28 CASIA2: Anterior Segment 3D Swept-Source OCT

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Introduction

CASIA2 (Fig. 28.1) was launched in 2015 from Tomey Corporation (Nagoya, Japan) as the successor to SS-1000 which was the world's first commercialized swept-source 3D optical coherence tomography in 2008. CASIA2 achieves deeper penetration and wider image by adopting the higher scanning speed light source with 1310 nm wavelength (Table 28.1), and it can acquire high-quality 3D images from the anterior surface of cornea to the back surface of the crystalline lens in short time in noncontact and noninvasive at one measurement (Fig. 28.2). CASIA2 can also provide the reliable quantitative evaluation by the stable scanning system.

The touch alignment system same as OA-2000 is employed. It can provide a stable measurement and a high reproducibility between operators because CASIA2 align itself automatically to patient eye once an operator only touches the center of the pupil on the screen. Operators can capture optical coherence tomography (OCT) image easily without any special skills.

The latest model of CASIA2 employs the color observation camera. Additionally, it makes possible observing the toric axis marking dots directly on the front camera images by optimization of the optical performance. CASIA2 is continually advancing.

Fig. 28.1 Anterior segment swept-source 3D OCT CASIA2

Table 28.1 Specifications of CASIA2

Light source	Type wavelength principal	Swept-source laser 1310 nm Fourier domain
Resolution	Axial (depth) Transverse	10 μm or less (in tissue) 30 μm or less (in tissue)
Scan speed	50,000 A-scans/s	
Scan range	16 × 16 × 13 mm	

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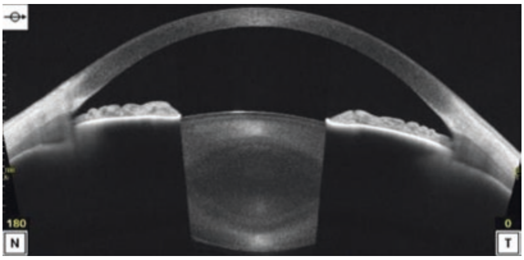


Fig. 28.2 OCT image of normal eye by CASIA2

Various Functions for Cataract Surgery

The deep and wide 3D images (Fig. 28.3) from the anterior surface of cornea to the back surface of the crystalline lens provides various functions, especially for pre- and post-operative cataract surgery.

CASIA2 has an application suite named CICS (CASIA IOL Cataract Surgery) which can sup-

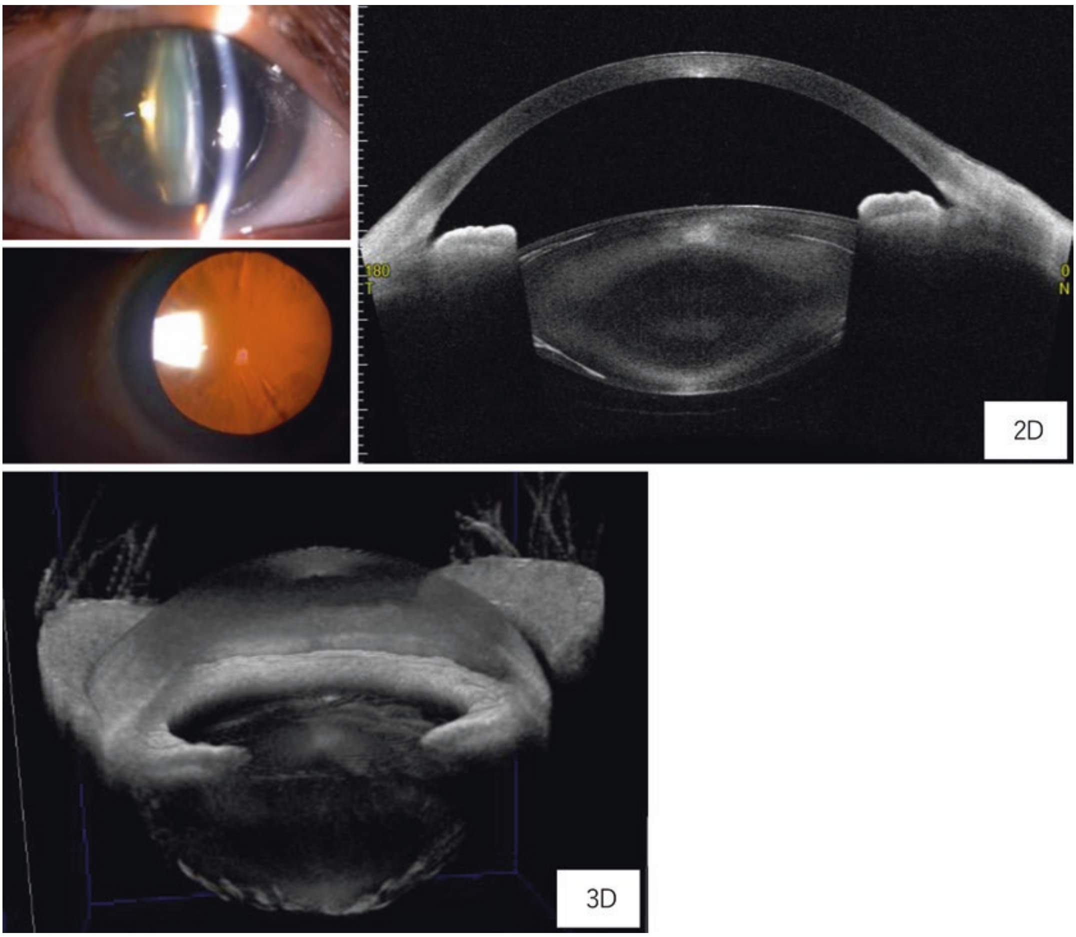


Fig. 28.3 Observation of a cortical cataract eye by 3D view function of CASIA2. Cortex opacity condition can be observed in 3D. Data are provided by Dr. Yuta Ueno, Department of Ophthalmology, Institute of Clinical Medicine, University of Tsukuba

port users on cataract surgery. CICS includes pre-op cataract and post-op cataract applications so that doctors can perform a perfect cataract surgery from planning to post-operative evaluation.

IOL Screening on Pre-op Cataract

Intraocular lens (IOL) screening display (Fig. 28.4) provides various analysis results on the anterior segment of the eye including useful information to select premium IOLs. Topography maps and basic indices of corneal shape (Fig. 28.4a), indices to select IOLs including corneal regular astigmatism and irregular astigmatism (high-order aberrations [HOAs], spherical aberration [SA]) (Fig. 28.4b), OCT image (Fig. 28.4c), indices-related anterior chamber (Fig. 28.4d), and the simulated retinal image of Landolt ring based on corneal HOAs (Fig. 28.4e) are displayed on one report. The indices are indicated in yellow or red when they are outside of normal range.

To ensure efficient screening of corneal topography in candidates of cataract surgery, Goto and Maeda propose four steps for the interpretation of the results [1] (Table 28.2).

First, check for corneal irregular astigmatism. When HOAs are high as indicated in yellow or red on Fig. 28.4f, there is higher risk of insufficient visual recovery. Multifocal IOLs should be avoided.

Second, check the abnormal topographic pattern caused by refractive surgery. Figure 28.5 shows IOL screening report of a post-Lasik eye. Axial power map shows the central flattening pattern (Fig. 28.5a) and pachymetric map shows thinner pattern (Fig. 28.5b). Average K (AvgK) and central corneal thickness (CCT) are also indicated in red (Fig. 28.5c, d). In the case of

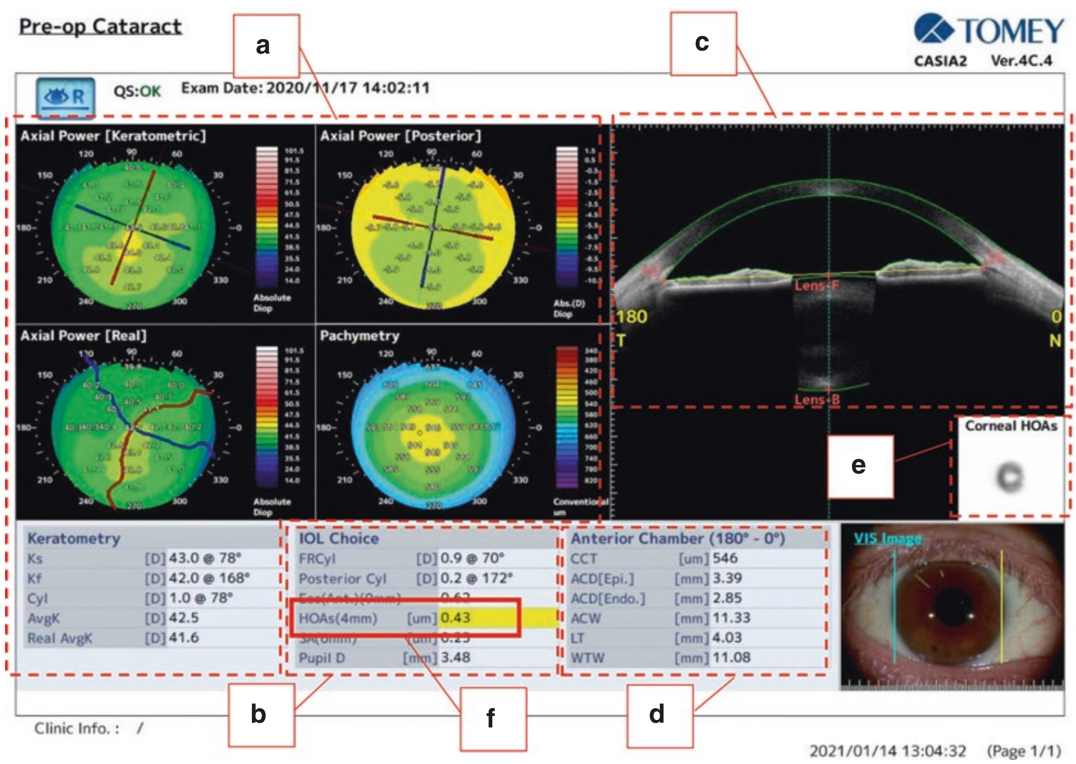


Fig. 28.4 IOL screening report, which is developed under supervision of prof. Naoyuki Maeda, Department of Ophthalmology, Osaka University Graduate School of Medicine and Associate Prof. Kazuhiko Onuma, Center for Frontier Medical Engineering, Chiba University

such a typical post-Lasik eye, IOL formula for post-Lasik should be used instead of standard formulae to prevent post-operative hyperopia surprise.

Table 28.2 Four steps in corneal topography for screening before cataract surgery [1]

Step 1: Corneal higher-order aberration (HOAs) If corneal HOA is abnormal, multifocal or toric intraocular lens (IOLs) should be avoided and informed consent should be conducted for irregular astigmatism.
Step 2: Topographic pattern If topographic pattern indicates post-refractive surgery, special IOL formula should be used in place of routinely used formula.
Step 3: Corneal astigmatism If topographic pattern indicates regular astigmatism without asymmetry for both surfaces, toric IOL can be considered.
Step 4: Corneal spherical aberration If corneal spherical aberration shows negative values, spherical IOLs should be considered.

Third, check regular astigmatism. Figure 28.6 is an example of IOL screening report for with-the-rule astigmatism. The anterior and posterior topography maps show the bowtie pattern without asymmetry (Fig. 28.6a). The indices in red are only for the anterior cylinder (Fig. 28.6b, Cyl) and the total cylinder (Fig. 28.6b, FRCyl), and other indices are in the normal range. In such case, toric IOL would be a good choice, and also multifocal and aspherical IOL can be considered.

Fourth, check for corneal spherical aberration. Figure 28.7 is an example of IOL screening report for a typical keratoconus eye. Spherical aberration (Fig. 28.7a, SA) is indicated in red with negative number. Implanting an aspherical IOL into such eye may increase irregular astigmatism, so the use of a spherical IOL should be considered.

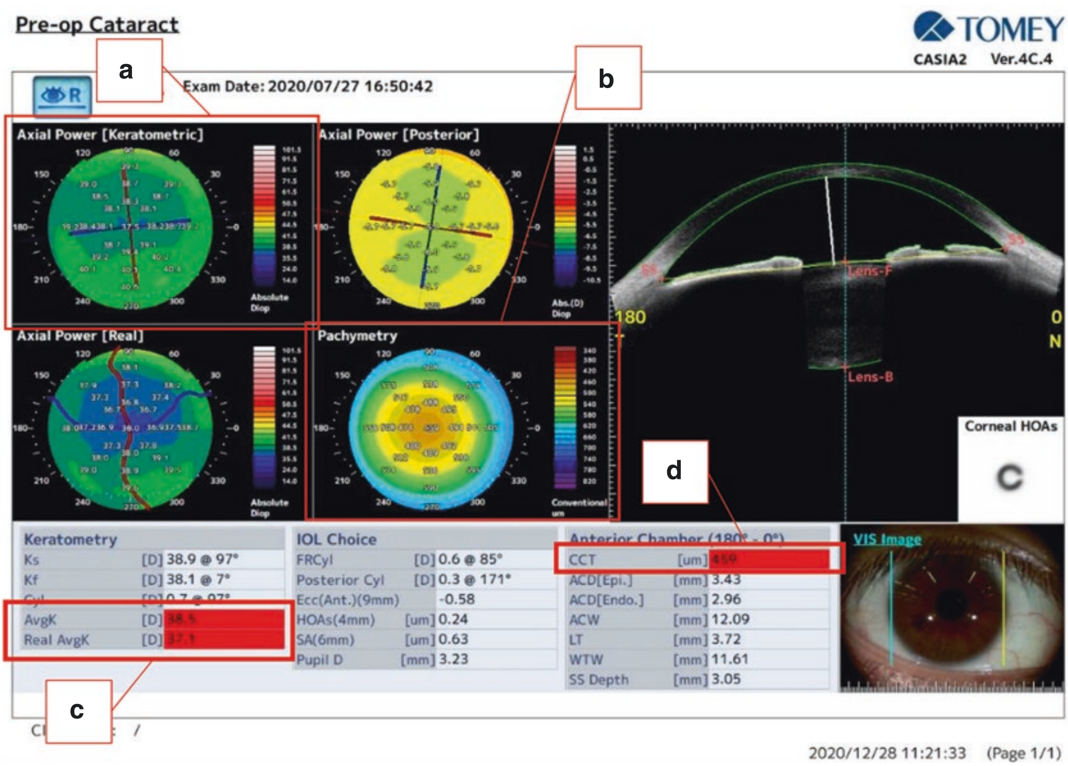


Fig. 28.5 IOL screening report of post-Lasik eye

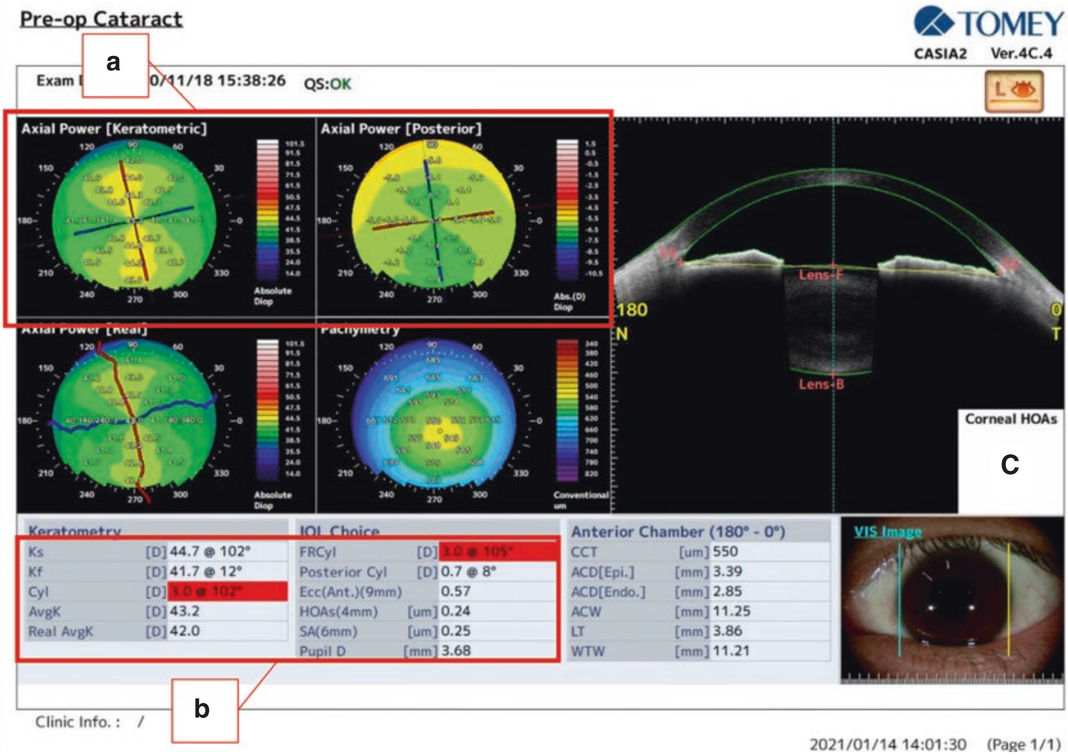


Fig. 28.6 IOL screening report of regular astigmatism eye

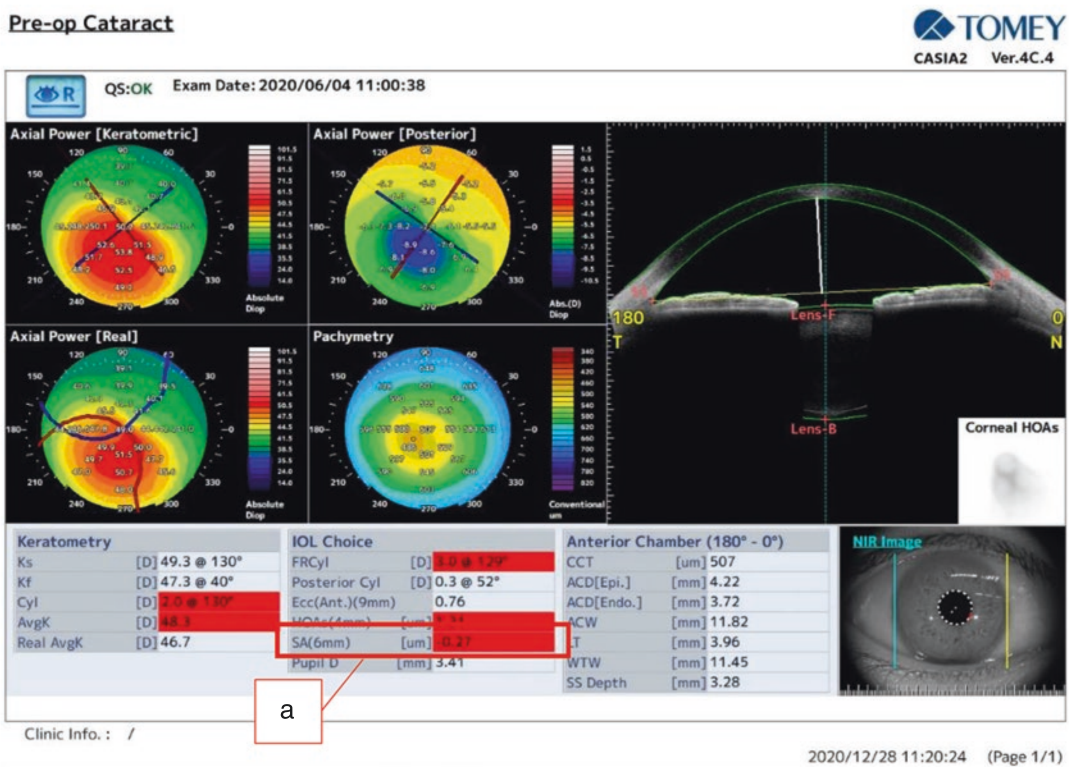


Fig. 28.7 IOL screening report of keratoconus

IOL Power Calculation on Pre-op Cataract

Pre-op cataract app includes IOL power calculation function (Fig. 28.8). Different kinds of IOL formulae, which are standard IOL formulae, toric IOL formulae and post-Lasik IOL formulae, are available on CASIA2 (Table 28.3). Other various new IOL formulae using parameters (posterior cornea, ACD, Lens thickness, ATA, etc.) obtained by anterior segment OCT are proposed [2–4]. It is expected that new concept IOL formulae will be put into practical use near future. Function for optimization of IOL constants is included in CASIA2, and it can support users to calculate personal lens constant for each surgeon. CASIA2 can connect with OA-2000 (Fig. 28.9), measurement results of axial length and corneal power by OA-2000 are automatically transferred to CASIA2 based on patient ID, and IOL calculation results can be obtained with these values.

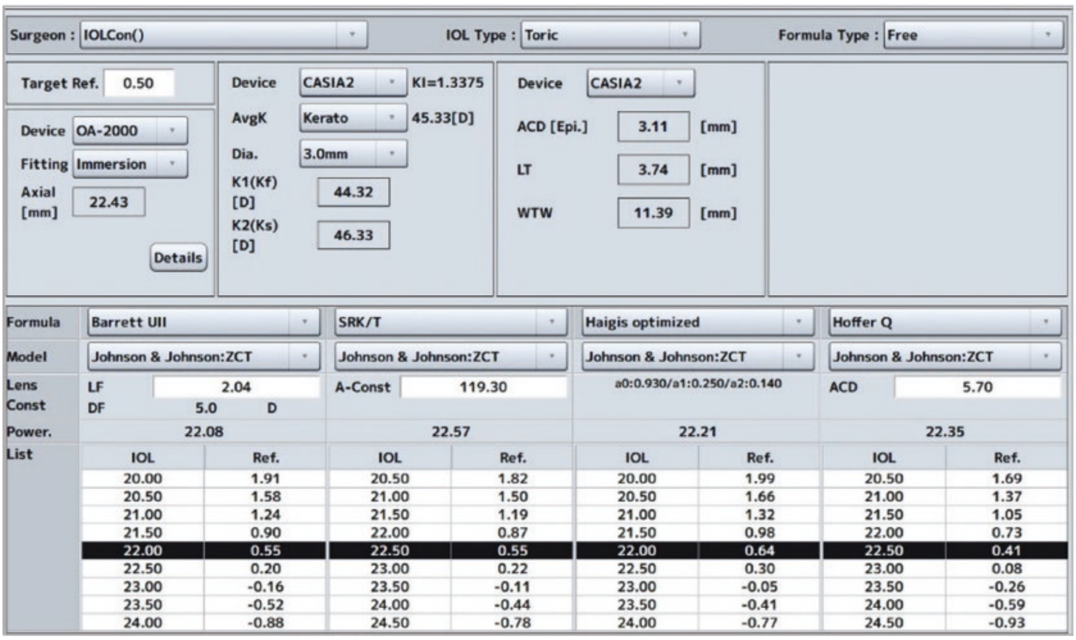


Fig. 28.8 IOL power calculation screen

Table 28.3 Available IOL formulae on CASIA2

Standard IOL formulae Barrett Universal II, Haigis standard, Haigis optimized, Hoffer® Q, Holladay 1, SRK/T, OKULIX[a]
Toric IOL formulae CASIA Toric (simple vector calculation), Barrett Toric Calculator, Barrett True K Toric Calculator, OKULIX[a]
IOL formulae for post-Lasik Barrett True K, Shammas-PL, A-P method, OKULIX[a]

[a]Optional, depending on sales area

Fig. 28.9 Data linkage with OA-2000

Toric IOL Calculation and Axis Registration Support on Pre-op Cataract

Pre-op Cataract app includes toric planning function with toric calculator and axis registration function. It can support surgeons to mark the target axis based on the reference axis of iris pattern or conjunctival blood vessels. The color front image is available on the latest CASIA2, and blood vessel as reference points can be observed clearly (Fig. 28.10, The color front image is available on the newest hardware.).

Lens Analysis Function

Crystalline lenses are analyzed in 3D, its curvature of radius for front and back surfaces, tilt, and decentration are calculated automatically by lens analysis function (Fig. 28.11).

Kimura reports that a strong correlation was found between the average tilt and decentration values of the crystalline lens and the IOL. These results suggest that an aspherical lens should not be chosen for the IOL if there is a significant tilt or decentration of the crystalline lens before surgery [5].

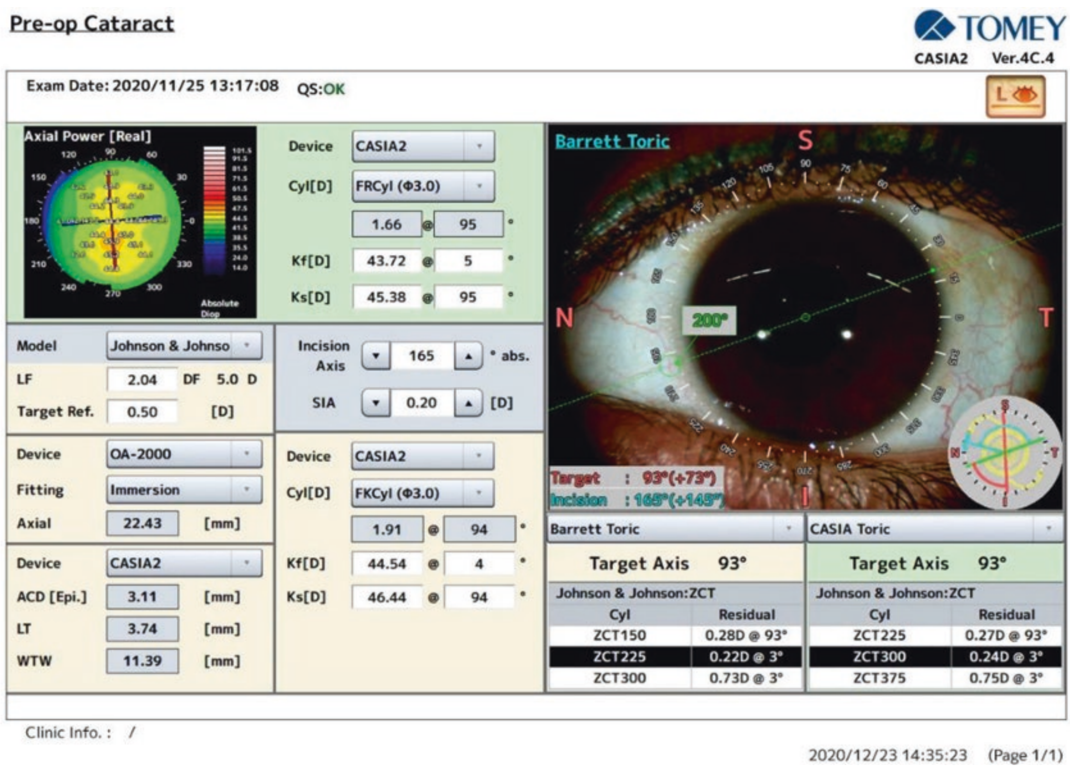


Fig. 28.10 Toric calculation and planning report

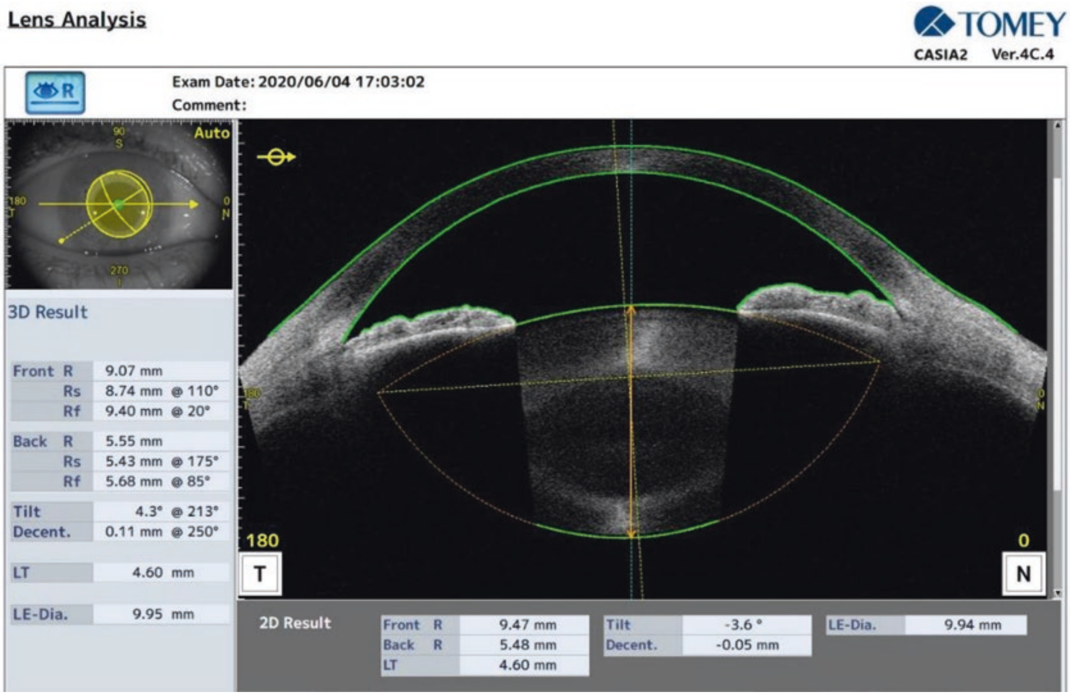
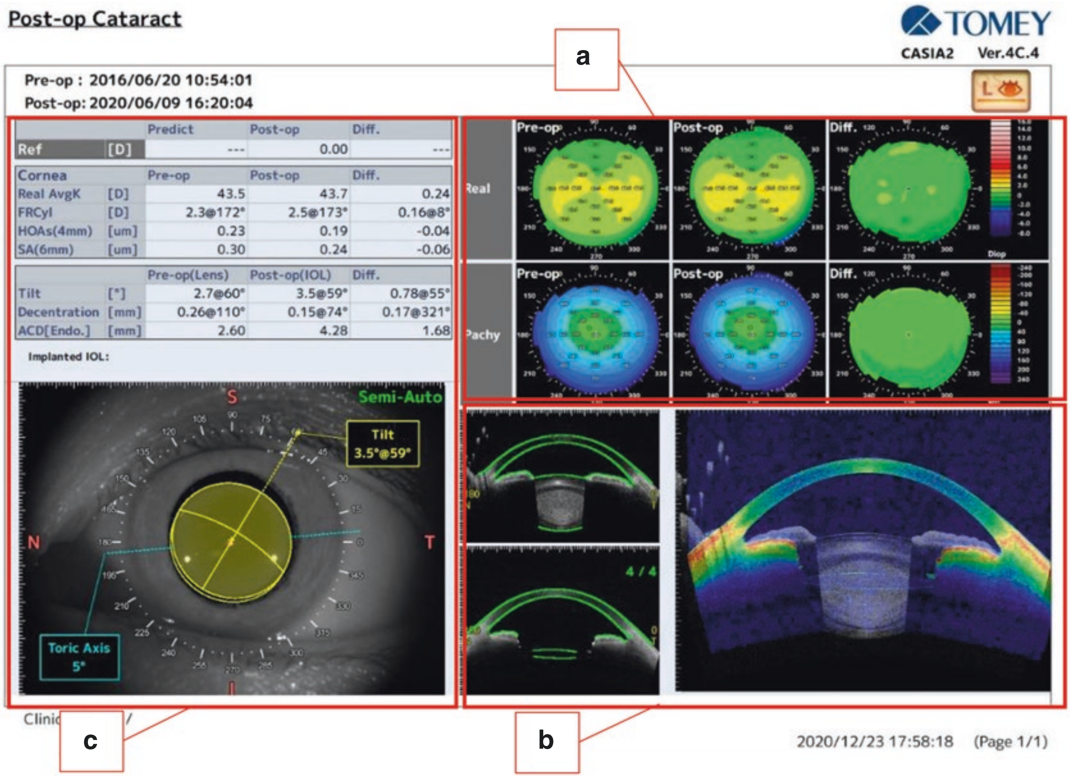


Fig. 28.11 Lens analysis report

Post-op Cataract

Post-op cataract (Fig. 28.12) is an application to compare data between pre- and post-operative. It can support doctors to evaluate, analyze the results of cataract surgery, and explain the results to patients. The corneal shape change by cataract surgery can be confirmed on the differential map of the total corneal map and the pachymetry map (Fig. 28.12a). By superimposing OCT image before and after cataract surgery, it is possible to intuitively understand the fixed position of the IOL and the change in the angle opening due to the surgery (Fig. 28.12b). In addition, the pre- and post-operative and that's difference of total average K, corneal astigmatism, HOAs, SA, lens tilt, lens decentration, and ACD are displayed numerically, and the IOL-fixed image diagram with IOL tilt in 3D and axis of toric IOL are displayed on the front camera image (Fig. 28.12c).



		Predict	Post-op	Diff.
Ref	[D]	---	0.00	---

Cornea		Pre-op	Post-op	Diff.
Real AvgK	[D]	43.5	43.7	0.24
FRCyl	[D]	2.3@172°	2.5@173°	0.16@8°
HOAs(4mm)	[um]	0.23	0.19	-0.04
SA(6mm)	[um]	0.30	0.24	-0.06

		Pre-op(Lens)	Post-op(IOL)	Diff.
Tilt	[°]	2.7@60°	3.5@59°	0.78@55°
Decentration	[mm]	0.26@110°	0.15@74°	0.17@321°
ACD[Endo.]	[mm]	2.60	4.28	1.68

Fig. 28.12 Post-op cataract report

Direct Observation of Toric Axis Marking Dots

Toric axis marking dots of implanted IOL can be observed directly on the latest CASIA2 by optimization of optical performance (Fig. 28.13, red arrows. It is available on the newest hardware). Doctors can measure toric axis directly, and it is useful for identifying the cause when astigmatism correction is unsatisfied.

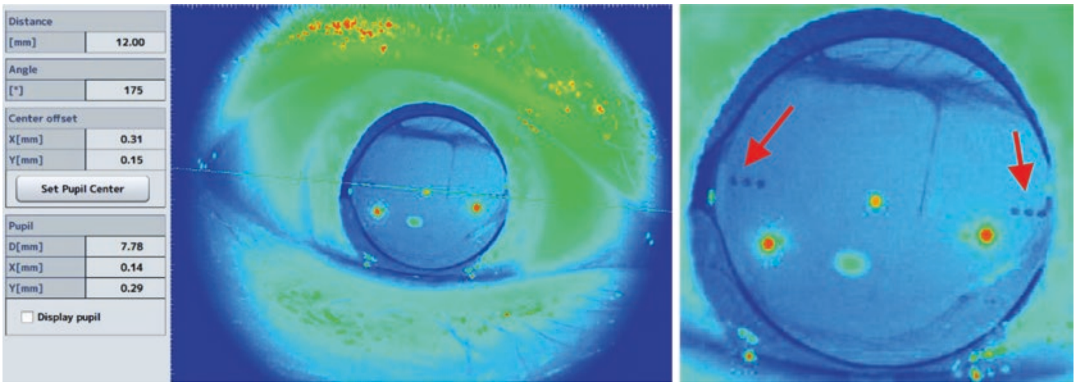


Fig. 28.13 Observation of toric axis marking dots by latest CASIA2

Various Functions for Other Clinical Fields

In addition to pre- and post-cataract examinations, CASIA2 is equipped with applications to support daily practice in various clinical fields such as corneal diseases, refractive correction, and glaucoma.

Functions for ICL®

CASIA2 includes two ICL® size determination formulae which calculate predicted vaults after surgery and optimal ICL® size using the distance between scleral spurs (NK formula [6]) or angle-to-angle (KS formula [7]) obtained from AS-OCT image (Fig. 28.14a). In addition, function to measure vaults of ICL-implanted eyes is included, and it supports doctors for post-operative management (Fig. 28.14b). In the recent study, Gonzalez-Lopez reports importance of vaulting under light-induced maximum miosis and proposes a new method of vault dynamic assessment using CASIA2 [8].

Trend Analysis

The change over time in corneal shape is displayed using a topography map and a graph of indices so that it can be grasped intuitively on the trend analysis function (Fig. 28.15). By using the corneal thickness, the best fit sphere on the posterior surface of the cornea, Kmax (Keraometric), etc., it supports analysis of keratoconus progression and judgment of performing cross-linking treatment.

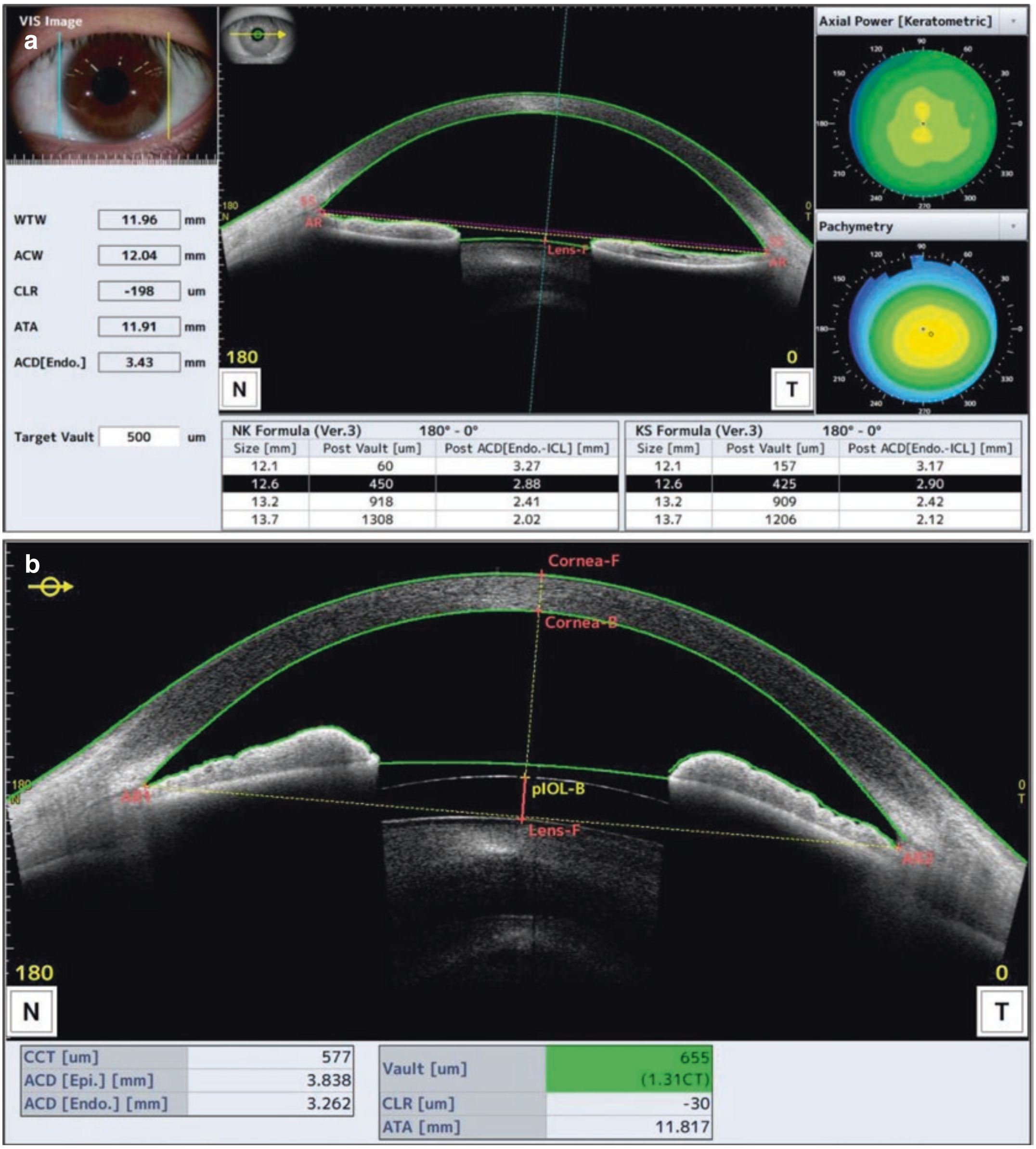


Fig. 28.14 Application for ICL®. (**a**) ICL® sizing app, (**b**) Measurement of vaulting

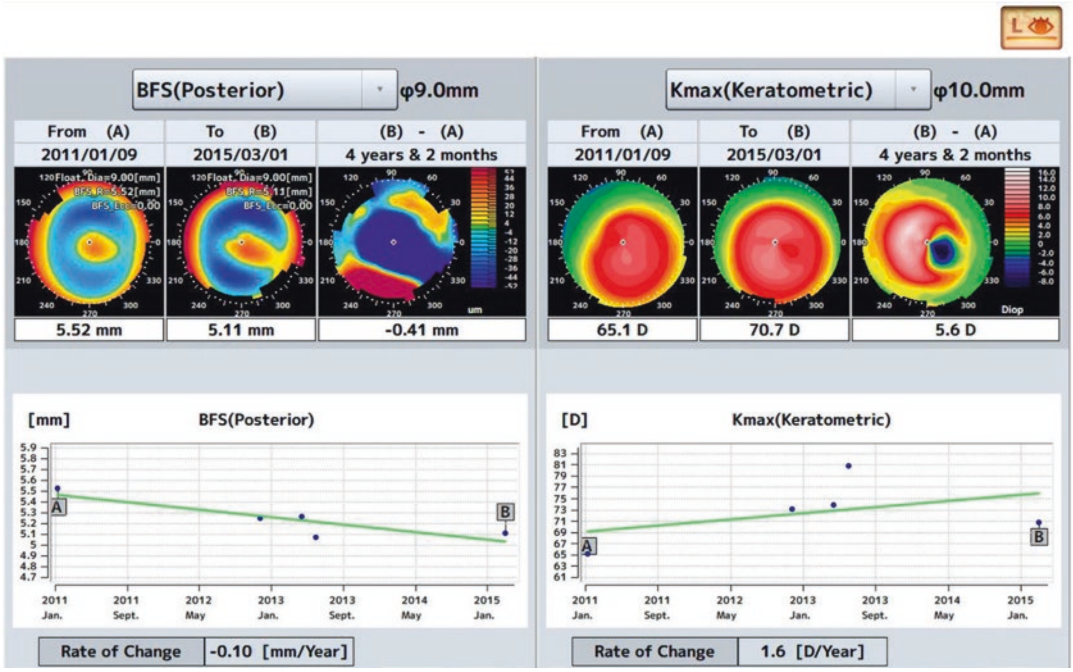


Fig. 28.15 Trend analysis on progressive keratoconus eye

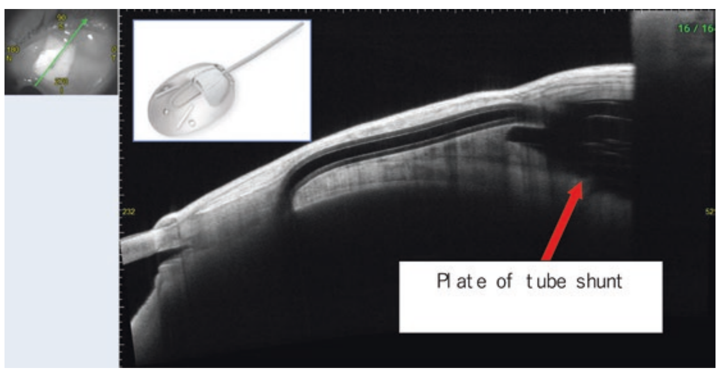


Fig. 28.16 Observation of implanted tube shunt by wide averaging image of CASIA2. Provided by Dr. Hideo Nakanishi, Department of Ophthalmology, Eye Center, Hidaka Medical Center, Toyooka Hospital

Wider and Deeper Image with Averaging

CASIA2 provide wider and deeper image with averaging technique due to the higher scan speed, which can reduce noise and enhanced signal. Figure 28.16 is an example of a wide range image of CASIA2. It can be observed clearly from angle to plate of implanted tube shunt and tissue structure.

STAR360°

STAR360° (Scleral spur Tracking for Angle analysis and Registration 360°) analyzes the whole 360° of anterior camber angle (ACA), describes various ACA parameters such as *iridotrabecular* contact (ITC) and angle opening distance (AOD) with visual chart, and calculates 360° quantitative indices (Fig. 28.17).

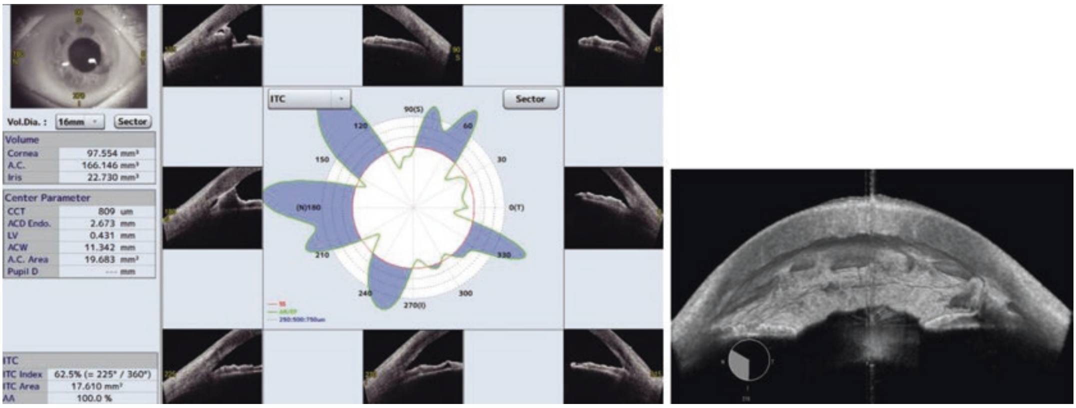


Fig. 28.17 ITC chart on STAR360°. Data provided by Dr. Hideki Mori, Department of Ophthalmology, Tokyo medical university

This application is developed under supervision of Prof. Christopher Leung MD, MB ChB, Department of Ophthalmology, The University of Hong Kong [9].

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