Contact Lens and Anterior Eye 46 (2023) 101872

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Review article

Visual discomfort and contact lens wear: A review

Erin M. Rueff

The Southern California College of Optometry at Marshall B Ketchum University, 2575 Yorba Linda Blvd, Fullerton, CA 92831, USA

ARTICLE INFO

Keywords:
Discomfort
Dry Eye
Binocular Vision
Presbyopia
Contact Lens Discontinuation

ABSTRACT

The purpose of this manuscript is to describe how vision influences contact lens discomfort and review the evidence supporting the hypothesis that contact lens discomfort can be caused by vision and vision-related disorders. Contact lens discomfort is a misunderstood and difficult to manage clinical condition. Most treatments and strategies aimed at alleviating discomfort focus on optimizing the contact lens fit and its relationship with the ocular surface, but these strategies commonly fail at relieving discomfort symptoms. Many vision and vision-related disorders share symptoms with those reported by uncomfortable contact lens wearers. This paper will review evidence and literature that describes how these vision and vision-related disorders may influence comfort in contact lens wearers. Acknowledging how vision influences contact lens discomfort will improve future research intended to better understand the condition, allow for more effective clinical management, and reduce rates of discontinuation.

Dissatisfaction with contact lens wear, no matter what the cause, leads to decreased or discontinued wear patterns. Contact lens dissatisfaction and subsequent dropout are most often attributed to contact lens discomfort [1–6]. Ocular discomfort can be described as an adverse sensation in or around the eye. Ocular discomfort could, therefore, be used to describe a wide variety of sensations like pain, itch, irritation, or mild disturbance. For most ocular pathology, the cause of discomfort is known and can be targeted with treatments and medication. In contact lens wear, however, discomfort is a poorly understood phenomenon.

In an effort to better understand contact lens discomfort in order to more effectively study and treat the condition, the Tear Film and Ocular Surface Society (TFOS) defined contact lens discomfort in 2013 as, "a condition characterized by episodic or persistent adverse ocular sensations related to lens wear, either with or without visual disturbances, resulting from reduced compatibility between the contact lens and the ocular environment, which can lead to decreased wearing time and discontinuation of contact lens wear [3]". This group of contact lens discomfort experts acknowledged that, despite significant advancements in material technology and extensive research on the condition, much is still unknown and misunderstood about what factors influence discomfort and how best to manage and prevent uncomfortable contact lens wear.

Contact lens discomfort, while appearing as the ubiquitous cause of contact lens dropout, has proven to be difficult to prevent and treat. Discomfort symptoms are most easily attributed to a poor relationship between the lens and the ocular surface and, therefore, dry-eye-type etiologies are usually blamed for contact lens discomfort [7–16]. The severity of objective signs of dryness, however, rarely correlates with the severity of discomfort symptoms in contact lens wearers [17–19]. This mismatch between subjective symptoms and objective signs makes discomfort treatments difficult to determine and oftentimes ineffective [20]. A patient's most common self-treatment, unfortunately, is to decrease or completely discontinue contact lens wear [4,5].

While contact lens discomfort symptoms are similar to dry eye symptoms, they also correlate with symptoms of binocular vision disorders (both accommodative and vergence disorders) [21] and have been shown to be associated with perceived visual compromise [22]. Eyestrain or discomfort associated with under/overcorrection, insufficient astigmatic correction, accommodative insufficiency, fatigue, and/or presbyopic decline can affect a wide range of contact lens wearers. Young, pre-presbyopic wearers with accommodative deficiencies and/or binocular vision disorders that are exacerbated by contact lens wear may assume their symptoms are caused by an incapatability between the contact lens and ocular surface and, after failing to treat the true cause of symptoms, abandon contact lens wear. Presbyopes and emerging presbyopes may have discomfort symptoms caused by accommodative strain that are mislabeled as age-associated dryness. Convergence and accommodative demands associated with long hours of computer and near work could also contribute to visual and accommodative fatigue that results in perceived contact lens discomfort. If discomfort treatments are focused on the ocular surface and not these vision-related causes, wearers may discontinue contact lens wear after treatment of

E-mail address: erueff@ketchum.edu.

https://doi.org/10.1016/j.clae.2023.101872
Received 22 February 2023; Received in revised form 22 May 2023; Accepted 30 May 2023
Available online 4 June 2023

the incorrect problem fails to alleviate symptoms.

The TFOS concluded that contact lens discomfort was primarily a result of reduced compatibility between the contact lens and the ocular environment. It was also emphasized that contact lens discomfort is alleviated by contact lens removal – a fact that confirms that contact lens wear itself induces discomfort symptoms. At that time, it was acknowledged that the causation of this incompatibility was unclear. As well, it was acknowledged that discomfort can occur with or without visual disturbance, but there was minimal discussion on how vision and vision-related disorders may influence contact lenses discomfort.

When one hears "ocular environment," it is easiest to assume the environment being referred to is the one in which the contact lens makes direct contact with the ocular surface. What if the "ocular environment" that a contact lens interacts with included more than just the ocular surface? What if one considered the "ocular environment" that the contact lens interacts with to also include the eye's internal accommodative and vergence systems, refractive error and inherent optics, and the visual pathway and its associated processes? Considering how visual causes, in the presence or absence of observable ocular surface disruption, influence discomfort is important to continue to advance our understanding of contact lens discomfort.

This review will summarize what is currently known about how vision and vision-related disorders influence ocular and contact lens discomfort. Other visual phenomena and factors like glare, light sensitivity, fixation disparity, screen use, and viewing distance have been studied and reported on how they influence general visual discomfort [23–37], but this review will aim to describe how vision influences comfort in contact lens wearers, specifically. First, a distinction will be made between discomfort caused by ocular surface etiologies and those caused by visual factors, based on existing literature. Next, studies exploring visual discomfort will be described as they relate to conditions that include binocular and accommodative disorders and general blur and visual quality. Rationale for how vision-related discomfort originates will be described in each section. Finally, studies investigating visual discomfort in contact lens wearers, specifically, will be described. The objective of this review is to summarize the existing evidence so eye care providers and researchers can more effectively consider visual causes of discomfort when developing research to study and treatment plans to manage contact lens discomfort.

1. Differentiating ocular and visual discomfort

While many symptoms of contact lens discomfort (dryness, watering, burning, scratchiness, etc.) suggest a dry-eye-type etiology, other hallmark contact lens discomfort symptoms (eyestrain, fatigue, blurry/changeable vision) do not immediately indicate a dry eye issue [3,21]. Considering the symptomology of uncomfortable contact lens wearers, one could argue that the general term "asthenopia" more succinctly describes an uncomfortable lens wearer's experience.

Asthenopia is a word that can be used to describe any discomfort sensation experienced in or around the eyes [38]. In fact, all of the following terms have been used in conjunction with "asthenopia:" ocular pain, headache, photophobia, diplopia, difficulty changing focus at various distances, burning, irritation, blur, dryness, and itch.[38,39] This list of symptoms describes sensations that result from quite different etiologies and leads one to assume that a complaint of "discomfort" or "asthenopia" cannot conclusively point toward one distinct cause. Perhaps, then, any disorder that is defined using the word "discomfort" will inevitably suffer from a failure to distinguish a distinct etiology.

Recognizing that asthenopic symptoms can be caused by several different conditions, Sheedy et al. set out to develop an asthenopia classification system [39]. Various asthenopic symptoms were induced by exposing participants to different ocular environments (astigmatic viewing, dry eyes, glare, flickering lights, changing accommodative targets, etc.) while they read. Participants read until their ocular comfort was "barely tolerable" and then rated the severity of their asthenopic symptoms (burning, ache, strain, irritation, tearing, blurred vision, double vision, dryness, and headache) on an analog scale from 0 to 100 (0 = no symptoms, 100 = severe). Symptoms were significantly related to their inducing conditions, and these relationships were statistically stronger when symptoms were classified into one of two groups: external and internal symptom factors. External symptom factors were common to dry eye (burning, redness, dryness, etc.) and internal symptom factors were associated with symptoms induced my accommodative and vergence demands (eyestrain, eye fatigue, headaches, etc.) [39]. It should be noted that if a participant reported "barely tolerable" comfort at any point in the study, one could assume that the participant's symptoms would be at maximum severity. Sheedy et al. did not comment on the correlation of participants who had "barely tolerable" symptoms and their subsequent symptoms severity rankings. A description of these results may have provided further insight into a participant's perception of comfort during a viewing activity and ranking of that discomfort subsequently.

The Sheedy investigation suggested that symptoms of eye discomfort can be caused by a disruption of the ocular surface (ocular discomfort) or a strain of the visual system (visual discomfort) [39]. While these two groups of symptoms originate from different causes, they may be difficult for a patient and/or clinician to differentiate from one another. Aakre et al. examined symptoms of asthenopia associated with computer use and found that asthenopia associated with computer use could have ocular and visual causes [40]. Prolonged screen viewing can lead to decreased blink rate and tear film disruption, causing ocular discomfort. Long periods of near work, however, can cause visual discomfort associated with accommodative fatigue and eyestrain. Adults in this study completed a survey about ocular symptoms (dryness, burning, etc.) and visual symptoms (blur, eyestrain, etc.) during computer use. Symptoms of visual and ocular discomfort were positively correlated, suggesting that participants were unable to differentiate the two groups of symptoms from one another [40].

"Asthenopia" is not a word a patient is likely to use when describing sensations they experience with contact lens wear, but "discomfort" or "uncomfortable" are words that are quite likely to be used by the lay person to describe symptoms to an eye care provider. Acknowledging that Sheedy et al. reported that asthenopic symptoms can be caused by quite different etiologies and Aakre et al. reported that symptoms associated with visual and ocular symptoms are difficult to differentiate, it is reasonable to consider that patients complaining of discomfort could have symptoms originating from either etiology. Knowing that many contact lens discomfort treatments targeted at the ocular surface are unsuccessful, it is possible that some proportion of uncomfortable contact lens wearers are experiencing symptoms related to a vision-based issue.

2. Binocular vision causes of visual discomfort

It has been suggested that visual discomfort may be caused by many different factors, including uncorrected refractive error, binocular vision disorders, and even hypersensitivity in cortical brain areas [41,42]. Previous studies have illustrated relationships between visual discomfort and accommodative lag. Measuring accommodative response with an autorefractor and using the Conlon Visual Discomfort Survey [43] to assess symptoms, Chase et al. reported that accommodative lag and symptoms of visual discomfort are positively correlated [44]. Tosha et al. recruited groups with high and low visual discomfort and also observed accommodative lag [24]. While the low discomfort group showed a normal accommodative response, the high visual discomfort group had significantly higher amounts of accommodative lag [24]. The higher discomfort group also had accommodative lag that increased over time, while the low discomfort group exerted a stable accommodative response [24]. These findings support the idea that visual discomfort symptoms are influenced by accommodative fatigue and/or insufficiency.

Uncomfortable contact lens wearers and patients with binocular vision disorders both report symptoms of ocular discomfort, sore eyes, tired eyes, and blurry/changeable vision [7,10,21,45–48]. Importantly, the described symptoms in both groups are noted to be more intense and frequent at the end of the day [7,9,10,49]. Contact lens discomfort that is a result of true ocular surface and tear film disruption is likely multifactorial and variable from person to person [50]. An optical etiology can explain how a contact lens introduces increased accommodative and convergence demands and, therefore, may induce visual discomfort symptoms in certain wearers.

Basic optical principles show that people with myopic refractive errors must exert more convergence and accommodation when they are corrected with contact lenses compared to spectacles [51]. The opposite effect (increased convergence and accommodative demand while corrected with spectacles versus contact lenses) is seen with hyperopic refractive errors [52]. Myopic spectacle lenses produce a base-in effect when looking at near, resulting in a decreased convergence demand [51]. Myopic contact lenses eliminate this base-in effect, so a greater convergence effort is required when a myope looks at a near target when wearing contact lenses compared to spectacles [53].

An increased accommodative demand is also experienced when myopes are corrected with contact lenses. The effective power of a myopic lens increases as it gets closer to the corneal plane. If this effective power increase is not adjusted for when determining the contact lens power, myopic patients will have to exert more accommodation, compared to spectacle correction, to maintain a clear image at both distance and near [51]. Similar to convergence, the opposite accommodative effect is seen in hyperopes [51]. This change in accommodative demand is significant. Hermann et al. suggested that, "It is possible to precipitate the state of presbyopia by placing a middle-aged myope in contact lenses. Conversely, it is theoretically possible to forestall the state of presbyopia in a hyperope by successfully placing them in contact lenses" [52].

Recognizing the optical demand changes induced by contact lenses, early investigations sought to prove these optical theories. These studies measured vergence and accommodation in myopic [52] and hyperopic [54] eyes and showed that less vergence and accommodation was exerted by contact-lens-corrected hyperopes, while more convergence and accommodation was used in contact-lens-corrected myopes [52]. These initial studies, however, employed methods that may have influenced the accommodative response unintentionally [52,54], so more recent investigations have continued to observe how accommodation and vergence change with different correction types [53,55,56].

In 2006, Hunt et al. tested the theory that myopes converge and accommodate more in contact lenses [53]. As suggested by optical theory, myopes in this study exerted more accommodation and convergence with contact lens correction while hyperopes exhibited less [53]. In a study that examined refractive and binocular vision changes in myopic children wearing spectacles and contact lenses, Fulk et al. reported that near heterophoria changed approximately 4.5 prism diopters in the exophoric direction when corrected with contact lenses [55]. Jimenez et al. also compared accommodative and vergence responses in myopic contact lens and spectacle wear [56]. In this study, higher accommodative lag and more esophoric near phoria was observed in contact lens-corrected myopes [56]. Recognizing the interaction and coupled nature of accommodation and convergence [57,58], this result is somewhat unexpected.

In a study that sought to determine if uncomfortable myopic contact lens wearers had an abnormally high prevalence of binocular vision disorders, Rueff et al. tested participants for dry eye and binocular vision abnormalities while wearing their contact lenses. Approximately half (48%) of the sample had significant signs of dry eye, but the same proportion (48%) had signs of a binocular vision disorders [21]. This prevalence was higher than previously reported binocular vision disorder prevalences (23–32%) by Lara et al. and Porcar et al. [59,60] although it should be noted that these previous studies had stricter diagnostic criteria. The prevalences reported by Rueff et al. could, therefore, be an overestimate of the true population binocular vision disorder prevalence. In a subsequent study also evaluating the prevalence of binocular vision disorders and contact lens discomfort in myopic contact lens wearers, Tilia et al. applied diagnostic criteria more similar to those of Lara et al. [59] and Porcar et al. [60] and reported a 25% prevalence of binocular vision disorders, suggesting that myopic contact lens wear did not significantly increase the prevalence of binocular vision disorders [61].

Rueff et al. also reported that accommodative lag $\geq$+1.00 D was observed in 48% of the sample [21]. Previous reports of non-contact lens wearers, for comparison, have reported accommodative insufficiency prevalences of 6–9% [59,60]. The authors suggested that the high prevalence of accommodative insufficiency in this sample could have been caused, at least in part, by the increased accommodative demands induced by myopic contact lens wear. Again, the diagnostic criteria applied by Rueff et al. was not as strict as the prevalence studies the results were compared to, and these studies used multiple tests to diagnose accommodative insufficiency (not accommodative lag alone). Similar to the overall binocular vision disorder prevalences described above, when Tilia et al. applied diagnostic criteria similar to Lara et al. [59] and Porcar et al. [60] to a group of myopic soft contact lens wearers, similar prevalences of accommodative insufficiency were reported [61].

Considering the symptom similarity of contact lens discomfort and binocular vision disorders, it can be hypothesized that discomfort associated with contact lens wear may be related to accommodative fatigue and discomfort. Optical principles illustrate how a myopic individual may experience accommodative and vergence demands that are comfortable and manageable when corrected with spectacles, but push past a threshold of comfort when corrected with contact lenses. Evidence investigating prevalence of binocular vision disorders has mixed results, although studies that employ strict clinical diagnostic criteria suggest that discrete prevalences of binocular vision disorders in myopic contact lens wearers is not different than the normal population. As a somewhat newly acknowledged phenomenon, these prevalences of clinical signs and symptoms of binocular vision disorders in uncomfortable contact lens wearers should continue to be studied.

3. Visual quality and blur causes of discomfort

General blur may also be a cause of visual discomfort. Acknowledging early evidence that blurred vision induced by defocused contact lenses result in ocular discomfort [29], Rao and Simpson [62,63] were among the first [29] to show a relationship between ocular comfort and vision quality. In a study that examined how participants responded to suprathreshold stimulation of the cornea using an esthesiometer, they reported that comfort ratings worsened more quickly under blurred conditions compared to clear conditions. They also performed a study that induced dioptric and spatial blur in a group of emmetropic participants and found that comfort ratings were worse under blurred conditions [62]. In this group of emmetropic participants with no history of contact lens wear, dioptric blur was induced by placing a +6.00 D contact lens on the eye. For spatial blur, a spatially filtered image (equal to +6.00 D of defocus) was presented with no contact lens on the eye [62]. Both blur conditions resulted in significantly worse comfort scores compared to clear vision viewing.

What is perhaps most interesting, however, is that the two different blur conditions (dioptric induced with a contact lens and spatial produced with an image) did not have significantly different comfort scores compared to one another. This is unexpected in a group of emmetropic participants that had, presumably, never worn contact lenses before. One could hypothesize that the dioptric blur induced by the contact lens would be more uncomfortable simply because the participants had never worn contact lenses before, but that was not the case. These findings suggest that blur alone was the primary instigator of perceived discomfort in this study [62]. It should be noted that relatively large amounts of blur were induced in these two studies (4 [63] and 6 [62] diopters), so it is unclear what a more real-word amount of under/over correction may induce.

In the previous section, rationale for how accommodative and vergence fatigue could influence a contact lens wearer's perception of comfort was described. Understanding how a visual stimulus (blurred or otherwise) initiates a sensation of ocular discomfort is less clear. Pain on the ocular surface is initiated by stimulation of corneal and/or conjunctival mechanical and/or polymodal nociceptors or thermoreceptors [64]. The pain signal is carried by the trigeminal nerve to the trigeminal brainstem nuclear complex, where second-order neurons decussate and synapse with third-order neurons in the thalamus [64]. Vision, conversely, is sensed first by photoreceptors in the retina, which transfer the signal to retinal ganglion cell axons. Retinal ganglion cell axons synapse in the lateral geniculate thalamic nucleus where the visual signal is transferred and carried via higher order neurons to the visual cortex [65,66].

While ocular surface pain and visual signal transduction appear to travel down completely unrelated pathways, it is important to recognize that most signals received by the brain undergo modification and receive input from other brain areas before they are consciously perceived. Studies have shown that, during a pain signal, there is brain activity in the cortices, thalamus and subcortical areas [67–69]. This modification of the pain signal before and during conscious perception is likely why pain is so subjective and experienced uniquely by each individual [64]. The visual signal, especially after synapse in the lateral geniculate nucleus, travels to areas unrelated to vision and is modified and informed by non-visual areas of the brain before it synapses in the visual cortex. Similar to pain, this signal modification alters the conscious perception of vision [66]. So, while stimuli that signal pain or vision may begin in different pathways, it is reasonable to hypothesize that they interact with one another before the conscious sensation of vision and/or discomfort is experienced. Visual discomfort in contact lenses wearers, therefore, could be a result of this intermingling and modification of multiple brain pathways in response to a blurred or degraded visual stimulus.

4. Visual discomfort in contact lens wearers

In recent years, investigations have examined how visual factors influence discomfort in contact lens wearers, specifically. Considering the rationale for how myopic contact lens wearers experience increased accommodative and convergence demands compared to spectacle correction, some studies have investigated the prevalence of binocular vision disorders in contact lens wearers [21,61]. As discussed in the previous section, Rueff et al. recruited a group of uncomfortable, myopic, pre-presbyopic soft contact lens wearers and found that the prevalence of binocular vision disorders was significantly higher than what is considered normal in an adult population [21]. Convergence insufficiency was the most common binocular vision disorder observed in this population and approximately half of the participants had accommodative lag of 1.00 diopter or more [21]. As mentioned in the previous section, however, Rueff et al.'s diagnostic criteria were not as strict as those employed by the prevalences studies that were compared to, so it is possible the reported prevalences were overestimated.

Tilia et al. also recruited a group of myopic, pre-presbyopic soft contact lens wearers and examined how symptoms of contact lens discomfort (measured by the Contact Lens Dry Eye Questionaire-8 [CLDEQ-8] [10]) and binocular vision disorders (measured by the Convergence Insufficiency Symptom Survey [CISS] [49]) independently influenced overall contact lens dissatisfaction (measured by the Ocular Surface Disease Index [OSDI] [70]) [61]. Tilia et al. reported higher OSDI scores (indicating more contact lens dissatisfaction) in those with contact lens discomfort (as diagnosed by the CLDEQ-8) and those with binocular vision disorders (as diagnosed by standard diagnostic criteria) [61]. As well, they reported that CISS scores were higher for participants with significant contact lens discomfort, suggesting that there is overlap of contact lens discomfort and binocular vision disorder symptoms [61]. This particular study is the first to differentiate between "contact lens dissatisfaction" (as measured by the OSDI) and "contact lens discomfort" (as measured by the CLDEQ-8) in this way. Because there were no significant differences between the CLDEQ-8 scores of the participants with and without binocular vision disorders, the authors concluded that binocular vision disorders contribute to contact lens dissatisfaction (not contact lens discomfort), independently.

Several studies have examined how residual astigmatism and/or toric contact lens correction influence subjective comfort in soft contact lens wearers. While spectacles typically are prescribed to correct all refractive astigmatism, soft contact lens wearers may or may not wear contact lenses that correct the majority of their astigmatic refractive error. Most commercial soft toric contact lenses begin correcting astigmatism at 0.75 diopters. While about half of all soft contact lens wearers have ≥0.75 diopters of astigmatism in one or both eyes, only about a quarter of all soft contact lens wearers are utilizing an astigmatic contact lens design [71]. It is possible, therefore, that eyestrain and/or blur associated with residual astigmatism could influence a soft contact lens wearer's visual comfort while wearing contact lenses and not spectacles.

Wiggins, et al. induced residual astigmatism in contact lens wearers and reported that more discomfort was experienced with screen use under the residual astigmatism condition, concluding that all wearers with demanding visual near tasks (i.e. screen time) should have astigmatism maximally corrected when wearing contact lenses [72]. Berntsen et al. used electromyography, a system that records the electrical activity produced by the contraction of the orbicularis oculi muscle, to objectively compare eyestrain with single vision soft spherical and toric contact lenses [73]. Compared to the spherical lenses, the toric lenses resulted in better high and low contrast visual acuity, and electromyography-measured eyestrain with the toric lenses was less at the initial fitting visit. At the follow-up visit (approximately one week after fitting), however, eyestrain was the same with the toric and spherical lenses [73]. The authors hypothesized that while eyestrain with the spherical lens may have been worse upon initial fitting, wearers may have adapted to that vision over time [73].

Cox, et al. compared soft spherical and soft toric contact lenses in participants with low to moderate astigmatism (0.75 to 1.75 diopters) [74]. They reported that, even in patients with relatively mild astigmatism, quality of life and subjective visual acuity was better with the toric lenses. Interestingly, this group also administered the CISS [49] to study participants. The CISS is a survey used to measure symptoms associated with convergence insufficiency in children and adults [49]. This instrument asks questions about symptoms and visual changes experienced while reading and looking up close, so it can be an indirect way of assessing general eyestrain. Cox et al. reported that CISS scores improved significantly while participants were wearing the toric lenses [74], suggesting that overall eye fatigue and eyestrain improved with full toric correction.

Rueff, et al. investigated how multifocal contact lenses influenced contact lens discomfort [75]. In this clinical trial, uncomfortable soft contact lens wearers in their 30′s wore a single vision and low-powered multifocal soft contact lens. Comfort and subjective preference for vision and comfort were evaluated [75]. For participants who were in a 30–35-year-old age range, comfort scores were better with the single vision lens. For participants between ages 35 and 40-years-old, there was no difference in comfort between the single vision and multifocal lenses [75]. The single vision and multifocal lenses used in this study had the same material, diameters and base curve. Optical design was the only difference. These results suggested that multifocal contact lenses may be beneficial for some wearers as they approach presbyopia. More importantly, the differences seen in symptom scores for the different optical lens designs support the idea that visual factors alone can influence comfort.

While the study above evaluated how multifocal contact lenses influenced comfort in non– or pre-presbyopic contact lenses wearers, it is important to consider the impact of visual comfort in presbyopes, a group a contact lens wearers that have unique visual needs. It's been reported that visual satisfaction has as much influence on presbyopic contact lens discontinuation as general discomfort [76]. Presbyopic contact lens wearers have several options to correct their vision. Some may opt to wear single vision contact lenses and utilize single vision reading glasses for near visual needs. Others may be fit into a monovision system that corrects one eye for distance and one eye for near vision. Multifocal contact lens options, like those mentioned previously, utilize various optical designs to hypothetically allow clear vision at a range of distance, intermediate, and near focal points. Little evidence exists on what presbyopic modality is specifically most comfortable, but it has been reported that presbyopic contact lens wears subjectively prefer the overall wearing experience of multifocal designs to monovision systems [77–79]. Considering the accommodative decline and near blur a presbyope experiences, it is rational to hypothesize that visual discomfort could occur during contact lens wear if the wearer was not wearing a modality that fully addressed their distance and near visual correction needs.

Contact lens wearers have multiple unique visual factors that could influence their visual experience and visual comfort while wearing contact lenses, but not spectacles. Factors like astigmatism, emerging presbyopia, presbyopia, and accommodative/vergence demand could all be corrected differently in spectacles and, therefore, causes different visual comfort sensations when corrected or not corrected while wearing contact lenses. Future studies differentiating comfort sensations experienced from these visual factors and those experienced from true contact lens and ocular surface incompatibility issue are necessary to further define visual discomfort in contact lens wearers.

5. Discussion & conclusion

Considering the relative misunderstanding of the etiology of contact lens discomfort and the eye care community's lack of success in treating and preventing discomfort associated with contact lens wear, it is reasonable to look to etiologies outside of the ocular surface for possible discomfort causation. The literature reviewed here supports the hypothesis that visual factors can influence ocular comfort and can uniquely influence a contact lens wearer's perception of comfort. It is important to acknowledge, additionally, that ocular surface health and tear film stability can influence vision and vision quality [37]. A comprehensive assessment and treatment plan for a patient complaining of uncomfortable contact lens wear should, therefore, consider how both ocular surface and vision-related issues could be influencing that unique patient's comfort experience.

Discomfort associated with visual causes may be under-diagnosed because there are no meaningful ways to objectively identify and quantify symptoms of visual discomfort in order to manage it. Most survey tools designed to quantify symptoms of ocular discomfort are targeted at dry-eye related discomfort [10,70,80]. While symptoms associated with visual discomfort are similar to dry eye in some ways, they are markedly different in others. The development of a tool to accurately measure and quantify symptoms associated with vision-related discomfort could, therefore, be very impactful in identifying, treating, and preventing contact lens discomfort.

In conclusion, although misunderstood and under-acknowledged in research and clinical practice, visual discomfort certainly influences ocular and contact-lens-related comfort and satisfaction. Future studies investigating contact lens discomfort should include protocols and assessments that account for clinical signs that contribute to visual discomfort. Testing for factors like acuity, accommodation, and over refraction should be considered alongside ocular surface testing like staining and tear break up time when considering what factors may be influencing a contact lens wearer's discomfort. When addressing complaints of discomfort clinically, eye care providers should place as much emphasis and importance on evaluating the visual system as the ocular surface in order to most effectively alleviate symptoms. As the collective eye care community continues to address contact lens discomfort complaints, a thoughtful emphasis should be placed on acknowledging how vision and the visual system impacts discomfort.

Funding

This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Dumbleton K, Woods CA, Jones LW, Fonn D. The impact of contemporary contact lenses on contact lens discontinuation. Eye Contact Lens 2013;39(1):93–9.
[2] Morgan PB, Efron N, Woods CA. Determinants of the frequency of contact lens wear. Eye Contact Lens 2013;39(3):200–4.
[3] Nichols KK, Redfern RL, Jacob JT, Nelson JD, Fonn D, Forstot SL, et al. The TFOS international workshop on contact lens discomfort: report of the definition and classification subcommittee. Invest Ophthalmol Vis Sci 2013;54(11):TFOS14-9.
[4] Pritchard N, Fonn D, Brazeau D. Discontinuation of contact lens wear: a survey. Int Contact Lens Clin 1999;26(6):157–62.
[5] Richdale K, Sinnott LT, Skadahl E, Nichols JJ. Frequency of and factors associated with contact lens dissatisfaction and discontinuation. Cornea 2007;26(2):168–74.
[6] Young G, Veys J, Pritchard N, Coleman S. A multi-centre study of lapsed contact lens wearers. Ophthalmic Physiol Opt 2002;22(6):516–27.
[7] Begley CG, Caffery B, Nichols KK, Chalmers R. Responses of contact lens wearers to a dry eye survey. Optom Vis Sci 2000;77(1):40–6.
[8] Chalmers R, Long B, Dillehay S, Begley C. Improving contact-lens related dryness symptoms with silicone hydrogel lenses. Optom Vis Sci 2008;85(8):778–84.
[9] Chalmers RL, Begley CG. Dryness symptoms among an unselected clinical population with and without contact lens wear. Cont Lens Anterior Eye 2006;29 (1):25–30.
[10] Chalmers RL, Begley CG, Moody K, Hickson-Curran SB. Contact Lens Dry Eye Questionnaire-8 (CLDEQ-8) and opinion of contact lens performance. Optom Vis Sci 2012;89(10):1435–42.
[11] Young G, Chalmers RL, Napier L, Hunt C, Kern J. Characterizing contact lens-related dryness symptoms in a cross-section of UK soft lens wearers. Cont Lens Anterior Eye 2011;34(2):64–70.
[12] Dumbleton K, Caffery B, Dogru M, Hickson-Curran S, Kern J, Kojima T, et al. The TFOS international workshop on contact lens discomfort: report of the subcommittee on epidemiology. Invest Ophthalmol Vis Sci 2013;54(11): TFOS20–36.
[13] Truong TN, Graham AD, Lin MC. Factors in contact lens symptoms: evidence from a multistudy database. Optom Vis Sci 2014;91(2):133–41.
[14] Nichols JJ, Sinnott LT. Tear film, contact lens, and patient-related factors associated with contact lens-related dry eye. Invest Ophthalmol Vis Sci 2006;47(4): 1319–28.
[15] Fonn D, Dumbleton K. Dryness and discomfort with silicone hydrogel contact lenses. Eye Contact Lens, 2003; 29(1 Suppl): S101-4; discussion S115-8, S192-4.
[16] Ramamoorthy P, Sinnott LT, Nichols JJ. Treatment, material, care, and patient-related factors in contact lens-related dry eye. Optom Vis Sci 2008;85(8):764–72.
[17] Young G, Chalmers R, Napier L, Kern J, Hunt C, Dumbleton K. Soft contact lens-related dryness with and without clinical signs. Optom Vis Sci 2012;89(8): 1125–32.
[18] Begley CG, Chalmers RL, Abetz L, Venkataraman K, Mertzanis P, Caffery BA, et al. The relationship between habitual patient-reported symptoms and clinical signs among patients with dry eye of varying severity. Invest Ophthalmol Vis Sci 2003; 44(11):4753.
[19] Pult H, et al. Clinical tests for successful contact lens wear: relationship and predictive potential. Optom Vis Sci 2008;85(10):E924–9.
[20] Papas EB, Ciolino JB, Jacobs D, Miller WL, Pult H, Sahin A, et al. The TFOS International Workshop on Contact Lens Discomfort: report of the management and therapy subcommittee. Invest Ophthalmol Vis Sci 2013;54(11):TFOS183–203.
[21] Rueff EM, King-Smith PE, Bailey MD. Can binocular vision disorders contribute to contact lens discomfort? Optom Vis Sci 2015;92(9):e214–21.
[22] Maldonado-Codina C, Navascues Cornago M, Read ML, Plowright AJ, Vega J, Orsborn GN, et al. The association of comfort and vision in soft toric contact lens wear. Cont Lens Anterior Eye 2021;44(4):101387.
[23] Wolska A, Sawicki D. Evaluation of discomfort glare in the 50+ elderly: experimental study. Int J Occup Med Environ Health 2014;27(3):444–59.

[24] Tosha C, Borsting E, Ridder III WH, Chase C. Accommodation response and visual discomfort. Ophthalmic Physiol Opt 2009;29(6):625–33.
[25] Thorud H-M, Helland M, Aarås A, Kvikstad TM, Lindberg LG, Horgen G. Eye-related pain induced by visually demanding computer work. Optom Vis Sci 2012;89(4):E452–64.
[26] Shibata T, Kim J, Hoffman DM, Banks MS. The zone of comfort: Predicting visual discomfort with stereo displays. J Vis 2011;11(8):11.
[27] Shibata T, et al. Visual discomfort with stereo displays: effects of viewing distance and direction of vergence-accommodation conflict. Proc SPIE Int Soc Opt Eng 2011;7863:78630P1–9.
[28] Park J, et al. 3D visual discomfort predictor: analysis of horizontal disparity and neural activity statistics. IEEE Trans Image Process 2015;24(3):1101–14.
[29] Papas EB, et al. Does the quality of vision affect the perception of ocular discomfort? Invest Ophthalmol Vis Sci 2003;44(ARVO E-Abstract 3694).
[30] O'Hare L, Zhang T, Nefs HT, Hibbard PB. Visual discomfort and depth-of-field. Iperception 2013;4(3):156–69.
[31] Mork R, Falkenberg HK, Fostervold KI, Thorud H-M. Discomfort glare and psychological stress during computer work: subjective responses and associations between neck pain and trapezius muscle blood flow. Int Arch Occup Environ Health 2020;93(1):29–42.
[32] Monger LJ, Wilkins AJ, Allen PM. Pattern glare: the effects of contrast and color. Front Psychol 2015;6:1651.
[33] Monger LJ, Shah D, Wilkins AJ, Allen PM. The effect of viewing distance on responses to the pattern glare test. Clin Exp Optom 2016;99(1):47–50.
[34] Lin M-W, Hsieh P-H, Chang EC, Chen Y-C. Flicker-glare and visual-comfort assessments of light emitting diode billboards. Appl Opt 2014;53(22):E61.
[35] Jaiswal S, Asper L, Long J, Lee A, Harrison K, Golebiowski B. Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know. Clin Exp Optom 2019;102(5):463–77.
[36] Glimne S, et al. Measuring glare induced visual fatigue by fixation disparity variation. Work 2013;45(4):431–7.
[37] Bettach E, et al. Influence of readongon smartphone screens on visual optical quality metric and tear film stability. Cornea 2021;40(10):1309–15.
[38] Neugebauer A, Fricke J, Russmann W. Asthenopia: frequency and objective findings. Ger J Ophthalmol 1992;1(2):122–4.
[39] Sheedy JE, Hayes JN, Engle J. Is all asthenopia the same? Optom Vis Sci 2003;80(11):732–9.
[40] Aakre BM, Doughty MJ. Are there differences between 'visual symptoms' and specific ocular symptoms associated with video display terminal (VDT) use? Cont Lens Anterior Eye 2007;30(3):174–82.
[41] Borsting E, Chase CH, Ridder 3rd WH. Measuring visual discomfort in college students. Optom Vis Sci 2007;84(8):745–51.
[42] Borsting E, Chase C, Tosha C, Ridder WH. Longitudinal study of visual discomfort symptoms in college students. Optom Vis Sci 2008;85(10):992–8.
[43] Conlon EG, Lovegrove WJ, Chekaluk E, Pattison PE. Measuring visual discomfort. Vis Cogn 1999;6(6):637–63.
[44] Chase C, Tosha C, Borsting E, Ridder WH. Visual discomfort and objective measures of static accommodation. Optom Vis Sci 2009;86(7):883–9.
[45] Guillon M, Maissa C. Dry eye symptomatology of soft contact lens wearers and nonwearers. Optom Vis Sci 2005;82(9):829–34.
[46] Barnhardt C, Cotter SA, Mitchell GL, Scheiman M, Kulp MT. Symptoms in children with convergence insufficiency: before and after treatment. Optom Vis Sci 2012;89(10):1512–20.
[47] Cacho-Martinez P, et al. Characterization of visual symptomatology associated with refractive, accommodative, and binocular anomalies. J Ophthalmol 2015;2015:895803.
[48] Scheiman M, Cotter S, Kulp MT, Mitchell GL, Cooper J, Gallaway M, et al. Treatment of accommodative dysfunction in children: results from a randomized clinical trial. Optom Vis Sci 2011;88(11):1343–52.
[49] Rouse MW, Borsting EJ, Lynn Mitchell G, Scheiman M, Cotter SA, Cooper J, et al. Validity and reliability of the revised convergence insufficiency symptom survey in adults. Ophthalmic Physiol Opt 2004;24(5):384–90.
[50] Efron N, Jones L, Bron AJ, Knop E, Arita R, Barabino S, et al. The TFOS International Workshop on Contact Lens Discomfort: report of the contact lens interactions with the ocular surface and adnexa subcommittee. Invest Ophthalmol Vis Sci 2013;54(11):TFOS98–122.
[51] Alpern M. Accommodation and convergence with contact lenses. Am J Optom Arch Am Acad Optom 1949;26(9):379–87.
[52] Hermann JS, Johnson R. The accommodation requirement in myopia. A comparison of contact lenses and spectacles. Arch Ophthalmol 1966;76(1):47–51.
[53] Hunt OA, Wolffsohn JS, Garcia-Resua C. Ocular motor triad with single vision contact lenses compared to spectacle lenses. Cont Lens Anterior Eye 2006;29(5):239–45.
[54] Hermann JS. The accommodation requirement in myopia and hyperopia. Contact lenses versus spectacles. Int Ophthalmol Clin 1971;11(4):217–24.
[55] Fulk GW, Cyert LA, Parker DE, West RW. The effect of changing from glasses to soft contact lenses on myopia progression in adolescents. Ophthalmic Physiol Opt 2003;23(1):71–7.
[56] Jimenez R, et al. Contact lenses vs spectacles in myopes: is there any difference in accommodative and binocular function? Graefes Arch Clin Exp Ophthalmol 2011;249(6):925–35.
[57] Schor C. Influence of accommodative and vergence adaptation on binocular motor disorders. Am J Optom Physiol Opt 1988;65(6):464–75.
[58] Schor CM, Alexander J, Cormack L, Stevenson S. Negative feedback control model of proximal convergence and accommodation. Ophthalmic Physiol Opt 1992;12(3):307–18.
[59] Lara F, Cacho P, García Á, Megías R. General binocular disorders: prevalence in a clinic population. Ophthalmic Physiol Opt 2001;21(1):70–4.
[60] Porcar E, Martinez-Palomera A. Prevalence of general binocular dysfunctions in a population of university students. Optom Vis Sci 1997;74(2):111–3.
[61] Tilia D, Bakaraju RC, Asper LJ, Papas EB. Associations between binocular vision disorders and contact lens dissatisfaction. Optom Vis Sci 2021;98(10):1160–8.
[62] Rao SB, Simpson TL. Influence of vision on ocular comfort ratings. Optom Vis Sci 2016;93(8):793–800.
[63] Basuthkar Sundar Rao S, Simpson TL. Impact of blur on suprathreshold scaling of ocular discomfort. Invest Ophthalmol Vis Sci 2015;56(4):2304–11.
[64] Rosenthal P, Borsook D. The corneal pain system. Part I: the missing piece of the dry eye puzzle. Ocul Surf 2012;10(1):2–14.
[65] Swienton DJ, Thomas AG. The visual pathway–functional anatomy and pathology. Semin Ultrasound CT MR 2014;35(5):487–503.
[66] Celesia GG, DeMarco Jr PJ. Anatomy and physiology of the visual system. J Clin Neurophysiol 1994;11(5):482–92.
[67] Baliki MN, Geha PY, Apkarian AV. Spontaneous pain and brain activity in neuropathic pain: functional MRI and pharmacologic functional MRI studies. Curr Pain Headache Rep 2007;11(3):171–7.
[68] Geha PY, Baliki MN, Chialvo DR, Harden RN, Paice JA, Apkarian AV. Brain activity for spontaneous pain of postherpetic neuralgia and its modulation by lidocaine patch therapy. Pain 2007;128(1):88–100.
[69] Wagner K, Sprenger T, Kochs E, Tölle T, Valet M, Willoch F. Imaging human cerebral pain modulation by dose-dependent opioid analgesia: a positron emission tomography activation study using remifentanil. Anesthesiology 2007;106(3):548–56.
[70] Schiffman RM, et al. Reliability and validity of the Ocular Surface Disease Index. Arch Ophthalmol 2000;118(5):615–21.
[71] Morgan PB, Efron N, Woods CA. An international survey of toric contact lens prescribing. Eye Contact Lens 2013;39(2):132–7.
[72] Wiggins NP. Effects of residual astigmatism in contact lens wear on visual discomfort in VDT use. J Am Optom Assoc 1992;63(3):77–81.
[73] Berntsen DA, Cox SM, Bickle KM, Mathew JH, Powell DR, Seidman SH, et al. A randomized trial to evaluate the effect of toric versus spherical contact lenses on vision and eyestrain. Eye Contact Lens 2019;45(1):28–33.
[74] Cox SM, Berntsen DA, Bickle KM, Mathew JH, Powell DR, Little BK, et al. Efficacy of toric contact lenses in fitting and patient-reported outcomes in contact lens wearers. Eye Contact Lens 2018;44(5):S296–9.
[75] Rueff EM, Jones-Jordan LA, Bailey MD. A randomised clinical trial of multifocal contact lenses and contact lens discomfort. Ophthalmic Physiol Opt 2021;41(1):93–104.
[76] Rueff EM, Varghese RJ, Brack TM, Downard DE, Bailey MD. A survey of presbyopic contact lens wearers in a university setting. Optom Vis Sci 2016;93(8):848–54.
[77] Woods J, Woods C, Fonn D. Visual Performance of a multifocal contact lens versus monovision in established presbyopes. Optom Vis Sci 2015;92(2):175–82.
[78] Richdale K, Mitchell GL, Zadnik K. Comparison of multifocal and monovision soft contact lens corrections in patients with low-astigmatic presbyopia. Optom Vis Sci 2006;83(5):266–73.
[79] Gupta N, Naroo SA, Wolffsohn JS. Visual comparison of multifocal contact lens to monovision. Optom Vis Sci 2009;86(2):E98–.
[80] Ngo W, Situ P, Keir N, Korb D, Blackie C, Simpson T. Psychometric properties and validation of the standard patient evaluation of eye dryness questionnaire. Cornea 2013;32(9):1204–10.