8 Clinical Refraction

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Postoperative refraction is one of the most important factors in determining the accuracy of intraocular lens (IOL) power calculation, as it plays a major role in the evaluation of each IOL formula and in the optimization of the IOL constant. Despite newer formulas, techniques, technologies, and IOL selections, patients still have postoperative refractive errors. This is where the method of back calculation using these postoperative refractions to evaluate and improve the accuracy of the next preoperative IOL power calculation can come into play. In addition, it has been reported that one of the three major sources contributing to the error of the IOL power calculation is the postoperative (PO) spectacle refraction [1]. Therefore, the most accurate PO refraction is essential to prevent future suboptimal refractive outcomes.

The accuracy of the IOL formula is usually evaluated by determining the prediction error (PE) [2] which is the difference between the predicted refraction from the IOL power implanted and the actual PO refraction. It is important to understand that this is not the same as the target refraction desired by the surgeon. For example, if the target refraction is −2.00 D and the IOL formula recommends a +22.0 D IOL with the prediction of the postoperative refraction of −2.15 D and the actual postoperative refraction is −2.25 D, then the prediction error (PE) is +0.10 D [(−2.15) − (−2.25) = (+0.10)]. The target refraction has nothing to do with the prediction error (PE).

Furthermore, optimization of the IOL constant also requires accurate postoperative refraction [3]. There are several methods for optimizing the IOL constant. For example, it can be calculated using the iterative method in which the IOL lens constant in each formula is varied in small steps (0.001) until the difference between the predicted postoperative refraction and the actual postoperative refraction is made equal to zero [3]. It can also be done automatically within some optical biometers by inputting the actual PO refraction or using an Excel spreadsheet (Microsoft, WA) Data Query function.

Basic Clinical Refraction

There are two types of clinical refractions: objective refraction and subjective refraction. The objective refraction includes the use of a retinoscope or an autorefractometer. The subjective refraction can be done using a trial lens set or a phoropter. The retinoscope is not commonly used in pseudophakic eyes, especially after the implantation of a multifocal IOL or an extended-depth-of-focus IOL. The luminous reflex from the retina can be ambiguous due to the aberration of the

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Table 8.1 The mean ± standard deviation values of sphere, cylinder, axis, and spherical equivalent value derived from autorefractometer and subjective refraction. Note that both sphere and cylinder value as well as spherical equivalent show statistically significant differences between the groups but not the axis

	Auto-refractometer	Subjective refraction	*p* value
Sphere	−0.75 ±0.31	−0.33 ± 0.39	*<0.05**
Cylinder	−0.60 ± 0.36	−0.35 ± 0.40	*<0.05**
Axis	90.51	90.71	0.65
Spherical equivalent	−1.05 ± 0.26	−0.50 ± 0.41	*<0.05**

IOL. Most of the time, the subjective refraction is the preferred method. There are some debates on whether to use the autorefractometer or subjective refraction. Bullimore et al. [4] found autorefraction to be more reproducible (SD ± 0.19 D) than subjective refraction. However, Zadnik et al. [5] reported differently. Srivannaboon et al. [6] also showed the difference between autorefractometer measurement and subjective manifest refraction in a group of monofocal pseudophakic patients as shown in Table 8.1. The spherical and cylindrical values as well as the spherical equivalent values show statistically significant differences between groups but not for the axis. Therefore, it is recommended to use subjective refraction for the evaluation of the accuracy of IOL power calculation and IOL constant optimization. If the autorefractometer is used, it must always be verified by the subjective refraction.

Key Points in Subjective Refraction

– **Standardization**

Since an accurate postoperative refraction is essential for optimal refractive outcomes in IOL calculation, a standardized refraction method must be carried out by anyone who performs refraction (surgeons and technicians). In the least, the network of co-management with any surgery center should apply a standardized method where all refractionists utilize the same methodology. This standardization leads to a better repeatability and reproducibility of manifest refraction for the evaluation of the refractive outcomes in IOL calculation. Taneri et al. [7] reported the intra-observer repeatability and inter-observer reproducibility of manifest refraction in a specialized refractive clinic with standardized protocol is better than the typical step used for manifest refraction (0.25 diopter). Reinstein et al. [8] also showed similar results. Therefore, it is imperative that a standardized protocol of refraction be achieved.

– **Accurate Spherical and Cylindrical Values**

Since the accurate PO refraction is very essential for the IOL power calculation, it is especially important to get the accurate spherical (Sph) and cylindrical (Cyl) values as well as the axis. Although the spherical equivalent (SE) refraction is mostly used for evaluation of the IOL formulas and optimization of the IOL constant, it is the combination of the spherical value and half of the cylindrical value [SE = Sph + (Cyl/2)]. Moreover, with the recent development of several toric IOL lens calculators, the toric evaluation also requires accurate cylindrical refractive measurement including the axis.

– **Best-Corrected Visual Acuity**

The best-corrected visual acuity must be the best visual acuity that can be achieved with refraction. Some technicians stop performing refraction when the patient reach 20/20 visual acuity, when in fact the patient can be better than that. Therefore, 20/20 visual acuity is not the end point of refraction.

– **Testing Distance**

The testing distance of the visual acuity chart must be set correctly. It is very important to understand that the measurement of the visual acuity at each refractive state of the eye is the measurement of minimal visual angle in which the patient resolves to see the letter (minimal resolvable acuity). It depends on the size of the letter and the testing distance. The required testing distance of each visual acuity chart must be checked. A 6-m distance (20 feet) is generally the preferred choice [9]. A 4-m chart test can be converted to a 6-m test chart by adding the value of −0.08 D to the spherical equivalent refraction derived by a 4-m chart [10].

– **Timing**

In general, postoperative refraction is recommended to be performed at least 1 month after the cataract surgery (preferably 3 months if a larger incision wound size is constructed) or when refraction is stable. With modern microincision cataract surgery (1.8–2.5-mm wound size) and foldable single-piece IOL, the refraction may seem stable at 2 weeks; however, it is still suggested to wait at least 1 month ideally.

– **Correct Technique**

The principle of subjective refraction in the pseudophakic eye is very similar to the phakic eye. The goal is to determine the strength of the corrective lens that will achieve the perfect focus of parallel rays of light from a distant object onto the retina as a single point. It is called the focal point of the eye. With the trial lens set or phoropter, the focal point of the eye can be identified by searching for the lens with the best-corrected visual acuity. Refining the power of the lens can be done using the same technique as in the phakic eye. The red-green duochrome test may be useful, but with some IOLs that filter a certain wavelength of the light, the red-green perception of the patient may be changed [11]. Thus, caution should be made with the red-green duochrome technique in these types of intraocular lenses. The fogging technique with a plus lens is recommended to get the most plus or the least minus focal point of pseudophakic eyes. Due to the modern technology of IOLs, the focal point of the lens can be varied, such as monofocal IOLs, multifocal IOLs (bifocal or trifocal), and extended-depth-of-focus IOLs (an elongated focal point). The best way to understand the least minus end point is to understand the defocus curves of these pseudophakic eyes.

Defocus curves are plotted by presenting a series of negative and positive lenses (from +3.00 to −5.00 D in 0.50 D increments, or from +2.00 to −4.00 D in some studies) in front of the patient's eye and measuring the amount of "blur or defocus" that the lens induces. The amount of blur is determined by the visual acuity. The *X*-axis represents the power of the presenting lens, and the *Y*-axis represents the visual acuity. In general, the zero reference on the *X*-axis is set by the best-possible distance visual acuity. This is because the defocus curve is designed to evaluate the performance of the IOL without the bias of the error produced by the IOL power calculation. Therefore, defocus curves must be tested on the best-corrected visual acuity. Understanding defocus curves in each type of IOL will help to understand how the lens performs inside the eye and how the end point of refraction in these pseudophakic eyes is reached.

Refraction in the Presence of a Monofocal IOL

A monofocal IOL has only a single focal point. It is not difficult to identify the focal point of this lens because there is only one peak of the best-possible visual acuity. Therefore, subjective refraction is not difficult. Any refraction that achieves the best-possible visual acuity is the final subjective refraction.

Figure 8.1 shows the defocus curve of monofocal IOLs. There is only one peak of the best visual acuity.

The subjective refraction method is similar to that of phakic eyes. The sphere with the most plus or least minus power giving the best visual acuity is identified. The cross cylinder is then introduced

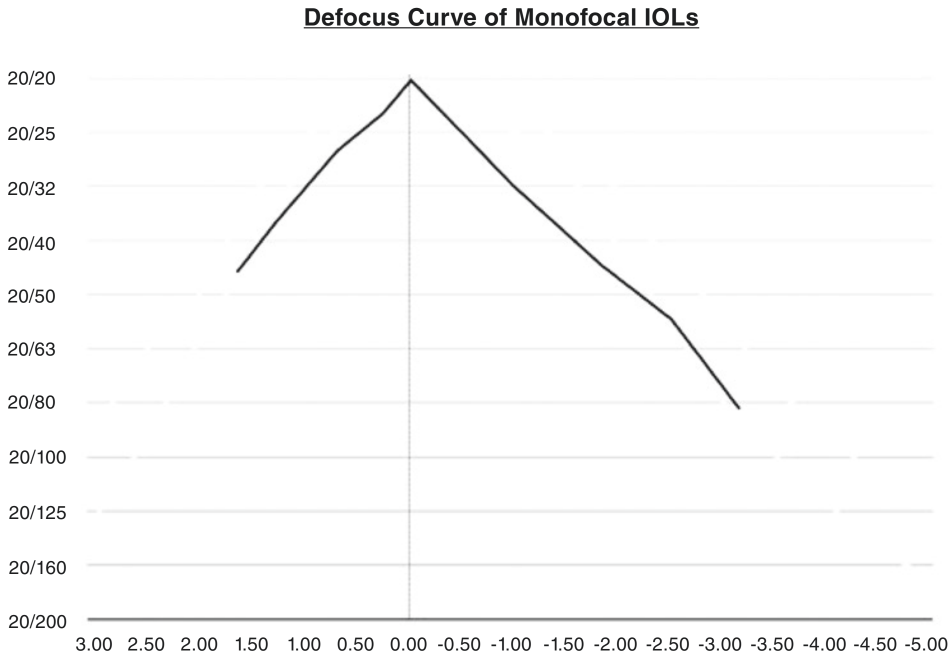

Fig. 8.1 A defocus curve of monofocal IOLs

to find the axis and amount of cylinder. Normally, the cylinder axis needs to be refined before the cylinder power, and it is recommended to use the ±0.25 D Jackson cross cylinder rather than the ±0.37 D or ±0.50 D for the evaluation of toric IOL outcomes. Refraction is measured with the natural pupil size in normal light conditions. Mydriasis can alter refraction outcome depending on the IOL design: certain aspheric and multifocal profiles are pupil dependent.

Generally, it is thought that there is no accommodation in pseudophakic eyes. Although this is true in most pseudophakic monofocal IOL patients, there are certain patients with monofocal IOLs who achieve good visual acuity for both distance and near. This phenomenon was previously known as apparent accommodation or pseudo-accommodation [12, 13]. In these cases, there is a range of refraction in which the patient can achieve best-possible visual acuity. This range is the amplitude of apparent accommodation. The final refraction should be on the most plus or least minus point of the best-possible visual acuity. Therefore, using the fogging technique with a plus lens is very useful in these cases.

Figure 8.2 shows a defocus curve of monofocal IOLs with pseudo-accommodation. There is a small range of refraction where patients can achieve the best-corrected visual acuity. The final refraction should be at point a (arrow).

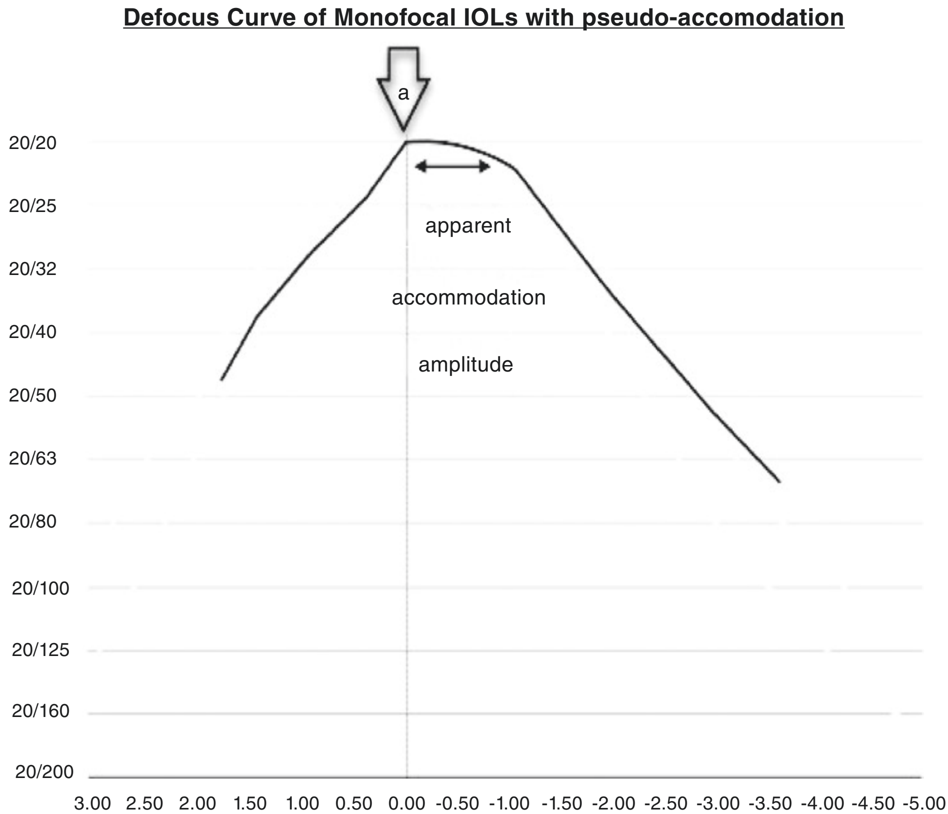

Fig. 8.2 A defocus curve of monofocal IOLs with pseudo-accommodation

Refraction in the Presence of Multifocal IOLs

A multifocal IOL has more than one focal point. It can be bifocal (two focal points) or trifocal (three focal points) depending on the design of the lens. There is only one "far" focal point, and this point should be the point of final refraction. In low-add power bifocal IOLs, the "near" focal point can be close to the "far" focal point. In trifocal IOLs, the "intermediate" focal point can also be very close to the "far" focal point. The proximity of these focal points can lead to an incorrect refraction. It is very crucial to locate the "far" focal point. In some eyes, identifying all focal points is very helpful to know which focal point is being measured. Because there are two or three points of the best-possible visual acuity in these lenses, the one with the most plus or least minus is the final refraction.

Figure 8.3 shows a defocus curve of bifocal IOLs . There are two points of the best-possible visual acuity in this lens: the far focal point (a) and the near focal point (b). There is a significant drop in visual acuity between both points. The final refraction should be at point a. Identify the existing point (b) should be identified to ensure that point (a) is the correct far focal point.

For example, if the refraction of −0.75 D achieves the best vision of 20/20 in a bifocal pseudophakic eye, searching for the other focal point is necessary to ensure that the far focal point is measured, not the near focal point (Fig. 8.4a, b).

Figure 8.4 shows a defocus curve of low-add bifocal IOLs. The second focal point (b) is moved

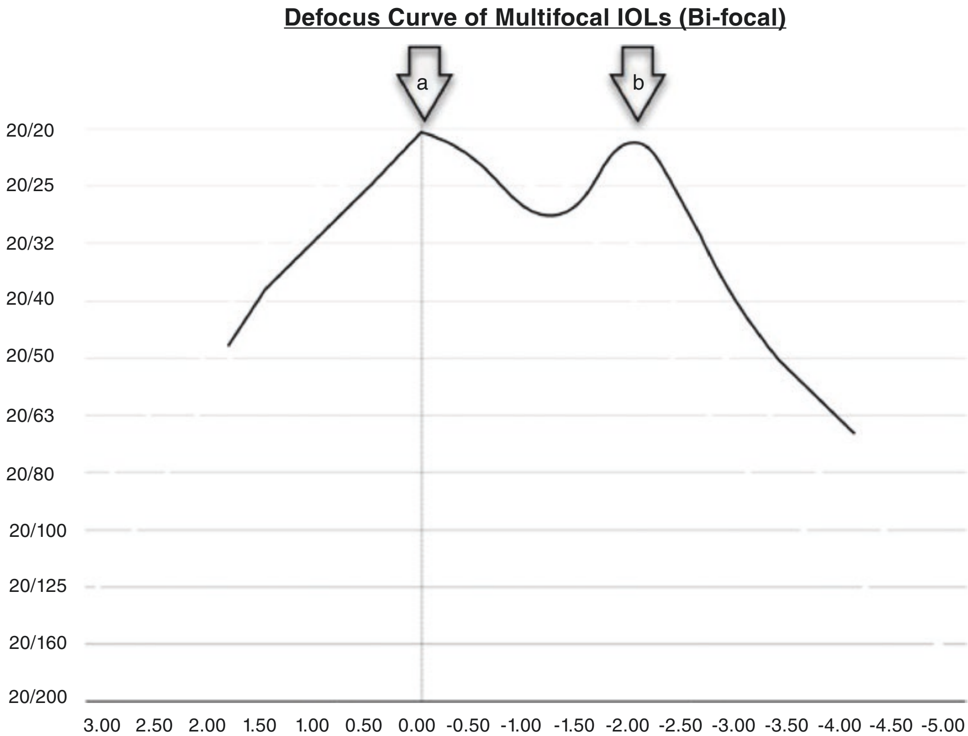

Fig. 8.3 A defocus curve of multifocal IOLs (bifocal)

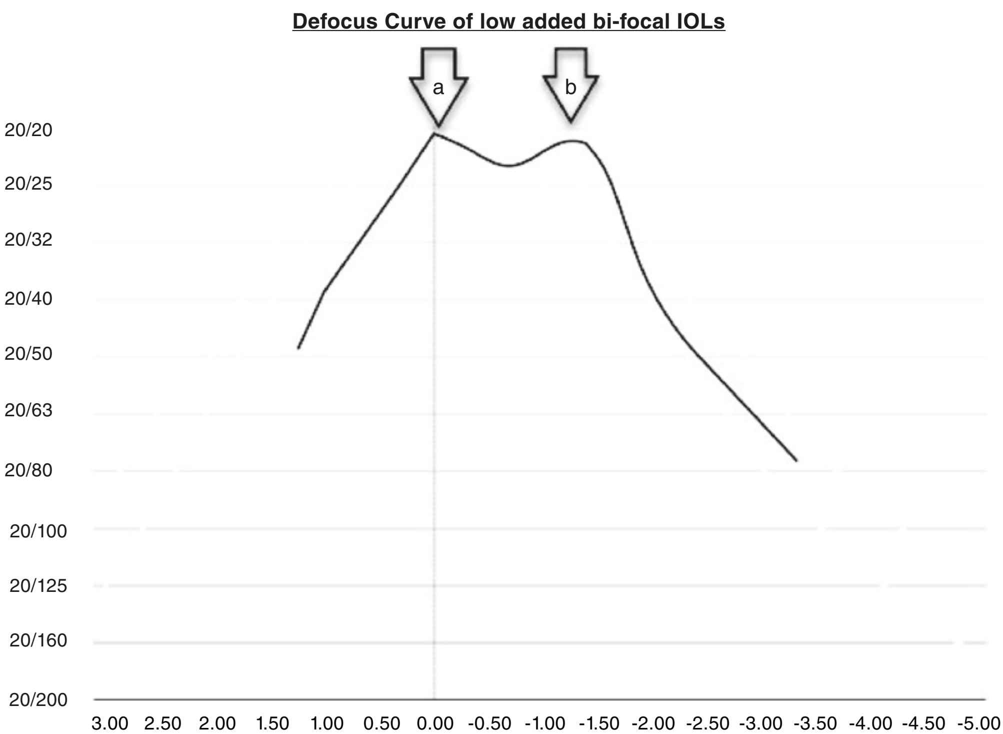

Fig. 8.4 A defocus curve of low-add bifocal IOLs

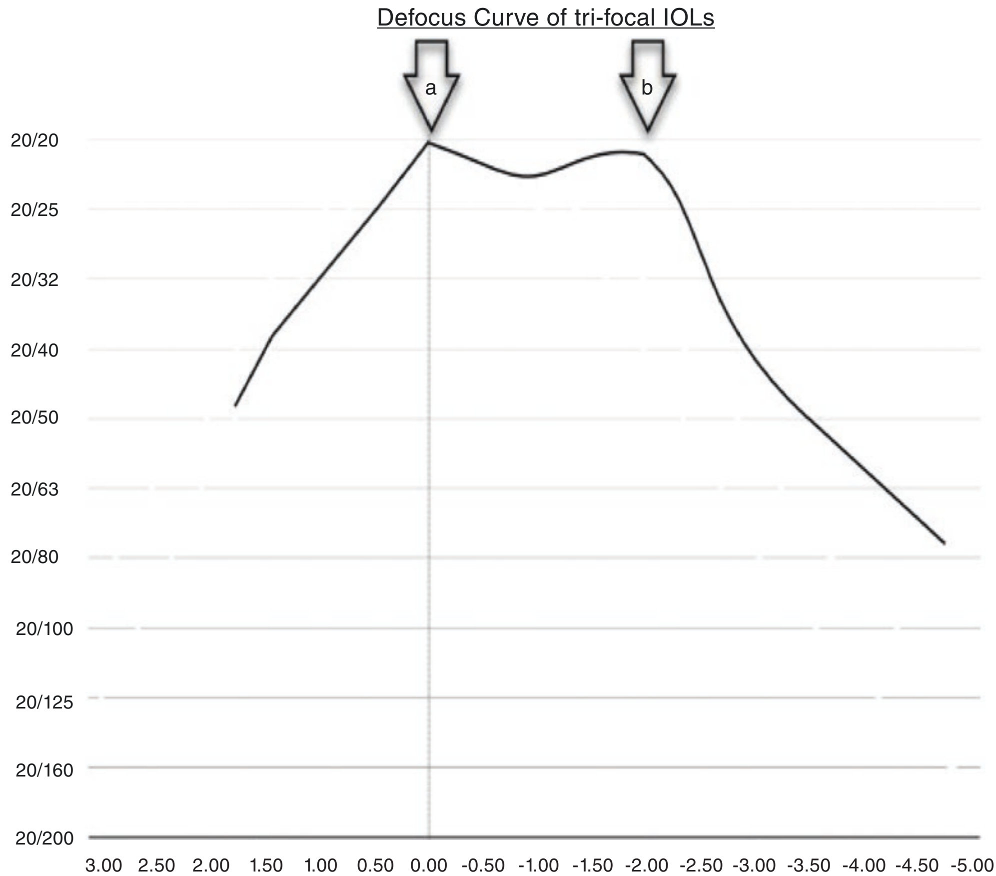

Fig. 8.5 A defocus curve of trifocal IOLs

close to the far focal point (a). The dropping of visual acuity between both points is less than high-add multifocal IOLs. Therefore, identifying the best-possible visual acuity is more difficult than high-add multifocal IOLs. The final refraction should be at point a.

Figure 8.5 shows a defocus curve of trifocal IOLs [14]. The intermediate focal point is not as distinct as the far (a) and near (b) focal points. Therefore, there are only two points of the best-possible acuity, but the dropping of visual acuity between these points is much less than bifocal IOLs. Again, identifying the best-possible visual acuity is more difficult than with bifocal IOLs. The final refraction should be at point a.

Refraction in the Presence of Extended-Depth-of-Focus (EdoF) IOL

Extended-depth-of-focus (EdoF) IOL technology has recently been introduced. It focuses incoming light into an extended longitudinal plane, rather than a focal point. Similar to phakic eyes with accommodation, there is a range of refraction that a patient can achieve their best-possible visual acuity. The final refraction should be on the most plus or least minus point of the best-possible visual acuity. Therefore, fogging technique with a plus lens is very useful in these cases.

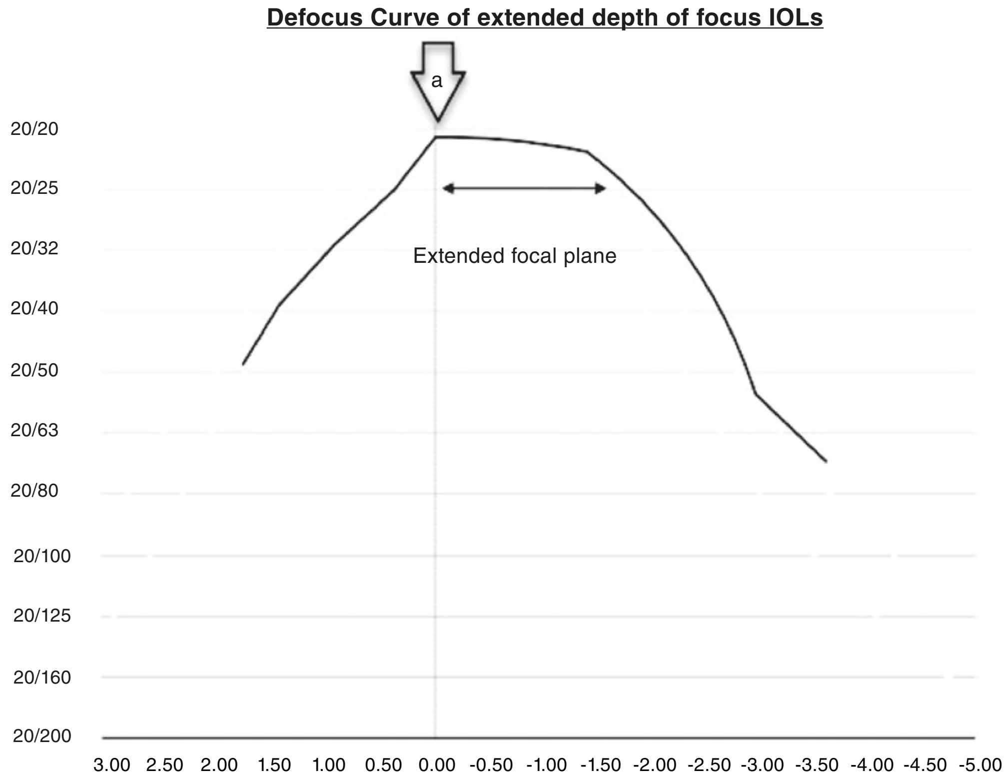

Fig. 8.6 A defocus curve of extended-depth-of-focus (EdoF) IOLs

Figure 8.6 shows a defocus curve of extended-depth-for focus (EdoF) IOLs. Note that there is a range of refraction that can achieve their best-corrected visual acuity. This is the extended longitudinal focal plane of the lens. The final refraction should be at point a.

Summary

Identifying the end point of a subjective manifest refraction is an art. It requires proper technique to locate the correct far focal point. In pseudophakic eyes, the optic of the whole eye changes according to the type of IOL implanted in the eye. Various types of IOLs produce different ways of refracting light. Therefore, understanding the optics of the implanted IOL is very beneficial to performing the most accurate subjective manifest refraction in these patients. The defocus curve of the implanted IOL should be known before performing the subjective refraction. In general, the end point is always on the most plus or least minus refraction that results in the best-possible visual acuity in that eye. The visual acuity of 20/20 is not always the end point of refraction. Using a pinhole occluder over subjective refraction might be useful to confirm the best-possible corrected visual acuity. Therefore, it is important to understand clinical refraction in the pseudophakic eye to achieve the most accurate postoperative refraction.

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