The aim of the subcommittee was to review published evidence and current practice in the management and treatment of contact lens–related discomfort (CLD) in order to present an evidence-based schema for applying the available management and treatment options. To do this, a literature review was undertaken and the results placed in the context of the quality of evidence provided by each relevant study. Categorization of evidence quality was made according to objective criteria for clinical and basic research studies adapted from the American Academy of Ophthalmology Practice Guidelines. These were identical to those used in the previous Tear Film & Ocular Surface Society (TFOS) reports1,2 and are shown in Table 1.

The approach presented in this report sets out a clinical framework for use when faced with an individual complaining of CLD. Beginning with history taking, the clinician then moves to identify any confounding conditions, such as coexisting disease, before turning to the examination of the contact lens itself. This conceptual framework is summarized in the Figure. The purpose of all these activities is to arrive at the point where everything has been done to optimize the contact lens environment within the needs and individual characteristics of the wearer. Only once this has been achieved can the true extent of the underlying CLD be appreciated and the identified remedial actions begun.

**Setting the Stage: Present Clinical Approaches**

The only report to address how practitioners diagnose and manage contact lens dry eye is from an online market survey (n = 457) conducted in 2012.3 The methods preferred for assessing contact lens dry eye were symptoms assessment (25%), corneal staining (19%), and tear breakup time (11%). In terms of diagnosing contact lens dry eye, practitioners classified most contact lens dry eye patients with evaporative (57%) rather than aqueous-deficient dry eye (43%), using the Dry Eye WorkShop (DEWS) classification schema. Further, most practitioners felt that most cases of contact lens dry eye were mild (65%) in severity, followed by moderate (27%) and severe (8%).

With regard to treating patients with contact lens–related dry eye, nearly half (47%) would refit their patients into a different contact lens as the first mode of treatment. This was followed by refitting into a lens with a more frequent
replacement schedule (24%), refitting into a different lens material with the same replacement schedule (23%), recommending topical lubricants (22%), and changing the care solution (15%).

This information provides an understanding of the current mode and practice patterns used in managing and treating the contact lens wearer with discomfort. These and other options are considered further in this evidence-based review and in making appropriate recommendations for management and treatment of CLD.

Establishing the Current Status of the Lens and Its Relationship With the Eye and Adnexa

A full and careful history of the presenting problem and the general status of the patient is a critical first step in the management process for CLD. Detailed information is essential to establish a background against which the reported complaints can be assessed and potential contributory factors identified. Elaboration of the significance of many of these issues is the province of other WorkShop reports, however, important elements to note follow.

Age and Sex

These factors give a context to the complaint, although unlike dry eye, which is more prevalent in females and with increasing age, the data for CLD are mixed. Although sex has not been found to be a related factor as measured through the use of survey questionnaires, younger individuals do seem more prone to reporting symptoms than older wearers.

Timing and Symptom Onset

Although there is relatively little information on the onset of discomfort with contact lenses, it is apparent that the situation worsens during the day, irrespective of lens type. This classic late-day presentation is likely to have a different etiology from the kind of discomfort that becomes evident immediately on insertion, and treatment strategies will also vary as a result.

Type of Lens

It is useful to obtain full details of the lens type (e.g., spherical, toric, multifocal) and material, as these factors will affect the choice and likely benefit of the treatment strategy.

Care System and Lens Replacement Schedule

The components of the care system and the frequency of lens changes need to be established, as these all bear on aspects, such as lens cleanliness and wettability.

Use of Additional Wetting Agents

Establishing whether the wearer’s routine incorporates wetting or lubricating drops either as a preconditioner before insertion or during wear is worthwhile.

Wearing Time/Pattern

Many wearers experience a reduction in their comfortable wearing time as a result of CLD, as a corollary, improved wearing time may be a useful indicator of treatment efficacy.

Compliance and Adherence to Instructions

Incorrect use of the lenses, their associated care products, and cases can precipitate a host of problems, including discomfort. Patients may be noncompliant because they do not understand the rationale for the care procedures or the potential consequences of misuse. Regardless of modality, compliant patients have better comfort at the end of the day and are more consistent with planned lens replacement, although those who actually dropout of contact lens wear do not appear to have worse compliance than those who remain. Compliance with lens case cleaning procedures influences the osmolarity of the solution in the case-well, which may impact insertion comfort. Discussing the various procedures and why they increase the probability of sustained comfortable and safe lens wear appears to have the potential to strengthen or change patient attitudes toward being more compliant.

Occupational Environment

It is important to understand the nature of the surroundings, both habitual and exceptional, in which the wearer is situated. Most will encounter challenging environments from time to time. The frequency and duration of these periods are important facts to consider when assessing the relevance and significance of reported symptoms.

Occupational considerations can influence the type of contact lenses worn and the choice of lens modality and material can influence the severity of discomfort, being fully informed on these factors is critical to the choice of management approach.
FIGURE. Summary of the management strategies for CLD.
Management and Treatment of CLD

Coexisting Disease

The possibility that the problem may be rooted elsewhere than in the contact lens itself needs to be eliminated; inquiry about relevant, known, current, or past disease should be made. For example, allergic rhino-conjunctivitis may contribute to contact lens intolerance. A history of prior treatment for dry eye or allergy is worth eliciting, as well as whether there was impact on contact lens discomfort. As with many of the items discussed in this section, a complete and detailed history will help avoid revisiting previously unsuccessful approaches to management.

Current Medications

Although many contact lens wearers may be perceived as “young and healthy,” such individuals, as well as other demographic groups, can be taking a range of agents, whether over-the-counter (OTC) or prescribed, that affect the ocular surface. It is not uncommon for healthy individuals to be using antihistamines, psychiatric drugs with anticholinergic effects, sex hormones, caffeine, or multivitamins, any of which might contribute to dry eye and discomfort during contact lens wear.

IDENTIFYING AND TREATING NONCONTACT LENS–RELATED, COEXISTING, SYSTEMIC, AND OCULAR DISEASES

In crafting a therapeutic plan to treat CLD, it is important to recognize the nonspecificity of the symptom “discomfort.” Because discomfort can result from many sources other than the contact lens, identification of any coexisting pathology that may be responsible for the patient’s symptoms is important. A complete review of all the conditions that can present with patient complaints of discomfort and signs of ocular surface disease is not the purpose of this report and the reader is referred to the relevant textbooks on this subject. What follows is a brief categorical review of noncontact lens–associated diagnoses that should be considered by clinicians in the differential diagnosis of CLD as well as in approaching its treatment.

Medicamentosa

Ocular medicamentosa can be defined as chemical irritation of the ocular surface by a topically applied drug, preservative, or cosmetic. Accompanying symptoms may be delayed for weeks or months, either as a consequence of a delayed hypersensitivity (cell-mediated) reaction on the ocular surface or some other unspecified mechanism. The condition presents with diffuse punctate staining of the cornea and/or conjunctiva that is evident with vital dyes, such as sodium fluorescein, rose Bengal, or lissamine green. Chronic epithelial defects (due to toxic inhibition of epithelial healing) are sometimes present with corneal edema, pseudo-dendritic healing ridges, and/or grey stromal haze that can be confused with an infectious infiltrate. As discomfort of varying intensity invariably accompanies these events, differential diagnosis relative to CLD is crucial.

It is well known to clinicians that the tear film can be affected in an adverse manner by the use of both topical and systemic medications, and that relief can be obtained simply by ceasing to use the offending agent. It is therefore imperative that the eye care provider evaluating complaints of CLD take a thorough history to identify the use of suspicious, prescribed, or OTC medications.

Systemic antihistamines are the most common oral medication associated with reduced tear film function and ocular discomfort, and these medications are now available OTC in many countries. Patients often do not report their use of such medicines to their caregivers. Other orally administered medicines that can induce tear film abnormalities that mimic CLD include isotretinoin, antipsychotics, and docetaxel.

Much has been published on the ocular surface toxicity of preservatives in topical medications and will not be repeated here. Clinicians should be particularly aware of the impact of timolol, prostaglandin analogues, brimonidine, atropine, acyclovir, neomycin, and nonsteroidal anti-inflammatory agents on the ocular surface.

Systemic Diseases

Autoimmune diseases and systemic atopy can produce abnormalities of the tear film and, consequently, symptoms and signs that mimic CLD. Although Sjögren’s syndrome is perhaps most commonly associated with ocular surface disease, other candidates include rheumatoid arthritis, systemic lupus erythematosus, inflammatory bowel disease, Whipple disease, and thyroiditis. Treatment of these systemic conditions may be necessary to gain control of the ocular surface disease and reviews of treatment strategies are published elsewhere. Of course, some patients with these systemic conditions will, at the same time, suffer from CLD and treatment of the two problems must occur simultaneously.

Immunological conditions that cause conjunctival scarring, such as ocular cicatricial pemphigoid, Stevens-Johnson syndrome, graft-versus-host disease, and lichen planus, can also produce symptoms and signs indistinguishable from CLD. In patients with diabetes mellitus, abnormalities of the basement membrane and possibly diminished tear secretion, predispose to superficial punctate keratitis, which may then produce symptoms that are confused with CLD. Although rarely observed in the developed world, systemic vitamin A deficiency in the absence of malabsorption must be considered in the evaluation of xerophthalmia. A thorough history and general physical examination are necessary to identify these important conditions.

Eyelid Disease

Anatomical and physiological abnormalities of the eyelids can produce symptoms similar to those of CLD, and it is often impossible to achieve relief without first treating the eyelid problem. Conditions including entropion, ecticropion, lagophthalmos, and trichiasis can each produce conjunctival inflammation, keratitis, and symptoms resembling CLD. Treatment may be palliative, including aggressive lubrication with eye drops or ointments, the use of adhesive tape to “normalize” eyelid malposition, or involve surgical correction of the anatomic abnormality. Details of these treatments are beyond the scope of this article, but are available elsewhere.

Inflammatory disease of the eyelid, including anterior and posterior blepharitis can also produce a comparable clinical picture. The complex subject of posterior blepharitis or meibomian gland dysfunction has been the subject of an earlier TFOS report, which should be consulted for reviews of current diagnostic and therapeutic approaches.

Tear Film Abnormalities

The overlap between the conditions labeled dry eye, dysfunctional tear syndrome, meibomian gland dysfunction and ocular...
surface disease is so great as to prevent discussion of each individually. Earlier TFOS reports, including the DEWS report67 and the International Workshop on Meibomian Gland Dysfunction,79–86 have attempted to review state-of-the-art knowledge about these conditions and should be read by all clinicians. With respect to recognition of the presence of either aqueous-deficient or evaporative tear dysfunction, it should be stressed that clinicians must strive to treat these conditions to the best of their ability before attributing residual patient symptoms to a contact lens–associated etiology.

**Conjunctival Disease**

Anatomic abnormalities of the conjunctiva, such as conjunctivochalasis, pinguecula, or hyperkeratinization (vitamin A deficiency or Bitot’s spot), can cause symptoms of ocular discomfort and these may be exacerbated with attempted contact lens wear.88,89 It may be necessary to correct these anatomic problems, whether with topical medication or surgically, before it becomes clear whether the contact lens has a specific role in causing symptoms. Likewise, immunologic diseases, such as the atopic family (seasonal and perennial allergic conjunctivitis, atopic and vernal keratoconjunctivitis), and conditions of uncertain etiology, such as superior limbic keratoconjunctivitis, should be considered as potential causes of corneal disease that can cause discomfort and contact lens wear.90

Control of allergic hyper-reactivity with mast cell stabilizers, topical antihistamines, and/or corticosteroids is often necessary to permit atopic patients to successfully wear contact lenses. Moreover, antiglaucoma drops such as topical dorzolamide and brimonidine can cause allergic reactions that may resemble CLD. Ruling out these possibilities is imperative, as intolerance of contact lens wear may result from insufficient control of the allergic process.

Clinicians should evaluate the eyelids for injection and follicular response to establish the contribution of allergic mechanisms, as measurement of tear film IgE is not discriminatory.91 The diagnosis of superior limbic keratoconjunctivitis is generally not difficult once the clinician is aware of the unique localization of conjunctival inflammation to the superior bulbar conjunctiva. Excellent reviews of the treatment of superior limbic keratoconjunctivitis have been published elsewhere.90

**Corneal Disease**

Diseases that are primarily corneal, as distinguished from those in which keratitis and/or anatomic changes occur secondary to another disease process (e.g., scleritis, dysfunctional tear syndrome, meibomian gland dysfunction (MGD), or peripheral ulcerative keratitis) can cause symptoms resembling CLD. Careful biomicroscopic examination will often reveal abnormalities in the anterior basement membrane that are indicative of recurrent corneal erosion syndrome due either to a dystrophy or following traumatic corneal injury. Because the use of a bandage contact lens is recognized as an effective treatment for corneal erosion syndrome, ordinary contact lens wear may confuse the presentations of CLD and recurrent corneal erosion. The management of corneal erosion syndrome has been reviewed elsewhere, including the use of hypertonic saline ointment and/or eye drops, contact lenses, superficial keratectomy, corneal micropuncture, and phototherapeutic keratectomy.92,93 The safety of hypertonic saline eye drops in the presence of a contact lens has not been evaluated.

Sulzmann’s nodular degeneration is another anatomic corneal disease that can cause discomfort and contact lens intolerance. Published reviews of this condition emphasize the value of surgical therapy to remove the nodular corneal elevations.94

Although it may not seem valuable to undertake a detailed differential diagnosis of the patient with complaints of CLD, consideration of the diagnoses and pathophysiologic processes mentioned above should make it clear that many therapeutic interventions can relieve symptoms of discomfort without the need for changes to the contact lens, its material, design, care solutions, or wear schedules.

**TREATING EVIDENT CONTACT LENS–RELATED PROBLEMS**

In many instances, the existence of a contact lens–related anomaly would be apparent during the course of the routine examinations suggested above. Whether or not that is the case, a comprehensive assessment of contact lens status is indicated, and the next step is treating and managing problems that then become evident once obvious ocular and systemic issues have been dealt with. The aim is to ensure that the lens in the eye is in a clinically acceptable ocular environment without obvious deficits of either a physical or behavioral nature.

Typical deficiencies can encompass physical defects, such as edge chips and tears, or fitting problems. Anterior and/or posterior surface deposits can also affect contact lens comfort, with the former also contributing to a nonwetting surface; although this can also occur in the absence of visible anterior surface deposition.

Perhaps because defective lenses are such an obvious source of discomfort, little in the way of manuscript citations exist. Standard textbooks provide adequate coverage as part of their discussion on fitting and follow-up care, however.57–100 Defective lenses are usually the result of mishandling, aggressive cleaning, or storage case mishaps and are rarely observed on removal from a fresh blister pack. Although biomicroscopic examination of the lens, either in situ or ex vivo, presents the most likely opportunity for detection of defects, other methods, most notably magnifying loupes, phase-contrast microscopes, and shadow boxes can also be used.

The lens-to-cornea fitting relationship can influence the comfort of a contact lens. This can be evaluated using a biomicroscope to judge the lens movement in both primary position and upgaze. Additional information can be gained by applying the standard push-up technique. Fluorescein is essential to the assessment of rigid lens fitting.

Generally speaking, an excessively flat soft lens fit will cause immediate discomfort that worsens on blinking. Lens inversion due to incorrect insertion is a common cause of this problem and usually manifests as an apparently flat fit.99 Reversing the contact lens typically provides relief.

Interactions between the lens and the ocular surface or eyelids101,102 and design features of the edge may create awareness and discomfort throughout the day. Stiffer lenses, or those with a higher modulus of elasticity (e.g., some silicone hydrogels) can exhibit edge clearance or standoff from the ocular surface. In extreme cases, this appears as fluting of the lens periphery and is most easily appreciated on a blink when discomfort is also more keenly felt.95–105 On the other hand, steep-fitting lenses may be initially comfortable, but become intolerable due to the build-up of cellular waste beneath the lens and compression onto the bulbar conjunctiva.106–108 The most apparent solution to either situation is to attempt to optimize the fit in the indicated direction: an apparent flat-fitting uncomfortable lens might be steepened and vice versa.

Surface deposits are another potential cause of CLD and where these are obvious during examination, steps should be
lysozyme and subjective comfort (\( r = 0.6\)–0.7; \( P < 0.001 \)). A more recent study found poor correlation between total protein/lysozyme and any subjective factor (\( r = 0.3; P > 0.05 \), and only weak correlations between dryness and more protein,95 whereas some silicone hydrogels can attract greater levels of lipid.109–114 Both the amount and type of protein deposit can be influenced by the surface charge of the material.115 The connection between deposits and CLD is closely linked to the perturbation of the prelens tear film and associated lack of wettability.111,113

Specifically with regard to protein deposits, however, the literature is inconclusive on the impact of their removal on CLD. One report found no correlation between lens protein and patient comfort, another demonstrated a decrease in comfort with even inconspicuous levels of protein.116,117 A more recent study found poor correlation between total protein/lysozyme and any subjective factor (\( r < 0.3; P > 0.05 \)), and only weak correlations between dryness and percent active lysozyme (\( r = 0.3–0.5 \) for all time points). However, stronger correlations were found between active lysozyme and subjective comfort (\( r = 0.6–0.7; P < 0.001 \)).118

Frequent replacement of the contact lens and strict compliance with replacement recommendations serve as the first steps in eliminating a deposited lens.110,119 In addition, adequate cleaning after removal and subsequent storage in an approved contact lens care solution can prevent contact lens deposits.95 Different care systems may have some effect, with polyquaternium (PQ)-containing products demonstrating decreased levels of deposition for Group IV lenses compared to polyhexamethylene biguanide (PHMB).120–124 PQ has also shown a greater level of lipid removal from senofilcon lenses compared with hydrogen peroxide systems.125 Citrate in a care system has been found to have efficacy in reducing protein deposition, whereas surfactants and alcohol-based cleaners are useful against lipids.126,127 Finally, transfer of contaminants from the hands or other areas (e.g., make-up) to the contact lens may be evident, reinforcing the importance of hand washing before handling.128

In terms of refractive correction, poor vision is reported to be a trigger for discontinuation of wear,129,130 and can also be a sign of contact lens dryness.131,132 Although there is some evidence133 that suboptimal vision correction may result in discontinuation due to visual discomfort and/or disturbance, the question of whether there is a direct association between vision and the comfort of the contact lens itself remains unanswered. Although many practitioners anecdotally express a belief in such a relationship and there is some supporting evidence (Papas EB, et al. IOVS 2003;44:ARVO E-Abstract 3694).134 this has yet to appear in the referenced literature. Nevertheless, together with the knowledge that monocular and binocular refractive errors or accommodative insufficiency can result in visual discomfort, it would be prudent to remove the potential for such a problem by ensuring that the contact lens presents as accurate a refractive correction as possible.135–138

### TREATMENT OF THE SYMPTOMATIC CONTACT LENS PATIENT WITH A CLINICALLY ACCEPTABLE LENS

Having eliminated possible nonlens-related causes and established that the lens as it sits on the eye is in a clinically acceptable condition, we now turn to the strategies available to manage any remaining symptoms of discomfort. The comments that follow relate primarily to soft contact lenses, except where rigid or rigid gas permeable (RGP) lenses are specifically referred to. A summary of these approaches is given in Table 2.

#### Adjusting Replacement Frequency

All soft lenses exhibit a gradual reduction in both comfort and wettability over time.139–141 These changes are potentially linked to deposition of elements from the tear film, such as denatured proteins or nonwetting lipids.142–146 Replacing lenses before these effects reach the level at which they become subjectively evident would seem a reasonable approach. Early attempts to implement more frequent replacement among extended wearers did indeed indicate the promise of enhanced subjective performance compared with the annual replacement schedules common until the early 1990s.147

### TABLE 2. Summary of Evidence Supporting Various Potential Management Strategies for CLD

<table>
<thead>
<tr>
<th>Treatment Strategy</th>
<th>Supporting Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust replacement frequency</td>
<td>Level I</td>
</tr>
<tr>
<td>Change material</td>
<td>Insufficient or contradictory evidence</td>
</tr>
<tr>
<td>Add internal wetting agents</td>
<td>Insufficient or contradictory evidence</td>
</tr>
<tr>
<td>Add external wetting agents</td>
<td>Level II</td>
</tr>
<tr>
<td>Eliminate the care system</td>
<td>Level III</td>
</tr>
<tr>
<td>Alter lens design factors</td>
<td></td>
</tr>
<tr>
<td>Change the care system</td>
<td></td>
</tr>
<tr>
<td>Use tear supplements, wetting agents, lacrimal inserts</td>
<td></td>
</tr>
<tr>
<td>Dietary supplementation (omega-6 FAs/evening primrose oil)</td>
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<tr>
<td>Punctal occlusion</td>
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<tr>
<td>Topical medication (azithromycin)</td>
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<tr>
<td>Improve environment</td>
<td></td>
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<tr>
<td>Alter blink behavior</td>
<td>Insufficient or contradictory evidence</td>
</tr>
<tr>
<td>Switch soft to RGP lens</td>
<td>Insufficient or contradictory evidence</td>
</tr>
<tr>
<td>Switch RGP to soft lens</td>
<td></td>
</tr>
<tr>
<td>Orthokeratology</td>
<td></td>
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<tr>
<td>Refractive surgery</td>
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<td>Spectacles</td>
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Closed circles (*) refer to soft lenses and open circles (•) refer to rigid lens. Blank cells indicate no data available.
In looking for evidence of the value of frequent replacement as a means of improving comfort, there have been no high-quality (Level I) studies to date. Although several Level II studies do exist (with most dealing with conventional hydrogels), the balance of evidence is equivocal. For example, although subjects in a cohort of 358 who wore a range of conventional hydrogel materials for 3 years on a no-replacement schedule were slightly less likely to report good comfort than those on frequent replacement schedules, in general, differences between the daily, 1- and 3-month replacement regimens were only marginal (Level II). Other relevant studies have had smaller samples but were controlled in terms of the lens types involved. For Group IV lenses, comfort was better when replacing lenses every 4 weeks compared with 12 weeks and a similar, if smaller, effect was seen for Group II materials (Level II). Later workers failed to confirm this second result, however, finding no difference between monthly and 3-month replacement of Group II lenses (Level II). Likewise Group I lenses have shown no discernible comfort advantage for either every 3-month versus monthly replacement or daily as opposed to biweekly replacement (Level II).

For silicone hydrogels, a large survey of more than 1300 patients across 158 practices found that replacement every 2 weeks was significantly less comfortable than monthly replacement; although as the nature of the study did not permit control over lens type, it is possible that factors other than replacement frequency may have been responsible for that outcome (Level II). However, recent work (Level II) with a single silicone hydrogel (senofilcon A) indicated that significantly better end-of-day comfort and dryness accompanied a daily disposable schedule than either (1) 2-week replacement using PHMB- or hydrogen peroxide–based care systems, or (2) 4-week replacement using PQ-based solutions.

In summary, support for increasing the frequency of soft lens replacement from once per month to twice per month is lacking in the current literature. Switching to a daily disposable schedule may be helpful, especially for silicone hydrogels, although data are available for only a single material. This is evidently an area that would benefit from better quality clinical studies. For RGP lenses, more frequent replacement does not appear to be valuable, at least on a 3-month replacement schedule, as this frequency conferred no comfort benefits compared with nonreplacement (Level I).

**Changing Material**

Some practitioners may seek to address discomfort issues by changing contact lens materials. The rationale for this is anecdotal and/or experiential, but presumably involves an effort either to increase oxygen transmissibility or enhance wettability. Changes may be made with or without clinical signs and are based on the clinical judgment of the individual practitioner. This may mean changing within material classes (i.e., hydrogel to hydrogel) or between classes (i.e., hydrogel to silicone hydrogel or vice versa).

Influences on comfort that might be produced by particular attributes of the material are difficult to isolate from one another. For example, increasing oxygen transmissibility by switching from a hydrogel to a silicone hydrogel will almost certainly alter other properties, such as modulus of elasticity or wettability. The overall result is, therefore, difficult to ascribe to one parameter in isolation and, not surprisingly, directed studies of these effects are uncommon in the peer-reviewed literature.

Oxygen effects on contact lens discomfort have been mostly studied using atmospheric control. In a small group of soft hydrogel contact lens wearers, reducing atmospheric pressure, while holding temperature, humidity, carbon dioxide concentration, and illumination constant, influenced comfort levels (Level II; although, as other significant complications arose during this experiment, it is uncertain that these effects were ascribable directly to hypoxia). Other studies of oxygen effects include both simulated and real altitude increases that resulted in a decreased comfort level in soft hydrogel contact lens wearers (Level II and III). In both studies, subjective changes were evident, with an inability to wear contact lenses resulting in at least one case. Again, however, it should be noted that the nature of the experimental set-up makes it impossible to link these effects solely with oxygen changes.

Perhaps of greater relevance to clinicians are the results of studies that have looked at comfort differences between hydrogel and silicone hydrogels; there are several of these in the literature. When patients were converted from hydrogel to silicone hydrogel contact lenses, a slight decrease in dry eye complaints was noted (Level II). However, other work has shown that nearly half of previously symptomatic hydrogel soft contact lens wearers experienced reduced symptoms, mostly dryness, when refitted to silicone hydrogel contact lenses in either a daily or continuous-wear modality (Level III). When refitting subjects into silicone hydrogels for continuous wear it did not appear to matter whether the previous modality was daily or extended wear, as reductions in dryness symptoms occurred in both cases (Level II). This symptomatic change in both frequency and severity was noted within 1 week of being refitted into silicone hydrogel lenses. In a large study, 278 hydrogel contact lens wearers were refitted into a latroseilicon A silicone hydrogel material and followed for 3 years (Level II). Results showed that symptoms of dryness abated after 1 week of wear and remained consistent throughout the 3-year study period; however, the study could not ascertain the precise reason for the improvement.

Similarly, a survey of 360 contact lens wearers showed that dry eye symptoms occurred with greater frequency among those using hydrogel compared with silicone hydrogel lenses, with high water content hydrogels being more problematic than low water lenses. These differences were thought unlikely to have been due to either corneal desensitization effects induced by relatively low oxygen transmissibility or lens dehydration (Level I).

Set against these outcomes in favor of silicone hydrogels are several studies that have failed to find any difference in terms of comfort (both Level II), and others in which the reverse was true. For example, one group of lapsed contact lens wearers experienced greater success when refitted in hydrogels from silicone hydrogel lenses (Level I) although, a direct analysis was difficult because the overwhelming majority of the subjects were refitted into hydrogel contact lenses (271 vs. 16). A decrement in comfort was also observed in daily disposable silicone hydrogels when compared with daily wear disposable hydrogel lenses. As has been pointed out in recent reviews, the outcomes of many of the studies mentioned above depended critically on the methodology used. It is also difficult to separate material effects (i.e., silicone hydrogel versus conventional hydrogel) from other aspects of lens construction, such as design or surface characteristics. Taking all this into account, there is currently no firm consensus on whether silicone hydrogel lenses alone can ameliorate CLD. Although new lens materials and designs continue to emerge, there has not been sufficient peer-reviewed literature on which to base an assessment of their value in solving CLD dilemma.

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Set against these outcomes in favor of silicone hydrogels are several studies that have failed to find any difference in terms of comfort (both Level II), and others in which the reverse was true. For example, one group of lapsed contact lens wearers experienced greater success when refitted in hydrogels from silicone hydrogel lenses (Level I) although, a direct analysis was difficult because the overwhelming majority of the subjects were refitted into hydrogel contact lenses (271 vs. 16). A decrement in comfort was also observed in daily disposable silicone hydrogels when compared with daily wear disposable hydrogel lenses.

As has been pointed out in recent reviews, the outcomes of many of the studies mentioned above depended critically on the methodology used. It is also difficult to separate material effects (i.e., silicone hydrogel versus conventional hydrogel) from other aspects of lens construction, such as design or surface characteristics. Taking all this into account, there is currently no firm consensus on whether silicone hydrogel lenses alone can ameliorate CLD. Although new lens materials and designs continue to emerge, there has not been sufficient peer-reviewed literature on which to base an assessment of their value in solving CLD dilemma.
Incorporation of Internal Wetting Agents

Soft contact lenses have been impregnated with internal wetting agents in an attempt to enhance comfort. Hyaluronic acid (HA) has been successfully incorporated into silicone hydrogel contact lenses.\(^{167}\) The presence and location of HA can be confirmed by techniques such as x-ray photoelectron spectroscopy, confocal laser scanning microscopy, and Fourier transform infrared spectroscopy—attenuated total reflectance. HA increases the hydrophilicity and the equilibrium water content of hydrogels, generally without affecting transparency. HA also significantly decreases the amount of lysozyme sorption, but has no effect on lysozyme denaturation in hydrogels containing less than 2% by weight methacrylic acid (MAA). Adsorption of proteins is considerably decreased by the presence of cross-linked HA.\(^{167,168}\) The presence of small amounts of cross-linked HA has been confirmed in a laboratory study by using material physical property techniques\(^ {169}\) and results in consistently lower water contact angles. This indicates that there is a continued availability at the interface without dissipation over time. There is, however, no direct evidence that HA incorporation leads to enhanced comfort.

Polynvinyl alcohol (PVA) is a successful tear film stabilizer and is widely used in comfort drops and some soft contact lens materials. A PVA-containing lens (nelfilcon A), modified to include additional (nonfunctional) PVA as an internal wetting agent for sustained release onto the ocular surface, achieves consistent near-zero-order release beyond 20 hours through polymeric delivery.\(^ {170}\) This approach was found to provide improved lens surface wettability and comfort both initially and at the end of the day (Level II).\(^ {171}\) Other studies, however, return a different picture, with the nonfunctional PVA lenses performing worse than other daily disposable contact lenses in terms of comfort, wearing time and comfortable wearing time, corneal staining, and lens fit (Level II, Level III).\(^ {172,173}\) When this same lens material was used in combination with external wetting agents, enhanced lens surface wettability, measured objectively by using noninvasive tear breakup time, was observed, but comfort still decreased toward the end of the day and wearing time did not increase (Level II).\(^ {174}\) Nevertheless, it was noted that when subjects were refitted from their habitual fortnightly and monthly replaced lenses, common symptoms of discomfort were reduced and biomicroscopy signs, such as bulbar and limbal redness and conjunctival staining improved (Level II).\(^ {175}\) To what extent the observed benefit came from the internal wetting agent as opposed to the new lens material, more frequent lens replacement, or absence of care solution is unclear; however, and the overall value of these agents remains equivocal.

In an effort to enhance the comfort of their RGP lenses, some manufacturers have endeavored to improve the hydration characteristics of the lens surface. One way this has been done is to incorporate what is essentially a water-containing (silicone hydrogel) polymer into the material as a means of providing better hydration at the lens surface. Evaluation of this modality relative to a standard RGP lens did show some significant improvements in subjective ratings of end-of-day comfort, but the authors deemed these to be too small to be of clinical significance (Level I).\(^ {176}\) However, as these comments were based on the group means, it may be that a minority of cases will derive some benefit from this strategy.

Use of External Wetting Agents

Since studies have demonstrated that symptoms of dryness are related to the surface wettability of a soft CL,\(^ {177}\) some practitioners instruct patients to lubricate their lenses with wetting drops before applying them, especially if the recommended care solution does not itself have an intrinsic wetting effect.\(^ {178}\) For example, prelubrication with methylcellulose or guar to protect the cornea from hydrogen peroxide may improve comfortable wearing time (Level II).\(^ {179}\) Likewise, use of a carboxymethyl cellulose–containing conditioning solution before insertion of a daily-disposable lens resulted in improved comfort after insertion and at the end of 1 day of wear (Level II), although only one lens material was studied.\(^ {179}\)

During continuous wear, better comfort on insertion, better visual quality, and less mucus discharge on waking were reported when using rewetting drops containing surface active surfactants compared with a saline solution control (Level II).\(^ {180}\) However, the symptom of dryness persist for a longer period of time was not different between treatment groups in this study. It appears that addition of surface-active agents can aid in removal of protein deposits with continuous-wear silicone hydrogel lenses and that this may improve comfort for the wearer.\(^ {180}\) To maximize effectiveness, patients may use wetting drops before the eye feels dry because hydrophobization will increase tear breakup time.\(^ {95}\)

The addition of the ocular lubricant hydroxypropyl methylcellulose (HPMC) to a multipurpose contact lens solution conditions the hydrogel lens surface, but also is adsorbed by both Group I and IV materials, then gradually released beyond 12 hours, improving the wetting of the lens surface and enhancing lens-wearing comfort (Level III).\(^ {181}\) Although HA has been shown to be efficacious as an internal wetting agent in laboratory studies\(^ {167–169}\) and is incorporated in some commercially available multipurpose solutions (MPSs), there has been no research that has examined its effect on comfort as a surface wetting agent.\(^ {181}\)

Certain physical properties of blister pack solutions differ between products\(^ {121}\) and can influence lens comfort, particularly on initial insertion (Level II/III).\(^ {122,124}\) Where an individual reports unsatisfactory comfort early in the wearing cycle, and particularly with a daily disposable lens, it is possible that the blister pack solution is responsible. Rinsing the lens with sterile saline before insertion can be diagnostic for this problem, as well as being a management option. As residual solution may remain in the lens bulk after rinsing, full resolution may require switching to a different manufacturer, provided that suitable parameters and lens properties are available.

The wettability of lens care solutions can have a positive impact on blink rate and visual comfort, especially visual performance during the interblink interval (Level II).\(^ {13}\) End-of-day discomfort could be related to the solution, but it is often due to poor surface wettability of the contact lens itself.\(^ {95}\)

In summary, although the incorporation of external wetting agents into the lens care solution appears to be useful in increasing wearing comfort, the benefits are mainly evident during the early portion of the daily wearing cycle.

Elimination of the Care System

Care systems and the solutions involved may contribute to contact lens discomfort. One treatment option is to eliminate the care system as a variable by switching to a daily disposable lens. The benefits of daily disposable lenses are discussed in an earlier section but appear to be at least partly due to the removal of the need for a care system, which in turn reduces the potential for interaction between solution components and the ocular surface or lens.\(^ {182}\) These lenses are designed and labeled for single use: the lenses are removed from a blister pack, inserted directly in the eye, and then removed and
discarded after 1 day of wear. A recent analysis of data collected from multiple studies at a single center showed greater comfort and less subjective dryness when a single material was used as a daily disposable compared to when it was worn on a daily wear schedule using any of a range of care systems (Level II). 152 Although one of these systems was hydrogen peroxide based, it should be noted that this did contain a surfactant, so a truly chemical-free system was not achieved. Peroxide disinfection with soak and rinse in saline before insertion, or peroxide disinfection with chemical neutralization involving no additional agents should be studied further.

With that insight it should be borne in mind that switching to a daily disposable with the goal of eliminating the care system is confounded by the presence of the solution in the blister pack. In effect, this fluid is the “care system” of the disposable lens; its contents and physical characteristics vary between manufacturers and potentially may cause problems for individual wearers. Symptomatic daily disposable patients (Group IV) preferred lenses that were preconditioned with carboxymethyl cellulose drops to those fresh from the packaging (Level II). 179 This report highlights that completely eliminating the care system by switching to a daily disposable modality remains confounded by factors intrinsic to any particular lens, such as its material and packaging solution.

Collectively, these data suggest that elimination of the care system may be beneficial to patients with contact lens discomfort and, in most cases, a switch to daily disposables will be beneficial. In cases in which it is desirable to eliminate even the residual packaging solution, preconditioning of either daily wear or daily disposable lenses may be of value for any patient prone to discomfort.

Lens Factors

Soft Lenses. In considering the evidence base for using parameter changes to manipulate lens comfort, it is important to bear in mind the temporal characteristics of the effects that may be induced by various interventions. Thus, although some changes may have an impact on late-day dryness and discomfort, others will be more effective at mitigating insertion and short-term problems.

There is good evidence (Levels I–II) that a thin, knifepoint edge is superior to a rounded edge in terms of late-day comfort. The response to a chisel-shaped edge lies between these two extremes. 181 Mechanistically, it is suggested that the thinner edge more closely approaches the ocular surface, minimizing the interaction with the eye lid during blinking. While use of knife-edge lenses is likely to be accompanied by increased circumlimbal staining, this does not appear to be a factor in determining the final level of comfort.

Several reports support the strategy of fitting a steeper base curve as a means of improving comfort and, although all deal with only a single lens type, some degree of generalization is possible, as materials vary between the investigations. The most reliable evidence comes from two silicone hydrogel studies (Levels I–II) that agree, showing an advantage for steeper base curves, specifically 8.3 mm versus 8.6 mm or 8.4 mm versus 8.8 mm. 183 Only in the latter case did the difference reach statistical significance. A third silicone hydrogel study (Levels II–III) indicated that when discomfort resulted from trial fitting the flatter (8.6 mm) of two available base curves (as it did for 26% of the sample), a high proportion of eyes (45 of 49) improved when refitted to the steeper lens (8.4 mm). 184 Similar results were obtained with midwater hydrogel lens (Levels II–III), where the number of comfort complaints diminished significantly as the base curve was steepened from 9.0 to 8.4 mm. Given that this series of studies includes examples of assessment after short and longer wearing periods, the advantages of steeper base curves appear to apply to both situations.

Larger diameter lenses have been shown to be beneficial in improving short-term comfort 184 (Levels I–II). However, the relative effectiveness of different base curves depended on its size. One of these systems was designed specifically for the cornea to use a range of sizes that has been investigated stretches only from 12.0 to 13.5 mm, which represents the lower end of what would be acceptable in contemporary soft lens practice. Although there appears to be an advantage in increasing diameter up to 13.5 mm, the benefit of lenses larger than this has not been formally studied.

Alterations to the back surface shape of the lens (i.e., its design) have been investigated for their impact on comfort, 106 as well as other aspects of fitting (Levels I–II). Designs tested included monocuscure, aspheric, and bicurve alternatives and, although short-term comfort differences between these shapes were observed, no systematic pattern emerged. It is difficult to discern an evidence-based strategy for influencing comfort by manipulating the lens back surface shape, other than to say that a monocuscure design is least preferred.

The evidence for altering the center thickness as a useful tool for manipulating comfort is very weak. Only one study 185 has assessed this directly (Levels II–III) and, although the authors state that comfort was better with the thinner of the two compared lenses (0.035 mm vs. 0.07 mm), they also found that dryness became worse. This apparently contradictory outcome is likely a reflection of the statistical approach taken during this analysis, as on inspection, the differences in the presented data look unlikely to be either statistically significant or practically useful.

Two important practical considerations must be borne in mind when attempting to use these features. The first is that although it may be desirable to strategically manipulate certain contact lens parameters, it will not be possible (or indeed desirable) to adjust individual elements in isolation from the rest of the lens due to the potential for aspects of behavior other than comfort to be affected in the process. As an example, recall that increasing the diameter usually requires the base curve to be flattened to avoid excessively tightening the fit. The effect of each intervention on overall lens behavior will have to be considered, together with any compensatory adjustments that might be necessary, if satisfactory performance is to be maintained. The second point is that due to the nature of the contemporary marketplace, unless custom-designed lenses are chosen, control over most lens parameters does not reside with the clinician, but is dictated by the manufacturer. In many cases, this will limit the scope for achieving meaningful improvements via these means.

Rigid Lenses. Improving the fit of an RGP lens in cases in which it is deemed to be imperfect can improve comfort. Avoiding excessively steep fitting appears to be of value in the short term, as both optimally fitted and slightly flat lenses were preferred in terms of initial comfort (Level II). 186 In the longer term, having lenses that more accurately approach the shape of the cornea resulted in improved comfort after 2 weeks of wear. It was particularly noted in this study that nonrotationally symmetrical designs (i.e., toric back surfaces or toric peripheries) were beneficial in cases in which significant astigmatism was present (Level III). 187 The implication for clinical practice is that respecting the corneal shape is important when attempting to reduce rigid lens comfort issues.

Other parameters that may confer benefits include larger diameters (i.e., 10 mm) (Level II) 186 and a rounded anterior edge shape (Level II). 188 It may also be advisable to avoid excessively thin lenses that permit flexure (Level I). 189 As the experimental exposure in all of these three cases was for a relatively short period, the potential for longer-term benefits has not been verified.
Changing the Care System

It has long been appreciated that contact lens care systems and solutions may contain ingredients that contribute to hypersensitivity or toxicity, leading to discomfort, intolerance, and ultimately discontinuation of contact lens wear (Level III). Patients with these problems might benefit from switching among care systems in a single category; that is, from one multipurpose solution to another with similar preservatives but different accompanying ingredients, or to a different care system entirely, such as one that is peroxide based. Solutions developed for use with one lens material may have different effects on the user when used with other lenses.

There are conflicting studies regarding the impact of solutions on contact lens discomfort. Beginning with those that were the best conducted, a regression analysis did not find any statistically significant association of solution or disinfecting ingredients on self-reported dry eye among contact lens wearers (Level I). Next, studies with daily wear lenses of a single material using two different MPSs, found an increase in symptoms with wear time that again was not related to solution type (Level I). In more recent work, however, two studies suggest that certain solutions can offer comfort advantages. The first, a controlled, masked comparison of two multipurpose solutions in wearers of various soft lenses, including both silicone hydrogel and hydrogel lenses, showed statistically significant improvements in comfort when the solution specifically developed for use with silicone hydrogels by the study sponsor was used (Level I). Finally, crossover comparisons of three care systems (two MPS) solutions and a peroxide system) with a daily disposable control, found that MPSs containing wetting agents reduced discomfort when assessed using the Ocular Surface Disease Index (Level I).

A very recent study offers a degree of clarity to this rather confusing situation by comparing comfort ratings for several contact lens materials when each was used with a range of different care systems (Level II). The implication from this study is that for any given lens type, the average comfort response in a population of wearers varies according to the care system in use and that lens manufacturers do not necessarily produce the best solutions for their own lenses. As it has also been shown that optimizing the lens-solution combination can confer comfort benefits that are large enough to be appreciated by many wearers, changing the care system to one more suited to the particular lens type may be a practical strategy to improve comfort. An important point to bear in mind is that the solution offering the best comfort may have drawbacks in other areas, such as an increase in the rate of adverse events.

There is scant evidence that changing care systems can increase RGP contact lens comfort. In a small study involving two systems from the same manufacturer, although there was a preference in favor of the one-bottle MPS system over the two-bottle cleaner plus conditioner alternative, this was not statistically significant. Furthermore, the wearing schedule involved overnight orthokeratology, which does not offer the best platform for assessing end-of-day discomfort (Level III).

However, this lack of formal evidence does not necessarily mean that certain solutions will not perform better with particular materials.

Use of Tear Supplements and Wetting Agents

Although fewer in number relative to studies conducted to establish the usefulness of tear supplements in noncontact lens wearers, there are several published reports that support the use of tear supplements and wetting agents in the management and treatment of CLD. Treatment with a preservative-free 0.9% sodium chloride ophthalmic solution has been found to reduce ocular surface discomfort and extend the duration of contact lens wear, although wearers of first-generation silicone hydrogel lens material, who were symptomatic for dry eye, preferred saline drops that were hypo-osmotic rather than hyper-osmotic (Level II).

An investigation conducted at six clinical sites in North America found that 47% of contact lens wearers reported obtaining moderate relief using rewetting drops (Level II). In a study in which lens hydration was monitored together with discomfort, symptomatic hydroxyethylmethacrylate contact lens wearers gained short- and long-term relief using both lubricants and saline, but without any differential benefit between the two. The symptomatic relief provided by the drops was attributed to psychological factors, as there was no substantial hydration effect observed.

A study conducted in a sample of 59 subjects indicated that the use of a carboxymethylcellulose (CMC)-containing conditioning agent with brand new hydrogel lenses provided improved comfort on insertion, although the advantage was no longer significant by the end of the day. Evidence from a comparison of tear supplements with differing viscosity indicates that these drops also helped reduce postinsertion discomfort for both hydrogels and silicone hydrogels during the first 6 hours of wear. Although both lubricants (i.e., drops containing either CMC or PVA) were more effective in reducing the dryness symptoms of silicone hydrogel wearers than the 0.9% saline control (Level III), there was no advantage to having a more viscous drop. Drops containing surface-active agents also provided greater subjective satisfaction than saline (Level I).

Eliminating preservatives from ocular preparations will avoid possible toxic complications. Preservative-free drops were preferred by hydrogel lens-wearing patients who had symptoms of dryness with habitual lens wear. The use of 2% povidone preservative-free eye drops was also associated with an improvement in symptoms of ocular tiredness, dryness, and difficulty during sustained computer use (Level III). When the combination of MPS and rewetting drop was studied, a PQ- and myristamidopropyl dimethylamine-based MPS used in conjunction with a polyethylene glycol 11-containing drop was rated as being more comfortable than the alternative PHMB MPS used with povidone-based drops. However, the difference did not become statistically significant until the 1-month point and, as only one lens type was used in this study, the result may not be generally applicable (Level II).

It is well established that when any ophthalmic solution is administered to the eye, most of the drop rapidly leaves through the nasolacrimal duct, leaving only a fraction available for absorption by the cornea, conjunctiva, and nasal mucosa. The ocular surface residence time for such drops is short and,
as a consequence, tear supplements usually need to be regularly re-instilled to maintain efficacy throughout the wearing day. Despite this limitation, tear supplements and wetting agents (also referred to as rewetting drops, lubricant drops, or artificial tears) are regarded as the mainstay treatment for CLD. They are widely and easily available OTC and for many sufferers are an effective means of managing the problem.

The development of alternatives that can provide day-long sustained comfort and relief from CLD is a desirable target for future research and this may involve the use of new surface active agents, demulcents, and ingredients, such as hyaluronic acid, which has been proposed to improve comfort and wettability of lenses.\textsuperscript{205,206} Further randomized controlled masked clinical trials are necessary to determine the efficacy of tear supplements across varying levels of severity of CLD.

One other treatment option that bears a mention is the hydroxypropyl cellulose (HPC) ophthalmic insert, which has been available for more than 2 decades. It was shown in multicenter, two-visit, open-label, 4-week registry studies that contact lens patients experienced significant reductions in the mean severity of eye discomfort, burning, dryness, grittiness, and stinging after 1 month’s use of this treatment (Level II).\textsuperscript{207,208} Smaller studies and case reports have also indicated similar improvements in patient-reported dryness (Level II).\textsuperscript{209,210} Despite these apparently attractive results, the use of HPC inserts remains limited, presumably due to the relatively invasive nature of the insertion procedure. They do, however, provide a useful alternative for difficult cases.

Nutrition

Most reported nutritional intervention strategies to treat and manage contact lens dry eye are anecdotal and follow the treatments that have been suggested for the general dry eye disease population. As in most other areas of medicine, nutritional interventions fall under the umbrella of alternative and complementary medicine. However, few controlled studies currently exist on which practitioners can base their advice to patients.

**Essential Fatty Acids.** Long-chain essential fatty acids (FAs) traditionally described as being necessary for ocular health include omega-3 FA isolates, such as eicosapentaenoic acid and docosahexaenoic acid: both are converted to prostaglandin E\textsubscript{3} and function as anti-inflammatory agents. The use and indications for omega-3 and omega-6 FAs can be found in the TFOs DEWS report as well as the TFOs MGD workshop.\textsuperscript{79,211}

The use of omega-3 and omega-6 FAs in contact lens dry eye has little in the way of peer-reviewed literature to suggest that it is efficacious. The only relevant study (Level I)\textsuperscript{212} was of 76 female soft contact lens wearers who were randomized to use either a placebo (olive oil) or omega-6 FAs (evening primrose oil). Subjects in the evening primrose oil group demonstrated a significant improvement in dryness symptoms at 3 and 6 months, as well as better overall lens comfort and increased tear meniscus height at 6 months. It was suggested that omega-6 FAs taken as evening primrose oil might be useful as a therapeutic adjunct for contact lens dry eye discomfort.

There is good evidence that omega-3 and omega-6 FAs are useful in decreasing inflammation in the bodily diseased states. Additional evidence supports their use in dry eye, especially severe states such as keratoconjunctivitis sicca and Sjögren’s syndrome, and the little that has been published relative to soft contact lens discomfort or dryness is also suggestive of their utility. In summary, although omega-6 FA supplementation may help reduce CLD, the use of omega-3 FAs has not been directly studied.

**Hydration.** Dietary advice is often given to patients with dry eye and in turn contact lens dry eye relative to hydration status and, indirectly, alcohol consumption. No research exists on the exact amount of water that is needed on a daily basis, although six to eight, 8-ounce glasses per day have been suggested as a target.\textsuperscript{213,214} The influence of hydration status on the tear film has been studied, but not with any specific reference to contact lens wearers. In one study conducted during the course of fasting, decreases in tear proteins and enzymes were noted,\textsuperscript{215} and in a small interventional study of dry eye sufferers, nearly 76% had decreased symptoms after being asked to increase their daily water intake for a 2-week period.\textsuperscript{216}

Alcohol consumption has been shown to significantly shorten tear breakup time, increase fluorescein staining, and increase tear film osmolarity.\textsuperscript{217} However, contact lens-wearing status was not explicitly indicated in this study.

Likewise there is no clear, peer-reviewed evidence addressing the issue of hydration status and contact lens-related discomfort or dryness. Anecdotal suggestions abound in relation to both topics, but more controlled studies are necessary to define the likely influence on contact lens discomfort.

**Punctal Occlusion**

Punctal occlusion is a therapeutic option for dry eye syndrome and, for the purposes of this review, refers to punctal or canalicular occlusion of the lacrimal drainage system. Either dissolving, intracanalicular, collagen plugs that last only days, or other polymers that may last months, can be used. More permanent, yet reversible, occlusion can be obtained with silicone rubber or conforming polymers, or with silicone rubber plugs that are retained at the punctum. Finally, electrocautery or laser ablation can be used to obtain more permanent and complete occlusion by inducing fibrosis of the canaliculus and or punctum. Occlusion may be partial or total depending on the method chosen and can be applied to either or both of the lower and upper punctal/canalicii.

A Cochrane review found a relative scarcity of controlled clinical trials assessing the efficacy of punctal occlusion therapy for dry eye, with data suggesting that silicone plugs can provide symptomatic relief in severe dry eye, and that temporary collagen plugs appear similarly effective to silicone plugs on a short-term basis (Level I).\textsuperscript{218} Although contact lens-related discomfort was not addressed in this particular review, other reports have done so.

Occlusion of the lower punctum with a silicone plug resulted in increased wearing times for 18 of 25 symptomatic wearers of soft contact lenses (Level II).\textsuperscript{219} Silicone intracanalicular plug occlusion of upper and lower drainage systems improved symptoms in symptomatic hydrogel contact lens wearers, an effect that decreased over time (Level I).\textsuperscript{220} Occlusion of the lower punctum only seemed to induce a short-lasting subjective benefit in contact lens wearers (Level III).\textsuperscript{221} A study using high-definition OCT demonstrated that occlusion of both upper and lower puncta in symptomatic and asymptomatic contact lens wearers increased tear meniscus, and this increased volume was associated with better comfort in both groups (Level II).\textsuperscript{222} These positive findings are opposed by one study that found no treatment effect when the lower punctum only was occluded with an absorbable polymer (Level I).\textsuperscript{223} Specifically, there was not a difference in tear film thickness or subjective responses when comparing a group that received punctal plugs and a group that received a sham procedure.

In total, the balance of evidence slightly suggests that punctal occlusion can improve contact lens discomfort and
that silicone plug occlusion is more likely to be effective than dissolvable types. Similarly, occlusion of both upper and lower lids is more likely to be beneficial than the lower lid alone.

This analysis, however, addresses only the effectiveness of punctal occlusion as a strategy for treating contact lens discomfort. Practitioners must also consider the risks, benefits, relative safety, and cost-effectiveness of the various approaches before proceeding.

**Topical Medications**

Data are very limited on the use of topical medications other than lubricants. However, based on the view that CLD is commonly associated with the evaporative form of dry eye disease, clinicians may consider approaching its management by applying similar treatments to those appropriate for evaporative dry eye. Topical medications may play an important role in this regard. Note that manifest signs of underlying ocular surface disease should already have been detected and treated as described above. A complete review of medications and their properties is beyond the scope of this report, but commonly used ones, their dosages, and their benefits and risks are briefly described.

**Azithromycin.** Azithromycin is a macrolide antibiotic. As well being one of the few antibiotic classes that achieve therapeutic concentrations in the eyelids, topical azithromycin is known to have anti-inflammatory properties, having recently been shown to decrease corneal inflammation and inflammatory cytokines in a murine model. Since the introduction of azithromycin ophthalmic solution 1%, a number of groups have investigated its efficacy in the management of blepharitis and associated symptoms. Although these studies provide Level II evidence, they do support the use of daily topical azithromycin ophthalmic solution 1% for the improvement of physical findings of blepharitis, which may be a precipitating condition for CLD. They also show concurrent reduction in related dry eye signs and symptoms, without significant treatment side effects.

Topical azithromycin ophthalmic solution 1% therapy clearly resulted in the reduction of the signs and symptoms of blepharitis and dry eye findings, with one study showing a sustained effect lasting at least 4 weeks after discontinuation of therapy.

To date, only one study has directly considered the safety and efficacy of azithromycin in patients with contact lens–related dry eye (CLDE). This was a 4-week, single-center, open-label clinical trial (Level II) in patients diagnosed using the Contact Lens Dry Eye Questionnaire (CLDEQ). Fifty patients were randomized to use either twice-daily azithromycin ophthalmic solution 1% or a potassium sorbate and edetate disodium preserved contact lens rewetting drop containing hypromellose and glycerozin administered four times per day. The azithromycin treatment was well tolerated and resulted in a significant improvement in comfortable contact lens wearing time in the patients with CLDE. However, given the short-term nature of this study and its relatively small sample size, further work is required to confirm the findings, as well as to establish the potential for undesirable side effects, such as the development of bacterial resistance.

**Cyclosporine.** Cyclosporine A (CsA) is a neutral, hydrophobic, cyclic peptide of amino acids that acts as a selective inhibitor of IL-2 release during the activation of T cells and suppresses the cell-mediated immune response. More specifically, it increases tear production and conjunctival goblet cell density based on its effects on subconjunctival and lacrimal gland inflammation in a significant number of moderate-to-severe dry eye patients.

Reports of the clinical efficacy of topical CsA in CLD are contradictory. A small ($n = 17$), 5-week, randomized, investigator-masked study (Level II) in which CLD patients were randomized to CsA 0.05% or carboxymethylcellulose 0.5% drops twice per day (before and after lens wear), demonstrated a decrease in CLD symptoms and less use of rewetting drops during the day for the CsA users, as well as an increase in wearing time. However, a larger ($n = 44$), longer-duration (3 months) double-masked study (Level I) found that there was no significant difference in signs or symptoms between the CsA treatment group and a control group using a preservative-free tear supplement. At this point in time, there is no strong evidence that CsA treatment is useful in CLD and additional trials are needed.

**Steroids.** There is still debate regarding the role of topical corticosteroids in the treatment of dry eye and related conditions, as inflammation may be present or absent in these clinical presentations. If, as in CLD, there are no vision-threatening aspects to the disease process, steroid use is especially hard to justify. There are no published studies supporting corticosteroid therapy for CLD.

**Nonsteroidal Anti-Inflammatory Drugs.** Like corticosteroids, the rationale for considering the use of a nonsteroidal anti-inflammatory drug (NSAID) is to reduce any underlying inflammation. Given that the presence of such inflammation in CLD is controversial, the case for using NSAIDs, like that for corticosteroids, has not been made. There is no evidence supporting NSAID use in the treatment of soft lens–related CLD.

For RGP s, two studies evaluated 0.1% diclofenac sodium. In the first, four-times-a-day treatment with 0.1% diclofenac for 3 days before dispensing had no effect in unadapted contact lens subjects (Level II). The second investigation involved a contralateral comparison with subjects reporting a preference for the eye that was given 0.1% diclofenac sodium four times a day for 1 week after the initial fitting (Level III). No difference in corneal or lid sensitivity was reported. Combined, these reports suggest that although diclofenac has no value in ameliorating initial discomfort issues, there may be some longer-term benefit. More evidence is required to confirm this.

**Anesthetics.** Proparacaine and other topical anesthetics indiscriminately target corneal nerve sodium channels. They are effective at eliminating ocular surface pain, but the effect is short-lived and these agents are prone to abuse. Furthermore, topical anesthetics have been shown to cause delayed wound healing and ulceration in the cornea. Although topical anesthesia has been shown to be effective in improving discomfort, both initially and out to 2 weeks of rigid lens wear, there is some resistance among clinicians to using this approach. No studies have evaluated the efficacy of these drugs in treating soft contact lens–related discomfort. This notwithstanding, the longer-term use of anesthetics as a treatment for any kind of contact lens–related discomfort is not supportable.

**Environment**

Most contact lens wearers encounter a range of conditions during the course of their daily lives. When asked about circumstances when they always or frequently wore lenses, responses from 80% of a large ($n = 496$) group of hydrogel wearers included reading, sitting in an air-conditioned or heated car, using a computer, and driving at night, whereas approximately 30% mentioned more extreme situations, such as airline travel and napping or sleeping. Contact lenses that cause only minor symptoms of dryness in a normal environment can precipitate significant discomfort when the wearer...
experiences prolonged exposure to adverse conditions (Level III). Dust, pollution, or smoke are especially problematic (Level III). Refitting the members of this cohort into silicone hydrogel lenses brought about significant comfort improvements in most environments, suggesting that this may be a viable clinical strategy. However, the study design used was prone to Hawthorne-type effects (i.e., subjects respond positively simply because they are being studied), so the outcomes must be interpreted cautiously.

There has been little research on the effects of environmental conditions on CLD in vivo. Comfort may be lower when RGP lenses are worn in low-humidity environments in some patients (Level III). In a small pilot study (n = 6), dehydration of soft contact lenses was found to be similar after 200 minutes of exposure to arid (5% humidity, 30°C temperature), temperate (70%, 22°C), and arctic (90%, 5°C) environments and there were no differences in subjective comfort (Level II).

Air quality aboard commercial aircraft varies significantly and is one situation in which many wearers choose to remove their lenses rather than suffer the ensuing discomfort. Interestingly, contact lenses are well tolerated by military aircrews (Level II/III), perhaps suggesting that the air quality within their cockpits or flight suits is of a higher standard, although there may be psychological factors involved as well. Nevertheless, it seems prudent to advise patients to avoid situations in which discomfort is known, or expected, to increase. Where contact with potentially threatening conditions is unavoidable, the use of protective eyewear should be considered.

**Blinking Behavior**

The suggestion that inadequate wetting of the anterior surface of the contact lens is a factor in precipitating late-day dryness and discomfort has led to scrutiny of the mechanism responsible for achieving the rewetting cycle, namely eyelid blinking. Occupational tasks, such as sustained viewing of a computer screen, for example, can alter the blink rate, causing symptoms, such as discomfort, dryness, and eyestrain. Inefficient blinking, which may be due to either reduced frequency or amplitude of lid movement relative to the lens surface (or both), has been put forward as a cause of this problem and modification of lid dynamics through blink-efficiency exercises proposed as a treatment. Although detailed instructional material is available for this method, data supporting its efficacy appear to be completely absent. Despite the fact that several authors have proposed the use of exercises in problem cases, there is a paucity of even anecdotal-level reporting on the outcomes of these treatment efforts. Their usefulness in providing symptomatic relief is therefore unknown and this is clearly an area in which well-conducted research is required. In a sample of 360 contact lens wearers, the type of blink was characterized for each subject (as complete, forced, or twitch); the type of blink was not related to contact lens dry eye status.

There is some evidence (Level II) that blink rate responds to the type of care system used with the contact lens. MPSs that contain wetting agents have been associated with lower blink rates than hydrogen peroxide-based systems, which do not have such additives. However, this slower rate was associated with better comfort; the opposite of what would be expected if blinking were the main cause. Although changing care systems may be a valid way of improving comfort, the mechanism involved does not seem to be one that directly influences blink frequency. It is more likely that the solution addresses the underlying comfort problem by some other, unspecified means, and the blink rate slows down as a consequence. Nevertheless, the introduction of additional lubrication to the ocular environment might well be considered as an option for CLD, as has been covered elsewhere in this report.

**Alternatives**

**Soft to RGP and Vice Versa**

Soft lens patients who wore low-water-content lenses that maintained their hydration generally reported that their eyes “never felt dry” during wear, suggesting that preventing lens dehydration is an important factor in reducing symptoms. Repeated failure with soft lenses may prompt consideration of RGP lenses, as they are much less prone to dehydration. There are, however, no recently published evidence-based data on refitting modern-day contact lens wearers with complaints of CLD into RGP contact lenses. On the other hand, there are several reports supporting refitting into soft lenses for those who experience poor comfort in RGP contact lenses. Subjects fitted with a soft lens in one eye and an RGP lens in the other preferred the comfort, although not the vision, of the soft lens after 3 months (Level II). Likewise, toric hydrogels were rated as being more comfortable than RGP contact lenses after 5 weeks of wear, with vision preference again in favor of the RGP lens (Level II). Younger wearers (8–11 years) experiencing discomfort problems with RGP lenses might gain, in terms of reduced frequency of symptoms, by switching to soft contact lenses. Once again vision was significantly better in the rigid lens modality (Level II).

Clearly, switching uncomfortable RGP lens wearers into soft lenses is a viable approach, but one that may be accompanied by inferior vision. Some wearers may also find the different lens maintenance and handling procedures problematic.

**Reduced Wearing Time**

Many patients choose to limit their wearing time to avoid periods in which their discomfort is at unacceptable levels. For some, this will involve wearing lenses during working hours, whereas others will choose to favor leisure periods. Although this is often a useful compromise, it is doubtful whether the total daily wearing time can be extended using this method (Stahl U, et al. J OIVS 2013;54:ARVO E-Abstract 5462).

**Orthokeratology**

Orthokeratology (OKK) lenses are worn during sleep and are removed on awakening, at which point the refractive error of the unaided eye is reduced or eliminated. In the best case scenario, patients are thus relieved of the need to wear a refractive correction of any kind during their waking hours and so do not experience CLD. It is this aspect that gives OKK its potential as a management option for those with intractable discomfort related to soft contact lens use.

There are no studies that directly compare OKK as an alternative for patients who experience soft contact lens discomfort; however, corneal epithelial health, a potential surrogate for ocular discomfort, has been studied. A crossover study that measured the tear concentration of lactate dehydrogenase before and after overnight OKK wear, found markedly increased levels of the enzyme, suggesting that corneal hypoxia results from OKK overnight wear. Similar findings have also been observed after extended-wear soft contact lens use. Tear lactate dehydrogenase levels have not been compared between OKK and soft contact lenses.

OKK is not without its limitations and risks of side effects or complications. The corrective effect from OKK is not...
Management and Treatment of CLD

OBJECTIVE

The purpose of this review is to summarize current evidence on the management and treatment of CLD (i.e., contact lens–related dry eye) and to discuss potential future developments.

METHODS

A comprehensive literature search was conducted to identify relevant studies. Evidence was graded using the Oxford Centre for Evidence-Based Medicine criteria.

RESULTS

Surgical interventions, such as refractive surgery and OOK, are effective in improving vision and reducing discomfort. However, they are not without risk and require careful consideration.

Lighting conditions and pupil dilation can affect visual acuity. Pigmentation of the lens can cause higher-order aberrations, such as spherical aberration.

Permanent and lenses must be periodically worn overnight to reproduce the effect. Unlike the effect of contact lenses or spectacles, there is slight regression of the effect and a change in refraction from 0.25 to 0.75 diopters can occur throughout the course of the day.

Keratorefractive surgery, like OOK, can cause the induction of higher-order aberrations, such as spherical aberration, which can be more problematic in low-lighting conditions and with pupil dilation.

Pigmentation of the cornea has also been reported. Of these complications, microbial keratitis remains the most feared, as it can result in permanent vision loss. There have been more than 20 publications describing microbial keratitis in case reports and case series; however, the relative frequency with which microbial keratitis occurs in OOK as opposed to soft lens wear is not clear. There are no studies that have Level I evidence for microbial keratitis in OOK. In two studies that have Level II evidence, no adverse events were reported after 15 months of OOK use in 65 adult patients, or with more than 3 months of follow-up in 14 patients.

Refractive Surgery

Most practitioners are aware of individuals who have abandoned contact lenses in favor of refractive surgery, and there is good evidence (Level II) that contact lens–related dryness is an important precipitating factor. In a survey of refractive surgery patients who had previously worn contact lenses, 23% cited dry eyes as the reason for their decision to undergo refractive surgery. Utilization of refractive surgery as a means of managing CLD requires careful thought and counseling of the individual patient, as there are several aspects that need to be considered before proceeding. Not the least of these is that the procedure itself is commonly associated with dry eye in the postsurgical period. Other potential complications include ocular pain and visual disturbance due to halos, glare, and spherical aberrations. Faced with these issues, the question of whether the overall situation of the patient will be improved postsurgery is an important one to consider. In a study that assessed the preoperative quality of life and psychological factors that influence decision making in Laser In Situ Keratomileusis (LASIK) surgery, SCL wearers, not interested in LASIK, reported better vision function (P = 0.001), felt more attractive (P = 0.007), had a lower frequency of disturbing visual and ocular symptoms (P = 0.027), and had a higher overall satisfaction with their current optical correction (P < 0.001) than patients seeking LASIK surgery (Level II). There is some evidence (Level II) that quality of life after LASIK refractive surgery is better overall than that of contact lens wearers. However, no studies have evaluated the change in subjective satisfaction that contact lens wearers with discomfort have after opting for surgical refractive correction. Not all patients are candidates for laser keratorefractive surgery and careful screening is required to eliminate those with keratoconus, herpetic eye disease, and history of autoimmune disease. Serious complications, such as infection and corneal ectasia, can result in significant loss of best-corrected visual acuity (BCVA). In fact, 2.55% of eyes treated with either LASIK or photoablative keratectomy (PRK) have been shown to lose two or more lines of BCVA. Infections are rare after LASIK; however, more than 80 cases have been reported and reports in the literature put the incidence at between 1 per 1000 to 5 per 1000. This compares with average rates of 0.35 and 3 per 1000 in daily and extended contact lens wear respectively.

Spectacles

Although there are no published data on spectacle wear as a management strategy for CLD, it is fairly obvious that this will be the default option for the vast majority of lapsed contact lens wearers. Unarguably, spectacles provide a convenient, accessible, and effective alternative in cases of persistent CLD. Given that freedom from spectacles is the main driver for patients to begin contact lens wear in the first place, an enforced return is unlikely to be viewed positively in most cases, however. For many sufferers, intermittent contact lens wear, interspersed with periods of spectacle wear, will be an acceptable middle ground requiring maintenance of an up-to-date spectacle prescription. It is important to instruct the patient in the care and hygiene conditions that are necessary for contact lenses worn on this sporadic basis. Daily disposables offer advantages in this respect and are the preferred option.

FUTURE POSSIBILITIES

Therapeutics that reduce pain directly or through neuromodulation potentially could be used to treat contact lens discomfort that exists in the absence of coexisting disease. The treatment of ocular surface pain is an active area of research because safe, prolonged pain relief is difficult to achieve. Furthermore, the sensitive nature of the cornea contributes to the challenge of providing successful analgesia.

In animal studies, other therapeutics have been used to treat ocular surface pain. For example, resiniferatoxin exhibited prolonged analgesia without delaying corneal wound healing in rats and selectively targeted specific cornea sodium channels within nociceptive neurons, which are triggered by irritating chemicals.

Opioids are another class of drugs that are predominantly administered systemically, affect the central nervous system, and have analgesic effects when administered topically to the eye. Morphine has been found to act on local opioid receptors in the cornea, to decrease corneal inflammation, and lessen corneal hyperalgesia. Topical morphine has also been shown to provide corneal analgesia for up to 4 days without causing a delay in re-epithelization.

Neuromodulation of the cornea is another area of ongoing research that is related to CLD. In this respect, one of the most studied therapeutics is autologous serum tears, which are biological subproducts of blood. Autologous serum tears have been shown to contain significantly more neurotrophic factors than human tears and have been reported to restore corneal sensitivity in eyes that suffer from neurotrophic keratopathy. These findings were reported from retrospective noncomparative case series where it was also demonstrated that 20% autologous serum could promote the healing of corneal epithelial defects associated with neurotrophic keratopathy. Although most of the literature published on autologous serum includes predominantly retrospective case series, investigators have performed small prospective, randomized trials. A double-masked randomized prospective crossover clinical trial found that 12 severe dry eye patients had a significant symptomatic improvement when treated with autologous serum compared with artificial tears during a 2-week treatment period. Another small prospective, randomized, masked clinical study demonstrated significantly faster wound healing than hyaluronic acid drops, a commonly used artificial tear product. There have not been any published reports on the use of autologous serum specifically for treatment of CLD and its widespread use for this application may be limited by production barriers that include the need for phlebotomy, a standardized manufacturing method compliant with regulatory measures, and long-term storage.
CLD presents a considerable clinical challenge. Although the causes of the short-term discomfort associated with post-insertion difficulties are generally understood and appropriate remedies relatively easily applied, symptoms of discomfort and dryness that persist and increase toward the end of the day pose a more intractable problem. Managing patients in these circumstances requires careful, individual assessment to eliminate concurrent conditions that may confuse the clinical picture, followed by a determination of the most likely cause or causes and identification of corresponding treatment strategies. The Figure again shows a recommended treatment algorithm for clinicians to follow in managing CLD. With this in mind, it should be appreciated that the subjective effects of these tactics may have reasonably limited magnitude. In many cases, therefore, incremental improvements may be all that can be reasonably expected from any single intervention and the addition of treatments in a stepwise manner may be required to provide the maximum possible relief. Unfortunately, given the current state of knowledge surrounding the condition, a proportion of patients will remain with residual levels of CLD that are sufficiently bothersome, causing them to resort to discontinuation of contact lens wear. Continued research is needed to support the development of technologies that will permit the progressive elimination of the problems experienced by this portion of the contact lens-wearing population.

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