A New Paradigm in Corneal Topography

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Relevant Financial Relationships

Consultant to:

Intelligent Diagnostics
NIDEK
NTK Enterprises
Oculus (spouse)
SMARTPHONE EVOLUTION

• Legacy ophthalmic instruments were powered by PC’s for 3+ decades
• Apple releases its 1st iPhone in 2007
• iPhone 3 + 1st Android released in 2008
• By 2016 mobile device sales > desktops
WHY SMARTPHONES?

Widespread commercialization enables:

• Low cost
• Ultrahigh resolution imaging
• Computational power
• Multiple communication avenues
• Virtually unlimited data storage
SMARTPHONES IN OPHTHALMOLOGY

• External photography
• Fundus imaging
• AI - based screening for D.R.
• Front end to tele-ophthalmology
  • Remote sensing, diagnostics
  • Monitoring patients at home
  • Scheduling, billing
• Etc, etc
Current Measurement Technologies

Reflection:
A. Mire Placido
B. Grid
Interferometry
C. OCT
Slit scan
D. Scheimpflug
Current Measurement Technologies

Reflection:
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B. Grid
Interferometry
C. OCT
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Cassini - Endothelial Astigmatism
Current Measurement Technologies

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Current Measurement Technologies
Placido

Oculus
Keratograph 5M

Medmont E300
Current Measurement Technologies
Placido + Aberrometry

Visionix VX120

NIKEK OPD-Scan 3
Current Measurement Technologies
Slit Scan + Placido

Topography (both surfaces w/cyl) and pachymetry

Galilei G4  Sirius  TMS-5
Current Measurement Technologies
Slit Scan + Axial Length ± Placido

Aladdin HW3.0

Galilei G6

Pentacam AXL + Wave
Challenges for Screening Algorithms

• Lack of standard imaging
  • Many corneal topography models
    • Different Placido targets
    • Using tomography in place of topography
  • Many different fundus cameras
    • Different resolutions
    • Varying exposure, white balance, etc
Fundus Screening
Variations in mire geometry

Large target, coarse mire
Variations in mire geometry
CHALLENGE

Make a device-independent classifier for corneal topography to reduce the guesswork in interpretation of topography maps.
METHOD

Use 2D FFT to formulate a Butterworth filter for spatial filtering
DETERMINE 2DFFT CUTOFF

Spatial domain  →  Frequency domain
METHOD

- Map filtered data onto a standardized ring structure using bilinear interpolation
- Extract topographic indexes
- Train AI screener on wide mire set
- Test with fine mire set
Keratoconus Severity Index - KSI = 61.1%

This corneal topography has the characteristics associated with clinical keratoconus (KC=99.0%) with a severity index (KSI) of 61.1%.
VALIDATION IS CRITICAL

The diagram shows the sensitivity, specificity, and accuracy for different categories: NRM, AST, KCS, KC, PMD, PKP, MRS, HRS, and OTH. The data indicates that the accuracy is consistently high across all categories, with percentages ranging from 80% to 100%. The specificity and sensitivity are also high, with values close to 100% for most categories.
Paradigm Shift from Legacy Instruments with a Smartphone

- Low cost topographer
- Allow wide distribution to referral network
- Efficient, portable, space saving (slit lamp mount)
- Store exams in the cloud
- Very large aggregate database of standardized exams for AI screener
Slit lamp mounted, joystick enables +/- 25 µm z-axis positional accuracy for +/- 0.1 D power accuracy
Ergonomically similar to slit lamp with angled components.
Smartphone-Based Topography – Alpha Prototype

Pending FDA approval
Comfortable, even, diffuse illumination, pleasing to look into, no flash
Placido Reflectance

Placido Design

- Soft, even ring illumination
- No flash, no photophobia
- Good area coverage
- 28 rings, 56 ring edges, 20,160 points
- Small central ring - 230μm
Placido Design

Magellan

0.5 mm

Delphi

0.2 mm
Auto-capture
Repeat Alignment: 20.6 ± 8.1 μm
SMART PHONE APP

- Home Screen
- Enter Patient Data
- Align and Auto-capture Image
- Verify
- View OS, OD Maps
Image Processing

Edge Detection & Axial Mapping will run on smartphone

- Can Display results even in Wi-Fi outage
- And/or power outage
- Sends image + data file to cloud when Wi-Fi up
Tele-Ophthalmology

**Cloud Server**
- Data Storage & Retrieval
- Advanced Mapping & Display
- HIPAA & GDPR Compliant

**Big Data Access**
- AI development of smarter screening algorithms

**Remote Management**
- Patient transfer/Triage
- Second Opinion Consults
- Virtual Screenings
Virtual Corneal Topography Screening

This corneal topography has the characteristics associated with keratoconus suspect (KCS=90.6%). There are also features of this topography similar to clinical keratoconus (KC=83.4%) with a severity index (KSI) of 2.5%.
Delphi

• Meets current needs for Advanced Corneal Topography
  • Smart Screening
  • Dry eye diagnostics
• Paradigm shift from legacy diagnostic instruments:
  • Efficiency - portable, space saving (slit lamp mount)
  • Low acquisition cost ~$1K per unit
  • Networked, a Cloud-based storage
  • Medical big data availability in the digital health era
Thank You