Chemical Components of Contact Lens Solutions

V.J. Lum*
W.M. Lyle†

With the myriad of contact lens solutions on the market today, it becomes difficult to choose the appropriate contact lens system for the patient. Three major factors to be considered in the choice are safety, efficacy and cost. To determine the efficacy of a solution, an understanding of its components is required. Unfortunately, certain manufacturers are unwilling to disclose their formulations. The authors encourage practitioners not to use such solutions. Most manufacturers, however, do list the active ingredients.

Most solutions contain more than 95% purified water. Small quantities of preservatives, wetting agents, viscosity building agents, buffers, surfactants, cleaning agents and disinfecting agents are added to give the solutions different functions. These basic components are used time and again in various combinations and concentrations to make up new solutions. Each component will be discussed with respect to known efficacy and potential to cause adverse effects. It should be noted, however, that individual patient characteristics also play a factor in determining efficacy and safety.

With long term contact lens patients, cost may be an important factor in choosing the right solutions. This will also be discussed. Appendices I and II summarize the commercially available contact lens solutions in Canada, their components and approximate retail cost.

*B.Sc. (Pharm)
†O.D., Ph.D., School of Optometry, University of Waterloo

This study was made possible by a grant from the Canadian Optometric Education Trust Fund and was carried out at the School of Optometry, University of Waterloo.

PRESERVATIVES

Preservatives in contact lens solutions are to provide protection against chance contamination. Current evaluation of the antimicrobial activity of preservative systems, apart from manufacturers' studies have yielded conflicting results because of the lack of standardization in testing techniques.[1] More in-field evaluations of contact lens solutions are required to fully elucidate the effectiveness of preservative systems. However, the antibacterial effect of the individual components have been well documented. Benzalkonium chloride, alkyltriethanol ammonium chloride organomercurials, chlorhexidine, ethylenediaminetetra-acetate (EDTA) and its salts, sorbic acid and chlorobutanol are the usual preservatives in contact lens solutions at present. Other antibacterials used for disinfecting and cleaning lenses such as isopropyl alcohol, iodine and hydrogen peroxide are discussed in a later section.

Benzalkonium Chloride (BAK)

BAK is an antibacterial agent effective against both gram-positive and gram-negative bacteria. Its mechanism of action includes surface activity on living cell surfaces and interference with respiration and glycolysis of the organism.[2,3] The concentration of this preservative is especially important in determining its efficacy and safety in the eye. Too high a concentration may be injurious to the corneal and conjunctival epithelium and too weak a concentration may be ineffective in providing a germicidal effect.[4,5] The effect of BAK is cumulative; a single application may be well tolerated, but the second or third may produce irritation. Solutions of 0.02% are apparently well tolerated even when used three or four times daily.[6,7] BAK should not be used in soft lens solutions because of adsorption by the HEMA polymer and subsequent rapid release of the preservative causing ocular tissue damage. BAK is also adsorbed by CAB lenses but its clinical significance has not yet been determined.[8-11]

A 0.01% solution of BAK has been shown to be effective even against resistant strains of pseudomonas if given sufficient time.[12] However, its germicidal activity at that concentration is rather slow. Other antibacterial agents should be used in combination to enhance its effect.

BAK is also a cationic surfactant and can be used for its cleaning properties. Because of its ionic nature, many drug interactions are possible. BAK is incompatible with nitrate, thimerosal in certain concentrations, salicylate, fluorescein solutions, some local anesthetics and sulfonamides.[13] The bactericidal activity is also reduced in the presence of cotton, methycellulose, soaps, metallic ions and rubber.[6,14] Thus contact lens cases should be thoroughly rinsed of soap and rubber ring case liners should be avoided if optimum activity of BAK is to be obtained.

BAK is employed at minimum concentration in wetting solutions because it can decrease the wetting properties of polyvinyl alcohol. Conversely, polyvinyl alcohol can decrease the preservative activity of BAK.[15,16] Thus, wetting solutions for hard lenses are generally poor antibacterials. BAK can also enhance the transcorneal penetration of drugs.[13,17] Both EDTA and chlorobutanol are synergistic with BAK; the BAK/EDTA combination being the best system available at this time in polymethyl methacrylate contact lens solutions.

Adverse ocular reactions to even low concentrations of BAK are not uncommon. Most damage is fairly superficial (i.e. epithelial damage, conjunctivitis or disruption of the pre-corneal tear film) and is reversible after the drug is discontinued. However, punctuate keratitis, loss of endothelium, permanent vascular changes and corneal edema have been reported.[7,17,18] As well, retardation of epithelial regeneration can occur with the use of BAK[19].

Organomercurials

The two most commonly used organomercurials are thimerosal and phenylmercuric nitrate. These agents are primarily bacteriostatic and fungistatic but they have a notoriously slow rate of kill.[20-22] They act through the sustained release of the mercurial ion which penetrates into the bacterial cell and combines with the sulfhydryl groups of respiratory enzymes to inhibit metabolism.[23] Pseudomonas organisms can survive exposure to a 0.04% solution for longer than one week. The mercurial ion may also bind to other tissues such as the conjunctiva, cornea, and tear proteins so that it becomes unavailable to the microorganism.[6,22,23] Mercurial deposits are seen around blood vessels near the cornea, in the periphery of Descemet's membrane and possibly on the crystalline lens around the pupillary area.[17] However, mercurialentis has not been seen with thimerosal at concentrations of 0.005%.[17,26] Organomercurials are generally used at concentrations of 0.002% to 0.004%. The maximum concentration of thimerosal for use in the eye is 0.01% and that of phenylmercuric nitrate is 0.004%.

Thimerosal, a basic salt, can be inactivated by corneal fluids and must be used in neutral or slightly alkaline conditions. At a pH greater than 5.0, thimerosal does not bind to polyHEMA lenses.[11,27,28] Most soaking solutions are manufactured between pH 6-8. Phenylmercuric nitrate is not precipitated in an acid pH. However, phenylmercuric nitrate binds to soft lenses and is readily precipitated by halide ions.[29,30] Both agents are said to be incompatible with rose bengal and with BAK in certain concentrations.[14] Both agents are also reported to be inhibited by EDTA and are inactivated by rubber.[6,15,31,32] The effectiveness of the thimerosal and alkyl triethanol ammonium chloride combination is still controversial.[33,34]

Most adverse effects to the organomercurials are allergic. Chemosis, keratitis, conjunctival hyperemia, burning and irritation have been reported. Most of these adverse reactions are reversible upon discontinuance of these agents.[17,18,26] However, most reactions to combinations of organomercurials and E.D.T.A. solutions are probably toxic.

Chlorhexidine

Chlorhexidine is one of a number of biguanides with potent antiseptic activity. Chlorhexidine is effective against both gram-positive and gram-negative organisms although it is somewhat less effective against the latter. A solution of 0.005% was found to be bacteriostatic to both *Pseudomonas pyocyanea* and *Staphylococcus aureus*.[35] The agent disrupts the plasma membrane of the bacterial cell and is most potent at neutral or alkaline pH.[23,25] Chlorhexidine is a more effective germicide than thimerosal. However, at low concentrations (e.g. 0.005%) the clinical effectiveness of chlorhexidine is variable. Optimal activity is obtained when used in combination with thimerosal and EDTA, but soaking or disinfecting requires a minimum of four hours, preferably more (i.e. overnight).[36-39]

Chlorhexidine binds strongly to polyHEMA lenses especially in the presence of other adjuvants such as electrolyte or hydrophilic polymers.[11] However, its binding capacity is about one sixth that of BAK and a large percentage is absorbed by tear proteins which subsequently flow from the eyes via the canaliculi.[10,40-26]. Protein can also sequester and increase the concentration of chlorhexidine in a lens. Thus it is important to remove protein deposits regularly before soaking in chlorhexidine. Reports indicate that chlorhexidine can eventually cause lens filming, yellowing and decreased wettability.[37,42]

Chlorhexidine is incompatible with soaps, other anionic materials and fluorescein solutions. Cork, starch, magnesium, zinc and calcium compounds inactivate chlorhexidine.[23,35] Chlorhexidine is incompatible with many anions.[14]

With extended contact time, solutions of 0.005% appear non-cytotoxic to eye tissues. However, skin sensitivities, eye discomfort and irritation of the conjunctiva have been reported. Direct instillation may cause circumcorneal injection and conjunctivitis.[19,23,40]

Chlorobutanol or chlorbutol

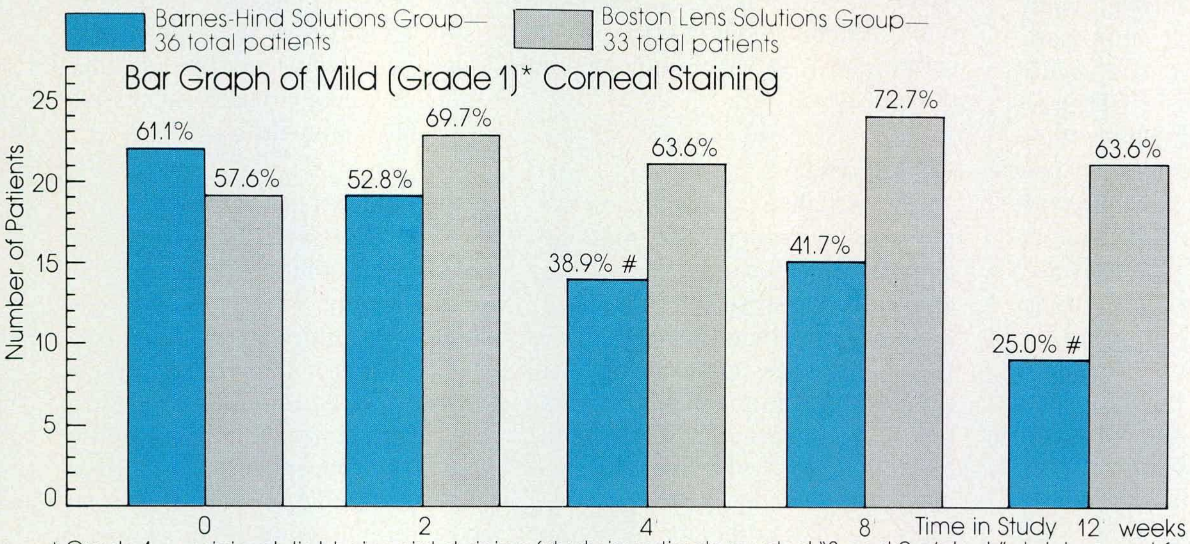
Chlorobutanol is used in only two contact lens solutions; Blink n Clean and Soquette. It is a volatile, relatively insoluble, slow-acting bactericide which has no advantages over BAK. Because of its volatility, exposed solutions may fall below effective concentrations.[41,42] It is also susceptible to thermal decomposition and cannot be autoclaved.[35] At concentrations greater than 0.35% chlorobutanol is bacteriostatic against both gram-negative and gram-positive bacteria. It also inhibits fungi and pseudomonas. It is bactericidal only when exposure is prolonged for more than 24 hours.[11] Chlorobutanol is effective only after it permeates into the bacterial cell. It is converted to an epitoxoid by the bacterium and thereby becomes lethal to the organism.[7,13]

Chlorobutanol is synergistic with phenols and quaternaries such as BAK, but it can only be used in solutions having a pH of less than 6 because of chemical breakdown to hydrochloric acid and other hydrocarbons (eg. carbon monoxide and acetone).[12,47,48] The use of chlorobutanol in Blink n Clean and Soquette is not appropriate since these

BARNES-HIND
SPECIFICALLY
THE BOSTON™ AND OTHER

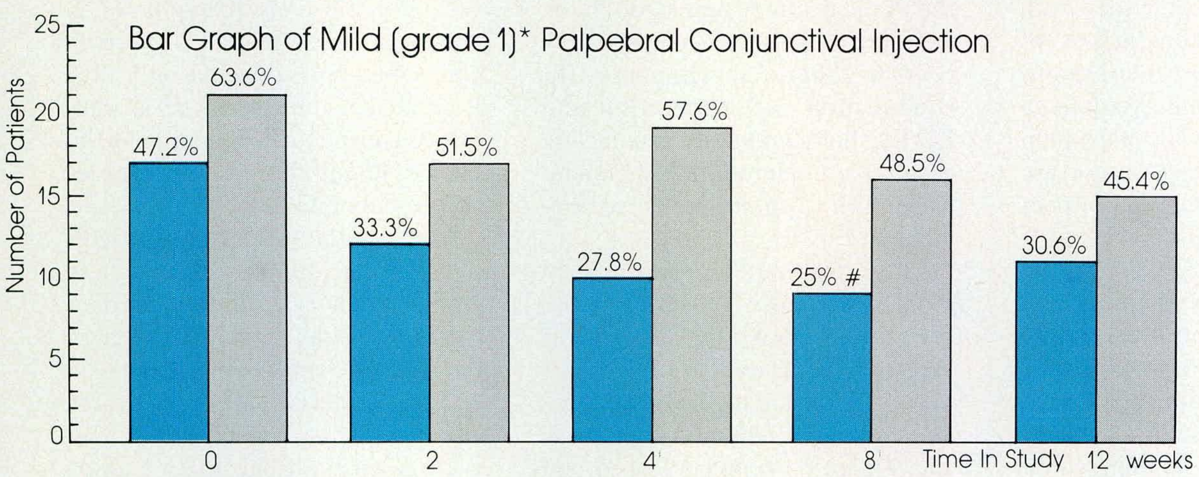
Clinical tests prove superior comfort and safety [1]

- Significantly reduced 3 and 9 o'clock staining
- Reduced the risk of corneal abrasion and ocular injection



* Grade 1 = minimal, light pinpoint staining (study investigators noted "3 and 9 o'clock" staining most frequently)

- Maximized comfort by reducing ocular redness and irritation
- Assures longer and more comfortable wearing times



*Grade 1 = mild, diffuse injection.

#The difference in performance of BH Wetting & Soaking solution & Boston Lens Wetting & Soaking Solution was statistically significant.

[1]controlled Clinical study of well adapted Boston Lens wearers
Data on file: Barnes-Hind Pharmaceuticals Inc.

SOLUTIONS-*
DESIGNED FOR GAS-PERMEABLE LENSES

Tests prove superior disinfecting ability

- Killed Pseudomonas and Staphylococcus 24 times faster than other leading disinfectants
- Reduces the risk of ocular infection

DISINFECTION END–POINTS

Microorganism	Barnes-Hind Solution	O_2 Care	Boston Lens Solution
1. Pseudomonas aeruginosa	Negative at 1 hour	Negative at 24 hours	Negative at 24 hours
2. Staphylococcus epidermidis	6 hours	6 days	6 days
3. Proteus vulgaris	4 hours	48 hours	5 days
4. Serratia marcescens	24 hours	4 days	4 days
5. Candida parapsilosis	6 hours	>5 days	>5 days

Tests prove outstanding cleaning ability

- Demonstrated excellence in cleaning the 5 major gas permeable lenses
- Maintains optimal oxygen transmissibility

For a complimentary supply of **BARNES-HIND STARTER KITS** for Hard Gas Permeable Lenses contact your optical wholesaler or **BARNES-HIND, Canada.**

*Barnes-Hind® Wetting & Soaking Solution & Cleaning Solution for Gas Permeable Hard Contact Lenses

BARNES-HIND®

BARNES-HIND CANADA
DIVISION OF BARNES-HIND PHARMACEUTICALS, INC.
1821 ALBION ROAD
REXDALE, ONTARIO M9W 5S8

solutions are manufactured at pH's greater than 7. The pharmacologic activity of ophthalmic medications is not reduced by chlorobutanol.

Prolonged contact with chlorobutanol solutions may cause epithelial damage to the cornea lasting several hours. Biochemical studies indicate that chlorobutanol inhibits oxygen utilization by the cornea and reduces epithelial adhesion to the basement membrane.[13,19]

Alkyltriethanolammonium Chloride (AKTAC)

AKTAC, like BAK is a quaternary ammonium compound. It acts as an antimicrobial agent, and a surfactant. However, its antimicrobial effects outweigh its surfactant property. The disinfecting action reported by the manufacturer is slow but effective.[14] A 0.03% solution of AKTAC was found to alter the physical parameters of a hydrogel lens by only a small amount over a period of 365 days. The water content of the lens increased by 9.0% and the refractive index decreased by 0.3%. These changes were found to be reversable upon saline soaking. Absorption of AKTAC into the lens matrix was minimal (solid/solution = 0.05 to 0.70)[37]

With respect to toxicity a 0.03% solution of AKTAC alone will cause corneal erosion in less than 6 hours. However, in formulation, no detectable corneal problems arise in greater than 180 days. AKTAC is apparently complexed or bound when in soaking solutions, thus minimizing toxic effects to the eye.

Cetylpyridinium chloride

This cationic disinfectant resembles cetrimide and might cause sensitivity reactions.[21] Concentrations should be between 0.001% and 0.01%.

Sorbic Acid

Sorbic acid is an antibacterial and antifungal agent. It is active against moulds and yeasts and to a lesser degree against bacteria. Sorbic acid is most effective at a pH of 4.5 and is not effective at a pH greater than 6.5. The use of sorbic acid in wetting and soaking solutions is not justified since the pH of these solutions is about 7. Its fungistatic activity is increased by the addition of acids and sodium chloride. It is effective as a preservative at concentrations of 0.1% to 0.2%.[3,23]

The concentration of sorbic acid in a polyHEMA lens is minimal and it diffuses freely from the lens to the surrounding fluid.[9] It is compatible with nonionic surfactants and is relatively nontoxic. However, irritation of the eyes and allergic dermatitis have been reported.[23]

EDTA and its salts

Ethylenediaminetetra-acetate is an antimicrobial agent which disrupts the integrity of bacterial cell walls by a detergent action.[12,37] It enhances the activity of BAK, chlorobutanol, chlorhexidine and thimerosal by chelating divalent calcium and magnesium ions which compete with preservatives for sites on the organism.[37,43,49] Some reports indicate that EDTA can antagonize the action of thiomersalate.[14] EDTA can also remove superficial calcium deposits from the eye at a concentration of 0.35% to 1.85%[50] As well, it possesses a weak buffering capacity[3] at pH 6 to 8. The salts of edetate, disodium edetate and trisodium edetate differ somewhat in solubility but do not differ significantly in capacity to chelate deposits.

Irrigation of the human cornea for periods of 15 to 20 min with a 0.01M solution of sodium edetate at pH 8.0 does not cause recognizable ocular damage.[13] However, conjunctival chemosis, hyperemia and irritation are possible and edema of the corneal stroma has been reported.[18,26] As a preservative the usual concentration of EDTA is between 0.01% and 0.1%.[12]

Wetting and Viscosity Agents

Wetting is an important phenomenon in the use of hard contact lenses. A wetting agent aids the spreading of a liquid over a solid surface by lowering the interfacial contact angle. The contact angle is the angle between a liquid droplet and the surface over which it spreads. An angle of zero degrees signifies complete wetting and an angle of 180 degrees signifies lack of wetting. Wetting agents are colloidal surfactant molecules of irregular shape with polar and non-polar groups. With a hydrophobic solid such as a contact lens, the wetting agent adsorbs onto the surface such that the polar groups face the liquid making the surface appear more hydrophilic.[3,51,52] The critical surface tension of PMMA is 39 dynes/cm. Commercial plastics may have other additives which bring the critical surface tension up to about 41 to 42 dynes/cm. To obtain maximum wetting of the plastic, a contact lens solution must have a surface tension of less than 39 dynes/cm.[3,46]

Soaking solutions commonly contain the same preservatives as wetting solutions but the concentration may be greater in the soaking solution.

The human tear film is an amazing fluid. It wets and hydrates the cornea, provides an optically smooth curved surface, provides a source of nutrients, has buffering capacity and antibacterial activity. The probable wetting agent in the tear film is sialomucin, a high molecular weight glyco-protein. This is secreted by the goblet cells and is spread over the cornea by the blinking action of the lids. The surface tension of mucin is 38 dynes / cm and it is an excellent wetting agent for PMMA, provided lipid (i.e. meibomian gland secretions and sebum) is not coating the lens.[53] Some feel that the tears are such good wetting agents that a wetting solution is not required while others feel that wetting solutions may lessen the symptoms of some patients who suffer from an overproduction of lipids which disrupt the mucoid layer.[54-57]

The three most commonly used wetting agents are polyvinyl alcohol (PVA), polyvinyl pyrrolidone (povidone or PVP) and adsorbobase povidone. These are all synthetic polymers which have lipophilic and hydrophilic groups. They mimic the action of mucin by orientation of the lipophilic group towards the contact lens and the hydrophilic group towards the tear film.[51]

A 1.4% solution of PVA has a surface tension of 47 dynes/cm. Commercially available solutions have lower surface tension due to the presence of other surfactants such as BAK and the use of partially acetylated PVA. The higher the residual acetate, the greater the surface activity. However, in alkaline pH, this form of PVA can decompose into polyvinyl alcohol and acetic acid which irritates the eyes. Thus many wetting solutions are adjusted to a pH between 5 and 6.[16,53,58,60] PVA also has some viscosity building effect and unlike some viscosity agents (e.g. methylcellulose) does not retard the regeneration of the corneal epithelium.[12]

A 1% solution of PVP has a surface tension of 68 dynes/cm. The presence of PVP is reported to greatly reduce the chemical binding characteristics of the soft lens without reducing antibacterial activity.[11,61-63] However, its wetting capacity is less than that of PVA.

Adsorbobase povidone is a product of Alcon/BP. The exact structure has not been released for proprietary reasons. This polymer has mucomimetic properties and is capable of forming a hydrophilic coating on solids. However, it has very little surface activity. The surface tension of Adapt is 53 dynes/cm.[53,58,59]

The effect of wetting agents is not long lasting; generally about 5 to 15 min. They aid in reducing the foreign body sensation on insertion of the lens. They are fairly inert chemicals but may slightly retard healing of the corneal epithelium, and may reduce excess mucus on some eyes.[26,56] Allergic reactions to PVA have been reported.[18,63]

Viscosity building agents are large colloidal molecules dispersed in a liquid to give greater resistance to flow. This imparts a cushioning effect which acts as a shock absorber and a lubricant between the lens and the eyelid and the lens and the cornea. These agents are indicated when the tear film is thin and easily disrupted. Use of viscosity agents in soaking solutions is not recommended since the diffusion of lens contaminants into the solution is retarded.[57,65]

The two most commonly used viscosity agents are methylcellulose and hydroxyethylcellulose. Thixotropic gels may be used as vehicles for cleaning agents. Thixotropy refers to the ability of some gels to decrease in viscosity upon agitation.

Methylcellulose is a long-chain cellulose polymer in which, on an average, two hydroxyl groups in each hexose unit have been methylated. By varying the length of the polymer chain, wide variations of thickening capacity have been obtained. The viscosity range is from 10 to 15,000 centipoises (soft gel) for 2% solutions.[60,66] Methylcellulose is nonionic and therefore stable over a wide pH range. There is practically no limit on the alkaline side (stable to pH 12), but on the acid side (below pH 2) the viscosity drops. Temperatures greater than 50°C cause precipitation of the macromolecule in water.[66]

Methylcellulose is nearly inert chemically and is entirely compatible with the drugs commonly used topically on the eye. Methylcellulose will form complexes with most of the hydroxybenzoates.[21] Growth of micro-organisms is not supported by methylcellulose.

Hydroxyethylcellulose is another synthetically modified cellulose, in which the hydroxyethyl group is the substituent. Like methylcellulose, it is nonionic and water soluble. Various viscosity grades can be obtained by varying the chain length. The viscosity dispersions in water are unaffected by pH variations between 5 and 10. Unlike methylcellulose, hydroxyethylcellulose is not precipitated from water by elevated temperature.[66]

Adverse effects of the cellulose derivatives are few although granulation on the eyelids and conjunctiva is possible under dry conditions. Corneal edema has also been reported to occur with the instillation of methylcellulose.[16,43]

Buffers

Buffers are compounds or mixtures in solution which resist changes in pH upon the addition of small quantities of acid or alkali. The magnitude of the resistance of a buffer to pH changes is referred to as the buffer capacity and depends on the amount and type of buffer added.[3,51]

Buffers are used in contact lens solutions to stabilize the components and improve comfort on instillation. Normal tears have a pH of 7.4 to 8.0 and possess a high buffering capacity due to their protein constituents.[67] The instillation of one or two drops of solution into the eye stimulates the flow of tears and the rapid neutralization of any excess hydrogen or hydroxyl ions within the capacity of the tears.[46,67] In general, solutions of pH 6 to 8 can be readily tolerated.[46,67,68] Thus, solutions which are acidic or alkaline (to insure ingredient stability) should be unbuffered or minimally buffered such that rapid neutralization by the tears can occur upon instillation.[16,60]

The following buffers are used in contact lens solutions at present: sodium carbonate, boric acid, sodium borate, sodium citrate, EDTA salts, potassium bicarbonate, sodium bicarbonate, sodium phosphate and disodium phosphate. Most of these buffers have only weak buffering capacity. Buffers can also be used along with sodium chloride to make solutions isotonic. The disodium phosphate and sodium phosphate system has the greatest buffering capacity and provides a choice of pH ranging from 5.9 to 8.0.[3,67] However, one author advocates the use of a borate buffer system on the basis of patient acceptance.[5]

Irrigation of rabbit eyes with weak buffer solutions showed no corneal damage. Only when these solutions are excessively alkaline or acidic can corneal damage occur.[26] A clear solution of borate buffers will react with PVA forming a gummy precipitate. Thus mixing of solutions with these components is not recommended.[5,16,160]

CLEANING AND DISINFECTING AGENTS

Surfactants

Surfactants or surface active agents are composed of molecules with polar and nonpolar groups. Like polymers they can also lower interface tension. They exert a cleaning action by solubilizing unwanted particles through micelle formation. Micelles are aggregations of 50 to 150 single surfactant molecules oriented in a near spherical structure such that the polar groups are oriented towards the water while the nonpolar groups are oriented in toward one another. The daily accumulated residue of oil and sebaceous deposits on contact lenses become entrapped in the nonpolar centres of the micelle and thus become solubilized. The effectiveness of the surfactant depends on the degree of polarity of the groups.[51] Physically rubbing the lens helps to loosen the particles and rinsing frees the lens of the surfactant and solubolized deposits. Surfactant based cleaning products will effectively retard deposit formations if used vigorously and regularly but are incapable of removing previously formed deposits.[69-71] Adequate cleaning of lenses facilitates disinfection of the lens and helps to prevent accumulation of deposits on the lens surface.

The classification of surfactants is arbitrary, but one based on chemical structure is most popular in the pharmaceutical industry. The major polar groups found in most surfactants are (1) anionic (negatively charged) (2) cationic (positively charged) (3) amphoteric (positively and negatively charged) and (4) nonionic (no charge). Only anionic and nonionic surfactants are listed in the presently available contact lens solutions.

Anionic surfactants such as sodium lauryl sulfate react with cations such as calcium, magnesium and BAK by forming precipitates; thus their effect may be limited in hard water which is high in ion content. As well, solutions containing BAK should not be used in conjunction with these surfactants. Generally anionic surfactants are less stable than nonionic surfactants.[3,16,43]

Nonionic surfactants such as poloxamer 407 are advantageous with respect to compatability, stability and potential toxicity. There is a wide range of choices and they generally function quite well as cleaners.[3]

Because cleaning of the lens is performed while the lenses are off the eye it is possible to employ somewhat stronger agents than would be safe directly on the eye. Surfactant solutions should be thoroughly rinsed from the contact lens and hands since chemical keratoconjunctivitis, stinging, allergic reactions, conjunctival hyperemia, eyelid edema and injection can occur. As well, a surfactant residue may produce a permanent coating on the lens if the lens is subjected to repeated heat disinfection treatment.[18]

Enzyme Cleaners

Papain is a proteolytic enzyme derived from the fruit of the tropical melon tree, *Carica papaya*. The enzyme exhibits broad spectrum specificity. Peptides, amides, esters and thioesters are all susceptible to papain-catalyzed hydrolysis.[3] Papain has no deleterious effects on the lens polymeric matrix and is effective in retarding the formation of protein deposits and removing some previously formed protein deposits.[68-76] Papain may be more effective when used with heat disinfection.[77] This occurs because the enzyme attacks denatured protein more readily and the heat (temperatures from 40-60°C) denatures protein more easily than chemical disinfectants. Papain is ineffective against lipid, lipid-protein complexes and non-proteinaceous deposits.[24]

Papain can adsorb onto HEMA lenses and cause adverse ocular responses. Burning, pain, photophobia, conjunctival hyperemia, punctate keratitis, corneal edema, giant papillary conjunctivitis, and chemosis have all been reported. Thus thorough rinsing of the lens after enzyme cleaning is important.[16,18]

Isopropyl Alcohol

Isopropyl alcohol is a disinfectant and solvent. As a cleaning agent, it solubolizes lipid and proteinaceous build-ups[78,79] It is compatible with both hard and soft lenses but adsorbed into soft lenses. Thus the solution must be thoroughly washed out and the lens soaked in saline to remove residual isopropyl alcohol. Severe burning and corneal epithelial damage is possible if isopropyl alcohol is allowed to contact the eye.

Hydrogen Peroxide

Hydrogen peroxide acts as a germicide which is active by the release of nascent oxygen. It is a very short acting compound for the reason that this release occurs rapidly. The effervescence caused by the release of oxygen affords a secondary mechanical means for the removal of debris from the matrix of the soft lens.[3,78] Lens expansion helps to crack deposits. Thus, the removal of proteinaceous build-up can be facilitated by hydrogen peroxide. Cleaning the lens with a surfactant, followed by thorough rinsing and then ten (10) minutes of soaking in 3% hydrogen peroxide, disinfects the lens.

Hydrogen peroxide is decomposed by practically all organic matter and other reducing agents. Light accelerates its decomposition.[3,23] However, decomposition to water and oxygen by a catalyst (Septicon Disc) is important in reducing the concentration of the peroxide in the lens to an ocularly acceptable level. A severe burning sensation will be experienced if hydrogen peroxide comes into contact with the eye. However, according to Gasset et al. instilling 3% hydrogen peroxide into the eyes three times a day for 5 days did not initiate any damage.[80] Reports concerning the effect of hydrogen peroxide on contact lens integrity vary. Some authors report no increased rate of deterioration while others indicate there is gradual deterioration.[81]

Iodine

Elemental iodine in the form of solutions is widely used as a germicide and fungicide. Unfortunately, in aqueous solutions it is ineffective against spores.[3,78] When iodine is solubilized in the presence of surface active agents it is known as an iodophor.[82] Only a few drops of an iodophor solution are required to disinfect a lens. A slow acting (2 to 4 hours) neutralizing solution must also be added to reduce the iodine to the iodine ion.[70,78] There is a potential for iodophors to stain high water content lenses.[38,83] Iodine vapors can irritate and stain the corneal epithelium. If inadvertently instilled into the eye the corneal epithelium will slough off and the eye will be temporarily painful and inflamed.[26]

Improper methods

Patients should be warned not to attempt lens cleaning or disinfection by use of unauthorized methods. Some have used toothpaste, laundry detergents, dishwater detergents, hair shampoo, and skin cleansers with harmful effects on the eyes and on the lenses.

COST

Regular lens cleaning and changing of storage solutions is very important in obtaining optimum results in the care of contact lenses. However, compliance to the proper use of solutions may be hindered because of high costs. The cheaper solutions are not necessarily the best to recommend, but selecting a care system of lower cost could help to persuade the patient to carry out proper lens hygiene.

Many solutions are completely interchangeable; they have the same constituents, in the same concentrations, and may even be manufactured by the same plant. Yet the cost difference between interchangeable solutions may be as much as $2.50 per bottle. Table I summarizes the solutions which are interchangeable.

The suggested retail costs as of July 1981 from Drug Trading Company, a major pharmaceutical wholesaler in Ontario, are tabulated in the appendices. The exact pricing of products may vary from pharmacy to pharmacy, but the suggested retail costs are used as a guide. The costs were calculated assuming use of the solutions in the largest available sized container. The estimates used in determining cost are listed in Table 2.

Conclusions:

The components of the contact lens solution determine its effectivity, its reactivity with other solutions or materials and potential to cause adverse ocular reactions. Careful consideration of the components and cost of the contact lens solution is suggested before selecting the care system for the patient.

TABLE I (Interchangeable Products)

Hydrocare Tablets	*	Soflens Cleaning Tablets
Hydrocare Cleaning and Soaking Solution	*	Soflens Soaking Solution
Allergan Saline Solution	*	B & L Saline Solution
Hydron Comfort Drops	*	Hydrosol
Hydron Cleaning Solution	*	Hydroclean
Hydron Soaking Solution	*	Hydrosoak
B & L Daily Cleaner	*	Preflex
B & L Lens Lubricant	*	Adapettes
Flexcare	*	Normol

* interchangeable with

TABLE 2 (Estimates for Cost)

Products	Volume/period of time
Lubricant and rewetting drops	3 ml/week
Cleaning solutions	4 ml/week
Wetting solutions	3 ml/week
Soaking solutions	5 ml/week
Gel cleaners	1.75 g/week
Heat disinfecting solutions	5 ml/day
Salt tablets	30 tab/month
Rinsing solutions	4 ml/week
Hydrogen peroxide	7.2 ml/day
Lensrins	14.4 ml/day
Enzyme cleaners	2 tab or packets/week

APPENDIX I

Hard Contact Lens Solutions

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservative	Other	Approximate Cost/Mo.**
(1) Lubricating/Rewetting Solutions					
Adapettes (Alcon/BP)	rewetting	Povidone 1.67% water soluble polymers	thimerosal not exceeding 0.004% edetate disodium 0.1%	buffers unspec.	$3.18
Adapt (Alcon/BP)	preinsertion	adsorbobase povidone	thimerosal not exceeding 0.004% edetate disodium 0.1%		$3.10
Aquaflow (Cooper)	rewetting		benzalkonium chloride 0.0002%		$2.51
Blink n Clean (Allergan)	rewetting cleaning (within eye)	polyethylene glycol 300	chlorobutanol 0.5%	polyoxy 40 stearate buffers	$2.95
Comfort Drops (Hard) (B-H)	rewetting	wetting agents unspecified	benzalkonium chloride 0.005% edetate disodium 0.02%	nonionic surfactant	$2.67
(2) Cleaning Solutions					
Boston Lens Contact Lens Cleaner (Polymer Tech. Corp.)	cleaning			anionic sulfate surfactant	$1.17
Cleaning Solution Gas Permeable (B-H)	cleaning		thimerosal 0.004% edetate disodium 2.0%		$1.46
Clens (Alcon/BP)	cleaning		benzalkonium chloride 0.02% edetate disodium 0.1%	poloxane derivatives sodium phosphate	$1.01
D-Film Cleaning Gel (Cooper)	cleaning			nonionic detergent	$4.88
Gel-Clean (B-H)	cleaning			thixotropic gel - nonionic surfactants	$3.94

***Based on Drug Trading Co. (Toronto) suggested retail cost to the patient as of July, 1981.*

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservative	Other	Approximate Cost/Mo.
LC-65 Solution (Allergan)	cleaning		thimerosal 0.001% edetate disodium	buffering and stabilizing agents	$1.95
Titan (B-H)	cleaning	viscosity building agent unspec.	benzalkonium chloride disodium edetate	nonionic surfactant buffering agent	$1.54
(3) Wetting Solutions					
Hy-Flow (Cooper)	wetting	wetting agent unspecified	benzalkonium chloride 0.01% edetate sodium	mildly hypertonic	$0.97
Liquifilm Wetting Solution (Allergan)	wetting	polyvinyl alcohol methylcellulose	benzalkonium chloride 0.004% edetate disodium	NaCl KCl	$0.72
Wetting Solution (B-H)	wetting	polyvinyl alcohol	benzalkonium chloride 0.004% edetate disodium 0.02%		$0.68
(4) Soaking Solution					
Soquette (B-H)	soaking	polyvinyl alcohol	benzalkonium chloride 0.01% chlorobutanol 0.4% disodium edetate 0.2%		$4.21
(5) Cleaning and Soaking Solutions					
Clean N Soak (Allergan)	cleaning soaking		pherylmercuric nitrate 0.004%	buffers	$5.61
Cleaning and Soaking Solution (B-H)	cleaning soaking		benzalkonium chloride 0.01% disodium edetate 0.2%	cleaning and buffer agents unspec.	$5.00
Duo-Flow (Cooper)	cleaning soaking		benzalkonium chloride 0.013% edetate sodium 0.25%		$6.33
(6) Wetting And Soaking Solutions					
Boston Lens Soaking and Wetting (Polymer Technology Corp.)	wetting soaking				$5.19

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservative	Other	Approximate Cost/Mo.
Soaclens (Alcon/BP)	wetting soaking		thimerosal not exceeding 0.004% edetate disodium 0.1%	hydration factors	$5.02
Wetting and Soaking Solution Gas Permeable (B-H)	wetting soaking	wetting agent unspecified	thimerosal 0.002% chlorhexidine gluconate 0.003% edetate disodium 0.02%	isotonic buffered vehicle	$5.40
(7) Multifunction Solutions					
Lensine-5 (Cooper)	cleaning wetting soaking cushioning rewetting	polyvinyl alcohol hydroxyethyl-cellulose PEG 6000	benzalkonium chloride edetate disodium	poloxamer 407 NaCl KC1	$13.00
One Solution (B-H)	wetting cleaning soaking	wetting agent unspecified	benzalkonium chloride 0.01% edetate disodium 0.03%	isotonic, cleaning agent unspec.	$5.70
Total (Allergan)	wetting soaking cleaning	polyvinyl alcohol	benzalkonium chloride edetate disodium	buffers unspec. isotonic	$8.71

APPENDIX II

Soft Contact Lens Solutions

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservatives	Other	Approximate Cost/Mo. **
(1) Lubricating/Rewetting Solutions					
Adapettes (Soft Lenses) Alcon/BP	rewetting	povidone 1.67%	thimerosal not exceeding 0.004% edetate disodium 0.1%	water soluble polymers buffers	$3.34
Clerz (Cooper)	rewetting		sorbic acid 0.1% edetate disodium 0.1%	poloxamer 407 Na Borate 0.2%	$2.87
Hydron Comfort Drops (Hydron)			thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate 0.0025%		$1.81

***Based on Drug Trading Co. (Toronto) suggested retail cost to the patient as of July, 1981.*

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservatives	Other	Approximate Cost/Mo.
Hydrosol (Contactisol Ltd.)	preinsertion wetting		thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate		$2.07
Soflens Lens Lubricant (B&L)	rewetting	povidone	thimerosal 0.004% edetate disodium 0.1%		$3.00
Soft Lens Comfort Drops (Alcon/BP)	rewetting		thimerosal 0.004% edetate disodium 0.1%	nonionic surfactant buffer	$2.83
(2) Cleaning Solutions					
Hydroclean (Contactisol Ltd.)	cleaning		thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate 0.0025%	surfactants unspecified	$2.81
Hydron Cleaning Solution (Hydron)	cleaning		thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate 0.0025%		$2.79
Lens Cleaner (Softcon)	cleaning		thimerosal 0.004% edetate disodium 0.1%	cleaning agent (unspecified)	$1.64
Mira Flow (Cooper)	cleaning		isopropyl alcohol 20%	detergent	$4.33
Pliagel (Cooper)	cleaning		sorbic acid 0.1% trisodium edetate 0.5%	poloxamer 1.5% unspecified surfactants	$2.81
Preflex (Alcon/BP)	cleaning	hydroxyethyl-cellulose polyvinyl alcohol	thimerosal 0.004% edetate disodium 0.2%	phosphate buffer NaCl, tyloxapol isotonic	$1.41
Soflens Daily Cleanser (B&L)	cleaning	hydroxyethyl-cellulose, poly-vinyl alcohol	thimerosal 0.004% edetate disodium 0.2%	Na Phosphate buffer, NaCl, isotonic, tyloxapol	$1.37
Softcon Lens Cleaner (Softcon)	cleaning		thimerosal 0.004%	isotonic	$2.20
Soft Lens Cleaning Solution (B-H)	cleaning		edetate disodium 0.2% thimerosal 0.004%	nonionic surfactant	$1.46

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservatives	Other	Approximate Cost/Mo.
Soft Lens Weekly Cleaning Solution (B-H)	cleaning		thimerosal 0.001%	surfactants	$2.44
(3) Chemical Disinfecting Solutions					
Flexcare (Alcon/BP)	rinsing soaking disinfecting		thimerosal 0.001% edetate disodium 0.1% chlorhexidine 0.005%	Na Borate Boric Acid NaCl	$2.63
Flexsol (Alcon/BP)	storage disinfecting	adsorbo base povidone	thimerosal 0.001% edetate disodium 0.1% chlorhexidine 0.005%		$3.51
Hydrocare Cleaning & Soaking (Allergan)	soaking cleaning		thimerosal 0.002% alkyl ethanol ammonium chloride	surfactant in special polymer vehicle	$4.00
Hydron Soaking Solution (Hydron)	storage disinfecting		thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate 0.0025%		$3.94
Hydrosoak (Contactisol Ltd.)	storage rinsing sterilizing		thimerosal 0.0025% EDTA 0.1% chlorhexidine gluconate 0.0025%		$3.46
Normol (Alcon/BP)	rinsing		thimerosal 0.001% edetate disodium 0.1% chlorhexidine 0.005%	NaCl	$2.43
Permasol (Cooper)	storage wetting irrigation		sorbic acid 0.1% disodium edetate 0.1% thimerosal 0.001%	sodium borate 0.22% poloxamer 407	$4.55
Soflens Soaking Solution (B&L)	soaking		alkyl triethanol ammonium chloride thimerosal 0.002%	surfactants in a special polymer vehicle	$3.09
Soft Lens Rinsing & Storage (B-H)	rinsing storage		chlorhexidine gluconate 0.005% thimerosal 0.001% edetate disodium 0.2%	buffers unspec.	$2.86

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservatives	Other	Approximate Cost/Mo.
(4) Thermal Disinfecting and Rinsing Products					
Alcon/BP Saline Solution	heat disinfecting rinsing storage		thimerosal 0.001% edetate disodium 0.1%	boric acid Na Borate NaCl 0.7%	$3.12
Allergan Saline Solution	heat disinfecting rinsing storage		thimerosal 0.001% edetate disodium	NaCl	$4.36
Aquaflex Tablets (Union Optics)	heat disinfecting			NaCl 270 mg./ tablet	$0.58
Barnes-Hind Saline Solution	heat disinfecting rinsing storage		thimerosal 0.001% edetate disodium 0.1%		$3.90
Bausch & Lomb Saline Solution	heat disinfecting rinsing storage		thimerosal 0.001% edetate disodium 0.1%	NaCl buffers unspec.	$4.42
Bausch & Lomb Salt Tablets	heat disinfecting			NaCl 250 mg./ tablet	$0.68
Boil N Soak (Alcon/BP)	heat disinfecting rinsing storage		thimerosal 0.001% edetate sodium 0.02%	boric acid Na Borate NaCl 0.7%	$4.78
Hydrocare preserved Saline (Allergan)	heat disinfecting rinsing storage		thimerosal 0.001% edetate disodium 0.01%	NaCl 0.85%	$4.36
Pliasol (Cooper)	heat disinfecting rinsing		sorbic acid 0.1% edetate disodium 0.1%	Na Borate 0.2%	$3.03
Soft Lens Buffered Tablets (B-H)			edetate disodium	buffers unspec. Na Bicarbonate NaCl 270 mg./ tablet	$0.65
(5) Enzyme Cleaners					
Clean-O-Gel (Alcon/BP)	protein remover			bacterial enzyme extract	$4.76
Hydrocare Tablets	protein remover			papain 10 mg.	$2.98
Soflens Cleaning Tablets	protein remover			papain	$2.60

Product (Manufacturer)	Suggested Use	Wetting And Viscosity Agent	Preservatives	Other	Approximate Cost/Mo.
(6) Disinfecting Systems					
Lensept (Softcon)	disinfecting		hydrogen Peroxide 3%		$2.76
Lensrins (Softcon)	rinsing		thimerosal 0.001% edetate disodium 0.1%	NaCl 0.85% buffers unspec.	$2.76
Septicon Disc (Softcon)	neutralizing hydrogen peroxide				$1.09
Pliacide (Cooper/Flow)	disinfecting		0.12% iodine		$4.79
Nutraflow (Cooper/Flow)	neutralizer for pliacide		sorbic acid 1 mg./ml edetate disodium 0.1%	Na Borate 0.2%	$5.55

References

1. Richards R.M.E. The antipseudomonal activity of contact lens solutions. *J Pharm Pharmac.* 27:381-382, 1975.
2. Dabezies O.H. Contact lenses and their solutions: A review of basic principles—Part II, *Eye, Ear, Nose, and Throat Mon.* 45(2):68-72, 1966.
3. Hoover J.E. and A. Osol (Eds): Remington's Pharmaceutical Sciences, 15th ed. Easton, PA, Mack Publishing, 1975.
4. Swan K.C. Reactivity of the ocular tissues to wetting agents. *Am J Ophthalmol.*27:1118-1122, 1944.
5. MacKeen D.G. and K. Bulle. Buffers and preservatives in contact lens solutions. *Contacto*, 21(6):33-36, 1977.
6. Lamy P.P. and R.F. Shangraw. Contact Lens Products in Kleinfield, C. Ed. Handbook of Nonprescription Medications, Washington D.C., Am. Pharmaceutical Assoc, 1979.
7. Mandell R.B. Contact Lens Practice: Hard and Flexible Lenses. 2nd ed. Springfield, Ill. Charles C. Thomas, 1974.
8. Lemp M.A. Bandage lenses and the use of topical solutions containing preservatives. *Ann Ophthalmol.* 10(10):1319--1321, 1978.
9. Petricciani R. and J. Krezanoski. Preservative interaction with contact lenses. *Contacto*, 21(3):6-10, 1977.
10. Lieblein J.S. Overview of soft contact lens hygiene. *Rev Optom.* 115(4):29-32, 1978.
11. Sibley M.J. and G. Yung. A technique for the determination of chemical binding to soft contact lenses. *Am J Optom Arch Am Acad Optom.* 50:710-714, 1973.
12. Dabezies O.H. Contact lens hygiene: Past, present and future. Contact Lens Medical Bulletin 3(2):2-15, 1970.
13. Havener W.H. Ocular Pharmacology 4th ed, St. Louis, C.V. Mosby, 1978.
14. Stewart-Jones, J.H., G.A. Hopkins and A.J. Phillips. Drugs and solutions in contact lens practice and related microbiology in Contact Lenses. Vol I ed by J. Stone and A.J. Phillips, London, Butterworths, 1980, pp59-90 and 365-375.
15. McBride R.J. and M.A. Mackie. Evaluation of the antibacterial activity of contact lens solutions. *J. Pharm Pharmac.* 26:899-900, 1974.
16. Krezanoski J. Contact lens products. *J Am Pharm Assoc.* NS10(1)13-18, 1970.
17. Fraunfelder F.T. Drug Induced Ocular Side Effects and Drug Interactions. Philadelphia, Lea & Febiger, 1976.
18. Fraunfelder F.T. Director, National Registry of Drug Induced Ocular Side Effects, July 1977 - July 1978.
19. Zand L.M. Review: The effect of non-therapeutic ophthalmic preparations on the cornea and tear film. *Aust J Optom.* 64(2):44-70, 1981.
20. Dabezies O.H. Contact lenses and their solutions: a review of basic principles, Part III, *Eye, Ear, Nose and Throat Mon.* 45(3):82-84 passim f, 1966.
21. Riegelman S., D.G. Vaughan Jr. and M. Okumato. Antibacterial Agents in Pseudomonas Aeruginosa Contaminated Ophthalmic Solutions. *J Am Pharm Assoc Sci Ed.* 45:93-98, 1956.
22. Norton D.A. et al. The antimicrobial efficiencies of contact lens solutions. *J Pharm Pharmac.* 26:841-846, 1974.
23. Blacow N.W. Ed., Martindale, The Extra Pharmacopoeia. London. The Pharmaceutical Press 1975.
24. Trottier L. Ophthalmic/Contact Lens Products in Fevang, L. President Canadian Self Medication: A reference for the health professions, Canadian Pharmaceutical Assoc, Ottawa 1978.
25. Goodman L.S. and A. Gilman. The Pharmacological Basis of Therapeutics. 5th ed, New York, Macmillan Publishing Co Inc. 1975.
26. Grant W.M. Toxicology of the Eye. 2nd ed. Springfield Ill., Charles C. Thomas 1974.
27. Lawrence C.A. An evaluation of chemical preservatives for ophthalmic solutions. *J Am Pharm Assoc* Sci Ed. 44:457-464, 1955.
28. Eriksen S. et al. Suitability of thimerosal as a preservative in soft lens soaking solutions, in Bitonte J.L. and R.H. Keates, (Eds): Contact Lens Symposium on the Flexible Lens. St. Louis, C.V. Mosby, 1972.
29. Krezanoski J.Z. The significance of cleaning hydrophilic contact lenses. *J Am Optom Assoc.* 43:305-307, 1972.
30. Ganju S.N. The disinfection of hard and soft contact lenses. *Ophthalmic Optician.* 14:1202-1208, 1974.
31. Brown M.R.W. Survival of *Pseudomonas aeruginosa* in fluorescein solution. Preservative action of PMN and EDTA. *J Pharm Sci* 57:389-392, 1968.
32. Richards R.M.E. and J.M.E. Reary. Changes in antibacterial activity of thimerosal and PMN on autoclaving with certain adjuvants. *J Pharm Pharmac.* 24:84P-89P, 1972.
33. Shively C.D. Hydrophilic flexible lens cleaning and chemical disinfection systems. *Contacto* 19(3):33-37, 1975.
34. Morgan J.F. Evaluation of a cleaning agent for hydrophilic contact lenses. *Can J Ophthalmol.* 10:214-217, 1975.

35. Anonymous. Hibitane-Chlorhexidine. Imperial Chemical Industries Ltd. Pharmaceutics Division, Winslow, Cheshire (undated).
36. Shively C.D. Accessory solutions utilized in contact lens care and practice In Ruben M. (Ed): Soft Contact Lenses: Clinical and Applied Technology, New York, J Wiley and Sons, 1978, pp383-424.
37. Ruben M: Ocular pathogens and contact lens hygiene. In Ruben M. (Ed): Soft Contact Lenses: Clinical and Applied Technology, New York, J Wiley and Sons, 1978, pp335-347.
38. Lo Cascio G.L. Soft contact lens care. *Contacto* 21(4):34-36, 1977.
39. Grosvenor T., A. Charles and M. Callendar. Soft contact lens bacteriological study. *Ophthalmic Optician*, 12:1083-1091, 1972.
40. Browne R.K., A.N. Anderson and B.W. Charvez. Ophthalmic response to chlorhexidine digluconate in rabbits. *Toxicol Appl Pharmacol* 32:621-627, 1975.
41. Richardson N.E., D.J. Davies, B.J. Meakin and D.A. Norton. Interaction of preservatives with polyhydroxy ethylmethacrylate (polyHEMA). *J Pharm Pharmacol* 30:469-475, 1978.
42. Mackeen D.L. and K. Green. Chlorhexidine kinetics of hydrophilic contact lenses. *J Pharm Pharmac* 30:678-682, 1978.
43. Phillips A.J. Contact lens solutions. *Contact Lens J* 6(2):3-23, 1977.
44. Hind H.W. Aspects of contact lens solutions. *Optician* 169(4380):13-29, 1975.
45. Roth H.W. The etiology of ocular irritation in soft lens wearers: Distribution in a large clinical sample. *Contact Intraocular Lens Med J* 4(2):38-47, 1978.
46. Lamy P.P. and R.F. Shangraw. Physicochemical aspects of ophthalmic and contact lens solutions, *Am J Optom Arch Am Acad Optom* 48(1):35-51, 1971.
47. Holly F.J. and M.A. Lemp. Tear physiology and dry eyes. *Surv Ophthalmol* 22(2):69-87, 1977.
48. Dabezies O.H. Soft contact lens hygiene. *Contact Intraocular Lens Med J* 1:103-108, 1975.
49. Snyder A.G., R.M. Hill and N.J. Bailey. Home sterilization: Fact or fiction? *Contact Lens Forum*. Feb 41-43, 1977.
50. AMA Drug Evaluation, 3rd ed Littleton, Mass, PSG Publishing Co Inc. 1977.
51. Martin A.N. et al. Physical Pharmacy, Philadelphia, Lea & Febiger, 1973.
52. Gelfer D.M. and P.G. Maurice. Contact lens solutions and wetting angles of contact lens materials. *Contact Lenses*, Oct 21, 1976.
53. Holly F.J. and M.A. Lemp. Surface Chemistry of the Tear Film: Implication for dry eye syndromes, contact lenses and ophthalmic polymers. *J Contact Lens Soc Am*. 5(1):12-19, 1971.
54. Holly F.J., J.T. Patten and C.H. Pohlman. Surface activity determination of aqueous tear components in dry eye patients and normals. Exp Eye Res 24:479-491, 1977.
55. Holly F.J. Tear film physiology, *Am J Optom Physiol Opt*. 57(4): 252-257, 1980.
56. Phillips A.J. Contact lens plastics, solutions and storage—some implications. Part 6, *Ophthalmic Optician*, 8:1405-1413, 1968.
57. Phillips A.J. Selection of contact lens solutions. *Ophthalmic Optician* 9:394-395, 1969.
58. Lemp M.A. and F.J. Holly. Ophthalmic polymers as ocular wetting agents. *Ann Ophthalmol* 4:15-20, 1972.
59. Lemp M.A. and E.S. Szymanski. Polymer adsorption at the ocular surface. *Arch Ophthalmol* 93:134-136, 1975.
60. Troy G. Contact lens solutions: Your first aid to a successful fit. *Optometric Management*, 11(3):49-75, 1975.
61. Kaspar H. Binding characteristics and microbiological effectiveness of preservatives. Barnes-Hind reprint.
62. Sibley M.J. Considerations for development of a convenient soft lens care system. Barnes-Hind reprint.
63. Grosvenor T. Evaluation of soft contact lens use in Canada. *Can J Opt*. 33(3)56-63, 1971.
64. Obstfeld H. Allergy to contact lens wetting solutions—Letter to the editor, *Optician*. 151:306, 1966.
65. Nayanabhirama S.V. and K.D. Tatwawadi. Physiochemical properties of viscosity building agents used in contact lens solutions, *Indian J Hosp Pharm*, Nov-Dec 1976.
66. Martin E.W., Ed., Husa's Pharmaceutical Dispensing, 6th ed., Easton P.A., Mack Publishing Co 1966.
67. Committee of Revision, The United States Pharmacopeoia, 19th Revision, Board of Trustees, Washington D.C., July 1975.
68. Moses R.A. (ed). Adler's Physiology of the Eye, 6th ed, St. Louis, C.V. Mosby, 1975.
69. Arons I.J. Your guide to contact lens care products, *Contact Lens Forum* 3(8):48-55, 1978.
70. Hathaway R.A. and G.E. Lowther. Soft lens cleaners, their effectiveness in removing deposits. *J Am Optom Assoc* 49(3):259-266, 1978.
71. Eriksen S. Cleaning hydrophilic contact lenses: An overview. *Annals Ophth*. 7(9):1223-1232,1975. This paper is cited in Eriksen, S. Prevention of destructive deposits with enzymatic cleaning. *Contact Lens J*. 9(2):20-23, 1980.
72. Kleist F.D. and J.C. Thorson. How effective are soft lens cleaners? *Rev Optom* 115(4):43-49, 1978.
73. Blanco M., B. Curry and M.P. Boghosian. Studies of the effect of enzymatic cleaning on the physical structure of hydrophilic lenses. *Contacto*. 19(5):17-20, 1975.
74. Lowther G.E. Effectiveness of an enzyme in removing deposits from hydrophilic lenses. *Am J Optom Physiol Opt* 54(2): 76-84, 1977.
75. Koetting J.F. Contact lens products in Ocular Therapeutics and Pharmacology, ed by P.P. Ellis, St Louis, C.V. Mosby, 1981, pp 217-223.
76. Kleist F.D. Prevention of inorganic deposits of hydrophilic contact lenses. *International Contact Lens Clinic*. 8(3):44-47, 1981.
77. Stein H., D. Boyaner and J.P. Demers. Soft contact lens care system alternatives. *International Contact Lens Clinic* 8(4):11-16, 1981.
78. Inns, H.D.E. Soft contact lens and solutions in Canada. *Can J Optom* 42(1):27-37, 1980.
79. Josephson J.E. and B.E. Caffery. Selecting an appropriate hydrogel lens care system. *J Am Optom Assoc* 52(3):227-234, 1981.
80. Gasset A.R., R.M. Ramer and D. Katzin. Hydrogen peroxide sterilization of hydrophilic contact lenses. *Arch Ophthalmol* 93:412-415, 1975.
81. Krezanoski J.Z. Where are we in the development of pharmaceutical products for soft (hydrophilic) lenses. *Contacto* 20(1):12-16, 1976.
82. Stecher P.G. (ed). The Merck Index, 8th ed., Rahway, Merck, 1968.
83. MacKeen D. The safety and efficacy of chemical disinfection with hydrophilic gel contact lenses. *Contact Lens Soc. Am*. 8(3):17, 1974.