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Ophthalmology PG Exam Notes

1st Edition

Instruments & Investigations

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MD (AIIMS)

I notes
(Ophthalmology PG Exam Notes)

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This is a compilation effort from my preparation notes and other sources, thus any contributions or comments are welcomed in the effort to improve this book. Therefore, feel free to e-mail me at
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I notes

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Thank you GOD

This manual is collection of the notes I made, found in books or internet while studying for the Final MD exams for ophthalmology.

I have segregated topics just like book chapters to find them back easily. Though these all might be far less then other preparation notes available, I am proud of what I have made and I feel nice to present them to my upcoming ophthalmology friends.

Good luck!

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Vision

Visual acuity is a highly complex function that consists of

• Detection of presence or absence of stimulus, i.e. **Minimum visible**

• Judgement of location of visual target relative to another element of the same target, i.e. **Minimum separable**

• Ability to distingush between more than one identifiable feature in a visible target, i.e. **Minimum resolvable**.

The various ways of classifying the available visual acuity tests are

• Depending on type

• Depending on age

Depending on Type

- Recognition acuity tests
  - Direction Identification
    - Snellen E
    - Landolt C
  - Letter Identification
    - Snellen Letter
    - Lipman HOTV
  - Picture Identification
    - Allen's picture
    - Beale collin's picture
- Detection acuity tests

  - Dot visual acuity tests
  - Preferential looking test
- Resolution acuity tests
  - Optokinetic nystagmus

Visual Acuity

- Visual acuity is defined as the "spatial resolving capacity" of the eye
- Theoretically, this represents macular function, but really it represents the state of the entire ocular system, including the visual pathways

Snellen chart

- Dutch ophthalmologist Dr Hermann Snellen in 1862
- Each letter on the chart subtends an angle of 5 minutes (min) of arc at the appropriate testing distance, and each letter part subtends an angle of 1 min of arc. Thus, it is designed to measure acuity in angular terms. In a healthy adult, the resolution limit is between 30 seconds and 1 min of arc
- Snellen acuities are usually expressed as a fraction with the numerator equal to the distance from the chart and the denominator being the size of the smallest line that can be read.
- The reciprocal of the fraction equals the angle, in min of arc, that the stroke of the letter subtends on the patient's eye and is called the minimum angle of resolution (MAR).
- Disadvantages
  1. each line has a variable letter size and there are variable letters per line
  2. when testing Snellen acuity, the tester uses a line assignment method. Thus, missing 1 letter on the good acuity lines has less effect than missing 1 letter on the poor vision lines

3. lack of standardized progression between lines, Snellen visual acuity is difficult to assess statistically

4. there is an irregular and arbitrary progression of letter sizes between lines. This introduces considerable error when changing the viewing distance of the chart and leads to overestimation of vision at the lower end of acuities

5. the letters on a Snellen chart are not always the same legibility. Some letters (eg, C, D, E, G, O) are easier to read than others (eg, A, J, L).

6. the distance between letters and rows is not standardized. Studies have shown that when letters are spaced too closely, there is an effect from the adjacent contours called a crowding phenomenon, that diminishes acuity

7. the term "Snellen chart" has never been standardized, so the criteria to label a chart design as "Snellen" are not defined. Snellen charts from different manufacturers may use different fonts, different letters, and different spacing ratios, and they may be illuminated or projected differently

8. its TRV between visits is very large, varying from ±5 to 16.5 letters in normal subjects, and up to 3.3 lines in cataractous, pseudophakic, or early stage glaucoma patients

- Theoretically, if visual acuity is tested multiple times on a particular chart, the expected difference should be zero. However, in reality, even in the absence of any clinical change, there is a distribution of scores that reflects the underlying variability in the chart measurement. This is called test-retest variability (**TRV**).

Bailey-Lovie chart

- Drs Ian Bailey and Jan Lovie in 1976
- design features
  - The letters had almost equal legibility. While not the ideal legibility as the "Landolt C" or "illiterate E" letters, the letters on the Bailey-Lovie chart did have a height equal to 5 stroke widths and were without serif
  - Each row had 5 "Sloan" letters, and there were 14 rows of letters (70 letters).
  - There was consistent spacing between letters and rows, proportional to letter size. The between-letter spacing was 1 letter-width and the between-row spacing was equal to the height of the letters in the smaller row.

  - There were equal (0.1) logarithmic intervals (a ratio of 1.26×) in the progression of letter sizes between lines. Thus, the letters double in size every 3 lines, and a 3-line worsening of vision is the same regardless of initial vision
  - There was a geometric progression of the chart difficulty based on the distance from the patient. The chart was designed to be read at a standard 6 meters with visual acuities that could be measured at this distance equal to 6/60 to 6/3 (Snellen equivalent of 20/200 to 20/10). If the chart was moved closer to the patient by a 0.1 log step (6 to 4.8 meters or 4.8 to 3.8 meters), then there was a 25% increase in angular size of the letters and the patient should be able to read 1 additional row on the chart. Thus, one could precisely vary the size of the letters based on testing distance allowing the testing distance to be varied as desired.
  - easily scored in logMAR (logarithm of the minimal angle of resolution) units
  - By scoring in this method, one knew the exact size of the letters on the chart. This also made adjusting visual acuity scores based on non-standardized viewing distances easier
  - consistent TRV with different days, examiners, and clinical sites

- The Bailey-Lovie chart was further modified in 1982 Dr Rick Ferris for use in ETDRS.
  - gold standard" for most current clinical trials.
  - Still not generalized for use because clinical testing with ETDRS charts is felt to take longer, require specialized lanes, and be more difficult to administer than testing with Snellen charts, so widespread adoption of ETDRS charts has not occurred

Pediatric Visual Acuity

- Infants (Pre Verbal child)
  - Fixation pattern
  - Catford drum

  - Forced Preferential looking test (Teller acuity cards, Cardiff acuity cards),
  - Optokinetic Nystagmus (OKN)
  - Pattern VEP
- 1 – 2 years (Pre Verbal child)
  - Forced Preferential looking test (Teller acuity cards, Cardiff acuity cards)
  - Boeck candy bead test
  - STYCAR graded ball test
  - Worth ivory ball test
- 2 - 3 years (Verbal preliterate child)
  - Allen's picture cards
  - Kay's picture test
  - Sheridan's miniature toy test
  - LEA symbols (Language skills sufficient to name pictures)
- 3 – 4 years (verbal preliterate child)
  - Tumbling E test
  - Landolt's C test
  - Sheridan – Gardener test
  - HOTV test (Able to match letter optotypes)
- Age more than 6 years (literate child)
  - Snellen's chart
  - ETDRS chart

DO

- Types
    - Hand held direct ophthalmoscope
    - PanOptic
    - Fundus contact lens
    - Hruby lens

- Metrics
    - Image: Virtual/Erect
    - Field of view: 2DD = 10°
    - Magnification: 15X
    - Area of fundus seen: 50-70% with moving it, never beyond equator
    - Image brightness: 1/2 = 4 watts
    - Working distance: 1-2 cm
    - Stereopsis: None

- **Advantages**
    - Ease in performance
    - Comfort
    - Dilation not necessary
    - Ease in documentation
    - Less expensive
- **Disadvantages**
    - No stereopsis
    - Close distance
    - Small field

  - Limited illumination
  - Refractive error

- **Field of View (FOV)**
  - 10° or 2DD
  - Limited by Peripheral light rays
  - Expanded by Decreasing working distance, Maximizing pupil dilation, Decreasing myopia
- **Magnification**
  - Depends on refractive powers of the patient and the doctor; axial lengths, compensating lenses
  - 15X = 60/4
  - Refractive error
  - Aphakes
  - Hyperopes
  - Myopes
- **Features**
  - Wide aperture
  - Bull's eye fixation target – visuoscope
  - Filters
  - Red free
  - RNFL, blood vessels, choroidal lesions
  - Cobalt blue
  - Abrasions, foreign bodies, infiltrates, CL, GAT
- **Tong's DO Dance Technique**
  - **7 steps to distance ophthalmoscopy**
  - 1) Turn DO on to moderate setting
  - 2) Hold DO in right hand to be used with right eye
  - 3) Dial in lens up to +3.00 D with right index finger

- 4) Look through aperture with right eye
- 5) Stand at arm's length (30-40 cm)
- 6) Shine light toward patient's right eye
- 7) Evaluate all quadrants

- **What to look for while dancing…**
    - Orange-red fundus reflex
    - Black spots
    - Localization
    - While focused at plane of lens
    - Against motion - in front of lens
    - Cells, flare, hyphema
    - No motion - at plane of lens
    - Mittendorf dot, PSC, vacuoles
    - With motion - behind lens
    - Vitreous hemorrhage, asteroid hyalosis
- **Anterior Segment Evaluation**
    - 6 steps to evaluate from the lids to the retina
    - 1) Dial in approximately +20.00D to evaluate lids and lashes
    - 2) Reduce + to evaluate conjunctiva and cornea
    - 3) Further reduce + to evaluate iris
    - 4) Continue to reduce + to evaluate lens
    - 5) Then vitreous
    - 6) All the way back to the retina

- Normal-Orange-red reflex
- Clear, no opacity
- Bright red-Hemorrhage
- White-Arterial occlusion, Coloboma, Retinoblastoma

- Blue/Black- Choroidal melanoma
- Grey- Retinal detachment
-

Color Vision

- **Color**: visual description of an observer by which he distinguishes two fields of same size, shape and structure by **difference in spectral activity**.
- **Primary Colors**, ADDITIVES: Red, Green, Blue (mixing them gives white)
- **Secondary Colors,** SUBSTRACTIVE: Cyan, Magenta, Yellow (mixing them gives black)
- **Color sense:**
    - Ability of the eye to discriminate between different colors excited by light of different wavelengths
    - Function of cones
    - Better appreciated in photopic vision
    - In scotopic vision all colors seen as gray-called **Purkinje shift**
- **Three attributes**
    - Hue – Dominant spectral color, ability to detect difference in wavelength.
    - Intensity – Luminosity, ability to detect difference in brightness.
    - Saturation – Degree of freedom from dilution with white

Theory of colour vision

- Theory of trichromacy (**Young-Helmholtz-Maxwell**)
    - postulates three different receptors maximally sensitive to wavelength in different regions of visual spectrum

- Three kinds of cones
  - 440 to 450 nm - blue spectrum
  - 535 to 550 nm - green spectrum
  - 570 to 590 nm - red spectrum
- Drawbacks
  - Though it accounts well for laws of color mixing, has difficulty with other basic phenomena
  - Dichromats who confuse red with green can see yellow
  - Difficulty in explaining complementary color after-images

- Opponent colour theory (**Ewald Hering**)
  - Colours are mutually exclusive or opponent
  - Two chromatic (red-green and blue-yellow) and one achromatic (black and white) mechanism
  - Presence of one of the color of the pair excludes the other color perception and presence of both nullify each other
  - Color vision trichromatic at photoreceptor level
  - Color opponency occurs at ganglion cell onwards
  - Merits
    - Accounts well for color contrast and color blindness
    - 2 color opponent ganglion cells
      - Red green opponent color cells
      - Blue yellow opponent color cells

- **Granit's Dominator – Modulator Theory**
  - In addition to the retina's three kinds of cone cells, which respond to different colors, certain optic-nerve fibers (dominators) respond either to the whole spectrum or to specific colors (modulators)
  - He also proved that light inhibits as well as stimulates optic-nerve impulses

Factors

- Pre-receptoral factors
  - Pupil
  - Lens (absorbs low wavelength)
  - Macular pigment
- Photoreceptors
  - Short wavelength sensitive (440 nm)
  - Middle wavelength sensitive (535 nm)
  - Long wavelength sensitive (565 nm)
  - Principle of univariance
- Post receptoral factors
  - Red-green channel
  - S-cone channel
  - Luminance channel

Colour vision defects

- Congenital
  - Stationary
  - Both eyes equally affected
- Acquired
  - Progressive/ Asymmetric
  - Type 1 red green
    - Luminous function affected
    - Macular cone damage
  - Type 2 red green
    - Luminous function normal
    - Optic nerve involvement
  - Type 3 blue

                - Most common
                - Increased density of pre-receptoral factors
                - Choroid / RPE / Retinal / Neural diseases
            - Glaucoma: Type 3 defect early, SWAP
            - Leber's optic atrophy: Type 2 red-green
            - Optic neuritis: Type 2 red-green mostly
            - Papilloedema / AION: Type 3
            - Toxins:
                - Digitalis / Quinine – Type 1 red-green
                - Antibiotics – Type 2 red-green
                - Chloroquine – Type 3

- Colour vision testing
    - Natural daylight
    - Fixed test distance: **0.75 m** for plate tests
    - Check pupil diameter
    - Tinted / Heavy lenses alter responses
    - Lantern tests
    - Plate tests
    - Arrangement tests
    - Anomaloscope
-
- Blue defects unlikely to be congenital
-
    -

Glare Acuity

- contrast-lowering effect of stray light on a visual scene.
- Extra light thrown onto the retina tends to wash out the contrast of the event we are viewing
- we cannot see intensity differences efficiently in the presence of a high background of light intensity.
- 1926: L.L. **Holladay**, described the relationship between glare and contrast sensitivity.
- 1970: Miller, Wolf, Nadler → first clinical glare tester
- Glare testers offer two types of targets: a standard Snellen visual acuity chart and a variable contrast sensitivity target. The variable contrast targets may be presented as (1) sinusoidal contrast gratings; (2) the Snellen chart printed in different contrasts; or (3) the Landolt ring presented in different contrasts.
- Management:
- Non-surgical
    - Using side shields on the temples of spectacles prevents glaring sidelong rays from striking the eye
    - Watching the television set with the room lights off
    - Wearing polarized sunglasses will cancel out the reflected glare from shiny surfaces
    - Wearing a peaked cap or wide-brimmed hat prevents the overhead rays of the sun from striking the eye.
    - Replacing scratched or pitted automobile windshields reduces glare from the sun and oncoming headlights.
- Surgical
    - surgical removal of the scattering lesion should be considered.
    - Significant corneal edema or permanent corneal scars can be treated by a corneal transplant.
    - A significant cataract should be extracted.

Contrast Sensitivity

- Contrast sensitivity is the ability to perceive slight changes in luminance between regions that are nor separated by definite borders and is just as important as the ability to perceive sharp outlines of relatively small objects
- Campbell and Green, in 1968, first measured contrast sensitivity using sinusoidal gratings
- TYPES OF CONTRAST SENSITIVITY
  - **Spatial contrast sensitivity**
    - striped patterns at various levels of contrast and spatial frequencies: Arden gratings
    - A high spatial frequency implies narrow bars, whereas a low spatial frequency indicates wide bars.
  - **Temporal contrast sensitivity**
    - contrast sensitivity, function is generated for time-related (temporal) processing
- MEASUREMENT OF CONTRAST SENSITIVITY
  - **Arden gratings**
    - booklet containing seven plates: one screening plate (No. 1) and six diagnostic plates (No. 2-7).
    - studied at 57 cm
  - **Cambridge low-contrast gratings**
    - of ten plates containing gratings in a spiral bound booklet
    - booklet is hung on a wall at a distance of 6 m
  - **Pelli-Robson contrast sensitivity chart**
    - letters that sub tend an angle of 3° at a distance of 1 m.
    - The log contrast sensitivity varies from 0.00 to 2.25.
    - Normal should be >1.50
  - **The Vistech chart**

- **FACT chart**

Photostress Test

- The Photostress test is a simple clinical technique that can differentiate between retinal (macular) and postretinal (e.g.optic nerve) disease. The test involves exposing the eye to the light from the ophthalmoscope for 10 s and measuring the time taken for acuity to return to within one line of pre-bleach acuity. Subject with normal healthy macular function should be able to read line in the 50-60 s.
- Patients with a macular problem may have recovery times lasting 1.5 to 3 min or longer. In car drivers with macular degeneration photostress effects from opposing cars may bleach retinal pigments and cause a dramatic drop in visual acuity. In patients with optic nerve disease the bleaching of the retina will have no effect on the recovery time. Photostress recovery time increases with age but is independent on pupil size, ametropia and visual acuity.
- Testing is done monocularly. Ask the subject to cover or occlude one eye. Measure the visual acuity of the other eye by Snellen´s optotypes. Afterthat, the ivestigated eye is subjected to a bright light from ophthalmoscope directed onto macula for 10 s. Then, the subject is asked to read the line of letters just above his/her best line of acuity. The timing starts when the ophthalmoscope or penlight is removed. Photostress recovery time is measured. The same procedure is then repeated for the fellow eye.
- Note the values for recovery time for both eyes and compare them with reference values.

LI

- Principle:
  - light interference.
  - **Dr Daniel Green**
  - patterns can be produced on the retina by the interaction of waves from two coherent light beams (each less than 0.1 mm in diameter).

  - The spacing of a fringe pattern (fringe pitch) is a function of the separation of the two pinpoint beam areas (grating angle). increasing the separation produces a finer fringe pattern which requires greater macular resolution
  - Thirty-three maxima per degree of visual angle correspond to Snellen's equivalent of 6/6
  - The field size of the interference fringe ranges from 1.5 to 8.0°.
  - The procedure is independent of refractive errors and correction need not to be used.
- Two types
  - **Laser interferometer**
    - safe, low-power He-Ne laser (Helium-Neon gas laser; A = 632.8 nm)
  - **White-light interferometer**
    - polychromatic white-light incandescent bulb
- predictive value: good but variable ??
- **False positive test**
  - Tilted retinal receptors generally result in poor Snellen's acuity (Stiles-Crawford phenomenon).
  - Healthy photoreceptors in cystoid macular edema can also show false positive result.
  - Viable parafoveal tissue stimulation is also believed to produce false positive result in patients with cystoid macular oedema, geographic atrophy of macula, macular hole and macular cystoid.
- **False negative results**
  - Poor pupillary dilation
  - Very dense cataract
  - Dense vitreous haemorrhage

PAM

- **Guyton and Minkowski** in l980
- small device that mounts on a slit lamp and projects an image of a Snellen's visual acuity chart, using a 0.15-mm diameter aperture
- patient should be using his refractive correction
- **Predictive value**: PAM correctly predicts the postoperative visual acuity in patients with moderate cataracts (20/200 vision or better) to within three lines on Snellen's chart in 100% of cases and to within two Snellen's lines in 91% cases.
- Errors: erroneously predict improved or worse vision in eyes with cystoid macular oedema. serous detachment of the sensory epithelium of the macula, recent postoperative reattached retina, geographic atrophy of the retinal pigment epithelium of the macula, macular hole or cyst, dense opacities (e.g. dense cataract) or glaucoma.
- Unlike laser interferometry (LI), amblyopia does not appear to interfere with the ability of the PAM to make accurate predictions.

Specular Microscopy

- **Reflected light microscope** as against transmitted light used for biologic microscope
- Used **primarily for the corneal endothelium,** although other structures (eg corneal epithelium, stroma, ant. & post. Surface of lens) also can be visualized
- History
  - 1968 **Maurice** photographed the specular image of the corneal endothelium of rabbit & so named it SPECULAR MICROSCOPE
  - **Laing** & colleagues modified Maurice's instrument producing photomicrograph with cellular details, leading to creation of first specular microscope suitable for in vivo clinical use
  - **Sherrard & Buckley** developed objective lens using fluorite front surface reducing reflection from objective lens-epithelium permitting use of wider slit with wider field of cells to be imaged

- Principle
    - Reflection of light; specular- smooth surface (mirror), diffuse- rough surface
    - At smooth endothelium-aqueous surface reflected portion 0.022%
    - These lights are collected by the objective lens & an image of the plane at which the instrument is focused is formed at the film plane of the microscope

- Analysis
    - Cell Density
        - **Comparison Method**: compare to known "honey comb" pattern
        - **Fixed Frame Method**: count the number of cell within a frame
        - **Variable Frame Method**
    - Cell Area
        - **Corner Method:** determine cell area from a polygon digitization by locating cell border intersections
        - **Center Method:** determine cell area from adjacent polygon centers, "center to center"

- SPECULAR PHOTOMICROGRAPH
    - **4 distinct zones**
        - Zone 4 aqueous humor
        - Zone 3 endothelium
        - Zone 2 stroma
        - Zone 1 lens-coupling fluid interface/coupling fluid-epithelium interface
    - 2 boundaries
        - Dark boundary – between 3 and 4
        - Bright boundary – between 2 and 3
    - With narrow slit beam: All 4 zones clearly seen
    - With broad beam: Zone 2 disappears and Zone 3 becomes larger

- Corneal Endothelial Cell Morphology
  - Cell Area ± S.D. (μm2)
  - Cell Density (cells / mm2)
  - Polymegethism
    - Coefficient of Variation
    - CV = SD cell area/ mean cell area
    - Normal young adult, 0.27 to 0.28
    - Literature convention uses 27 to 28
  - Pleomorphism (%H)
    - % hexagonality
    - Normally more than 50%

- Clinical Specular Microscopes Available
- Contact
  - Keller-Konan: SP-580 manual photo digitized
  - HAI Labs: HAI CL-1000xyz manual or automatic
  - TOMEY: EM-1000 automatic

- Non-Contact
  - Bio Optics: LMS-12000 automatic with manual
  - Topcon: SP-2000P automatic limited
  - Konan: ROBO Pachy SP-9000 manual digital
  - Konan: ROBO CA SP-8800 manual digital

Confocal Microscope

- Invented by **Marvin Minsky** (1957), fellow at Harvard University
- microscopy technique that imaged tissue parallel to its surface.
- Principle
    - '**confocal**' to describe this conjugate focal point design.
    - two pinholes, the first before the condenser, which focuses the light rays into the tissue, and the second before the eyepiece or camera, which focuses the reflected light rays into an image
    - Modern confocal microscopy replaced the condenser with either white light or a focused laser beam, and the eyepiece with an electronic digital detector.
- lateral and axial resolution to 1–6 and 4– 15mm, respectively, and increased magnification up to 600 times
- **Tandem scanning**
    - Petran et al
    - **Nipkow Disk**, originally developed for encoding and decoding telegraph messages.
    - 14 000 pinholes that are systematically positioned 1800 opposite each other, allowing simultaneous alignment with the detector and illuminator
    - to view the tissue in real-time.
- **Scanning confocal microscope**: Koester and Maurice
- Corneal edema may limit the effectiveness of standard specular microscopy; however, the confocal microscope can view the endothelium and inflammatory cells through a relatively edematous cornea. This device can search for hyperreflective, round bodies typical for inflammatory cells, potentially avoiding unnecessary regrafts
- **Normal cornea confocal appearance**
- Epithelium:
    - epithelial thickness to be 54+7mm centrally and 61+5mm peripherally
    - three cell layers – basal, wing and superficial.
- Bowman's layer: It is an acellular layer composed of randomly dispersed collagen fibrils, measuring 12mm thick.
- Stroma:

  - keratocytes, collagen and ground substance.
  - anterior keratocyte density of 1058+217 cells/mm2 that progressively decreased to 771+135 cells/mm2 posteriorly.
- Descemet's membrane:
  - basal lamina of the corneal endothelium.
  - 3–4mm at birth to 10–12mm in adulthood
- Endothelium:
  - cell loss rate of 0.6+0.5% per year in adult
- Corneal innervation:
  - most densely innervated superficial tissues in the human body.
  - 60–80 nerve bundles enter into the anterior one-third of the corneal stroma.
  - 16000 nerve endings per 1 mm2 within the superficial epithelial layer
- **Diseases**
  - Epithelial Diseases
  - Stromal Abnormalities
  - Endothelial Pathologies
  - Corneal infections
    - visualize fungus, acanthamoeba, bacteria and microsporidium.
    - fungal infections are characterized by the presence of hyperreflective, elongated, filaments or budding yeast
    - acanthamoeba appears as highly reflective, round or ovoid double-walled cyst with a diameter of about 10–25mm
    - Nocardia asteroids – filamentous bacteria – appear as highly reflective, short, thin, beaded branching filaments that often branch at right angles
  - Refractive surgery
- Advantages
  - it is noninvasive
  - facilitating examination of the same subject at different times
  - it allows observation of corneal structure at high magnification

  - it allows visualization of keratocytes and corneal nerve fibers.

- Confocal biomicroscopy requires a coupling gel to reduce light scattering at the corneal epithelium

Keratometry

VKG

indications for computed topography of the cornea

- Refractive instability
- Reduced best spectacle corrected visual acuity
- Contact lens wear, especially rigid lenses
- Design and simulation of rigid contact lens fitting
- Diagnosis of contact lens-induced corneal distortion
- Management of therapeutic and refractive corneal surgeries
- Diagnosis and management of corneal disease such as keratoconus
- Determination of corneal power for correct intraocular lens (IOL) power calculation in cataract surgery
- Evaluation of corneal surface abnormalities and determination of their affect on the optical quality of the eye

FOCOMETER

- developed by Drs. Ian Berger and Larry Spitzberg at Houston, Texas
- simple, inexpensive means for measuring refractive error in human vision
- **monocular hand held device**, which is used in natural lighting and allows an individual's refractive power to be read off a linear dioptre scale
- Patients rotate the focometer till the best focus is achieved
- reads accurately **only up to +9 D sphere**
- Astigmatism can also be measured using a "clock target" with the device

Lensometer

- It is also known as **Focimeter** or **Vertex refractionometer**
- **Principle:** image of a target; which is usually a ring of dotted circle, is focused by a standard lens when seen through a telescope. When an unknown lens is inserted into this optical system the position of target is changed. The excursion required to bring target back into focus is directly proportional to the back vertex power of lens

Uses of Lensometer

1. To check the power of unknown lens
2. To check the axis of unknown lens
3. To mark axis of unknown lens
4. To check and mark optical center of a lens
5. To detect and measure power of unknown prism.

Sources of Error

1. If eyepiece is not adjusted prior to putting the lens on platform. 0.25 D error can creep in by this mistake.
2. If calibration of instrument is not done.
3. If there is a lag in the movement of knob.
4. If focusing of target is not done properly.
5. If reading is not taken properly. Ideally our eyes should be at the same level as the level of the scale to avoid error.

Use:

- First of all the instrument should be calibrated. Focus the scale with eyepiece. Focus the green colored target with knob. Target is seen as a circle of dots. Note down the reading. It should be zero. Now place the lens with unknown power on the platform of lensometer. Adjust the knob to refocus the target. Take fresh reading. This gives the power of unknown lens.

- In case of a cylindrical lens after focusing the target, axis of target should also be noted. This is the axis of the unknown lens. If the unknown lens is a spherical one, the green colored target is seen as circle of dots. If it is a cylindrical or compound lens the dots become a series of lines. The length of lines is directly proportional to the power of the cylinder.

- In case of a compound lens after placing the lens, the target is focused and reading taken. Here the target is focused in form of series of lines with some particular direction. This is the power of spherical component. Now refocus the target. Now the direction of lines is at right angles to the previous direction. Now take second reading. The difference between the first and second readings is the power of the cylindrical component. The axis shown at second reading is the axis of the cylinder. In simple words:

  First reading = Power of spherical
  Second reading—First reading = Power of cylinder
  Axis of the second reading = Axis of cylinder.

Autorefraction

Optical Principles

1. **Schiener's Principle**
   - nulling refractors
   - double pinhole apertures before the pupil
   - modern version: IR-LED that are optically presented in substitution for the apertures in a schieners disc
   - concept of the Badal optometer
2. **Optometer Principle**
3. **Retinoscopic principles**
   - meridional refractors.
   - Ophthalmometron: based on direction of fundus streak motion

- Retinomax, NIKON: based on speed of fundus streak motion

4. **Best- focus principle**

- both nulling and meridional refractors.
- The refractive end point of a best focus autorefractor is obtained when the referred image of a secondary fundus source attains highest contrast at a plane of a photodetection device.

5. **Knife- edge principle**

- Foucault knife-edge test

6. **Ray- deflection principle**
7. **Image-size principle**

- Collins (1937) developed the first semiautomated objective refractometer(electronic **refractionometer**).
- Safir (1964) automated the retinoscope and this work led to the first commercial autorefractor-the **Ophthalmometron**.
- **6600 Autorefractor** was the second commercial autorefractor (1969).
- Munnerlyn (1978) design using a best contrast principle with moving gratings led to the **Dioptron**, an automated objective refractor.

- **Basic Optometer types**
  1. Early subjective optometers: Badal's optometer, Young's optometer
  2. Early objective optometers: Rodenstock refractometer
  3. Zeiss-Jena coincidence refractionometer:
  4. The Fincham coincidence optometer

- **Modern refractometers**

  Based on Instrument design and method

  1. Objective: Nikon autorefractometer NR 1000F, AR2000, Canon autoref R-1, Shin-Nippon SR 7000, Humphery automatic refractometer, Dioptron, Nidek AR 2000

2. Photorefractors:

3. Electrophysiological methods

LenSTAR

- LENSTAR LS 900® THE FIRST OPTICAL BIOMETER OF THE ENTIRE EYE
- 1 Scan — **9 Measurements** — 30 seconds
- Aside from the exquisitely accurate measurement of axial length, anterior chamber depth and lens thickness by optical biometry, one of the more impressive features of the LENSTAR is that the 2-zone autokeratometry feature can be used for the toric IOL with the same degree of accuracy as manual keratometry.
- LENSTAR® Benefits:
    - first optical biometer which uses the precision of **OLCR** (**Optical Low-Coherence Reflectometry**) ***820 μm super luminescent diode*** technology to capture nine measurements in a single scan:
        1. **keratometry**
        2. **white-to-white distance**
        3. pachymetry
        4. **anterior chamber depth**
        5. lens thickness
        6. pupillometry
        7. **axial length**
        8. eccentricity of the visual axis
        9. retinal thickness.
    - consists of **16 individual full eye scans** and 4 individual keratometric scans, taken on 2 concentric rings, along the patient's visual axis.

- software runs on an **external PC**. This minimizes costly upgrades, software crashes and hardware repairs, and allows direct communication with EMR and networks as well as auto-population of data fields from third party IOL calculators such as Holladay II, eliminating the risk and liability potential of transcription error.
- All of the standard IOL prediction formulas (Holladay I, SRK-T, Haigis and Hoffer Q) are built
- proprietary intelligent detection system.
- The LenStar LS 900 device comparing to the IOL Master additionally enables ***pachymetry, macular retinal thickness, lens thickens and pupil diameter measurement. LMPEP***

- high correlation between the axial length and keratometry (K) measurements obtained by IOL Master & Lenstar. Lenstar to measure slightly deeper anterior chamber depth (ACD). (shammas)

IOLMaster

- non-contact optical device that measures the distance from the corneal vertex to the retinal pigment epithelium
- FDA→ March 2000
- Principle:
  - based on partial coherence interferometry within ±0.02 mm or better (A-scan ultrasonography 0.10- 0.12mm) so ***fivefold* increase in accuracy**.
  - Special feature incorporated is use of dual beams. In interferometer eye needs to be absolutely stable so as not to disturb interference patterns. Use of dual beams makes IOL Master insensitive to longitudinal movements and measurements can be made with ease.
- OCB measures the axial length from corneal apex to retinal pigmentary epithelium while A scan measurers up to vitro retinal interface only. IOL Master thus gives the true refractive length than anatomical axial length.
- Highly ametropic patient can wear glasses while sitting on IOL Master which aids in fixation. ***(NOT CONTACT LENS)***
- it measures
  1. Axial length (9 different modes available)
  2. Keratometry (takes 3 measurement and then averages it)
  3. Anterior chamber depth
  4. "White-To-White" (cross bar to be focused on the iris rather than cornea.)

- axial length of eyes ranging from 14.0 mm to 40.0 mm.
- **Signal Curves:** Valid signal curves are characterized by very good signals (signal to- noise ratio>10), clear signal (SNR>2.0) or borderline signal (SNR 1.6-2.0).
- **Optimisation**: A constants which are provided by the manufacturer are based where we anticipate the IOL to sit in relation to cornea. IOL Master which can calculate the new optimised lens constant for that type of lens for that particular surgeon.
- **Advantage**
    - Non-contact measurements.(Patient comfort)
    - No risk of cross infection
    - Single instrument performing AL, Km & ACD
    - Learned very quickly. (User Friendly)
    - Observer independent reliability
    - More accurate than conventional A-scan(approx five times)
    - **Five formulae** are integrated. **(SRK 2, SRK/T, Holladay, Hoffer Q, Haigis)**
    - Power calculation for phakic implants: calculation of iris, chamber angle or posterior angle supported phakic implants.
- **Limitations**
    - Dense media opacity along the visual axis
    - Unsteady (non-fixating) patient
    - Strong ametropia
    - Patients with nystagmus
    - Retinal detachment

LENSTAR LS 900 vs. IOL Master

Haag-Streit White Paper

- Axial length and K-readings did show very good correlation
- LENSTAR provided slightly deeper ACD measurements than IOL Master.

- (LENSTAR uses laser interferometry to assess all axial dimensions of the eye, including the ACD; IOL Master uses a lateral slit illumination and video image analysis to measure ACD.)

IOL Master

Zeiss

FDA approved March 2000

infrared diode laser (780 nm)

partial coherence interferometry

Lenstar LS900

Haag-Streit

FDA approved October 2009

superluminescent diode (820 nm)

optical low coherence reflectometry

OCT

- Low Coherence interferometry became possible in late **1980**
- First 2-D in vivo image of human fundus – SAT conference 1990
- Further development in 1990 by Naohiro Tanno and in particular since 1991 by **Huang et al.** optical coherence tomography (OCT) with micrometer resolution and cross-sectional imaging capabilities became a prominent biomedical tissue-imaging technique
- First in vivo OCT images – displaying retinal structures – were published in 1993
    - OCT 1: 1996
    - OCT 2: 2000
    - OCT 3: Stratus :2002
    - Fourier domain OCT: 2006 (spectrometer based/ tunable laser based)
- Principle:

- Based on principle of *Michleson Interferometry*
- In vivo histology
- Low coherence infra-red (830 nm) light used
- Axial resolution of <10 um
- Ultrahigh resolution research OCT scanners use a **titanium sapphire laser** (800 nm) & give an axial resolution of 2-3 um

- Time domain & Fourier domain OCT:
  - In time domain OCT, a mirror in the reference arm of the interferometer is moved to match the delay in various layers of the sample. The resulting interference signal is processed to give the axial scan data. ***The reference mirror must move one cycle for each axial scan***. The need for mechanical movement limits the speed of image acquisition.
  - In Fourier domain OCT, the reference mirror is kept stationary. The interference between the sample and reference reflections is split into a spectrum and captured by a line camera. The spectral interferogram is Fourier transformed to provide an axial scan. ***The absence of moving parts allows the image to be acquired very rapidly.***
  - FD-OCT can capture 2000 pixels simultaneously, while TD-OCT captures one pixel at a time.
  - Because TD-OCT systems depend on the mechanical movement of a reference mirror to measure the reflectivity of the tissues, the speed of these systems is limited by the mechanical cycle time of the reference mirror driver.
  - Currently, the fastest commercial TD-OCT system is the Visante anterior segment OCT (Carl Zeiss Meditec, Inc., Dublin, CA), which acquires 2000 A-scans per second.
  - In contrast, FD-OCT uses a stationary reference mirror, which poses no mechanical limitations. The **RTVue** (Optovue, Inc., Fremont, CA) is an FD-OCT system that can be used for either retinal or anterior segment imaging (when used with a corneal adaptor module, or CAM). Its spectrometer is fitted with a high-speed line camera that captures 26 000 A-scans per second.

ASOCT

- non-contact, cross sectional, three dimensional, high resolution imaging technology that uses low coherence inferometry to achieve a high axial resolution images (tomography) of internal structures in biological tissues
- superluminescent diode with a wavelength of 1310 nm
- OCT at 1300 nm wavelength of light is better suited for the anterior segment imaging as
    - The amount of **scattering in tissue is lower** at this wavelength, enabling better penetration through the ocular structures.
    - This wavelength is **strongly absorbed by water in ocular media** with a resultant of only 10% of light incident on cornea reaching the retina. Thus improved retinal protection facilitates use of high power illumination.
    - The high speed imaging **eliminates motion artifacts**, reduces examination time and allows for rapid survey of relatively large areas.
- The Visante OCT is slower however its longer wavelength (1310 nm, compared with the 830-nm RTVue) has better penetration through the sclera and iris, the longer wavelength has reduced scattering in opaque tissues such as the limbus, sclera, and iris. Its 16-mm scan width and almost 6-mm scan depth in tissue is sufficient for AC biometry.
- two types of ASOCT are commercially available
    - Visante OCT (Carl Zeiss Meditec)
    - Slit Lamp OCT (Heidelberg Engineering GmbH
- **AS-OCT in Corneal Disorders**
    - Ectatic Disorders
    - Corneal Opacification
    - Keratoplasty assessment and planning
    - Microbial Keratitis
    - Evaluation of Lasik flap
    - Intracorneal ring segments
    - Corneal collagen crosslinking
    - Phakic intraocular lenses
    - ***Screening of Angle Closure Glaucoma***
    - ***Other Applications of AS-OCT in Glaucoma:*** iris syndrome, malignant glaucoma, and pupillary block glaucoma
    - ***Anterior chamber width and other biometric parameters***

  - *Application in Imaging Trabeculectomy Blebs*
  - *Assessment of tumors of iris and ciliary body*
  - *Others*
  -

UBM

- **Dr. Charles Pavlin & Prof. Stuart Foster** developed UBM at the **Princess Margaret Hospital at Toronto, Canada in 1989**. They developed three probes - 50,80 & 100 Mhz for clinical trials
- 80 & 100 MHz probes used to see the cornea and the anterior chamber as the depth of penetration is only 2 mm.
- 50MHz is an ideal compromise between depth and resolution to visualize the entire anterior segment.
- The first commercially available machine was developed by **Zeiss in1991**. It is now available with Paradigm USA. **Only 50 MHz probe available now**.
- *The anterior segment has a depth of **4-5 mm and** the structures are close to each other so we require a higher frequency probe*
- The resolution is **30-40 microns** (just as light microscope)
- Instrumentation: three main components
  1. **Transducer**: frequency of 50 MHz, open crystal and there is no membrane covering the crystal.
  2. **signal processing unit**:
  3. **Precise motion control device**:
- Indications for UBM
  - Glaucoma:
  - Uveitis:
  - Trauma:
  - Opaque media:
  - Tumor

  - Scleritis:
  - Strabismus: quantify resection recessions and to locate insertion of muscles
- Limitation: the depth is 4 mm.

ASOCT vs UBM

- Advantages of UBM:
  - Study of angle recess and beyond like the ciliary body and the supraciliary space and the suprachoroidal space can be done.
  - Tumors of the iris root, ciliary body with extension can be visualized well.
- Advantages of anterior segment OCT
  - **Corneal morphological** details seen in detail
  - Easy to learn with shorter learning curve
  - Quick **non-contact** procedure with greater patient comfort.
  - Anterior chamber cells and reactions seen well
  - Vector measurements possible
  - Serial analysis of disease possible with respect to progress due to ability of data storage.
- Disadvantage of UBM
  - Contact method that requires immersion technique causing patient discomfort and cooperation.
  - Takes a long time to carry out
  - Longer learning curve
  - Vector measurement absent, manual measurement needs to be done
  - Corneal and anterior chamber morphological not seen in detail.
- Disadvantage of anterior segment OCT

  - Iris root and beyond like the ciliary body, supraciliary space and suprachoroidal space not viewed with their details.
  - Lesions and tumors situated beyond the angle recess are not seen well.

ORA

- Reichert Ocular Response Analyzer
- biomechanical properties of the anterior segment, such as hydration, elasticity, hysteresis and rigidity, have substantial and widely variable influence on IOP measurement. However, assessing the biomechanical properties of corneal tissue in-vivo had previously not been possible. Because of this, practitioners and researchers have been confined to measuring purely geometrical aspects of the cornea, such as thickness and topography. So, achieving accurate estimates of intraocular pressure had been difficult. Newer modalities like the Ocular response analyzer developed by Reichert, Inc. have provided a break through in the study of corneal iomechanics.
- Corneal Biomechanics
  - Elastic materials are those for which strain (deformation) is directly proportional to stress (applied force), independent of the length of time or the rate at which the force is applied. Viscous materials are those for which the relationship between strain and stress depends on time or rate e.g. pushing a spoon into a jar of honey. The resistance to the applied force depends primarily on the speed at which the force is applied (greater speed = greater resistance). Structures that are said to be “visco-elastic” contain characteristics of both types of material. The response of such a system to an applied load depends upon the material properties, the magnitude of the force, and the rate at which the force is applied.
  - Human corneal tissue is a complex visco-elastic structure. **The Corneal hysteresis measurement is an indication of viscous damping in the cornea**. In other words, the ability of the tissue to absorb and dissipate energy.
- Principle
  - It utilizes a dynamic **bi-directional applanation** process to measure the biomechanical properties of the cornea and the Intraocular Pressure of the eye. The basic output of the measurement process is a Goldmann-correlated pressure measurement (IOPG), and a new measure of corneal tissue properties called Corneal Hysteresis (**CH**).

- The CH measurement also provides a basis for two additional new parameters: Corneal-Compensated Intraocular Pressure (**IOPCC**) and Corneal Resistance Factor (**CRF**).

- Operation
  - It utilizes a rapid air impulse to apply force to the cornea, and an advanced electro-optical system to monitor its deformation. Alignment to the patient's eye is fully automated. A precisely metered collimated-air-pulse causes the cornea to move inwards, past applanation, and into a slight concavity. Milliseconds after applanation, the air pump shuts off and the pressure declines in a smooth fashion. As the pressure decreases, the cornea begins to return to its normal configuration. In the process, it once again passes through an applanated state. The applanation detection system monitors the cornea throughout the entire process, and **two independent pressure values are derived from the inward and outward applanation events.**
  - One might expect these two pressure values to be the same. However, due to the dynamic nature of the air pulse, the viscous damping in the cornea causes delays in the inward and outward applanation events, resulting in two different pressure values. The **average of these two pressure** values provides a repeatable, Goldmann-correlated IOP value (IOPG). The difference between these two pressure values is **Corneal Hysteresis (CH).** The ability to measure this effect is the key to the understanding the biomechanical properties of the cornea and their influence on the IOP measurement process.

- CH-Corneal Hysteresis is a phenomenon that results from the dynamic nature of the air pulse and the viscous damping inherent in the cornea and has been shown to be significant and useful in its own right, but in addition, the dynamic bi-directional applanation process can be used to derive other valuable information; namely Corneal- Compensated IOP (IOPCC) and Corneal Resistance Factor (CRF). Both of these parameters are the result of largescale clinical data analysis and are derived from specific combinations of the inward and outward applanation values using proprietary algorithms.

- IOPcc is an Intraocular Pressure measurement that is less affected by corneal properties than other methods of tonometry, such as Goldmann (GAT). IOPcc has essentially zero correlation with CCT in normal eyes and stays relatively constant post-LASIK. CRF appears to be an indicator of the overall "resistance" (viscous and elastic resistance) of the cornea, and is significantly correlated with Central Corneal Thickness (CCT) and GAT, as one might expect, but not with IOPCC.

- Uses
  - Diagnosis and management of Glaucoma
  - Identifying and classifying corneal conditions
  - Evaluation and follow up of LASIK patients

  - Identification of corneal diseases such as keratoconus and Fuchs' Dystrophy, Glaucoma diagnosis and management, screening potential LASIK candidates, and accurate IOP measurement.

- Norma value of CH is 12.5 mmHg.

Pentacam

- It is Elevation Based Topographer.
- **Rotating Scheimpflug camera**
- 3D model of anterior eye segment from 25000 points
- ordinary camera: limited depth of focus because the picture plane, the objective plane and the film plane are parallel
- Scheimpflug camera: Higher depth of focus, sharp image but distorted. The picture plane, the objective plane and the film plane cut each other in one line or one point of intersection
- Corneal Surface can take 3 shapes:
  - spherical cornea: The curvature radii are equal at all points
  - aspheric oblate cornea: This shape is an ellipse which is rotationally symmetric around its minor axis
  - aspheric prolate cornea: This shape is an ellipse which is rotationally symmetric around its major axis
- Spherical cornea= multifocal lens
- Oblate cornea= multifocal lens
- Prolate cornea = monofocal lens
- Q value:

- By applying certain mathematical equations, eccentricity can be calculated and given a value from which Q-value can be derived.
- **Positive**: center of the cornea is flatter than the periphery, **oblate** cornea
- **Zero**: center equals the periphery, **sphere** cornea
- **Negative**: center is steeper than the periphery, **prolate** cornea
- Q-value is considered normal when it falls between 0 and -1 [-1,0].
-

- Measurement of asphericity: "a' is the center of curvature of the steepest point of the cornea, "b" is the center of curvature of the flattest point. "ab" represents eccentricity.
-

MAPS

CURVATURE MAPS

The Sagittal (Axial) Curvature Map

- The curvature power of the measured surface in point "a" is calculated using a tangent line in this point, the normal in this point intersects the reference axis at point b, ab is the radius (r) of point "a", finally the equation is applied to calculate the power (K) at point a.
- Normal cornea:
  - WTR: vertical symmetric bow tie
  - ATR: horizontal symmetric bow tie
  - Oblique: oblique bow tie
- enantiomorphism: each cornea is mirror image of each other

The Tangential (Local) Curvature Maps

- uses circles tangential to the examined corneal surface at the points to be measured
- highlight any irregularity in the cornea whatever small it is.

CLINICAL DIFFERENCES BETWEEN SAGITAL AND TANGENTIAL CURVATURE MAPS

- The **tangential map is more susceptible to local curvature changes**, because it depends on circles. Therefore, it is more capable of revealing corneal irregularity.

- Each point on the **tangential map is calculated independently**, i.e. there is no reference axis. Therefore, it is, to some extent, less affected by misalignment during taking captures.
- The tangential map is better for evaluating **corneal periphery**.
- Despite all these advantages of the tangential map, the **sagittal map is widely adopted**.
- Both maps are **affected by tear film disturbance** and use of contact lenses. Systems not using the Pladdo disk, like the Pentacam, are less affected by tear film disturbance and use of contact lenses.
- The tangential map is more **capable of locating the cone in KC**.

ELEVATION MAPS

- reference body
    - Best Fit Sphere (BFS)
    - Best Fit Toric Ellipsoid (BFTE)
    - enhanced spherical reference body: Michel Belin,
- values within the *central 4 mm circle* using the best fit sphere *float* reference body (BFS).
    - The elevation values on the front surface map should not exceed +12 μ.
    - The elevation values on the back surface map should not exceed +17 μ
    - The difference between the back and front surfaces (back-front) should not exceed +5 μ at the same point.
    - If there is any isolated island on either front or back surfaces, it would be suspected, even with values within the normal limits
- Float and No-Float Mode:
    - No-Float mode: reference body is adjusted in contact with the apex of the cornea
    - Float Mode: reference body is represented to be optimized with respect to the cornea

CORNEAL THICKNESS MAP

- main points: three
    1. thinnest location
    2. the corneal apex
    3. the pupil center
- gives idea about the shape of the cornea

- relation between the apex of the cornea and the center of the pupil
- relation between the apex of the cornea and the thinnest location
- There should be no more than 30 µ difference between the superior and inferior points in 5 mm circle
- **Corneal thickness and LASIK**
    - The first standard: The remaining thickness of stromal bed should not be less than 55 percent of the original corneal thickness at the thinnest location.
    - The second standard: The ablated amount should not exceed 18 to 20 percent of the original corneal thickness at the thinnest location.
-

REFRACTIVE POWER MAP

- permits an assessment of the optical performance of the cornea.
- calrulation of the refractive power using focal distances rather than curvature values

TRUE NET POWER MAP

- considers the true optical performance of the entire cornea

KERATOMETRIC POWER DEVIATION MAP

- calculated by excluding the effect of the anterior curvature power map from the true net power map, i.e. it represents the effect of the back surface of the cornea on the true net power map in every corneal point.

MAIN PAGE ANALYSIS

- The main page in Pentacam consists of figures on the left and four maps on the right
- four main refractive maps
    1. anterior sagittal curvature map
    2. anterior elevation maps
    3. posterior elevation maps
    4. thickness map
- Quality specification (QS)→ should be 'okay'

- Abbreviations
  - K1: Curvature power of the flat meridian of the cornea measured within the central 3 mm drcle and expressed in diopters.
  - K2: Curvature power of the steep meridian of the cornea measured within the central3 mm circle and expressed in diopters.
  - Km: Mean curvature power of the cornea within the central3 mm expressed in diopters.
  - Rh: Horizontal curvature radius of the central3 mm expressed in millimeters.
  - Rv: Vertical curvature radius of the central3 mm expressed in millimeters.
  - Rm: Mean curvature radius of the central3 mm radius expressed in mm.
  - Qs: Quality specification. It specifies the quality of the topographic capture and should be displayed "OK." Otherwise, there is some missed information which was virtually produced (extrapolated) by the computer and the capture should preferably be repeated.
  - Q-val: Value of Q within the central 6 mm as shown between two brackets. Any other central circle can be chosen through the program settings.
  - Astig: Amount of corneal astigmatism on the front cornea surface, i.e. the amount of differentiation between the two curvature radii (K2 - K1) within the central3 mm.
  - Axis: The axis of corneal astigmatism within the central3 mm.
  - Rmin: Minimum radius of curvature expressed in millimeters. It is shown as a symbol as shown in Figure 8.4. It is not necessarily central. The importance of the Rmin will be discussed as in the next paragraph.
  - Rper: Radius of corneal curvature in the peripheral 9 mm of the cornea expressed in millimeters

- K-readings:
  - **The flat K law**: in Myopia 1 D flattens LK by 0.75 D, so after ablation it should not be , 34D as then cornea becomes OBLATE and more positive spherical aberration results
  - **The steep K law**: In Hyperopia 1D steepens K by 1.2 D, should not end up >48D
- Corneal astigmatism
- Topometric map = Q-value: This value describes the slope of the cornea
  - in the four sectors of the cornea within circles centered on the apex of the cornea with 6, 7, 8, and 9 mm diameters
  - normal value is < -0.5 (as an absolute value).
  -

- Thinnest location
- Pupil center location

Special Cases

Keratoconus

Topographical DD

- Use of contact lenses, most often with the RGP lenses
- Post-corneal surgery
- Scars
- Peripheral ulcerative diseases
- Salzmann's nodular degeneration
- Tear film disturbance.

- **criteria for abnormalities**
  - **INFERIOR-SUPERIOR RABINOVICH LAW:** cornea is normally slightly steeper inferiorly than it is superiorly. It is abnormal when the difference is> +2 D.
  - **ROWSEY'S RULE OF 2s**
    - K-max steeper than 45 by >2 D (> 47D)
    - K-max in one eye steeper than the fellow eye by >2 D
    - I-S ratio (Rabinovich law) >2 D.
  - **SRAX law**: It stands for Skewed Steepest Radial Axis Index. It is an index of the angulation between the two lobes of the bowtie. SRAX > 22° is a risk factor.
  - Peripheral thickness (at 5 mm central circle) is more than the central thickness by >20 percent

- The **three criteria of progression** during a period of less than one year are:

  1. Increase in K-max >= 1D
  2. Increase in topographical astigmatism: >= 1 D
  3. Decrease in corneal thickness at the thinnest location >= 30 microns.

- Forme Fruste Keratoconus: positive identification of a subclinical form of KC

Keratoconus Indices

1. Thickness Location Diagram
2. Thickness Location Percentage Diagram
3. Table: describes changes in corneal thickness on the concentric rings as absolute values or as progression index.
4. progression index: index of thickness/ location relationship
   a. normal <= 1.1
5. Indices of Corneal Irregularity: 8 indices
6. KC staging: according to amsler's classification

Keratoectasia

Corneal ectasia after laser in situ keratomileusis (LASIK) or photo refractive keratectomy (PRK) is characterized by:

1. A progressive keratometric steepening
2. With or without central and paracentral corneal thinning
3. With or without increasing myopia
4. With or without increasing astigmatism

5. Topographic evidence of asymmetric inferior corneal steepening on the anterior sagittal curvature map.

- first reports in 1998
- after LASIK ranges from 0.04 to 0.6 percent
- Risk Factors:
  - KC and PMD, FFKC, low residual stromal bed (RSB) thickness, young age, low preoperative corneal thickness, and high myopia
  -
- **Randleman's Five factor Ectasia Risk Score**
  - topographical pattern
  - proposed residual stromal bed (RSB)
  - patient's age
  - preoperative corneal thickness (CT) in the thinnest location.
  - Degree of myopia

Hot-Spot Syndrome

- an area of relatively high refractive power on the anterior sagittal curvature map
- Etiology
  - KC and keratoectasia
  - Keratoglobus
  - PMD and PLK
  - Pre-stage KC or FFKC
  - Misalignment as an artifact
  - Tear film disturbance: It will be discussed in the next paragraph
  - Use of contact lenses: Contact lens use should be stopped for at least two weeks (for soft contact lenses) and 1 month (for RGP contact lenses) before examination and doing topography.
  - Salzmann's nodular degeneration

Displaced Apex Syndrome

- errors due to the difference between the curvature map's reference axis, the visual axis and the corneal apex
- so-called KC patients have what is now recognized as a displaced corneal apex
- abnormal I-S ratio
- one of the cause of hotspot
    - Patient's Error Misalignment
    - Examiner's Error Misalignment
- Misinterpretation
    - False negative
    - False positive
-

Disparity between Topographical and Clinical Astigmatism

1. Misalignment
2. Corneal irregularity: It is more obvious on the tangential curvature map
3. Hotspot
4. Tear film disturbance
5. Corneal opacities, particularly central
6. Lenticular astigmatism

Artifacts

a. Shadows on the cornea from large eye-lashes or trichiasis

b. Ptosis or non-suffident eye opening

c. Irregularities of tear film layer (dry eye, mud no us film, greasy film)

d. Incomplete or distorted image (corneal pathology)

e. Misalignment.

PMD

- The **"kissing birds" sign** on the anterior elevation map (arrowheads). This sign exists when the cone is peripheral.
- **the bell sign**: This sign is due to inferior corneal thinning encountered in this disease.
- **The CRAB CLAW sign**

Fugo Blade

- Dr. Richard Fugo, who developed the Fugo blade (also Dr Daljit Singh)
- The U.S. Food and Drug Administration has cleared the device for use in capsulotomy, a novel form of glaucoma surgery called "transciliary filtration" or "Singh filtration," iridotomy, and dental surgery.
- Types of Matter
    - The universe is composed of four states of matter: solids, liquids, gases, and plasmas. Although 99% of the universe is composed of plasma, it is the least understood state of matter simply because the other three states are those predominantly found on Earth.
    - Solids, liquids, and gases (also called "SLG matter") contain atomic structures—electrons, protons, and neutrons.
    - Plasma is the state of matter that generally possesses the highest level of energy. Also, more forms of plasma exist than all of the other types of matter combined.
- The Fugo blade is a solid-state electronic system that produces efficient plasma surgery with primary plasma.
- The instrument consists of a console, a handpiece with a disposable tip. Three rechargeable battery cells provide the energy. The power generated is **about 1 W**, and little energy is needed to energize the cutting tip

- It is visible under high magnification, looking like bees on a honeycomb. This plasma ablates in such a fashion that it creates a smooth wall along the ablation/incision path.
- The plasma energy at the tip is at a very high temperature. However, the heated field does not extend beyond **25 μm of the plasma**, thus meaning that little or no heat is generated. Therefore, it does not burn or cauterize.
- Uses
  - Anterior Capsulotomy
  - Large Capsulotomy
  - Managing Posterior Capsule Problems
  - Posterior Capsular Plaque
  - Cutting Fibrovascular Membranes
  - Iridotomy
  - Pupilloplasty
  - Capsulotomy in a Subluxated Lens
  - Anterior Vitrectomy
  - Making a Filtration Track
-

ULTRASOUND

History

- 1880: the **Curie** brothers → **piezoelectric effect**: difference in electric potential could be created by mechanically pressing opposing surfaces of a tourmaline crystal.
- first applied in underwater sonar systems during World War II

- 1949, Ludwig used ultrasound to detect gallstones in patients.
- The first use of ultrasound for ophthalmic diagnosis was reported in 1956 by **Mundt and Hughes**
- The first clinical use of **A**-scan in ocular diagnostic problems was described in 1957 by **Oksala**
- **B**-scan diagnosis was first developed by **Baum and Greenwood** in 1958.
- **Janssen** & associates-1960-Biometry
- 1970-First commercial B-scan (immersion)
- 1975-First contact B-scan
- **M**-scan diagnosis, first described by **Coleman and Weininger**
- **Silverman, Kruse, and Coleman** pioneered the use of **swept-scan** analysis
- Color-flow Doppler (**CFD**) imaging of the orbital vessels was first described by **Erickson** et al in 1989.
- **3-D** imaging of the eye was first described by **Coleman** et al. in 1987

Physics of Ultrasound

- 1 MHz: 50 million cycles per second
- Ultrasound is an ***acoustic wave comprising compressions and rarefactions*** that propagate within fluid and solid substances
- They exhibit **frequencies above 20 kHz**, and they differ from sound waves because these high frequencies render them inaudible.
- **reflective ("pulse-echo") systems** analogous to those used in radar and sonar. This approach allows examination within a thin "slice" through tissue structures.
- A **piezoelectric transducer** serves as the ultrasonic transmitter and receiver.
- A-mode, or A-scan, systems graphically display these echoes as a function of time on a video monitor. B-mode systems generate cross-sectional gray-scale images (the gray scale corresponds to the **A-scan amplitude**) by scanning the transducer to address a series of lines through the eye; the amplitudes of received echoes control the **brightness** (or gray scale) along corresponding lines of a video image (B-scan). The terms A-scan and B-scan as well as C-scan and M-scan derive **from early radar terms**, using pulse position indicator **(PPI) display**.

- **AXIAL RESOLUTION:** The smallest tissue thickness that can be resolved by an ultrasonic system is termed its axial resolution and is determined by the time duration of the ultrasonic pulse.
- **LATERAL RESOLUTION**: Lateral resolution is defined by the width of the ultrasonic beam generated by the transducer.
- **Acoustic interface**: difference in reflectivity from different parts (due to Difference in sound velocity of the media; Lens 1641 m/s; aqueous 1532 m/s; 1550 m/s)
- **Gain**: The reflected wave show different reflectivties due to factors mentioned above. To visualize waves of very low reflecivity they have to be magnified. This is accomplished by adjusting gain.
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Ultrasonic Systems

- ***The ultrasound system consists of the following components:***
  - Transducer/probe
  - Servo (for B-mode systems)
  - Pulser
  - Receiver
  - Scan converter and display
- **The frequency of the ultrasound cannot pass through air; therefore, a coupling medium is needed.**
- The sclera is the most strongly reflecting structure on ocular ultrasonography.

- ***A-MODE SYSTEMS***
  - The A-mode format consists of a **plot of signal amplitude versus range in a single line** of sight.
  - A-mode systems exist in ophthalmology because of their special role in determining biometric properties of the eye, such as axial length, which play a crucial role in surgical planning. The most common use of A-scan is for **axial length** measurement. These units generally operate at a **10-MHz** center frequency with weakly focused transducers: a 5-mm aperture and 20-mm focal length are typical.

- Corneal pachymetry (derived from the Greek pachy, meaning "thick," and metron, meaning "measure") is a form of A-scan, whose aim is to measure corneal thickness, which is, in principle, no different from axial length measurement. In the case of corneal pachymeters, a transducer frequency of 20 MHz and aperture less than 2 mm are typical.
- A special purpose A-scan probe is used in an ophthalmic ultrasound technique called standardized echography.
- Normal peaks in A-scan
    - Tall echo from cornea – one in contact scan & double peaked in immersion technique
    - Tall echoes from ant. & post. Lens surface
    - Tall, sharply rising echo from retina
    - Medium-tall to tall echo from sclera
    - Med . To low echoes from orbital fat
    - A-scan axial length measurement (biometry):distance between initial peak and retina

- ***B-MODE SYSTEMS***
    - B-mode systems combine transducer scanning and signal processing to produce *cross-sectional images of the eye and orbit.*
    - Axial Scan: placing the probe in the center of the cornea with the transducer tip oriented toward 12 o'clock in order to image the **posterior pole and optic nerve**. Next, the transducer can be turned temporally 90° to obtain images through the **macula**.
    - Radial scans are acquired when the probe is placed perpendicular to the limbus and the transducer tip is oriented toward the cornea
    - Transverse scans are obtained by turning the probe 90°, orienting the transducer tip parallel to the limbus. The images obtained are the acoustic reflections from the opposing inner surface of the globe.
    - The sector scan is most popular in that it is compact, most amenable to high scan rates, and provides approximate normality to the posterior retinal surface. The linear scan is the most simple conceptually and has the advantage that vectors do not diverge with range. The arc scan is complex in implementation but offers near normality to both the anterior and posterior surfaces of the eye.
    -
- ***M-MODE***

- a cross between A- and B-modes. As in A-mode, the transducer interrogates a single line of sight, but as in B-mode, a two-dimensional image is formed. In M-mode, however, the ***vertical axis represents time rather than lateral position***
- useful for ***demonstration of tissue motion***.

- **SWEPT-MODE**
  - combines M-mode and B-mode
  - In conventional B-mode imaging, vectors are usually placed a beam width apart or less. In swept-mode, vectors are placed much less than a beam width apart.
  - swept-mode image is equivalent to a B-mode image composed of overlapping M-scans. Swept-mode is thus capable of showing tissue motions, including blood flow, in the context of a B-mode image.

- **DOPPLER MODES**
  - detection of frequency shifts associated with tissue motion

- **TISSUE HARMONIC IMAGING**
  - It was discovered serendipitously late 1990, as a consequence of attempts to develop a means for improved detection of flow, using ultrasound contrast agents. Such agents consist of microbubbles, lipid shells filled with air, or other substances with a high acoustic impedance inhomogeneity compared to blood.

- VERY HIGH FREQUENCY ULTRASOUND/**ULTRASOUND BIOMICROSCOPY** (**VHFU/UBM**)
  - frequencies of **25 MHz or higher**
  - **Pavlin and Foster** described clinical findings with a 50-MHz ultrasound biomicroscope that was later developed into a commercial instrument, the ultrasound biomicroscope, or UBM
- **Standardized echography** combines A and B scan.

Ultrasound in intraocular pathology

- **OCULAR DIAGNOSTIC TECHNIQUES**
  - 1. B-scan with A-scan ultrasonography

    2. Standardized echography
  -

- **INDICATIONS FOR DIAGNOSTIC ULTRASOUND**

  Evaluation in Opaque Media
  - Corneal Opacity
  - Hyphaema
  - Cataract
  - Pupillary / Retrolental MEMB.
  - VIT.H'GE / Endophthalmitis

  Evaluation in clear ocular media
  - Iris & Ciliary Body Lesions
  - CD
  - RD
  - Tumors
  - Optic Disc Abnormalities
  - IOFB Detection & Localization

- **ARTIFACTS ENCOUNTERED IN OCULAR ULTRASONOGRAPHY**
  - electronic artifacts
  - reduplication echoes
  - refraction artifacts
  - absorption effects.

- Staphyloma: ectasia typically has a smaller radius of curvature then the normal sclera, axial cross-sectional scans
- *Scleral buckle:* looks similar to a staphyloma, encircling band around the anterior sclera
- Microphthalmos: abnormalities in the vitreous and posterior segment can be there, coloboma of the retina or optic nerve head, orbital cysts or PHPV
- Phthisis: thickened outer scleral wall, calcification or ossification (due to degenerative processes and from metaplasia RPE
- Vitreous degeneration: Vitreous syneresis
- Asteroid hyalosis: calcium-containing lipids **suspended** in vitreous, distinctive sound reflectors

- *Synchysis scintillans:* cholesterol crystals, **freely float** in vitreous, will sink toward the bottom of the cavity.
- PHPV-PFV: microphthalmos and cataract, two distinct features: The first is a ***strand of membrane*** that extends between the posterior surface of the lens and the area of the optic nerve head. The second is the ***reduced axial length*** of the globe from microphthalmos on ultrasound biometry
- Vitreous hemorrhages
    - *Neovascularization:* The normal **aftermovements** that should occur in the vitreous after eye movements are **extinguished** in the presence of peripheral neovascular tufts. The vitreous tufts create adhesions that encircle the posterior pole. This is an ominous sign, which is indicative of early retinal tractional detachment from these circular adhesions
    - Terson syndrome: **Terson's sign** is a multilayered, intraocular hemorrhage at the posterior pole that typically occurs after blunt trauma to the head
- Intraocular infections:
- Vitreous inflammation: Inflammatory and hemorrhagic vitreous changes cannot be differentiated on the basis of ultrasonographic findings alone
- Intraocular foreign bodies: signal artifact, acoustic shadow
- Acute retinal detachment: appears as a membrane in the vitreous space
    - RD or Vitreous Membrane

1. **spatial extent:** detached retina connects to the nerve head while the membrane passes over the optic nerve head
2. **shape of a cross-section of the membrane:** in a sagittal section, a total detachment looks like an isosceles triangle which is open toward the anterior segment. In frontal planes, conical shape of the detachment will appear oval to nearly circular in the various sections.
3. **aftermovements:** quality of tissue movement at the end of the ocular saccade. An acute **rhegmatogenous retinal detachment** shows aftermovements of short duration that extend with a ***whiplash effect*** from the area where the retina is still attached, which is usually the optic nerve head. The amplitudes of these aftermovements are smaller and less extensive than those seen in the ***sinusoidal movements*** of a **vitreous hemorrhage** or in asteroid hyalosis.
4. **difference of the spike:** difference in the echo of the retina compared to that of the sclera, extending from 8 to 15 db.

- Chronic retinal detachment: decrease in the aftermovement amplitude of the retina, cyst-like cavities
- *Retinoschisis:* aftermovements in retinoschisis are less conspicuous than in a retinal detachment.
- *Coats disease:* Retinoblastoma typically shows calcifications with high reflectivity. The exudative detachment that is seen in Coats disease has different echo quality due to the subretinal cholesterol deposits

- Retinoblastoma: The presence of calcium deposits in retinoblastoma lesions produces a high sound reflection that creates an acoustic shadow on more distant structures such as the sclera.
- Retinopathy of prematurity
- Coloboma of the ocular fundus
- optic nerve cupping
- Changes in the ocular layers due to hypotony: choroidal detachment. In contrast to a retinal detachment, the choroidal detachment extends beyond the ora serrata; the detachment extends from the iris diaphragm to the posterior pole without reaching the optic nerve head. apices of the choroidal detachment touch each other in the vitreous and are seen on the echogram. This finding is commonly termed "kissing choroidals." Strand-like structures (possibly taut vortex veins) course through the intrachoroidal space.
- Choroidal neovascularization: *Peripheral choroidal neovascularization membranes can appear similar to choroidal melanomas.*
- Choroidal melanoma:

  B-mode:

  biconvex lesion, highly vascularized choroidal tumors

  internal structure is relatively homogeneous

  If the tumor has broken through Bruch's membrane, then a **mushroom-shaped lesion**, or a collar button, can be demonstrated in cross-section and serves as a pathognomonic sign.

  In some sections, the **collar button** of a tumor may even simulate a tumor mass lying free in the vitreous.

  In the area of the tumor base, a "**choroidal excavation**" can be seen

  A-mode:

  spikes of relatively uniform amplitudes within the large biconvex tumor

- Metastatic choroidal tumors: breast (40%) and lungs (29%).
- Choroidal hemangioma: Isolated circumscribed choroidal hemangiomas: posterior pole, diffuse, slightly elevated, and may have indistinct margins. strongly reflecting, nearly concentric widening of the outer layers of the eye. ***In spite of the abundant vascularization, ultrasound images of choroidal hemangiomas do not show the circulating blood as in choroidal melanomas***. Instead it is similar to that of metastatic adenocarcinoma or disciform macular degeneration, which may be indicative of a slower circulation.
- Choroidal osteoma (metastatic calcifications): localized area of high reflectivity at the outer wall.
- Choroidal tuberculoma: can also appear similar to choroid melanoma

- uveal effusion syndrome:
- Posterior scleritis: The normal high reflectivity of the sclera will be decreased by changes in the tissue from inflammatory swelling. The result is a low reflective signal from a thickened choroid, which is suggestive of posterior scleritis. slight exudation into the subretinal space with accompanying disc edema. In 50% of the patients, fluid accumulates in the Tenon's space. **T sign**
-

DD

Choroidal folds

- Myositis Graves orbitopathy: Thickened extraocular muscles
- Periorbital space-occupying lesion: Change in the relief of the orbital wall, sound propagation into perinasal sinuses
- Orbital neoplasm: Directly evident (it may be difficult to demonstrate a small cavernous hemangioma because of its high acoustic reflectivity)
- Inflammatory orbital pseudotumor: Widening of normal orbital structures, low acoustic reflectivity, Tenon's space may be demonstrated
- Disc edema: Widened dural diameter of the optic nerve
- Axial hyperopia: Axial length below 22 mm, ocular walls concentrically thickened
- Ocular hypotony: Ocular walls concentrically thickened
- Macular degeneration: Thickening of the ocular walls in the area of the macula, high acoustic reflectivity
- Scleritis: Circumscribed widening of the ocular walls, Tenon's space apparent

Leukocoria

Normal axial length for the patient's age

- Retinoblastoma: Widening of the ocular walls, extremely high acoustic reflectivity, shadowing effect, atypical findings possible

- Congenital cataract: Increased reflectivity from the posterior lens surface, vitreous space empty, ocular walls normal

Shortened axial length

- Retinopathy of prematurity: In stages IV and V, beginning or complete traction detachment (normal findings in stages I–III)
- Persistent hyperplastic primary vitreous (PHPV): Dense strand of tissue between optic nerve head and posterior lens pole; formes frustes may occur (posterior or anterior PHPV)
- Retinal anomalies: Membranes in the vitreous, atypical detachment, which in part appears solid (no typical echogram)
- Fundus coloboma: Directly demonstrable protrusion of ocular wall, sometimes with orbital cyst (microphthalmos with cyst)
- Coats disease: Floating crystals in the vitreous and subretinal space (fast-flickering spikes on A-mode)

Vitreous hemorrhage

- Symptomatic posterior vitreous detachment: Thickened detached posterior hyaloid membrane, occasionally early retinal detachment
- Recently formed retinal break with torn vessel: Blood-covered vitreous strands converge toward the retinal break; occasionally a high-floating operculum may be detected
- Proliferative retinopathy: Strands or membranes extending from the optic nerve head or the posterior pole, high acoustic reflectivity
- Terson syndrome (vitreous hemorrhage after subchoroidal bleeding): Vitreous opacities in front of the optic nerve head or behind the detached vitreous
- Disciform macular degeneration: Widening of the ocular walls in the macular area, high acoustic reflectivity, vitreous strands extending from the macula
- Choroidal melanoma: Biconvex thickening of the ocular wall, low acoustic reflectivity, sometimes mushroom-shaped; accompanying retinal detachment distant from the tumor

Wavefront Analysis

- **Definition**: ***In considering a field of electromagnetic energy emanating from a source, the wavefront is a surface connecting all field points that are equidistant from the source.***
- Refractive error
    - 90% Sphere/Cylinder
    - 10% Other Aberrations: spherical aberrations, coma, trefoil, others
- Irregular Astigmatism -generic term for higher order aberrations with more than one axis. Wavefront assesses ocular aberrations.
- Examples of different wavefronts
    - **a) Spherical wave**: The wave starts from the geometrical center and the wavefronts of constant phases are spheres. The propagation speed of the wave is equal in all directions that are given by the normal of the wavefronts (dotted arrows).
    - **b) Plane wave:** The oscillators with the same phase are all arranged in planes. The propagation is perpendicular to these planes at each point of the plane. The wave keeps its plane-like shape during further propagation.
    - **c) Arbitrary wave:** the surfaces of oscillators that have the same defined oscillation state or relative phase are neither planar nor spherical. As a result the different parts of the wavefront propagate into different directions that are given by the normal at the respective point under observation
- Methods to Measure a Wavefront
    - **Tscherning Aberrometer:**
        - projects a grid onto the retina
        - Camera views distortion of image in retinal surface
    - **Dynamic Skiascopy**
        - Projects a moving slit into the eye

        - Relative motion of the slits image used to calculate refractive error along each segment
    - **Ray Tracing**
        - Projects numerous single rays of light onto the retina through various points of the pupil
        - Measured location of each ray as it exits is calculated against the known position as it entered the eye
    - **Hartman - Shack aberrometer:**
        - laser light is projected on to the retina. Exiting light is imaged onto an array of small lenslets that focus the passing light onto a camera. Deviations from expected vs. actual spot array calculate aberrations.
        - Shapes extracted from centroid information are mathematically reconstructed to determine the wavefront shape. (240 spots - lens lets 0.4mm)
- **Fritz Zernike**: Dutch Physicist, 1953 Nobel Laureate in Physics
    - Developed mathematical model of optical aberrations.
    - Zernike polynomials simply describe a "best fit' shape.
    - Actual deviations are measured and Polynomials create a 3-D model of the errors.
    - It is essentially - Complex mathematics that split the visual system into individual terms.
    - Limitations:
        - Mathematically complex (unstable at 191h order)
        - Pupil dependent
        - information can only be derived in a circular pattern
- **Fourier Analysis**
    - **Jean Baptiste Joseph Fourier**
    - Better method of describing wavefront than Zernike
    - Repetitive waveform could be broken down into a series of sine waves
    - Uses sine waves to build the wavefront
    - All data points weigh same Works well for noncircular pupils-Independent of pupil size
    - Upto 64 fourier waves

- **Current Method: (2006)**
    - Fourier analysis to calculate wavefront
    - Zernicke polynomials to create quantifiable descriptors of wave shape

- **Principle of Wavefront Analysis (Hartmann Shack System)**
    - The displacement of the single spots which is displayed by the lens array is proportional to the aberrations of the actual wavefront
    - Mathematical description of the aberrations with "Zernicke polynomials"
    - 1^{st} order: tilt (prism)
    - 2^{nd} order: Sphere and Cylinder
    - 3^{rd} order: coma, trefoil
    - 4^{th} order: spherical
    - 5^{th} order: pentafoil
    - 6^{th} order: hexafoil
- ***RMS value***: A criteria of how "strong" aberrations are can be given by the so-called RMS (root mean square) value. It allows for a quantification and, hence, comparison of aberrations from different measurements, patients and amongst each another.
- The cornea has a positive spherical aberration that changes only moderately during life
- The crystalline lens changes from negative to positive spherical aberration
- Therefore, with age, the positive aberration of the cornea can no longer be corrected by the lens
- The design of conventional IOL correlates with the optical properties of a mature crystalline lens
- In 90% of cases, Tecnics should result in increased visus quality compared to conventional IOLs, because 90% of cataract patients have a positive aberration of the eye, which will be corrected by the negative aberration of Tecnis.
- Improvement of visual faculty is due to better image projection on to the retina (sharper image on the retina), particularly at dusk or in darkness.
- wavefront guided:
    - advantages

    - Refraction measurements (sphere, cylinder and axis) are possible and very precise. Especially cylinder and axis has put out to be very precise.
    - The influence of higher order aberrations to the sphere and the cylinder can be brought into conjunction. This is the determination of the sphere and cylinder according to the "Seidel" calculation
    - Measurements of the refraction at patients with irregular eyes (e.g. re-treatments)are mostly possible and more accurate than other objective methods.
    - The complete optical system is measured - all refractive errors are therefore computer , not only the cornea.
- Disadvantages
    - Although the aberrometer fogs the target by +1.5 diopter; with the intention to guide the patient to a far view; the measurement depends on accommodation.
    - Restricted pupil size leads to a restricted application of a working zone.
    - In dark pupils extreme caution to extrapolate dilated data to application.
    - The measured cylinder only represents the corneal component. This does not necessarily mean the patient adapts to this cylinder because other optical measurements are not taken

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iTRACE

Read presentation form tracey website.

Femtosecond Laser

- ruby laser → T. H. Maiman
- normally, optically transparent refractive layers of the eye, such as the cornea and lens, do not absorb electromagnetic radiation in the visible or near-infrared spectrum at low power densities, allowing light to pass through without alteration of these tissues. At **higher power densities**, however, these structures **do absorb the light energy**, leading to plasma generation and tissue disruption.
- first practical use of near-infrared lasers in clinical ophthalmology was the focused Nd:YAG laser
- Nd:YAG laser
    - pulse duration in the nanosecond (10^{-9} second) range
    - photodisruption
    - expanding cloud of free electrons and ionized molecules ("plasma")
    - zone of collateral tissue damage with the nanosecond Nd:YAG laser may easily exceed 100 µm
- ***shortening the pulse duration***: from the nanosecond to the picosecond (10^{-12} second) domain and then to the femtosecond (10^{-15} second) domain, the zone of collateral tissue damage is progressively reduced.
- The femtosecond (FS) laser
    - similar to a Nd:YAG laser, but with an ultra-short pulse duration
    - smaller shock waves and cavitation bubbles that affect a tissue volume about 10^3 times less than picosecond-duration pulses
- prototype of the first ophthalmic surgical FS laser: **Dr Juhasz**
- **IntraLase** Corporation was founded in 1997
- near-infrared FS laser can be focused anywhere within or behind the cornea, unlike the unfocused, far-ultraviolet excimer laser, which is absorbed at the anterior surface
- first introduced as a 10-kHz laser in 2002, progressed to **30 KHz → 60 KHz → 150 KHz**
- an accuracy of approximately 1 µm and allowing contiguous placement of laser pulses in either raster (zigzag) or expanding (centrifugal) spiral patterns
- three newer U.S. FDA-approved FS laser systems have entered the American market:
    1. the **Femtec** (20/10 Perfect Vision, Heidelberg, Germany)
    2. the **Femto LDV** (previously Da Vinci, Ziemer Ophthalmic Systems, Port, Switzerland)

3. the **VisuMax** (Carl Zeiss Meditec AG, Jena, Germany).

FS LASIK Flaps

- major advantages
  - reduced incidence of flap complications, such as buttonholes, epithelial abrasions, short flaps, free caps, blade marks, and irregular cuts
  - greater surgeon choice of flap diameter and thickness, side cut angle, hinge position and length, spot size and separation, and firing patterns (**spiral vs raster**)
  - absence of moving parts
  - increased precision with improved flap safety and thickness predictability
  - capability of cutting thinner flaps (90 μm or even less) to accommodate thin corneas and/or high refractive errors
  - Greater accuracy of flap creation
  - Thin yet stable flaps
  - Fewer flap complications
  - Better centration
  - Stronger flap adherence
  - Less IOP rise during suction
  - Fewer high order aberrations
  - Less dry eyes
  - Less epithelial ingrowth
  - Better contrast sensitivity5
  - Reduced high order aberrations6
- Possible disadvantages
  - Suction breaks
  - Incomplete flaps
  - Transient light sensitivity
  - Persistent bubbles – stroma / anterior chamber
  - Harder to lift flaps
  - Granular bed

- *Comparison* **microkeratome** Vs **Intralase**

  Flaps Lenticular Planar
  Bed Truncated 360 degrees
  Side cut Beveled More vertical (can be customized to desired angle)
  Bed Wet Dry

Ocular Electrophysiology

VER

- Record of electric potential of the visual cortex in response to visual stimulation
- EEG record of the occipital lobe
- EEG is of 50 mv amplitude & occur continuously, whereas VER is about 5-10 mv and is time locked
- EEG has Response averaging whereas VER is always present.
- Primarily generated from central 5 degree of visual field
- Central 10 degree of visual field is represented by atleast 50 to 60% of posterior striate cortex and central 30 degree by 80% of posterior striate cortex
- Abnormality can result from lesions of retina,optic nerve,optic tract,optic radiations,visual cortex
- **Flash VER**
  - Cortically evoked response to a brief white flash light
  - M shaped wave – two positive and two negative waves
  - First positive wave occurs with a peak delay of 95 to 120 sec
  - High intersubject variability
  - However sensitive test of visual pathway function if one pathway is normal for comparison
- **Pattern VER**
  - VEP record to a patterned stimulus
    - Checkerboards
    - Gratings

- Stimuli presented in
  - Pattern reversal mode(black and white checks in checkerboard alternate)
  - Pattern appearance disappearance mode(less sensitive to confounding factors like poor fixation or ocular movements, so useful in cases of malingering and nystagmus)
- Can be recorded as
  - Transient pattern VER(slow reversal rate and single response complex)
  - Steady state pattern VER(rapid reversal rate and mutiple responses elicited)
- Simpler in waveform than flash VER and much less variable among individuals
- Two negative waves and one positive wave
- Checks which subtend 10 to 15 mins of arc elicit largest amplitude and shortest latency

- Recording:
  - Normal pupillary diameter(no miotics or mydriatics)
  - Optimal refraction
  - Monoocular stimulation (may not be practical in infants)
  - Placing the electrodes
    - Scalp electrodes placed relative to the bony landmarks in proportion to the size of the head
    - Active electrode over occipital cortex above the inion in the midline
    - Reference electrode placed at Fz
    - Ground electrode postions can be forehead,mastoid or earlobe
    - Electrodes are connected through a preamplifier to the averaging computer
  - **Stimulus**
  - ***Flash stimulus***
    - Flash should subtend visual angle of atleast 20 degree
    - 100 flashes of light in a dimly illuminated background
    - Strength of 1.5 – 3 cd sec per sq metre
    - Frequency <1.5 Hz
  - ***Pattern stimulus***

        - Black and white checkerboard
        - Uniform luminance of 80 cd per sq. metre
        - Visual angle of each check – 10 to 15 mins of arc
        - Pattern reversal – reversal frequency (0.5 to1.5 MHz)
        - Pattern appearance disappearance – 100 to 200 ms pattern presentation and 400ms background

- **Normal Record of VER**
    - Pattern VER: Amplitude > 7.5 uv, Latency < 110 msec
    - Flash VER: Amplitude > 5 uv, Latency < 100 msec
- Reduced amplitude is very non-specific, can be seen in
    - refractive errors
    - poor co-operation
    - optic nerve hypoplasia
    - Amblyopia
    - Purposeful defocussing
    - Optic nerve compression
    - AION
- Change in latency is a useful sign as it is less influenced by volition
- Uses:
    - Optic Nerve disease: afferent pathways e.g.
    - optic neuritis (increased latency)
    - compressive lesions(reduced amplitude)
    - during orbital / neurosurgery
    - Measurement of visual acuity in infants/mentally retarded / aphasic patients
    - Malingering and Hysterical blindness
    - To assess visual potential in opaque media
    - To detect cases of multiple sclerosis
    - Unexplained vision loss

  - Amblyopia:
  - Decrease in amplitude with relative sparing of latency
  - response to occlusion
  - Glaucoma : detecting central field defects

- **Multifocal VER**
- A method of objective perimetry
- A bipolar electrode, placed 2 cm above and 2 cm below the inion, allows the recording of a response of similar magnitude but opposite polarity from upper and lower visual hemifields.
- Stimulus is presented in the form of dartboards and kernels
- Comparable results to Humphrey Visual Field testing

- **Sweep VEP**
- Technique that allows VEP to be measured in a few seconds
- Useful is assessing the visual acuity in pre school children
- Reduction in the problems pertaining to the maintenance of attention and stable fixation, even in newborns
- Employs vertical stripes for testing and the feature size is simply the width of the stripe

Fluorescein Angiography

- Luminescence:
  - emission of light from any source other than high temperature.
  - shift from a shorter wavelength (higher energy) to a longer wavelength (lower energy).

- Fluorescence:
  - luminescence that is maintained only by continuous excitation
- Sodium fluorescein
  - Relatively inert organic plant resin, (carrot juice)
  - hydrocarbon that responds to light energy between 465 and 490 nm and fluoresces at a wavelength of 520–530 nm
  - Blue to green
  - 80% of the fluorescein becomes bound to protein and 20% remains free
  - **low molecular weight (376.27 Da)**
  - 500 mg fluorescein are available in vials of 10 mL of 5% fluorescein or 5 mL of 10% fluorescein.
  - eliminated by the liver and kidneys within 24 hours
  - side-effects and complications
    - Extravasation and local-tissue necrosis
    - Inadvertent arterial injection
    - Nausea: Restriction of food and water for 4 hours, Promethazine
    - Vomiting
    - Vasovagal reaction (circulatory shock, myocardial infarction)
    - Allergic reaction, anaphylaxis (hives and itching, respiratory problems, laryngeal edema, bronchospasm) → diphenhydramine hydrochloride (Benadryl)
    - Nerve palsy
    - Neurologic problems (tonic-clonic seizures)
    - Thrombophlebitis
    - Pyrexia
    - Death
- Pseudofluorescence
  - when nonfluorescent light passes through the entire filter system
  - If green-yellow light penetrates the original blue filter, it will pass through the entire system.

  - If blue light reflected from nonfluorescent fundus structures penetrates the green-yellow filter, pseudofluorescence occurs
  - Therefore the excitation (blue) and barrier (green-yellow) filters should be carefully matched so that the **overlap of light between them is minimal**

- **Principle:** blue filter has been placed in front of the flash → blue light goes into patient's eye → blue reflected light and the green-yellow fluorescent light are directed back toward the film of the fundus camera → filter is placed that allows the green-yellow fluorescent
- ***Camera:***
  - 35° to 200° (OPTOS wide field camera)
  - 35° to 50° are routinely
- fluorescein filters: the transmission curves of the filter combination to be sure that no significant overlap exists; pseudofluorescence results when there is overlap
- Focusing:
  - perfect focus is a major factor
  - first turns the eyepiece counterclockwise (toward the plus) to relax his or her own accommodation → then slowly clockwise to bring the crosshairs into sharp focus.
- Film based vs Digital Imaging
- **Interpretation**
  - sensory retina into two layers
    - inner vascular half: from ILM to INL → the ***larger*** retinal arteries and veins are located in the **nerve fiber layer**; the retinal ***capillaries*** are located in the **inner nuclear layer.**
    - outer avascular half: OPL, ONL and Photoreceptor layer → ***OPL*** is primary interstitial space in the retina. Edema and cystoid spaces, deep retinal hemorrhages and exudates (lipid deposits)
  - macula:
    - fovea is the center of the macula and contains only four layers of the retina: (1) the internal limiting membrane; (2) the outer plexiform layer; (3) the outer nuclear layer; and (4) the rods and cones.
    - outer plexiform layer in the fovea, which in the macula is oblique.
    - stellate appearance of cystoid edema in the macula
    - FAZ: 400-500 microns
- ***Hypofluorescence***
  - reduction or absence of normal fluorescence

- **Blocked fluorescence:**
- Fluorescein is present but cannot be seen in blocked fluorescence
- key to differentiatidon: the hypofluorescence on the angiogram with the ophthalmoscopic view.
- Blocked retinal fluorescence: anything that reduces media clarity
- Blocked choroidal fluorescence: accumulation in front of the choroidal vasculature and deep to the retinal vasculature

4. **vascular filling defect:**

- vascular obstruction, atrophy, or absence
- total or partial
- *Retinal vascular filling defect:* BRVO, CRVO
- *Vascular filling defects of the disc:* coloboma, optic atrophy, vascular occlusion
- *Choroidal vascular filling defect:* choroideremia, choroidal atrophy

- ***Hyperfluorescence***

1. **Preinjection fluorescence:**

- Autofluorescence: emission of fluorescent light from ocular structures in the absence of sodium fluorescein →optic nerve head **drusen** and **astrocytic hamartoma**
- Pseudofluorescence:

2. **Transmitted fluorescence**

- pigment epithelial window defect: atrophy of the pigment epithelium
- four basic characteristics
    1. It appears early in angiography, coincidental with choroidal filling.
    2. It increases in intensity as dye concentration increases in the choroid.
    3. It does not increase in size or shape during the later phases of angiography.
    4. It tends to fade and sometimes disappear as the choroid empties of dye at the end of angiography.

3. **Abnormal vessels**

- changes in the retinal vasculature:
  1. tortuosity and dilation
  2. telangiectasis
  3. neovascularization
  4. anastomosis
  5. aneurysms
  6. tumor vessels
- *Abnormal choroidal vessels*: neovascularization and vessels within a tumor.

4. **Leakage**

- after the retinal and choroidal vessels have emptied→ extravascular fluorescence and represents leakage
- Four types of late extravascular hyperfluorescent leakage in NORMAL EYE
  1. fluorescence of the disc margins from the surrounding choriocapillaris
  2. fluorescence of the lamina cribrosa
  3. fluorescence of the sclera at the disc margin if the retinal pigment epithelium terminates away from the disc, as in an optic crescent
  4. fluorescence of the sclera when the pigment epithelium is lightly pigmented.
- late extravascular hyperfluorescent leakage in ABNORMAL EYE
  1. *Vitreous leak:* NVD/NVE, inflammation; and intraocular tumors
  2. *Disc leak:* Papilledema
  3. *Retinal leak:* CME
  4. *Choroidal leak:* Pooling is defined as leakage of fluorescein into a distinct anatomic space; staining is leakage of fluorescein diffused into tissue
-

ICGA

- 1970 **Kogure**: intra-arterial choroidal absorption angiography in monkeys

- 1973, **Flower and Hochheimer**: method of ICG fluorescence angiography
- Indocyanine green
  - water-soluble tricarbocyanine dye
  - molecular weight of **775 daltons**
  - peak absorption in serum between 790 and 805 nm and a peak emission at 835 nm
  - excellent penetration of the retinal pigment epithelium, macular xanthophyll, other ocular pigment, and even blood, allowing superior viewing of the choroidal vasculature
  - 98% of circulating ICG is bound to various serum proteins, such as albumin and a-lipoprotein
  - is rapidly eliminated by the liver and exhibits minimal uptake in the peripheral tissues
  - **25 mg (12.5 to 50 mg) of ICG dye**
- FUNDUS CAMERA based ICG
  - modified to include antireflective coatings and filters for maximal transmission of infrared wavelengths
  - computer coupling device (CCD) containing light-sensitive elements called pixels.
- SLO based ICG
  - Heidelberg Retina Angiograph (HRA)
  - Rodenstock SLO
- Phases
  - “early” phase (0-3 minutes after injection)
    - period from the first appearance of ICG dye in the choroidal arterial circulation to the point of maximal ICG choroidal hyperfluorescence
  - “middle” phase of the angiogram (5–15 minutes after injection)
    - the choroidal veins become less distinct as a nearly homogeneous, diffuse choroidal fluorescence emerges
  - “late” phases (beyond 18–22 minutes)

        - details of normal retinal and choroidal vessels are lost as the hyperfluorescence fades even further

- uses
    - ARMD: occult and classic CNVM, PEDs
    - IPCV
    - RAP
    - CSCR
    - Choroidal tumors

Wide Angle Viewing System

- Disadvantages of handheld irrigating contact lenses :
    - Limited field of view. Meridional view of upto 60 degrees permitted by prismatic lenses.
    - View affected by small pupils and corneal or lenticular opacities.
    - View affected in air filled phakic eye. Biconcave lenses produce peripheral abberations.
- Disadvantages of Wide angle viewing systems:
    - Perfect co axial alignment needed.
    - Reduced stereopsis.
    - Inverter needed.
    - Assistance needed in contact systems.

- Classification
    - <u>CONTACT:</u>
        - Indirect surgical lenses used with the ROLS (*Reinverting Operating Lens System*)

- NON CONTACT
  - BIOM: *Binocular Indirect Ophthalmo Microsope*
  - PWL lens system: *Peyman-Wessels-Landers vitrectomy lens system.*
  - EIBOS: *Erect Indirect Binocular Ophthalmic System*

- **Mini Quad XL:**
  - Widest field of view.
  - Image mag.: 0.39x
  - Indications:
    - RD surgery.
    - GRT repair.
    - Anterior PVR.

- **Mini Quad.**
- **Central Retinal:**
  - Visualisation of the equatorial region.
  - Image mag: **0.71x**
  - Indications:
    - Diabetic vitrectomy.
    - Membrane peeling in PVR

- **Super Macula:**
  - Highest magnification: **1.03x.**
  - Indications:
    - Macular hole surgery.
    - Epiretinal membranes.
    - Submacular surgery.

- **Modifications:**

- **ACS: Autoclave Sterilisable Lens design.**
- **SSV: Self Stabilising Vitrectomy Contact design.**

- **Available Systems**
  - ClariVit Lens Systems: Proprietary VOLK lens design. ACS variant has a two piece disassembly design.
  - Ocular Lens Systems:
    - **WIDE FIELD VITRECTOMY LENS: 0.38x, FOV: 130/146**
    - **EQUATORIAL II VITRECTOMY LENS: 0.65x, FOV: 101/131**
    - **HIGH MAGNIFICATION LENS SYSTEM: 0.90x, FOV: 57/100**

- **Technology and Optics**
  - Two optical lens elements housed in an air tight aluminum holder separated by a fixed distance.
  - Weight: 4 gm
  - Height: 11mm
  - **First Component:**
    - Inferior contact lens element.
    - Acrylic.
    - Diameter: 10mm; Thickness: 2mm; Power: 4 D (in air).
    - Radius of curvature: 7.7mm
    - RI of 1.488
    - power of the anterior surface of the eye changes from +48.8D to -14.5D
    - The remaining effective refractive element, the lens, forms a virtual image of the fundus at F'
    - Following refraction by the first component the rays emerging from the eye have a vergence close to zero.
  - **Second Component:**
    - Superior biconvex aspherical lens.
    - Located 0.5mm anterior to the first component.

    - Effective power: 150 D (in air).
    - The second component acts like an indirect ophthalmoscope.
    - Real inverted image formed 5.8 mm anterior to the anterior optical surface.

- **BIOM: *Binocular Indirect Ophthalmo Microscope, Oculus BIOM 3 system***
  - Aligned coaxially with the operating microscope.
  - Upto 120° of non- contact observation.
  - Inverted view corrected by the Stereo Diagonal Inverter (SDI)
  - 90 D Lens: FOV: 90°.
  - Wide field lens: FOV: 100-110°.
  - Wide field enhanced lens: FOV: 120°.
  - High Resolution Macula lens: FOV: 60°.
  - ADVANTAGES
    - Non contact system.
    - No corneal stress.
    - Assistant not required.
    - Minimally influenced by pupil size and corneal or lenticular opacities.
    - Superior resolution and depth of focus with wide observation angle.
  - DISADVANTAGES
    - Perfect coaxial alignment needed.
    - Lens may get contaminated.
    - Inverted image.
    - Mobility and field restricted by axis of the microscope.

- **OCULAR PEYMAN-WESSELS-LANDERS SURGICAL VIEWING SYSTEM**
  - 132 D indirect vitrectomy lens
  - Image mag: 0.45x

- FOV: 100°/135°
- OSVS flexible arm.
- Attaches to the wrist rest or surgical bed.
- Hands free positioning of wide angle lenses.
- Can hold indirect lens with separate inverter.
- Upright image.
- Wide non contact view of the fundus upto 135° dynamic field of view.
- Allows clear view in air and fluid filled eye

- **EIBOS: *Erect Indirect Binocular Ophthalmic System***
    - Non-contact surgical lens system.
    - Provides a visual field of approximately 100°-124°
    - Simultaneous observation of fundus and incision area.
    - Integrated reversing optics for left-right correction.
    - Integrated focusing device
    - May be swung away without interfering with cataract operations

- **SSV: SELF STABILISING VITRECTOMY LENS DESIGN**
    - Designed by Dr KV Chalam.
    - Utilises a foot plate with a ROC of 12 mm corresponding to sclera.
    - Negative suction holds the lens against the cornea.

- **ROLS: REINVERTOR OPERATING LENS SYSTEM**
    - Used in conjunction with the LASER filter.
    - Reinverts the real inverted image formed by the contact lens.
    - Creates a true, erect, stereoscopic fundus image.

- Other systems

- BIOM with SDI (Binocular Indirect Ophthalmo-microscope with Stereoscopic Diagonal Inverter)
- OFFISS (Optical Fibre Free Intravitreal Surgery System)
- EIBOS (Erect Indirect Binocular Ophthalmo microscope System)
- contact systems used are VPFS (Vitreous Panfunduscope System)
- CWFS (Contact Wide Field System)
- AVIS (Advanced Visual Instrument System)
- ROLS (Reinverting Operating Lens System)

- **Care of Lenses**
- **CLEANING**: Rinse in tepid water followed by cleaning with mild soap solution and lint free cloth. Proceed with disinfection or sterilisation.
- **DISINFECTION**:
  - Immerse in: Glutaraldehyde: 2% aqueous solution; soak time: 20 min.
  - Sodium hypochlorite: 10% aqueous solution; soak time: 10-25 min.
  - Rinse the lens thoroughly using atleast 3 cycles of cleaning.
  - Dry the lens and place in dry storage case.
- **STERILISATION**:
  - Ethylene oxide
  - Autoclave: 134°C-15 min, 121°C-30 min
-

Synaptophore

- principle of haploscope: two physical locations projected to create one physiological localization.
- Aka **Worth-Black amblyoscope**
- Clement-Clarke International Ltd→ **2051** (most comprehensive), 2052, 2053
- ***A wide variety of slides are available:***

  - Series A, Maddox test slides, white binding.
  - Series S, Special purpose slides, blue binding (used with automatic flashing, after images) or with Haidinger brushes.
  - Series D, **stereoscopic** vision slides, **yellow** binding.
  - Series F, **Fusion** slides, **Green** binding.
  - Series G and H, **simultaneous perception** slides, **Red** binding.
  - Mayou series of 8, simultaneous perception slides, orange binding.
- Uses
  - Diagnostic
    - To measure interpupilary distance (IPD).
    - To measure angle of deviation.
    - To assess Anomalous retinal correspondence (ARC).
    - To measure angle kappa (K).
    - To assess various grades and anomalies of Binocular vision.
    - To measure fusional reserve.
    - To measure AC/A ratio.
    - To measure primary and secondary deviations.
  - Therapeutic uses
    - For various orthoptic exercises
    - To treat convergence insuf ciency.
    - To improve fusional reserve.
    - To combat suppression & ARC.
  -

CT

Indications

1. Globe and orbital trauma
2. Assessment of bony abnormalities including fractures
3. Detection of calcification in lesions
4. Assessment of acute intracranial hemorrhage
5. When magnetic resonance imaging (MRI) is contraindicated
    a. Ferromagnetic foreign body
    b. Pacemaker
    c. Metallic cardiac valves
    d. MRI - incompatible intracranial aneurysm clips
    e. Cochlear implants
    f. Claustrophobia, obesity

Contraindications

1. Allergy to contrast media
2. +/- pregnancy
3. Repeated studies in childhood or when risk of radiation induced secondary tumors is increased
4. Renal insufficiency if using contrast

Disadvantages

1. Soft tissue details can be lost when in close proximity to bony structures such as the orbital apex and optic canal and in the posterior fossa
2. Dental fillings, braces may cause artifacts
3. Poor visualization of posterior fossa
4. Radiation risks to eye, orbit, head and neck

MRI

- based on nuclear magnetic resonance without using ionizing radiation

Indications

1. Most useful to image the full extent of inflammatory, ischemic and neoplastic processes, particularly at the skull base
2. Confirmed nonmetallic foreign bodies

Contraindications

1. Trauma causing injury that could be exacerbated by manipulation of patient in scanner
2. Unstable medical condition
3. Metallic foreign body
4. Cardiac pacemaker/defibrillator
5. Cochlear implants
6. Neurostimulators
7. Claustrophobia
8. Large body size
9. Pregnancy (relative contraindication)

- MRI is sensitive to soft tissue changes in water content. Pathologic processes in general have an increase in water content compared to normal tissues
- **Gadolinium injection**
  1. Paramagnetic substance
  2. Can cross disrupted blood-brain barrier as can occur in CNS disease
  3. Can help distinguish normal from abnormal tissue, whether inflammatory or neoplastic
- **T1 weighted images**
  1. Most useful for demonstrating anatomy

  a. Fat is brightest and increasing water content in structures seen as darker image

- **T2 weighted images**

  1. Maximize differences in water content and most sensitive to inflammatory, ischemic or neoplastic alterations in tissue

  a. Water containing structures brightest, fat containing structures less bright

- Fat-suppression techniques removes intense whiteness of fat signal that can obscure other signals. Particularly useful for orbit imaging.

- **Fluid-attenuated inversion recovery (FLAIR)**

  1. Disease processes which often show high T2 signal may be difficult to identify against the high signal of the CSF. FLAIR provides T2 weighted images without the high (white) cerebrospinal fluid signal.

  2. FLAIR imaging is CSF suppression, analogous to fat suppression on T1 images.

  3. FLAIR is thus ideal for viewing periventricular white matter changes:

     a. Demyelinating process such as multiple sclerosis

     b. Edema

     c. Changes from cortical stroke, and other white matter disease

- **Diffusion weighted images**

  1. Sensitive to vascular perfusion alterations

  2. Ideal for identifying acute ischemia

- **MRA / MRV**

  1. Can be used to obtain images of the proximal large vessels of the chest and neck as well as CNS arteries and veins

  2. Records signals from fast-moving particles such as blood, while signals from stationary tissues are suppressed

Surgical Instruments

All surgical tools should be as light as possible and held in the surgeon's fingertips. They should be contoured rather than cylindrical to reduce the force required to prevent dropping and constrain grip at a consistent position. They should be no longer than the distance from the fingertips to the point of contact with the hand. Shorter handles reduce the torque produced by the weight and reduce friction as the cables, fibers, and tubing used to connect surgical tools slide on the drape. Minimizing forces required to hold tools increase the surgeon's proprioceptive sense (**Weber-Fechner law**) and decrease fatigue and tremor. Standardization of tip-to-grip across all tools facilitates so-called muscle memory; the surgeon's cerebellum, motor strip and frontal lobe trajectory generator knows where the tip is located if view is suddenly lost.

Cautery

- **Blue side is coagulation**, Yellow side is Cut.
- Monopolar (Needs separate "return electrode")
  - Coagulation (6% "on"duty cycle)
    - Argon Plasma (non-contact coagulation)
    - Contact coagulation
  - Cut
    - Pure (100% "on"duty cycle)
    - Blend (12-80% "on"duty cycle); usually 25-50%
- Bipolar(active and return electrode are side-to-side)
  - Coagulation
-

General Instruments

- Forceps:
  - Working end:, smooth or toothed, with or without tying platform, with or without serrations
  - Shaft: narrow or broad, angled or straight
  - Handle: round or flat with or without grip
- Scissors

  - Working end: sharp or blunt, straight or curved or angled
  - Size: depending on the surgery
  - Handle: spring action
- Needle holder
  - Working end: (jaws) grooved or flat, curved or straight
  - Size: depending on the type of needle used
  - Handle: spring action, locking or non locking

- Ocular Speculum
  - Barraquer's Eye Speculum
    - Most common eye speculum
    - Fenestrated blades
    - Light weight
    - Minimal pressure on the globe
    - Available in pediatric(14 mm) and adult sizes(16- 18 mm)
  - Universal Eye Speculum (William's)
    - Screw adjustment- holds the speculum open
    - Controlled retraction
    - Used in corneal surgeries like DALK, ALTK
    - Greater rise in IOP
  - Eye speculum with guard (Lancaster)
    - Solid blades
    - Keeps lashes away from the field of surgery
    - Predominantly used in squint surgery

Cataract Surgery

- Westcott’s Spring Scissors: aka Conjunctival scissors
    - Stout, spring scissors
    - With straight or curved blades and sharp or blunt tips
    - For cutting and undermining conjunctiva in various operations

- Corneoscleral Scissors
    - Blades kept apart by spring action
    - Lighter than Westcott's spring scissors
    - Have curved blades with sharp tip
    - Used for wound enlargement in ECCE or ICCE

- Keratomes
    - Triangular blade with cutting edges
    - Available in 2.80 or 2.75 or 5.25 mm size
    - Angled at 45 degree to the handle
    - Used for making corneal incision

- Diamond Keratomes
    - 0.2mm blade thickness
    - Angled clear cornea keratome with sharp sides, tip angle 45 degrees
    - For anterior chamber entrance, wound extension
    - Can be reused

FYI: Diamond blades consist of four components: diamond crystals, a bonding system, a segment, and a metal core. Advantages: ultra-sharp, low friction, multiple time use, long-life span, resist corrosion etc.

- Slit knife
    - Available in 15°, 22.5°, 30°, 45° angulation of blade
    - Used for making stab incisions 1 mm wide
- Crescent Blade
    - Blade with cutting and dissecting property
    - Used for making scleral tunnel during SICS and scleral flaps in trabeculectomy
    - Also used in pterygium surgery
    - lamellar dissection in keratoplasty
- Lim's Forceps
    - Curved forceps with 1x2 teeth at the tip for holding tissue
    - **Fenestrated tying platform** for holding and suture tying
    - Used for holding the corneal or scleral edge while suturing
- McPherson Forceps
    - Fine, medium sized, **plain, angled forceps**
    - Angled at 8mm from the tip
    - Has a tying platform
    - Used in suturing and suture burial
- Arruga's Intracapsular Forceps

- Curved forceps with **cup on inner side**
- Holding the lens capsule at lower pole for lens delivery during ICCE

- Khokhar Capsule Painting Cannula
  - 23-gauge cannula has a curved terminal with a closed tip
  - The posterior of the polished curved part has 3 pores arranged in a linear fashion over a distance of 1.5 mm each
  - Advantage: minimal amount of dye is used at the appropriate plane and maintains a stable anterior chamber during staining

- Utrata Capsulorhexis Forceps
  - Angled forceps with **sharp bent tip**
  - **Iris stop platforms** at 8.5mm from tips
  - 45° angled curved shafts, tip to curve length 13.0mm
  - Used to Initiate capsulorhexis and hold the flap

- Kratz Cystotome
  - Sharp tipped with curved hollow shaft
  - Shaft angled at 60 degree
  - 2 ml syringe attached to the hub of the cystotome
  - Used for continuous curvilinear capsulorhexis.

- Iris Repositor
  - Long narrow flattened extremities with blunt edges
  - One end is curved and other end is angled
  - Uses:

  - To reposit the prolapsed iris tissue during surgery
  - Deepithelization of cornea during C3R, BSK removal

- Phaco Tips
  - Angulation of cutting end of phaco tip can vary from 0 to 60 degrees
  - ↑ **angle** → ↑ excavation → **better cutting**
  - **Small angle** →quick occlusion →quick build up of vacuum → **better hold**
  - 30 degree needle : good compromise of both the functions → most commonly used
  - Kelman tip: axis is bent at 22.5º 3.5 mm from the tip.
    - Advantage:
    - Less clogging
    - Better tissue holding
    - Easier occlusion
  - Straight Tip
  - Tip diameter variable:
    - Internal diameter:
    - Standard : 0.9 mm
    - Microtip : 0.5 to 0.7
  - Reduction in size:
    - **Advantages :**
    - Smaller wound of entry
    - Reduction of surge
    - **Disadvantages :**
    - Less ability to aspirate & hold nuclear fragments
    - Requires more levels of vacuum
    - Easier to occlude

- Wire Vectis
    - Mc Intyre irrigating vectis
    - Loop has irrigating ports (3 in no)
    - Used for nucleus delivery during ECCE
    - Non irrigating vectis (nucleus delivery in subluxated lens or after PCR)

- Simcoe Irrigation and Aspiration
    - Has a 15mm long 0.3mm diameter aspiration port
    - 23 G Front opening irrigation port
    - Aspiration through tubing hub attached to a 2 or 5 ml syringe and irrigation through luer-lock hub.
    - Other models: reverse simcoe, U shaped simcoe (right or left)

- Chopper
    - Round bodied with blunt or sharp tip
    - Angled at 60º to the shaft
    - Used to divide the nucleus during phacoemulsification (horizontal or vertical)

- Sinskey Hook
    - Round body instrument with straight or angled shaft
    - Has a 0.25mm diameter blunt bent tip
    - Tip to angle length is 10.0mm
    - Used as lens Manipulating Hook

- Lester Hook

  - Straight or angled Ideal for multi-directional manipulation
  - Angled for engaging the inferior haptic without touching the dome of the IOL

- Castroviejo's Needle Holder
  - Spring action needle holder
  - Working end has straight jaws
  - With a locking mechanism
  - Suturing corneoscleral incision

- Barraquer's Needle Holder
  - Spring action needle holder with narrow curved jaws
  - Fine serrations at for better grip
  - For suturing with 10-0 nylon

Keratoplasty

- Flieringa Scleral Fixation Rings
  - Available as a set of 8 rings from size 14 mm to 22 mm
  - Sutured to sclera with 7-0 vicryl before surgery
  - Maintains rigidity of the recipient's globe after trephination

- Handheld Corneal Trephines
  - Most commonly used trephine
  - Available in sizes from 3 to 17 mm diameter
  - Can be attached to a handle for greater stability and control
  - Obturator guided trephine to control depth
  - Donor trephination done with endothelial side up

- Hessburg-Barron Vacuum Corneal Trephine
    - Suction fixation corneal trephine
    - Used for controlled complete or partial trephination of the host
    - Crosshairs for centration over the host cornea
    - It goes up to 250 micron depth with each 360 degree rotation.
    - Size: 6 to 9 mm with 0.5 mm increments
    - Advantage: consistency of cut, can be used in perforated eyes

- Skin Biopsy Punches
    - Disposable punches
    - Available from sizes 2mm to 5.5mm
    - Used to harvest small patch grafts for tectonic purposes

- Troutman-Castroviejo Keratoplasty Scissors
    - Blunt tip spring scissors with angled blades
    - Inner blade is1 mm longer than the outer blade
    - Used for cutting host cornea after trephination.

- Barron Vacuum Punch
    - Solid stainless steel blade which is permanently mounted in a nylon housing
    - Base of the punch features a circular groove for aspirating the epithelial side of the cornea, immobilizing it for cutting the button
    - Blade is placed on vacuum fixed donor button and pressed with thumb to yield a sharply cut corneal button

- Tudor Thomas Stand
  - Cup at the top for positioning and fixing whole eye globe (donor)
  - Trephination for both lamellar and full thickness grafts can be done with epithelial side up

- Endothelial Punch
  - Donor cornea place endothelial side up on cutting block
  - Disposable trephine to cut appropriate size of graft fixed at the bottom end of the stand
  - Advantage: yields sharp vertical cuts without beveling

- King's Clamp
  - Used to fix the donor corneoscleral button
  - Lamellar dissection of donor cornea

- **Lamellar Dissectors**
  - **Tooke's Knife**
    - Straight blade with curved cutting edge
    - Blade is 3mm x 18 mm in size
    - For initiation and pocket creation during lamellar dissection
  - **Gill's Lamellar Dissector:**
    - Corneal knife straight or curved cutting edge
    - Has a 3mm wide blade
  - **Paufique Knife:**
    - Has an angled tip with curved cutting edge
    - It outlines graft, helps in pocket formation and dissection.

- Paton Spatula
    - Blunt and grooved instrument with corrugated handle
    - Used for transferring graft to the recipient

- Corneal Marker
    - Marker stained with gentian violet and kept on host cornea before trephination
    - 8 arms act as a guide for interrupted sutures (Anis)
    - 20 arms for continuous sutures (Vajpayee)
    - **DSAEK corneal marker:**
        - Size 8 and 9 mm
        - Marks the area to be stripped on the host cornea

- Forceps With Special Functions
    - **Polack double corneal forceps**
        - Used for the first corneal suture
        - The graft is grasped at junction of epithelium and stroma
    - **Colibri forceps**
        - These are tooth forceps
        - Used for graft tissue holding

DSAEK

- **Ogawa DSAEK Forceps.**
    - The tips of the forceps remain separated when the handles are closed, to minimize injury to the folded donor tissue.
    - The folded graft is then easily released into the anterior chamber.

- **DSAEK Busin Glide**
  - The donor lamella is loaded endothelial side up into the glide
  - Glide inserted via 3.2 mm incision
  - Facilitates the unfolding of the graft and centration of the donor button in the anterior chamber
  - Helps to minimize the manipulation of the graft and thus endothelial loss

- **DSAEK Busin forceps**
  - Microincision forceps with 20 G diameter
  - It helps to position the graft in the glide and pull it in the anterior chamber of the host

- **DSAEK Spatula**
  - Is available in 45˚ and 90˚ angle tip model in both irrigating and non irrigating versions
  - Used to strip the recipient Descemet's membrane of the recipient

Glaucoma Surgery

- Dewecker Iris Scissors
  - Spring scissors with cutting blades bent at an angle of 60º
  - **Winged** for the placing index finger and thumb
  - One pointed blade other rounded
  - For iridectomy, trabeculectomy.

- Vannas Scissors

- Spring action scissors with straight, curved or angled forward cutting blades
- Used to:
  - Prepare conjuntival flaps
  - Cut 10-0 suture
  - Cut the trabecular flap in trabeculectomy
  - Cut iris tissue in iridectomy

- Kelly Descemet's Membrane Punch
  - Serrated squeeze action handle.
  - Clean 0.75 mm round hole without tissue tags
  - This punch is used to create a trap door after making a scleral flap. The punch ensures that the trap door is full thickness

- Harms Trabeculotomy Probe
  - Two parallel arms (probe and guide) connected to the shaft
  - Available as right or left sided
  - The internal arm is threaded into the Schlemm canal using the external parallel arm as a guide.

Posterior Segment Surgeries

- Micro Vitreo Retinal Blade
  - Micro vitreo retinal (MVR) blade has a lancet tip that makes a symmetrical incision around the initial entry point
  - 1.4 mm blade width to make 0.89-mm incision for 20-gauge tools
  - Shaft is 20 gauge to make a round opening from the linear incision

- 23 G Valved Cannula
  - 23 G valved entry ports
  - Advantage: decreased wound leakage, less chances of incarceration at port site.
  - Post operative faster recovery

- Infusion Cannulas
  - 20 Gauge beveled tip with luer lock adapter
    - 4mm tip: phakic patients
    - 6 mm tip: aphakic, pseudophakic, bullous RD, endophthalmitis
  - 23 Gauge
    - Macular hole surgery, vitreous hemorrhage

- Irrigating Contact Lens
  - **Biconcave** irrigating vitrectomy lens (-90D)
    - Designed to view the fundus in air-filled phakic and pseudophakic eyes
    - Lens has a refractive power of -90d, a field of view of 24 degree
    - Used in macular surgery and traction detachments
  - Machemer **Planoconcave** Irrigating Vitrectomy Lens (Plano/-45D)
    - Designed to visualize the structures deep in the vitreous in phakic & pseudophakic eyes
    - Has a 36 degree field of view
    - Used in macular surgery and traction detachments
  - Paymen **Wide field** Irrigating Vitrectomy Lens
    - Designed for wide angle viewing of phakic, fluid filled eyes during vitrectomy.
    - For peripheral vitrectomy and endolaser

- Wide Angle Viewing System
    - Available in **contact and noncontact varieties**
    - Primarily useful for peripheral dissection, internal drainage of SRF through peripheral breaks in phakic or pseudo-phakic eyes, and endophotocoagulation of peripheral breaks
    - Disadvantage: inadequate for macular surgery, decrease axial (depth) and lateral resolution, and increase inadvertent lens contact. Skilled assistant required.

- Vitrectomy Scissors
    - Vertical or curved scissors
    - Used to cut the fibrous vascular fronds, bands
    - Used during segmentation or delamination of ERM

- Intraocular Cautery
    - Bipolar available in 20 G, 23G, 25G.
    - Used for achieving hemostasis or controlled drainage retinotomy

- Silicon Tip Needle
    - Silicon tip needle comes with a needle with a soft silicon tip for automatic removal of intraocular fluids
    - Silicon brush needle (straight/curved) comes with 20-G needle with a soft silicon tip that is split to create a brush like quality.
        - for non traumatic brushing of the retinal surface with simultaneous aspiration.
        - for repositioning of retinal folds or breaks.

- Back Flush Flute Needle
    - Silicon back flush reservoir on the conventional flute needle

  - Safe back flushing of the incarcerated tissue during passive aspiration of intraocular fluids.

- End Grasping Forceps
  - Serrated or flat tips which open when the handle is pressed
  - Useful to peel ILM, ERM
  - Available in both disposable and reusable handles

- Diamond Dusted Membrane Scraper
  - Silicon tipped for non traumatic contact with retina
  - Coated with chemically inert diamond dust, leads to traction while scraping
  - Lifts the epiretinal membrane or internal limiting membrane.

Extraocular Instruments

Chalazion Surgery

- Chalazion Clamp
  - Has a solid plate like end and a fenestrated ring
  - Fenestrated end on the conjunctival side to aid incision
  - Achieves localization, support and hemostasis

- Chalazion Scoop
  - Small round scoop like end

- Helps in non traumatic curetting of chalazion

Entropion/Ectropion Surgery

- Snellen's Entropion clamp
  - Right and left variety
  - Plate design supports the lid
  - Helps achieve hemostasis

- Jaeger Lid Spatula
  - Slight convex surface
  - **Lid surgeries-** entropion , ectropion , ptosis
  - Protects globe
  - Provides support
  - Helps in creating dissection planes during orbitotomy

- Desmarre's Lid Retractor
  - Retraction of soft tissues
  - Ptosis , orbitotomy, buckling, DCR surgeries
  - Double eversion of eyelids
  - Used to unroll AMG over corneal surface

Ptosis surgery

- Berke's Ptosis Clamp
  - Used to support and clamp the levator muscle during levator resection

  - Helps achieve hemostasis

- Crawford's Fascia Lata Stripper
  - Used in ptosis surgery – during autologous fascia lata harvesting
  - Proximal slot for holding fascia lata
  - Harvests fascia lata through a small incision

- Wright's Fascia Needle
  - Needle tip bent at 90^0
  - Large eye for passing harvested fascia lata.

- Castroveijo's calipers
  - 0-20 mm range
  - Used to measure exact distances

Evisceration/Enucleation Surgery

- Mules Evisceration Scoop
  - Used to scoop out the intraocular contents i.e uveal tissue
  - Has a gentle curve to slide along corneal surface

- Enucleation Spoon
  - Has a groove for the optic nerve to pass through
  - Supports the globe and aids in giving slight traction to the optic nerve

- Enucleation Scissors

- Curved scissors- pass along the orbital wall smoothly
- Blunt end- non-traumatic to the globe
- Help to maximize the length of the optic nerve resected

DCR Surgery

- Nettleship's Punctum Dilator
  - Used to dilate the puncta prior to any probing
  - Available in multiple sizes, corresponding to probe sizes

- Bowman's Probes
  - Available in sizes ranging from 0000 to 4
  - Size 0=1mm diameter, with 0.1mm gradation
  - Used for probing nasolacrimal duct
  - DCR surgery
  - Therapeutic probing in pediatric population

- Freer Periosteum Elevator
  - Slight concavo-convex ends
  - Used to lift periosteum and lacrimal sac from underlying fossa

- Muller's Self Retaining Retractor
  - Helps to retract the skin incision in DCR surgery
  - Helps to achieve hemostasis
  - Self - retaining

- Kerrison Bone Punch
    - Available in multiple sizes
    - Size 0=1mm
    - Size 4=5mm
    - Cutting end up or down designs
    - Predominantly used to create an ostium in DCR surgeries

Orbitotomy surgery

- Bard – Parker handle with blade
    - Slot for attaching disposable blades
    - Pen like grip
    - Used to make incisions

- Kelly's Malleable Retractor
    - Used to retract soft tissue during orbitotomy
    - Increases the field of view
    - Helps to achieve hemostasis

- Tenotomy Scissors
    - Fine blunt tipped scissors
    - Used to separate Tenon's from underlying sclera
    - Used in buckling surgery, enucleation, eviseration, squint surgery

Strabismus surgery

- Strabismus/ muscle hook
    - Used to clip long end of sutures
    - Squint surgeries, ptosis surgery

- Castroveijo's needle holder
    - Needle holder with or without locking
    - Used to hold 4-0 to 7-0 sutures
    - Used to suture periocular skin incisions, extraocular muscles , explants in retinal detachment surgery.

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