Dept. of Physiotherapy

Aberrations

- **Aberration** in optics refers to the deviation from perfect image formation caused by various factors.
- Defects or imperfections that cause deviations from ideal image formation in lenses, mirrors, and other optical systems.
- They result in distortions, blurriness, or other image quality issues, making objects appear unclear or warped. There are several types of aberrations

1. Diffraction of light

- Diffraction is bending of light by edge of an aperture or the rim of lens.
- Even a perfect lens free from abberation will not focus light to a point due to diffraction.
- The actual pattern of a diffracted image point produced by a lens with a circular aperture or pupil is a series of concentric bright and dark ring
- The airy disc after is a bright point located in the center of the pattern.
- The diameter of the concentric ring spot in an eye with a 2 mm pupil is 0.01 mm.
- Retinal illumination is the outcome of diffraction and spherical aberration together.
- Ideal visual acuity is achieved within a moderate range of 3–4 mm for pupil diameter. Diffraction blur is increases as the pupil gets smaller.

2. Spherical aberrations

- **Spherical aberration** is an optical phenomenon that occurs when light rays passing through a spherical lens or reflecting off a spherical mirror do not converge at a single focal point.
- This results in a blurring of the image and reduced image quality.
- Because spherical lenses refract peripheral light more strongly than paraxial light, more peripheral light is brought into focus closer to the lens in the case of convex lenses, causing spherical aberration
- It was long believed that different degrees of spherical aberration affected the human eye, which has a power of roughly 160 D.
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3. Chromatic aberration

- **Chromatic aberration** is an optical phenomenon that occurs when a lens is unable to focus all colors of light to the same point. This results in a distortion of the image, often appearing as color fringes around the edges of objects.
- Causes- Different colors (wavelengths) of light bend by different amounts when passing through a lens due to varying refractive indices. Shorter wavelengths (like blue and violet) are refracted more than longer wavelengths (like red)
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- Because the index of refraction of any transparent material changes with the wavelength of transmitted light, chromatic abberation occurs.
- In human eye which optically act as a convex lens, blue light is focused slightly infront of the red.
- another way, the emmetropic eye is actually myopic for blue and green light and slightly hypermetropic for red light
- This fact forms the basis of biochrome test used in subjective refraction
- Due to the long and mid wavelength cones' relatively small spectral sensitivity bands and the blue cones' generally absent fovea, the effect of chromatic abberation is reduced.
- Furthermore, because the eye is generally focused, the effect is somewhat mitigated by the strongest light coming from the sharpestly defined image

4. Oblique aberration

- **Oblique aberration** is an optical distortion that occurs when light rays enter a lens or optical system at angles that are not perpendicular to the optical axis. This can result in various image quality issues, particularly in systems with large apertures or when using wide-angle lenses

Causes:

- **Angle of Incidence**: When light rays hit the lens at steep angles, they do not focus at the same point as rays entering the lens perpendicularly, leading to distortion.
- **Lens Shape**: The design and curvature of the lens can exacerbate the effects of oblique aberration, especially in spherical lenses.

Types of Oblique Aberration:

- **Lateral Color Aberration**: Different wavelengths of light may focus at different points when entering at oblique angles, leading to color fringing.

- **Spherical Aberration**: Oblique rays can contribute to spherical aberration, where light rays from the periphery do not converge at the same focal point as those from the center.

5. Coma
    - **Coma** is a type of optical aberration that occurs when off-axis light rays (light entering a lens or optical system at an angle) fail to converge at the same focal point as light rays that enter on-axis (perpendicular to the optical axis).
    - This results in a distorted image that appears to have a tail or comet-like shape, hence the name "coma.

Causes:

- **Lens Design**: Coma typically arises in spherical lenses and mirrors, where the curvature of the surface does not provide uniform focusing for off-axis rays.
- **Angle of Incidence**: The greater the angle at which light rays strike the lens or mirror, the more pronounced the coma effect will be.

Types of Coma:

- **Positive Coma**: This occurs when light rays from a point source appear to be drawn towards the optical axis, creating a tail that points away from the axis.
- **Negative Coma**: Rarely encountered, this occurs in some specific configurations, causing the tail to point towards the optical axis.

6. Decentring aberration

- **Decentering aberration** occurs when an optical element, such as a lens or mirror, is not perfectly aligned with the optical axis of a system. This misalignment can lead to various distortions in the image quality and is particularly important in complex optical systems like cameras, microscopes, and telescopes.