The challenge of cataract surgery in a patient previously treated with corneal refractive surgery

Jaime Aramberri, MD, PhD[1]; Alfredo Castillo, MD, PhD[2]; Victoria de Rojas, MD, PhD[3,4]

ABSTRACT: The approach to cataract surgery in a patient with previous corneal refractive surgery is usually focussed on the difficulties involved in calculating the IOL power, which is pivotal to the success of the surgery. However, other factors must also be taken into consideration. This article discusses the additional explorations that should be included in the preoperative examination, the criteria that the intraocular lens should fulfil and the precautions that the surgeon should take during the procedure. Eventual refractive surprises are also discussed, since the patient must be fully informed of all the risks involved and should be given realistic expectations.

J Emmetropia 2016; 4: 241-252

Performing cataract surgery in a patient who has undergone previous corneal refractive surgery (PCRS) is a major undertaking. Principle among the many challenges faced in this setting is accurately calculating the power of the intraocular lens (IOL), a factor that is pivotal to both the success of the surgery and patient satisfaction. Although the 30 or so different calculation methods put forward in recent years have improved predictability in patients with untreated corneas, they are less accurate in those with PCRS. In addition, these patients are particularly interested in achieving good vision without glasses and have high expectations of the surgical outcome, but PRCS limits the possibility of correcting any residual refractive errors after cataract surgery.

[1]Clínica Begitek, San Sebastián and Clínica Ókular, Vitoria, Spain.
[2]Hospital Universitario Quironsalud Madrid, Spain.
[3]Complexo Hospitalario Universitario A Coruña, A Coruña, Spain.
[4]Victoria de Rojas Instituto Oftalmológico, A Coruña, Spain.

Financial Disclosure: The authors declare that there is no conflict of interest in relation to the publication of this paper.

Corresponding Author: Victoria de Rojas
Victoria de Rojas instituto Oftalmológico. Rúa Federico García, 4, 15009 A Coruña
E-mail: derojas.v@gmail.com

Although the approach to cataract surgery in a patient with PCRS is usually focussed on the difficulties involved in calculating the IOL power, other factors must also be taken into consideration, namely: the preoperative assessment must include a number of additional examinations; the IOL must fulfil particular, at times controversial, criteria; certain precautions must be taken during surgery; and finally, it is important to be prepared to correct any eventual refractive surprises. The patient must be fully informed of all the risks involved and should be given realistic expectations of the treatment and its outcomes. All these aspects will be discussed in this article.

1. Preoperative assessment

The preoperative assessment in a patient with cataracts who has undergone PCRS is largely similar to that performed in an untreated patient, with the following exceptions.

1.1 Anamnesis

We need to know what type of corneal refractive surgery (CRS) was performed, when the procedure was done, and whether the refractive error was fully corrected or whether undercorrection or regression have been diagnosed. Some patients will have undergone monovision surgery, and may wish this to be maintained after cataract surgery.

The number of dioptres corrected will affect the extent of surgery-induced aberrations and will help calculate the power of the lens to be implanted. This will be discussed further below.

© 2016 SECOIR
Sociedad Española de Cirugía Ocular Implanto-Refractiva

1.2 Eye examination

Some tests are common to all patients undergoing cataract surgery: distance, intermediate and near corrected and uncorrected visual acuity, near and distance refraction, keratometry, slit lamp examination, fundoscopy, intraocular pressure (IOP), macular optical coherence tomography (OCT) scan, and contrast sensitivity test (optional). Biometry will be discussed in the section dealing with IOL power calculation. The most important tests are those described below.

a) Tear film assessment: PCRS patients may present tear film insufficiency. It is essential to analyse the ocular surface, because the presence of pre-existing moderate to severe dry eye may lead to poorer visual outcomes and less accurate keratometry measurements. For this reason, a multifocal IOL is not recommended. Dry eye can be treated preoperatively and then re-evaluated using the following tests: fluorescein and lissamine green staining, tear break up time, tear meniscus height, and questionnaires (OSID, SANDE)[1]. Additional, though less widely used tests include: osmolarity testing, high-speed videokeratoscopy, interferometry, aberrometry, etc.

b) Pupilometry: The pupil, which acts as a diaphragm, plays an important role in the ocular system. The mean pupil size under mesopic conditions is 6.19 ± 0.88 mm[2]. The greater the diameter, the greater the number of total aberrations (corneal and intraocular) and photic phenomena (PP). Implantation of IOLs in PCRS patients can be considered if mesopic pupil size is 6 mm, but is contraindicated when mesopic size is greater than 7 mm. In corneas with higher order aberrations (HOA) of >0.3 µm, the mesopic pupil size should be less than 6 mm.

c) Corneal topography/tomography and aberrometry must be performed in PCRS patients. Topography studies the anterior surface of the cornea and tomography measures both the anterior and posterior surfaces. It is important to evaluate corneal changes after CRS. Topography will show the morphology of the ablation in terms of its homogeneity, position with respect to the centre, and diameter, and can calculate asphericity, eccentricity, surface irregularity and the toric keratometry. Total corneal astigmatism must be calculated, because after LASIK/PRK for astigmatism, the posterior and anterior corneal curvature ratio will have altered, and this will most likely lead to errors in toric IOL selection. The total astigmatism value can usually be found among the total corneal power values and in the total corneal aberrometry values.

Most topography systems include programmes that can calculate corneal aberrometry values, which will account for the largest proportion of the total aberrations in PCRS patients. Several commercially available instruments can calculate not only corneal and total aberrations, but also intraocular (crystalline lens-induced) aberrations. These include iTrace (Tracey Tech), OPD scan (Nidek Co), and KRW-1 (Topcon Co).

The sum effect of corneal aberrations in PCRS patients and lenticular aberrations caused by changes in the crystalline lens lead to an earlier indication for cataract surgery (average 10 years)[3].

In terms of aberrations, the most important values to be considered are real pupil size; peripheral corneal values can be ignored. HOA values under normal conditions are 0.327 ± 0.13 µm, spherical aberrations (SA) 0.192 ± 0.115 microns, and coma 0.192 ± 0.115 microns. SA and coma values in excess of 0.3 µm are considered pathological. Trefoil and tetrafoil will depend on paracentral and peripheral irregularities. Abnormal trefoil and tetrafoil values are 0.40 µm and 0.30 µm, respectively[4].

Maeda et al. put forward HOA root mean square values for safe implantation of multifocal IOLs of <0.3 mm in 4 mm, values between 0.3 and 0.5 can be implanted in certain cases, and the procedure is contraindicated in values higher than 0.5 µm[5]. After studies evaluating the Galilei system, Carlos G Arce suggested that if coma (> ±0.50 µm), trefoil (> ±0.40 µm), tetrafoil (> ±0.30 µm) and/or fifth-order aberration (> ±0.20 µm), multifocal IOLs should probably not be implanted (personal correspondence). In aberrations in excess of these values, monofocal or extended depth of focus IOLs should be considered.

2. Intraocular lens power calculation

Central corneal curvature is an essential variable in the calculation of IOL power. CRS-induced curvature changes modify the basic measurement conditions, and invariably result in postoperative hyperopia or myopia, depending on whether surgery was performed to correct myopia or hyperopia, respectively[6]. Calculations, therefore, must be adjusted to reduce or eliminate this error.

2.1 Causes of error

In these cases, the miscalculation arises from two simultaneous same-sign errors: error in the effective lens position (ELP) prediction in the standard IOL formula, and incorrect keratometric and topographical measurement of corneal power[7].

a) Prediction of ELP after keratorefractive surgery

After keratorefractive surgery, the corneal curvature is changed but not the anterior chamber depth, leading to a prediction error in IOL calculation formulae that use K to predict ELP: When corneal curvature has been flattened by myopia surgery (LASIK, PRK or radial keratotomy [RK]), the formula assumes the ELP will be more anterior, leading to underestimation of the required IOL power and hyperopia. The opposite is true following the steepened central curvature produced by hyperopia surgery; in other words, the formula assumes a more posterior ELP and therefore overestimates the required IOL power, causing a higher degree of myopia than expected. The most widely used K-based formulae are: Holladay 1 and 2, Hoffer Q, SRK/T, Olsen, and Barrett Universal II. The Haigis formula does not use keratometry to estimate ELP, and is not affected by this problem (Table 1).

It is important to note that not all algorithms are equally affected. The Hoffer Q, which bases ELP on a curve equation, decreases the K-based ELP shortening[8], and is therefore more accurate than the SRK/T and Holladay 1 formulae.

This is why, as other authors have pointed out, this formula produces less hyperopia in the case of standard (not double K) calculations[9, 10] (22,23).

The magnitude of these errors is proportional to the dioptric correction achieved by keratorefractive surgery, and can be as high as 3.25-3.50 IOL dioptres (approximately 2.3 D at the spectacle plane) for 10-12 myopic dioptric corrections.

b) Measurement of corneal power

Surface ablation surgery (LASIK or PRK) results in flattening or steepening of the anterior surface of the cornea without significantly changing the posterior surface[11]. This alters the ratio on which the standard keratometric index of refraction is based (1.3375), and leads to keratometry and videokeratoscopy measurement errors: overestimation of the K value following myopic ablation and underestimation of this value following hyperopic ablation. Example: a measurement of 37 D is obtained following myopic LASIK surgery, when the correct value is 36 D. The normal r(anterior)/r(posterior) ratio in the population is 1.21 ± 0.02. This is presented inversely in many studies — r(posterior)/r(anterior) —, giving an average ratio of 0.82 ± 0.02[12]. Following myopic surgery, the anterior/posterior ratio increases linearly as a function of the anterior flattening, and therefore, of dioptre correction. A similar, though reverse, change occurs after hyperopia surgery. Given the high correlation, a function that corrects the resulting error can easily be calculated, and this is why many of the linear regression formulae published in the literature are relatively accurate.

The error has been estimated at 14%–30% of the surgically-corrected keratometric power[13,14]. Experience has shown 15% of corneal correction to be an acceptable mean reference value, so that, for example, if K measured on keratometry is 37 and 10 dioptres of

Table 1. ELP prediction variables used in different formulae.

Formula	K	AXL	ACD	Lens thickness	Others
Binkhorst 2	No	Yes	No	No	No
SRK/T	Yes	Yes	No	No	No
Hoffer Q	Yes	Yes	No	No	No
Holladay 1	Yes	Yes	No	No	No
Holladay 2	Yes	Yes	Yes	Yes	Rx; Age; HWTW
Haigis	No	Yes	Yes	No	No
Olsen	Yes	Yes	Yes	Yes	No
Barrett UII	Yes	Yes	Yes	Yes	HWTW

K: mean keratometry; AXL: axial length; ACD: preoperative anterior chamber depth; Rx: preoperative refraction; HWTW: horizontal white to white.

myopia have been corrected, the corrected K value is 37 – 1.5 = 35.5 D.

Another source of systematic error also contributes, albeit to a lesser extent, to this measurement error: incomplete measurement of the centre of the cornea. This occurs because the K and sim K measurements are obtained from a paracentral annular region whose diameter is determined by corneal curvature: this diameter increases in the case of flat corneas, thus overestimating the true value[15]. Moreover, the more oblate the centre of the cornea as a result of myopic ablation, the greater the dioptric gradient between the centre and a point located 2 mm off-centre. This is why, following myopic LASIK/PRK surgery, the topographic sim K is usually greater than the K obtained by the autokeratometers built into many optical biometers.

Both the foregoing factors distort measurements in a similar fashion: overestimation of K following myopic LASIK/PRK and underestimation following hyperopic surgery.

Radial keratotomy is a different matter. This procedure flattens both the posterior and anterior central curvature which, in direct contrast to the post-LASIK/PRK phenomenon, reduces the anterior/posterior ratio. Camellin reported a value of 1.12 ± 0.07 in a sample of 29 eyes measured using the Pentacam[16]. In a series of 59 eyes presented by us at the annual meeting of the IOL Power Club in 2013 in Haarlem, we reported a mean value of 1.15 ± 0.09 measured with the Pentacam and Sirius. The error, therefore, stems from underestimation of the K value, and is less significant than errors following LASIK/PRK surgery. It is interesting to note the wide range of measurements observed. This variability, which could be due to the manual nature of this procedure, prevents the formulation of an accurate K adjustment function when only anterior surface measurements are used (keratometry or reflection topography). In our series, we observed that the number of incisions (usually 8 or 16) was not a good predictor of corneal flattening.

Another source of error that has been largely ignored in the literature is the level of HOA present in these corneas, a factor that can affect both post-LASIK/PRK and post-RK outcomes. These are heterogeneous corneas with a high prevalence of HOA, mostly SA and coma, usually caused by small optical zones and decentration, particularly in procedures performed many years ago. The higher the degree of HOA, and therefore multifocality, the more inappropriate it is to represent the central corneal optics using a paraxial parameter such as K and the more unaccurate IOL power calculation becomes. This might explain the different results reported in the literature in this sort of eyes.

2.2 Solutions

In order to accurately calculate IOL power, both these errors must be corrected simultaneously:

a) Correct ELP calculation.

The simplest solution is to use a non-K-based algorithm to predict the position of the implant in the eye. The only formula available today that is not based on K measurements is that devised by Haigis. This formula accurately predicts ELP provided the 3 IOL constants (a0, a1 and a2) have been determined correctly. Professor Haigis's website (www.ocusoft.de/ulib/) gives empirically calculated values for the most widely used IOL models. In my experience in post-LASIK/PRK eyes, this formula slightly underestimates IOL power compared with 3rd generation double K formulas, and therefore tends towards a slightly hyperopic outcome.

If a K-based formula is used to estimate ELP, the K variable must be correctly sequenced within the formula, so that pre-corneal surgery K measurements are used in the ELP prediction algorithm, and the actual K measurement is used to calculate the power of the implant. The use of 2 different K values to predict ELP is called the Double K Method[17]. Most commercially available formulae and those included in optical biometers use the double K method when the post-LASIK mode is activated. An important warning for users of the Holladay IOL Consultant programme: the double K method is only used in the Holladay 2 formula. It is not used in other formulae, even when the post-LASIK mode is activated. Online ASCRS (www.ascrs.org) and APACRS (www.apacrs.org) calculators use the double K method in the Holladay 1 and Barrett True-K formulae, respectively. Another option is to modify the result of the formula's "normal" mode (single K) using the conversion table published by Koch[18].

If no pre-surgery K (preK) measurement is available, an average value of 43.5 D can be used. Another option is to guess the anterior radius of curvature (ROC) if the posterior ROC can be measured using Scheimpflug or OCT tomography, if available. Applying this value, assuming it remains constant after LASIK/PRK, to the normal posterior/anterior ratio of 0.82 ± 0.02[13] gives the result: for example, an r(posterior) of 6.15 mm gives an r(anterior) of 7.5 mm, 6.15/0.82 = 7.5. Applying the formula (n2–n1)/r with n2 = 1.3375, preK = (1.3375–1)/7.5 = 45 D.

The accuracy of the double K formula to predict ELP is based on the assumption that it will perform equally well in eyes that have not undergone corrective surgery. However, these formulae have intrinsic biases that are less apparent in non-operated myopic eyes due to the low power of the lens, but that can have a significant effect in post-LASIK/PRK/RK eyes where higher IOL powers are calculated: the SRK/T algorithm estimates higher ELP values when preK is higher than 45 D, and therefore tends to overestimate IOL power, thus shifting the final refraction towards myopia. The Hoffer Q tends to overestimate ELP when preK values are less than 42, showing a myopic shift in these cases.

When using these formulae intelligently, it is important to remember that the SRK/T, Hoffer Q and Holladay 1 ELP prediction algorithms do not account for differences in anterior chamber depth (ACD), lens thickness and horizontal corneal diameter. In other words, predicted ELP will be the same in eyes with a deep and with a shallow anterior chamber. This is not only illogical, but also goes against clinical experience[20]. To compensate for this, preK, even when known, can be adjusted to obtain a more accurate ELP prediction. The algorithm used in this case is shown in Table 2. ACD can be measured using both ultrasound and optical instruments, and is defined as the distance (in mm) from the corneal epithelium to the anterior surface of the lens along the visual axis. Lens thickness can be measured using ultrasound or optical devices, and is defined as the distance from the anterior to the posterior surface of the lens along the visual axis.

This gives a wide margin of error, which can affect ELP prediction calculations. For example, in normal eyes, in which the algorithm gives the best results, 1 preK dioptre error (being, in this case, the K value used solely in ELP prediction) generates a 0.50 D error in IOL power, and ultimately results in a 0.35 D error at the spectacle plane.

The double K concept, which does not use the K value to predict the position of the IOL, can be used in any calculation where an anomalous K value can distort the ELP prediction algorithm: severe keratoconus, irregular astigmatism with scarring, etc.

Table 2. PreK values for SRK/T double K and Holladay 1 double K, depending on the anterior chamber depth measurement in phakic eyes, a variable defined as the sum of the ACD (anterior chamber depth from the corneal epithelium) and lens thickness (LT).

ACD + LT (mm)	PreK (D)
< 7.5	42
7.5 – 8.10	43.5
> 8.10	45

b) <u>Correct K calculation</u>

The K value used in IOL power formulae is based on the use of the standard keratometric index of refraction 1.3375 to calculate the total corneal power. This, it should be borne in mind, is an arbitrary value and does not correspond to the effective power or the corneal vertex power. The post-refractive surgery K value will, ideally, be the same as the preoperative value plus the effect of the surgery.

Various methods for correctly determining corneal power in these eyes have been described:

1. *The clinical history method*: The postK value is obtained by subtracting the change in refraction at the corneal plane induced by the refractive surgical procedure from the corneal power values obtained before refractive surgery. It is a simple, direct method that yields the number that needs to be entered into the formula[21]. However, it is seldom feasible in practice for 2 reasons: unavailability of the preK value, and the difficulty involved in determining whether a postoperative change in refraction occurred in the cornea (regression) or in the lens. The latter problem can be prevented by evaluating the evolution of both the refractive error and ocular topography, if possible. If all the data needed to determine the number of dioptres reduced are available and the analysis is performed correctly, it is an excellent method for determining postK. In my experience, it is only useful in eyes that have recently undergone surgery for myopia/hyperopia.
2. *Hard contact lens method*: Corneal power is calculated as the difference between uncorrected and corrected refraction using a hard contact lens with known base curve and power. The resulting difference is added to the base curve to obtain the corneal power. This method was popularised by Holladay in 1989 for eyes that have undergone RK[21]. However, it is complicated and inaccurate, and is rarely used in clinical practice.
3. *Topography/Keratometry K modification*: Various methods to correct the K value using topography and/or keratometry have been put forward since this problem was first recognised. It is important to bear in mind that the older studies do not distinguish between the corneal power error and the ELP estimation error, so over-correcting the former often compensated for the latter. Several videokeratoscopic indices have been put forward, including: power of

the prepupilary area (with or without the Stiles-Crawford effect)[15, 22] (28,37); subtraction of 1 D[23]; anterior corneal power – posterior corneal constant. This was first described by Seitz, who calculated the posterior constant as 5.9 D[6]. It was later popularised with the Maloney method, in which 6.1 D was subtracted[24]; empirical adjustment using Shammas's linear regression. This method is included in several optical biometers as Shammas-PL[25]; correction of the ROC according to the dioptres treated and axial length (AXL)[26]. Many of these studies observed that the post-myopia surgery K value was underestimated by between 15% and 25% of the final corneal correction. One simple method, therefore, would be to simply subtract this value if we know, or can estimate, the dioptre change produced by corneal surgery. Randleman proposed averaging the K value using different methods, which he called the consensus-K technique. Various methods were used to calculate K: refractive history, contact lens, manual K, Hamed, Shammas, Maloney and topography. The outlying values were eliminated (1.5 D over the mean), and the remaining values within a range of 0.75 D were averaged to generate the consensus K. The final Holladay 2 error was −0.23 ± 0.61 D[27]. From a practical perspective, any methods, such as Shammas and the modified Maloney, that do not rely on the availability of pre-surgical data are particularly useful.

- Posterior corneal curvature: The introduction of technologies, such as Scanning Slit, Scheimpflug photography, OCT and posterior keratometry for measuring posterior corneal thickness and curvature enabled the total corneal power to be calculated without the need to invent a value for the posterior surface or rely on pre-surgical data. Nevertheless, central corneal power calculated by ray tracing using normal refraction indices (1.376 for the cornea and 1.336 for aqueous) cannot be used in standard formulae because, by definition, they do not match the K value. These powers are given different names, depending on the topographer: TCRP in Pentacam, TCP in Galilei, PMP in Sirius, etc., and must be converted to a K (1.3375) equivalent value. Holladay calculated a conversion factor after estimating the anterior curvature from normal corneal proportions[28]. This parameter is called the Equivalent K Reading (EKR), and can be calculated for various diameters. According to Holladay, the EKR performed best in a diameter of 4.5 mm. The EKR is found in Pentacam and Cassini. However, experience in using this parameter as it is programmed in Pentacam has been unsatisfactory, and its use is widely debated. Seo et al. recently proposed a new EKR value, adding 0.7 to the TCRP of 4 mm measured on Pentacam. This improved on the results obtained with the Holladay EKR[29]. In my experience, the Cassini EKR gives good results, with a predictive error of −0.16 ± 0.73 D in a series of 26 eyes from 18 patients. The IOL power was calculated using the Haigis formula.

- A more interesting alternative is to directly enter the anterior and posterior ROC measurements, if available, into a pseudophakic eye model in which calculations are performed using ray tracing. Two programmes are currently available: Phacooptics®, programmed using the Olsen formula, and Okulix®. Both methods are also included in the software of some optical biometers and topographers. Tomographers manufactured by the Italian company CSO, Sirius and MS-39 have a ray tracing module in which ELP is calculated on the basis of the anterior segment of the eye, without using corneal data. Savini reported a predictive error of −0.19 ± 0.49 D in a series of 21 eyes[30]. The use of ROC measurements avoids errors derived from incorrect anterior/posterior ratio estimation or from conversion to an equivalent K value. In the case of post-RK calculations, variations in the anterior/posterior ratio increase the likelihood of error in any method where the posterior curvature is estimated on the basis of the anterior curvature. In this case, the posterior surface will need to be measured by Scheimpflug or OCT, and the power calculated using a thick lens formula with both radii (Phacooptics), or a thin lens formula with an appropriate EKR.

4. *Other methods:*

- Intraoperative refraction/aberrometry: This involves measuring refraction intraoperatively after extraction of the lens, and multiplying the value obtained by a factor that converts it to the IOL plane. It was first performed using automated refractometry[31], but was later improved with the use of an aberrometer attached to a surgical microscope. It is a simple approach that avoids potential errors in AXL and does not require the patient's refractive history. The drawback, however, is that it requires ELP and accurate IOP measurement to ensure adequate corneal curvature. In a multicentre study in 246 eyes, Ianchulev et al. reported an excellent absolute prediction error of 0.42 ± 0.39 D[32].

- PreLASIK/PRK calculation method: This has been used by ophthalmologists for many years, and was published as the AS technique[33] and the Corneal power bypass technique[34]. It consists in calculating IOL power using the preK value and choosing an IOL that would have given the same refraction in the spectacle plane as that achieved by surgery. The method is attractive for its simplicity; however, clinical history data are often unavailable, and formulae used in the implantation of more powerful IOLs are often inaccurate, as discussed in the section on ELP. It can only be used on recently operated eyes, or for estimating the power of an IOL to be implanted at a later date.

- Mean value of several methods using online IOL calculators: The website www.ascrs.org includes a free IOL calculator for post-LASIK/PRK and RK eyes. Programmed by Drs Hill, Wang and Koch, it uses different methods depending on the keratometer or topographer used to measure K and different formulae: Barrett TrueK, Wang-Koch-Maloney, Shammas PL, Masket, Potvin-Hill, OCT, etc. In addition to individual values, it also determines which methods use preLASIK/PRK data and calculates the mean of all the results.

3. Intraocular lens selection – optical quality

Various types of IOL can be used in cataract patients: monofocals, multifocals (MIOL), extended depth of field (EDOF) and any of the foregoing in toric IOLs. Studies have shown that approximately 95% of patients are satisfied with their refractive surgery outcomes, so after cataract surgery they will expect highly accurate outcomes and to remain spectacle-free in their daily activities[4].

This goal must be achieved by maintaining quality of vision evaluated on the basis of visual acuity (VA) and contrast sensitivity. Achieving spectacle independence and good quality of life depends on choosing an IOL with a number of characteristics that will be discussed below.

The two pseudophakic lens features associated with the refractive index and reflectance (the difference in the indices of refraction of the materials composing the interface) are glistenings and negative and positive dysphotopsia. These effects are in no way related with the focality of the lens. Glistenings are typical of hydrophobic high refractive index IOLs, and dysphotopsia is also associated with high refractive index IOLs[35]. Therefore, these IOLs are not suitable for PCRS patients.

Another factor to take into consideration is the chromatic aberration (CA). White light is composed of different colours (wavelengths) in the visible spectrum, from red (700 nm) to violet (400 nm). Violet rays are refracted more than red rays. The study of axial dispersion of colour is called longitudinal chromatic aberration (LCA), and that of lateral dispersion is called transverse chromatic aberration (TCA). In a photograph, LCA shows as a blurred image, while TCA would cause a rainbow effect around the image. LCA is more serious than TCA, and is measured in Abbe numbers[35]. The Abbe number of the human lens is 47, while that of IOLs will depend on the material used, the curvature, the power of the lens and the diffractive surface. Table 3 shows the different Abbe numbers for different IOL models and their refractive index; note the correlation between these parameters. High refractive index hydrophobic acrylic IOLs are usually associated with a low Abbe number, and would therefore cause more chromatic aberration. The lower the chromatic aberration, the greater the contrast sensitivity, so patients with PCRS will need lenses with a high Abbe number but similar optical characteristics.

Spherical aberration (SA) is the only monochromatic HOA that can be corrected or compensated by means of an IOL. Because spherical IOLs increase the total SA of the eye, aspherical or negative SA IOLs have been developed in recent years to compensate for corneal SA. The advantages of these lenses have been analysed in 2 large meta-analyses in a total of 4000 eyes[19,36]. Although best corrected visual acuity (BCVA) was not

Table 3. Abbe numbers and refraction indices of different IOL models. Adapted from Chang et al.[34].

Material	Refraction index (n)	Abbe number
Human lens	1.34	47
Silicone (Staar)	1.41	57
PMMA	1.49	58
Acrylic (Tecnis)	1.47	55
Acrylic (Envista)	1.54	40.5
Acrylic (AcrySof)	1.55	37

improved with monofocal aspherical IOLs, contrast sensitivity in mesopic conditions was increased. In another study in which corneal SA was compensated with a monofocal IOL, high spatial frequency contrast sensitivity was improved[19]. Variations in visual quality can be even more significant in PCRS patients due to the sum of corneal aberration caused by refractive surgery. Patients who have undergone CRS for myopia will need a negative SA IOL (positive corneal SA), while those operated for hyperopia (negative corneal SA) will need a spherical or positive SA IOL to reduce the total SA. SA does not need to be totally compensated (zero SA), since a moderate degree of positive or negative SA increases depth of focus, and with it, intermediate and near vision. However, increasing depth of focus purely on the basis of SA can degrade image quality, so it is important to balance these 2 parameters.

Implantation of MIOLs gives excellent near and distance vision in patients undergoing cataract surgery or refractive lensectomy. However, diffractive MIOLs distribute incoming light across 2 or more focal points, thereby reducing contrast sensitivity and causing PP, such as halos and glare. These latter are measured by scatter indices and visual satisfaction questionnaires[37].

Only a few studies have analysed the results of MIOL implantation in PCRS patients[38,39]. Those published so far have only measured visual capacity in terms of VA, and focus on the predictability of refractive outcomes. Hardly any reference is made to binocular VA, intermediate VA, contrast sensitivity, quality of vision, and night vision disturbances. Only 1 study has so far analysed these parameters in patients treated with myopic LASIK with respect to series in which the same diffractive MIOL model was used in patients with no PCRS[40]. The authors observed worse contrast sensitivity at a spatial frequency of 3 cycles per degree (cpd) ($p < 0.05$) in the PCRS group, and 50% of patients reported moderate/severe halos and glare ($p < 0.05$). Overall, more patients in the PCRS group were dissatisfied compared to other series with no PCRS (17% vs. 7%). This study makes no reference to the degree of myopia correction or corneal topographic or aberrometric measurements.

EDOF lenses increase the depth of focus, and have the potential to improve intermediate vision without disrupting distance vision[41]. Other authors define them as lenses that produce a clear image in the 1.5 to 2.00 D range of accommodation[35]. EDOF lenses use different optical principles (diffraction, refraction, pinhole effect, etc.). The first EDOF IOL marketed was the Symfony (Johnson &Johnson), which was based on a diffractive echelette design that corrected chromatic aberrations to increase contrast sensitivity and depth of focus[42].

Compared with multifocal IOLs, EDOF IOLs have the advantage of preserving contrast sensitivity in normal corneas in much the same way as monofocal lenses, and of significantly reducing PP. This has been shown in both in vivo and in vitro studies (by means of modulation transfer function [MTF]). In the largest of these studies, which included 411 patients implanted with the Symfony lens, 368 (90%) patients reported no PP compared with PP rates of between 40% and 80%, depending on the series, in patients implanted with multifocal, trifocal or bifocal lenses[42]. This is important, because PP are the most common cause of explantation of MIOLs. In vitro studies have shown that the MTF of both the aspherical Mini Well Ready (SifiMedtech) and the Symfony EDOF lenses are superior to the MTF of trifocal models[43]. Nevertheless, the Mini Well Ready should be used with caution in patients with myopic CRS, because the positive SA of its 1.95 mm central zone could add to the corneal SA, thereby reducing contrast sensitivity. EDOF lenses are not affected by decentration (0.5 mm) and tilt (up to 9°), which compensate for corneal ablations that are not perfectly centred or cases of hyperopia with a high angle kappa[44]. The only study reporting the use of an EDOF IOL in PCRS patients is a case study of a patient with no manifest cataracts who had previously undergone myopic LASIK surgery and presented a high optical scatter index of 2.8. After phaco-lensectomy and implantation of Tecnis Symfony IOLs, he achieved a BCVA of 20/25, with no PP[45].

IOLs that apply the same small-aperture optics as the Kamra inlay to increase depth of vision using the pinhole principle have recently been developed. The IC-8 (Acufocus Inc.) is a single-piece hydrophobic acrylic IOL with an opaque mask 3.23 mm in diameter, which creates a 1.36 mm aperture (equivalent to the Kamra inlay). Under normal conditions, the IOL should be implanted in the non-dominant eye for a spherical refraction target of −0.75 D. The advantage of this lens is that it can achieve near vision of around 20/32 without PP[46]; the disadvantage is that it degrades contrast sensitivity by reducing retinal illumination, and so binocular implantation is not recommended. Outcomes with these lenses in PCRS patients have not been investigated in the literature, but we would recommend their use in corneas with high aberrometric values or in patients with previous RK.

4. Description of the surgical procedure

Patients undergoing LASIK

The main issue in patients previously treated with LASIK surgery is localisation of the edge of the flap, because the path of the incision must run below this edge in order to avoid the risk of the infusion liquid penetrating the interface and causing an oedema. Fluorescein staining can be used to identify the edge of the flap, irrespective of the length of time between LASIK and cataract surgery[47].

In the postoperative period, it is important to bear in mind the risk of interface fluid syndrome. An increase in IOP or surgery-induced endothelial damage can cause fluid to accumulate in the virtual space that all corneas treated with LASIK present in the interface[47]. This causes loss of visual acuity, increases the mean keratometry value and causes a myopic shift. Tonometry measurements over the flap will give falsely low readings, when in fact IOP has increased. This is treated with ocular hypertension drugs while suspending steroids, and the symptoms will resolve once IOP has normalised. If postoperative residual myopia is observed, interface fluid syndrome should be ruled out before taking action to correct the residual error.

Patients treated with surface ablation

The only difficulty encountered in patients previously treated with PRK or any other type of surface ablation will involve calculation of IOL power.

Patients treated with radial keratotomy

In these patients, it is important to bear in mind that phacoemulsification incisions must not intersect those made during radial keratotomy, as this can cause dehiscence of the radial incisions. Space permitting, new clear cornea incisions can be made between the previous ones, although this is not always possible, particularly in interventions involving 16 incisions. In this case, clear cornea microincisions can be made between the previous incisions[47,48], or a straight or "frown" scleral incision can be made, taking care to ensure that the corneal edge of the incision does not intersect the previous radial incisions either[47,48]. The posterior location of this type of incision, however, restricts manoeuvrability and forms corneal folds. Another recently published approach involves a wave incision in the sclera at around 3 mm from the limbus, with the midpoint of the crest of the wave coinciding with one of the radial incisions[48]. This type of incision provides adequate fracture resistance that prevents dehiscence but does not restrict manoeuvrability. Slightly lifting the crest of the wave prevents the formation of corneal folds[48].

Given the depth of the radial incisions, low irrigation and aspiration settings must be used due to the risk of high intra-ocular pressure-induced tearing and to prevent, as far as possible, excessive hydration[47]. It is also important to minimise instrumental manipulation of the main incision[47,48]. Should a perforation occurr through one of the incisions, , the surgeon must be prepared to resolve this by filling the chamber with viscoelastic and suturing the incision[47,48]. Some studies have also described dehiscence of radial incisions caused by hydration of the main incision[48]. This can be avoided by the cautious use of hydration, or by suturing the incision, if it is not self-sealing.

A hyperopic shift in final refraction may be observed in the immediate postoperative period. This is caused by central corneal flattening due to the paracentral corneal oedema induced by hydration of the radial incisions. The symptoms will gradually resolve as the oedema subsides and central keratometry increases, which will reduce the residual hyperopia. Refraction may not stabilise until 6 or even 12 weeks after surgery[49,50]. It is important to be aware of this self-limiting complication in order to avoid hasty interventions, such as lens exchange or treatment of the residual refractive error.

In any event, surgeons must follow the general recommendations for cataract surgery in long and short eyes. In view of the risk of a refractive surprise and eventual need for IOL exchange, it is best to implant a capsular tension ring and use an easily exchanged IOL.

5. Refractive surprises: correction options

As explained in the previous sections, IOL power calculation is less predictable in patients with PCRS than in patients without previous surgery. PCRS patients are more demanding because, after having undergone surgery with the aim of becoming independent from spectacles or contact lenses, they expect to remain spectacle-free after cataract surgery. In addition, given their previous treatment, corneal laser surgery, one of the options for treating residual refractive errors, may not be feasible or may give limited results. Therefore, it is important to plan the most appropriate procedure for correcting refractive surprises and inform the patient of this eventuality.

There are several different options available for correcting a residual refractive error after cataract surgery: PRK or LASIK, implantation of a secondary IOL using the piggyback technique, or exchanging the implanted IOL[47,51,52]. Few studies have compared the efficacy of these procedures in cataract surgery patients without previous corneal surgery, and none have studied them in pseudophakic patients with PCRS.

For low residual errors, the best and simplest approach is corneal laser surgery, provided the previously treated cornea is thick enough for this treatment. Both PRK and LASIK have been shown to be effective, safe and more versatile in untreated corneas, and give more accurate results than lens exchange or piggyback[47,51,52]. Surface ablation is preferable to LASIK, as it will not interfere with the previously created flap in cases of LASIK, and will avoid dehiscence of radial incisions in patients who have already undergone RK. In patients with previous LASIK, it will be difficult to lift the existing flap in eyes treated some years earlier, and creating a new flap could compromise corneal biomechanics[47]. In addition, surface ablation may have advantages over LASIK when treating patients who, due to their age, can present more postoperative ocular surface morbidity, such as dry eye or epithelial basal membrane dystrophy[47,52]. A recent study comparing corneal refractive surgery, piggyback lens implant and lens exchange for the treatment of residual errors after cataract surgery found LASIK to be the most predictable. However, the group undergoing LASIK in this series presented lower preoperative spherical equivalents than the other 2 groups, and the outcomes of intraocular procedures were superior to LASIK in patients with higher residual errors[53]. In this study, patients undergoing cataract surgery had no PCRS, which is why LASIK was used in all cases. Either way, it is important to advise the patient of the unlikelihood of achieving full visual acuity without correction due to the combined effect of age, subclinical retinal changes, and IOL- and LASIK-induced aberrations[54].

In case of higher residual defects, or if laser treatment is not possible, inserting a piggyback lens is preferable to lens exchange. The piggyback technique permits more accurate lens power calculation, the procedure is simpler, more effective and safer than exchange, and the outcome is more predictable[53,55].

Piggybacking is also less traumatic than replacement and is less likely to lead to complications, particularly when the capsular bag surrounding the lens to be replaced is already fibrosed, with small capsulorhexis, or if a YAG capsulotomy has already been performed. In those cases, there is a risk of posterior capsule rupture, zonular dehiscence, vitreous loss, cystoid macular oedema, or endothelial decompensation. In addition, the piggyback technique is reversible, and IOL power calculation is simpler than with lens exchange, since there are fewer parameters susceptible to change and it is not necessary to know the power of the implanted lens. In lens exchange, the power of the previously implanted lens must be known, there is always the uncertainty of whether the new lens will have the same effective position as the explanted lens, and there is a greater degree of surgery-induced astigmatism due to the larger incision required, even if the lens is dissected before removal[51,52]. Lens exchange should only be performed if early correction of high refractive errors following cataract surgery is required[55]. In these cases, if the lens to be extracted is foldable, it can be dissected and extracted by extending the previous incision to 3.2 - 3.4 mm. Finally, these cases could benefit greatly in the future with the use of light-adjustable IOLs, which allow optical power to be adjusted non-invasively using ultraviolet light[56].

CONCLUSIONS

A number of important factors must be considered before performing cataract surgery in a patient with previous refractive surgery: a detailed preoperative examination, calculation of IOL power, selecting the best type of lens, and choosing the most appropriate procedure for the surgery and for the correction of possible refractive surprises. The latest diagnostic technology can provide important information that will guide IOL selection, and the availability of calculators and formulae built into optical biometers has simplified lens power calculation. However, these aids are only useful if the clinician has an in-depth understanding of the problems involved and their solutions. Surgery in patients with previous LASIK or PRK is largely similar to the procedure used in untreated eyes, but in patients with previous radial keratotomy, particular care must be taken when making the incision. Before treating a refractive surprise, it is important to first rule out interface fluid syndrome in patients with previous LASIK treatment, or incision hydration in the case of radial keratotomy. A refractive surprise should ideally be treated with refractive laser surgery, whenever possible. This technique is more accurate than piggybacking or lens exchange, which should be used in eyes with higher refractive errors; piggybacking is generally preferable to lens exchange. A well-informed patient is as important as a thorough preoperative examination, accurate lens selection and power calculation, and the best surgical approach. It is essential to ascertain the patient's expectations, explain the difficulties involved in each case, warn them of the possibility of a refractive surprise and anticipate the treatment needed to correct the error, and to summarise all the information given in an informed consent form.

REFERENCES

1. Wolffsohn JS, Arita R, Chalmers R, Djalilian A, Dogru M, Dumbleton K, Gupta PK, Karpecki P, Lazreg S, Pult H, Sullivan BD, Tomlinson A, Tong L, Villani E, Yoon KC, Jones L, Craig JP. TFOS DEWS II Diagnostic Methodology report. Ocul Surf 2017; 15:539-574.
2. Soler F. Pupila y profundidad de campo y de foco. In: Ruiz-Mesa R ed, Optica para el cirujano facorrefractivo. Barcelona, Elsevier, 2015; 137-141.
3. Iijima K, Kamiya K, Shimizu K, Igarashi A, Komatsu M. Demographics of patients having cataract surgery after laser in situ keratomileusis. J Cataract Refract Surg 2015; 41:334-338.

4. Cadarso L, Catalán S, Gómez A, Piñero M. Aplicación práctica de la aberrometría a la cirugía ocular. In: Ruiz-Mesa R ed, Optica para el cirujano facorrefractivo. Barcelona, Elsevier, 2015; 169-172.
5. Maeda N. Evaluation of Corneal Optical Quality for Premium IOLs with Pentacam HR. In: Belin M, Khachikian S, Ambrosio R eds, Elevation based corneal tomography. Panama, Jaypee-Highlights medical Publishers, Inc., 2012; 197-204.
6. Seitz B, Langenbucher A, Nguyen NX, Kus MM, Kuchle M. Underestimation of intraocular lens power for cataract surgery after myopic photorefractive keratectomy. Ophthalmology 1999; 106:693-702.
7. Aramberri J. Cálculo de la potencia de la LIO tras cirugía refractiva. In: Fernñandez-Vega L ed, Facoemulsificación y Emetropia Monografía de la SECOIR. Madrid, SECOIR, 2001; 55-65.
8. Hoffer KJ. The Hoffer Q formula: a comparison of theoretic and regression formulas. J Cataract Refract Surg 1993; 19:700-712.
9. Odenthal MT, Eggink CA, Melles G, Pameyer JH, Geerards AJ, Beekhuis WH. Clinical and theoretical results of intraocular lens power calculation for cataract surgery after photorefractive keratectomy for myopia. Arch Ophthalmol 2002; 120:431-438.
10. Stakheev AA. Intraocular lens calculation for cataract after previous radial keratotomy. Ophthalmic Physiol Opt 2002; 22:289-295.
11. Smadja D, Santhiago MR, Mello GR, Roberts CJ, Dupps WJ, Jr., Krueger RR. Response of the posterior corneal surface to myopic laser in situ keratomileusis with different ablation depths. J Cataract Refract Surg 2012; 38:1222-1231.
12. Ho JD, Tsai CY, Tsai RJ, Kuo LL, Tsai IL, Liou SW. Validity of the keratometric index: evaluation by the Pentacam rotating Scheimpflug camera. J Cataract Refract Surg 2008; 34:137-145.
13. Kalski RS, Danjoux JP, Fraenkel GE, Lawless MA, Rogers C. Intraocular lens power calculation for cataract surgery after photorefractive keratectomy for high myopia. J Refract Surg 1997; 13:362-366.
14. Gobbi PG, Carones F, Brancato R. Keratometric index, videokeratography, and refractive surgery. J Cataract Refract Surg 1998; 24:202-211.
15. Maeda N, Klyce SD, Smolek MK, McDonald MB. Disparity between keratometry-style readings and corneal power within the pupil after refractive surgery for myopia. Cornea 1997; 16:517-524.
16. Camellin M, Savini G, Hoffer KJ, Carbonelli M, Barboni P. Scheimpflug camera measurement of anterior and posterior corneal curvature in eyes with previous radial keratotomy. J Refract Surg 2012; 28:275-279.
17. Aramberri J. Intraocular lens power calculation after corneal refractive surgery: double-K method. J Cataract Refract Surg 2003; 29:2063-2068.
18. Koch DD, Wang L. Calculating IOL power in eyes that have had refractive surgery. J Cataract Refract Surg 2003; 29:2039-2042.
19. Schuster AK, Tesarz J, Vossmerbaeumer U. The impact on vision of aspheric to spherical monofocal intraocular lenses in cataract surgery: a systematic review with meta-analysis. Ophthalmology 2013; 120:2166-2175.
20. Olsen T. Prediction of the effective postoperative (intraocular lens) anterior chamber depth. J Cataract Refract Surg 2006; 32:419-424.
21. Holladay JT. IOL calculations following radial keratotomy surgery. Questions and answers. Refract Corneal Surg 1989; 5:36A.
22. Celikkol L, Pavlopoulos G, Weinstein B, Celikkol G, Feldman ST. Calculation of intraocular lens power after radial keratotomy with computerized videokeratography. Am J Ophthalmol 1995; 120:739-750.
23. Lyle WA, Jin GJ. Intraocular lens power prediction in patients who undergo cataract surgery following previous radial keratotomy. Arch Ophthalmol 1997; 115:457-461.
24. Wang L, Booth MA, Koch DD. Comparison of intraocular lens power calculations methods in eyes that have undergone LASIK. Ophthalmology 2004; 111:1825-1831.
25. Shammas HJ, Shammas MC, Garabet A, Kim JH, Shammas A, LaBree L. Correcting the corneal power measurements for intraocular lens power calculations after myopic laser in situ keratomileusis. Am J Ophthalmol 2003; 136:426-432.
26. Rosa N, Capasso L, Romano A. A new method of calculating intraocular lens power after photorefractive keratectomy. J Refract Surg 2002; 18:720-724.
27. Randleman JB, Foster JB, Loupe DN, Song CD, Stulting RD. Intraocular lens power calculations after refractive surgery: consensus-K technique. J Cataract Refract Surg 2007; 33:1892-1898.
28. Holladay JT, Hill WE, Steinmueller A. Corneal power measurements using scheimpflug imaging in eyes with prior corneal refractive surgery. J Refract Surg 2009; 25:862-868.
29. Seo KY, Im CY, Yang H, Kim TI, Kim EK, Kim T, Nam SM. New equivalent keratometry reading calculation with a rotating Scheimpflug camera for intraocular lens power calculation after myopic corneal surgery. J Cataract Refract Surg 2014; 40:1834-1842.
30. Savini G, Bedei A, Barboni P, Ducoli P, Hoffer KJ. Intraocular lens power calculation by ray-tracing after myopic excimer laser surgery. Am J Ophthalmol 2014; 157:150-153 e151.
31. Ianchulev T, Salz J, Hoffer K, Albini T, Hsu H, Labree L. Intraoperative optical refractive biometry for intraocular lens power estimation without axial length and keratometry measurements. J Cataract Refract Surg 2005; 31:1530-1536.
32. Ianchulev T, Hoffer KJ, Yoo SH, Chang DF, Breen M, Padrick T, Tran DB. Intraoperative refractive biometry for predicting intraocular lens power calculation after prior myopic refractive surgery. Ophthalmology 2014; 121:56-60.
33. Sambare C, Naroo S, Shah S, Sharma A. The AS biometry technique--a novel technique to aid accurate intraocular lens power calculation after corneal laser refractive surgery. Cont Lens Anterior Eye 2006; 29:81-83.

34. Walter KA, Gagnon MR, Hoopes PC, Jr., Dickinson PJ. Accurate intraocular lens power calculation after myopic laser in situ keratomileusis, bypassing corneal power. J Cataract Refract Surg 2006; 32:425-429.
35. Chang DH, Rocha KM. Intraocular lens optics and aberrations. Curr Opin Ophthalmol 2016; 27:298-303.
36. Schuster AK, Tesarz J, Vossmerbaeumer U. Ocular wavefront analysis of aspheric compared with spherical monofocal intraocular lenses in cataract surgery: Systematic review with metaanalysis. J Cataract Refract Surg 2015; 41:1088-1097.
37. Breyer DRH, Kaymak H, Ax T, Kretz FTA, Auffarth GU, Hagen PR. Multifocal Intraocular Lenses and Extended Depth of Focus Intraocular Lenses. Asia Pac J Ophthalmol (Phila) 2017; 6:339-349.
38. Khor WB, Afshari NA. The role of presbyopia-correcting intraocular lenses after laser in situ keratomileusis. Curr Opin Ophthalmol 2013; 24:35-40.
39. Vrijman V, van der Linden JW, van der Meulen IJE, Mourits MP, Lapid-Gortzak R. Multifocal intraocular lens implantation after previous corneal refractive laser surgery for myopia. J Cataract Refract Surg 2017; 43:909-914.
40. Chang JS, Ng JC, Chan VK, Law AK. Visual Outcomes, Quality of Vision, and Quality of Life of Diffractive Multifocal Intraocular Lens Implantation after Myopic Laser In Situ Keratomileusis: A Prospective, Observational Case Series. J Ophthalmol 2017; 2017:6459504.
41. MacRae S, Holladay JT, Glasser A, Calogero D, Hilmantel G, Masket S, Stark W, Tarver ME, Nguyen T, Eydelman M. Special Report: American Academy of Ophthalmology Task Force Consensus Statement for Extended Depth of Focus Intraocular Lenses. Ophthalmology 2017; 124:139-141.
42. Cochener B. Clinical outcomes of a new extended range of vision intraocular lens: International Multicenter Concerto Study. J Cataract Refract Surg 2016; 42:1268-1275.
43. Gatinel D, Loicq J. Clinically Relevant Optical Properties of Bifocal, Trifocal, and Extended Depth of Focus Intraocular Lenses. J Refract Surg 2016; 32:273-280.
44. Bellucci R, Curatolo MC. A New Extended Depth of Focus Intraocular Lens Based on Spherical Aberration. J Refract Surg 2017; 33:389-394.
45. Black S. Successful Restoration of Visual Acuity with an Extended Range of Vision Intraocular Lens after Multifocal Laser Ablation. Case Rep Ophthalmol 2016; 7:193-197.
46. Dick HB, Piovella M, Vukich J, Vilupuru S, Lin L. Prospective multicenter trial of a small-aperture intraocular lens in cataract surgery. J Cataract Refract Surg 2017; 43:956-968.
47. Alio JL, Abdelghany AA, Abdou AA, Maldonado MJ. Cataract surgery on the previous corneal refractive surgery patient. Surv Ophthalmol 2016; 61:769-777.
48. Jin H, Zhang Q, Zhao P. Modification of the wound construction to prevent dehiscence of radial keratotomy incision in cataract surgery: Wave-shaped scleral incision. J Cataract Refract Surg 2017; 43:449-455.
49. Koch DD, Liu JF, Hyde LL, Rock RL, Emery JM. Refractive complications of cataract surgery after radial keratotomy. Am J Ophthalmol 1989; 108:676-682.
50. Osher RH. Transient pseudophakic hyperopia after previous radial keratotomy. J Cataract Refract Surg 2009; 35:2176; author reply 2176.
51. Abdelghany AA, Alio JL. Surgical options for correction of refractive error following cataract surgery. Eye Vis (Lond) 2014; 1:2.
52. Sales CS, Manche EE. Managing residual refractive error after cataract surgery. J Cataract Refract Surg 2015; 41:1289-1299.
53. Fernandez-Buenaga R, Alio JL, Perez Ardoy AL, Quesada AL, Pinilla-Cortes L, Barraquer RI. Resolving refractive error after cataract surgery: IOL exchange, piggyback lens, or LASIK. J Refract Surg 2013; 29:676-683.
54. Jin GJ, Merkley KH, Crandall AS, Jones YJ. Laser in situ keratomileusis versus lens-based surgery for correcting residual refractive error after cataract surgery. J Cataract Refract Surg 2008; 34:562-569.
55. El Awady HE, Ghanem AA. Secondary piggyback implantation versus IOL exchange for symptomatic pseudophakic residual ametropia. Graefes Arch Clin Exp Ophthalmol 2013; 251:1861-1866.
56. Ford J, Werner L, Mamalis N. Adjustable intraocular lens power technology. J Cataract Refract Surg 2014; 40:1205-1223.

First author:

Jaime Aramberri, MD

Clinica Begitek, San Sebastian and Clinica Okular, Vitoria, Spain.