UNIT 9 EYELIDS, LACRIMAL APPARATUS AND TEAR FILM DYNAMICS

Structure

9.0 OBJECTIVES

After completing this unit, you should be able lo understand:

- the functions of the eyelids;
- the formation, composition and draining of the tear film;
- tear film dynamics; and
- the tests for tear film dysfunction.

9.1 INTRODUCTION

This unit is dedicated to the structures external to the eyeball, sometimes also collectively referred to as the adnexa. Although these structures are outside the eye and do not directly deal with vision, their role in the eye is equally important. Various important aspects are attributed to these organs like protection of the eyeball, provision of nutrients, maintaining the integrity of the eyeball, preserving the transparency of the cornea, etc.

9.2 STRUCTURE AND FUNCTIONS OF THE EYELIDS

Functionally eyelids protect the eyes and help maintain tear film integrity structure of eyelids has been explained in previous units.

9.2.1 Functions of the Eyelids

The eyelid forms the outer most layer, covering the eye. Due to its strategic position, the eyelid serves a very important function of acting as a physical barrier between the eye and the external environment. This barrier protects the eye from physical elements including heat, radiation, excessive light and most importantly a foreign particle (referred to as a "foreign body"), which could physically damage the delicate inner coats of the eye if the eyelids were not there. Their protective functions include blinking to remove dust particles. The eyelashes play a sensory role to detect the presence of an intruding element, which in turn initiates the protective mechanisms, i.e.,blinking.

The eyelids play an important role in maintaining the health of the ocular surface and the physical position of the eye within the orbit. The significance of the lids. in relation to the tear film needs to be clearly emphasised. Production of tears, reflex blinking to aid in distribution of tears, and closing of the eyelids which cause propulsion of tears in the direction of lacrimal puncta to facilitate drainage of the tears are among the most significant roles played by the eyelids. The lacrimal pump responsible for the filling and emptying of the lacrimal sac is intricately linked to the movement of the eyelids.

9.2.2 Physiology of Eyelid Movements

It is quoted that the eyelids move more than any other part of the body. The major movement of the eyelids include opening and closing of the eye. Other movements that need to be understood are blinking, winking, peering and forceful closure. The opening movements of the upper and lower lids are determined by the contraction of yoke muscles known as the levator palpebrae superioris (LPS) (supplied by the 3rd nerve) and the smooth muscle fibres which arise from the under surface of the LPS (sympathetic nerve). Opening movements are bilaterally symmetrical in direction and amplitude. The upper eyelid can be raised by 15 mm by the LPS muscle and an additional elevation of 3-5 mm by the frontalis muscle.

The closing action of the lids occurs through the movement of the orbicularis oculi muscle and is supplied by the 7th cranial nerve. The muscle contains pretarsal, preseptal and orbital fibres. The pretarsal fibres function in spontaneous blinking and tactile corneal reflex. The preseptal fibres are responsible for voluntary blinking and sustained activity. Lastly, the orbital fibres are used in forceful closure of the eyelids. The exposed zone between the upper and lower eyelids is known as the palpebral fissure. In adults, it is 27-30 mm long and 8-11 mm wide.

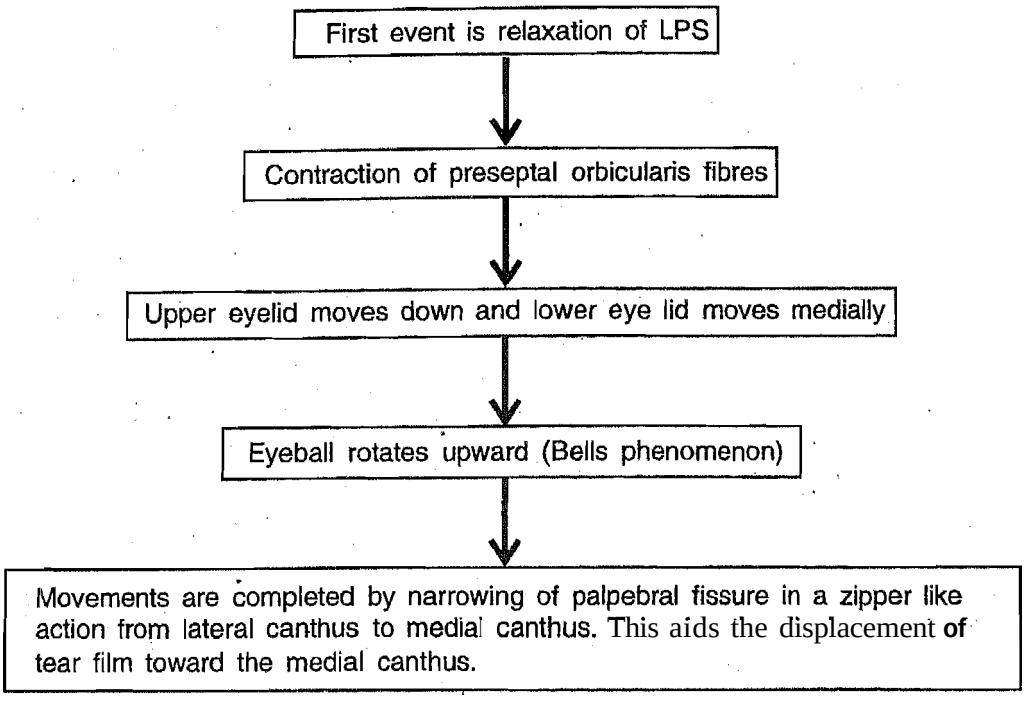
The upper lid moves vertically downwards while the lower lid moves medially. Their rate of movement is similar but the lower lid movement begins 10-20 milliseconds earlier than the upper lid. In this mechanism Shesington's law of reciprocal innervation is obeyed.

9.2.3 Blinking and Peering

Blinking refers to the opening and closing movements of the eyelid. The function of blinking is to keep the cornea moist and clean, help in drainage of tears, and to eliminate blurring of images during eye movements. With each blinking movement of the lids the eyeball moves upwards and inward, similar to the position the eye takes during sleep. In a coinplete blink the superior and the inferior fornices are

compressed by the preseptal fibres and the eyelids move towards each other, with the upper lid moving a greater distance and exerting more force on the globe. Peering refers to the act of looking at some object with great interest, In the process of peering both upper and lower eyelid moves down by 2.5 mm. Along with this the lower eyelid also moves medially by 1 mm.

Course of Events During Spontaneous Blinking: Following ate the course of events which take place in the following order. The process is also responsible for drainage of tear film across the cornea to drain ultimately into Lacrimal apparatus.



The function of blinking movements can be categorised into voluntary and involuntary with sub-categories—.spontaneous and reflex. **A voluntary blink** is a coordinated closure and opening movement carried out in both eyes. The muscles used in this action are the oribtal and palpebral portions of the orbicularis. An **involuntary blink** is composed of spontaneous and reflex types. The **spontaneous blink** occurs without any obvious external stimulus. Its function in addition to protection is to reform and redistribute the precorneal tear film. The rate for a

Table 9.1: Mechanism of Reflex Type of Involuntary Blink

Reflex Types	Mechanism
Tactile	Excited by a sudden unexpected touch to the cornea, conjunctiva, eyelashes, eyebrow or eyelids.
Optic	Occurs because of the dazzle reflex (bright light), menace reflex (unexpected object coming into the field of vision); occurs through the afferent pathway supplied by the 2nd cranial nerve and efferent supplied by the 7th cranial nerve.
Auditory	Excited by a loud noise, afferent pathway supplied by 8th nerve and efferent, pathway supplied by 7th cranial nerve.
Stretch	Excited when the orbicularis is stimulated by a stretch type stimulus such as a tap or blow.

spontaneous blink is about 12-20 times/minute and the opening phase is always greater than the closing phase. The effect of a blink on vision is the discontinuity of the visual sensation. The **reflex type of involuntary blink** occurs as a coordinated closing and opening movement of the eyelids that occur as a reflex in response to a direct stimulus (can be tactile, optic, auditory or stretch).

Cheek Your Progress 1

Enlist the muscles which control the opening of the eyelids?

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9.3 FUNCTIONS OF THE LACRIMAL APPARATUS

Tear film is composed of three layers. Each layer is secreted by a particular gland, and each layer has its specific function. It is described in following section.

9.3.1 Tear Secretion

Aqueous tears are secreted by the main (reflex secretion) and accessory (basic secretion) lacrimal glands. The main lacrimal gland is innervated by both parasympathetic and sympathetic nerve fibers. The goblet cells and meibomian glands, respectively, secrete mucus and lipid. The normal race of tear production is 1.2 microlitre/minute. The tear turnover rate is 5-7 limes per minute. It is of interest to know that abnormal tearing starts only after 4 months of age. The absence of abnormal tearing in very young infants may be explained by the fact that cornea of infant have a low innervation.

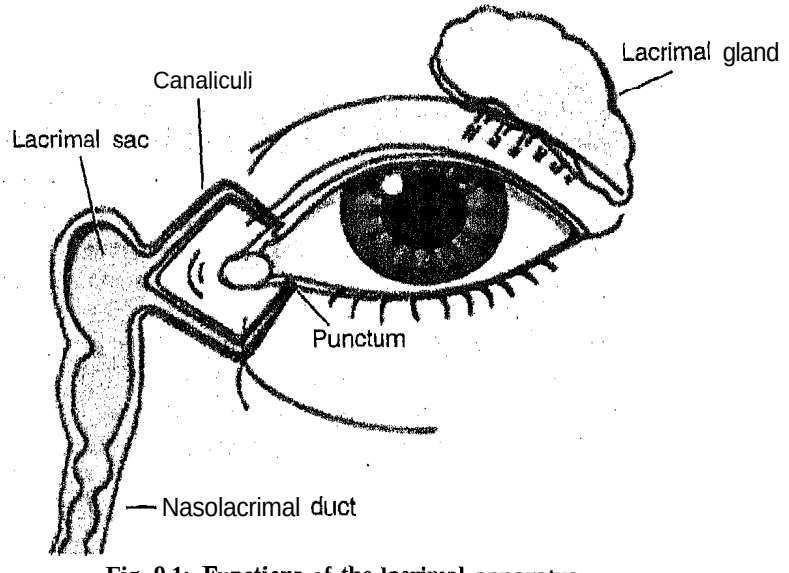

Fig. 9.1: Functions of the lacrimal apparatus

9.3.2 Control of Tear Production

The lacrimal secretary system was initially thought to be comprised of two parts— ***basic*** *secretors* and ***reflex*** *secretors.* **Basic secretion** corresponds to the accessory glands of Krause and Wolfring and **reflex secretion** to the main lacrimal gland.

Check Your Progress 2

What is the nervous control of the lacrimal system?

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9.4 TEAR FILM DYNAMICS

Functions of tear film are not only optical but also lubrication and protection. All these depend upon its constitution and dynamics.

9.4.1 Functions of Tear Film

The normal function of the eye is dependent on sufficient supply of tear fluid— a secretion comprised of aqueous, lipid, and mucus components. The tear film produced by the lacrimal glands smoothens out any irregularities in the cornea and acts as the first interface between air and a liquid medium.

The key functions of the tear film are to form and maintain a smooth refractive surface over the cornea, to keep the cornea and conjunctiva moist, to provide oxygen to the conjunctiva and cornea and to flush away foreign bodies.

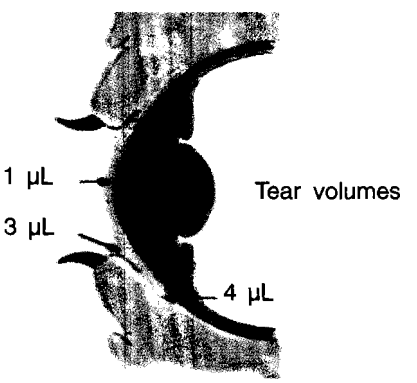


Fig. 9.4: Tear volumes

9.4.2 Physical Properties of Tear Film

The tear film is a three-layered structure:

a) **Outermost Layer: Lipid Layer**

This layer is secreted by the meibomian glands and is 0.1 mm thick. The main function it performs is to spread over the liquid layer and retard the evaporation of the aqueous layer and maintain the stability of the tear film.

b) **Middle Layer: Aqueous Layer**

Forms a bulk of the tear film and is secreted by the main and accessory lacrimal glands. It contains essential nutrients and substances necessary for the health and integrity of the cornea. It is approximately 7 mm in thickness.

c) **Inner Layer: Mucin Layer**

Mucin layer is secreted by the goblet cells of the conjunctiva. This layer is approximately 1 mm thick and functions to convert the hydrophobic corneal epithelium to hydrophilic, allowing the aqueous layer to spread over it.

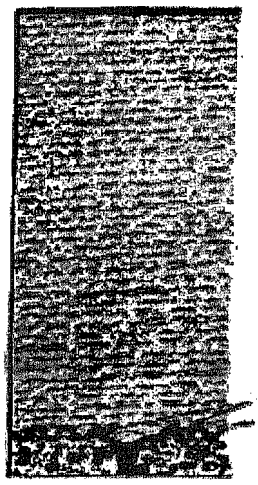


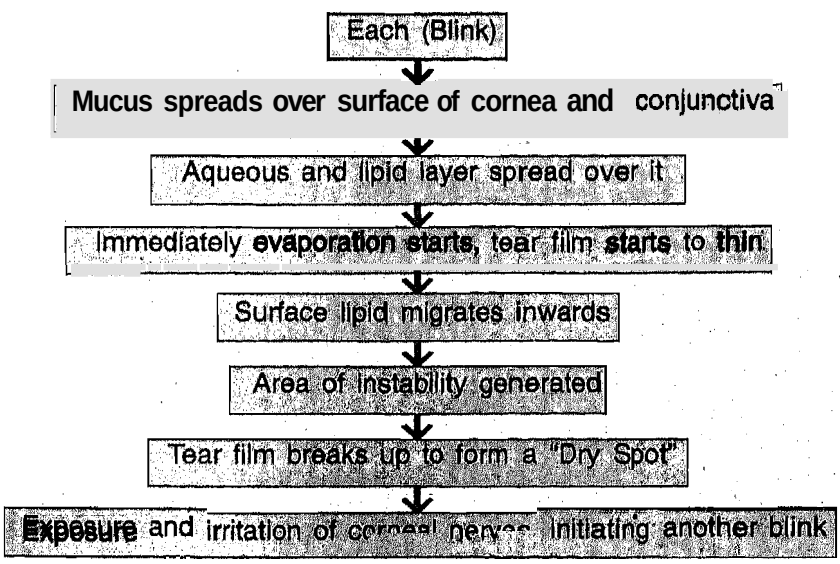
Fig. 9.5: Three layers of the tear film, drawn to scale

Table 9.2: Physical Properties of Tear Films

Composition	Water	98.2 %
	Solid	1.8 %
Volume	Unanesthetized	7.4 µl
	Anesthetized	2.6 µl
Thickness	Total	6.5 - 7.5 µm
	Lipid layer	0.1 - 0.2 µm
pH		6.5 - 7.6
Refractive Index		1.336
Electrolytes (mmol/l)	Na+	134-170
	K+26-42	
	Ca^{2}+	0.5
	Mg^{2}+	0.3-0.6
	Cl+	120 - 135
	HCO_3	26

9.4.3 Tear Dynamics

Tear dynamics is explained as under:



Ultimately, excess tears flow out of the eye via lacrimal canaliculi, lacrimal sac and Nasolacrimal duct.

9.4.4 Tear Film Dysfunction

An abnormality in tear film may occur because of a change in tear film constituents, a change in the composition of tear film, uneven dispersion of the tear film due to corneal-surface irregularities, or ineffective distribution of the tear film caused by an incompatible ratio of the eyelid to globe. The causes of dry eye are many—an aqueous deficiency due to Keratoconjunctivitis Sicca, inflammation, infiltration or a neuroparalytic condition; a decrease in mucin production due to vitamin A deficiency, trachoma, or chemical bums: a decrease in lipid production due to chronic blephritis or meibomianitis. Also, a lid surface abnormality and change in blink rate can occur due to entropion, ectropion, chemical burns, lid coloboma, or symblepharon, which prevent reformation of tear film.

Eticology of deficiency in each layer is as below:

Mucin Deficiency
(Fault in Goblet Cells)

GOBLET CELL DEFICIENCY	• Vitamin A deficiency
GOBLET CELL DESTRUCTION	• Alkali, acid and thermal burns Cicatricial pemphigoid Stevens Johnson syndrome • Trachoma • Trauma
DRUG INDUCED	• Echothiophate

Aqueous Tear Deficiency
(Fault in Lacrimal Gland)

CONGENITAL	• Familial dysautonomia – Riley-Day syndrome • Alacrima — absence of lacrimal gland • Paresis of 7th cranial nerve • Multiple Endocrine Neoplasia (MEN)
ACQUIRED	• Trauma : Injury, radiation, surgical removal • Inflammation : Sjogren's syndrome, Primary amyloidosis, RA, PSS, SLE, Polymyositis, Wegener's granuloma tosis, Mumps, Trachoma • Infiltration : Sarcoidosis, lymphoma, leukemia, amyloidosis • Drugs : Antihistamines, Antimuscarinics, GA's, Isotretinoin, Hydrochlorothiazide • Neuroparalytic : Brainstem, cerebello ponting angle and petrous bone lesions, sphenopalatine ganglion lesions

Lipid Abnormality
(Fault in Meibomian Glands)

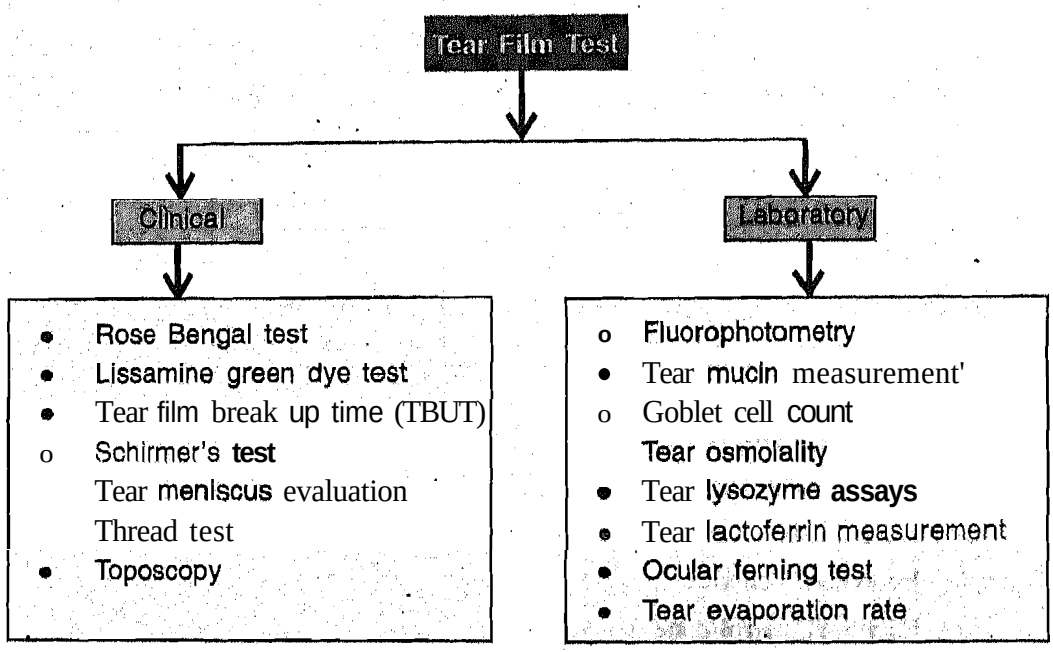
CONGENITAL	• Absence: Severe anhidrotic ectodermal dysplasia
ACQUIRED	• Blepharitis (FFA formation ↑ → tear film break up ↑) • Meibomianitis

Lid Surface Abnormalities

LID PROBLEMS	• Exposure keratitis • Entropion • Ectropion • Symblepharon • Large lid notches • Lagophthalmos
SURFACE IRREGULARITIES	• Dellen formation (Local corneal thinning)
	• 3 and 9 o'clock stain in hard contact lens wearers

Tests for Tear Film Dysfunction

Several tests can be done to test the tear film:



Commonly used tests in clinical practice include the Schirmer's Test and TBUT tests. Most of the other tests are complex, expensive or require a laboratory setting and hence are of academic interest alone and are performed for research purposes only.

Schirmer's Test

The Schirmer's test is performed for secretion analysis. It is done by using a 5 mm * 35 mm strip of Whatman's filter paper No. 41 (bent 5 mm from edge). The bent portion is placed in the lower fornix in both eyes for 5 minutes at the junction of medial 2/3rd and lateral 1/3rd of lid. Remove the strip and measure the wet part from the bent edge. This should result in the following:

Wetting of 11-25 mm: Normal/hypersecretion

5-10 mm : Borderline

< 5 mm : Secretion impaired,

TBUT Test

Another method to evaluate tear film is to perform the TBUT (Tear Film Break Up Time) test. This is done to measure tear film stability. First, one drop of 2 per cent Flurorescein is put in the eye and the patient is told to blink 2-3 times. Next, the patient is told not to blink and the eye is examined under cobalt blue light of slit lamp or ophthalmoscope. The TBUT is the time taken from the last blink to the appearance of a dry spot. A normal value is greater than 10 seconds.

9.4.5 Treatment of Dry Eye

a Goal: The goal is to lower the tear film osmolarity.

- Enigma: Treatment with artificial tears - with/without preservatives.
- The electrolyte content and balance of lubricating drops should match with that of tear film → otherwise epithelial toxicity and aggravation of goblet cell loss occurs — a clinical syndrome called medicamentosa.

Modalities:

SUPPLEMENTATION OF TEARS (WITH/WITHOUT PRESERVATIVES)	1) Artificial tear drops 2) Ointments 3) Inserts (Lacriserts)
PRESERVATION OF EXISTING TEARS	1) Goggle type treatments 2) Punctal occlusion 3) Bandage contact lens (BCL)
TEAR STIMULATION	1) Bromhexine
SURGERY	1) Tarsorrhaphy 2) Parotid duct Translocation
MISCELLANEOUS	1) Hot compresses 2) Lid hygiene 3) Tetracyclines

- **Artificial Tear Drops**
  1) Methyl cellulose and derivatives
  2) Hydroxyethyl cellulose
  3) Polyvinyl alcohol
  4) Polyvinyl pyrrolidone
  5) Dextran
  6) Hydroxypropylmethyl cellulose

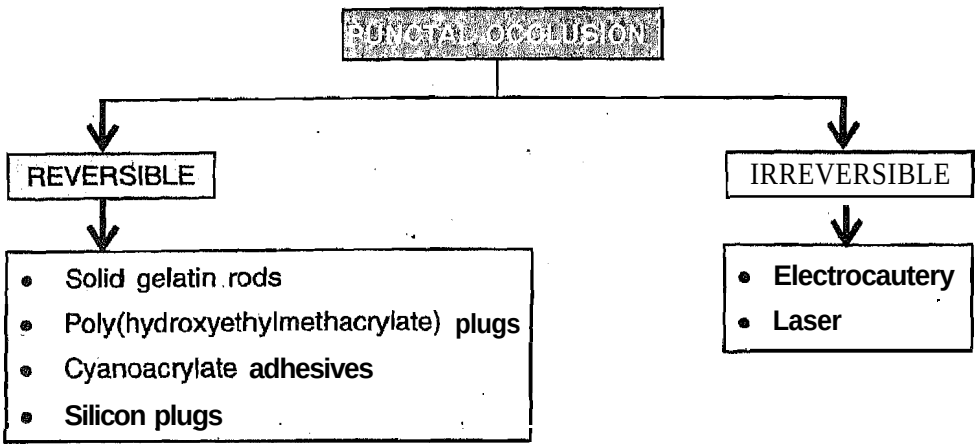
Low osmolarity drops (Hypotears) were considered useful but the effect on. tonicity is extremely brief. It is approximately 60-90 seconds.

Preservatives disrupt the precorneal tear film and damage the epithelial surface.

- Ointments: Ointment coat the tear film and retard evaporation.
- Lacriserts: Small pellets of 5 mg hydroxypropylcellulose in cylinder form are available. We place the pellet below the inferior edge of the tarsal plate so that it fails to pop out. The pellet absorbs tears and becomes a soft, like a gelatinous blob. It releases its polymer into the tear film and lasts for hours.

- **Goggle type treatments:** They form a moist chamber spectacles, which is as airtight as possible. This prevents tear evaporation. But this technique lack social acceptability.

Punctal occlusion: It is occlusion of puncta to retard tear drainage. It can be reversible or irreversible.



The mechanism of action is decrease in tear film osmolarity by:

a) Increasing the tear volume.

b) Decreasing the tear drainage.

Silicon plug insertion (Steps):

1) Punctum is dilated with a dilator of diameter 1.2 mm.

2) This is the minimum opening required for plug insertion.

3) Usually placed in lower punctum first; then in upper, if needed.

4) Plug has 3 portions:

   a) Dome portion: Sits over the lid surface.

   b) Middle shaft portion: Sits within the distal canaliculus.

Check Your Progress 3

1) What are the consituents of normal tear film?

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2) What is the filter paper used in Schirmer's test?

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3) How can existing tears be preserved?

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9.5 LET US SUM *UP*

In this unit you have learnt that the main function of the eyelids is to maintain the health of the ocular surface and to protect the eyeball. The LPS and Orbicularis

oculi are involved in the opening and closing movements. Aqueous tears are secreted by the main and accessory lacrimal glands. Basic secretion is controlled by the sympathetic system and reflex secretion is controlled by parasympathetic system. Tears are drained by the combined action of gmvity, capillary action, and lid movements (Lacrimal pump). Subsequently you have learnt that the normal function of the eye is dependent on sufficient supply of tear fluid — a secretion comprised of **aqueous,** lipid, and mucus components. The key functions of the tear film are to form and maintain a smooth refractive surface over the cornea, to keep the cornea and conjunctiva moist, to provide oxygen to the conjunctiva and cornea and to flush away foreign bodies. Dry eye is caused by keratoconjunctivitis Sicca, vitamin **A** deficiency, chemical burns, and blepharitis. In next unit you will **learn** about aqueous humour and intra ocular pressure.

9.6 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

i) Levator Palpebrae Superioris

ii) Frontalis

Check Your Progress 2

Parasympathetic and Sympathetic Nerve Fibres

Check Your Progress 3

1) Water—98.2 per cent Solid—1.8 per cent

Sodium, Potassium, Calcium, Magnesium, Chloride, Bicarbonate

2) Whatman's Filter Paper No. 41

3) i) Goggle Type Treatments

ii) Punctal Occusion

iii) Bandage Contact Lens (BCL)