Critical Preoperative Assessment to Improve the Outcome of Cataract Surgery

Xiaolin Gu¹, MD, PhD
Li Wang², MD, PhD

¹. Alcon Medical Affairs, North America; Fort Worth, TX
². Cullen Eye Institute, Department of Ophthalmology, Baylor College of Medicine
Key Take-Aways

1. Managing ocular surface diseases (OSD), especially dry-eye disease (DED), is critical to improve visual outcomes and patient satisfaction after cataract surgery. The ASCRS Cornea Clinical Committee recommended algorithm for preoperative diagnosis and treatment of OSD is available for adoption.

2. Performing a spectral-domain or swept-source macular optical coherence tomography (OCT) on every single cataract patient preoperatively, and not just on premium intraocular lens (IOL) patients, may prevent “visual surprise”.

3. Other preoperative steps to improve outcomes include: minimizing the biometry measurement error by ensuring “no touching, no drops” before measurement, selecting highly accurate and reproducible technology, keeping consistency in measurement and technology usage, understanding the limitation of technology and utilizing additional measurements when necessary, and implementing advancements in measurement technology.

Introduction

With the advancement in IOL technology, cataract surgery has evolved to have the similar patient expectations as a refractive procedure. A larger proportion of the baby boomer generation, which has a greater awareness and knowledge of cataract surgery, is now in need of presbyopia correction with cataract surgery. Their visual outcome expectations, especially those who are willing to pay for premium IOLs, are much higher.

This white paper will focus on the critical steps during preoperative assessment of cataract surgery that help surgeons to provide better visual outcomes and patient satisfaction.

Ocular surface evaluation and Dry-eye Disease (DED) management

Ocular surface disease (OSD), most commonly DED, can reduce vision or visual quality and adversely affect biometric measurements before refractive corneal or cataract surgeries; all of which can lead to poor visual outcome and lower patient satisfaction.

OSD is more common in aging population and is more prevalent in women. Additionally, with environmental and lifestyle changes, such as the widespread usage of computers, tablets and digital phones, more patients are now affected by DED. The DED incidence in cataract patients, especially asymptomatic patients, is now considered highly under-estimated. Signs and symptoms of DED are also been shown to be poorly correlated and patient-reported symptoms alone cannot be used to accurately assess the ocular surface. Trattler et al reported in a prospective health assessment of cataract patients’ ocular surface study (PHACO) that almost 60% of routine cataract patients were asymptomatic, but 63% patients had abnormal tear film breakup time and 77% had positive corneal staining. Gupta et al showed that 80% of all studied cataract patients and 85% in the asymptomatic group had at least 1 abnormal tear test result (osmolarity or MMP-9) suggestive of ocular surface dysfunction.

American Academy of Ophthalmology and the Cornea ASCRS Clinical Committee have recommended preoperative evaluation, especially for refractive cataract surgeries, to comprehend all the aspects of potential deleterious effect on post-operative outcomes, including the ocular surface. Recently, the ASCRS Cornea Clinical Committee published a consensus-based diagnostic OSD algorithm (Appendix 1) for efficiently diagnosing and treating visually significant OSD before refractive cataract or corneal refractive surgery, to improve postoperative visual outcomes and patient satisfaction.

Any OSD that results in corneal staining or hyperosmolarity and/or irregular astigmatism is considered as visually significant OSD, which requires postponing surgery and commencing OSD treatment in
order to achieve accurate preoperative biometric measurement for accurate IOL power calculation in the case of cataract surgery to improve postoperative visual outcomes.

Based on the recommendation from ASCRS Cornea Clinical Committee\(^3\) and TFOS DEWS II (Tear film & Ocular Surface Society Dry Eye WorkShop II)\(^10\), preoperative OSD screening includes:

1. OSD symptom investigation: For example, ASCRS SPEED II pre-operative questionnaire.

2. OSD signs investigation: combination of two simple objective noninvasive screening tests, which have been shown to help identify OSD in asymptomatic preoperative cataract patients.\(^7\)

<table>
<thead>
<tr>
<th>Test</th>
<th>Positive Sign for OSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tear Osmolarity (mOsm/L)</td>
<td>&gt;307 in one eye or &gt;7 inter-eye difference</td>
</tr>
<tr>
<td>MMP-9 (inflammatory marker)</td>
<td>≥40 ng/ml</td>
</tr>
</tbody>
</table>

3. Topography and Tomography: Koch and Wang\(^11\) recently shared their preoperative assessment recommendations and emphasized the importance of including corneal topography and tomography. They found that: 1) placido ring topography is helpful to visualize and rule out corneal surface pathology, such as DED, epithelial basement membrane dystrophy and Salzmann’s nodular degeneration (Figure 1); and 2) Tomography aids in ruling out corneal ectatic disease.

4. Clinical examination: lid, Meibomian gland, cornea/conjunctiva exam including cornea staining, fluorescein tear film breakup time test (TBUT) and Schirmer’s test.

5. Other optional objective OSD tests to help to establish OSD subtype and visual significance. Tests include meibograh, non-invasive TBUT, ocular scatter index (OSI), aberrometry, lipid layer thickness (LLT), quantification of tear meniscus height measurement using anterior segment OCT or multipurpose corneal topographer.

Figure 1a. A case of dry eye showing irregularities on the corneal topography map and placido ring image.

Figure 1b. A case of epithelial basement membrane dystrophy treated with the epithelial debridement: before the epithelial debridement (left) and after epithelial debridement (right).
Macular OCT Scan

Preoperative evaluation of the retina, especially at the macula region may help rule out the conditions that could limit overall visual outcome after cataract surgery, especially in those patients considering advanced technology IOLs. It also provides a valuable baseline to monitor patients who may develop problems postoperatively. Recent studies of routine OCT in preoperative evaluation found the rate of clinically undetectable macular disease ranged from 4.6% to 13.2%. Performing an OCT scan of the retina is quick, safe and easy. Retinal specialist Dr. Steve Charles urges 1) performing an OCT on every single cataract patient preoperatively, not just premium IOL patients to help prevent “visual surprises”; 2) performing a spectral domain or swept source OCT; and 3) carefully reviewing multiple scan images, not just one image.

Preoperative biometry for accurate IOL power determination

In addition to excluding or managing any ocular pathology that may affect post-operative visual outcomes, a critical step to improve the refractive outcome is to avoid preoperative biometry error to ensure the input parameters (Table 1) for IOL power formulas are accurate. As Dr. Warren Hill stated, multiple components are involved in IOL power calculation, perfection of one individual component may not significantly affect the outcome in a series of patients. However, if one measurement is incorrect, for that individual patient, a refractive miss is guaranteed.

Table 1: Preoperative measurements for Cataract Surgery

<table>
<thead>
<tr>
<th>Measurement</th>
</tr>
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<tbody>
<tr>
<td>Axial length (AL)</td>
</tr>
<tr>
<td>Corneal power (K)</td>
</tr>
<tr>
<td>Pre-op phakic anterior chamber depth</td>
</tr>
<tr>
<td>Lens thickness</td>
</tr>
<tr>
<td>Horizontal white to white (HWTW)</td>
</tr>
<tr>
<td>Refraction</td>
</tr>
</tbody>
</table>

Efforts to minimize the biometry error include:

1. Standardizing biometry to ensure measurements are taken before any procedures that could alter the tear film or ocular surface, such as applying eye drops. For contact lens users, measurements should be taken at least two weeks after discontinuing soft contact lens wear or one month without rigid gas permeable lens wear and followed by topography exam to confirm stabilization. For visually significant OSD, biometry measurement should be repeated after OSD management.

2. Standardizing biometry technique and instrument use to ensure measurements are consistent and mostly operator independent. Noncontact optical biometry, such as LenSTAR LS900 (Haag-Streit), IOLMaster 700 (Zeiss) and ARGOS (Alcon), has become the gold-standard because of its ease of use, accuracy and reproducibility.

3. Understanding the limitation of the technologies, use additional measurements when data do not meet the validation criteria.

Ocular Optical biometers have excellent accuracy and reproducibility. However, some patients need additional measurements when the data fail the validation criteria set forth by the manufacturers (Appendix 2 and 3) or based on personal experience. Many successful practices adopting a “preflight checklist” proposed by Dr. Hill, to incorporate those preoperative
measurement validation guidelines, either from industry or individually developed by each practice, is an excellent way to warrant additional investigations to avoid “refractive miss”. The validation criteria guide users to obtain accurate keratometry and axial measurements. To apply the validation criteria, we recommend inspection of the following aspects:

a. **Quality of the reflected LED images:** to ensure accurate keratometry, it is required that the reflected LED images have good quality. A case example with irregular LED reflection using IOLMaster 700 (Zeiss) is shown in Figure 2a; repeated exam using LenSTAR 900 (Haag Streit) showed much better LED images in the same eye (Figure 2b) and a significant difference in astigmatism (Figure 2c).

Figure 2: Case example of importance on quality inspection of reflected LED images

![Case example of importance on quality inspection of reflected LED images](image)

<table>
<thead>
<tr>
<th>Quality of the reflected LED images</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Irregular LED reflection on IOLMaster 700 (Zeiss) (OS Astigmatism = 2.48 @ 3°).</td>
</tr>
<tr>
<td>b. Better quality of LED images on LenSTAR900 (Haag Streit)(OS Astigmatism = 0.88 @ 4°).</td>
</tr>
<tr>
<td>c. Difference in measured keratometry and astigmatism.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean Ks</th>
<th>Astigmatism</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOLMaster 700</td>
<td>42.16 D</td>
<td>2.48 @ 3°</td>
</tr>
<tr>
<td>LenStar 900</td>
<td>41.91 D</td>
<td>0.88 @ 4°</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>0.25 D</strong></td>
<td><strong>1.60 D</strong></td>
</tr>
</tbody>
</table>
b. **Individual parameters:** the manufacturer’s validation criteria (Appendix 2 & 3) list the reasonable range for several parameters, such as the average keratometry, anterior chamber depth (ACD), and lens thickness. For example, if a phakic ACD is >4.5 mm for either LenSTAR 900 (Haag-Streit) or IOLMaster, additional measurements are recommended.

c. **Standard deviation (SD):** a smaller SD indicates more consistent repeated measurements. If the SD is greater than the criterion, inspection of raw data should be performed, outlier data should be deleted, or additional exams should be added. Figure 3 is an example to show a large K SD adjustment.

**Figure 3: Case example of large Standard Deviation (SD) adjustment**

<table>
<thead>
<tr>
<th>Measuring mode</th>
<th>Mode</th>
<th>OD</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial length</td>
<td>Phakic</td>
<td>26.66 mm ±0.013 mm</td>
<td>24.95 mm ±0.032 mm</td>
</tr>
<tr>
<td>Cornea thickness</td>
<td>Phakic</td>
<td>576 µm ±2.1 µm</td>
<td>590 µm ±3.6 µm</td>
</tr>
<tr>
<td>Aqueous depth</td>
<td>Phakic</td>
<td>2.91 mm ±0.006 mm</td>
<td>2.77 mm ±0.008 mm</td>
</tr>
<tr>
<td>Anterior chamber depth including cornea ACD</td>
<td>Phakic</td>
<td>3.38 mm ±0.005 mm</td>
<td>3.35 mm ±0.010 mm</td>
</tr>
<tr>
<td>Lens thickness</td>
<td>Phakic</td>
<td>3.99 mm ±0.006 mm</td>
<td>3.94 mm ±0.006 mm</td>
</tr>
<tr>
<td>Retina thickness</td>
<td>Phakic</td>
<td>200°* µm ±0.0 µm</td>
<td>200°* µm ±0.0 µm</td>
</tr>
<tr>
<td>Flat meridian</td>
<td>K1</td>
<td>44.56 D @ 167° *</td>
<td>44.47 D @ 9° *</td>
</tr>
<tr>
<td>Steep meridian</td>
<td>K2</td>
<td>46.08 D @ 77° *</td>
<td>46.87 D @ 99° *</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>AST</td>
<td>1.53 D @ 77° *</td>
<td>2.40 D @ 99° *</td>
</tr>
<tr>
<td>Keratometric index</td>
<td>n</td>
<td>1.3375</td>
<td>1.3375</td>
</tr>
</tbody>
</table>

**OS:** original measurements

**AL:** SD = 0.032 mm

**K2:** SD = 1.558 D

**Mean K:** 45.67 D

**Astigmatism:** 2.40 @ 99°

<table>
<thead>
<tr>
<th>Measuring mode</th>
<th>Mode</th>
<th>OD</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial length</td>
<td>Phakic</td>
<td>24.94 mm ±0.008 mm</td>
<td>24.84 mm ±0.008 mm</td>
</tr>
<tr>
<td>Cornea thickness</td>
<td>Phakic</td>
<td>580 µm ±4.0 µm</td>
<td>580 µm ±4.0 µm</td>
</tr>
<tr>
<td>Aqueous depth</td>
<td>Phakic</td>
<td>2.77 mm ±0.007 mm</td>
<td>2.77 mm ±0.007 mm</td>
</tr>
<tr>
<td>Anterior chamber depth including cornea ACD</td>
<td>Phakic</td>
<td>3.35 mm ±0.011 mm</td>
<td>3.35 mm ±0.011 mm</td>
</tr>
<tr>
<td>Lens thickness</td>
<td>Phakic</td>
<td>3.94 mm ±0.006 mm</td>
<td>3.94 mm ±0.006 mm</td>
</tr>
<tr>
<td>Retina thickness</td>
<td>Phakic</td>
<td>200°* µm ±0.0 µm</td>
<td>200°* µm ±0.0 µm</td>
</tr>
<tr>
<td>Flat meridian</td>
<td>K1</td>
<td>44.47 D @ 9° *</td>
<td>44.52 D @ 12° *</td>
</tr>
<tr>
<td>Steep meridian</td>
<td>K2</td>
<td>45.68 D @ 102° *</td>
<td>45.68 D @ 102° *</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>AST</td>
<td>1.92 D @ 102° *</td>
<td>1.92 D @ 102° *</td>
</tr>
<tr>
<td>Keratometric index</td>
<td>n</td>
<td>1.3375</td>
<td>1.3375</td>
</tr>
</tbody>
</table>

**OS:** after adjustment

**AL:** SD = 0.009 mm

**K2:** SD = 0.072 D

**Mean K:** 45.08 D

**Astigmatism:** 1.52 @ 102°
d. **Difference between right (OD) and left (OS) eyes**: if the difference for a parameter between OD and OS exceeds certain amount as recommended by the manufacturer (Appendix 2 & 3), for example, greater than 0.3 mm for axial length difference, additional exams are required. This is true for both LenSTAR 900 (Haag-Streit) and IOLMaster (Zeiss). For average K power difference between two eyes, the criterion for LenSTAR 900 (Haag-Streit) and IOLMaster (Zeiss) is 1.25D and 0.90D respectively.

4. Topography and tomography are highly recommended in addition to routine biometry for refractive cataract surgeries.\(^{11}\) In addition to the usage of helping to rule out OSD and confirming cornea stability after rigid contact lens wear as stated above, the corneal topography may reveal if the astigmatism is regular and may provide useful information for toric IOL selection. Topography and tomography can also help in confirming the presence of prior myopic or hyperopic corneal laser refractive surgery and IOL power calculation in those post-refractive surgical eyes.

5. Following and implementing the advancement in measurement technology. The newly developed IOLMaster 700 (Zeiss) and ARGOS (Alcon) utilize swept-source OCT technology increase the acquisition speed and can now measure AL in eyes with dense cataracts that previously would require immersion ultrasound.\(^{17,18}\)

**Conclusion**

To achieve high post-operative refractive accuracy and patient satisfaction in cataract patients, it is critical to accurately detect OSD, retina/macular pathology and any other potential ocular diseases that may affect refractive and visual outcomes, and to avoid biometry measurement errors in order to make sure the input parameters in advanced IOL formulas are accurate.
Appendix

Appendix 1: The ASCRS preoperative OSD algorithm.3

**ASCRS PREOPERATIVE OSD ALGORITHM**

PREOPERATIVE VISIT

- ≥ 2 weeks CL holiday / no drops within 2 hours prior

NONINVASIVE REFRACTIVE PREOP MEASUREMENTS

- (e.g. keratometry, topography, optical biometry, aberrometry, etc.)

OSD SCREEN

- SYMPTOMS?
  - ASCRS SPEED II PREOP Questionnaire
  - Ocular Surface Disease Index (OSDI)
  - Inflammatory Marker (MMP-9)

- SIGNS?

NEGATIVE SCREEN

- (All normal)
- OSD UNLIKELY

POSITIVE SCREEN

- (Any abnormality)
- OSD LIKELY

To help establish OSD subtype and visual significance

OPTIONAL NONINVASIVE OSD TESTS

- (e.g. meibography, topography, NO TBUT, OCT TMH, OSI, aberrometry, LLT)

CLINICAL EXAM (LLPP)

- LOOK:
  - Blink, lids, lashes, interpalpebral surface
- LIFT:
  - Upper lid, examine superior surface
- PULL:
  - Assess lid laxity, floppy eyelids, fornices
- PUSH:
  - Meibomian gland expression

STAIN (dye instillation): corneal staining? TBUT? +/- Schirmer’s

NEUROPATHIC PAIN

- Symptoms / NO Signs / Normal Exam / Stain

NEUROTROPHIC CORNEA

- NO Symptoms / Signs / Exam / Stain

NON-VISUALLY SIGNIFICANT OSD (NV-SOSD)

- (e.g. normal cornea, normal topography / regular astigmatism, no corneal stain, stable vision)

Surgery Proceeds

- Counsel patient OSD may worsen postoperatively.
- Start prophylactic treatment.

OSD RULED OUT

- NO Symptoms / NO Signs / Normal Exam / NO Corneal Staining

OSD RULED IN

- Any combination of abnormal signs and / or symptoms.
- Visual significance based on results of above.

SURGERY DELAYED

- Refractive measurements unreliable.
- Identify all OSD subtypes.

SURGERY PROCEEDS

- Counsel patient OSD may worsen postoperatively.
- Start prophylactic treatment.

NEXT VISIT IS SURGERY

- NONINVASIVE REFRACTIVE TESTS
  - (e.g. immersion and / or contact A, B scans etc.)
  - Finalize refractive surgical plan
  - (e.g. IOL, LRI, LVC, etc.)

- TREATMENT PLAN
  - Based on subtype and severity of each OSD.
  - Combined medical and procedural interventions.

Optional Data Collection

Essential Data Collection

Decision / Informational

Start / End

Diagnosis

Optional Data Collection

Essential Data Collection

Start / End

Start here

End here

Next office visit in 2-4 weeks. Start at beginning of algorithm.

ADDE= aqueous-deficient dry eye; CL= contact lens; DED= dry-eye disease; EBMD= epithelial basement membrane dystrophy; EDE= evaporative dry eye; IOL= intraocular lens; LLPP= Look, Lift, Pull, Push; LLT= lipid layer thickness; LRI= limbal relaxing incisions; LVC= laser vision correction; MGD= meibomian gland dysfunction; MMP-9= matrix metalloproteinase-9; NI-TBUT= noninvasive tear breakup time; NVS-OSD= nonvisually significant ocular surface disease; OCT= optical coherence tomography; OSD= ocular surface disease; OSI= ocular scatter index; SPEED= Standard Patient Evaluation of Eye Dryness; TBUT= tear breakup time; TMH= tear meniscus height; VS-OSD= visually significant ocular surface disease
Appendix 2: LenStar LS900 (Haag Steit) Validation Criteria.

LENSTAR LS 900 Calibration
Weekly nullification..........................SUCCESSFUL

Keratometry
Ocular surface (improvement necessary?)........NORMAL
K1 & K2 SD (maximum value, each eye)...............±0.25 D
Avg K power difference (between eyes)..............< 1.25 D
Avg K power (each eye)..........................> 40.00 D and < 48.00 D
Steep meridian SD..................................< 3.5°
AST (maximum value, each eye)....................< 4.00 D
Reflected LED images (all meridians)........GOOD QUALITY
Soft contact lenses (at least 1 week)........OUT
RGP contact lenses (until topography & Rx are stable)....OUT

T-cone Topography
Calibration..................................SUCCESSFUL
All measurements..........................CORRECTLY CENTERED
Topo maps (AC, T, E, & RINGS)................GOOD QUALITY
K1, K2, & A1 (all five measurements)........CONSISTENT

Axial Measurements
Measurement mode (phakic, silicone oil, etc.)........CORRECT
Fixation light (confirm visualization by patient)......STEADY
5 consistent measurements........................CONFIRMED
Caliper placement (cornea, lens, & retina)............CORRECT
CCT (prior myopic LASIK/PRK?)....................> 480 µm and < 620 µm
Phakic ACD (each eye)............................> 1.9 mm and < 4.5 mm
Lens thickness (each eye)............................> 3.0 mm and < 6.2 mm
OD & OS axial length...........................WITHIN 0.30 mm
AL consistent with oldest Rx SphEq.................CONFIRMED
Outliers (either eye)................................DELETE & REPEAT

White to White
Limbus ring........................................ADJUST AS REQUIRED
Avg WTW (unusual Ks, ACD, or AL?).............> 10.0 mm and < 13.0 mm
Avg WTW (each eye)...............................WITHIN 0.1 mm
Avg WTW (between eyes).........................WITHIN 0.2 mm

Additional Validation/Studies
Phakic ACD > 4.5 mm or < 1.9 mm...........MD CONFIRMS
OD/OS AL difference > 0.30 mm.................MD CONFIRMS
OD/OS avg K power > 1.25 D....................MD CONFIRMS
AST > 4.25 D (KCN or PMD?)...............TOPOGRAPHIC AXIAL MAP
Avg K power > 48.00 D or < 40.00 D..........MD CONFIRMS

Warren E. Hill, MD - LENSTAR LS 900
**Appendix 3: IOLMaster (Zeiss) Validation Criteria.**

### IOLMaster - Calibration

**Test block (AL, K, ACD)**
CORRECT, PRINTED, & FILED

### Axial Length

- Correct setting (phakic, acrylic, silicone oil, etc.)

- Patient able to see red fixation light

- Double peaks (anterior peak is likely the ILM)

- Poorly formed primary maxima

- Significant Outliers (look at primary maxima)

- At least 5 measurements within 0.05 mm

- Composite SNR > 10 (typically > 100)

- OD & OS AL within 0.30 mm

- AL consistent with oldest Rx

### Autokeratometry

- Ocular surface

- K1 & K2 within 0.25 D in each meridian

- Astigmatism lines up with Rx cyl & axis

- Astigmatism for each eye < 3.50 D

- Avg K power for both eyes within 0.90 D

- Avg K power < 47.00 D or > 41.00 D

- No “x” appearing in any LED location

- Soft contact lenses

- RGP contact lenses

### Optical ACD Measurement

- Aphake & pseudophake

- 5 consistent measurements (green light)

- ACD < 4.5 mm and > 2.0 mm

### White to White

- 3 measurements within 0.2 mm

- OD & OS within 0.2 mm (check arc position)

### Exceptions & Additional Studies

- AL < 22.0 mm (ACD & LT for H2)

- AL > 30.0 mm

- OD/OS AL difference > 0.30 mm

- Astigmatism > 3.50 D

- Avg Ks > 0.90 difference

- Avg K power > 47.00 D or < 41.00 D

- ACD < 2.0 mm or > 4.5 mm

- White-to-White < 10.2 mm or > 13.0 mm

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Warren E. Hill, MD - IOLMaster software version 5.4
References


Alcon Medical Affairs