Irregular astigmatism: definition, classification, topographic and clinical presentation

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- No financial interest.
Irregular astigmatism

- Definition and classification;
- Statistical indices and KC risk indices;
- Clinical causes;
- Other visually significant corneal changes;
- Topo-WF correlates of irregular astigmatism;
- Treatment.
Definition and classification

Irregular astigmatism, defined as astigmatism where the principle meridians are not 90 degrees apart and associated with loss of vision, represents one of the most serious and frequent complications of corneal refractive surgery.
Regular vs irregular astigmatism

- **Regular astigmatism** is correctable using a cylindrical spectacle lens;
- **Irregular astigmatism** occurs when the orientation of the principal meridians changes *from one point to another across the pupil*, or when the amount of astigmatism changes from one point to another;
- The further distinction of irregular astigmatism includes *regularly or irregularly* irregular astigmatism and relates to the presence of pattern recognition on computerized topography. Irregularly irregular astigmatism is rough or uneven, and shows no recognizable pattern on topography.
Classification

• Irregular astigmatism with defined pattern (Macroirregular, or regularly irregular astigmatism): There is a steep or flat area of at least 2 mm of diameter, which is the primary cause of the astigmatism.

• Irregular astigmatism with undefined pattern (Microirregular, or irregularly irregular astigmatism): Multiple irregularities; big and small, steep and flat, and profile maps are almost impossible to calculate.
Regular astigmatism
Irregular astigmatism: Astigmatism in which different parts of the same meridian have different degrees of curvature
Irregular astigmatism

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Statistical indices and KC risk indices

- SimK, SAI, SRI;
- SF, CIM, MTK,
- KC risk index panel.
Sim K, SAI, SRI.

- **Simulated keratometry (SimK)** provides the power and axis of the steepest and flattest meridian similar to values provided by the keratometer. They are calculated from rings 7 to 9 corresponding to the position on the cornea at which keratometry measurements are obtained.

- **The surface asymmetry index (SAI)** is a centrally weighted summation of differences in corneal power between corresponding points 180° apart on 128 equally spaced meridians. The SAI approaches zero for a perfectly radially symmetrical surface and increases as the corneal shape becomes more asymmetrical.

- **The surface regularity index (SRI)** is calculated from a summation of local power fluctuations along 256 equally spaced meridians. The SRI rises with increasing irregular astigmatism and approaches zero for a smooth corneal surface.

- Numerous other indices have been developed such as potential visual acuity, average corneal power, coefficient of variation of corneal power, and algorithms for the detection of keratoconus.
Shape Factor (SF) is the measurement of corneal asphericity. A negative SF usually indicates a post-refractive surgery eye with the center flatter than the periphery (oblate).

- Normal 0.13 to 0.35
- Borderline 0.02 to 0.12
- Abnormal -1.0 to 0.01
CIM

- *Corneal Irregularity Measurement (CIM)* is an index which represents the *irregularity* of the corneal surface. **Higher the value** of CIM predicts more irregularity.

- Normal 0.03µm to 0.68µm
- Borderline 0.69µm to 1.0µm
- Abnormal 1.1µm to 5.0µm
A high CIM suggests some corneal irregularity, which could be an indication of contact lens distortion.
Mean Toric Keratometry (MTK) indices use elevation data to compare the toric reference to the actual cornea. The mean apical curvature value helps select the best toric fit using a sphero-cylinder design. This provides the most accurate toric representation of a patient's cornea.

- Normal 43.10 diopters to 45.90 diopters
- Borderline 41.80 diopters to 43.00 diopters and 46.00 diopters to 47.20 diopters
- Abnormal 36.00 diopters to 41.70 diopters and 47.3 diopters to 60.0 diopters
Combining CIM, SF and MTK, to determine KC risk
CL Distortion

A high CLM suggests some corneal irregularity, which could be an indication of contact lens distortion.
Subclinical keratoconus

Corneal curvature at the steepest point is upwards of 53 diopters despite the normal “bow-tie” type pattern.

All statistical indices are in the “red” and are abnormal.
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Clinical causes of irregular astigmatism

- Irregular but **stable** cornea (e.g., irregular scar surface): cornea is irregular because of **LOCAL** geography;
- Irregular but **unstable** cornea (biomechanical decompensation): cornea is irregular because of **GLOBAL** corneal weakness;
- Clinical causes:
  - CL warpage/overwear
  - FFKC/KC/Pellucid
  - Chalazion
  - Pterygium
  - Trauma
  - Limbal/corneal dystrophies
  - Keratorefractive surgery (LASIK, PRK, CK, ectasia)
  - Others
CL warpage
Irregular astigmasim (dry eyes)

Our most common irregularity without defined pattern post LASIK is dry eye (47% of HOA in on study)
Irregular astigmatism (dry eyes con’t)
KC
Elevation and curvature flipped with KC
Pellucid curvature and elevation maps
Corneal scarring
Extreme GPC or other lid disorders may affect corneal shape
HPV CIN causing changes
Peripheral melt/Mooren’s
Pterygium
CK (left) vs. LASIK (right) for presbyopia (optical zone issues)
Decentered treatment
The power of 3 – 3-D stereo corneal topographer
3-D stereo corneal topography:
Initial Images (3-camera, checker board)
S/P myopic LASIK with ridge
S/p LASIK (irregularity map)
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Other visual significantly corneal changes

- Extremely flat (or steep) corneas;
- Small optical zones;
- Posterior corneal changes (anterior and posterior corneal surface become decoupled after anterior ablative procedure).
Flat cornea s/p LASIK (visual **quality** issues)
Posterior Surface changes after LASIK
Posterior changes with normal anterior corneal surface (visual quality issue)
S/P H-LASIK, small optical zone (night vision problems)
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Corneal topographers

- **Placido disc**: Humphrey, EyeSys, Tomey Optikon, Topcon, Magellan, Orbscan, AstraMax 3-D;
- **Scanning/projecting slit**: Orbscan, AstraMax 3-D;
- **3-D stereo**: AstraMax 3-D;
- **Schimpflug rotating camera**: Pentacam; Precisio;
- **Ultrasound**: Artemis.
3-D stereo checkboard AstraMax
Magellan
Pentacam
Corneal topo and combined systems

- **Placido disc**: Humphrey, EyeSys, Tomey Optikon, Topcon, Magellan, Orbscan, AstraMax 3-D;
- **Scanning/projecting slit**: Orbscan, AstraMax 3-D;
- **3-D stereo**: AstraMax 3-D;
- **Schimpflug rotating camera**: Pentacam;
- **Ultrasound**: Artemis;
- **Topo-WF combined systems**.

New Book: “Irregular Astigmatism” (SLACK)
## Topo-WF correlates of irregular astigmatism

<table>
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<tr>
<th><strong>TOPOGRAPHY</strong></th>
<th><strong>WAVEFRONT ABERROMETRY</strong></th>
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<td>Loss of prolate cornea, small optical zone</td>
<td>Increase in spherical aberration</td>
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<tr>
<td>Irregular astigmatism</td>
<td>Increase in coma and trefoil</td>
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<tr>
<td>Decentered ablations</td>
<td>Coma</td>
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</table>
Decentered ablation (topo)
Decentered ablation (WF: coma)
Small optic zone s/p H-L (topo)
Small optical zone s/p H-L (WF: spherical aberration)
Irregular astigmatism (topo): night glare and decreased BSCVA
Irregular astigmatism (topo, 3-D)
Irregular astigmatism (WF: trefoil, SA, coma)
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Treatment options for irregular astigmatism

- RGP;
- C-CAP for decentered treatment;
- Wavefront-driven custom;
- Topo-driven custom;
- Intacs for KC;
- Topo-wavefront combined approach (ACAP);
- Others.
RGP
C-CAP for decentered treatment
C-CAP: pre and post and difference (volume of corneal tissue removed) map
Wavefront-driven custom: Irregular astigmatism (coma, trefoil)
Wavefront-driven custom Rx for irregular astigmatism (coma and trefoil, volume of corneal tissue removed Rx plan)
Wavefront-driven custom for irregular astigmatism: preop WF and corneal removal volume Rx plan

Preop WF

Rx plan (corneal tissue to be removed)
Topography-guided custom LASIK

- **Orbscan/Astramax**
  - 3-D topography
  - Pupilometry
  - Spatial pachymetry
  - Cornea asphericity

- **CIPTA**
  - Customized Ablation planning software

- **Surgeon**
  - Refraction data
  - Functional customization
  - Wavefront aberrometry data
    (used to enhance Astramax data e.g. targeted asphericity)

- **AstraScan**
  - 200 Hz Pulse Rate
  - 0.5 mm spot size
  - Active/passive eye-tracking
Topo-driven custom: preop topo (central island) and postop topo, comparing custom (OD) with non-custom (OS) (Stojanovic)
What to base to treat, topo or WF?

- **Topo-driven**: correct where the problem is (s/p keratorefractive surgery). Can create ideal cornea, but can have non-ideal overall WF, and hence may not have as good vision as WF-driven; Let the cornea bear what is rightfully its burden;

- **WF-driven**: Can create ideal overall WF, but can have irregular cornea. Vision can be good (but can be temporally, since cornea is corrected to compensate HOA of lens, and lens HOA changes more sensitively over time). Let the poor cornea bear the ENTIRE visual axis WF error correction burden (i.e., assuming location of aberration, i.e., lens vs cornea, does not matter).

- **Topo-WF weighted approach**: Alpin’s. But, how about the issue of non-simultaneity of optimization of lens and cornea?
Location of aberration along visual axis DOES make a difference: Treating anterior corneal astigmatism on cornea gives good result (lesser untreated cylinder).

Circular incoming light.

End result: a nice circular image on retina, minimal residual uncorrected cylinder.
Location of aberration along visual axis DOES make a difference: treating *non-anterior* corneal cyl on cornea gives unsatisfactory result (more cyl left untreated)

Circular incoming light.

**End result:** a bizarre imperfect image on retina, due to more residual *uncorrected* cylinder.
Combined topo-WF approach

VISX model: the Advanced Corneal Ablation planner (ACAP)
ACAP-topo-WF combined approach

- Integration of wavefront, topography, and VISX laser using WaveStar software;
- Software allows surgeons to build various models representing the “optical target”, defining the desired optical properties of the cornea after surgery based on combinations of wavefront and topographic information.
ACAP-topo-WF combined approach

Various models for treatment (corneal tissue removal volume) based on various weighted combinations of wavefront and topography data.
Intacs for KC

PRE-OP

POST-OP
The first case of femtosecond laser- Intacs for recurrent KC on graft

BSCVA=20/200
Diplopia
RGP intolerant
Needs repeat graft

BSCVA=20/20
Happily wearing SPECTACLES
No diplopia
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