26 The Pentacam Family

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Introduction

Cataract surgery is the most frequently performed eye surgery today—and IOL power calculation is a fascinating discipline in Ophthalmology!

May we introduce, your partners:

The use of the Pentacam family (Fig. 26.1) in modern cataract surgery can be described like a continues process (Fig. 26.2):

A few topics as listed below should be touched in this chapter:

Fig. 26.1 Pentacam Family

- Pentacam history and basic principle.
- Some basic questions.
- Every patient is an individuum = customization.
- IOL power calculation formulas in the Pentacam.
- Post-op visual assessment.

History and Basic Principle

The Pentacam family was born in 2002 and further expanded by the Pentacam HR in 2006. Both devices are based on a rotating Scheimpflug camera (Fig. 26.3), capturing high-resolution pictures of the anterior eye segment, from the cornea, down to the crystalline lens. The benefits of this technology are the snapshot-capturing of the single images, highest density in the corneal center, full cornea and scleral coverage, and a minimum of nose shadow.

The Pentacam contains since day one, a second camera, the iris camera, detecting eye motions during the scan process. The captured Scheimpflug images, up to 100, are composed to

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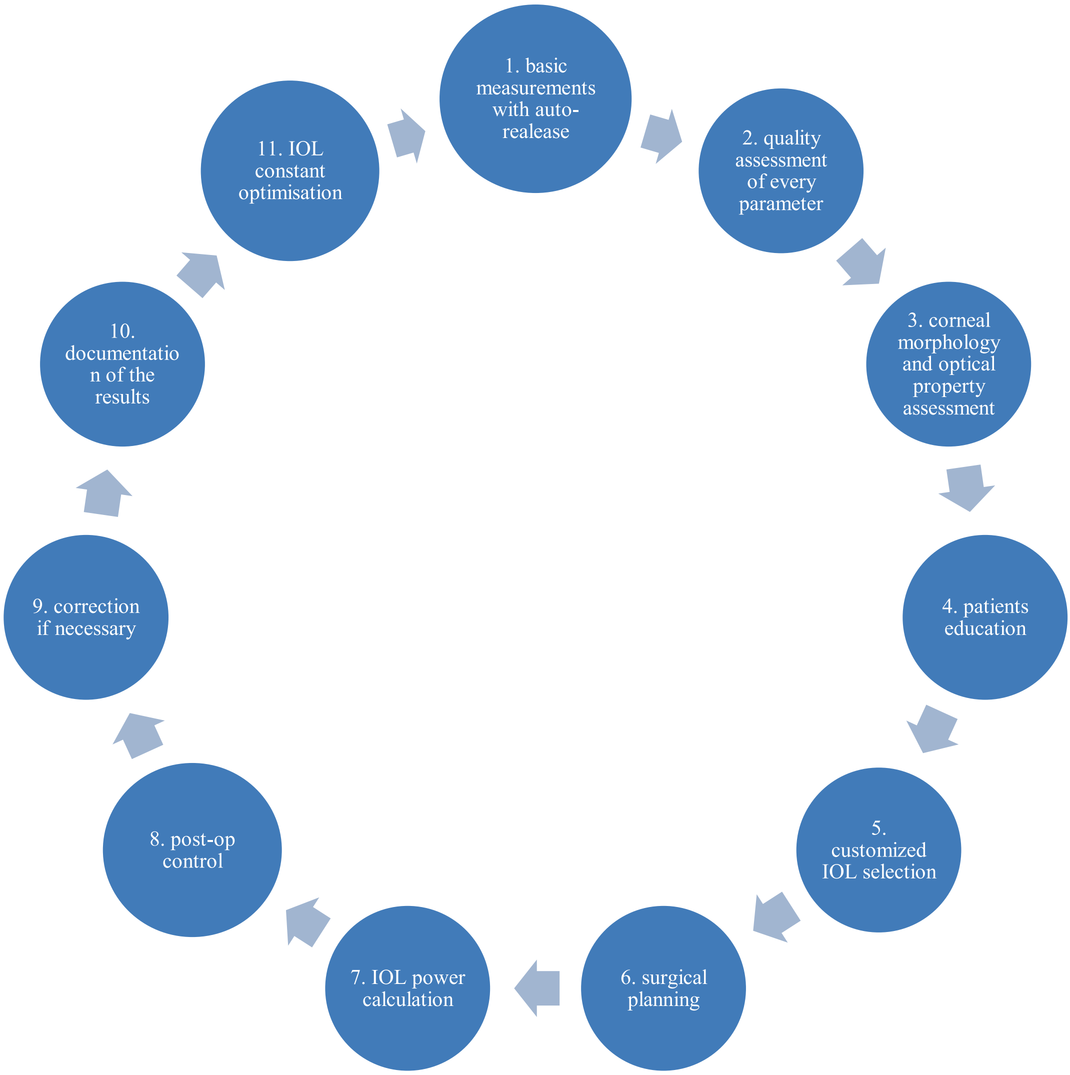

Fig. 26.2 Modern cataract surgery process

a three-dimensional model of the anterior eye segment in which the eye motions are corrected. A quality specification informs the user regarding the quality of the exam (Table 26.1).

This proven concept is reflected by its highest repeatability of keratometry [1–4], the most influential component in IOL power calculation. This might be due its tear film independency since Scheimpflug tomography does not require an intact tear film to reflect Placido rings or keratometry LEDs. No artificial tears should be applied before the measurements since this might change the normal conditions of the cornea. Moreover, objective crystalline lens density analysis [5] and grading of the nucleus [6] are possible.

In 2015, the Pentacam AXL was launched, combining the proven Scheimpflug tomography with optical biometry based on PCI technology and its comparability to the gold standard was proven [7]. This model includes the IOL calculator, containing IOL power calculation formulas for almost every cornea status, including IOL constant optimization. The IOL database is included, so no time-wasting collection of whatever IOLs are necessary. It contains up to 500 different IOL models from up to 35 manufactures who provided all details. Moreover, the IOL geometries are included for many IOLs, allowing total ray-traced-based IOL power calculation using the Olsen [8] formula.

The Pentacam AXL Wave launched in 2019 contains, besides the Scheimpflug tomography and optical biometry, a Hartmann–Shack wavefront sensor and retroillumination. These two features allow an assessment of the total eye visual performance, including objective refraction and high-order aberration analysis, and a post-op assessment of the IOL position in the human eye. The true separation of the internal wavefront from the total corneal wavefront (not possible with Placido technology) is the basis for a better understanding of individual visual quality and possible reasons for visual disturbance.

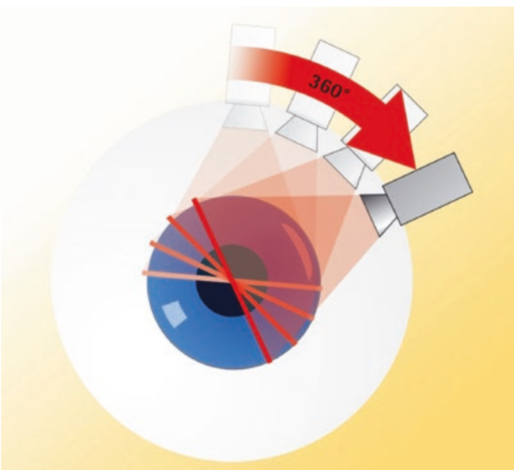

Fig. 26.3 Pentacam rotating Scheimpflug Scan

Some Basic Questions

Is Pure Keratometry and Axial Length Enough for IOL Power Calculation Today?

The most often used IOL power formulas like SRK/T [9], Haigis [10], Hoffer Q [8], and Holladay 1 [10] use axial length and keratometry for the calculation of the IOL power and for the prediction of the position of the IOL in the pseudophakic eye—whereby the Haigis formula uses the anterior chamber depth, measured from the epithelium as well. Every IOL formula has at least two components, the calculation of the power and the prediction of its position in the pseudophakic eye, and the second component is of highest interest and the biggest source of errors today. To improve this, many more factors are taken into account like HCD (corneal diameter), thickness of the human lens, and others are necessary. To achieve low prediction errors and less post-op surprises, more parameters have to be considered like the Barrett Universal 2 [11].

Table 26.1 Pentacam model specifications

Model Specs	Pentacam®	Pentacam® HR	Pentacam® AXL	Pentacam® AXL wave
Camera	Digital CCD camera			
Light source	Blue LED (475 nm UV-free)			
Speed	50 images in 2 s	100 images in 2 s [a]		
Axial length	–	–	14–40 mm	
Curvature	3–38 mm/9–99 D			
Precision	±0.2 D	±0.1 D		
Reproducibility	±0.2 D	±0.1 D		
Operating distance	80 mm/3.1 inch			

[a] Cornea fine scan

Does One Formula for Every Purpose Exist?

One formula for every purpose which should achieve best results no matter what the cornea look like may still not exist today. Many formulas exist for corneas after laser refractive interventions [11–15], for keratoconus [8], for the correction of astigmatism [16, 17] and ray tracing formulas for every corneal shape, including corneal transplants and all the odd corneal shapes like corneal transplants and others.

Every IOL for Every Patient?

The development of different IOL designs to improve our patients' visual performance is a blessing but requires careful patients selection. Our patients are entitled to understand about the possibilities and limitations to adjust expectations and avoid disappointments after surgery.

Every Patient Is an Individuum = Customization

Considering the fact that just keratometry and axial length is not enough to achieve top- outcome, that individual formulas might be necessary and patients selection is key to success [18], more than just a pure standard optical biometer is necessary.

The OCULUS Pentacam addresses this in particular (Fig. 26.4):

Corneal Morphology Assessment

Corneal Tomography = total cornea assessment has its benefit over pure corneal topography [19]. The total cornea is analyzed and described like a thick lens: anterior and posterior surface and its thickness at every single position are known. Scheimpflug tomography analyzes the cornea in almost every detail and provides important information to detect abnormalities and diseases:

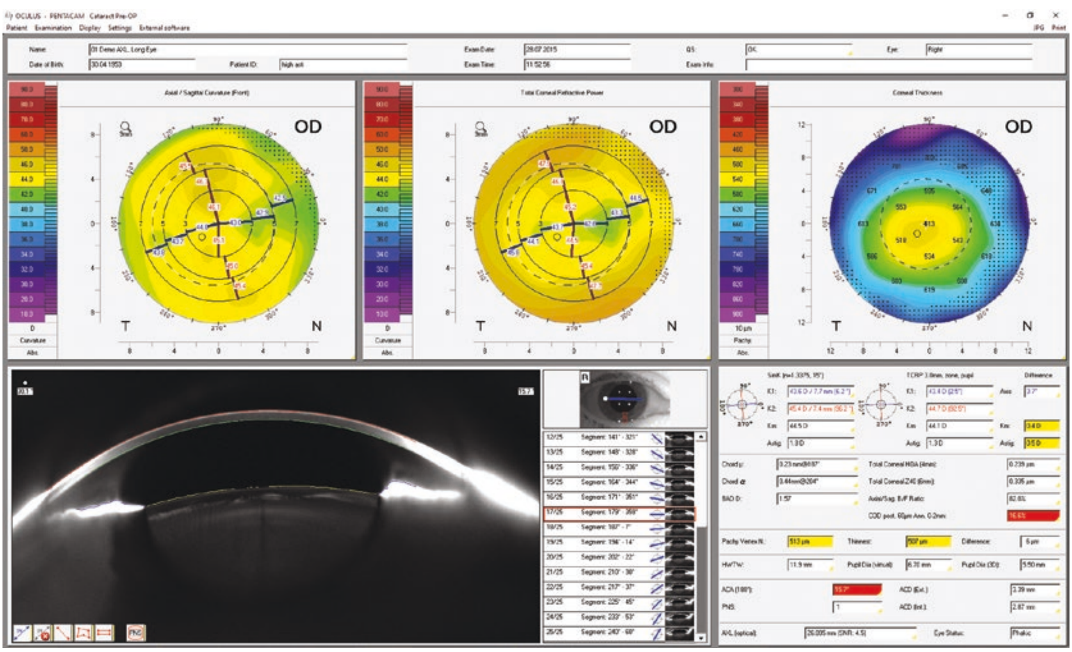

Fig. 26.4 Cataract pre-op display

- The keratometry and the assessment of the corneal astigmatism is basic knowledge. Moreover, the low astigmatism and the consideration of the posterior surface providing Total Corneal Refractive Astigmatism without any assumptions is a step forward [15, 16].
- The topography maps of the anterior and posterior surface highlights irregular corneal shape [20].
- The analysis regarding possible laser refractive or other surgical interventions using tomography, the B/F-ratio (back to front ratio) of the cornea, which is for normal eyes around 82% [21], plays an important role too. This factor is lower for post-myopic and higher for post-hyperopic laser surgery and for post-RK (radial keratotomy).
- The Belin/Ambrosio Enhanced Ectasia separates normal from abnormal patients and supports in the detection of corneal ectasia while having a final color-coded parameter, the “D”-value [20].
- The early detection of Endothelium Fuchs Dystrophy became more important. It is a progressive disease which requires sooner or later a posterior cornea transplant (DMEK or DSEK). The Pentacam supports in the early detection [22]. This often results in a post-op hyperopic shift. Arising questions are first, the best surgical planning, combined or in two steps and second the formula which should be used after the corneal transplant. A good option could be the Olsen ray tracing formula.

The More Complex Corneas: How to Deal with It?

These corneas, often after refractive surgery or other surgical interventions, are always a challenge in IOL power calculation. The corneal power distribution display is a powerful assessment tool for these cases. But not only these challenging cases might be of interest, it just starts with the assessment of the astigmatisms (Fig. 26.5):

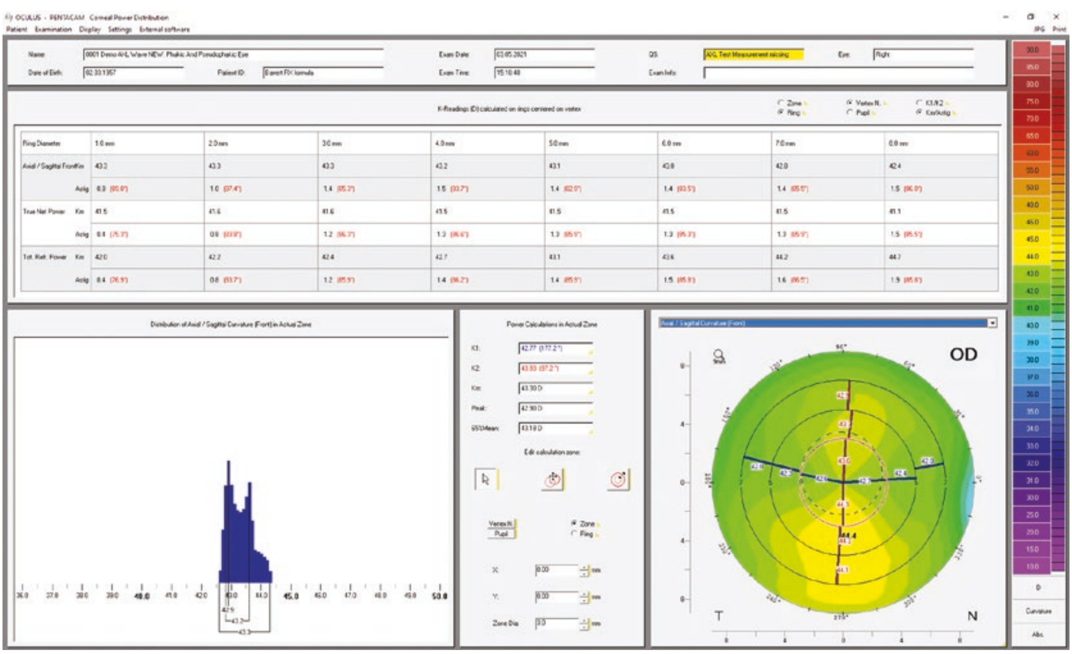

Fig. 26.5 Corneal power distribution of a regular astigmatism

- Is the magnitude and the axis in the central zone same or different compared to the periphery?
- Does it change and if yes how much?
- How is this related to the pupil diameter, does it matter?
- What about the orientation of the axis of the astigmatism, for a WTR (with the rule), ATR (against the rule), or oblique astigmatism?
- What about the influence of the posterior corneal surface in terms of possible axis shifts? Does it matter and if yes, which IOL formula approach should be used?

The example below shows a patient after LASIK with a homogenous ablation zone and a small corneal power distribution (Fig. 26.6).

On the other hand, an example of a post-LASIK patients with a decentered ablation and flap problems (Fig. 26.7).

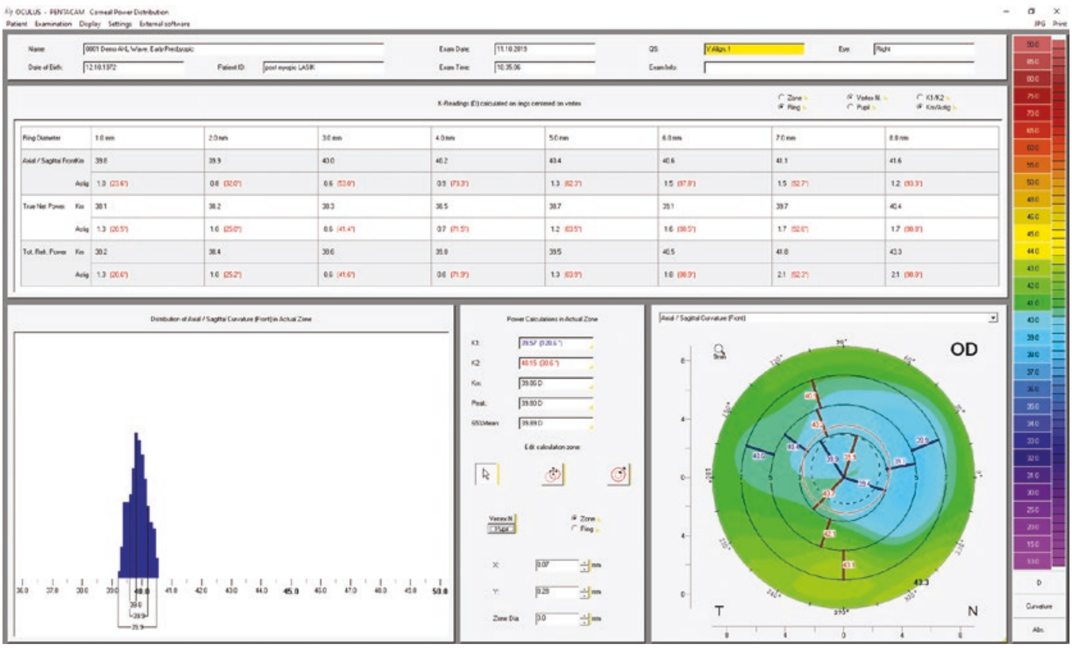

Fig. 26.6 Small corneal power distribution after LASIK

Fig. 26.7 Huge corneal power distribution after LASIK

Corneal Optical and Anterior Chamber Properties Assessment

The human eye is not an optical bench. Hence, it requires individual assessment of corneal optical and anterior chamber properties which are "solid-factors" for IOL selection.

The Pentacam tomography calculates the total corneal wavefront, considering the posterior surface.

- The total spherical aberrations, which are often associated with halos, starburst, ghost images, and loss of contrast sensitivity, are important to measure. This supports the selection of an aspherical or an aberration-neutral IOL design. Normative values are provided [23].
- Increased coma, which causes an optical effect like a comet tail and may result in double-vision, might be contraindication for multifocal IOLs.
- Increased trefoil, which spreads the light in three directions, is important to quantify as well.

They do not occur individually, and they are limiting factors for the visual performance per se. The Pentacam provides all these values, including cut-off suggestions, supporting in the selection of multifocal IOLs.

The Pentacam provides the anterior chamber depth, measured form the epithelium as well as the anterior chamber depth measured from the endothelium. angle is calculated in every Scheimpflug image and is used for the selection if a patient might be suitable for a pIOL implantation. Please note that for pseudophakic eyes the anterior chamber depth should be double-checked.

Centration of Optical Elements and Pupil Diameter

Pentacam tomography provides parameters associated with the optical path of the individual eye.

The vectorial distance between the vertex normal—the reference for all Pentacam measurements—and the pupil center, called chord μ and chord α which is the distance between vertex normal and the corneal geometric center. If they are high, there might be a risk for reduced visual performance.

The Pentacam AXL Wave provides the pupil diameter under day and night conditions. In combination with the corresponding refraction, additional support for cataract refractive surgery is provided.

Total Eye Visual Performance

The Pentacam AXL Wave with its built-in Hartmann–Shack sensor for total eye wavefront has the ability to display the source, or the reasons for visual impairments. The example below (Fig. 26.8) shows an early presbyopia case of a female aged 47 with a previous myopic LASIK. The reason for her typical problems, like driving at night or when it is rainy and foggy, is the crystal lens. This picture helps her understand immediately the reason.

The example below shows a patient with previous RK (Fig. 26.9) having high expectations in the cataract surgery. No matter which lens you are going to implant, the visual quality will never be as good as expected. The patient understood—the image told more than 1000 words.

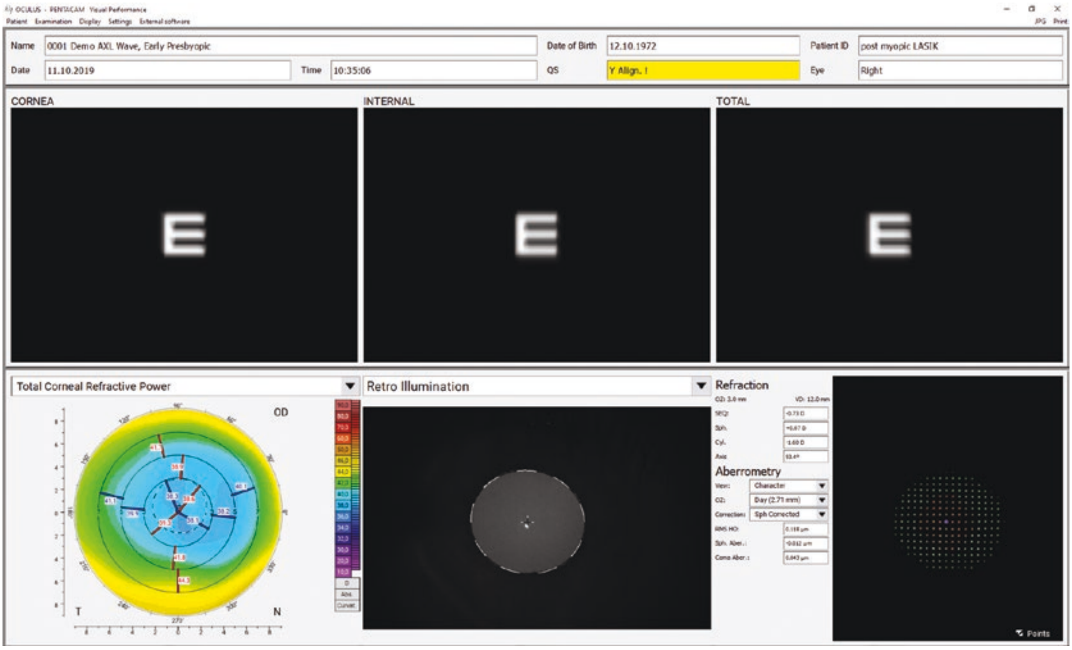

Fig. 26.8 Myopic LASIK patient, early presbyopia

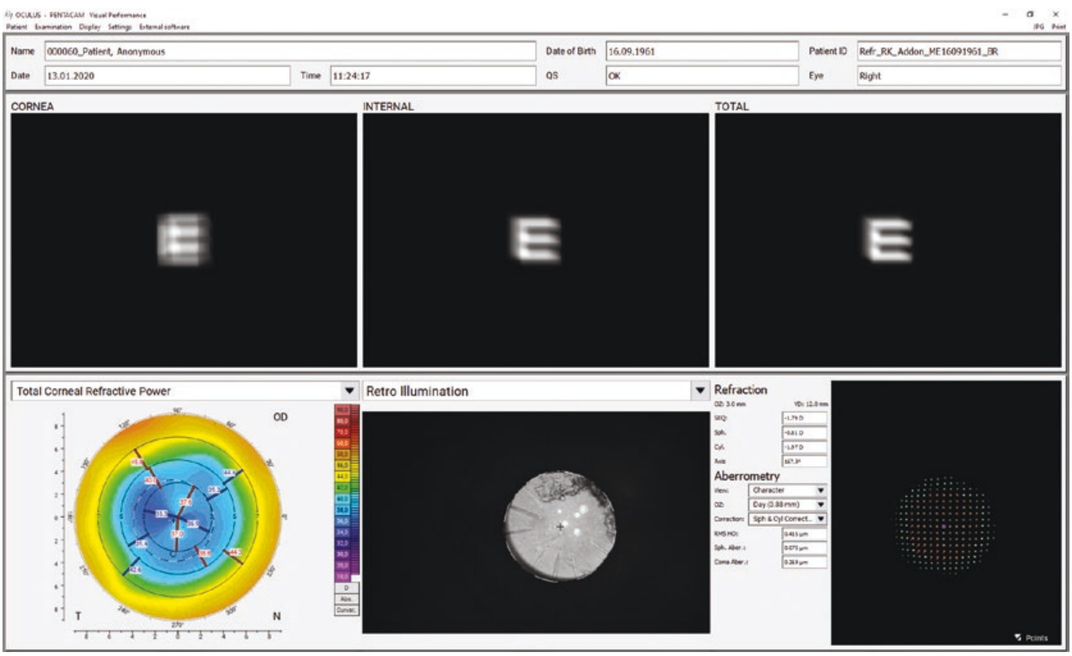

Fig. 26.9 Patient after RK (radial keratotomy)

IOL Power Calculation Formulas in the Pentacam

The improvement of IOL power calculation formulas is a process. The IOL calculator built into the Pentacam AXL and Pentacam AXL Wave includes IOL power calculation formulas for almost every purpose and the IOL database—ready to use. No online calculators have to be assessed.

The Pentacam keratometry was proven to be most accurate, for normal and abnormal corneas [2, 4, 12]. Combined with precise axial length and other required parameter, the basis is made to achieve very good refractive outcomes [21].

Every single surgeon in a bigger clinic can have his/her own profile with individual combinations of IOLs with IOL power calculation formulas. For the calculation of toric IOLs, the SIA (surgical-induced astigmatism) has to be entered and is considered in the respective formulas. The IOL calculator displays the standard parameters as well as total corneal spherical and high-order aberrations. Abnormal values are highlighted to inform the user (Fig. 26.10).

Monofocal IOL Formulas for Virgin Corneas

The IOL formulas for monofocal IOLs are intuitively organized and contain the most common standard and modern IOL formulas (Figs. 26.11 and 26.12).

Toric IOL Formulas for Virgin Corneas

The IOL power calculation for toric IOLs offers formulas (Fig. 26.13) with measured and with estimated posterior surface. The estimated postop refraction as well as the orientation of the toric implant are shown (Fig. 26.14).

IOL Formulas for Patients After Corneal Laser Refractive Surgery and RK (Radial Keratotomy)

This is still a challenge today. The IOL calculator offer customized formulas [13, 14] for the Pentacam (Fig. 26.15) as well as the Barrett

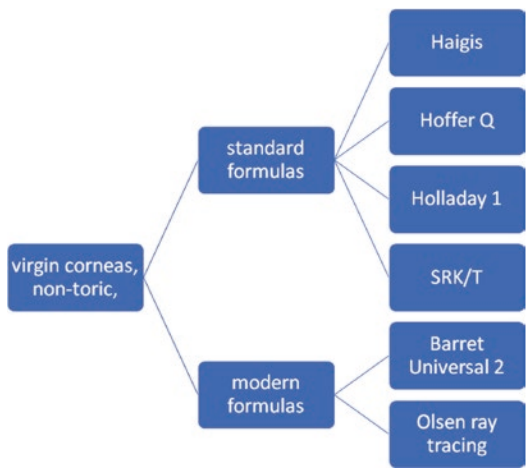

Fig. 26.11 Standard and modern IOL formulas

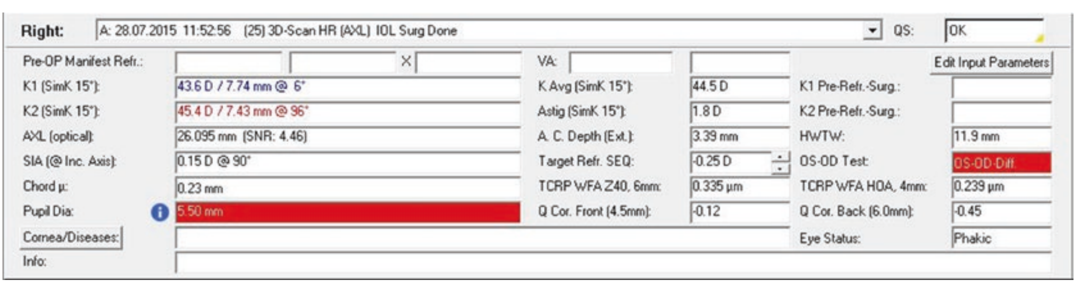

Fig. 26.10 Parameters in the IOL Calculator

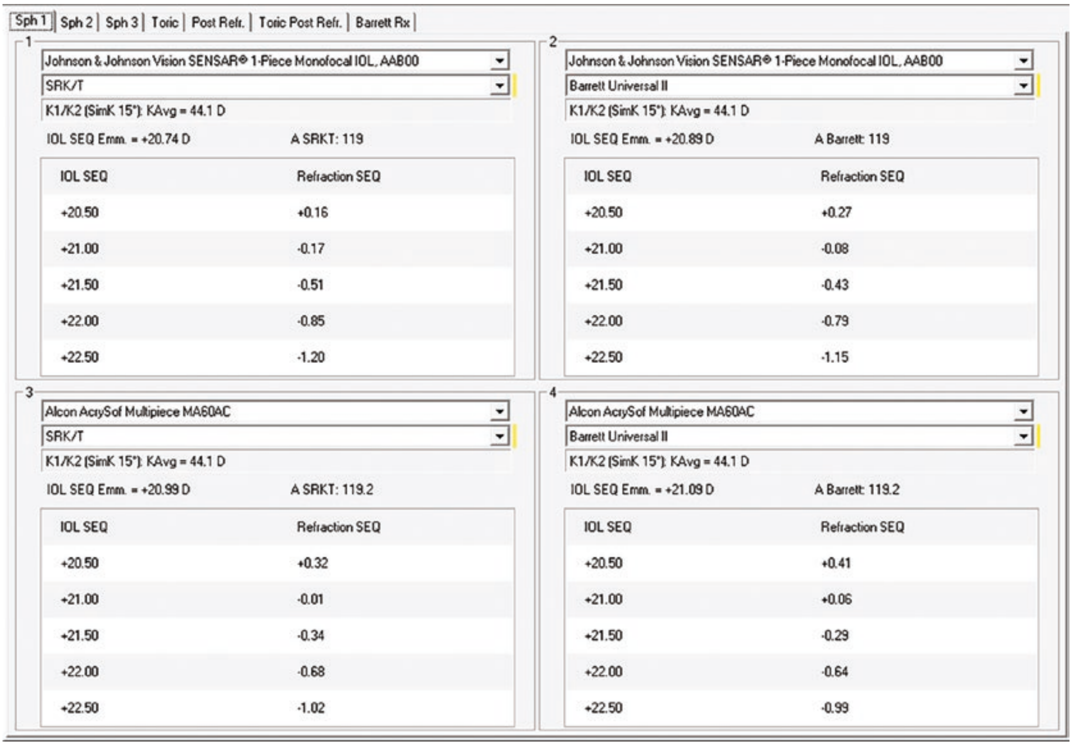

Fig. 26.12 IOL formulas for monofocal IOLs in the IOL Calculator

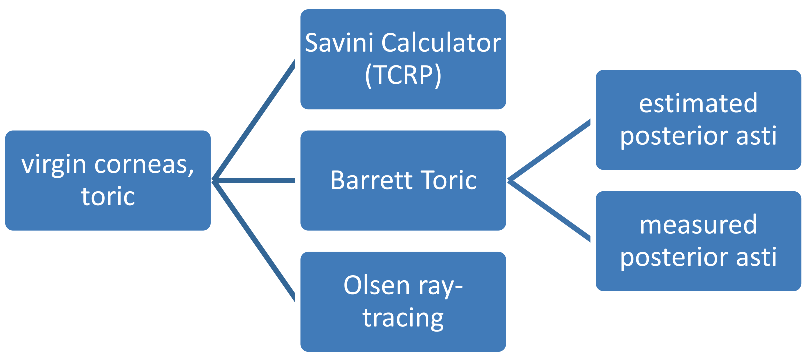

Fig. 26.13 IOL formulas for toric IOLs

True K and the double-K formulas [17]. Latest study has shown very good results using the Barrett True K formula with increasing precision the more information prior history are available [24]. On the other hand, the Olsen ray tracing formula is fully independent of any information prior refractive surgery [25] (Fig. 26.16).

The Pentacam with its rotating Scheimpflug tomography allow to measure even the very irregular corneas. For patients having had previous corneal refractive surgery with a remaining high astigmatism as well as for patients having had PKP (penetrating keratoplasty), the Olsen formula can be used (Fig. 26.17).

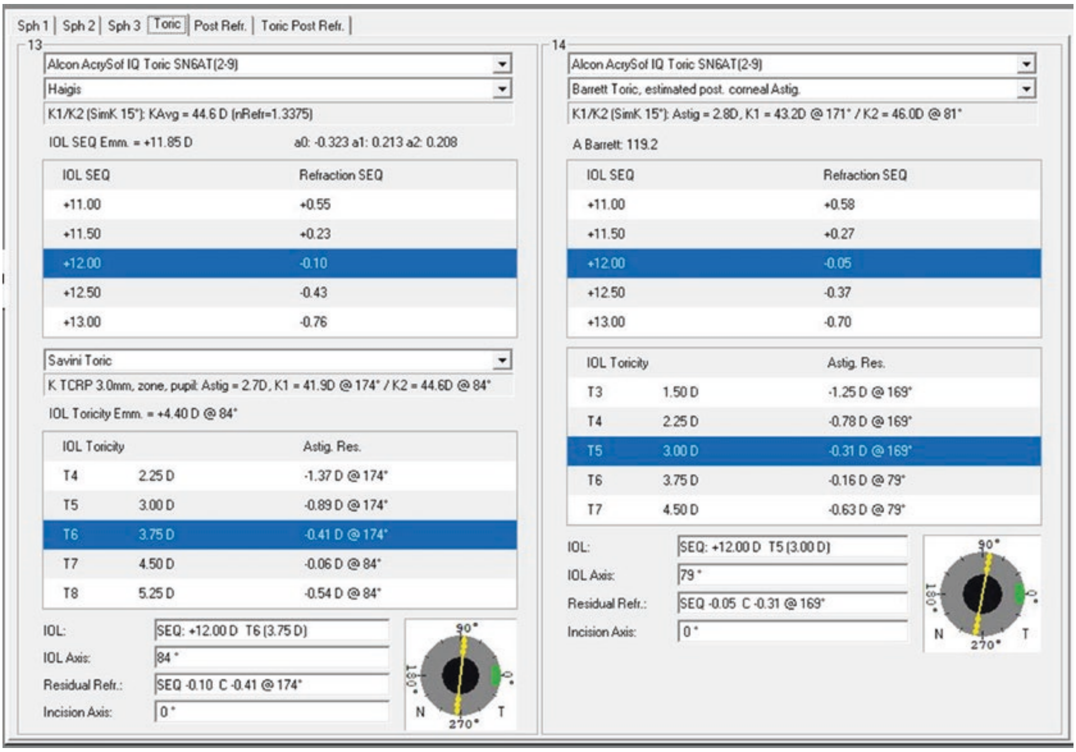

Fig. 26.14 Toric IOL formulas for virgin eyes in the IOL calculator

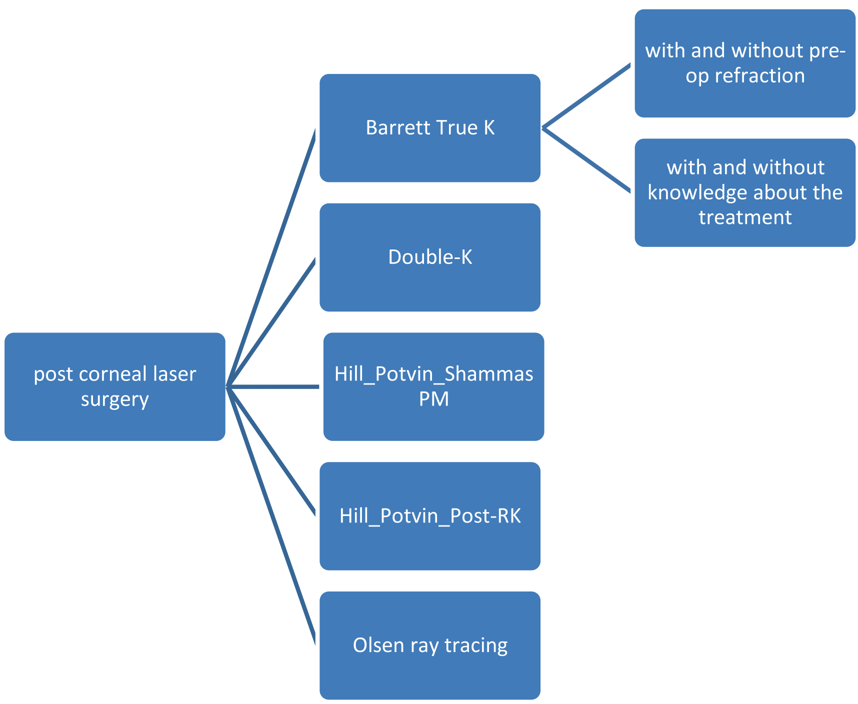

Fig. 26.15 IOL formulas for patients after refractive surgery and RK

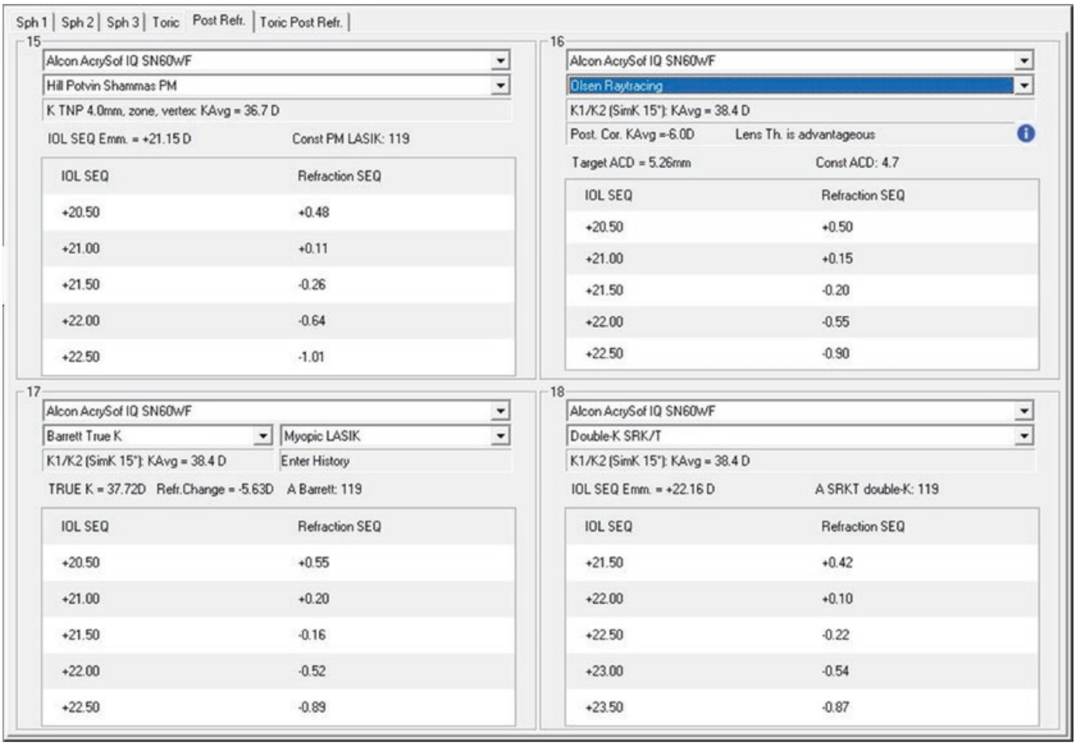

Fig. 26.16 IOL formulas for patients after refractive surgery in the IOL calculator

Fig. 26.17 Olsen ray tracing formula in the IOL Calculator

The Post-op Visual Assessment

The post-op visual assessment for documentation, quality assessment, and continuous improvement is a must today in modern cataract surgery.

The subjective refraction is one parameter combined with the slit-lamp exam, and a final short talk to the patients is routine anyway. But, what to do and how to handle unhappy patients? We all heard about the "20/20 unhappy patients." Here, the Pentacam can be of help again.

The Pentacam AXL Wave performs total eye wavefront, objective refraction, biometry, and tomography, providing a solid basis for further diagnosis—before the physicians starts the conversation with the patient.

The first example shows a happy patient after multifocal-toric implantation (Fig. 26.18). The refraction is almost plano, the Total Visual Performance is very good, and the IOL is on axis.

The example below is an example of an unhappy patient with bad visual quality after cataract surgery (Fig. 26.19). The Pentacam AXL Wave shows the Total Visual Performance and the refraction at a glance.

The retroillumination image below gives the answer, and it is a decentered IOL (Fig. 26.20).

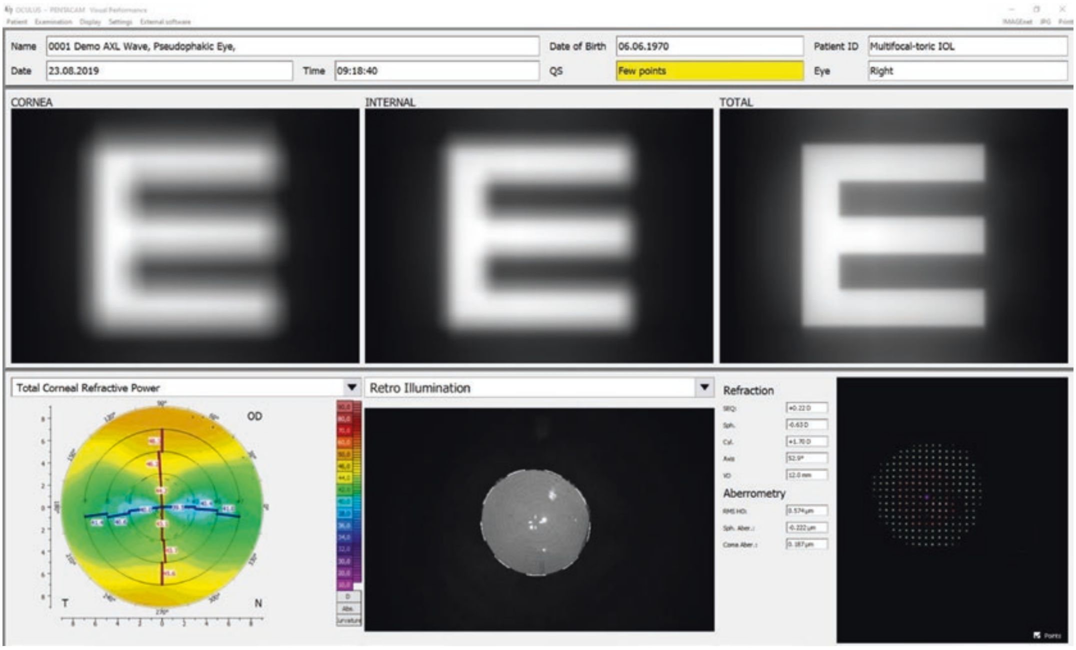

Fig. 26.18 Visual performance after multifocal toric implantation

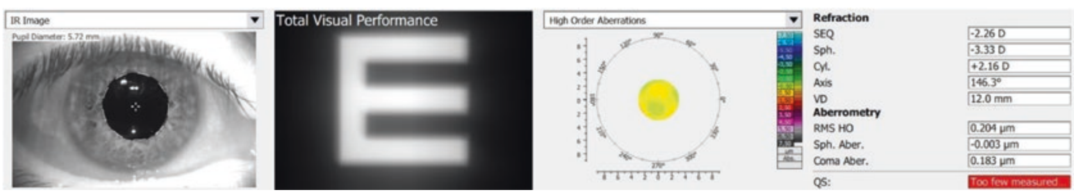

Fig. 26.19 Refraction and visual performance, decentered IOL

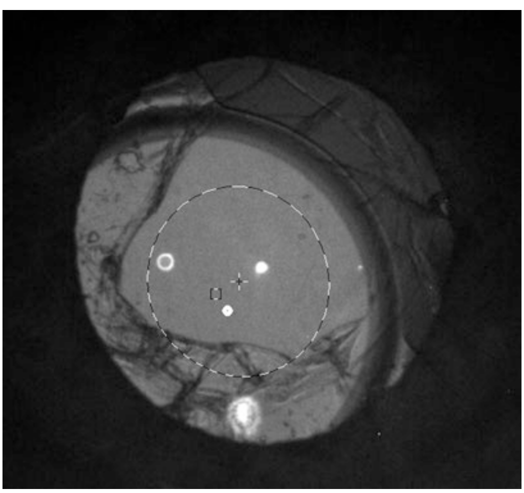

Fig. 26.20 Decentered IOL in the retroillumination image

Summary and Take-Home Message

The Pentacam AXL as well as the Pentacam AXL Wave offer the full-capacity performing IOL power calculation on the highest level. Besides this, it offers so many other clinical applications, making it the “swiss-army-knife” for every eye clinic.

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