CHAPTER - 1

INTRODUCTION
CHAPTER 1

INTRODUCTION

1.1 Definition and Types of Contact Lenses

Contact lens is an optical/therapeutic ophthalmic device. It is an aid to vision and acts as substitute for exterior surface of the cornea that can not be corrected by conventional spectacles.

Contact lenses (CL's) are small curved lenses which lie directly on the anterior segment of the eyeball that is on the cornea and bulbar conjunctiva and beneath the eyelids. Such lenses practically eliminate the cornea as a major refractive media and the refraction of light rays occur mostly at the anterior face of the lens. The lacrimal fluid in the space between the lens and the cornea fills the irregularities in the contour of the anterior corneal surface. Basically, there are two types of contact lenses.

i) Scleral lenses and
ii) Corneal lenses

Scleral lenses are made up of glass or plastic material poly methyl methacrylate, (PMMA), a derivative of acrylic acid. They are produced from a mould of the eye and cover the cornea and bulbar conjunctiva covering the sclera over the ciliary region. They are employed in condition where corneal contact lenses are not indicated like in some ophthalmic conditions such as corneal ulcers or burns, anesthetic cornea and entropion.

The drawbacks of scleral lenses are:-

i) These are difficult to insert and remove
ii) These can not be tolerated for more than 4-5 hrs

Due to these drawbacks these lenses are not used now a days.

Corneal contact lenses are lighter, unbreakable and safe as these are made of plastic and not glass. The diameter of the corneal lens varies from 11 to 13 mm.
Corneal contact lenses can be subdivided into:-

- **i)** Hard contact lenses (PMMA lenses) (Polymethyl methacrylate)
- **ii)** Semisoft contact lenses (CAB lenses) (Cellulose acetate butyrate)
- **iii)** Soft contact lenses (HEMA lenses) (Hydroxy ethyl methacrylate)
- **iv)** Disposable lenses (HEMA lenses) (Hydroxy ethyl methacrylate)
- **v)** Extended wear lenses [Medicated type]

The lens consists of central optical zone and narrow peripheral zone of about 1-2 mm wide with a slightly flatter curvature which allows a free flow of lachrymal fluid under the lens. Total surface area of the corneal lens is 16 mm.

### 1.2 Chemical Composition of Corneal Contact Lenses of Various Types:

Hard contact lenses are made up of Poly methyl methacrylate (PMMA). It can be prepared by polymerising Methyl methacrylate with cross linking agent such as Ethylene glycol dimethacrylate (EGDMA).

It has got good optical properties and is nontoxic. PMMA has excellent moulding and machining qualities but is practically impermeable to oxygen. The oxygen permeability and other properties of PMMA can be improved by copolymerising Methyl methacrylate with other monomers such as Methyl methacrylate styrene.

Methyl methacrylate alpha methyl styrene compared to PMMA, have higher light transmission, higher refractive index and lower density. The market share of hard contact lenses is now only 5%, due to their demerits, these lenses were not used in the present study.

Semisoft contact lenses also called gas permeable lenses and are made up of Cellulose acetate butyrate (CAB). This is a class of thermoplastics prepared by various treatments of purified cotton or special grades of wood cellulose. Cellulose which has got three free -OH groups in the repeat units can be converted to Cellulose acetate butyrate (CAB) with
Acetic anhydride and butyric anhydride Cellulose acetate butyrate (CAB) used for the manufacture of semisoft CL contains 26 to 39% butyryl and 12 to 15% acetyl groups. It has hard, stiff, strong, tough and has excellent moulding and machining properties. The market share is about 10% which is also not appreciable (1). Therefore these were also not used in the present study.

The molecular structure of the materials used in contact lenses are elaborated by Dada(1).

Soft contact lenses (Hydrophilic contact lenses) are made of hydrophilic material and was first discovered by Wichterle(1) in 1960. Several materials have been used in the fabrication of contact lenses. The first material used was glass however owing to its brittle nature it was soon dropped. With the progress of science and technology a large number of polymeric materials have been made available for the preparation which brought a rapid orientation in the contact lens industry. Materials used in contact lens industry should ideally have the following characteristics.

a) It should be biologically inert.
b) It should be non selective in the absorption of metabolites and toxins and not take part in enzymatic activity.
c) It should not exhibit strong molecular adhesive forces.
d) It should not show excessive electrophoretic osmotic properties.
e) It should have little friction effect between the surface of the material and the eye tissues.
f) It should have a high gas permeability
g) It should be compatible with the surface eye tissue electrical charges without a change of properties.
h) It should not change its properties within the normal biological range of pH.
i) It should not excite an inflammatory or immune response.
Most of the above characteristics are present in the materials used for making soft contact lenses hence these lenses were selected in the present study.

In 1950, Wichterle (1), a polymer chemist from Czecho-Slovakia conceived the idea of soft lenses while working on hydrogels for possible biological applications. The base of all soft contact lens is the hydrogel polymer. The term ‘hydrogel’ refers to a coherent three dimensional polymeric network that can imbibe large quantities of water without its dissolution. In these materials, the large water uptake occurs because of the presence of hydroxyl group in the monomers used.

The soft contact lenses, in contrast to hard contact lenses, are not dimensionally stable and swell in water to form a pliable soft lenses. The presently available soft lenses are mostly based on Poly (2-hydroxyethyl methacrylate) [PHEMA].

The other names of soft contact lenses are:
1) Hydron
2) Soflens
3) Geltakt
4) Spofalens
5) Hydrophilic contact lens
All are made up of Poly HEMA [PHEMA]

Poly HEMA is unique in itself as it is brittle if dry but soft and pliable when wet in water. Soft contact lenses have a market share of about 70 to 80%. Owing to their popularity, demand and merits over the hard and semisoft lenses (1-4), these were used in the present research work.

The photographs of various types of contact lenses are given in Fig. 1.
Hydrophilic Contact Lenses

1.3.1 Difference Between Hydrophilic and Hard Contact Lenses

Hydrophilic CL’s are synthesised by co-polymerisation of HEMA with ethylene glycol dimethacrylate (EGDMA). Its hydrophilic nature is in marked contrast to hydrophobic nature of PMMA and to a lesser extent to CAB. Its increased permeability to water oxygen and other constituents of tears having low molecular weight appears to offer metabolic advantages. Lenses of this type have high water level at equilibrium i.e. 40% to 85%. Gel lenses of different water content can be formed depending on the co-polymer used like EGDMA, PVP (Polyvinyl pyrrolidone) and other hydrophilic monomer.

The various differences between hydrophilic and hard contact lenses are given in Table 1.
Table I: Differences between Hydrophilic and Hard Contact Lenses

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Hard contact lenses</th>
<th>Soft contact lenses (Hydrophilic type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dimensionally stable</td>
<td>Dimensionally unstable</td>
</tr>
<tr>
<td>2.</td>
<td>Made up of PMMA</td>
<td>Made up of PHEMA</td>
</tr>
<tr>
<td>3.</td>
<td>Not swell in water</td>
<td>Swells in contact with water and swelling depends on various factors like medication, variation in tear flow and changes in the atmospheric conditions.</td>
</tr>
<tr>
<td>4.</td>
<td>Eye cannot tolerate these for more than 3 hrs.</td>
<td>Eyes can tolerate these for more than 7 to 8 hrs.</td>
</tr>
<tr>
<td>5.</td>
<td>Oxygen permeability is less due to the nature of the material.</td>
<td>Oxygen permeability is more due to the texture nature of the construction material.</td>
</tr>
<tr>
<td>6.</td>
<td>Exhibit strong molecular forces</td>
<td>Does not exhibit strong molecular forces</td>
</tr>
<tr>
<td>7.</td>
<td>Not very compatible with surface of the eye</td>
<td>Very compatible with surface of the eye</td>
</tr>
<tr>
<td>8.</td>
<td>There is a friction between the surface of the material and the eye tissues</td>
<td>There is no or very little friction between the surface of the material and the eye tissues.</td>
</tr>
<tr>
<td>9.</td>
<td>No problems of deposition (only merit)</td>
<td>Problems of deposition which may cause Giant papillary conjunctivitis (GPC), keratitis but can be solved by using multifunctional solution, proper lens hygiene and proper hygienic conditions</td>
</tr>
</tbody>
</table>

1.3.2 Chemical Composition, Production and Features of Hydrophilic Contact Lenses

Soft lenses based on PHEMA are resistant to biodegradation or attack by any enzyme present in the normal or abnormal tear and can withstand sterilization. The copolymerisation technique which not only increases the hydration level but help the lenses to withstand boiling or autoclaving.
Hence soft lenses are made up of hydrophilic monomer i.e. HEMA, cross linking with hydrophobic monomer or copolymer called ethylene glycol dimethacrylate (EGDMA) or Polyvinyl pyrrolidone (PVP) which is more hydrophilic than EGDMA although it is also a hydrophobic monomer (5). The chemical composition of hydrophilic contact lenses is given in Fig. 2.

\[
\begin{array}{c}
\text{CH}_3 \\
\text{H} & \text{C} & \text{H} \\
\text{C} = \text{O} - \text{O} - \text{CH}_2 - \text{CH}_2 - \text{OH}
\end{array}
\]

\[n\]

Fig 2: Structure of P-HEMA

This polymeric network is hydrophilic contact lens - the material which consist of hydrophilic polymer chains, joined by the bridges of cross linking compound. The number of bridges, or cross links, are small compared with the number of repeating units on the main polymeric chains. These cross links are responsible for the coherent structure of the system. A covalently cross linked hydrophilic polymer cannot dissolve, but it will swell by absorbing water. The tendency to swell, caused by the osmotic pressure of the polymer segments is opposed by elastic retractive forces arising as the chains between the cross links elongate. Ultimately an equilibrium between the forces due to osmosis and retractive forces is reached. This is referred to as equilibrium swelling of the gel under given conditions. This equilibrium swelling should occur equally in all three dimensions. The above mentioned properties are important in maintaining the optical quality of a particular lens. The amount of water that hydrogel can absorb depends on the number of hydrophilic groups and its kind and the amount of cross links in the network (i.e. cross link density). A higher water content of the hydrogel means higher permeability to water and water soluble molecules; the lower is the strength of the gel and more sensitive is the gel to the environment.

The degree of swelling of a gel can be changed by varying the chemical composition of the polymer, cross link density, pH, temperature and hydrostatic and osmotic pressure.

The presently available soft contact lenses are made using the following polymers:
HEMA (Hydroxy ethyl methacrylate)

Copolymers of HEMA + PVP (Poly vinyl pyrrolidone)

Copolymers of HEMA + EGDMA (Ethylene glycol dimethacrylate)

GDHPMA [Glyceryl (2, 3 dihydroxy propyl methacrylate)] + TEGDMA [Tetraethylene glycol dimethacrylate].

Glyceryl HPMA [2,3 dihydroxy propyl methacrylate] + TEGDMA

Copolymers of Propylene glycol monoacrylate.

Graft copolymer of Vinyl pyrrolidone onto Silicone rubber.

Soft CL's with 30-40% water content have refractive index of 1.52 and CL's with 70-80% water content have 1.38 as refractive index.

Polyelectrolyte complex hydrogel.

Complexes of Poly (Vinyl benzyl trimethyl ammonium chloride) also known as VBTAC with Poly (Styrene sulphonate) known as NASS.

Hydrophilic Monomer + Hydrophobic Monomer (Cross linking agent)

= Polymeric network

All these have been studied and used as contact lens materials. The water content can be varied between 30% to 75%. The refractive index of contact lens decreases with increase in water content.

General procedure is to combine hydrophilic monomer with the hydrophobic monomer which is also known as cross linking agent to give rise to a contact lens polymeric material called thermosetting plastic as shown above.

All these polymeric materials were investigated for their biological tolerance by implanting them subcutaneously. The histopathology of the skin and subcutaneous tissue did not show any inflammatory reaction. These results have proved beyond doubt that all these polymers are biocompatible. The lenses prepared from these polymers retained their shape and clarity on keeping them in water or saline. These results thus indicate the potentiality of HEMA—alkyl acrylate copolymers for soft contact lenses (1).
1.3.3 Advantages and Disadvantage of Hydrophilic Contact Lenses

Already the difference in the hard and soft contact lenses have been mentioned. The advantages and disadvantages can be summarized as :-

i) Soft contact lenses can be adopted easily particularly by first time wearers.

ii) They have maximum wearing time upto 10-12 hrs. compared to 6-8 hrs. of semisoft and 4-5 hrs. of hard contact lenses.

iii) They are most comfortable to wear due to high water level upto 70-80% with maximum oxygen permeability.

iv) The typical vision blurring associated with a transition from eye glasses to hard lenses is absent.

v) Field of vision is not restricted as in case of spectacles. It is also present in both hard as well as soft contact lenses.

Hence a gel lens is advantageous due to more comfort, minimum spectacles blur, least displacement, lack of entry of dust and particles behind the lens, quick adaptation with rare causation of flare, less photophobia, easy fitting and infrequent corneal staining.

The hydrophilic lens has following limitations:

i) They require far more care than their hard and semisoft counterpart. This is mainly due to the very basic nature of the material of construction which allows penetration of contaminants deep into the lens matrix. This sorption of contaminants leads to deposition of various unwanted components which lead to many complications like giant papillary conjunctivitis, microbial keratitis, decreased visual acuity, photophobia, ocular irritations, blepharospasm, redness, itching, watery mucoid, mucopurulent discharge.
ii) Apart from this if the lens is very loose or tight then there can be poor visual acuity limitation of correction (astigmatism), especially higher cylinders along with possibility of tearing and splitting.

The demerits can be overcome by the judicious use of proper lens care solution which is well formulated keeping in view the multifunctions the solution has to perform like cleaning, disinfecting, rinsing, soaking, lubricating, deproteinising and the maintenance of lens hygiene (4,6).

1.3.4. An Ideal Lens Care Regimen for Soft Contact Lens

The ideal lens care regimen for soft contact lenses are :-

i) It should remove all types of surface deposits like dirt, fats, tear deposits, protein and cosmetics.

ii) It should remove micro-organisms and its spores like bacteria, fungi, viruses and should provide maximum antimicrobial coverage.

iii) It should provide isotonicity to the lenses as well as hydration so that lenses remain in their optimum shape.

iv) It should be compatible with tears so as to provide maximum comfort.

v) It should not sensitize ocular tissue, should be free from all allergic syndromes.

1.3.5 FDA Classification of Hydrophilic Contact Lenses

The various groups according to FDA are given below:-

Gp I Contact lens is made up of 61.4% Poly (2 Hydroxy ethyl methacrylate) and 38.6% of Water and is known as Netrafilcon A.

Gp II Contact lens is made up of 30.0% Poly (2 Hydroxy ethyl methacrylate) and 70.0% of Water and is known as Lidofilcon A.
Gp III  Contact lens is made up of 55.0% Poly (2 Hydroxy ethyl methacrylate) and 45.0% of Water and is known as Bufilcon A.

Gp IV  Contact lens is made up of 42.0% Poly (2 Hydroxy ethyl methacrylate) and 58.0% of Water and is known as Etafilcon A (7,8).

The hydrophilic contact lenses can be classified as per FDA. The details are given in Table II.

Table II: FDA Hydrogel Classification

<table>
<thead>
<tr>
<th>Group</th>
<th>Water Content</th>
<th>Type</th>
<th>Other name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gp I</td>
<td>Low water content (38-45%)</td>
<td>Non ionic polymer</td>
<td>Netrafilcon</td>
</tr>
<tr>
<td>Gp II</td>
<td>High water content (64-79%)</td>
<td>Non ionic polymer.</td>
<td>LidoFilcon</td>
</tr>
<tr>
<td>Gp III</td>
<td>Low water content (38-45%)</td>
<td>Ionic polymer</td>
<td>Bufilcon</td>
</tr>
<tr>
<td>Gp IV</td>
<td>High water content (55-71%)</td>
<td>Ionic polymer</td>
<td>Etafilcon</td>
</tr>
</tbody>
</table>

1.3.6 Other Features of Hydrophilic Contact Lens Care System

From a vision and eye health perspective, the period of optimal lens performance (the useful life of the lens) may vary from days to years depending on the physical and chemical properties of the CL material, the lens wearing schedule, the age of the lens, the tear chemistry of the CL wearer, the environmental contaminants to which the lens is exposed, the mechanism of action of CL care system and most importantly, the patient compliance with lens care system instructions.

A disposable FDA Group IV (high water content) ionic soft contact lens is stored in all in one solution without first being cleaned after removal may have a useful life of only 2 weeks but, a rigid gas permeable CL which is cleaned daily with a surfactant combined with regular enzymatic protein removal, may have a useful life of several years or more because debris is simply deposited on the surface of a rigid gas permeable (RGP) lens rather than within the lens matrix itself. The useful life of all other CL’s would fall
somewhere in between these two extremes. For the purpose of classifying the physical properties of various soft contact lens materials, the U.S. Food and Drug administration has developed a classification system given earlier.

Generally speaking, non ionic soft lens polymers are preferable to ionic soft lens polymers because tear proteins, such as Lysozyme, which are overall positively charged molecules tend to bind electrostatically to the negatively charged surfaces of Group III and IV ionic materials. Thus, soft contact lenses made of Group III and IV ionic polymers tend to become deposited more quickly and heavily than non ionic soft lens materials. Hence preference is given to non ionic contact lenses.

1.3.7 Manufacturing Process of Hydrophilic Contact Lenses

Manufacturing of soft lenses involves methodologies like

(1) Spun Cast
(2) Lathe Cut
(3) Moulded

In spun cast a small amount of monomer is polymerised in a revolving mould. Outer surface of the lens is spherical Inner surface is aspheric and curvature depends upon speed of mould, amount of monomer, shape of mould and characteristics of the monomer. The lens is solid after polymerisation. It is then extracted in water for 22 hrs. to remove impurities of plastic. In lathe cut lens there is a greater flexibility in power, base curve and diameter for individual fitting which can be assumed by trial lens methodology, as in hard lenses. Lathe cut lenses are thicker and are difficult to duplicate. Lathe cut lenses are more preferred (1).

The photographs and sketch diagram showing the manufacturing aspect of spin cast and lathe cut soft contact lenses are given in Fig. 3 & 4.
Fig.3: Spin cast soft contact lens

Verification of soft lens is done by its overall diameter edges, surface qualities using hand magnifier. Base curve is measured by placing the lens over plastic templates of known radii (1).

1.3.8 Indications and Contraindications

With extensive use of contact lenses, fitters must have a clear concept of contact lens superiority for various indications.

I. Optical Indications: -

(1) Myopia: As compared to glasses, CL’S are better because of larger image, better transmission, little marginal aberration, larger field, brighter perception and avoidance of rim interference. In myopia, contact lenses are a little superior to glasses.
(2) Hypermetropia: Optically better corrected with CL's due to larger field, less marginal aberrations, better transmission, brighter image, little rim interference and less convergence compared to spectacles.

(3) Astigmatism: A corneal lens fills up the irregularities of the astigmatic surface, the irregular surface of the cornea is thus replaced by regular surface of contact lens.

(4) Presbyopia: Can be rectified using corneal lenses.

(5) Aphakia: CL's are better due to smaller magnification (8% compared to 33% in spectacles), wider field lens marginal aberration, more transmission, brighter field, less convergence.

(6) Anisometropia and Aniseikonia: Contact lenses provide a larger field, brighter and cleaner image due to the absence of aberration.

(7) Albinism: Contact lenses are better as they correct the associated myopic astigmatism, also better for the same reasons as in high myopia and astigmatism.

(8) Aniridia: Contact lens better corrects the associated ametropia transmission may be reduced through darker tint or painted iris lenses. There is immediate improvement in photophobia.

(9) Nystagmus: Contact lenses improve performance through better correction of the associated refractive anomaly, also decreasing the amplitude of nystagmus.

II. Therapeutic Indications:

Soft lenses have been found to be useful in the following diseases.

(1) Corneal Burns
(2) Indolent Ulcers
(3) Bullous keratitis
(4) Stevens-Johnson syndrome
(5) Neuroparalytic keratitis
(6) Exposure keratitis
(7) Corneal edema
(8) Corneal graft
(9) Pemphigus
(10) Kerato – conjunctivitis Sicca
(11) Descemetocele
(12) Trichiasis
(13) Symblepharon
(14) Leaking wound
(15) Small traumatic corneal wounds
(16) Recurrent erosions
(17) Dry eyes

Although hard contact lenses (PMMA) provide better visual acuity but in recent years soft lenses (2 hydroxy ethyl methyl methacrylate) are gaining ground over hard lenses, due to the advantages already mentioned.

III. Cosmetic Indications: -

The soft contact lenses can be used to hide the cornea or eye ball and provide good tinted or painted appearance. A deformed eye with useful vision is corrected by a painted lens with clear pupil bears the optical correction as in adherent leucoma.

Prosthetic indications include scleral lenses and corneal lenses. Contact lenses are also used by the actors as the colour of the underlying light coloured iris can be changed.

IV. Occupational Indications: -

The occupational indications are temperature variations wherein fogging of spectacles is avoided while shifting from cold or hot humid temperature, as contact lenses are at same temperature as the body. News casters and television actors, anchors are unable to avoid reflection that occurs with spectacles and here soft contact lenses can be used.
Contact lenses are also used by sports athletes as contact lenses have an advantage because of better performance, due to wider field, better optics and lesser hazards of serious injury compared to spectacles.

V. Diagnostic Tools: -

Contact lenses are used in different instruments where they are used to neutralize cornea to pick up its potentials or as markers. Soft contact lenses are also used in gonioscopy, fundoscopy and in electrodiagnostic procedures. The gel lenses are also used in research.

(1) Gonioscopy: This is to see angle, and to operate on angle in infantile glaucoma.

(2) Fundoscopy: It has a high minus central lens, neutralizes the cornea so that fundus can be viewed directly. It is much more comfortable if soft lens is placed underneath.

(3) Electrodiagnostic procedures: Electrode incorporation is used in the lens to pick potentials at the cornea, gold, silver or platinum wires can be used

VI. Research: -

CL's can be used in research for

(1) Stimulating accommodations with minus lenses.

(2) Relaxing accommodation with positive lenses.

(3) Noting the eye movements by seeing movements of reflected light.

(4) Temperature measurements: There are different applications of temperature measurement e.g.
(i) By implanting thermister through a haptic lens. This is a small ceramic device which creates different electrical potential with changes in temperature.

(ii) It is also done by noting changes in colour of heat sensitive crystals laminated with contact lens.

(iii) Measurement of lid pressure through planting a transducer on the front surface of haptic lens.

(5) Getting a stabilised retinal image through a scleral lens, used to neutralize small involuntary movements of the eye.

(6) Study of surface tension as it is affected by alteration of lens parameters.

(7) Experimental studies on animals for occlusion, hemianopic effects, to stimulate or relax accommodation and protection of the eye under anesthesia and also used as splints in corneal grafts.

Contraindications to soft contact lenses are acute and subacute inflammation of the anterior segment, infections of cornea and conjunctiva, lachrymal insufficiency, corneal hypoasthisia in early pregnancy and in systemic disease affecting the eyes.

1.3.9 Basic Guidelines for the Fitting of Hydrophilic Contact Lenses

The following basic guidelines for fitting of contact lenses in the eye common to all types of soft contact lenses may be adhered to get a good scientific start.

1. There should be 3 touch fitting i.e. one at corneal open and two at periphery.

2. Diameter of the lens is usually 12-15 mm which is at least 0.75 mm bigger than the 11-13 mm corneal diameter and hence smaller eyes require smaller diameter lenses and steeper base curve.
3. Soft lenses are fitted flatter than 'K' by 2.00 to 5.00 Diopter depending on the diameter of the lens.

4. In lathe cut lenses 0.50 mm increase in overall diameter, demands 1.50 D flattering of the base curve to achieve similar fit.

5. Bausch & Lomb contact lenses are spun cast in 13.5 and 14.5 mm diameter and lathe cut in 14 mm diameter. Soft lenses must fulfill the following criteria to give an ideal fit called as CMC i.e

\[ C = \text{Centering} : \text{Lenses must be centered well. There should not be more than 0.5 mm decenteration on any side.} \]

\[ M = \text{Movements} : \text{On blinking or looking up, movements should not exceed to 0.5 to 1.0 mm.} \]

\[ C = \text{Coverage} \]

6. In over refraction: Higher or lower minus lens indicates a steep or a flat lens, otherwise if lens power is proper then there is no need of steepness or flatness. Higher power means a steeper lens and lower power means a flatter lens. There should be optimum curvature. CL is a flattered curvature lens.

7. In visual acuity: It. should be uniformly clear before, during and after the blink. Flatter lens which fulfills all the above criteria is the ideal lens.

An ideally fitted lens should be well centered, comfortable and must provide crisp vision, proper corneal coverage and adequate oxygen supply to the cornea (1 - 4). The photographs of various fits of soft contact lenses are given in Fig. 5.

The various instruments used for checking the lenses are lens analyzer, lensometer and keratometer. The photographs are shown in Fig. 6.
Fig. 5: Various fits of the contact lenses in the eye
Fig. 6: Instruments used for checking of lenses
1.4 CONTACT LENS SOLUTIONS

1.4.1 A Brief Introduction to Soft Contact Lens Solutions:

The subject of a contact lens solution (CLS) is a broad one embracing the knowledge of a large number of chemicals and plastics and their properties and interaction in clinical use. The practitioner is concerned with the mechanism of action, efficacy, toxicity and use of drugs involved but the formulator is concerned with the antimicrobial activity of the basic drug, the interaction of the basic drugs and other pharmaceutical adjuvants with the plastic container, contact lens material and their compatibilities, shelf-life, stabilities, surface activities, wetting, lubricating and cushioning activities. The formulator is therefore, concerned with the patient or the contact lens wearer overall compliance (10).

During the early stages in the development of hydrophilic lenses it was thought that the hydrophilic nature of the surface would obviate the need for most solutions, since wetting agents were obviously unnecessary for the same reason and it was thought that the cleaning would also be unnecessary. However, as experience has been gained over the last few years the complexities of dealing with new materials for use in contact with eye has become increasingly apparent. Further, whilst the large majority of hydrophobic lenses are still made from a single material (PMMA), while hydrophilic lenses are made from many materials including different additives and widely varying physical and physiological properties.

Perhaps the most difficult problem that has arisen with hydrophilic lenses is that of sterilization. Fortunately a considerable number of conjunctival sacs do not contain pathogenic bacteria. Knoll (1972)(11) reported 5000 cases in which swabs were taken from conjunctival sac of apparently normal eyes and 47% of them showed no bacterial contamination in the sac. Other authors quote between 20-70% as the incidence of sterile conjunctival sacs. In general, the majority of the conjunctival floras are harmless saprophytes involved in the destruction of dead cells. Only 25% of conjunctival sacs appear to contain potential pathogens(11). Bacteria such as Pseudomonas aeruginosa are rarely found in the sac. Staphylococcus aureus is found more often but still only in the few
cases (2-15%). Even if an organism is a potential pathogen, it has been established that the conditions in the sac are likely to reduce the virulence of the organism. This is because of the:

(i) relatively low temperature of the eye than the body temperature.

(ii) action of the lysozyme of the tear

(iii) mechanical action of the blinking and slicing effect of the lacrimal secretion.

In addition to the physical and chemical factors inhibiting the pathogens, non pathogens also contribute to the protection of eye by competing with pathogens for nutrients. These factors combine to provide a relatively stable protective system for eye against infection but this protective mechanism of eye is disturbed in kerato conjunctivitis sicca due to insufficient or inadequate tears; exposure keratitis due to the inability of the lids to sweep the cornea and bandaging the eye which causes an increase in the number and virulence of the organism and discharge often being noted. Contact lenses unfortunately interfere with the eyes defence mechanisms. Hydrophilic lenses in particular prevent the lids from sweeping the cornea and interface with the tears washing the cornea.

They probably raise the corneal temperature and can also induce breaks in the corneal epithelium. In reports that appear in the literature of corneal infection - The contact lens wearers suffer from bacterial contamination which may be due to the lens contamination or the use of contaminated solutions. If the contact lens is new then it is very difficult for bacteria to enter into it but if it is old with ridges the bacteria can easily penetrate and spoil the lens (11). The tears liquid absorbed by lenses serves as an excellent bacterial culture medium.

Further, due to surface irregularities in the lens occurring during manufacture, the eye secretions adhere to the lens surface may permit a nidus to form where bacteria can aggregate and possibly be protected from disinfection process (12).

It was also pointed out by Pentley (1981) (13) that fungi can grow into hydrophilic lenses. Many researchers have shown penetration effect of Aspergillus fumigatus, and
Trichotecium roseum (mould found in tap water) into the polymeric network of hydrophilic contact lenses. The mechanism penetration is probably by means of enzymes present in micro-organisms which cause degradation of the lens material and permit entry for them. Therefore the lenses which show spots on or within the lens substance should not be dispensed even though they may not necessarily be fungal growth or mould, for example, rusting of ferrous particles in cosmetics use (12). Even though there is no apparent damage to the lens there is always a possibility that endotoxins synthesized by the fungus are bound within the plastic and hence disinfectants may not remove the toxins, bacteria or fungi. Therefore the solutions used for cleaning and soaking of contact lenses should be changed daily. Thus apart from antibacterial activity, the soft lens disinfection must also have a fungicidal capability (13).

A further problem occurring with hydrophilic lenses is that of deposits adhering to the lens surface. The main sources of these deposits are ocular secretions, tap water contaminants which may have been adsorbed by the lenses, eye drops, finger dirt, eye make up and contaminants introduced during manufacture and from the atmosphere. The bulk of deposits, however, are mucoproteins from the tear liquid. Also found are calcium, iron and other insoluble divalent and trivalent metal salts if impure water for storage or rinsing solutions has been used (14). Environmental and occupational factors also affect the cleanliness of lenses. Rusting ferrous particles are commonly seen in the surface of the lenses deeper if introduced during manufacture (or possibly from high speed projectile particles). Some eye drops containing Phenylephrine, Adrenaline or Barberine cause discolouration and some preservatives from sterilizing and hydrating solutions may concentrate in the matrix of soft lenses causing either discolouration or surface filming and consequently discomfort the lenses. The use of cosmetics such as lipstick, mascara, oily creams and shampoos may also contaminate the lens. Nicotine deposition on to the lenses in smoking persons is also observed. Further Wilson et al found fungal contamination in 12% of eye make up samples and bacterial contamination in about 43% of samples (14).

Repeated disinfection by boiling and to a lesser extent with chemical/disinfecting solution denature the surface mucoproteins, slowly building up a tenacious irregular surface layer.
This may cause symptoms of discomfort, lowered acuity, lens discoloration and conjunctival infection. For these reasons, the development has taken place for daily cleaning solutions to prevent surface deposits from building up and rejuvenating products to remove deposits already present on the lenses.

The eye may get infected by:

1) Dirty hands of the patients.

2) Contaminated flourescene solution.

3) Infected water used to clean the lenses.

4) The normal flora of the skin or infected skin of eyelid.

5) Infection from lacrimal sac.

6) Infection from surrounding air and

7) Saliva used for wetting.

The gradual build up of deposits on the lenses require a more effective cleaning treatment is required at periodic intervals depending on the patient, lens material, method of disinfection etc. Ganju et al (15) and Gasson (16) have shown measurable drops in UV and visible light transmission through many lenses only a few months old which had not been correctly cleaned. The light transmission of UV and visible light through old and new contact lenses are given in Table III.
### Table III: Light transmission through contact lenses (own readings)

<table>
<thead>
<tr>
<th>Age of contact lens</th>
<th>UV light transmission</th>
<th>Visible light transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>New CL</td>
<td>0.459</td>
<td>0.562</td>
</tr>
<tr>
<td>1 year old CL</td>
<td>0.243</td>
<td>0.325</td>
</tr>
<tr>
<td>2 years old CL</td>
<td>0.114</td>
<td>0.029</td>
</tr>
<tr>
<td>1 year old CL (deposits removed)</td>
<td>0.352</td>
<td>0.310</td>
</tr>
<tr>
<td>2 years old CL (deposits removed)</td>
<td>0.291</td>
<td>0.256</td>
</tr>
</tbody>
</table>

Although hydrophilic lenses offer many advantages over hard contact lenses but still some discomfort is experienced or temporary drop of vision occurs while the lenses are worn. The main demerit / disadvantage of hydrophilic contact lens is the deposition due to the construction of the material being used. The photographs showing the deposits on soft contact lenses are given in Fig. 7.
There may be some other physical discomfort while wearing hydrophilic contact lenses due to the inadequate tear formation and distortion or movement of the lenses.

The Pharmacist can control only the cleaning of dirty lenses and not tear formation and idiosyncrasies by providing a well balanced multi functional disinfection system. The solution should also be rehydrating type since sometimes drop in the environmental humidity causes a change in lens curvature resulting in discomfort and impairment of
vision. Study at R.P. Centre in AIIMS showed the presence of *Pseudomonas aeruginosa*, *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Aspergillus*, *Streptococcus* and *Candida* on the contact lenses (10). Such types of studies were also performed in other countries (10) as shown in Table IV.

Table IV: Common Micro Organisms found on contact lenses

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>U.K. Study Type of microorganism</th>
<th>U.S. Study Microorganism</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus albus</em></td>
<td>Protozoa:</td>
<td><em>Acanthamoeba polyphaga</em></td>
</tr>
<tr>
<td><em>Aspergillus species</em></td>
<td>Fungus:</td>
<td><em>Aspergillus fumigatus</em></td>
</tr>
<tr>
<td><em>Penicillium</em></td>
<td>Yeast:</td>
<td><em>Candida albicans</em></td>
</tr>
<tr>
<td><em>Streptococcus viridians</em></td>
<td>Gram –ve bacteria:</td>
<td><em>Pseudomonas aeruginosa</em></td>
</tr>
<tr>
<td><em>Pneumonococci</em></td>
<td>Gram +ve bacteria:</td>
<td><em>Staphylococcus epidermidis</em></td>
</tr>
<tr>
<td><em>Rhizopus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mucor</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Staphylococcus</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Diphtheroids</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mima Polynormpha</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.4.2 Soft Contact Lens Care Regimen Using Different Solutions

The usual sequence of events followed conventionally before the advent of multipurpose solution during soft lens wear and care initially:

i) Cleaning of the contact lenses after removal from the eye.

ii) Rinsing with a suitable saline rinsing solution.
iii) Disinfecting using another solution containing antimicrobial substance.

iv) Deproteinising gently so that no sensitization reactions occur and for this purpose enzyme tablet is used.

v) Lubricating with the lubricating solution.

vi) Soaking in preserved saline solution (15).

1.4.3 Multipurpose Solution for Hydrophilic Contact Lenses

Multifunctional solutions are generally intended to combine the actions of cleaning, storing, wetting and rinsing in one single lens care product. The rationale behind the manufacture of such solution is to avoid confusion of multiplicity and overall expenses of the conventional lens care solutions. Most contact lens practitioners came across patients who omit one or more steps of the hygiene regimen in using conventional lens care solutions simply because they run out of the appropriate solution. The basic components of combination cleaning and storage solutions are similar to the individual solution with these functions. Most cleaning ingredients are nonionic or amphoteric in nature (10). Wetting and storage solutions are similar to cleaning and disinfecting formulation but with a lower viscosity. The combination of different lens hygiene functions into multifunctional solution has elicited a discussion about a possible compromise of efficacy in these products. For example, the relatively high viscosity required for a mechanical buffer action is contrary to the low viscosity required for diffusion of surface contaminants into the storage solution. Further, solution viscosity of any degree would appear to retard bactericidal activity as shown by the poorer performance of all combination wetting and soaking solutions tested by Ruben (14) compared to soaking solution alone.

The very basic idea of formulating a multipurpose solution is to formulate a single step solution for contact lens wearers due to the non acceptance and non compliance of the traditional 5-6 steps solution by the wearer. Although contact lenses were introduced in the year 1961-62, their popularity was limited to a special class of people. This was mainly due to its old technology and high cost and the very difficult six steps maintenance
regimen (16) i.e. cleaning, disinfecting, rinsing, soaking, lubricating and wetting and deproteinizing.

The contact lens wearer previously had to carry out the six different steps using six different solutions and it was really cumbersome exercise and omission of even a single step could have led to serious consequences that included giant papillary conjunctivitis, microbial keratitis, corneal ulcer, inflammation of the eye, lagophthalmos, insensitive cornea, neuroparalytic keratitis, scarring of cornea / perforations and even permanent loss of vision.

Out of hard, semi soft, soft and disposable, the soft contact lenses have a market share of 70-75%. This parameter also prompted the authors to carry the present study on hydrophilic contact lenses and multipurpose solutions.

Despite several advantages and immense popularity of hydrophilic contact lenses. These require far more care than their hard counterpart. This is due to the very basic nature of material of construction which allows penetration of contaminants deep into the lens matrix. This sorption of contaminants leads to deposition of various unwanted components that leads to many complications. Soft contact lenses suffer from several disadvantages of surface deposits that tend to build up on its surface mainly dirt, lipids, proteins mucin, pigments, calcium salts, iron, mercury salts, chemical preservatives and microbial contamination that includes bacteria, fungi, yeast and protozoa. These deposits result in variety of problems mentioned earlier which may ultimately cause loss of vision. Disfigurement of soft contact lens may take place like change in curvature and diameter changes if storage conditions are not maintained. The contact lens solution which is multifunctional is actually all in one solution. In this solution six steps are clubbed to give a single solution(17).

1) **Ideal Multipurpose Solutions:**

An ideal multifunctional solution/multipurpose solution should contain the following properties:
(i) It should remove all types of surface deposits like dirt, fats, tear, protein, cosmetics and chemicals.

(ii) It should provide maximum anti microbial coverage against bacteria, fungi, yeast, virus and protozoa.

(iii) It should provide hydration, isotonicity to the lenses and keep it in an optimum shape.

(iv) It should be compatible with tears so as to provide maximum comfort.

(v) It should not sensitize eye tissues and should be free from all allergy syndromes.

II) Functions of Multipurpose Solutions:

The solution has to fulfill the diverse criteria of the lens care regimen like,

(i) Cleaning - to remove dirt, lipids, fats, cosmetics and pollutants.

(ii) Disinfecting - to provide antimicrobial coating

(iii) Rinsing solution - to rinse the lens after cleaning.

(iv) Soaking solution - to restore hydration and antimicrobial treatment and overnight storage.

(v) Lubricating solution - to lubricate and rewet the lens during wear. (vi) Deproteinising - to remove protein deposits (18).

III) Composition of Multipurpose Solution (Contents):

All six steps if carried out by different solutions in conventional cleaning regimen one by one then omitting even a single step can lead to serious consequences which may ultimately lead to loss of vision. Hence there is a need of single formulation that it should fulfill all the diverse criteria. The multipurpose -all in one- multifunctional solution should have:
Basic drug: Preservative and antimicrobial agents. Preservatives used in contact lens solution need to be effective against common Gram negative bacteria, fungi, yeast, without being toxic to the eye and without interfering with basic chemical action of the solution used. Preservatives used should be broad spectrum, nontoxic, rapidly acting, non allergic, non sensitizing, non irritating and compatible (chemically and pharmaceutically) with the other ingredients. Contact lenses should not alter the pH and tonicity of the solution. The preservative should pass MIMCT test (Multi item microbial challenge test in ophthalmic disinfecting testing) according to U.S.A. Pharmacopoeia standards.

Passing MIMCT test means absence of a number of micro organisms i.e. Gram +ve: Staphylococcus epidermidis (ATCC 6538), Gram -ve: Pseudomonas aeruginosa (ATCC 15442), Gram -ve: Serratia marcescense (ATCC 14041), Yeast: Candida albicans (ATCC 10231), Protozoa: Acanthamoeba and Mold: Aspergillus fumigatus (ATCC 10894).

Chelating agents: The Chelating agent should be capable of inactivating metals in a solution and enhance the effectiveness of the other agents. It should also prevent discoloration due to trace metals, prevent oxidation catalysed by trace metals.

Cushioning Agent: - These compounds are used as thickeners, protective colloids, binders, stabilizers and as suspending agents. Their primary purpose is to cushion the lens against the eye, Cushioning agents act by lubricating the lens and by providing the surface of the lens with the mechanical buffer for a short time after insertion of the contact lens in to the eye. Through this action they also prevent contamination from fingers. Cushioning agents are also good wetting agent because they increase the contact time of drugs on the surface of the eye. The examples of cushioning agents are methyl cellulose, Polyvinyl Pyrrolidone, Polyvinyl alcohol and Octoxynol.

Surfactant/cleaner: One of the most important aspects of any lens care regimen is the use of a prophylactic cleaning step in the normal daily hygiene routine to remove mucus, dirt, cosmetics and other environmental contaminants. From
microbiological point of view, a clean lens is far easier to disinfect than a dirty lens as the removed contaminants cannot inactivate the preservative. Furthermore, these deposits can build up in due course of time and are sufficient to interfere with the vision, lens wettability and wearing comfort unless adequate prophylactic cleaning is carried out daily. For formulating and developing multipurpose solution for contact lenses, a non toxic, non ionic cleaning agent has to be used for providing cleaning, rinsing, soaking, disinfecting and deproteinising action. Cleaning agent selected should not be a detergent type as should not be harsh to the contact lenses as well as should not damage cornea. Surfactants used can be Polysorbates, Poloxamers, Triton, Tyloxapol, Pleuronics and Polaxamine. The functions of daily surfactant contact lens cleaners are given below:

- Removes mucous, lipids and loosely bound protein deposits.
- Remove large number of all types of micro-organisms.
- Improve the effectiveness of enzymatic cleaners.
- Antimicrobial properties reduce the risk of infection
- Maintain good vision.
- Contact lens comfort.
- Extend useful life of all contact lenses.

Isotonic and Buffering Agents: Sodium and Potassium Chloride may be added to make the solution isotonic with tears. However the importance of isotonicity has been over emphasised in the past, especially for the small quantities involved on a contact lens and a range of 0.7-1.2% Sodium chloride equivalent is acceptable and is the normal range of tears (18-22).

Deproteinising Agents: Since most deposits on the lens are primarily protein deposits it seems logical that enzyme cleansers would be effective. Enzyme cleansers do not damage the lens, are non toxic and are fairly specific for lens deposits but they may have the potential for sensitising the eye. The protein bath may develop an odour after a few hours of use and enzyme preparations may
produce discolouration of the lens. The enzymes available are - Purified papain, Pancreatin and Trypsin. The non enzymatic protein cleansers are - Citrate and Hydranate™ and Tris buffer. Ideally, contact lenses should provide clear vision at all times, be completely comfortable and safe for extended wearing periods, not interfering with corneal metabolism, not cause ocular disease, be long lasting, easy to use and economical. Unfortunately such contact lens does not exist. One reason in this context is that pre corneal tear film layer of the human eye contains organic substances such as lipids, proteins, pigments, bacteria, viruses, environmental contaminants and inorganic substances, all of which interact with each other and the contact lens material to form a complex biofilm layer which binds to the contact lens material within minutes of placing the lens on the eye. This biofilm layer increases in thickness with each successive wearing period, eventually causing blurred vision, ocular discomfort, allergic eye diseases or potentially serious ocular infections. Non enzymatic protein cleansers are preferred due to the fact that these are non allergic. The basic functions of enzymatic and non-enzymatic protein cleaners are given below:-

- Loosen ionically bound protein deposits from each other and from the lens surface.
- Permits the mechanical removal of loosened protein deposits by friction rubbing.
- Pancreatin/citrates assist in removing mucoid and lipid deposits.
- Helps prevent giant papillary conjunctivitis.
- Maintains good vision and comfort.
- Extends the useful life of all lenses.

IV) **Goal of Contact Lens Care System:**

Ideally contact lens care system should maintain all types of contact lenses in a perfectly clean and sterile condition, not cause ocular discomfort or irritation, be simple and easy to use and economical. Development of such a solution for hydrophilic contact lenses titled
A multipurpose solution that comes very close to satisfy the above requirements has been formulated and more research work is underway in this field.

Contact lens care system is an integral and essential part of successful contact lens wear for optimal, physical, physiological and optical performance as well as safety of the eye and a contact lens should be perfectly clean and free of microbial contamination. The goal of the contact lens care system is to create a sterile environment. However, maintaining contact lens in a completely, clean and uncontaminated state, particularly while being worn is an impossible task for any contact lens care system regardless of its mechanism of action.

More realistically, over a given period of time a contact lens care system should be expected to maintain contact lens in a sufficiently clean condition and provide clear vision and good comfort, while at the same time, maintain sufficiently low levels of microbial contamination so that the eye will not be exposed to significant risk of infection. From a vision and eye health perspective, the period of optimal lens performance may vary from days to years depending on the following:-

(i) physical and chemical properties of contact lens material

(ii) lens wearing schedule (iii) the age of the lens

(iii) age of the lens

(iv) tear chemistry of contact lens wearer

(v) environmental contaminants to which the lens is exposed

(vi) mechanism of action of contact lens care system.

(vii) patient compliance with lens care system instructions.

An FDA group IV soft lens which is simply stored in multipurpose solution without first being cleaned after removal may have a useful life of only a few weeks. However, a rigid gas permeable contact lens which is cleaned daily with a surfactant combined with regular
enzymatic protein removal, may have a useful life of several years or more because debris is simply deposited on the surface of a rigid gas permeable (RGP) lens rather than within the lens matrix itself. The useful life of all other contact lens would fall somewhere in between these two extremes. For the purpose of classifying the physical properties of various soft lens material the U.S. Food and Drug Administration has given the classification mentioned in Table II (9).

V) **Advantages of Non Ionic Contact Lenses (Hydrophilic)**

Generally speaking, non ionic soft lens polymers are preferable to ionic soft lens polymers because tear proteins, such as lysozyme, which are overall positively charged molecules tend to bind electrostatically to the negatively charged surfaces of Gp III and IV ionic materials. Thus, ionic soft contact lens tend to become deposited more quickly than non ionic soft lens materials.

To increase the useful life of the lens, the deposits on the lens are to be removed. Cleaning of lenses maintains clear vision, good comfort and normal eye health.

Undesirable organic substances within tear film layer such as lipids, mucoproteins, albumin, immunoglobulins, glycoproteins, mucin and lysozyme combine with inorganic compounds, bacteria and micro organisms to form a complex biofilm deposit on contact lens surfaces within minutes of placing the lens on the eye. These deposits continue to build on the contact lens surface with each successive wearing period, eventually causing discomfort from mechanical irritation of the ocular tissues, as well as blurred vision as the optical quality of contact lens surface degrades. This biofilm can also act as an antigenic stimulus causing allergic lid reactions such as giant papillary conjunctivitis (GPC). GPC causes blurred vision, redness of eye, reduced wearing time itching, stinging, ocular discomfort and mucous discharge. Giant papillary conjunctivitis was more frequent in soft contact lens users whereas there are less incidences in case of disposable lens applications (9).

All contact lenses, particularly soft lenses absorb surface deposits, FDA group IV (high water ionic soft lenses) also absorb proteins (primarily lysozyme) into the internal lens
matrix. These lenses have a shorter useful life than lenses made from other polymers. GP IV soft lenses in use today are frequently manufactured as disposable lenses with replacement recommended after 2 weeks of wear. Loosely absorbed surface deposits on these and all lenses should be removed at the end of the day by mechanically rubbing the lens in the palm of the hand using a surfactant cleaner or all in one solution. Enzymatic cleaning on a daily or weekly basis removes the majority of proteins which have become ionically bound to the lens surface. Absorbed proteins in the matrix of soft contact lenses may partially be removed by overnight soaking in solutions containing surfactant cleaners.

In order for the cornea to remain transparent and in its normal state of deturgescence, it must receive sufficient quantities of oxygen from the pre corneal tear film. Even a perfectly clean contact lens is itself a barrier to oxygen, and absorbed lens deposits and tear proteins which act as further diffusion barriers to oxygen. Contact lens users who over wear soft contact lenses particularly heavily deposited lenses, run the risk of developing chronically hypoxic corneal tissues which if present for several weeks or more, cause edema, conjunctival hyperemia and limbal vascular injection. Changes in corneal tissues and curvature may also occur causing blurred vision due to changes in refractive error. The chronic corneal edema may also cause stinging, burning, reduced contact lens wearing time and abnormal eye fatigue - particularly at the end of the day. Patients with these symptoms often believe that they have an ocular infection or allergy to their contact lens solutions. These patients should be referred to their optometrist or ophthalmologist for evaluation and differential diagnosis.

VI. Method and Mechanism of Action of Contact lens Care System using Multipurpose Solution.

Contact lens care system titled multi solution has six major functions to perform i.e. cleaning, disinfecting, rinsing, soaking, wetting/ lubricating/ cushioning and deproteinsing as discussed earlier. However still weekly or monthly cleaning with enzyme tablet is important aspect.

Daily cleaning of contact lens surfaces is important to remove mucus, lipids and loosely bound protein deposits. Surface active cleaners are used either as a separate component in
multi-step contact lens care systems, or as an integral component of popular all in one solutions. Surfactants are amphipathic molecules with a hydrophobic chain and hydrophilic chain i.e. polar and non-polar ends. Surfactants have the property of accumulating at the interface between the contact lens surface and the lens deposit, displacing them from the lens surface. The hydrophobic end attaches to organic debris on the contact lens surface, while the polar end is attracted to water molecules, solubilizing the debris and floating it away from the lens surface. In addition to their cleaning action, surfactants exhibit their antimicrobial properties by disrupting the normal functioning of bacterial cell membrane. Hence surfactant cleaning is also an important part of contact lens disinfection process. Mechanically rubbing the contact lens in the palm of the hand for 10 seconds using a surfactant cleaner can remove up to 90% loosely bound lens deposits and microbial contamination. This improves the effectiveness of enzymatic cleaning and facilitates contact lens disinfection by dramatically reducing the number of microorganisms on the lens. Some surfactant cleaners may cause irritation of ocular tissues due to their ionic nature, while others such as Poloxamine are more likely to be compatible with ocular tissues due to their non ionic structure (23, 24).

Tear proteins such as lysozyme are large multivalent molecules containing both positive and negative local areas of charge. The positively charged sites on protein molecules can form ionic bonds with negatively charged surface of FDA group III and IV contact lenses binding proteins to the lens surface.

The most serious complication of contact lens wear is a sight threatening ocular infection. A number of potentially pathogenic microorganisms, normally exist in the eye as normal ocular flora without causing disease. However under the right conditions, opportunistic microorganisms can give rise to serious ocular infections. There are a number of foreign pathogenic microorganisms (viruses, bacteria, yeast, fungi and protozoa) which can inadvertently be introduced into the eye via contact lenses and hence disinfection is vital part of multipurpose solution. The most widely used methods of contact lens disinfection have been heat and cold chemical disinfection (23, 24).
The other functions of components of multipurpose solution is to provide rinsing and soaking effects of the contact lenses. The basic mechanism of rinsing process is to remove the foreign material and undesirable materials from the lens. The soaking aspect of the contact lenses is actually providing a suitable atmosphere for the storage of soft contact lenses for night period i.e. when the contact lens wearer do not wear it. Under the process the vitality i.e. shape, size, texture etc. of the contact lens is maintained. For providing such effects the multipurpose solution should have buffering capacity upto certain extent and it is to be isotonic along with the preservatives and other components.

Another effect of multipurpose solution is to provide a wetting / lubricating/ cushioning effect on the lens and these are generally provided by the inclusion of Hydroxy propyl, methyl cellulose (HPMC), Poly vinyl alcohol, Poly vinyl pyrrolidone and surface active agents.

VII. Successful Contact Lens Wear Using Multipurpose Solution: -

Successful contact lens wear depends on many factors. It is important to conceive the contact lens as only one part of the system. The other parts are lens care solutions (Multipurpose solution) and users environment. After consideration of factors that relate to indications and contra indications for lens wear, the practitioner must carefully select a lens polymer and care solutions appropriate to user’s needs, fit the lens and supply necessary instructions and follow up (9).

VIII. Interaction at the Boundaries Using Multipurpose Solution: -

For the development of multipurpose solutions it is very important to observe the interaction that occur at the contact lens / tear boundary, cornea / tear boundary and solute / solvent boundary.

This is an interfacial phenomena, which includes wetting, adsorption, surface tension reduction and micelle formation. Numerous factors must be considered when a solution is formulated for use in contact lenses. Various parameters for the formulation of contact lens solution include the followings:-
The eye tolerates a wide range of tonicity. The Sodium Chloride (equivalent) concentration of an ophthalmic solution may safely range from 0.7—1.5%. A wide pH range is also tolerated in the eye as well because of the following factors (19).

(a) tears have a neutralising action

(b) most ophthalmic solutions have a low buffer capacity when compounded in distilled water or isotonic saline.

(c) There is rapid tear production on instillation of an irritating substance into the eye.

(d) There is a relatively small amount of medication normally instilled into the eye.

IX. **Criteria for the Formulation of Multipurpose Solution:**

Multipurpose solutions are to be formulated in a very optimized way since single solution has to perform the job of six different conventional solutions earlier used. The cleaning contact lens solution has to be hypertonic to extract lipids, proteins, mucoproteins, dirt, cosmetics, micro organisms, and their spores but at the same time soaking solution has to be isotonic - to match with tears. Soaking solution if hypertonic will irritate the ocular tissues and there will be a feeling of foreign body sensation hence a multipurpose solution has to be balanced so that it becomes cleaning as well as soaking solution. The formulation of combined cleaning and soaking solutions include the components found in the individual solutions with these functions and with the exception of lower concentrations of viscosity building agents, the same comment may be made with reference to triple function of the second group of solutions. This lowered viscosity is necessary to allow both diffusion of the cleaning surfactant and to reduce the retarding
effect that solution viscosity of any degree has on the bactericidal activity of incorporated antimicrobial agents. It must be acknowledged that in multifunctional preparations some compromise has to be made in their formulation. This explains why one product is superior in one aspect say wetting or in cleaning and the other in deproteinsing or in soaking or in disinfecting. Hence the formulation of multipurpose solution (MPS) is an important task.

X. Disinfection / Sterilization and Other Aspects of MPS:

Before we proceed it may be appropriate here to mention that the thorough washing, soaking and drying of patient's hands immediately before insertion and removal of any contact lens is also an essential part of lens care routine with which the contact lens users must be fully conversant (Fig. 8). The instructions on lens care routine and its hygienic aspects should be meticulously carried out by the practitioner himself as it is too important to be delegated to auxiliary staff. Both verbal and printed instructions should be given to the users. If the user intends to use cosmetics he/she must be warned not to do before the lenses are inserted.

Cleaning can decrease deposit build up as well as decrease complications caused by deposits. It also aids the disinfection process by removing bacteria sometimes inactivate the preservatives in cold disinfection solutions. Protein can bind to preservatives and disinfectants and block their action. The protein coat on a lens can prevent the action of these agents by blocking their access to an organism. Thus, appropriate lens care can help prevent and remove deposits as well as enhance preservation and disinfection must be instructed that cleaning and disinfecting their hydrophilic lenses are two separate but essential
Holding contact lens

Inserting contact lens

Worn contact lens (off the centre of the eye)

Fig. 8: Wearing of contact lens
procedure in their daily routine. As pointed out by Stone (24) so aptly emphasised that it is pointless inserting a sterile lens covered with sterile contaminants which may mechanically irritate or abrade the tissues of the eye or lids and cause allergic problems.

On removal of the lens from the eye extra ocular contaminants (e.g., dust, cosmetic material, lipo proteinaceous matter adsorbed by the lens surface from tear fluid and meibomian glands) should be removed by cleaning before proceeding to the disinfection routine.

It is important also to remove this surface film contaminant, which may act as a media for the growth of bacteria and fungi in addition to protecting microorganism. embedded in it from disinfectant action of subsequent boiling of chemical solutions. This has been demonstrated by the reduced time required for disinfection routine.

Besides tear film constituents (e.g. protein, lysozyme, albumin, various salts including calcium) that form a lipoprotein surface film, other contaminants that may be adsorbed or absorbed on hydrophilic lenses are environmental pollutants such as nicotine, cosmetic ingredients, oils, finger dirt, chemical vapours, water impurities and the preservative and the active ingredients from ophthalmic products. The range of contaminants found will vary not only with the individual lens wearers, basic physiology, habits and environment but also with the material ingredients that influence the physical and chemical make up of the individual lens types. Some lens materials become cloudy and hazy with rough deposits accumulating and ordinary cleaning often fails to remove it. Some time the deposit in the form of white spots becomes visible to the naked eye.

The formulation of a hydrophilic lens cleaner that includes all such above criteria such as excellent cleaning ability for all types of contaminants, non binding detergents and preservatives, complete absence or minimal ocular irritation if accidentally transported to the eye; rinsed from the lens; sterile and isotonic, physically and chemically compatible with all soft lens materials, whilst at the same time not affecting their surface or optical qualities, is obviously a very difficult task but not impossible. Some compromise in one or more of these ideals has to be accepted. In addition, it is conceded that some are contra indicated with some materials, for example, it is probably advisable with high water
content lenses to avoid cleaners incorporated with thiomersolate as the small molecules of the latter can easily enter the fairly open pore structure of such lenses and leach out later on the corneal tissue during a day's wearing, possibly causing solution or chemical keratitis. Stone (24) indicated that in some countries like Japan this is the reason why mercurial compounds are banned in contact lens solutions. On the other hand, it is fair to comment that a summary of the extensive literature on this aspect has shown, that, to varying degrees, virtually all the common contact lens solutions preservatives including Chlorobutanol, Benzalkonium chloride, Phenylethyl alcohol, Methyl hydroxy benzoate (Methylparaben USP), Propyl hydroxybenzoate (Propyl paraben USP), Benzyl alcohol, Chlorhexidine as well as Thiomersolate, concentrate on hydrophilic lenses. Hence these were not used in the present research work.

For cleaning and disinfecting many compounds given in the literature were reviewed and experimentally tested in the formulation.

XI. Methods of Sterilization / Disinfection of Contact Lenses:

The contact lenses can be sterilized by means of heat and chemicals. Although heat disinfection by boiling in saline is an effective method of killing vegetative microorganism of all types, including the motile and cyst form of Acanthamoeba. It is also useful method for allergic contact lens wearer who may be allergic to chemical disinfectants and preservatives. A disadvantage of heat disinfection is that it cannot be used with rigid gas permeable lenses or FDA group II and IV (high water soft lenses) without permanently altering the physical parameters of the lenses. Soft lenses made from Hydroxy ethyl methacrylate can tolerate repeated heating, but even these lenses will eventually wrap as protein deposits denature on the lenses. Heat disinfection requires a heat unit, a heat resistant contact lens case and electrical power which is not always available. Heat is therefore rarely used today as a contact lens disinfection method (24).

The chemical disinfectants and preservatives which can be used in multipurpose contact lens solutions are:-
Hydrogen Peroxide

Hydrogen peroxide (25) was the first chemical disinfection system introduced for soft contact lenses in 1972. It is still in use today due to its effectiveness against virtually all microorganisms, safe to use with all soft contact lenses, and economical reasons. It is, however, more complicated to use than one-bottle systems. Hydrogen peroxide is a potent oxidizing agent, forming free radicals which attack microbial cell membranes and intracellular organelles resulting in cell death. A major disadvantage of hydrogen peroxide is its toxicity to ocular tissues in the concentrations used for contact lens disinfection (3-5%). It must therefore always be thoroughly removed from the contact lens prior to insertion into the eye; failure to do so will result in severe stinging and corneal epithelial damage lasting up to 48 hours. Hydrogen peroxide concentration may be reduced to safe non-irritating levels (50-100 ppm) by serial dilution with sterile saline, or by chemical neutralization by Catalase, Pyruvate, Thiosulfite or Platinum discs. Hydrogen peroxide systems do not normally contain preservatives or other anti-microbial agents, so they are well-suited for patients with allergic hypersensitivity to preservatives or anti-microbial agents. Hydrogen peroxide is also a cleaning and bleaching agent, removing pigment and discoloration from all types of soft lenses. Its cleaning action may be responsible for the improved comfort and increased wearing time which was found in soft contact lens wearers who have used hydrogen peroxide systems. This can not be used in one bottle system like in the multipurpose solution. Since it requires neutralization step as well (25).

Polyquaternium-1 (Polyquad™)

Polyquad™ is a polymer of benzalkonium chloride with low toxicity to ocular tissues. At a 0.001% concentration, it is an effective disinfecting agent against most Gram positive bacteria and algae but not the fungus Aspergillus. Its major advantage is its low toxicity and low incidence of allergic reactions. It is currently used in all-in-one solutions for soft and rigid contact lenses. Although a rare occurrence, one disadvantage is that the fungus Aspergillus may grow on lenses which have been stored for more than one week without changing the contact lens storage solution(9).
**Polyaminopropyl biguanide (Dymed™) and (PAPB™)**

Dymed™ is a cationic polymeric biguanide which is effective at 0.5 ppm against more microorganisms found on contact lenses. The major advantage of Dymed™ is that it has low corneal toxicity and does not appear to cause allergic reactions. It is therefore well-suited for use in simple, easy-to-use, all-in-one contact lens solutions. Polyaminopropyl biguanide as PAPB™ is 30-50 times more concentrated in contact lens solutions than other preservatives of second generation type. Its major advantage is that it is more effective against microorganisms, including *Acanthamoeba*. Its major disadvantage is its higher toxicity to ocular tissues in certain individuals (9).

**Polyhexanide HCl**

Polyhexanide HCl at a 0.0001% concentration is an effective chemical disinfecting agent against the microorganisms typically found on contact lenses. There have been no reports of corneal toxicity or allergic reaction to date. It is currently used in an all-in-one contact lens solution for soft and rigid gas permeable contact lenses. Polyhexanide™ has a faster kill rate than Polyquad™ for *S. marcescens*, *P. aeruginosa*, *S. epidermidis* and *C. albicans* (9).

**Alkyl Triethanolammonium Chloride (ATEAC) and Thimerosal**

ATEAC is effective against Gram positive bacteria but relatively ineffective against fungi, yeasts and Gram negative bacteria. It is used in combination with Thimerosal to increase its effectiveness against all microbial contaminants. ATEAC is toxic to corneal epithelium and tends to bind to high water lenses, thus enhancing toxicity. Thimerosal is an excellent disinfecting agent but stimulates allergic responses in significant numbers of contact lens wearers. Thus contact lenses disinfected with these chemical agents should be rinsed thoroughly with saline before insertion (9).

**Chlorhexidine**

Chlorhexidine gluconate is capable of killing most vegetative forms of bacteria, but is ineffective against the Gram negative microorganism like *Serratia* spp and certain yeasts.
and fungi. Thimerosal increases its antimicrobial activity but may cause allergic responses in certain individuals. Chiorhexidine binds to protein deposits which increases its toxicity to corneal epithelial cells causing punctate keratitis (9).

**Sorbic Acid**

Sorbic acid (sorbate) is a mild preservative used mainly in rinsing solutions. It is not sufficiently active as a disinfecting agent to be effective on its own. It also discolours soft contact lenses and stimulates allergic reactions. In many cases it is used with combination of Thiomersal.

Benzalkonium chloride (BAK) and Chlorobutanol are used as disinfectants and preservatives for hard (PMMA) contact lenses. BAK is not suitable for use with rigid gas permeable lenses as it binds to the siloxyanyl groups on the lens which interferes with surface wettability. BAK and Chlorobutanol are both toxic to corneal epithelium and must be thoroughly rinsed off the lenses before insertion (9).

**Second Generation Multipurpose Solution:**

Modern contact lens care systems have evolved to the point where virtually all patients can use them successfully the majority of the time with a minimum adverse reactions.

The multipurpose solutions which are used now a days generally contain polyquad™ and PHMB™. Apart from disinfectant activity the other five steps that include surface activity, lubrication, soaking, rinsing and deproteinizing effects are also desirable and hence generally such suitable constituents are included in the preparations.

The well formulated multifunctional solution therefore contains a disinfectant/preservative, surfactant, sequestering agent, buffers, isotonic agent, viscosity imparting agent, wetting agent and a deproteinizer (26).