CHAPTER 2

Voyage of Contact Lenses

HISTORY OF CONTACT LENSES

The genesis of contact lenses started with the idea of neutralizing corneal refractive error with water. This was the brainchild of the versatile genius Leonardo da Vinci, whose 1508 pencil drawings depict glass shells full of water resting on the eye.[1] However, it took almost four centuries for his ideas to be implemented and it was in 1801 that Thomas Young employed the same idea to correct his own myopia using a homemade device of a glass tube filled with water, attached with wax to a lens taken from his old botanical microscope. He used this tube on his eye, in an attempt to replace his myopic cornea with a regularly ground lens. This idea was refined by Sir John Herschel in 1830, who gave the concept of placing spherical lenses over cornea for correcting refractive errors and suggested making such lenses using impressions of corneal surface. To him is thus accorded the status of being the ***father of contact lenses***.[2]

The first actual lens was, however, made in 1888 by Adolf Fick using blown glass shells and was called the *Kontaktbrille*. After using this lens, he made the important observations of corneal clouding, conjunctival/limbal injection and recommended inserting an air bubble behind the lens to reduce this clouding. The concept of lens disinfection and adaptation was also given by him. In the same year, Eugene Kalt used such a lens for the first time to improve the vision of a keratoconus case, after cauterizing the cone with silver nitrate. This prompted Thomas Lohnstein, himself a keratoconus patient, to develop lens cups filled with saline (*water spectacles or hydrodiascope*) which could be worn successfully for a few hours.[3] A high myope of 14 D, August Müller in 1889 suggested confirming posterior lens surface to corneal surface by utilizing capillary attraction of tears to ensure lens adherence. He recommended incorporation of an edge lift to lens, to enhance tear circulation under the lens and used the newly introduced cocaine as a local anaesthetic during the fitting procedure.

It was in early twentieth century that Carl Zeiss manufactured the first trial set of lenses to correct keratoconus from lathe-cut moulds. The commonest problem faced by these early pioneers was corneal oedema after lens wear, which was named *Sattler's veil* after the gentleman who studied this phenomenon extensively.[4] It took many years before the physiological reasons for this was found to be hypoxia and negative hydrostatic pressure which led to modifications in lens material.[5–7]

Material and Type of Lenses

In 1930, Röhm and Haas Company (USA) isolated a novel plastic from an acrylic resin base called *Plexiglass*. This forerunner of polymethyl methacrylate (PMMA) was sold to US aviation industry and used to manufacture cockpit roofs of fighter plans during Second World War. This fact led to the

Oxygen transmissibility (Dk/L): Expressed as Dk/L, it refers to the oxygen permeability/exchange of a lens of given thickness where Dk = oxygen permeability and L = lens thickness. Oxygen exchange across a lens is proportionate to oxygen permeability of polymer (Dk value) and inversely related to lens thickness. The central thickness of a – 3.0 D contact lens is taken as standard by most lens manufacturers. Oxygen requirement of cornea under a CL has been calculated to be $Dk/t = 24$ for daily wear and $Dk/t = 87$ for extended wear.[1] Poor oxygen transmission during lens wear causes hypoxic corneal changes like epithelial microcyst, endothelial blebs and polymegathism. Carbon dioxide retention under a CL results in an acidic pH which reduces efficiency of endothelial pump leading to corneal oedema.

- Oxygen permeability = Dk value

$$Dk = \frac{\text{Amount of oxygen} \times \text{thickness}}{\text{Lens area} \times \text{time} \times \text{pressure difference}}$$

- Oxygen transmissibility Dk/t = Dk/central lens thickness

Water content: Crosslinked monomers used in a CL result in a porous structure which is able to retain water. Water-holding capacity of a lens in turn is directly proportional to its oxygen permeability, with a 20% increase in water content serving to double the oxygen permeability. Water content alters durability, thickness, with wearers of higher water content lenses being more vulnerable to changes in atmospheric humidity. Anatomical and optical parameters of high water content lens alter significantly in dry dusty environments and/or dry eye conditions.

Wettability: Soft lenses are hydrophilic in nature and absorb water depending on their hydration level. Rigid gas permeable lenses, on the other hand, are either hydrophobic, proportionate to silicone content or partly hydrophilic. Despite the umbrella of a wetting agent incorporated in the silicone impregnated rigid lens, such lenses dry more rapidly and bind more lipid containing tear debris. In situations of diminished tear flow, these debris adhere to back surface of lens, generate friction during blink-induced lens movements and a gritty feel.

Sessile drop/water-in-air test: This test is used to measure contact lens wettability. It measures angle θ (theta) between a tangent drawn to surface of drop at its point of contact with the horizontal test surface. A zero angle implies completely wettable surface and a large angle >90° implies a poorly wettable surface (Fig. 3.2). Poor water adherence lenses with large θ values have poor vision quality, are prone to deposits and uncomfortable to wear.[2]

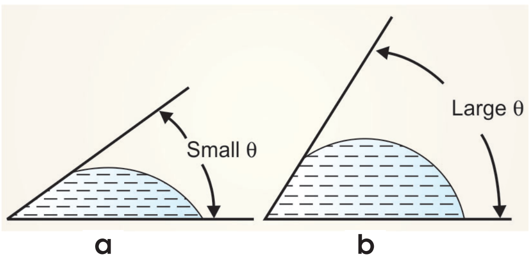

Fig. 3.2: (a) Small wetting angle θ (theta): Greater wettability, enhanced comfort; (b) Large wetting angle: Lesser wettability, poorer comfort

Light transmission and refractive index are optical property measures and ***heat resistance and lens flexure*** are measures of mechanical property of lens material.

RELEVANT APPLIED ANATOMY AND PHYSIOLOGY

Corneal Refraction and Haemostasis

Cornea is the principal optical surface accounting for two-thirds refractive power of the eye. It is a meniscus lens with a mean front apical radius of 7.8 mm, back apical radius of 6.5 mm, a refractive index of 1.376 and power of 43.27 D (Fig. 3.3). The ***visual axis*** is line joining fixation point to fovea and passes through the nodal point of eye. **Fixation axis** is line joining fixation point to center of rotation of eye. **Optic axis** is the line through nodal point in which optical center lies (Fig. 3.4).

a *plus power tear lens* and a flat fit would create a *minus power tear lens* (Fig. 3.7a and b). The power of this tear lens has been calculated to be *0.25 D for every 0.05 mm* radius of curvature difference between base curve of lens and flat K of the cornea. The mnemonic to remember this is**: SAM FAP**, for steeper fit add minus and for flatter fit add plus, since steeper fit creates a plus tear lens requiring a minus overcorrection for neutralization.

The scenario for a soft lens is different. A snugly moulding soft lens entraps minimal tear fluid with similar anterior and posterior surfaces which generates a zero ***power plano tear lens.***

Spectacle Blur

This is a phenomenon associated with older PMMA lenses and with poorly fitted, cornea unfriendly RGP lenses. Long-term wear of such poorly fitted lenses cause corneal warpage, which translate into poorer vision when patient switches back to corrective spectacle wear. This effect of CL wear on corneal topography initiated the concept of programmed modification of cornea surface by CL in reducing myopia called orthokeratology.[13]

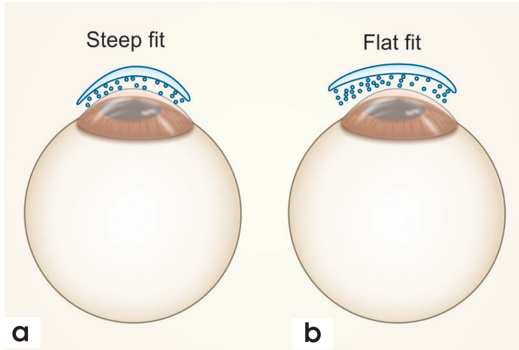

Fig. 3.7: (a) Steep fit RGP lens generates a positive tear lens optics; (b) Flat fit RGP lens generates a minus powered tear lens optics

Figures 3.8 to 3.10 depict some basic optics which would be required to understand contact lens optical aspects. They also explain about the distortion with high-powered spectacle lenses which are taken care of by contact lenses.

A brief review of astigmatism is required for understanding of contact lens properties in neutralizing this refractive error.

Astigmatism

Astigmatism is an optical error where two line foci get focused in front, behind or partly on

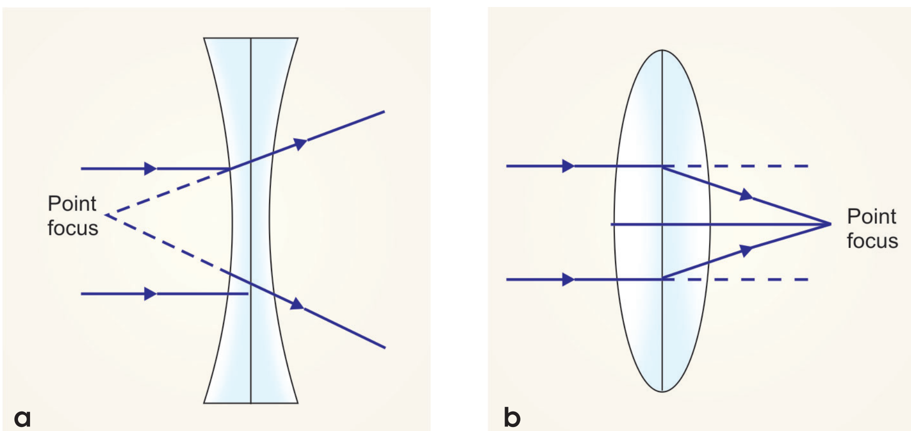

Fig. 3.8: Ray diagrams of: (a) Convergence and point focus of a convex lens; (b) Divergence and point focus of a concave lens

- *Mechanical support*: This includes forehead band, chin rest, fixation target power supply unit and locking controls.
- *Observation system*: This includes binocular eyepieces, observation tube, and magnification changer. The magnification can be varied in a stepped or continuous manner from low (7–10X) to medium (20–25X) to high (30–40X) for detailed evaluation.
- *Illumination system:* This includes lamp housing unit, slit control of width and height, filters (neutral density/cobalt blue/red-free/green), field size control, diffuser and a prism.

Structures to be evaluated during contact lens evaluation:

- *Epithelium*: Any surface irregularities, opacification, dry spots, vacuoles and microcysts need to be ruled out before deciding for lens fitting. Presence of vacuoles (20–50 mm round spaces with distinct edges) and small microcysts (collection of dead cells and metabolic by-products) signify lens induced hypoxia.
- *Stroma*: The things to be specifically looked for are striae, ghost vessels, pigment deposits and opacities. Stromal edema can be diagnosed by presence of fine, non-branching vertical striae in posterior stroma which indicate corneal swelling greater than 5–6%. Corneal folds are intersecting lines observed in direct illumination or as dark intersecting lines viewed against the endothelial mosaic in retro-illumination. Presence of corneal folds implies corneal swelling of 8–10% and indicates buckling of posterior stroma. Stromal edema and corneal folds both imply hypoxic states. Vogt's striae are fine vertical parallel lines in deep posterior stroma and Descemet's membrane in patients of keratoconus.
- *Endothelium:* The aspects to be seen in endothelium are visualized by method of "zone of specular reflection", with normal endothelium being visible as a mosaic of fitted hexagonal cells. Abnormal structures which indicate early endothelial dysfunction, need to looked at are: Polymegethism (variable endothelial cell size), guttata (excrescences of Descemet's membrane) seen as dark spots and blebs (minute black spots in endothelium).

Examination Techniques using a Slit Lamp

These techniques are diffuse, direct, indirect, retro-illumination, specular reflection, sclerotic scatter and tangential.

Diffuse Illumination

It uses a wide open slit-width with angle of 30–45 degree between light and observation system along with a diffusing filter to reduce glare. This examination method is used to view details of anterior segment structures at a glance.

Direct Illumination

In this technique both observation and illumination systems are focused at same point. Variation in width and/or height of slit creates a parallelopiped optic section or conical beam. Parallelopiped section is used to measure corneal thickness and see details of any lesion within the corneal layers. In order to rule out corneal nerves/infiltrates or ghost vessels, high magnification is required. This is important since a patient with ghost vessels must be fitted only with a high Dk value CL to prevent hypoxia stimulated growth of this obliterated vessel.

Indirect Illumination

In this technique observation and illumination systems are not focused at the same point. Instead the focal light beam is directed adjacent to the area of observation and angle of illumination is varied by rotating body of the illumination system. It is used to view epithelial and iris details like epithelial erosions, infiltrates and microcysts.