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ScienceDirect
Contact Lens & Anterior Eye 30 (2007) 37–51
contactlens & ANTERIOR EYE
The Journal of the British Contact Lens Association
www.elsevier.com/locate/clae

Incomplete blinking: Exposure keratopathy, lid wiper epitheliopathy, dry eye, refractive surgery, and dry contact lenses[☆]

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Abstract

Exposure keratopathy, including that which occurs following laser assisted keratomileusis, appears to be associated with incomplete blinking. Incomplete blinking may contribute to the signs and symptoms of lid wiper epitheliopathy. In addition, precipitation of contact lens surface deposits and other contact lens surface drying phenomena, appear to be accelerated by incomplete blinking. For the inferior cornea or contact lens surface an incomplete blink approximately doubles the interblink interval and tear evaporation time, becoming even longer as blink rates reduce for computer and reading tasks. Inadequate aqueous, mucous and lipid distribution, as well as tear thinning over the exposed ocular or contact lens surface, may further increase the rate and significance of tear break-up and evaporation following an incomplete blink. Increased tear osmolarity that is associated with accelerated tear evaporation may also contribute to tissue changes and symptoms. Behaviour modification and habit reversal methods can be employed in the provision of blink efficiency exercises that are used to overcome incomplete blinking habits, with the potential to improve lipid, mucous and aqueous distribution so that exposure keratopathy, lid wiper epitheliopathy, and any associated symptoms are alleviated and/or prevented. Similarly, improved blink efficiency may help maintain lens surface condition and alleviate dryness symptoms for contact lens wearers. Lubricant drop instillation that is combined with blink efficiency exercises may increase the therapeutic benefit to corneal, conjunctival and lid wiper epithelium, as well as improving contact lens performance. Conditions of drop instillation, that reduce reflex blinking and tearing, may increase drop contact time and therapeutic benefit.

Keywords: Dry eye; Blinking; Exposure keratopathy; Contact lens; Lid wiper; Refractive surgery

1. Introduction: dry eye; tearing thinning; interblink intervals; contact lens symptoms

Dry eye, or keratoconjunctivitis sicca, is a rubric for a number of clinical disease states, accounting for a high percentage of patient visits to ophthalmologists [1]. In a large sample of the general population, 33% reported dry eye problems [2]. Marginal dry eye syndromes in the general population include those that only reach clinical significance under provocative conditions associated with air-conditioning, central heating, cigarette smoke, smog, and the use of certain medications, for example [3]. In addition to dry eye problems in the wider community, tear function is further challenged by contact lens (CL) wear, and even marginal tear deficiency may significantly reduce CL performance [4]. For example, symptoms of CL dryness are a very common source of discomfort and are associated with reduced or abandonment of lens wear [5–8]. Dryness symptoms are most common in the evening [8] and, anecdotally, patients report that dryness symptoms increase toward the end of their lens replacement cycle. When recommended replacement schedules are not followed, dryness symptoms appear to be one of the triggers for both early and late lens replacement. Subjects with a history of CL intolerance were found to have significantly more primary (unprovoked) dry eye symptoms, when not wearing CLS, compared to those with a history of good CL tolerance [9]. In the same study, average corneal tear break-up times for each sample were 7 s (CL intolerant) and 20 s (CL tolerant) [9]. This finding suggests that tear layer evaporation is accelerated for CL intolerant patients. In a similar comparison, a CL intolerant sample was found to have

☆ Presented at the Annual Conference of the British Contact Lens Association, Birmingham, May 2006.
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1367-0484/$ – see front matter
doi:10.1016/j.clae.2006.12.002

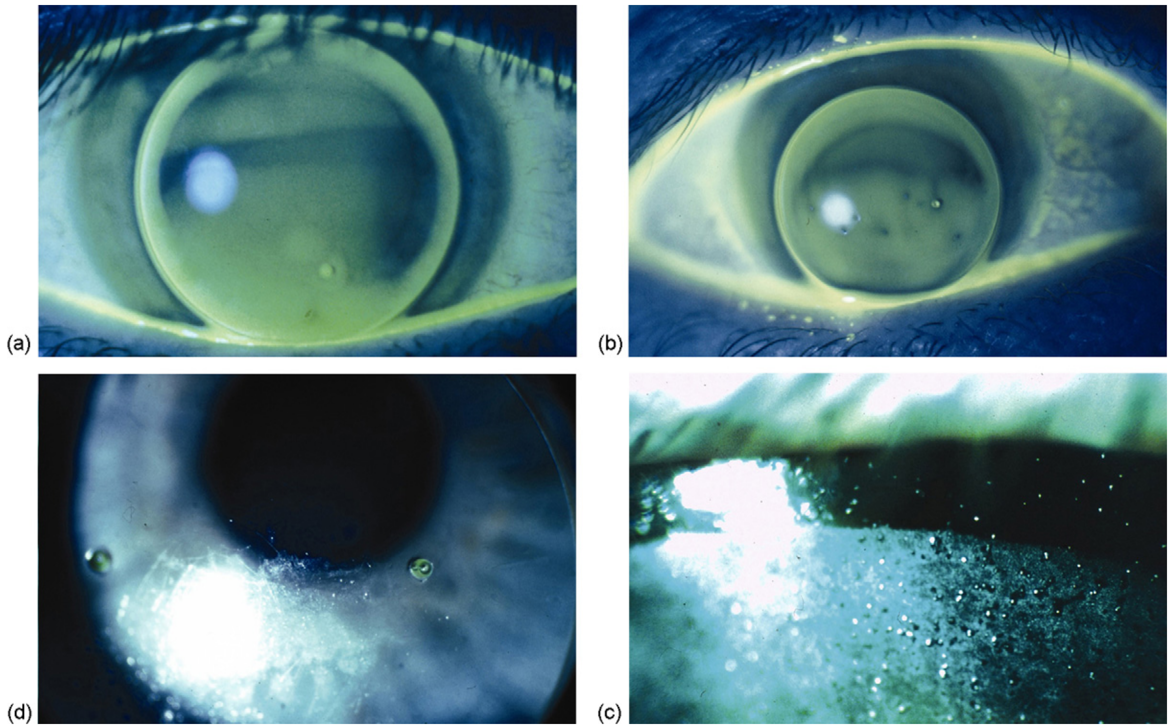

Fig. 1. Reading clockwise from top left—(a) Top left: The band of thinned tear layer provides evidence of an incomplete blink prior to this photograph. (b) Top right: Downward lens displacement and tear break-up on the inferior lens surface following an incomplete blink. (c) Bottom right: An incomplete 'twitch' blink appears to have occurred prior to this photograph of a rapidly drying lens surface. (d) Bottom left: Deposits that are restricted to the inferior contact lens surface on non-rotating (e.g. prism ballast) lenses appear to be due to incomplete blink habits.

reduced tear volume scores based on lower lid tear meniscus and phenol red thread assessments [10]. CL intolerant people appear to have a lot in common with people who suffer from dry eye because aqueous deficiency and evaporative mechanisms are major classes of dry eye [11] and, as discussed below, both mechanisms may contribute to CL related dryness symptoms. For example, in the case of soft CL wear, experimental results suggest that bulk material dehydration may not be as important as anterior surface dehydration for the production of symptoms of dryness [7]. Water lost by dehydration of the lens material was found to make a relatively minor contribution to the increase in evaporation from the eye during lens wear [12]. Loss of water from the anterior CL surface appears to be the primary mechanism. For example, non-invasive pre-lens tear break-up time was found to reduce significantly with hours of wear [7]. This finding suggests that the anterior lens surface becomes increasingly less wettable within the time frame of a single wearing period. This explanation is supported by the finding that the tear thinning rate on silicone hydrogel lenses increases significantly over a two week period of daily lens wear [13]. Compared with about 7 μm for the normal pre-corneal tear layer thickness, the pre-lens layer is much thinner on the surface of conventional hydrogel lenses, and is estimated to be about 2 μm following a normal fast blink [14]. Using a wavelength-dependent-fringe interferometer, the average pre-lens tear film thickness was found to be 2.54 μm on HEMA-based lenses [15] and 2.48 μm on silicone hydrogel lenses [13].

For an uncorrected eye, the bulk of the surface tear volume is located in the marginal tear strips [16] but the tear meniscus at the edge of CLS, or tears retained under CLS, may further reduce the volume of tears available to form a pre-lens layer (Fig. 1a). However, tear volume is not the only consideration. Depending on the adequacy of the lipid layer, the pre-lens tear layer may be more susceptible to evaporation, tear break-up and dry spot formation [12]. For example, Fig. 1b shows dry spot formation on what appears to be an otherwise thick tear layer in the area of a rigid lens that has been exposed by an incomplete blink. The leading cause of evaporative dry eye is Meibomian gland dysfunction involving deficiency and/or alteration in lipid secretions that are frequently associated with lid margin inflammation [1]. A CL disrupts the integrity of the lipid layer [17], which can be invisible with some CLS [18]. When drying occurs on the anterior lens surface, deposits may precipitate [19] (Figs. 1c and d and 2a). Lens surface wetting can be improved by blinking to create an adequate coating of protein and/or polysaccharides, but wettability tends to reduce as the lens surface goes through wet and dry cycles [19]. Atmospheric conditions may contribute significantly to CL performance, although lens dehydration can be more affected by airflow than reduced humidity [20]. Surface drying and precipitated deposits may contribute to

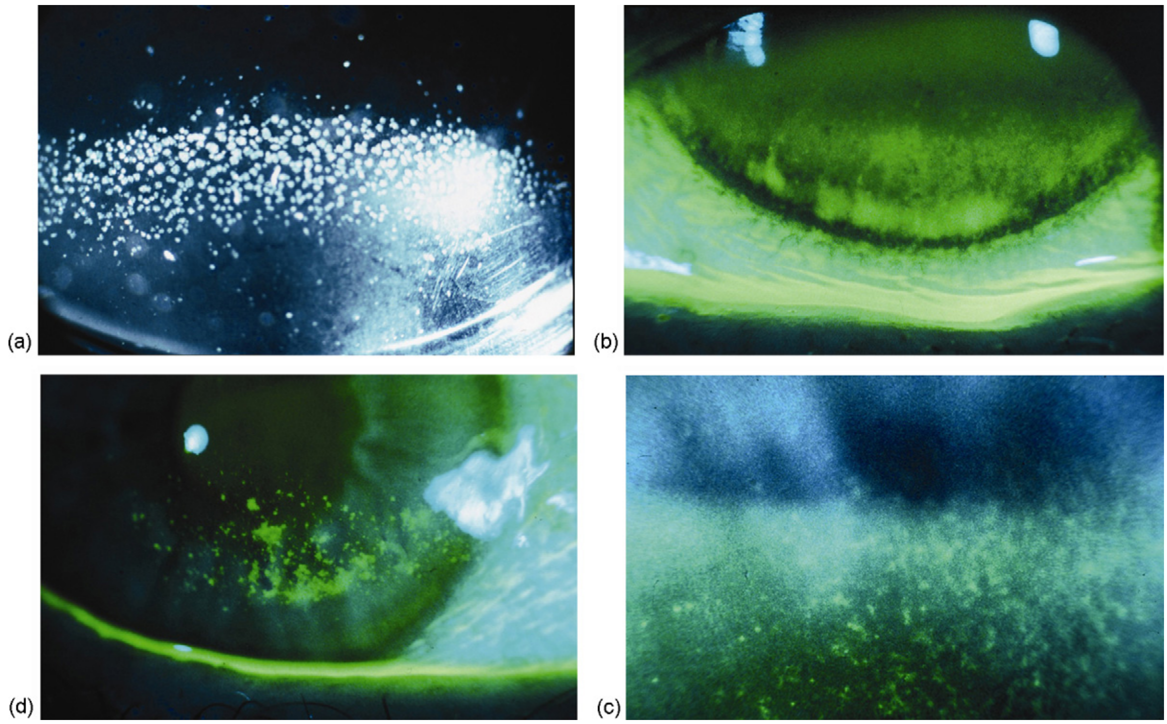

Fig. 2. Reading clockwise from top left—(a) Top left: For a non-rotating (e.g. prism ballast) lens designs, a horizontal band of mid-peripheral deposits suggests that incomplete blinking, and associated tear thinning and evaporation, can play a crucial role in deposit precipitation. (b) Top right: The band of thinner tears immediately above the stained exposure keratopathy appears to define the limit of downward excursion of the top lid for the blink immediately prior to this photograph. The keratopathy below the thinned tear layer suggests that this type of incomplete blink is common. (c) Bottom right: Punctate inferior corneal epithelial keratopathy that developed with soft lens wear without symptoms and appears to indicate a high rate of incomplete blinking in association with intensive (proof) reading. (d) Bottom left: A causal role for incomplete blinking is suggested by exposure keratopathy that occurs following a laser assisted keratomileusis procedure, especially when the keratopathy involves the normally innervated region outside the flap.

the perception of dryness (Figs. 1c and d and 2a). However, apart from adequate tear quantity and quality, and favourable atmospheric conditions, the maintenance of wetness and comfort of eyes and contact lenses also depends on efficient blinking. Low blink rates, and the associated longer interblink intervals, increase the risk of significant ocular and/or lens surface drying. When hydrogel lenses are worn, pre-lens non-invasive tear break-up times of 6–8 s [21] suggest that interblink intervals need to be less than 6–8 s to maintain lens surface wetness and to slow precipitation of deposits (Figs. 1c and d and 2a). When blink rates fall below 10 per minute, and average interblink intervals increase to 6 s, the risk of surface drying and deposit precipitation is greater. Apart from evaporation, tear layer thinning appears to depend on dewetting, Marangoni flow (that is, surface tension gradients), and pressure-gradient flow [15]. Although the pre-lens tear film thickness on silicone hydrogel lenses was found to be similar to that found on HEMA-based lenses, much higher rates of pre-lens tear film thinning were found for the silicone hydrogel lenses [13]. Thinning rates were also found to vary widely for individual subjects (2–20 μm/min [15]) and these variations may be correlated with the degree to which symptoms are experienced by CL wearers and non-CL wearers. Advances in silicone hydrogel materials may result in a lowering of pre-lens tear thinning rates [22,23].

2. Inter- and intra-subject variations in blink rate

A review of studies that examined blink rates in human subjects, indicated sample-average blink rates that ranged between 10 and 22 blinks per minute [24]. The disparities between studies demonstrate how blink rate is dependent on varying experimental conditions for measurement. For example, blink rate during computer use was found to be 4 blinks per minute, only 20% of the rate recorded for the same subjects during a period of general conversation [25]. Another group was found to record an average of 8 blinks per minute while reading and 21 blinks per minute while engaged in general conversation [24]. Blink rate has been found to reduce significantly as task difficulty increased from watching a film, to reading, to counting the number of times the letter ‘a’ appeared in reading material [26]. These results are consistent with the finding that there is a tendency for non-blink periods to be sustained until difficult target recognition tasks are completed, and that there is a mechanism for inhibiting spontaneous blinks [27]. However, apart from intra-subject blink rate variation according to visual task demands, there is also a large range of inter-subject blink rate variation. For the same experimental conditions of watching an educational film, the blink rate for 20 subjects varied between 6 and 30 blinks per minute [28].

3. Benefits of complete blinks: mucin distribution; lipid secretion; tear stability

Blinking is a protective mechanism for the cornea and conjunctiva, serving to maintain a tear layer over the ocular surface that is necessary for epithelial health and optical performance [29]. Complete blinks help to maintain a clean and wet anterior CL surface. Complete blinks cause debris to be swept into the inferior marginal tear strip allowing a cleaner tear layer to be distributed as the upper lid ascends [30]. Complete blinks maximize the extent of distribution of tarsal goblet cell mucin. Forceful blinking can significantly increase lipid layer thickness providing the Meibomian glands have adequate reservoirs of secretion, and the gland orifices are not blocked with clusters of keratotic cells [31]. The normal apposition of the lids during a complete blink is a means of promoting lipid secretion from Meibomian glands [32,33]. The lipid layer is spread across the cornea by the upper lid [31] and incomplete blinking, or a reduced blink rate, may be associated with poor maintenance of lipid layer integrity. For example, during prolonged reading, when blink rate is significantly reduced [24], the lipid layer can disappear and then reappear with conscious blinking [32].

4. Consequences of incomplete blinking: deficient mucin and lipid distribution; longer interblink intervals for the inferior cornea (keratopathy) and contact lens (deposition)

For a sample of normal subjects under experimental conditions of watching an educational film, incomplete blinks were found, on average, to represent 10% of the total number [28]. In another group of normal subjects, the rate of incomplete blinking, for an unspecified vision task, was 20% of the total [34]. Incomplete blinks appear to have occurred immediately prior to the photographs shown in Figs. 1a–c and 2b. The incomplete blink immediately prior to Fig. 1c is also described as a twitch blink [34]. However, as is the case for overall blink rate, incomplete blink rates may vary widely between individuals. Incomplete blink rates may also vary for the same individual according to the ambient conditions and the state of fatigue and/or mental alertness, for example, as well as the difficulty of the vision task involved. For example, some incomplete blinks may result from incomplete or partial inhibition of spontaneous blinking during a difficult recognition task. An incomplete blink may be the result of partial or unsuccessful inhibition of a spontaneous blink. Thus visually and/or intellectually demanding tasks may be associated with higher than normal rates of incomplete blinking. Compared to the superior cornea, fluorophotometry assessment shows that tear layer thickness reduces over the inferior cornea, as the upper lid ascends following complete closure with a normal blink [30]. In addition, partial blinking substantially reduces tear film thickness, [30] (Figs. 1a and b and 2b). Significant tear evaporation and break-up problems appear to be more likely to occur in regions of a thinner tear layer. Close apposition of the lid margins during a complete blink may involve the combination of the tear meniscus of the upper and lower lids, providing a larger volume of tears for distribution over the cornea by the ascending upper lid. In contrast, an incomplete blink is only able to re-distribute the tears of the upper lid tear meniscus and the superior cornea during the upper lid ascending phase. The bands of thinned tear layer evident in Figs. 1a and b and 2b appear to have been created as the upper lid tear meniscus reforms during an incomplete blink. Assuming that the concave tear meniscus at the margin of the upper lid is deformed by any tears collected and pushed downward during the blink descending phase, reformation of the concave meniscus may draw fluid upwards as the blink ascending phase commences. Thus, tear thinning inferiorly may sometimes be a consequence of an incomplete blink sequence. Loss of tear layer thickness inferiorly, possibly to critical levels, also appears to be at least partly due to incomplete blinks and the associated longer evaporative interblink periods for the inferior cornea. In the case of a blink rate of 12 per minute (average interblink interval of 5 s) an incomplete blink creates an interblink interval of approximately 10 s for the corneal, conjunctival and/or CL surface areas that are exposed by the lack of completeness. When the blink rate is reduced to 8 per minute while reading [24], the average interblink interval is 7.5 s and an incomplete blink increases the interblink interval for the exposed cornea, conjunctiva or CL surface to approximately 15 s. However, when the blink rate is only 4 per minute (during computer use, for example [25]), and the average interblink interval is 15 s, an incomplete blink creates an interblink interval of approximately 30 s for the exposed cornea, conjunctiva or CL surface. It is a well-known clinical phenomenon that desiccation occurs in the exposed cornea (Fig. 2b–d) in consistent partial blinkers [30,34]. For example, incomplete blinking for subjects with superficial inferior punctate keratopathy was found to represent 90% of the total [34]. This finding raises the question as to what extent do incomplete blinking habits contribute to the development of inferior punctate keratopathy, and to what extent are they also partly a consequence of the epitheliopathy and any associated symptoms. If symptoms of inferior punctate keratopathy irritation occur with blinking, blinking may be inhibited and/or the rate of incomplete blinks may increase [14]. However, when the superior cornea is normal, and inferior punctate keratopathy is symptomless (Fig. 2c and d), the incomplete blinking rate, that appears to have contributed to the development of the keratopathy, may be unchanged. For example, Fig. 2c shows inferior punctate keratopathy that developed without symptoms under a soft CL in association with intensive proof reading.

To the extent that lipid secretion depends on lid margin contact, incomplete blinking appears likely to contribute to lipid layer deficiencies. Incomplete blinking will not express the Meibomian glands or reform those portions of the lipid layer that are not wiped by the blinks; the tear layer over the un-wiped areas of cornea will continue to thin until re-wiped by a subsequent complete blink [35]. The classical view of tear film structure is that of an aqueous layer sandwiched between a very thin layer of mucus bound to the corneal epithelium and a lipid layer [36]. A review of the mucous contribution to tear film structure indicated that the classical aqueous layer is really an aqueous/mucous gel [36]. The concentration of the mucous component reduces toward the lipid layer, from a maximum at the epithelial surface [36]. Apart from the possibility of deficient Meibomian gland secretion and inadequate lipid spreading, incomplete blinking results in reduced opportunities for the tarsal goblet cells to contribute to the integrity of the mucin layer of the exposed cornea and tear film. In Fig. 2b, the bottom of the zone of thinner tears immediately above the stained exposure keratopathy appears to have been the limit of downward excursion of the top lid for the blink immediately prior to this photograph. The relative normality of the epithelium (freedom from staining), in the zone above the exposure keratopathy, raises the possibility that tear thinning alone may not be a sufficient basis for keratopathy to develop. For example, reduced delivery of tarsal goblet cell mucin to the exposed area may be a more important factor for the development of keratopathy than a thinned tear layer. Conjunctival stain is increased in symptomatic patients with both sodium fluorescein and lissamine green stains being discriminating factors for symptomatic non-CL wearers [37]. However, only lissamine green staining could discriminate symptomatic from asymptomatic soft lens wearers [37]. These findings suggest that the exposed conjunctiva may also be disadvantaged by incomplete blinking. It is assumed that deposits are more easily precipitated on a CL anterior surface when the pre-lens tear layer thins or evaporates, and leads to a concentration of tear constituents. In the case of non-rotating lens designs (prism ballast toric lenses for example) a horizontal band of deposits (Fig. 2a) suggests that incomplete blinking can play a crucial role in deposition. It appears that incomplete blinks may thin the tear layer in the region of the deposit as well as allow the tear film over that area to evaporate, per medium of longer interblink intervals. It is presumed that regular surface re-wetting associated with complete blinks inhibits deposition over the superior portion of the lens in Fig. 2a. The lower lid margin tear meniscus appears to have kept the lower region free of significant deposits by preventing tear layer thinning and evaporation (Fig. 2a). Similar deposits appear unlikely to be as evident for the same patient wearing a lens design that is not prism-ballasted, and so free to assume different meridional positions on the eye from day to day. In this case the deposits could be precipitated, but because they are distributed over 360° of the lens mid-periphery, the band of deposit would not develop, and the patient's incomplete blinking habits may not be as apparent. Incomplete blinking is frequently observed during a biomicroscopy examination (Fig. 1a–c) with patients having to be instructed to blink completely, in order that a clearer view of the cornea through a CL can be achieved.

5. Refractive surgery: corneal denervation; incomplete blinking; exposure keratopathy

Dry eye signs and/or symptoms are frequent complications following laser in situ keratomileusis (LASIK) [38]. Fluorescein, lissamine green and/or rose bengal staining of superficial epithelial keratopathy occurs in the exposed area of the cornea in both the flap and the surrounding cornea (Fig. 2d) [38]. Patients can experience a foreign body sensation [38] although many patients can be totally asymptomatic despite the presence of exposure keratopathy [39]. The cause of exposure keratopathy may be neurotrophic in origin with nerves severed by the microtome during flap formation [39]. In addition, innervation damage also occurs during LASIK due to photoablation of the nerves of the stromal bed [40]. In vitro studies suggest that neurons and epithelial cells of an intact cornea support one another trophically through mutual release of soluble substances that promote cell growth, proliferation and differentiation [41]. Under 'resting' conditions mechanical movement of the lid over the cornea, as well as desiccation of the ocular surface due to low humidity or cooling air currents, are likely to provide adequate stimuli to induce release of neurochemicals from the nerves [41]. Additional neurochemicals, in concentrations appropriate for normal ocular surface maintenance, are probably supplied to the tear film by the conjunctiva, lacrimal gland, and the accessory orbital and eyelid glands [41]. Thus, in the healthy (normally innervated) eye, minor insults to the ocular surface are rapidly healed within a continuous trophic environment contributed by the tear film [41]. However, within hours of nerve injury, epithelium becomes swollen, microvillae are lost and cell slough-off rate increases, with the development of stippling [41]. In addition, cell mitogenesis is reduced with associated loss of corneal thickness and reduction of wound healing capacity [41]. Impaired corneal innervation due to herpetic keratitis, diabetes, prolonged CL wear, advanced age or refractive surgery procedures, puts the cornea at increased risk due to diminished trophic support provided by corneal nerves and tear film [41]. Corneal desiccation due to neurotrophic keratitis may be due to reduced lacrimal gland secretion, inhibition of the protective blink reflex and impaired epithelial metabolism, in addition to the loss of trophic influence of the corneal nerves [41]. For example, significant reductions in tear production and break-up time have been found at one and three month post-LASIK assessments [42,43]. However, a reduced blink rate associated with inhibition of the protective blink reflex may have increased significance in association with incomplete blinks, with the average interblink interval for the inferior cornea increasing at twice the rate of the increases in interblink intervals for complete blinks. Subsequent to LASIK procedures, the relatively normal superior cornea (Fig. 2d) suggests that tear quantity and quality as well as the overall blink rate are adequate, even if they are reduced from pre-surgery levels. By clinical assessment, impaired corneal innervation does not appear to be of any consequence to the unexposed superior epithelium. Consequently, incomplete blinking appears to explain the presence of keratopathy in the exposed inferior flap region, as well as any keratopathy in the exposed but normally innervated cornea surrounding the flap. On the basis that the cornea was normal prior to surgery, such a hypothesis suggests that, in cases of post-LASIK exposure keratopathy, the significance of incomplete blink habits may have increased since the surgically induced dennervation of the central cornea.

6. Corneal sensory experience with soft contact lenses in situ: tear and blink regulation

Long-term low Dk/t soft lens wearers were not found to have reduced corneal sensitivity compared to a control group of non-CL wearers [44]. A comparison between symptomatic and non-symptomatic soft lens wearers did not find any association between symptoms and corneal or conjunctival sensitivity [44]. However, although corneal sensitivity is unchanged, soft CLS form an artificial surface over the cornea and it appears to be impossible for the cornea to sense imminent tear break-up on the anterior surface of the lens [45]. The cornea–central nervous system–lacrimal (including accessory) gland loop for basal and reflex tear secretion may not function normally with soft CL induced depression of corneal innervation. The soft CL associated depressed rate of neural activity could be regarded as a form of functional hypaesthesia. Normally the cornea may be sensitive to upper lid margin (lid wiper) blink related friction or shear forces, but this mechanism appears likely to be greatly suppressed or eliminated by CL induced functional hypaesthesia. Apart from tear secretion, CL functional hypaesthesia may also influence blinking. With CL functional hypaesthesia, corneal innervation may fall short of the level required to contribute to the blinking that is associated with a normally innervated protective blink reflex. Because blink rate has been shown to reduce with corneal anaesthesia [46], functional hypaesthesia induced by soft CLS might also be expected to reduce blink rate [47]. After 10 min [48] and 3 weeks of soft lens wear [49], no significant change and a significant increase in blink rate were recorded, respectively. With long-term wear of soft CLS, a reduction in blink rate was found [50]. Blink rate may vary according to comfort levels. With soft lens induced functional hypaesthesia, it is possible that lid wiper sensations contribute significantly to blink rate. These sensations appear likely to vary with lens wetness and soiling for example.

A significant association was found between blink rate and tear break-up time in non-CL wearers [51]. It may be that changes in tear film stability, prior to tear film break-up, are detected by the sensory nerve endings in the cornea to trigger an involuntary blink [45,51]. Spontaneous blinks may be spontaneous only in the sense that the stimulus is not readily apparent [29] so that they are classified as endogenous rather than exogenous. A 0.8 °C cyclic variation of corneal temperature with blinks was found using infra-red imaging [52]. However, the possibility that temperature changes might contribute to the regulation of tear blink rate was ruled out on the basis that the corneal threshold for detecting temperature change is greater than 1 °C [52]. The alternative mechanism suggested was that increased tear evaporation provides a stimulus for blinking [52]. However, small localized areas of temperature change may be difficult to detect using a global assessment of surface temperature. Heat lost from the cornea due to tear break-up and/or evaporation may create small areas of reduced temperature. Temperature changes may be greater, and/or the threshold for detecting them may be lower, in an area of tear break-up, so that a contribution from temperature-based regulation of blink rate cannot be excluded entirely. The finding that blink rate reduced with corneal anaesthesia [46] supports the hypothesis that corneal sensitivity to tear break-up, or other surface changes, is involved in regulating blink mechanisms. However, following enucleation of both eyes, blink rate is reported to remain constant [53]. The control of spontaneous blinks during soft lens wear, when sensitivity to changes to the corneal surface is suppressed according to the degree of functional hypaesthesia, may be due to the same mechanism that controls spontaneous blinking after bilateral enucleation, presumably regulated endogenously.

7. Lid wiper epitheliopathy mechanisms and symptoms

A comparison of sodium fluorescein and rose bengal staining of the marginal conjunctiva of the upper lid that wipes the ocular and/or CL surface during a blink (lid wiper), was made between symptomatic dry eye patients and asymptomatic controls. Patients with dry eye symptoms (without corneal stain) were found to have lid wiper stain in 76% of cases compared with 12% for the asymptomatic controls [54]. Inadequate lubrication at the lid wiper–ocular surface interface with a concomitant increase in the frictional coefficient and an increase in the potential damage to either, or both of these ocular surfaces, appears to be applicable in the case of lid wiper epitheliopathy [54]. Exposure keratopathy may result in increased friction between an abnormal epithelium of the lid wiper and the desiccated inferior cornea (Fig. 2b and d). This frictional increase may be greatest for the complete blink that follows an incomplete blink, because the tear layer over the desiccated exposed cornea may be thinnest, and its lubricant properties most deficient, at the end of the prolonged interblink interval that is associated with an incomplete blink. The risk of mechanical trauma to the lid wiper epithelium appears to be significantly higher following an incomplete blink. Lid wiper epitheliopathy may be difficult to treat [54] and improved blink efficiency, that is achieved through a reduction in the rate of incomplete blinking, may be an important component of management. Lid wiper epitheliopathy was evident for 74% of the ocular irritation symptomatic CL wearers and 16% of the asymptomatic CL wearing control group [55]. The prime sensory mechanism for lens awareness or discomfort associated with an undamaged and well-fitted soft lens, appears to be the blink related action of the lid wiper over the CL surface. Any mechanical component in the aetiology of giant papillary conjunctivitis [56] suggests that the tarsal conjunctiva may also have the potential to contribute to CL awareness. The contrast in lubrication for the rewet and dry CL surface areas shown in Fig. 1c and the deposits in Fig. 2a indicate how lid wiper sensation and trauma may be associated with dry and/or harsh surfaces. Lack of wetness of the soft lens front surface (Fig. 1c), and associated symptoms of dryness, may be an important factor in increasing or decreasing the overall blink rate as well as the incomplete blink rate. For example, CL discomfort has been reported to have the effect of reducing the completeness and rate of blinking [14] so that awareness of lens dryness (and associated discomfort), that is detected by the lid wiper during a blink, may be a stimulus to reduced blink rate and/or incomplete blinks. Alternatively, awareness of lens dryness may be a stimulus to reflex tearing and blinking, although the high frequency of dryness symptoms in soft lens wear [5–8] suggests that awareness of a dry lens that is detected by the lid wiper, and any associated increased reflex aqueous production and blinking, is not usually an adequate stimulus for the significant relief of dryness symptoms. Reflex tear production may be poorly sustained over long periods of dryness symptoms. In addition, any reflex tears may be diluted with respect to dissolved protein [29], for example, and their lubricant performance may be reduced accordingly. An association between lid wiper epitheliopathy and symptoms suggests the possibility of a lowered threshold for lid wiper sensation in dry eye and dry CL conditions. Loss of superficial epithelium from a traumatized lid wiper may expose nerve endings and increase sensitivity. Conversely, the occasional observation that some patients are able to wear CLS that are very soiled and/or unwet, without apparent discomfort, suggests that such patients have high thresholds for lid wiper sensation. It is possible that the lid wiper in these cases has become toughened and desensitised through the development of an increased epithelial thickness including an increased density of keratinized cells.

8. Increased osmolarity: mechanisms and consequences

The evaporation rate from normal eyes increases by two-fold to three-fold with topical corneal anaesthesia [57]. The combination of reduced aqueous production, increased tear retention, disruption of the tear lipid layer and increased tear evaporation, appears to explain an associated increased tear osmolarity [57]. The ocular surface disease in keratoconjunctivitis sicca (including decreased goblet cell density) is associated with an elevation of tear film osmolarity [58]. Reduced goblet cell density has been found following LASIK, especially if management of ocular surface disease was not provided [59]. Exposure keratopathy may be associated with hyperosmolarity, especially when incomplete-blink-related increased tear thinning and evaporation combine with longer interblink intervals for the inferior areas of the cornea and conjunctiva. Any associated increases in osmolarity could contribute to lid wiper epitheliopathy as well as exposure keratopathy. Similarly, some CL wearers with marginal tear function may be susceptible to higher osmolarity that contributes to symptoms, lid wiper epitheliopathy and exposure keratopathy. However, when non-exposed regions of the cornea are healthy, hyperosmolarity alone does not appear to be a sufficient condition for keratopathy to develop. Any increased osmolarity contributions to exposure keratopathy appear to be secondary to incomplete blinking habits.

9. Indications for blink efficiency exercises: symptoms; exposure keratopathy; surface deposits; lid wiper epitheliopathy

Exposure keratopathy may be successfully managed if efficient (complete) blinking habits can be developed, or restored, to help re-establish healthy corneal, conjunctival and lid wiper epithelia. Improved regularity of complete blinks, may contribute to reduced tear thinning and evaporation rates by improving mucin, lipid and aqueous distribution. Accordingly, there may be the possibility of avoiding tissue changes and symptoms that might result from hyperosmolarity and drying that increases friction between lid wiper and the ocular surface. Similarly, improved blink efficiency may help to maintain a wet and clean CL surface, with a concomitant reduction in friction related trauma to the lid wiper and any associated symptoms. Blink efficiency exercises should not be introduced into patient care without consideration of other aspects of dry eye and dry CL management. For example, patients with exposure keratopathy in association with incomplete blinking can benefit from tear substitutes as well as a change in their blink pattern [34,60]. However, signs of exposure keratopathy may not be accompanied by symptoms. For example, post-LASIK exposure keratopathy may be symptomless (Fig. 2d). In addition, the keratopathy shown in Fig. 2c developed during soft lens wear, and periods of intensive proof reading, in the absence of any presenting symptoms. Nevertheless, these types of findings are an indication for blink efficiency exercises and tear substitutes, as well as representing a contraindication to extended wear, in particular, if they cannot be managed successfully. The findings that chronic dry eye conditions increased the risk for refractive regression after LASIK [61], and that ocular surface management minimized the impact of LASIK on goblet cell density reduction and dry eye symptoms [59], suggest the possibility that blink efficiency exercises may also have a beneficial role for refractive surgery outcomes (even when symptoms are absent). Wound healing and refractive outcomes may be enhanced. Given prophylactically, ocular surface management that includes blink efficiency exercises may also serve to allow some patients to present for surgery with an improved prognosis for optimum refractive outcomes. Indications for blink efficiency exercises based on signs without symptoms may be more difficult to manage if patient motivation to follow remedial recommendations is lacking. Conversely, the presence of symptoms may provide the basis for increased patient compliance with remedial instructions.

However, post-LASIK symptoms are often reported in the absence of exposure keratopathy [39]. Similarly, CL wear is often associated with symptoms without signs of exposure keratopathy [55]. In some post-LASIK cases and for some CL wearers, exposure keratopathy and/or lid wiper epitheliopathy may repair overnight and then return during the day following exposure to provocative conditions. For example, these provocative conditions may involve incomplete blinking that is associated with central heating, air-conditioning, computer use, reading, and other visually demanding tasks. An assessment in the early part of the day may not detect exposure keratopathy and/or lid wiper epitheliopathy, or may underestimate the significance of these findings. Similarly, with the exception of extended wear patients, lens soiling and unwetting that increases during the day may not be apparent at an assessment during the early part of the day. In the case of CL surface deposits that are accelerated by incomplete blinking, recognition of this association may be obvious on non-rotating lenses, but more difficult to detect when the deposits are distributed over 360° of the lens mid-periphery. Although surface unwetting, drying and deposits are likely to be non-specifically distributed in these cases, improved blink efficiency may be a significant factor in successful management. Soft CL comfort scales (Fig. 4) may help identify CL patients for whom blink efficiency intervention is indicated, especially when the scales examine end of wearing period performance when the opportunity to examine for signs is not available.

10. Lubricant therapy: modified drop instillation techniques; incomplete blink habit reversal; optimizing lid wiper and corneal therapy; combining lubricant therapy and blink efficiency exercises

Twenty-five percent of a general population sample of 2500 reported using lubricating eye drops, with the majority being dissatisfied with the therapeutic benefit experienced [2]. Lubricant drops, the first stage treatment for dry eye states, provide minimal and/or transient relief [35]. One of the principal problems associated with lubricant drops, is the limited opportunity for therapeutic effect due to rapid dilution, and short periods of retention on the ocular surface. A single drop (say 40–50 μl) combines with ocular surface tears (say 5–10 μl), and overflow is common. Apart from overflow, reflex blinking and tearing associated with the mechanical and/or chemical and/or thermal stimulus to the cornea and conjunctiva, may quickly dilute the potential for therapeutic effect. Attempts to extend the therapeutic benefit have included the development of drops that form a 'soft' gel when placed on the eye to increase the opportunity for cell repair in a healthy microenvironment [35]. Dermatological therapy involving creams, lotions, and ointments often appears to be enhanced when the therapeutic agent is massaged into the epidermis. In cases of exposure keratopathy, it is possible that the therapeutic benefit gained by the corneal (and conjunctival) epithelium from drop instillation, is enhanced by any lid wiper massaging effect gained from increased blink completeness. In particular, exposure keratopathy may respond more favourably from increased blink rate and completeness during the period of presumed maximum therapeutic potential, immediately after drop instillation. For the same reasons, CL rewetting drops may provide greater benefit if instillation is followed by a period of increased blink rate and completeness. In addition to the potential of benefit to the corneal or CL surface, the combination of drop instillation and blink exercises also has the potential for enhanced therapeutic results in cases of lid wiper epitheliopathy. However, patients for whom lubricant drop therapy is indicated, sometimes describe, or demonstrate, their fear of "putting drops in their eyes". For CL wearers, this aversion may be reduced when soft lenses are in situ (and the cornea is insulated from the drop contact), so that drop instillation might be achieved more successfully. Although the lid wiper may benefit when lenses are in situ, in cases of CL related keratopathy, any significant therapeutic benefit from lubricant drops appears to necessitate that instillation occurs without the lenses in situ. Thus, when drop instillation occurs before lens insertion, or after removal, to maximize treatment of keratopathy, CL wearers may share the same difficulties with drop instillation as do patients with dry eyes.

Some people react adversely to the temperature of drops from multiple-use bottles that have been stored in the refrigerator. This experience may initiate, or help to perpetuate an aversion or phobia toward drop use. When combined with the mechanical and chemical stimuli, the difference between room temperature drops (say at 22 °C) and corneal temperature (32–33 °C) [62] may contribute a significant stimulus to any reflex tearing that follows drop instillation. For some drop-aversive patients, line of sight drop delivery is confrontational, and avoidance eye movements and/or lid closure reduce accuracy of placement.

Some drop-aversive patients will benefit from using a hand mirror, held at an angle of about 45° in front of the contralateral eye. With the cornea of the receiving eye positioned nasally, the mirror allows guiding of drop placement onto the temporal conjunctiva. An alternative to using a mirror is for drop instillation to be guided by peripheral, rather than foveal vision, with the receiving eye directed nasally to expose the temporal conjunctiva. Temporal conjunctival placement is less psychologically confronting to the drop-aversive patient, and the conjunctiva is less sensitive to the mechanical and thermal drop stimuli compared with the cornea [63]. In addition, the thermal stimulus to reflex tearing and blinking can be reduced as drop temperature approaches ocular surface temperature. Consequently, for drop-aversive patients who react adversely to the mechanical and/or thermal and/or chemical sensations associated with room temperature drops, a unit dose drop container can be placed under a wrist watch band for 20–30 min to allow the drop temperature to approach eye surface temperature. A drop bottle can be placed in a shirt pocket or under an underwear-strap to raise drop temperature. Any benefit from this procedure may increase in cold climates or seasons, when there are greater differences between ambient and ocular surface temperature. For drop-phobic patients, the suggestion that reducing temperature differences will help reduce instillation shock may be as important as any modest increase in temperature achieved. Better drop retention, with the possibility of greater therapeutic benefit, can be achieved if instillation is made with the patient in a comfortable head-supported supine position so that the lid margins create a reservoir for higher volumes of drop retention. Supine instillation reduces the potential for tear overflow onto the adnexal skin, with head tilt toward the nasal side helping to reduce drop outflow at the temporal canthus. The quantity of drop retained may be greatly reduced when a tissue is applied to the eyelids and inner-canthus immediately after drop instillation and, ideally, should not be used. Before the therapeutic potential is lost through dilution and/or elimination, voluntary control and production of a series of complete/relaxed/rapid blinks to promote gentle distribution of the drop may optimize benefit to the exposed ocular surface and lid wiper. A supine body position is frequently inconvenient and a slouched sitting position, with backwards head tilt, is a more accessible alternative method for these potential benefits to be obtained. For CL wearers, the best time for this therapeutic approach is prior to lens insertion and in the evening, after lens removal, when any keratopathy is exposed to the therapeutic drop mechanisms. Extended wear patients with dryness symptoms in the evening may benefit from combining drop instillation with blink efficiency exercises, especially if the symptoms are associated with lid wiper epitheliopathy. In addition, blink efficiency exercises, and additional lid massaged contact time of the drop with the lens, may be a significant benefit to lens surface rewetting and end of day lens performance.

The emphasis during blink efficiency exercises is for voluntary blinking that is complete, relaxed and rapid as well as natural in appearance (Fig. 3). According to the principles of behaviour modification [64] and habit reversal [65], patient education is a key element of these forms of therapy. It is necessary to create an awareness of the significance of the problems associated with incomplete blinking. It is equally necessary to establish an appreciation of the advantages that are derived from normal complete blink habits. Explaining the links between incomplete blinks, the drying of the inferior corneal and/or CL surfaces, and symptoms, is greatly facilitated by the use of clinical photographs (Figs. 1a, c and d, and 2c). These are included in a consulting room (take-home) Blink Instruction Guide (BIG) [66] (Fig. 3). To be successful, this instruction must generate for the patient, a sense of personal responsibility for doing the exercises as recommended, in order that the chance of successful outcomes is maximized. Accordingly, the BIG includes the sine qua non statements: "Blink exercises may have great benefits, but nobody else can do them for you" and "Blink exercises don't have any chance of helping you if you don't do them." [66]. The goal is primarily an improvement in quality of blinks. An explanation may be required that the quantity of blinks is normally controlled by visual task [27], emotional state, mental effort, illumination level, atmospheric conditions [29], etc. Although an increased blink rate may be beneficial, it may be difficult to achieve given the powerful influence of common activities such as reading and computer use. For many patients with exposure keratopathy, their blink rate is apparently adequate for the superior cornea, and incomplete blinks appear to be the key causal factor. In such cases, the need to improve the quality of blinks is indicated. This explanation is intended to allay any patient concerns about the possibility that diligent adherence to the blink efficiency exercises could lead to the habit of blinking too frequently.

Drop instillation is frequently inconvenient and successful application, by combination with blink exercises, is greatly reduced if this recommendation is not qualified. As an alternative to drop instillation, greater benefit from blink exercises may be gained from four or five forceful blinks prior to commencing the exercise. Forceful blinking can substantially increase tear layer thickness, most likely as a result of squeezing tears from the inferior and superior cul-de-sacs [30]. It is also possible that forceful blinks increase tear volume by promoting release from the accessory lacrimal glands in the lids. In addition, forceful blinks provide an opportunity for the top lid meniscus to combine with the lower lid meniscus. This combination may allow the top lid to draw lower meniscus tears upwards and over the corneal surface. The thickness of the tear layer may be increased as a consequence. Another advantage of forceful blinks is the possibility of increasing secretion from the Meibomian glands [35] and the tarsal goblet cells. Some aqueous deficient eyes may not be able to benefit from preliminary forceful blinks, and routine drop instillation

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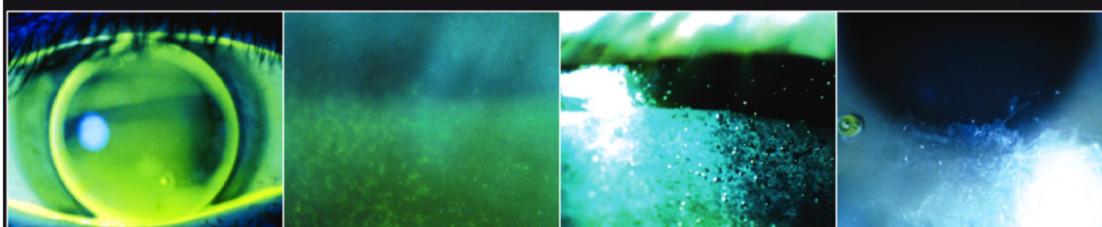
Blinking:
Dry Eyes and Dry Contact Lenses

Efficient blinking habits are essential for optimum contact lens performance and will help to re-establish and maintain the health of the surface of the eye in many dry eye conditions. How often we blink is determined by factors such as personality type, state of alertness, atmospheric conditions and visual task intensity, but the quantity of blinking is not usually as important as the quality of blinking. Blink quality determines blink efficiency, and optimum quality blinks maintain a healthy, wet and comfortable eye or contact lens surface. Conversely, poor quality (inefficient, incomplete) blinks allow the lower areas of the eye surface, or contact lens, to become dry, with associated symptoms of dryness.



Incomplete blink [1] | Partially dry cornea [1] | Dry contact lens | Partially soiled contact lens

Inefficient blinks are very common during intense visual tasks such as computer use, proof reading and working with numbers. Dry eyes or dry contact lenses are common under these conditions. Efficient (complete) blinks maintain comfort associated with complete wetness of the eye or contact lens. For contact lens wearers, cleanliness and optical clarity of the contact lens surface are maintained by efficient blinking. In addition, efficient blinks promote appropriate contact lens movement with healthy massage of the corneal surface and tear circulation.

The type of blink required for optimum blink efficiency has the following characteristics:

1. An efficient blink is full and complete, meaning that the top lid lightly touches the bottom lid
2. An efficient blink is relaxed and light, meaning that only the muscles of the eye are involved. Specifically, the muscles of the eyebrows and cheeks are not involved.
3. An efficient blink is quick and rapid, taking only one third of a second to complete.
4. Finally, an efficient blink looks confident and natural.

Memorising and consciously practicing the eight key efficient blink characteristics that are underlined above will help reduce the number of inefficient blinks at other times. For example, if the number of inefficient blinks can be reduced from two to one out of five, there will be the benefit of 33% more efficient blinks. Blink excercises can have great benefits, but nobody else can do them for you.

A practice session should take about 24 seconds with three cycles of each of the 8 key words repeated (silently or out loud) as prompts for reproducing 24 efficient blinks. To make significant changes to your blink efficiency levels, you will need to practise this exercise every half hour for at least a week. Repeating the exercises for a few days in subsequent weeks and months, especially if dryness symptoms recur, will help maintain the improvements achieved.

Triggers like switching your watch to your other arm, or putting a rubber band around your phone, for example, should help to remind you to practise. Good times for practising can be during advertisements on TV, while stopped at traffic lights, while travelling on or waiting for a train or bus etc.

1. McMonnies CW. After-care, signs, symptoms and management. In: Contact Lenses. Eds Phillips A J, Stone J. London, Butterworths. 1989. p709

Please enquire to: enquiry@ier.org.au

Photographs & Text: Charles McMonnies

Fig. 3. The Blink Instruction Guide is used for consulting room patient instruction prior to being issued to the patient for home reference. Published and supplied by the Institute for Eye Research: enquiry@ier.org.au.

prior to blink efficiency exercises is indicated. Some Meibomian gland deficiency conditions may not be capable of secretion with forceful blinks. Lid scrubs, massage, hot compresses etc may be required in order that flow is re-established in the gland orifices [67]. Any patient concerns that forceful blinks might become a habitual essential blepharospasm or tic can be alleviated by emphasising the need for relaxed, natural looking blinks to be performed during complete blink efficiency exercises. Significant improvement in blink efficiency appears likely to depend on the frequency with which the exercises are performed. Even when they have the best of intentions, patients still need help to remember to stop for 30 s to complete the exercises every half hour. Ruses used to prompt regular application to blink efficiency exercises include a wrist watch switch to the other wrist, putting elastic bands around the phone, programming the mobile phone alarm, setting a kitchen timer, etc. The provision of take-home written instructions, that include the clinical photographs, are intended to assist the development and maintenance of the patient motivation to achieve optimum results. For a computer user blinking at 4 blinks per minute [25], the recommended practice session of 24 complete blinks (in less than 30 s), can be the quantitative equivalent of over 6 min of efficient blinking. Even when incomplete blinking is not a major contributor to symptoms, significant lid wiper benefit may be gained from this period of increased blink quantity. The same session can also be qualitatively beneficial because incomplete blinks are eliminated. A patient who can understand how complete blinks are critical to the maintenance of a wet corneal or CL surface is in a position to appreciate negative reinforcement that derives from symptoms of dryness, as well as positive reinforcement from a symptom-free period following blink completeness practice. Symptoms of dryness may serve as a prompt for performing blink efficiency exercises. However, the possibility of preventing symptoms from developing, by performing the exercises routinely and prior to the onset of symptoms can usefully be explained to patients. The goal for patients should be to perform the exercises frequently enough in order that blink completeness habits are generalized across all conditions of spontaneous blinking.

11. Conclusions

Quantitative and qualitative aqueous, lipid and mucin deficiencies, hyperosmolarity, low blink rates, altered corneal innervation and lid wiper epitheliopathy may all contribute to exposure keratopathy. However, when the superior cornea is apparently normal, exposure keratopathy associated with dry eye, laser assisted keratomileusis and CL wear, appears to be due to incomplete blinking. Incomplete blinking appears to promote tear layer thinning over exposed ocular and CL surfaces, and the opportunity for significant tear evaporation to occur. The compounding effect of reduced blink rate and incomplete blinking greatly increases interblink intervals for the exposed corneal, conjunctival and CL surface. The complete blink that follows an incomplete blink may be the most traumatic to the lid wiper due to increased friction over dry and roughened ocular or CL surfaces. People involved in low blink rate activities, such as reading and computer use, appear to be at greater risk for incomplete blink associated problems. Even normal incomplete rates may have the potential to be clinically significant under these conditions, especially when combined with adverse ambient conditions involving wind, low humidity, air-conditioning or central heating. However, when incomplete blink rates are higher than normal, there is an even greater prospect for relief from exposure keratopathy and lid wiper signs and symptoms when management includes blink efficiency exercises. Blink efficiency guidance based on behaviour modification and habit reversal principles may give the best prospects for generalizing a reduction in incomplete blinking rates to all spontaneous blinking. The therapeutic benefit gained from both blink efficiency exercises and lubricant drop instillation may be enhanced when they are combined. The massage of exposed corneal and conjunctival tissue by the lid wiper, that is achieved by a rapid series of complete blinks, may be beneficial to all these tissues. This benefit may be greatest during the period immediately following instillation, before the therapeutic potential of the drop is lost to dilution and elimination. The therapeutic benefit of lubricant drops may be further enhanced when instillation is modified to reduce reflex blinking and tearing, so that elimination and dilution are delayed. For CL wearers, improved blinking habits may reduce surface drying and the associated soiling due to the deposition of precipitated tear constituents. Symptoms associated with surface drying and soiling, including those that increase at the end of the day and/or at the end of the lens-wearing cycle, may also be reduced in proportion to the degree that incomplete blinking habits and low blink rates are contributing to these problems. In some cases, the elimination of these symptoms may be the key to allowing extended wearing schedules to be maintained, or even to helping daily wear patients to maintain regular CL use.

Acknowledgements

I am grateful for the advice provided by Fiona Stapleton and Blanka Golebiowski during the preparation of this paper and for the graphic design assistance in developing the Blink Instructions Sheet provided by Baz Brown and Shane Parker of I-Media.

Appendix A. Measuring soft lens comfort and identifying drop-out risk

Prior to the introduction of soft CLS, the ability to wear rigid CLS was measured by the number of hours per day that the lenses could be tolerated. Performance was measured by patients on a relative discomfort scale. However, the expectations of patients in the case of soft lenses, when performance is measured on a comfort scale, appear to be higher. Accordingly, for the neophyte in soft lenses, comfort is relative to their expectations of how a CL, that is reputed to be comfortable, might feel. Ideally, their experience with trial or diagnostic lenses surpasses their expectations, especially when CLS are proactively recommended by the practitioner involved [68]. Self-motivated prospective CL patients are often more committed to proceed with the change to CLS, and may be more willing to accept higher levels of lens awareness, at least initially. Comfort in CLS is relative to any discomfort (visual, physical and/or psychological) that is experienced while wearing spectacles. In addition, comfort for any CL wearer might be relative to their state of mind and their level of preoccupation with other matters. Happiness, success, contentment and satisfaction for example, may be more likely to be associated with the perception of greater lens comfort. Conversely, sadness, misfortune, injustice and failure, for example, may be more likely to be associated with the perception of reduced lens comfort. Accordingly, dry-eye questionnaire scores were found to correlate positively with extroversion and negatively with subjective well being. These two psychological variables accounted for 32% of the variance in the questionnaire scores [69]. Similarly, there is a tendency to understate ocular symptoms when they are overshadowed by symptoms of connective tissue disease [70]. For experienced wearers, comfort in new lenses is relative to the levels of comfort experienced with those worn previously. When only one lens is worn, the requirement for comfort may be higher, with the non-lens-wearing eye setting the standard of comfort against which the lens-wearing eye is compared. Sometimes the lens-wearing eye is more comfortable than the non-lens-wearing eye. Similarly, when two lenses are worn, comfort in one eye is relative to the comfort experienced by the other eye. Ultimately, functional comfort is determined by the patient's ability to forget that they are wearing CLS. Unfortunately, there is a tendency for lens awareness to develop and for comfort to decrease as, for example, lens surfaces dry and soil. Deterioration in the integrity of the lid wiper epithelium may be significant in relation to comfort levels that reduce with hours of wear.

Many patients report symptoms of dryness [5–8] and improved blink efficiency may be an important part of their management. However, it is not possible to assume that patients who wear CLS all day every day experience high levels of comfort [8]. Some people, with a history of wearing CLS all day every day, eventually become occasional wearers (for social events or playing sport, etc.) or stop wearing CLS altogether. Unacceptable comfort levels are not always the basis for reducing or abandoning CL wear.

CONTACT LENS COMFORT SCALES

A. Under normal wearing conditions, can you feel your lenses if you blink deliberately to test their comfort? 1. One hour after insertion. 2. Just before you take them off. 3. Just before replacing them. Please mark the line with a 'slash' to indicate your responses.

1.Not at all--Definitely

2.Not at all--Definitely

3.Not at all--Definitely

B. On the average day, how often are you aware of your contact lenses?

Never--Constantly

C. On the average day, how often are your eyes irritated by your contact lenses?

Never--Constantly

D. Is your irritation mostly visual, Or mostly dryness, stickiness, soreness,
blurring, fogging, ghosting etc?...grittiness, burning, stinging etc?

100% ---100%
"visual" "dryness"

Fig. 4. Contact lens comfort scales used to identify lens performance that deteriorates with hours of wear and lens age.

There may be financial considerations or care and maintenance might become too bothersome. However, a survey of a large sample of CL drop-outs found that discomfort is the most common reason, accounting for 51% of the total [71]. Some of these patients may never have dropped out if their discomfort levels had been assessed and appropriate remedial action introduced. For example, signs of exposure keratopathy and lid wiper epitheliopathy may not manifest until after clinic assessment hours. High levels of comfort experienced an hour after inserting new lenses may become the reference against which subsequent performance is judged. Those who are at risk for dropping out might be identified using a questionnaire (Fig. 4) that was developed to assess the comfort levels over the full range of wearing experience. The first question asks: ''Under normal wearing conditions, can you feel your lenses if you blink deliberately to test their comfort?'' An analogue scale used to record responses has the scale limits of ''Not at all'' and ''Definitely''. Three responses to this question are required: the first in relation to 1 h after insertion; the second in relation to the period of wear just prior to lens removal at the end of the day; the third in relation to the period of wear prior to lens replacement.

The absolute values of the scores from the scales are not usually important. For descriptive purposes, the scores measured in millimeters along the 100 mm long scales can be described as percentages. A score of ''Not at all'' represents 100% comfort, and one of ''Definitely'', represents 0% comfort or 100% discomfort. However, for most clinical purposes, the significance of the scores is relative, one end of the scale to the other and one question to another. Compared with comfort experienced 1 h after insertion, scores closer to the right-hand end of the scales, at the end of the day, and at the end of the lens-wearing cycle, are likely to be more significant and indicate the possibility that remedial action could raise performance. If necessary, appraisal of comfort can continue to assess lens awareness and irritation. The next measure of comfort asks: ''On the average day, how often are you *aware* of your contact lenses?'' For this question, the scale limits are ''Never'' and ''Constantly.'' The third question asks ''On the average day, how often are you *irritated* by your contact lenses?'' with the scale limits ''Never'' and ''Constantly''. When inferior vision performance is suspected of being a contributing factor for reduced comfort, a further question may be useful. For example, patients who read letter charts fairly successfully despite uncorrected astigmatism, may still be troubled by visual discomfort. Uncorrected astigmatism, that was tolerable when CLS were first fitted, may become intolerable as accommodation amplitudes reduce with age or if vocational, educational or recreational vision demands increase. Visual discomfort may be a precursor to CL drop-out and an upgrade of a fitting to a toric lens design, for example, may be indicated. To examine for this possibility, the final question asks: ''Is your discomfort or irritation mostly visual, blurring, glare, fogging, ghosting etc?'' ''Or mostly dryness, stickiness, soreness, grittiness, burning, stinging, etc.?'' The scale limits are ''100% visual etc.'' and ''100% dryness etc.''. Patients who have reduced comfort at the end of the day or at the end of their lens-wearing cycle, or those who have abandoned routine daily lens wear for an occasional use schedule may be candidates for remedial action that could help establish or restore their original full time wearing routine. Blink efficiency exercises may be indicated. A significant association between the degree of incomplete blinking and the grade of corneal sodium fluorescein staining has been demonstrated in both non-CL wearers and soft CL wearers [72]. The comfort scales help to prime patients to the realization that past performance is not necessarily a reliable indication of what might be achieved if appropriate remedial actions are introduced. End of day, end of lens cycle performance that is closer to that experienced 1 h after insertion may be achievable.

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