A wide range of care products is available today and the specific lens care system prescribed will depend on the lens type, material and individual patient factors. This article aims to provide a general overview of the principles of lens care and solution properties. It will not deal with specific details of brands, but comprehensive reviews are available from the literature.1,2

During wear, contact lenses become contaminated by tear components such as proteins and lipids, tear debris such as desquamated epithelial cells or environmental pollutants, and in some cases eye make-up. Microbial contamination is also possible during handling and storage. The purpose of a lens care system is to combat microbial contamination, keep deposits to a minimum and maintain lens performance, in terms of health, comfort and vision. All of this has to be achieved with the understanding that most patients do not comply with the full recommendations of the care regimen labelling or the eye care practitioner.

Care system components

Care systems range from one bottle of multi-purpose solution to a number of solutions to achieve the bacterial kill rates which could otherwise lead to discomfort on lens insertion. For a rinse step to be effective in terms of removal of bacteria it requires significantly more time than most contact lens wearers would routinely allow.

Rinsing

Rinsing a contact lens is an integral part of the cleaning and disinfection process. Cleaning and rinsing together remove over 99 per cent of micro-organisms from the lens. Rinsing also removes loosely bound debris from the surface and any remaining cleaning solution, which could otherwise lead to discomfort on lens insertion. For a rinse step to be effective in terms of removal of bacteria it requires significantly more time than most contact lens wearers would routinely allow.

Disinfection

This is defined as the destruction of micro-organisms, but not necessarily bacterial spores. Disinfection is thus a critical step in the care of both soft and
hard contact lenses. Failure to disinfect has been shown to be a significant contributory factor in the aetiology of microbial keratitis. The International Organisation for Standardisation (ISO) has been active in developing standards for the testing and classifying of contact lens products. The current standard – ISO 14729 – sets primary and secondary standards for disinfection based on the selected test organisms which consist of three bacteria and two fungi as shown in Table 1. *Acanthamoeba* is not included in this standard at the present time.

A disinfecting solution must also maintain the lens in a microbe-free condition when in storage, and maintain lens hydration. The compounds used to disinfect the lens also serve as preservatives in maintaining the solution integrity once opened.

**Sterilisation**

Sterilisation is defined as the total removal of all living micro-organisms, including spores. It is a standard manufacturing procedure that all soft contact lenses be sterilised before dispatch. Sterilisation is most commonly achieved in an autoclave, where the product is sterilised at a particular heat for a given time, typically 115-118°C for 30 minutes.

**Wetting and surfactants**

The use of wetting solutions originated in hard contact lens practice to improve initial lens comfort. They had three principle uses:

- Minimising initial discomfort upon lens insertion by acting as a lubricant between the lens and the cornea
- Encouraging even distribution of tears over the lens on insertion
- Acting as a buffer between the lens and the finger on insertion to reduce contamination.

The effect of the wetting solution is an immediate one that dissipates after around 15 minutes of lens wear with an RGP lens. The development of silicone hydrogel soft lenses has brought wetting compounds back into consideration in the selection of a care product for soft lenses. Surfactants are added to the formulation of multi-purpose solutions both to act as a detergent and facilitate removal of debris, as well as improve the comfort of the lens through improving its wettability.

**Protein removal**

Proteins from the tear film enter the matrix of a soft lens and become loosely attached to the surface of both hard and soft lenses within minutes of lens insertion. With time these proteins may become more aggressively bound to the lens and become denatured. Denatured protein leads to reduction in lens comfort, vision and overall satisfaction and can also lead to atopic reactions such as contact lens-induced papillary conjunctivitis and red-eye reactions. Protein deposits are more prevalent in hydrogel than silicone hydrogel soft lenses.

Historically, protein removal was carried out using dedicated protein treatments. Protein-removing tablets contain enzymes, most commonly sublimes, which break down the bonds between protein molecules, enabling them to be rinsed away from the lens. It is important to note that protein-removing treatments are only effective on active proteins. Once the protein becomes denatured, then its chemical composition changes and the enzyme can no longer break the molecule down. Thus if protein removal treatment is to be carried out, it must be done on a regular basis.

Increasingly, protein removing ingredients, such as ethylene diamine tetra-acetic acid (EDTA) or citrate are added to the formulation of soft multi-purpose solutions to remove protein during the soaking period. Including protein removal as an integral part of the cleaning process and the use of more frequent replacement lenses, has resulted in the demise of separate protein removal treatments.

**Solution properties**

All lens care products that come into contact with the eye, either directly or indirectly, need to be chemically and physically balanced to achieve patient comfort and maintain ocular health. It is important to be familiar with the general properties of a solution, to enable alternative products to be recommended if a patient is experiencing a particular problem. The properties and effectiveness of care products can change with time and for this reason all solutions should be used before the expiry date. The general properties that require consideration include:

- **Tonicity** – the average osmolarity of the human tear film is around 320m mol/kg with a range from 300-350m mol/kg. This equates to a concentration of 0.9 per cent sodium chloride solution. Ideally, contact lens solutions should have a similar tonicity to the tear film to avoid discomfort when lenses with residual solution are placed on the eye. As solution tonicity increases, the comfort will decrease and conjunctival hyperaemia increase (Figure 2). While changes in solution tonicity did cause discomfort and hyperaemia, one study showed no effect on corneal staining of increasing the tonicity of solutions applied to the eye, suggesting that discomfort and hyperaemia are effective ‘early warning signals’ preceding corneal damage.
- **pH** – this is the hydrogen ion concentration or acid/alkaline balance of the solution, and for comfort should be in the range 6.6 to 7.8 pH, and as close as possible to the average pH of human tears (7.45 ± 0.16). It should be noted that tear pH is not a static value and like that of other body fluids shows diurnal variation. The tear pH following prolonged eye closure will change.

The eye does contain buffering agents that are able to return the tear film to a normal pH if solutions beyond the

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**TABLE 1 ISO 14729 performance requirements**

<table>
<thead>
<tr>
<th>Log reduction at disinfection time</th>
<th>Bacteria</th>
<th>Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pa</td>
<td>Sa</td>
<td>Sm</td>
</tr>
<tr>
<td>Primary criteria (stand alone)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Secondary criteria (regimen)</td>
<td>2*</td>
<td>2*</td>
</tr>
<tr>
<td>Pa – Pseudomonas aeruginosa</td>
<td>Ca – Candida albicans</td>
<td></td>
</tr>
<tr>
<td>Sa – Staphylococcus aureus</td>
<td>Fs – Fusarium solani</td>
<td></td>
</tr>
<tr>
<td>Sm – Seratia marcescens</td>
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</tbody>
</table>

* Total combined log reduction of at least 5 logs, with a reduction of at least 1 log for any single bacterium

![Graph](image)
normal range are inserted. However, the transient discomfort of this means solutions should be as close as possible to the eyes’ neutral pH. Differences do exist in the pH of solutions that can lead to discomfort in some patients. Two commonly used buffers in contact lens solutions are borate and phosphate.

Viscosity – viscosity agents can be incorporated to control the ‘thickness’ of the solution. The most commonly used viscosity-increasing agent is methylcellulose.

This can be added to a wetting solution to increase contact time of the wetting agent to the lens, or be added to artificial tears to increase contact time of the formulation with the eye. The viscosity of surfactant cleaners can also be increased with a view to increasing contact time.

Disinfection agents – once any contact lens solution has been opened, it is susceptible to microbial contamination. For this reason, all solutions other than single-use presentations have to be preserved. The function of the preservative is to kill invading microbes. The chemicals used to preserve passively a contact lens solution may also be used to kill microbes in a disinfection solution.

Most disinfecting agents work by breaking down the cell wall of the bacterium. Unfortunately, any compound that can break down bacterial cell walls is also able to break down epithelial cell walls and denature protein.

In formulating a disinfection or preservative solution, a balance must be struck between a formulation strong enough to kill bacteria, yet mild enough not to become toxic to the eye or to cause irreversible changes to protein films on lenses.

An early attempt to achieve the balance was to use solutions such as chlorhexidine and thimerosal at very low concentrations. This strategy is successful from a passive preservative standpoint, but the solutions were not sufficiently bactericidal for use as a disinfectant without the incidence of atopic and toxic reactions increasing.

Solution manufacturers have now moved towards the use of chemicals such as polyhexanide biguanide or polyquaternium-1 as the principle disinfecting agent in multi-purpose solutions. These chemicals are less toxic to the eye than the older preservatives mainly because of their larger molecular size.

Having said this each solution type interacts with the eye and the lens material in a different way and some solution/lens combinations can cause corneal staining (Figure 3) that can be reduced by changing to a different solution or lens material.6,7,8

Many also believe that it is important to ensure that a cleaning step is incorporated into the routine with these products to enhance the disinfection and removal of loose surface debris and lipids.

Most multi-purpose solutions have a surfactant element built into the formulation. The most common surfactants are referred to as tetroc or pluronic poloxamers.

These products do vary in their preservative concentration as well as surfactant type and buffering agent, which may affect performance.

Hydrogen peroxide is a very effective bactericidal agent but is also toxic to the eye, causing discomfort and conjunctival hyperaemia in concentrations over 100ppm. In developing strategies to overcome this, solution manufacturers have relied on the relative ease with which hydrogen peroxide can be broken down into water and oxygen: $\text{H}_2\text{O}_2 \rightleftharpoons \text{H}_2\text{O} + \text{O}_2$.

To overcome the toxicity, solution systems have been developed where the lens is placed first in hydrogen peroxide and after an appropriate period of time a catalyst is added which breaks down the peroxide.

After a minimum of 10 minutes the lens is in a suitable state to be placed on the eye without discomfort. Systems such as this add a third element into the efficacy/toxicity balance that needs to be considered – ease of use.

In general, as discussed later, the easier a solution system is to use, the more likely the patient is to comply. The complexity of the early peroxide systems was not appreciated by many patients, but as systems have become easier to use, for example with the advent of ‘one-step’ solutions, then the relative microbial efficacy of the solution reduces as lenses are subjected to a lower exposure time to hydrogen peroxide.

Hydrogen peroxide systems also change the parameters of lenses that are pH-sensitive. When ionic soft lenses are placed in hydrogen peroxide solutions, then the relative microbial efficacy of the solution reduces as lenses are subjected to a lower exposure time to hydrogen peroxide.
Compounding factors

Handwashing
Patients should always be encouraged to wash their hands before handling lenses. For contact lens wearers, a thorough hand wash with soap and water is sufficient. Non-perfumed anti-bacterial liquid soap dispensers are preferable to bars of soap, which can become contaminated more easily. All soap must be thoroughly rinsed off the hands before the lenses are handled to avoid contamination. Hands should be dried on a clean lint-free towel. It is both comforting and of educational benefit for patients to see practitioners wash their hands in the consulting room before handling lenses (Figure 6).

Case hygiene
As well as keeping the contact lens and the hands clean, it is important to keep the lens case clean. Lens cases are a significant source of bacterial contamination (Figure 7). This contamination is made worse as bacteria adhering to the contact lens case become coated in a biofilm, which reduces the efficacy of care products. In studies, more than 50 per cent of contact lens cases were contaminated with bacteria and four per cent with amoeboid species.

On lens insertion, contact lens cases must be emptied of solution, rinsed with fresh disinfecting solution and left to air dry on a daily basis. A dry case is important, as microbes cannot multiply in dry conditions. When case use is once again required for lens storage – fresh solution should be instilled and patients should be warned against any ‘topping up’ of solution.

Several manufacturers have introduced new concepts in case design, such as incorporating an element of mechanical agitation or more recently a lens case infused with a silver antimicrobial agent, designed to reduce contamination and prevent biofilm formation.

Cases should also be replaced on a regular basis, at least every three months. Ideally, for frequent replacement lens wearers the new lens case should coincide with lens replacement. Some practitioners might also advise a weekly mechanical clean using a cotton bud moistened with contact lens cleaner. The case should then be rinsed with disinfecting solution and left to air dry. This mechanical scrub disrupts the biofilm.

Tap water
Since UK tap water has been implicated as a major source of Acanthamoeba, it should never come into contact with either the lens or lens case. Rigid gas-permeable (RGP) lens wearers may also be susceptible to contact lens related Acanthamoeba infection and therefore caution should also prevail. Minimal advice to the RGP-wearing patient should be to avoid tap water for rinsing their lenses immediately prior to lens insertion.

Compliance

Perhaps one of the most critical aspects in contact lens care is patient compliance, in other words how well the patient follows the instructions required for safe contact lens wear. Patient compliance is an issue in both contact lens wear and in general medicine and excellent reviews are available in the literature.

The human belief model can be illustrated by a flowchart used by a patient in deciding if they are going to be compliant with a procedure (Figure 8). The model shows that there are far more opportunities for a patient not to comply with a procedure than to follow it, particularly if the consequences of not following the procedure are felt to be unlikely to occur.

While it is generally accepted that most patients are non-compliant, it is equally well accepted that most believe that they are. The best way to find out if a patient is being compliant is to ask open questions about their care regime and ask the patient to demonstrate what they do. The importance of open questioning has been stressed throughout this series. Asking ‘Do you look after your lenses correctly?’ is unlikely to produce a negative response, while ‘Show me what you do with your lenses when you remove them’ provides more illuminating information.

Many studies have been carried out on different aspects of compliance. The studies support the human belief...
model in that a patient must understand that there is a real benefit to following instructions before they do so. This can be reinforced verbally – patients respond well to the approval of practitioners when they carry out an instruction or activity correctly. This reinforcement must be communicated throughout the aftercare procedure. Practitioners must also be aware of the best ways of explaining the consequences of non-compliance. Patients are less likely to respond to something that will ‘stop you getting an infection’, an unlikely event to them, than they are to something that will ‘scratch the eyes’, a phraseology that they can associate with and wish to avoid occurring.

Studies have shown that patients are far more likely to carry out procedures that affect comfort than safety. Figure 9 shows the results of a study carried out among students in London showing the incidence of non-compliant behaviour. Nearly 30 per cent of patients failed to disinfect their soft lenses on removal.

From the work that has been carried out on the subject it is possible to develop a profile of the patients who are most likely not to comply with instructions. Compliance decreases with younger patients, those who have been wearing lenses for a longer period of time, existing contact lens patients who are refitted, patients who wear lenses for long periods of time, patients fitted for cosmetic rather than therapeutic reasons. It also decreases as care systems become more complex. However, patient non-compliance can be improved through practitioner re-instruction at every aftercare visit.

**Problem solving**

Table 2 is a guide to some of the common problems that can be resolved by changes or modifications to care systems. The approach to problem solving is the one advocated throughout this series – isolate the cause of the problem and then change the component in the lens/care system which affects that element.

**Summary**

Contact lens solutions play an increasingly critical part in the overall success of contact lens wear. An understanding of their properties and performance helps practitioners both to select an appropriate system for individual patients and lens material type, and resolve any problems that may arise during lens wear.

**Acknowledgement**

The author thanks Lyndon Jones for supplying Figures 3, 4 and 7.

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<th>Possible causes</th>
<th>Recommendations</th>
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</thead>
<tbody>
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<td><strong>Patient symptoms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor vision</td>
<td>Build up of protein</td>
<td>Introduce protein treatment</td>
</tr>
<tr>
<td></td>
<td>Protein film on surface</td>
<td>Increase lens replacement frequency</td>
</tr>
<tr>
<td>Poor comfort on insertion</td>
<td>Residual peroxide on lens</td>
<td>Replace lens if necessary</td>
</tr>
<tr>
<td></td>
<td>Residual solution on lens</td>
<td>Change or introduce surfactant</td>
</tr>
<tr>
<td></td>
<td>pH or toxicity imbalance with tear film</td>
<td>Change lens material</td>
</tr>
<tr>
<td><strong>Patient comfort</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ionic lens in overnight peroxide</td>
<td>Change disinfection system, eg peroxide, multifunction</td>
</tr>
<tr>
<td></td>
<td>Non-wetted lens</td>
<td>Change lens material</td>
</tr>
<tr>
<td></td>
<td>Atopic or toxic response</td>
<td>Introduce or change surfactant cleaner</td>
</tr>
<tr>
<td></td>
<td>Silicone hydrogel solution sensitivity</td>
<td>Ensure rubbing is being carried out</td>
</tr>
<tr>
<td><strong>Patient signs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctival hyperaemia</td>
<td>Atopic or toxic response</td>
<td>Change lens material</td>
</tr>
<tr>
<td></td>
<td>pH or toxicity imbalance with tear film</td>
<td>Increase time in neutraliser</td>
</tr>
<tr>
<td></td>
<td>Atopic or toxic solution reaction</td>
<td>Use different peroxide solution</td>
</tr>
<tr>
<td></td>
<td>Denatured protein film</td>
<td>Rinse before insertion</td>
</tr>
<tr>
<td>Tarsal palpebral hyperaemia/papillae</td>
<td>Atopic or toxic response</td>
<td>Rinse with buffered saline before insertion</td>
</tr>
<tr>
<td></td>
<td>Silicone hydrogel solution sensitivity</td>
<td>Change solution</td>
</tr>
<tr>
<td><strong>Diffuse corneal staining</strong></td>
<td>Atopic or toxic response</td>
<td>Shorter peroxide exposure/longer neutralisation</td>
</tr>
<tr>
<td></td>
<td>Silicone hydrogel solution sensitivity</td>
<td>Change to non-peroxide system</td>
</tr>
<tr>
<td><strong>Lens deposits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Poor lens care</td>
<td>Change disinfecting solution to different type</td>
</tr>
<tr>
<td></td>
<td>Old lens</td>
<td>Reduce concentration or type of protein remover tablet</td>
</tr>
<tr>
<td>Lip</td>
<td>Protein film</td>
<td>Change disinfection solution to different type</td>
</tr>
<tr>
<td>Make-up</td>
<td>Tear film quality</td>
<td>Change lens material or solution</td>
</tr>
<tr>
<td></td>
<td>Make-up on lens</td>
<td>Change lens material or solution</td>
</tr>
</tbody>
</table>
References
3. BS EN ISO 14729: 2001. 14729
4. Ophthalmic Optics – Contact Lens Care Products – Microbiological requirements and test methods for products and regimens for hygienic management of contact lenses.

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MULTIPLE-CHOICE QUESTIONS – take part at opticianonline.net

1. Which of the following ocular conditions would not be due to a solution reaction?
   A. Diffuse corneal staining
   B. Corneal ulceration
   C. Conjunctival staining
   D. Conjunctival hyperaemia

2. Which of the following statements regarding 3 per cent hydrogen peroxide is false?
   A. Hydrogen peroxide is an effective bactericidal agent
   B. Hydrogen peroxide can be broken down into oxygen and water
   C. Hydrogen peroxide can cause changes to soft lens parameters
   D. Hydrogen peroxide does not need neutralising before lens insertion

3. Poor comfort on lens insertion could not be due to?
   A. Residual peroxide on lens
   B. Non-wetted lens
   C. Tonicity imbalance with tear film
   D. Build up of active protein

4. The selection of an appropriate solution system for an individual patient should be based on?
   A. Lens type
   B. Replacement schedule
   C. Patient profile
   D. All of the above

5. Which of the following represents most closely the sterilisation used during contact lens manufacture prior to dispatch?
   A. 56°C for 30 minutes
   B. 115°C for 30 minutes
   C. 56°C for 60 minutes
   D. 115°C for 60 minutes

6. Which of the following statements is false?
   A. Dissolved protein can lead to reduced lens comfort and vision
   B. Active protein can cause reduced lens comfort
   C. Dissolved protein can cause red eye reactions
   D. Protein binds to soft lens surfaces as well as entering the matrix of the lens

7. Which of the following solution properties has the least effect on initial comfort?
   A. Low pH
   B. Viscosity
   C. Tonicity
   D. Preservative concentration

8. According to the health belief model, which of the following statements is true?
   A. Compliance will be enhanced if an individual is less susceptible to developing the medical condition
   B. Compliance will be enhanced if the individual believes the medical condition is not serious
   C. A patient has more opportunities not to comply with a procedure than to follow it
   D. Non-compliance is more likely when there are fewer reasons not to follow instructions

9. Non-compliance is more evident with?
   A. New fits
   B. Experienced contact lens wearers
   C. Simpler solution systems
   D. Older patients

10. Among student contact lens wearers, which of the following is the least commonly practised activity?
    A. Protein-removal cleaning
    B. Handwashing
    C. Lens case cleaning
    D. Surfactant cleaning

11. For ISO 14729 standard requirements, which of the following is not included during testing?
    A. Candida albicans
    B. Fusarium solani
    C. Staphylococcus aureus
    D. Acanthamoeba

12. In mmol/kg, which of the following is closest to the molarity of human tears?
    A. 120
    B. 220
    C. 320
    D. 420

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