"CUSTOMIZATION"

or

WAVEFRONT-GUIDED VISUAL CORRECTION

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# Wavefront Correction Strategy

1-NORMALIZATION: Correction based on average population wavefront data

2- CUSTOMIZATION: Correction based on individual wavefront measurements to guide higher order abberations on a " Customized" basis

Technology Requirements for Customized Corneal Ablation

✤ **Accurate wavefront measurement device**

✤ **Precise and robust eye tracking**

✤ **Scanning Spot Laser Delivery**

✤ **Wavefront- Laser interface**
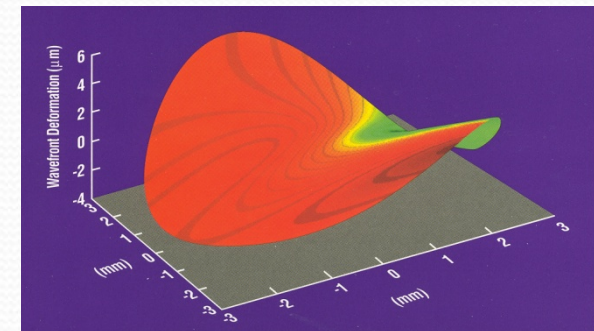
Accurate Wavefront Measurement Devices

Wavefront aberration information is collected and measured by four different principles

      1. **Outgoing refractive aberrometry**

      2. **Retinal imaging aberrometry (Tscherning)**

      3. **Incoming Adjustable Refractometry (Scheiner)**

      4. **Double Pass Aberrometry (Slit Skiascopy)**

1- Outgoing Refractive Aberrometry

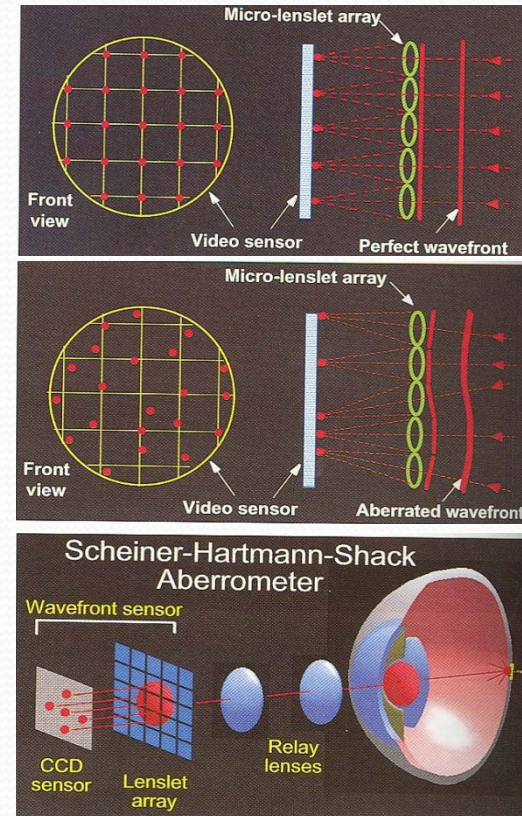## *Shack- Hartman wavefront sensor*

Low energy laser

Reflection from fovea

Optical structures of the eye

Array of lenslets to a small spot each segment of focused wavefront

CCD detection array   **ocular aberration**

1- Outgoing Refractive Aberrometry

Limitations:

- Multiple scattering from subfoveal   Choroidal structures
- Crossover of focused spots in highly aberrated eyes
- Does not take quality of individual spots formed by lenslet array

Shack-Hartman Devices

- **Alcon LADARWave: 170 spots within 6.5 mm pupil**
- **VISX Wave Scan: 180 spots within 6 mm pupil**
- **Schwind aberrometer**
- **Bausch & Lomb Zywave: 70 spots within 6mm pupil**
- **Meditec WASCA: 800 spots within 7mm pupil**

*Note:*   *Approximately 200 spots within 7 mm pupil is adequate*

2- Retinal Imaging Aberrometry

- Tscherning and Ray Tracing: subjective measurement of monochromatic aberration
- Seiler used a spherical lens to project 1 mm grid pattern onto retina
- *Principle:* 13x13 spot grid (168 spot)

Projection through 10mm cornea

100 spots within 7mm pupil

Paraxial aperture system
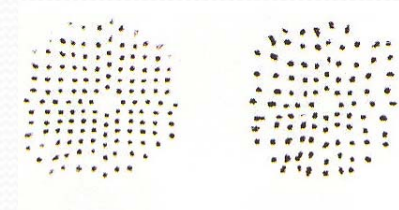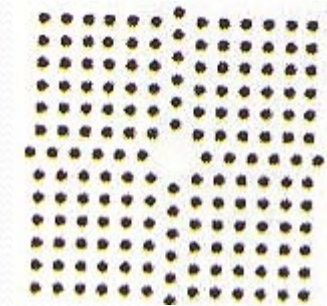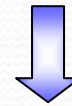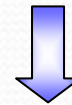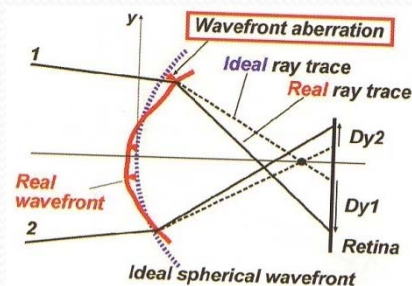
2- Retinal Imaging Aberrometry
## (cont)

Limitation: Use of an idealized eye

model (Gullstrand model I)

Ray tracing: Nearly 100 sequential spots

traced within 12ms within

7mm pupillary area

Examples: Wavelight analyzer

Tracey Ray Tracing

3- Ingoing Adjustable Refractometry (Scheiner)

(Spatially-Resolved Refractometer:SRR)

- **Subjective redirection of 37 peripheral beams of incoming light toward central target**
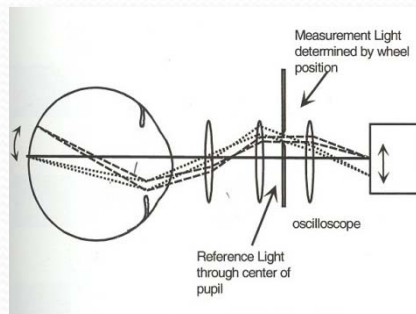
- **Limitation:** **time consuming procedure**

  Example: **Interwave SRR**

4- Double Pass Aberrometry (Slit Skiascopy)

- **Considers passage of light into the eye + reflection of light out of the eye**

- **Rapid scanning a slit of light along a specific axis (Skiascopy)**

  Captured fundus reflection: parallel photodetectors

- **360 meridia- 4 spot on each meridian=1440 data point**
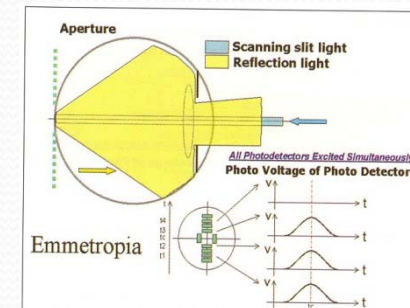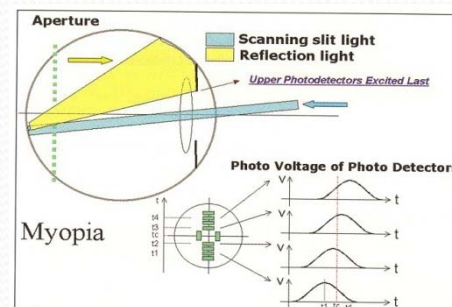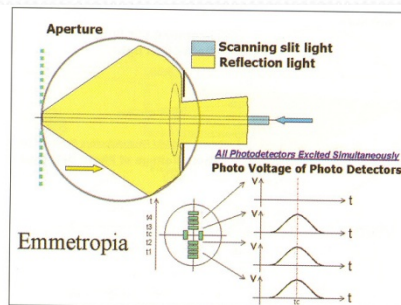
4- Double pass aberrometry (Slit Skiascopy) (Cont)

Limitation:

- Small amount of collected axial information
- Sequential nature of capture

Example: Nidek OPD-scan

II-Scanning Spot Laser Delivery

1. Scanning spot size

Huang et al:

- **Treating up to 4th order aberrations requires a spot beam diameter of 1 mm or less**

- **Up to 6th order aberrations correction: requires 0.6mm spot size**

Laser Device	Spot size (mm)	Scanning Rate (HZ)
LADARVision	0.8	60
Lasersight	0.6	200
Wavelight Allegreto	0.95	200-400
Schwind	1.0	200
Zeiss Meditec (MEL 80)	0.7	250
B & L Technolas 217Z	2+0.8	100-200
VISX STAR S4	2+1	>10
Nidek EC-5000 CXIII	2+0.8	200

2- Scanning Spot Shape (Profile)

- *Guassian Beam profile:* LADARVision, Laser sight, Wavelight, Schwind, Zeiss Meditec
- *Truncated Guassian beam:* Bausch & Lomb Technolas 217
- *Top Hat Beam profile:* VISX STAR S4
- The most desirable profile is Guassian beam:
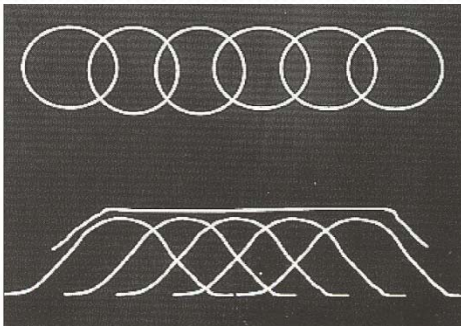
* very uniform overlap
* Avoids abrupt edges

3.Scanning Spot Rate

✜ **Majority of small spot Gaussian profile lasers:**

200Hz

✜ *Alcon LADARVision:* **60Hz**

volume ablated per shot   ablation time

✜ **Importance of rate:**

  * Slow rate   stromal dehydration

  * Higher rate > eye tracking   misplaced beams

misplaced ablations
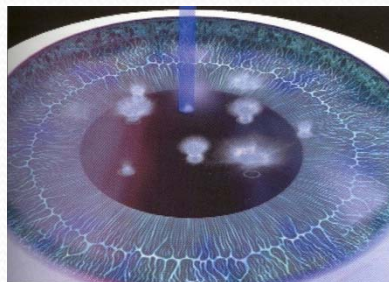
Advantages of Scanning Spot Delivery

- **Reduction of steep central Island formation in respect to broad beam**

- **Increased surface smoothness due to perfect overlap**

- **Reduction in Stress waves: in broad beam lasers:**
  - *** 40-80 atmospheres on cornea**
  - *** Pressure focus 7-8mm posterior to endothelium**

XVth Congress of Iranian Society of Ophthalmology
October 2005
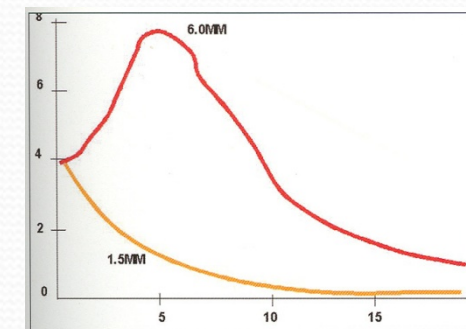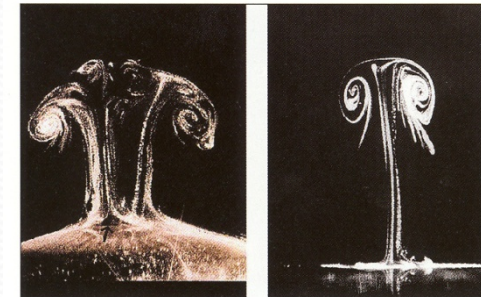
III- Fast Eye Tracking

Fixation- related eye movements:

Frequent saccadic eye movements

      1- random

      2- ~5/second

      3- rapid distance traversed

III –Fast Eye Tracking...
cont
Tracking Definitions

1. **Sampling rate:** Number of measuring the
   eye's location 60-4000Hz
2. **Latency:** * Time required to determine eye's
   location

   required response calculation

   laser tracker mirror move

- Videocamera-based tracking
  16.67ms (NTSC)to 20mS(PAL)
- Total processing delay: 33ms (NTSC) to 40ms (PAL)

3-Eye Tracker Types

Method of eye tracking	Laser radar	Charged-coupled device (CCD)/infrared
Laser system	LADARVision	B&L Technololas (120) Nidek (60 to 200) VISX, Laser sight (60) Wavelight, Zeiss Meditec (250)
Transmitted signal	905 nm diode	None
Detection frequency	4000 Hz	60,120,250 Hz
Response time	3.0 ms rise time	50ms rise time

4- Closed vs Open Loop Tracking

Open loop tracking (Video) ➡ new pupil image

➡ **comparison with old image**

⬇

single error calculation ➡ *mirror movement*

Closed loop (laser-radar) system ➡ 905 nm laser signal

4 (pupil) ➡ contrast boundaries

⬇

variable sized spots

⬇

Immediate readjustment

Spot A Reflection

Spot B Reflection

Spot C Reflection

Spot D Reflection

This Eye has moved down and to the left…..

A
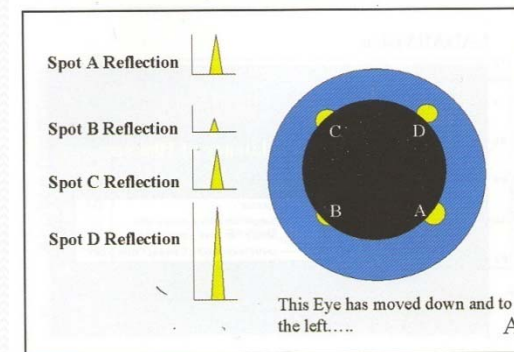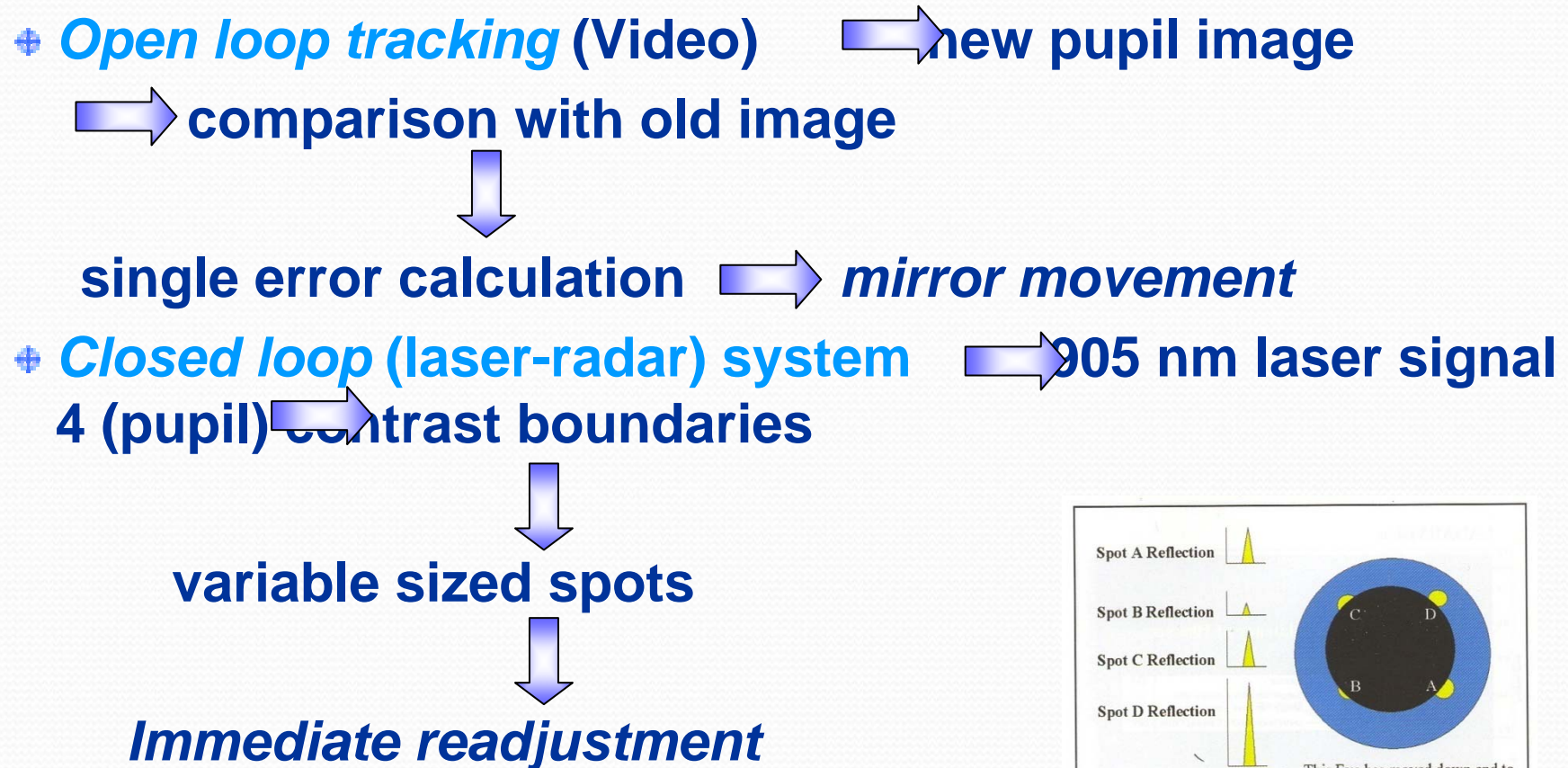
IV - LASER-Wavefront Interface
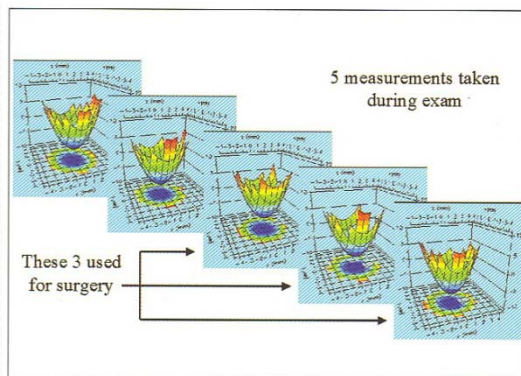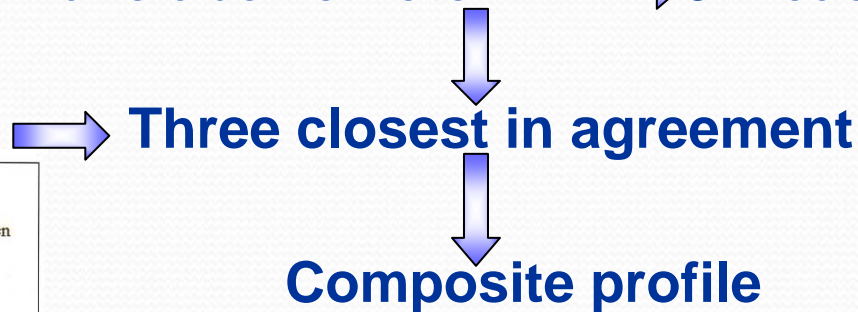
First step: Wavefront Capture & Comparion:

- Capturing the most accurate and reproducible wavefront
- Multiple captures ➡ comparisons
  generation of a composite map
- In Alcon LADARWave aberrometer ➡ 5 measurements

⬇

➡ **Three closest in agreement**

⬇

Composite profile

5 measurements taken during exam

These 3 used for surgery

Conversion to Ablation Profile:

- **Ablation profile is fundamentally inverse of wavefront error map**
- *Goal:* **Correction of refractive error and higher-order aberrations**
- **Pupil diameter at least 0.5mm larger than scotopic**
- **Limbal marking for cyclotorsion detection**
- **Wavefront measurement + corneal curvature + biomechanics ⟹ ablation profile *complex***

A Wavefront   Ablation Profile
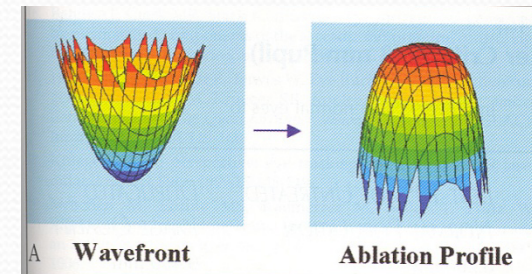
Final Step: Dynamic Registration

Ablation profile ➡️ **laser shot pattern**

⬇️

Customized Laser Correction

⬇️

Alignment with Center of undilated pupil

Dynamic registration ➡️ **engagement of eye tracker**

Ablation Profile   Laser Shot Pattern
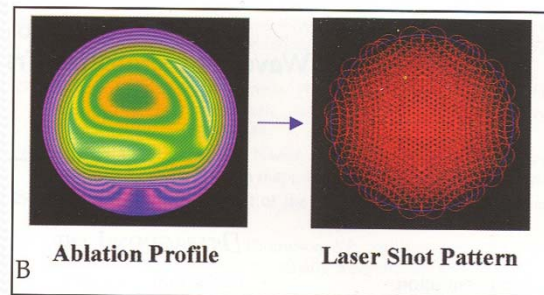
Dynamic Registration: Final Step
(Cont)

- **First reticle** ➜ **limbus ring alignment (X,Y)**

- **Second reticle** **cyclotorsion alignment with limbal markings** ➜

- **B&L Technolas 217z:** **iris detail used for registration and tracking**

Process of Registration

- **Most important technology requirement for customized ablation of HOA**
- **Required criteria for ideal registration and tracking:**

Lateral Decentration   *Torsional Alignment*

<50 μ **1 degree for ideal wavefront ablation**

<200μ **4 degrees: for achieving results consistent**

with best 10% of untreated normal

<400μ **10 degrees: only duplicate preop imagequality**

What can be the Future of Wavefront Customized Corneal Surgery?

Future of wavefront diagnostics

- **Improving accurate measurement and diagnosis above current devices (6-10th Zernike order)**
- **Measuring Corneal Wavefront aberration and surface changes**
- **Measurement of aberrations by non-Zernike (Fourier?) algorithms**
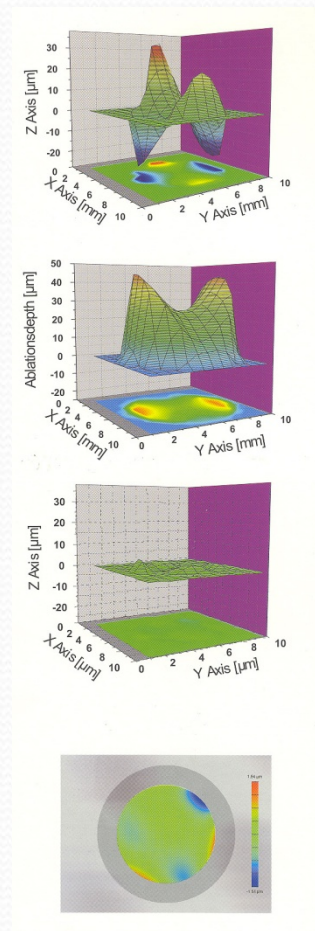
The Future of Customization

"Zonal reconstruction": providing accurate representation of the

underlying data set, minimize noise,

take multiple measurements

More sophisticated clinical aberrometer

greater density of lenslets

multiple sampling over time

adaptive optic capabilities

Future of Customized Corneal Ablation

LASIK vs Surface Ablation

- **Each microkeratome induces specific "flap only" aberration**

  (flap size, thickness)

- **Considering "flap aberrations" in total treatment calculations**

Future of Customized Corneal Ablation ... cont.

Surface Ablations:

➤ **Show promising results with use of**

● **immunomodulating agents**

● **Better control of cellular and biochemical reactions**

● **Introduction of new drugs to better regulate wound healing and Refractive Outcome**

● **Gene therapy for better control of post laser keratocyte activation and wound healing**

Multifocal Ablation

Presbyopia: Customized multifocal ablation

Aberrations may be induced when creating multifocality

Potential loss of contrast sensitivity and quality of visual function

Future results will be improved:

* **Wavefront mapping, sophisticated eye**

    trackers corneal registration

* **Preoperative simulation of postop condition**

Laser Delivery Refinements

- **Correction of higher orders of aberration needs smaller spot delivery**
- **>5th order** ➡ **requires 0.6-0.8mm spot size**
- **Smaller spot size needs faster and better eye trackers**
- **Smaller ablation depth per pulse provides ideal correction profile for higher orders**

Laser Delivery Refinements

- **Katana solid state excimer laser: very small spot (0.2 mm), rapid laser delivery rate, rapid eye tracker (even rotational)**

- **Accurate registration: iris recognition by B&L Technolas, VISX**

Environmental- Interface Corneal Ablation Control

- **Environmental factors**: temperature, humidity, physical variables of cornea
- **Operating suite control: already done**
- *Microenvironment* **(around cornea) control: essential for outcome predictability**
- **Online pachy- and topography for intraoperative control: more precise**

Adaptive Corneal Correction

- **Intraoperative measurement of refractive and ablation profile of the eye**
- *Not* **possible with LASIK or surface ablation**
- **Adaptive LTK: real-time intraoperative measurement of wavefront errors**
- **Developing threshold for certain refractive and Wavefront outcome: stop treatment when ablation corrected and goal reached**

Customized Corneal Ablation

- *Customized LASIK & PRK* will dominate in next few years
- Speedy recovery, good quality of vision satisfactory outcome
- *Disadvantage* of conventional refractive surgery in some patients:
  - * Increase in HOA
  - * Reduction in visual quality

Customized Corneal Ablation

Advantage of customized corneal ablation:

- **Reduction of HOA**
- **Sharper contrast**
- **Superior visual outcomes**

Customized corneal procedures seems to remain an option for next two decades

Wavefront Customized Visual Correction

Ocular wavefront sensing:

- **Will be increasingly employed**
- **Will become routine in vision assessment**

Wavefront customization **is employed to optimize any Refractive Surgery procedure**

Wavefront Customized Visual Correction
(cont)

Future wavefront customized refractive procedures

- **Implantation of optimized IOL's e.g Tecnis aspheric lens**

- **Customized IOL's preinsersion, customized phakic IOL's**

Wavefront Customized Visual Correction
(cont)

Customized IOL's post-insersion:

✦ **Calhoun laser adjustable lens**

✦ **Customized adaptive correction**

✦ **Accommodating IOL customization**

✦ **Capsular filling customization**

✦ **Customized corneal inlay/ on-lays**

✦ **Photophaco reduction and modulation**

Conclusion

✦ **Wavefront measurement devices and consequently wavefront correction procedures are still in process of evolution**

✦ **Achievement of *"supervision":* with advancement in current procedures will not be a dream in near future**

Thank You for Your Kind Attention!!