such as Onyx, orbital implants generally do not produce significant streak artifact. In addition, CT is often obtained in emergency situations due to its rapidity, widespread availability, and ability to safely screen for metallic foreign bodies. Administration of iodinated contrast can be useful for evaluating suspected infectious and inflammatory processes and tumors. Contrast is also necessary for performing CTA and CTV, which may be useful for evaluating the status of carotid cavernous fistulas and other vascular lesions after treatment. However, contrast is not necessary for assessing the positioning of implants. Furthermore, in patients with thyroid eye disease, iodinated contrast can aggravate thyroid orbitopathy.

1.4 Magnetic Resonance Imaging

Compared with CT, MRI offers superior soft tissue delineation and no exposure to ionizing radiation, which is particularly important in the pediatric population. Prior to obtaining a scan, it is important that patients are screened for MRI compatibility. A useful reference for determining whether certain implants are MRI compatible can be found at http://www.mrisafety.com/. Other factors that may limit the application of MRI include severe claustrophobia and obesity exceeding table weight limit. The main sequences obtained in orbital MRI are T1-weighted and T2-weighted sequences in multiple planes, including axial, coronal, and sagittal (Fig. 1.5). Administration of gadolinium-based contrast for T1-weighted sequences is useful for defining infectious and inflammatory processes, as well as residual tumors (Fig. 1.6). Implementing fat-suppression techniques with T2 and post-contrast T1-weighted sequences is also helpful for better defining lesions against the hyperintense background of the orbital fat. Many fat-suppression techniques are prone to failure near the air-filled sinonasal cavities due to susceptibility effects, which may lead to misinterpretation. However,

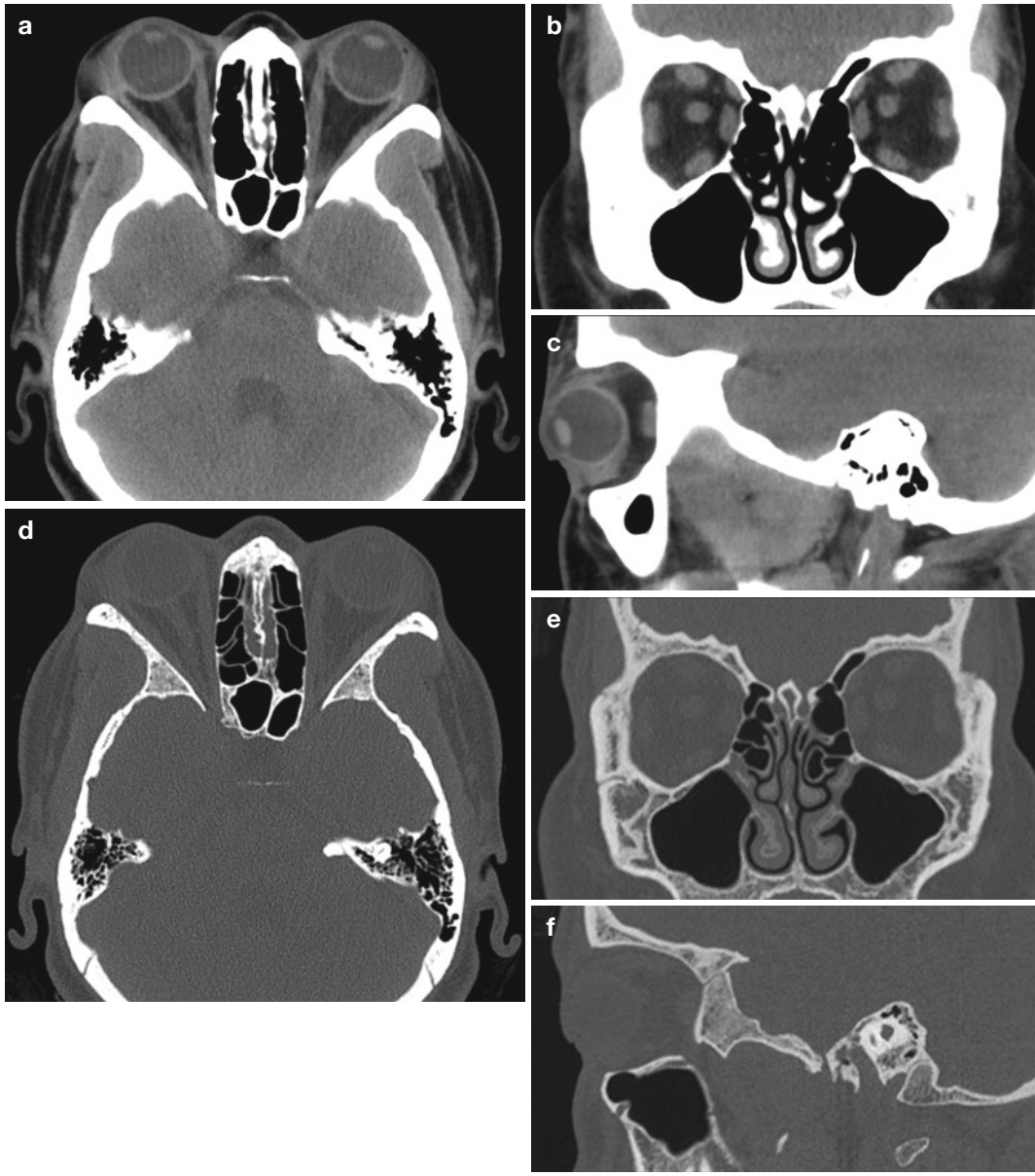

Fig. 1.4 Standard orbit CT images. Selected axial (**a**), coronal (**b**), and sagittal (**c**) soft window images and axial (**d**), coronal (**e**), and sagittal (**f**) bone window images of normal orbits

certain techniques such as Dixon and inversion recovery are less prone to such artifacts. The use of high-resolution microscopy surface coils can yield in-plane resolution of 312 μm and the display pixel dimensions of 156 μm even at 1.5 T. As a result, it is possible to obtain a detailed view of the orbital structures and globe, including Tenon's capsule, tarsal plate, ciliary body, lens zonules, and components of the superior rectus-levator complex. The use of diffusion-weighted imaging in orbital imaging for indications such as monitoring treatment response in tumors remains investigational at the time of this writing. Likewise, the utility of cine (oculodynamic) MRI

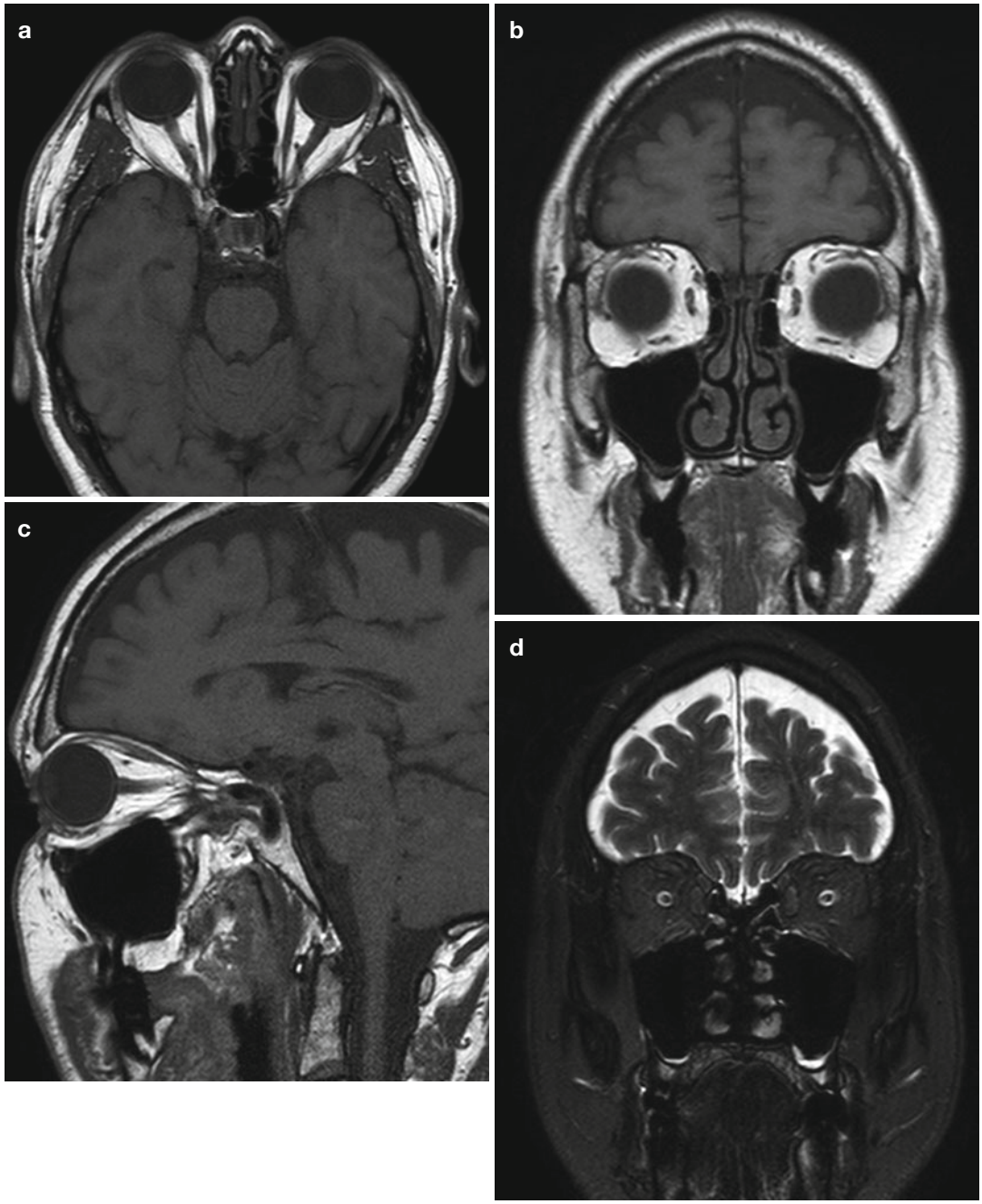

Fig. 1.5 Basic orbit MRI sequences without contrast include axial (**a**), coronal (**b**), and oblique sagittal (**c**) T1-weighted and coronal fat-suppressed T2-weighted (**d**) images

techniques for depicting the motion of the extraocular muscles in the postoperative setting is promising, but requires further validation. MRA can be used as a noninvasive method for evaluating patients after stenting and/or embolization of vascular lesions. Time-resolved MRA provides a higher quality imaging of the treated parent vessels compared with time-of-flight imaging.

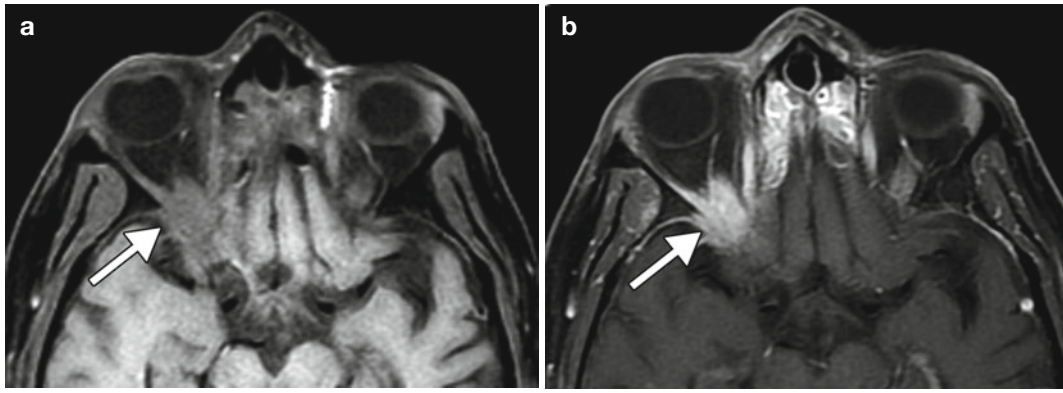

Fig. 1.6 Contrast-enhanced MRI for recurrent tumor assessment. Axial fat-suppressed T1-weighted image (**a**) and post-contrast axial fat-suppressed T1-weighted image (**b**) show an ill-defined, avidly enhancing tumor (squamous cell carcinoma) in the orbital apex (*arrows*)

1.5 Ultrasound

Ultrasound is an important imaging modality that is used for the initial clinical work-up and follow-up of many ophthalmic diseases, as it is relatively inexpensive to perform and readily available to ophthalmologists. The examination entails applying the surface of the probe or transducer to closed eyelids in contact with a gel or immersion fluid. Since a mild amount of pressure is applied to the globe, ultrasound examinations are contraindicated in patients with a possible open globe. Nevertheless, ultrasound is a versatile modality that is particularly well suited toward the evaluation of the intraocular contents, which is a relative limitation of CT and MRI. B-mode ultrasound is commonly performed, which provides a cross-sectional grayscale representation of the globe and surrounding structures in different planes, such as transverse and longitudinal (Fig. 1.7). The aqueous and vitreous are normally nearly anechoic on ultrasound and readily allow passage of the sound waves, while interfaces, such as the eye wall, tend to appear hyperechoic and may even cause shading in some cases. The in-depth spatial resolution that can be achieved with sonography is primarily dependent upon the frequency emitted by the transducer. The use of frequencies of 50 MHz and higher is known as ultrasound biomicroscopy, which can depict anatomic structures in exquisite detail, particularly in the anterior chamber and angle (Fig. 1.8). Another ultrasound modality is color Doppler imaging, which consists of simultaneous grayscale imaging of structure and color-coded imaging of blood velocity. This technique enables depiction of moderately small-caliber blood vessels, such as the central retinal artery, from which measures of blood velocity and vascular resistance can be obtained. The use of intravascular contrast agents, such as microbubbles, in orbital imaging is mainly investigational at the time of this writing, although these may have promising and intriguing applications in the realm of molecular diagnosis, therapy, and theranostics.

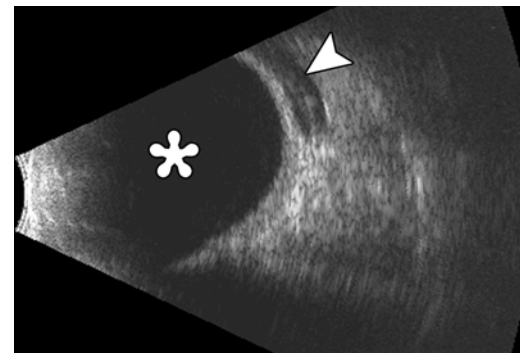

Fig. 1.7 B-mode ultrasound image of a patient with glaucoma drainage device (*arrow*). The vitreous body (*) is anechoic

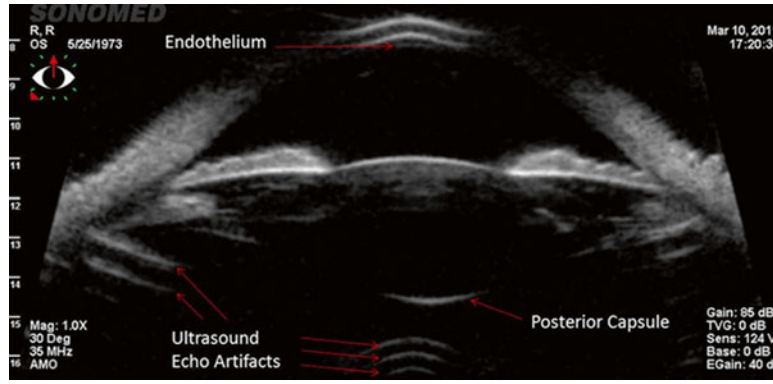

Fig. 1.8 Anterior-segment ultrasound biomicroscopy image depicting normal anatomy

1.6 Optical Coherence Tomography

Optical coherence tomography (OCT) is an optical imaging modality that performs low-coherence interferometry in order to create high-spatial axial resolution, cross-sectional, subsurface tomographic images of tissue microstructure. Thus, OCT is a valuable imaging tool for assessing and guiding the management of surgical complications after such procedures in the anterior chamber and retina. The modality uses infrared light waves for imaging and can provide a spatial resolution on the order of approximately 2–20 μm. OCT can function using time-domain or frequency-domain technology, which has applications in anterior segment as well as vitreoretinal imaging. The first-generation OCT machines used time-domain technology for signal processing allowing for acquisition of approximately 2,000 linear "A-scans" per second. This slow acquisition speed leads to poor resolution and motion artifact. The newer spectral-domain OCTs allow for faster and greater acquisition volume, performing in excess of 30,000 linear "A-scans" per second. These linear scans are then assembled together to create a two-dimensional "B-scan" which are the images seen through this text. Although three-dimensional reconstruction is available, if is of limited clinical utility due to current computer processing speeds. Nevertheless, this feature is useful when the volume of a lesion is a concern. A 1,310 nm wavelength is the standard light used in the Visante anterior-segment OCT (Carl Zeiss Meditec, Dublin, CA). Most other OCT scanners use 820–840 nm wavelength light. The 820–840 nm wavelength range yields excellent penetration and little absorption by water. This is a desirable feature for the examination of the retina. On the other hand, the 1,310 nm wavelength is subject to greater absorption by water and significantly more scattering. This results in approximately 20-fold reduction in its exposure to the retina, and thus, higher power can be utilized. The high signal intensity allows for faster image acquisition, which is associated with a reduction in motion artifact. Additionally, the 1,310 nm has the capacity to penetrate through partially opaque tissues, such as sclera and opaque cornea. Ultimately, OCT is a versatile imaging modality that is portable and does not require contact with the globe. This modality can provide detailed images of the scleral spur, ciliary body, ciliary sulcus, and even the canal of Schlemm in some cases (Fig. 1.9). In a well-centered cross-sectional scan, the reflection from the anterior vertex of the cornea can saturate the imaging system and produce a vertical flare. This phenomenon helps with the identification of the corneal vertex, from which central corneal thickness measurements and measurements of central graft thickness can

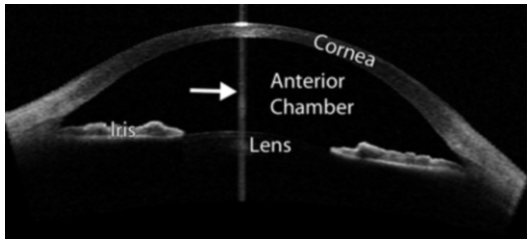

Fig. 1.9 OCT image of the anterior segment depicting normal anatomy. A vertical flare emanating from the apex of a well-centered cornea is present (*arrow*)

be obtained. The OCT images can also be displayed in "rainbow" color in order to visually enhance tissue contrasts. There are several limitations associated with OCT ocular imaging. For example, standardized protocols for image acquisition and quantification are often lacking, assessment of optical density and reflectivity is only qualitative, and there is often insufficient specificity to distinguish among different types of tissues.

1.7 Scheimpflug Optical Imaging

Pentacam-Scheimpflug imaging is a method used for anterior-segment imaging, whereby a central beam of light is shined on the eye. A camera (or two in some devices) placed at 45° angle takes a photograph, and then through ray tracing, the measurements on the image are generated. The slit beam and the camera are on a rotating drum that can produce a tomographic representation of the anterior segment. The commercially available units use an LED of 475 nm blue light. Scheimpflug imaging can produce detailed characterization of anterior-segment structures and can measure net corneal power, a feature particularly useful for cataract patients having undergone previous corneal surgery (Fig. 1.10), as well as provide quantitative information on the geometry of the lens. However, this modality is susceptible to image degradation by opacified tissues, which block or reflect light in the visible spectrum, among other artifacts (Fig. 1.11).

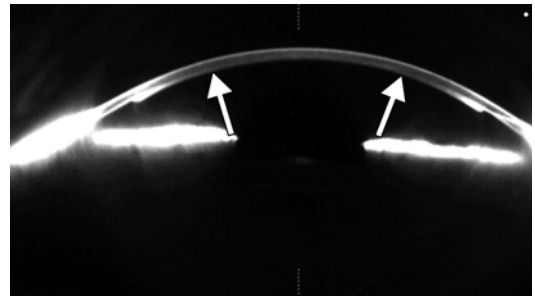

Fig. 1.10 The Scheimpflug image delineates the corneal graft (*arrows*) following successful DSEK operation

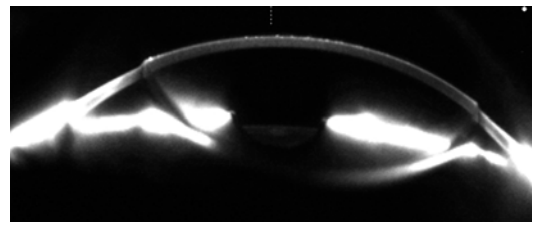

Fig. 1.11 Artifacts with Pentacam-Scheimpflug image of the anterior segment. The image was acquired with a hard contact lens on the cornea. Due to the 45° placement of the camera off the central axis beam of light, the edge of the hard contact lens and the associated optical distortions are evident

1.8 Summary

- Several imaging modalities are available for the evaluation of the orbit and globe after treatment, including radiographs, dacryocystography, CT, MRI, B-mode ultrasound, ultrasound biomicroscopy, optical coherence tomography, and the Scheimpflug camera.
- Each of these imaging modalities has advantages and disadvantages, and they may sometimes have complementary roles for evaluating certain conditions.
- The posttreatment imaging findings on the various modalities are reviewed and depicted in the subsequent chapters.

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