Contact lens induced dry eye and binocular vision disorders: A study of similar symptoms

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

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The Ohio State University
2014

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Abstract

Purpose: To determine a relationship between symptomatic contact lens induced dry eye (CLIDE) and non-strabismic binocular vision (BV) and accommodative disorders.

Methods: Twenty-nine myopic soft contact lens wearing subjects with subjective dry eye symptoms were recruited. Subjects completed symptom surveys to assess and grade severity of dry eye, CLIDE, and binocular vision disorder symptoms. Symptom surveys utilized were the Ocular Surface Disease Index (OSDI), the Contact Lens Dry Eye Questionnaire -8 (CLDEQ-8), and the Convergence Insufficiency Symptom Survey (CISS). Basic binocular vision assessment was performed on each subject when corrected with contact lenses. Binocular vision and accommodative tests included visual acuity, heterophoria at distance and near, near point of convergence (NPC), step positive and negative fusional vergence, and accommodative lag/lead assessment. Subjects removed their contact lenses and dry eye testing, including tear break-up time (TBUT), ocular staining, Meibomian gland assessment, and Schirmer test, was performed.

Results: Subjects with symptomatic CLIDE were more likely to have significant BV disorder signs than dry eye signs (50% vs 40%). However, this difference was not statistically significant. \( p = 0.782 \). 60% of subjects with no dry eye signs and 53.33% of subjects with \( \leq 1 \) dry eye sign had significant \( \geq 2 \) BV disorder signs. 48.28% of subjects had significant BV disorder signs. Pseudo convergence insufficiency (PCI) was the most common BV disorder (64.29%), followed by convergence insufficiency (21.43%), and...
convergence excess (14.29%). OSDI and CISS scores were not significantly correlated ($p = 0.167$). Presence of significant dry eye symptoms was related to the number of BV disorder signs seen in symptomatic dry eye subjects ($p = 0.014$).

Discussion: Subjects with few or no signs of ocular dryness may be experiencing a concurrent or stand-alone binocular vision disorder. BV and accommodative disorders, especially accommodative insufficiency and resultant PCI, were common in this population of myopic soft contact lens wearers. A future larger-scale study that utilizes a masked examiner will better define these relationships. Clinicians should screen symptomatic CLIDE patients for binocular vision disorders. CLIDE and general dry eye studies should assess basic BV function in order to exclude subjects with BV disorders.
Acknowledgments

This work would not have been possible without the sincere guidance provided by my advisor, Melissa Bailey, OD, PhD. I would also like to acknowledge Donald Mutti, OD, PhD for his help with the Grand Seiko autorefractor.
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Fields of Study

Major Field: Vision Science
# Table of Contents

Abstract.......................................................................................................................... ii

Acknowledgements.......................................................................................................... iv

Vita.................................................................................................................................. v

Fields of Study ................................................................................................................ v

Table of Contents ............................................................................................................ vi

List of Tables .................................................................................................................. vii

Introduction ................................................................................................................... 1

Methods ......................................................................................................................... 19

Results.......................................................................................................................... 30

Discussion ...................................................................................................................... 36

References ...................................................................................................................... 44

Appendix A: The Ocular Surface Disease Index (OSDI).................................................. 48

Appendix B: Contact Lens Dry Eye Questionnaire-8 (CLDEQ-8)................................. 49

Appendix C: Convergence Insufficiency Symptom Survey (CISS)................................. 50

Appendix D: Oxford Staining Scheme ........................................................................... 51
List of Tables

Table 1. Summary of Dry Eye and BV Signs ................................................................. 30

Table 2. Symptomatic Dry Eye and CI ................................................................. 31

Table 3. Chi-Square Test p-values ............................................................................ 31

Table 4. BV Symptoms and Signs in Subjects With Few or No Dry Eye Signs .............. 32

Table 5. Significant Accommodative Lag and Associated BV Signs and Symptoms ....... 32

Table 6. Binocular Vision Disorders Found in Sample ................................................ 33

Table 7. Chi Square Test p-values Compared to General Population .......................... 33

Table 8. Pearson Correlations ................................................................................... 34

Table 9. Independent T-Test p-values ...................................................................... 34

Table 10. Average OSDI Score for BV Related Questions ........................................... 35
Introduction

The purpose of this study was to investigate the relationship between symptomatic contact lens induced dry eye (CLIDE) and co-existing binocular vision disorders. CLIDE is a condition that is routinely encountered by clinicians and frequently cited by patients. Exhaustive academic and industry research has been dedicated to preventing and determining specific causes for CLIDE. Diagnosis and treatment of dry eye is challenging because clinical signs are often absent when subjective symptoms are significant. Treatment is frequently based solely on symptom assessment.

Dry eye and, specifically, CLIDE share several common symptoms with binocular and accommodative vision disorders. Asthenopia, increased end of day symptoms, and photosensitivity are symptoms noted frequently in both groups of conditions.\(^1\)\(^-\)\(^4\) While treatment of binocular vision disorders is largely symptom based, it is also heavily guided by correlating objective clinical data. When one considers the vergence and accommodative demand changes that occur with myopic lens wear,\(^5\)\(^-\)\(^7\) it is reasonable to suspect that contact lens wearing myopes who report CLIDE-like symptoms might actually be experiencing a binocular vision disorder that is induced or exacerbated by contact lens wear.

The most common strategy contact lens wearers employ to improve dryness symptoms is decreasing or discontinuing contact lens wear.\(^8\)\(^-\)\(^11\) Determining a
relationship between CLIDE symptoms and binocular vision disorders will aid clinicians in better assessing and treating symptomatic contact lens wearers. Additionally, this information could prevent contact lens discontinuation and promote longer, successful contact lens wear. This study recruited soft contact lens wearing subjects with dry eye symptoms. These patients completed surveys and were examined to determine if they displayed dry eye and/or binocular vision disorder signs.

Dry eye is a complex condition that progresses according to different factors in each affected patient. In its updated definition of dry eye in 2007, the Dry Eye WorkShop (DEWS) stated, “Dry eye is a multifactorial disease of the tears and ocular surface that results in symptoms of discomfort, visual disturbance, and tear film instability with potential damage to the ocular surface. It is accompanied by increased osmolarity of the tear film and inflammation of the ocular surface.” The DEWS report went on to further classify dry eye into categories according to primary causation. The two main categories are aqueous deficient dry eye, which can further be broken down into Sjogren Syndrome and Non-Sjogren syndrome varieties, and evaporative dry eye, which can be the result of intrinsic and extrinsic factors. Multiple dry eye etiologies can lead to different symptomology for each respective cause. This distinct symptomology has been well documented and is seen frequently with contact lens wear.

Contact lenses are a well-known cause of dry eye. Both soft and gas permeable lenses can influence corneal sensitivity and contribute to a likely minor
amount of aqueous deficient dry eye. Contact lenses are primarily thought to cause dry eye symptoms and ocular surface signs through an evaporative mechanism. The contact lens interrupts the natural pre-corneal tear film and produces a less stable pre-lens tear film. Properties of the contact lens itself may also affect the ocular surface causing dry-eye-like signs and/or symptoms. Material properties, water content, fitting relationships, and power have all been suggested as factors that contribute to CLIDE.

Contact lens wearers experiencing dry eye typically present with a set of symptoms that sets them apart when compared to dry eye patients from other etiologies. In general, contact lens wearers tend to report more intense and frequent overall dryness symptoms than non-wearers. Soft lens wearers classically report dryness symptoms that increase with wear time and are most intense at the end of the day. The frequency of dryness symptoms in soft contact lens wearers is greater than non-wearers, and symptoms decrease upon contact lens removal. “Dryness” has consistently been reported as the most common symptom. Symptoms also frequently reported, but with differing severity include discomfort, scratchiness, irritation, eye soreness, light sensitivity, and blurry/changeable vision. Regardless of the symptom, contact lens wearers consistently experience more intense and frequent symptoms at the end of the day.

A survey-based study showed that CLIDE is a distinct condition; not simply an extension of already present but potentially marginal dry eye. Chalmers (2006) found the epidemiology of contact lens wearers to differ from that of non-contact
lens wearers. Dry eye symptoms in non-wearers are significantly correlated with age and female gender. In contrast, this study found no correlation between gender and dry eye symptoms during lens wear. Unlike non-lens wear dry eye, age was inversely correlated with dry eye symptoms. These results suggest contact lens wear alone might induce dry eye and is not simply a means of exacerbating already existing dry eye.

While symptoms are frequently reported and easily assessed, clinical signs are difficult to illicit in dry eye and CLIDE patients. The magnitude of symptoms commonly outweighs clinical signs. In fact, the ocular surface of some significantly symptomatic dry eye and CLIDE patients may show no obvious signs of dry eye. After adjusting for age and artificial tear use in a group of non-contact lens wearing dry eye patients, Nichols (2004) found no correlation between patient symptoms and clinical signs. A similar study of dry eye patients revealed a high correlation between symptoms and both the patient and clinician’s assessment of dry eye severity. Ocular signs, conversely, showed a lower correlation. Young (2012) found that one quarter of symptomatic soft contact lens wearers showed no ocular signs. Additionally, no single ocular sign or combination of signs was effective in identifying symptomatic CLIDE patients.

The lack of correlation between signs and symptoms is evident in many forms of dry eye. This incongruity may be due to poor repeatability of dry eye clinical testing. Nichols (2004) showed that while subjective dry eye symptoms were repeatable over multiple visits, common dry eye tests (tear break-up time,
Schirmer test, phenol red thread test, corneal and conjunctival staining, Meibomian gland assessment) showed low to fair repeatability. Many dry eye objective tests exist, but a gold standard diagnosis pattern has not been set. Some common dry eye tests have variations and multiple interpretations that may cause inter-examiner diagnosis discrepancies. Additionally, a lack of consensus among practitioners makes diagnosis and treatment difficult over time. Mode of clinical practice and time available can influence a clinician’s mode of dry eye diagnosis. Overall, tear break up time and corneal/conjunctival staining tend to be popular and trusted tests among eye care practitioners. Still, most clinicians base dry eye diagnosis largely off of subjective patient symptoms.

Because dry eye can exist without ocular surface signs, the main goal of treatment is often to improve symptoms. Improvement of diagnosis and treatment can be achieved by better defining and quantifying symptoms. Both the National Eye Institute and the DEWS concluded that clinical trials evaluating dry eye should utilize a validated questionnaire that evaluates subjective symptoms and functional lifestyle in order to accurately assess the efficacy of various dry eye treatments. Several forms and versions of questionnaires have emerged in the last two decades to aid in understanding and managing dry eye and CLIDE. The DEWS determined that a valuable symptom survey should be reproducible and able to measure change and severity. They went on to encourage the use of structured symptom surveys in conjunction with objective clinical testing to accurately diagnosis dry eye disease. Questionnaires of various lengths have been designed and determined to have

5
variable amounts of validity. Commonly accepted dry eye questionnaires include the Dry Eye Questionnaire (DEQ), the Ocular Surface Index (OSDI), the Contact Lens Dry Eye Questionnaire (CLDEQ), and McMonnies Dry Eye Questionnaire.\textsuperscript{25}

Multiple etiologies and varied signs and symptoms lead to a myriad of treatment options for dry eye patients. If the cause or type of dry eye can be determined at the time of diagnosis, treatment can be more effective. Tear supplementation with lubricants that mimic natural tears and re-hydrate the ocular surface is generally the first line of treatment for mild-moderate cases of dry eye. Retention of tears on the ocular surface using permanent or temporary punctal plugs is another early treatment option. If the cause of signs and symptoms is determined to be inflammatory, cyclosporine or corticosteroids are used topically to decrease surface inflammation.\textsuperscript{27} In the cases of dry eye that is exacerbated by Meibomian gland stenosis or disease, use of tetracycline oral antibiotics is often effective.\textsuperscript{27} Dietary supplementation with essential fatty acids, specifically omega-3 fatty acids, can also improve overall Meibomian gland health and function.\textsuperscript{27} In CLIDE, treatment often centers on the contact lens itself. Lens material, water content, oxygen permeability, replacement schedule, and contact lens solution use are all considered as contributing factors. One or more of these factors are typically changed or eliminated in an attempt to decrease or cease dry eye symptoms.

Nonstrabismic binocular and accommodative disorders are a group of conditions that variably affect the visual system. Each respective disorder leads to distinct signs and symptoms. In general, common symptoms attributed to binocular
and accommodative disorders are headaches, asthenopia, intermittent blur, and light sensitivity. While each disorder can be present individually, it is not uncommon for certain pairs of disorders to be present in one subject. Full correction of ametropia is the first step in treating accommodative and binocular vision disorders. After this, treatment options vary based on the severity of symptoms and clinical signs. A description of some common binocular and accommodative disorders is listed below:

**Convergence Insufficiency (CI)**

CI subjects converge less when focused at near. Symptoms like asthenopia, headaches, sleepiness, diplopia, poor comprehension, and intermittent blur are generally associated with near tasks. Common signs include moderate-high exophoria at near, greater exophoria at near compared to distance reduced positive fusional vergence, and reduced near point of convergence (NPC). Other signs include reduced AC/A ratio, poor binocular accommodative facility, and reduced negative relative accommodation (NRA). Accommodative excess is an accommodative disorder that often presents concomitantly with CI. It is thought that these subjects use excessive accommodative convergence to make up for the poor positive fusional vergence. Vision therapy is the primary treatment option for CI. Various methods and types of vision therapy are available. Therapy centers on improving positive fusional vergence at near. It is well accepted that office
based therapy in conjunction with at home therapy exercises results in effective and efficient treatment of CI.\textsuperscript{28} Horizontal prism or added plus lens power at near may also reduce symptoms.\textsuperscript{28,29}

\textit{Convergence Excess (CE)}

Patients with CE over-converge at near. Symptoms, in general, are worse at the end of the day and are associated with near work.\textsuperscript{28,29} Common signs are esophoria greater at near compared to distance and reduced negative fusional vergence. Other signs include high AC/A ratio, poor binocular accommodative facility, and low positive relative accommodation (PRA).\textsuperscript{28,29} Added plus lens power at near is the recommended initial treatment. Vision therapy is another option if the addition of lenses is not completely successful. Horizontal prism, while still a treatment option, is rarely utilized since added plus power at near is so successful.\textsuperscript{28}

\textit{Basic Exophoria}

Basic exophores display relatively equal exophoria at distance and near.\textsuperscript{28,29} Asthenopia, intermittent blur at all distances, diplopia at all distances, poor comprehension while reading, and difficulty concentrating are frequently reported symptoms.\textsuperscript{28,29} Common signs include reduced NPC, reduced positive fusional vergence at distance and near, normal AC/A ratio, poor binocular facility, and low NRA.\textsuperscript{28,29} Horizontal prism at all distances is an
effective treatment. Vision therapy may also be utilized and is similar to strategies used with CI mentioned above. Exophoria therapy, in contrast, is targeted at near, intermediate, and far distances.28

Basic Esophoria

Basic esophores display relatively equal esophoria at distance and near. Common symptoms include asthenopia, intermittent blurred vision, diplopia, and difficulty concentrating at near.28,29 Clinically, these subjects display esophoria at all distances, normal AC/A ratios, and commonly have an associated hyperphoria.28,29 Added plus power at near and horizontal prism at all distances are common treatments. Vision therapy focused on normalizing negative fusional vergence and divergence ability at all distances can also be helpful in eliminating symptoms.28

Accommodative Insufficiency (AI)

Persons with AI don’t exert enough accommodation when performing near tasks. Stimulating and sustaining accommodation is a challenge for these subjects.28 Symptoms are associated with near tasks and include fatigue, discomfort, asthenopia, and blurred vision.28,29 Patients with AI often have trouble concentrating on near work. Reduced amplitude of accommodation, poor monocular and binocular facility, and low PRA are commonly noted signs.28,29 Adding plus power at near is the most common and effective
treatment strategy.\textsuperscript{28} Vision therapy targeted at normalizing the ability to stimulate and relax accommodation is also helpful.\textsuperscript{28}

\textit{Accommodative Excess (AE)}

Patients with AE over-accommodate when focused at near. They have difficulty with any task requiring them to relax accommodation. Most symptoms are associated with close work.\textsuperscript{28} AE subjects commonly complain of blurred distance vision following near work, asthenopia while reading, sensitivity to light, and increased symptoms at the end of the day.\textsuperscript{28,29} AE subjects often display variable acuity and retinoscopy findings due to the fluctuating accommodation system.\textsuperscript{28} They may also have reduced NRA and/or difficulty clearing plus powers on monocular and binocular facility. Because added plus power does not benefit these patients, vision therapy is the best treatment strategy.\textsuperscript{28} Therapy is aimed at normalizing accommodative amplitude and the ability to stimulate and relax accommodation.\textsuperscript{28}

\textit{Pseudo Convergence Insufficiency (PCI)}

PCI is a condition where the subject experiences symptoms and displays signs of convergence insufficiency and accommodative insufficiency. The main problem for these patients is under-accommodation. Insufficient accommodation results in increased exophoria at near compared to distance,
Reduced NPC, and/or reduced positive fusional vergences at near. A PCI diagnosis can be confirmed by repeating BV testing (cover test, NPC, etc.) with plus lenses. PCI treatment is focused on the accommodative insufficiency. Low added power at near is often sufficient to alleviate symptoms. Vision therapy can also be utilized. 

Nonstrabismic binocular and accommodative disorders are prevalent in pediatric and adult populations. Various studies have reported the prevalence rates of binocular and accommodative anomalies to be between 19.7-32.3%. After studying a pediatric population, Scheiman (1996) found 19.7% of 2,023 pediatric subjects had a binocular or accommodative anomaly. In that group, binocular disorders (14.3%) were more prevalent than accommodative (5.4%). CE (7.1%) was more common than CI (4.6%), and AI (2%) was slightly more common than AE (1.8%). In 1999, Lara sampled a population of both pediatric and adult subjects and found 22.3% showed accommodative and/or binocular disorders. In this sample 12.9% were binocular disorders and 9.4% were accommodative. Similar to Scheiman, Lara found CE (9.0%) had a higher prevalence than CI (3.5%). When comparing accommodative dysfunction, however, this sample had a higher rate of AE (6.4%) than AI (3.0%). Half of the CE patients had associated AE. Porcar (1997) studied a group of university students (mean age 22 years) and found 32.3% had binocular and/or accommodative dysfunctions with AE being the most common condition. Differences seen in prevalence rates when comparing the above studies...
are likely due to the varied definitions, clinical testing, and diagnosis criterion used for binocular vision and accommodative anomalies. In general, the greater number of signs required for diagnosis, the lower the prevalence found. Additionally, each study used different types of populations. Porcar, for instance sampled a group of university students while Lara studied a wider age range. It could be argued that Porcar’s prevalence rate was higher because he sampled a group with unusually high near visual demands.

Treatment of binocular and accommodative disorders is largely symptom based. Unlike dry eye, however, there is no literature describing circumstances where a patient would have binocular vision symptoms, but no clinical signs, and receive treatment for those symptoms. In addition, asymptomatic patients with positive clinical signs are unlikely to pursue treatment, so treatment has been historically initiated when both signs and symptoms are present. Symptom surveys are also utilized with binocular vision anomalies to determine what patients are most symptomatic and would benefit from treatment. The Convergence Insufficiency Symptom Survey (CISS) is a validated survey that grades CI symptoms. This 15-item questionnaire asks subjects to rank their symptoms based on frequency. Symptoms from the survey include blurred vision, asthenopia, fatigue, diplopia, and decreased comprehension while reading. Subjects with CI score significantly higher on the CISS when compared with normal binocular vision subjects. Scores obtained from the CISS help clinicians determine severity of CI and are considered with objective clinical data when determining a treatment plan.
When comparing the symptomology of CLIDE and binocular vision disorders, parallels and similarities are easily recognized. Regardless of which symptoms one would consider, frequency and intensity are consistently reported as increased at the end of the day for both conditions. Many of the common symptoms can logically be attributed to either group of conditions. Photosensitivity can be caused by dry ocular surface or inaccurate accommodation. Discomfort, a leading cause of contact lens dropout, could be due to dryness or asthenopia caused by a binocular vision issue. Intermittent blur could be the result of irregular tear coverage or poor vergence and accommodative ability. These symptoms are common across varied disorders. It’s not unreasonable to believe patients and/or clinicians could assume any one symptom or group of symptoms is related to a disorder that is not actually present.

While the symptomology of CLIDE and binocular vision disorders is remarkably similar, the presentation of signs is not. As discussed earlier, signs of ocular surface damage are often mild or completely absent in symptomatic dry eye patients. Patients seek care based on symptoms. Clinicians typically initiate care based on symptoms as well. Because significant clinical signs are often absent, treatment is commonly initiated to alleviate symptoms. Patients suffering from binocular vision disorders also seek treatment because they are symptomatic. In contrast to dry eye disorders, however, these patients show clinical signs that correlate with their symptoms. These data can be quantified and used to determine what treatment might be most effective. The presence or absence of objective
clinical data is the main factor where these groups of conditions differ in clinical diagnosis and management.

If CLIDE-like symptoms are being confused with binocular vision disorders, what is the reason? When considering myopes who wear single vision contact lenses, the explanation can be attributed to simple optics. Theoretical optical calculations show that, when compared to single vision spherical spectacle wear, contact lens-corrected myopes must exert more accommodation and vergence. When corrected with spectacles, a myope experiences a base-in effect while looking at near, resulting in a decreased demand for convergence. With contact lens correction, this myope does not appreciate the same base-in effect and must converge more than they would with spectacles. The opposite effect is seen in hyperopes.

These theoretical assumptions have been confirmed in recent years. In 2006, Hunt was the first to dynamically measure and compare accommodation and vergence when wearing glasses or contact lenses. Myopes were shown to exert more accommodative and vergence effort while wearing contact lenses. However, increased accommodative effort was only statistically significant on one of two autorefractors used. Jimenez similarly found, when compared to spectacle wear, myopic contact lens correction resulted in higher accommodative lag, higher negative relative accommodation, more esophoric near horizontal dissociated phoria, and lower near negative fusional vergence. If contact-lens-corrected myopes must exert more convergence and accommodation at near, it is logical to
think these patients may display binocular vision disorders when wearing their contact lenses.

Theoretical calculations suggest a myopic subject could display binocular vision anomalies when corrected with contact lenses. However, this theory has not been tested clinically. Dry eye studies traditionally focus on symptom surveys, various dry eye tests, and ocular surface evaluation. Visual acuity may be the only objective vision assessment and binocular vision testing is not part of a typical protocol. Nichols (2004) noted the lack of clinical signs in a symptomatic group of non-contact lens wearing dry eye patients. Begley (2003) also examined the relationship between dry eye symptoms and signs. In both studies, symptom surveys and typical dry eye testing (surface staining, tear break-up time, Meibomian gland assessment, etc.) were performed, but visual acuity and binocular vision testing were not assessed.

CLIDE frequently presents without signs, and treatment is symptom-driven. Therefore, studies evaluating CLIDE commonly do so with surveys, obtaining only subjective data from patients. Surveys have exclusively been used to evaluate symptom severity in relation to contact lens discontinuation. These survey-based evaluations did not assess visual acuity or function. Additionally, no objective measure of ocular surface dry eye signs was taken. When assessing dry eye symptoms in non-contact lens wearers and contact lens wearers, Chalmers (2006) assessed symptoms with surveys and also examined the ocular surface. However, the subjective data used from the symptom surveys was used to make conclusions.
in the study. Again, visual function was not assessed. Because CLIDE is known for its lack of signs, evaluation of the condition has become almost exclusively symptom-based. Without assessing basic visual and binocular function, one risks overlooking valuable objective data that may explain symptoms that arise without any other apparent cause or sign.

Contact lens discontinuation and drop out is a problem for both patients and eye care professionals. It has been reported that approximately one third of contact lens wearers have discontinued lens wear at some point in their lives. It is also estimated that 23-24.1% of contact lens wearers discontinue lens wear permanently. Discomfort has consistently been found to be the primary reason for contact lens discontinuation. Other common reasons include dryness, poor visual quality, cost, and convenience. A myriad of treatment options exist to combat symptoms of discomfort and dryness while wearing contact lenses. Changes in material type, modality, solution, or addition of artificial tears are options that often are not completely successful. Patients, instead, typically resort to decreasing or ceasing lens wear. The most frequent self treatment and coping strategy employed by uncomfortable contact lens wearers is removal of lenses.

The introduction of highly oxygen permeable silicone hydrogel materials and frequent replacement lens modalities in recent years was hoped to improve contact lens dropout rates and overall contact lens satisfaction. Yet, these advances do not seem to have a profound effect on contact lens discontinuation. A recent survey by Dumbleton (2013) found that a higher proportion of lapsed lens wearers were
wearing daily disposable lenses. Additionally, even though a larger number of non-lapsed wearers were in silicone hydrogel lenses, the difference was not considered significant. Young (2002) found that once re-fitted with contact lenses, previously lapsed wearers most often cited vision-related problems, not discomfort, as the reason for discontinuing wear. This finding could be interpreted to suggest that newer materials improved comfort in these patients. Conversely, one could argue that once comfort was eliminated as problem, the patient was now more aware of visual function issues that may have persisted with both lens modalities.

Patients pursue contact lens wear intentionally, whether their reasons are convenience, cosmetic, or improved visual performance. Half of all current contact lens wearers wish they could wear their lenses longer each day. Lapsed wearers who return to contact lens wear after a period of discontinuation cite convenience and cosmetic preference as their main motivating factors. Pritchard observed that 49% of patients who had dropped out of lens wear had pursued a refit at some point in their lives. These data indicate that although discomfort may hinder or decrease wear time, patients still wish to pursue contact lens wear. Doctors devote clinic time and resources to contact lens fitting and follow up care. Discontinuing contact lens wear can be costly to the patient and doctor.

The goal of this study was to determine if a relationship exists between symptomatic CLIDE and binocular and accommodative vision disorders. The investigators anticipate results will indicate a significant percentage of contact lens wearers with dry eye symptoms also display subjective symptoms and/or objective
signs of binocular vision disorders. Determining a correlation between myopic contact lens wear and nonstrabismic binocular vision disorders will prevent contact lens dropout and illustrate the true cause of discomfort in some contact lens wearers. This information may help eye care professionals more effectively and efficiently direct treatment to eliminate discomfort with contact lens wear.
Methods

Subjects

Soft contact lens wearing adults with dry eye complaints were recruited from the Ohio State University (OSU) Optometry Services primary care and contact lens clinics. Flyers describing the study were placed throughout the clinics and emailed to OSU College of Optometry students, faculty, and staff. Myopic adults aged 18 to 37 who were currently wearing soft contact lenses and had best corrected visual acuity of 20/25 or better in each eye were recruited. Subjects with a history of refractive surgery, strabismus, amblyopia, current use of prescription ocular medications, or pregnancy by self-report were excluded from the study. The Institutional Review Board of the Ohio State University approved the study. Twenty-nine subjects were recruited. Each subject signed a written informed consent and HIPPA form. Each subject participated in one visit that lasted approximately forty minutes.

Questionnaires

Three questionnaires were distributed to each subject to assess subjective dry eye and binocular vision disorder symptoms. A copy of each questionnaire is included in the Appendix. Items from each questionnaire were copied and combined into one common form. The combined questionnaire was distributed on paper and
subjects were asked to circle their responses. Upon completion of each subject visit, subject responses were scored into their respective surveys and the scores were recorded. The following questionnaires were used:

_Ocular Surface Disease Index (OSDI):_

The OSDI is a twelve-item questionnaire that has been validated as an effective tool to assess frequency of dry eye symptoms and how they affect vision, comfort, and everyday activities. The OSDI was developed by the Outcomes Research Group at Alergan Inc in 1997. The goal of the survey was to assess dry eye symptoms and how they affect vision-related functioning in order to better evaluate efficacy of various dry eye treatments. The twelve questions on the OSDI are broken down into three categories that specifically assess overall dry eye symptoms, symptoms while performing vision related tasks, and symptoms while in specific environments. Subjects are asked to rank the frequency of their symptoms on a scale of 0 to 4 (0 indicates none of the time; 1, some of the time; 2 half of the time; 3, most of the time; and 4, all of the time). The OSDI is scored on a scale of 0 to 100. Higher scores represent more symptomatic dry eye. The OSDI score was then calculated using the following formula: \[\text{OSDI} = \frac{\text{sum of scores for all questions answered}}{\text{total number of questions answered}} \times 25\]
**Contact Lens Dry Eye Questionnaire 8 (CLDEQ-8)**

The CLDEQ-8 was designed to evaluate dry eye symptoms in contact lens wearers. The items in this questionnaire reflect symptoms unique to contact lens wearers. The CLDEQ-8 is a shorter, 8-item version of the 36-item CLDEQ. The original CLDEQ was designed to be a contact lens version of the Dry Eye Questionnaire (DEQ). Both long questionnaires asked questions related to symptom frequency, diurnal intensity, and intrusiveness. Questions about treatment, environment, and computer use were also asked. Introduction of a shorter, five item DEQ (DEQ-5) highlighted the need for a shorter CLIDE survey. The CLDEQ-8 asks patients to rate the frequency and intensity of eye discomfort, dryness, changeable/blurry vision, and the effect of closing the eyes or removing the contact lenses has on their symptoms. CLDEQ-8 scores are ranked on a scale from 0 to 37.³

**Convergence Insufficiency Symptom Survey (CISS)**

The CISS is a 15-item survey that assesses the presence and frequency of convergence insufficiency symptoms. The survey has been shown to be a valid and reliable tool to discriminate between patients with normal binocular vision and convergence insufficiency.³³
Patient Contact Lens History, Information Collection, and Evaluation

Subjects were instructed to bring their current contact lens prescription information to the visit. Contact lens brand, base curve, and diameter were recorded for each eye. Subjects were asked about their average replacement schedule, approximate age of the current lens, primary solution (if any) used, and how many approximate hours the current contact lenses had been worn. Contact lens fit was assessed using a slit lamp. Gross centration, limbal coverage, and lens movement was recorded. Gross lens rotation was assessed in subjects wearing toric soft contact lenses.

Visual Acuity

Visual acuity was measured monocularly and binocularly at distance and near with each subject’s habitual contact lens correction. High contrast targets were used in normal room illumination. Distance acuity (6 m) was measured with a logMAR chart and near visual acuity (40 cm) with a near visual acuity card. Guessing was encouraged. Patients were required to provide responses to all five letters before moving onto the next line. The test was completed when the subject gave three incorrect responses on one line.

Heterophoria Determination

The Modified Thorington (MT) technique was employed in this study to determine distance and near vertical and horizontal heterophoria. Several methods
exist to measure heterophoria, but MT testing has been shown to be the most repeatable form of heterophoria measurement.\textsuperscript{36,37} In addition, because we did not have a masked examiner for this study, the MT is also an objective test that is not influenced by the biases of the examiner. Both distance (6 m) and near (40 cm) versions of MT testing cards contain horizontal and vertical rows of numbers that are calibrated to measure prism diopters at that distance. Each card contains a small central hole where a penlight is shown through. The subject held a Maddox rod over their right eye in a horizontal orientation. When the Maddox rod was oriented horizontally, subjects saw a red vertical line. The subject was asked to report what numbered row the vertical line passed through and this value was recorded as the horizontal heterophoria. The procedure was repeated with the subject holding the Maddox rod with the lines oriented vertically. The subject now saw a horizontally oriented red line and reported where the line crossed the vertical axis. This value was recorded as the vertical heterophoria measurement. This procedure was performed with distance and near MT cards.

\textit{Binocular Vergence Measurement}

Positive (base-out) and negative (base-in) horizontal vergences were measured at distance and near using a prism bar with sequential, increasing amounts of horizontal prism. To prevent effects on vergence recovery, both distance and near horizontal vergence testing were performed by first testing negative (base-in) vergences.
For near testing, the subject viewed a 20/20 row of vertical letters held at 40 cm. 2 diopters of base-in prism was placed in front of the subject’s right eye. Prism was increased in the same orientation. The subject was instructed to report when the line of letters first became blurry (recorded as the blur measurement) and first doubled (recorded as the break measurement). After the subjects reported doubling of the letter line, prism magnitude was decreased until subjective return of single vision was reported (recorded as the recovery value). This procedure was repeated with base-out prism. After near vergence testing, distance vergence testing was performed. The same technique and recording method was employed, except a 20/20 row of vertical letters placed 6 meters from the subjects was used as the visual target.

Near Point of Convergence (NPC)

NPC was evaluated binocularly with the subject’s habitual (contact lens) correction using a push-up technique. A vertical line target on a fixation stick was placed approximately 16 cm in front of the patient. The target was slowly moved closer to the subject’s central visual axis until the subject reported diplopia. The distance from the bridge of the subject’s nose to this point was recorded. This procedure was repeated two more times to obtain an average NPC and to determine if the value changed with fatigue.
**Accommodative Function: Accommodative Lag/Lead**

Measurements of accommodative response were performed using the Grand Seiko autorefractor. Accommodative response was measured at two stimulus levels: 0.00 D and 4.00 D. An accommodative target (3 rows of 20/20 letters) was placed on a Badal track in front of the right eye while the left eye was occluded. Measurement of accommodative response was taken on subjects wearing their habitual (contact lens) correction.

**Tear Break Up Time (TBUT) Assessment**

TBUT measurements quantify the time it takes for the tear film to break-up or become disrupted on the ocular surface after a complete blink. To measure TBUT, fluorescein sodium was instilled in the right inferior palpebral conjunctiva using a Ful-Glo fluorescein sodium ophthalmic strip that had been wetted with a drop of saline. After instillation, the subject was placed in the slit lamp and instructed to blink several times. After several blinks, the subject was asked to hold the blink as long as possible. While the patient was holding the blink, the tear film was observed through the slit lamp with a wide, diffuse cobalt blue light. A yellow barrier filter (Wratten #12 filter) was held over the slit lamp objective to improve fluorescein visibility. The time (in seconds) of the first apparent tear break up was recorded. This procedure was repeated two more times to obtain an average TBUT value.
Ocular Surface Staining with Fluorescein and Lissamine Green

Fluorescein sodium and lissamine green were used to assess ocular staining. Fluorescein instilled during TBUT was sufficient and additional Ful-Glo was not applied. Lissamine green was applied to the right inferior palpebral conjunctiva using a lissamine green impregnated strip that had been wetted with saline. The Oxford Scheme (Appendix D) was used to assess corneal staining under white and cobalt blue light. A yellow barrier filter was used with the cobalt blue light to improve fluorescein visibility. This scheme requires staining patterns to be classified into one of five categories based on severity.\textsuperscript{38} Patients were instructed to look up, down, left, and right in white and cobalt blue light in order to obtain the most complete staining classification.

Schirmer Test

The Schirmer test is a standardized method used to evaluate lacrimal function and diagnose aqueous deficient dry eye. It measures tear flow using a filter paper that is inserted into the conjunctival sac.\textsuperscript{25} For each subject, a Schirmer filter paper (5x35 mm Whitman No 1) was placed in the lower lid, midway between the middle and outer third of the lid. The tip of the Schirmer paper was tucked under the lower lid. The Schirmer test was performed without anesthetic. The subjects were instructed to close both eyes for five minutes. After five minutes, the Schirmer paper was removed and the tear flow measured on the filter paper was recorded. If
the patient's tears filled the filter paper before the five-minute cut-off, it was removed early.

*Meibomian Gland Assessment*

A general observation and assessment of Meibomian gland function was made using a graded scale, as suggested by Nichols, et al. Meibomian glands and lid margins were observed and assigned a grade of normal or Grade 1-4 Meibomian gland dysfunction. A “normal” assessment indicated that all glands were clear of blockage and the lid margin was covered in a thin, even oil layer. Grade 1 showed 1-2 blocked Meibomian glands. Grade 2 indicated 3-4 stenosed glands. Grade 3 was recorded if half of the glands were blocked, and Grade 4 was assigned if more than half of the glands were blocked. A Meibomian gland “blockage” was assigned when gentle pressure on the surrounding lid and lid margin did not produce meibum expression. Meibomian gland assessment was performed on the right eye only.

*Data Analysis*

Statistical results were calculated using SPSS Version 21 (IBM). Questionnaire responses were collected and scored. Subjects were categorized as having “significant” or “not significant” symptom scores on the OSDI and CISS (for dry eye and BV disorders, respectively). A significant OSDI score was classified as \( \geq 15 \), and a significant CISS score was classified as \( \geq 21 \).
The number of significant dry eye signs was determined for each subject. Staining scores >0 and Meibomian gland assessment scores >0 were determined to be significant.\textsuperscript{21,38} Average TBUT <7 seconds and Schirmer score <7 mm were considered to be significant dry eye signs.\textsuperscript{39} Each subject was classified as having “significant” or “not significant” overall dry eye signs. Subjects with ≥2 significant dry eye signs were classified as having significant dry eye signs.

The number of significant binocular vision signs was determined for each patient. The following binocular vision signs were considered significant:

- ≥4 prism diopters more exophoric at near compared to distance\textsuperscript{1,28}
- ≥3 prism diopters more esophoric at near compared to distance
- ≥4 prism diopters exophoria or esophoria, equal (or within 2 prism diopters) at distance and near\textsuperscript{28}
- ≥6 cm break NPC\textsuperscript{32}
- Insufficient positive fusional vergences (PFV) (break/recovery)\textsuperscript{28}:
  - Distance: <11/7 prism diopters BO
  - Near: <19/14 prism diopters BO
- Insufficient negative fusional vergences (NFV) (break/recovery)\textsuperscript{28}:
  - Distance: <7/4 prism diopters BI
  - Near: <13/10 prism diopters BI
- PFV and NFV at distance and near were considered significantly reduced if both values (break/recovery) were ≤3 prism diopters than the respective normal value for step vergence testing.\textsuperscript{28}
• Accommodative lag ≥+0.75 D

Each subject who had ≥2 significant BV signs was classified into a specific BV disorder. The disorders encountered in this study were convergence insufficiency (CI), convergence excess (CE), and pseudo-convergence insufficiency (PCI). The following criteria were used to classify each subject:

**Convergence Insufficiency:**
- ≥4 prism diopters more exophoric at near compared to distance
- ≥6 cm break NPC
- Insufficient PFV at near
- Normal (<+0.75 D) accommodative lag

**Convergence Excess:**
- ≥3 prism diopters more esophoric at near compared to distance
- Insufficiency NFV at near
- Normal to high (+>0.75 D) accommodative lag

**Pseudo Convergence Insufficiency (PCI):**
- Must have high accommodative lag (≥+0.75 D)
- ≥4 prism diopters more exophoric at near compared to distance
- ≥6 cm break NPC
- Insufficient PFV at near
Results

Mean subject age was 24.93 years with a range of 22-37 years. 86.2% (25/29) of the subjects were female. Mean binocular spherical equivalent contact lens power was -3.80 D with a range of -0.875 to -7.195 D. The number of significant dry eye and binocular vision signs and presence of significant symptoms (based on OSDI and CISS scores) was determined for each subject. 48.28% of the sample had significant (≥2) dry eye signs and 48.28% of subjects had significant (≥2) BV signs. Results are summarized in Table 1.

<table>
<thead>
<tr>
<th>Number of Signs</th>
<th>Dry Eye (%)</th>
<th>Binocular Vision (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>17.24</td>
<td>6.90</td>
</tr>
<tr>
<td>1</td>
<td>34.48</td>
<td>44.83</td>
</tr>
<tr>
<td>2</td>
<td>31.03</td>
<td>27.59</td>
</tr>
<tr>
<td>3</td>
<td>6.90</td>
<td>20.69</td>
</tr>
<tr>
<td>4</td>
<td>10.34</td>
<td>-</td>
</tr>
<tr>
<td>≥2</td>
<td>48.28</td>
<td>48.28</td>
</tr>
</tbody>
</table>

Twenty subjects were symptomatic for dry eye (OSDI ≥15). Of these subjects, 9 had significant dry eye signs, 11 had significant BV signs, and 4 had significant signs in both categories. Ten subjects were symptomatic for CI (CISS ≥21). Four of these subjects had significant dry eye signs, 5 had significant BV signs, and 2 had significant dry eye and BV signs. These results are summarized in Table 2.
Table 2: Symptomatic Dry Eye and CI

<table>
<thead>
<tr>
<th></th>
<th>Significant (≥2) Dry Eye Signs</th>
<th>Significant (≥2) BV Signs</th>
<th>Significant Dry Eye and BV Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic Dry Eye† (68.97%)</td>
<td>45% (9/20)</td>
<td>50% (10/20)</td>
<td>20% (4/20)</td>
</tr>
<tr>
<td>Symptomatic CI‡ (34.48%)</td>
<td>40% (4/10)</td>
<td>50% (5/10)</td>
<td>20% (2/10)</td>
</tr>
</tbody>
</table>

† ODSI ≥ 15
‡ CISS ≥ 21

Chi-square testing was performed to determine if subjects with significant dry eye signs or symptoms were more likely to have significant BV signs or symptoms. No statistically significant relationship was found between the four different groups. Results are displayed in Table 3.

Table 3: Chi-Square Test  p-values

<table>
<thead>
<tr>
<th></th>
<th>Significant (≥2) BV Signs</th>
<th>Significant BV symptoms‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant (≥2) Dry Eye Signs</td>
<td>0.57</td>
<td>0.52</td>
</tr>
<tr>
<td>Significant Dry Eye Symptoms†</td>
<td>0.78</td>
<td>0.93</td>
</tr>
</tbody>
</table>

† ODSI ≥ 15
‡ CISS ≥ 21

Five subjects had zero dry eye signs. Two of these subjects had significant CI symptoms (CISS ≥21) ad 3 had significant (≥2) BV signs. 15 subjects had ≤1 dry eye sign. Six of these subjects had significant CI symptoms and 8 have significant BV signs. Table 4 summarizes these results.
Table 4: BV Symptoms and Signs in Subjects With Few or No Dry Eye Signs

<table>
<thead>
<tr>
<th></th>
<th>Significant CI Symptoms†</th>
<th>Significant (≥2) BV Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Dry Eye Signs (17.24%)</td>
<td>40% (2/5)</td>
<td>60% (3/5)</td>
</tr>
<tr>
<td>≥1 Dry Eye Sign (51.72%)</td>
<td>40% (6/15)</td>
<td>53.33% (8/15)</td>
</tr>
</tbody>
</table>

† CISS ≥ 21

When we evaluated accommodative function, 75.86% (22/29) of subjects had an accommodative lag of +0.75 D or greater, and 48.28% (14/29) had accommodative lag of +1.00 D or greater. Table 5 displays what proportion of these groups were symptomatic for CI/dry eye or had other associated BV signs. Table 6 shows the prevalence of BV disorders found in subjects with significant BV signs. PCI was the most common binocular vision disorder found in subjects with ≥2 BV signs. CI and CE were the second and third most prevalent BV disorders, respectively.

Table 5: Significant Accommodative Lag and Associated BV Signs and Symptoms

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic CI</th>
<th>Symptomatic DE†</th>
<th>≥2 BV Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 0.75 D Lag (75.86%)</td>
<td>36.36% (8/22)</td>
<td>68.18% (15/22)</td>
<td>45.45% (10/22)</td>
</tr>
<tr>
<td>≥1.00 D Lag (48.28%)</td>
<td>42.86% (6/14)</td>
<td>50.00% (7/14)</td>
<td>64.29% (9/14)</td>
</tr>
</tbody>
</table>

† ODSI ≥ 15
Table 6: Binocular Vision Disorders Found in Sample

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Prevalence in Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergence Insufficiency (CI)</td>
<td>21.43% (3/14)</td>
</tr>
<tr>
<td>Convergence Excess (CE)</td>
<td>14.29% (2/14)</td>
</tr>
<tr>
<td>Pseudo-Convergence Insufficiency (PCI)</td>
<td>64.29% (9/14)</td>
</tr>
</tbody>
</table>

Chi-Square Testing was performed to determine if the prevalence of subjects with significant BV signs found in our sample (48.28%) was different from prevalences found by other investigators (Table 7). Compared to the prevalence found by Lara, the prevalence of binocular vision disorders in this sample was significant \(p < 0.001\). When compared to the prevalence found by Porcar, the prevalence was found to not be significantly different \(p < 0.10\). The prevalence of BV disorders was found to be significantly different from the mean prevalences found be Lara and Porcar \(p < 0.001\).

Table 7: Chi-Square Testing \(p\)-values Compared to General Population (df = 1)

<table>
<thead>
<tr>
<th></th>
<th>Lara(^{29}) (22.3%)</th>
<th>Porcar(^{30}) (32.3%)</th>
<th>Average (27.3%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant (≥2) BV Signs</td>
<td>(X^2 = 11.293)</td>
<td>(X^2 = 3.38)</td>
<td>(X^2 = 6.43)</td>
</tr>
<tr>
<td>(48.28%)</td>
<td>(p &lt; 0.001^*)</td>
<td>(p &lt; 0.10)</td>
<td>(p &lt; 0.005^*)</td>
</tr>
</tbody>
</table>

\(^*\)statistically significant \(\alpha = 0.05\)

Pearson correlations were performed to compare scores of the CISS, OSDI, and CLDEQ (Table 8). CISS scores were not significantly correlated with OSDI or CLDEQ scores. OSDI and CLDEQ were significantly correlated. Seven subjects had both CISS and OSDI scores that were considered significantly symptomatic. The OSDI and CISS scores of these 7 subjects had no significant correlation. A correlation
was also performed to determine if a relationship existed between amount of accommodative lag and average spherical equivalent refractive error (SEQ) between both eyes. This correlation was not significant.

Table 8: Pearson Correlations

<table>
<thead>
<tr>
<th></th>
<th>Pearson Correlation Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CISS and OSI</td>
<td>0.26</td>
<td>0.17</td>
</tr>
<tr>
<td>CISS and CLDEQ</td>
<td>-0.07</td>
<td>0.71</td>
</tr>
<tr>
<td>OSI and CLDEQ</td>
<td>0.48</td>
<td>0.009*</td>
</tr>
<tr>
<td>OSI and CISS (subjects with significant scores on both)</td>
<td>0.47</td>
<td>0.29</td>
</tr>
<tr>
<td>Average SEQ and Lag</td>
<td>0.22</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*statistically significant (α = 0.05)

Independent T-testing was performed and results are summarized in Table 9. Number of dry eye signs was not related to the presence of significant dry eye symptoms (p=0.9) or significant BV symptoms (p=0.2). Number of BV signs was not related to the presence of significant BV symptoms (p=0.2) or significant dry eye symptoms (p = 0.5).

Table 9: Independent T-Testing p-values

<table>
<thead>
<tr>
<th></th>
<th>Significant Dry Eye Symptoms</th>
<th>Significant BV Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Dry Eye Signs</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Number of BV Signs</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Subjects were separated into two groups, with and without significant BV signs. The mean severity score for each group was determined for 3 separate items from the OSDI. These items asked about eye soreness, difficulty with reading, and difficulty with near work and were determined to be specific to both dry eye and binocular vision symptomology. The results are summarized in Table 10.

Table 10: Average OSDI score for BV specific questions

<table>
<thead>
<tr>
<th></th>
<th>Item 3: Painful or sore eyes</th>
<th>Item 6: Difficulty with reading</th>
<th>Item 8: Difficulty with computer work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant (≥2) BV Signs (n = 14)</td>
<td>0.71</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>No significant BV Signs (n = 15)</td>
<td>0.53</td>
<td>0.93</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Discussion

This was the first study to evaluate concurrent signs and symptoms of soft CLIDE and general binocular vision disorders. In this sample, subjects with symptomatic CLIDE were more likely to have significant binocular vision signs than dry eye signs (Table 2), even though they enrolled in the study because they thought or had been told by an eye care practitioner that they had “dry eye.” Subjects symptomatic for CI were more likely to display binocular vision disorder signs than dry eye signs (Table 2). Potentially due to the relatively small sample size, this difference was not found to be significant (Table 3) when comparing symptomatic groups to significant sign groups in both disorders. Still, these data indicate that subjects with dry-eye-type symptoms may be experiencing a concurrent binocular vision disorder.

Five subjects in this study had no signs of dry eye on the ocular surface. Of this group, 40% had significant CI symptoms while 60% showed significant signs for CI (Table 4). Similarly, 40% of the 15 subjects with ≤1 dry eye sign have CI symptoms and 53.33% had significant CI signs. Although this sample size is small, the relative agreement in proportions implies that patients with few signs of dry eye on the ocular surface may be experiencing symptoms masquerading as dry eye. In fact, these subjects in our sample displayed more signs of a binocular vision disorder than dry eye. In a larger dry eye study, Young (2012) found 23% of soft
contact lens wearers with dry eye symptoms had no significant ocular signs. \(^{20}\) This value is similar to the 17.24% of subjects with dry eye symptoms, but without dry eye signs, found in this sample and would suggest that at least some of Young’s subjects may have been misclassified as “dry eye” when they really had a BV disorder.

Accommodative lag was the most common binocular vision sign found in the sample (Table 5). This finding supports theoretical calculations which demonstrate myopes must accommodate more with contact lenses. \(^{6,7}\) Because accommodative demand increases with contact lens wear, accommodative lag is a logical resultant sign. Jimenez (2011) also found high amounts of accommodative lag in myopic contact lens wearers. Although a different method was used to assess accommodative function (MEM retinoscopy), the mean lag in Jimenez’s contact lens wearers was +0.85 D. \(^{7}\) In the present study, we found a mean lag of +1.11 D.

Significant accommodative lag was examined at 2 magnitudes (≥ 0.75 D and ≥1.00 D)(Table 5). In both groups, dry eye symptoms were more prevalent than CI symptoms. More subjects with abnormal accommodative lag were symptomatic for dry eye than CI (Table 5). Prevalence of significant binocular vision signs was highest in the group with higher accommodative lag. It would be reasonable to assume that accommodative lag would increase with myopic refractive error; however, no significant correlation between accommodative lag and refractive error was found (Table 8, \(p = 0.3\)). A larger sample may give a more representative assessment of the correlation between accommodative lag and myopia magnitude.
Interestingly, Hunt also found no significant correlation between accommodative lead/lag and refractive error. This may also indicate that the source of the accommodative lag in something other than the fact that myopic patients were wearing contact lenses instead of glasses.

A primary goal of this study was to determine if the prevalence of general binocular vision disorders in a symptomatic CLIDE sample was different from that of the general population. The prevalence found in this sample was compared to Lara (22.3%)\textsuperscript{29}, Porcar (32.3%)\textsuperscript{30}, and the mean of their findings (27.3%)(Table 7). The sample was not compared to the prevalence found by Scheiman\textsuperscript{31} because that study observed a pediatric population. Compared to Porcar\textsuperscript{30}, the prevalence of BV disorders in this study sample was not significantly different (\(p < 0.10\)). The prevalence found was significantly different than that found by Lara\textsuperscript{29} (\(p < 0.001\)) and from the mean of the Porcar and Lora prevalences (\(p < 0.005\)). These results indicate that when a contact lens patient presents with significant symptoms of eye discomfort, a binocular vision disorder should be considered as an additional differential diagnosis.

Of the 14 subjects with significant (\(\geq 2\)) BV signs, 3 (21.43%) had CI, 2 (14.29%) had CE, and 9 (64.29%) had PCI (Table 6). Because PCI is primarily an accommodative insufficiency with coexisting CI signs/symptoms, it is considered an accommodative disorder. Therefore, accommodative disorders were significantly more prevalent in this sample. Scheiman (2008) and Lara (2001) found BV disorders to be more common than accommodative disorders in pediatric and
mixed adult/pediatric populations, respectively.\textsuperscript{29,31} In Lara’s sample, 22.3% had a general binocular vision disorder (12.9% BV and 9.4% accommodative). CE was more common than CI, and AE was more common than AI.\textsuperscript{29} Conversely, Porcar (1997) found accommodative disorders to be most common in a university population. AE was most prevalent in this university population (10.8%), while 7.7% had CI with AE and 6.2% had accommodative insufficiency (AI). CE with Al, basic esophoria, and fusional vergences all had a prevalence of 1.5%.\textsuperscript{30}

Porcar (1997) observed a population of 65 university students (mean age 22 years).\textsuperscript{30} Lara’s sample included 265 pediatric and adult subjects (10-35 year age range). Even though Lara’s sample contained pediatric subjects, the mean age was 20.75\textsuperscript{29}, and therefore comparable to this study (mean age 24.93 years). Porcar and Lara did not include contact lens wearers in their studies, and Porcar excluded any subject with significant refractive error.\textsuperscript{29,30} These factors make the compared samples different and may account for the difference in prevalences found for the respective binocular and accommodative disorders.

Pearson correlation was positive, but statistically insignificant when comparing OSDI and CISS scores (Table 8). Correlation between CISS and CLDEQ scores was slightly negative, but also statistically insignificant. OSDI and CLDEQ scores were significantly correlated. This correlation was expected because the surveys query the similar disease process and suggests that our sample population is relatively normal. No significant correlation was found between subjects with significant scores on both the CISS and OSDI.
Because binocular vision disorders and dry eye can produce similar symptoms, it was hypothesized that CISS and OSDI scores would be significantly correlated. In an un-published dry eye study conducted by Ewen King-Smith, 95 dry eye and normal subjects completed the CISS and OSDI. The scores of these surveys were significantly correlated (Pearson correlation coefficient = 0.70, \( p < 0.0001 \)).

In the current study, the correlation between OSDI and CISS, while positive, was not found to be significant (\( p = 0.17 \)). The sample in this study was much smaller than King-Smith’s and it did not include normal subjects. Both of these factors may have contributed to the insignificant, although positive, correlation.

Because BV disorders and dry eye symptoms are similar, it is possible the presence of symptoms generally attributed to one disorder could actually indicate the presence of the other. Independent t-tests were performed to determine if the presence of dry eye or BV disorder symptoms was associated with the number of dry eye or BV signs observed in each subject (Table 9). Dry eye and BV disorder symptoms were not significantly associated with the number of dry eye signs observed for each subject (\( p = 0.9 \) and \( p = 0.2 \), respectively). Similarly, dry eye and BV disorder symptoms were not significantly associated with the number of BV signs observed for each subject (\( p = 0.5 \) and \( p = 0.2 \), respectively). Although no significant relationship was noted between the groups in this study, a larger sample could yield more definitive results.

The OSDI and CISS are commonly used to assess dry eye and CI symptoms, respectively. These surveys assess symptoms of different disorders, but similar
questions appear on both surveys. The OSDI asks subjects to rank their symptoms of eye soreness, difficulty with reading, and difficulty at the computer. While these are symptoms of dry eye, there are also common symptoms of binocular vision disorders. In this study, it was hypothesized that subjects with positive signs of binocular vision may answer these three questions with a higher severity than subjects without BV signs. Interestingly, subjects without BV signs had higher symptom severity scores when asked about difficulty with reading and computer work. Subjects with signs of BV had a higher average score when asked about eye soreness. Relative mean scores for all three questions analyzed were low (< 1). Symptoms weren’t severe for either group (Table 10). A larger and/or more symptomatic sample may reveal more definitive results.

A primary limitation of this study was small sample size. Results may have been determined to be insignificant due to the small amount of data. This sample is small compared to other dry eye studies. Additionally, the sample consisted mostly of young (25 year or younger) female subjects. A larger sample that better represents the general soft contact lens population may have yielded more robust, definitive results and should be considered in the future.

Heterophoria magnitudes and differences at distance and near were obtained with the Modified Thorington (MT) technique. This technique has been shown to be repeatable, and is an objective way to obtain heterophoria values. Because data were collected by the same examiner, this test was utilized as an unbiased way to collect phoria data. Cover test, another common way to measure
phoria, has been shown to be more variable and subjective. Several methods exist to measure phoria. In order to obtain more accurate phoria measurements, future studies could employ more than one phoria measurement method and determine a mean value. As well, other studies could use multiple examiners to perform cover test and use a mean inter-examiner value in order to decrease errors due to subjectivity.

CLIDE is an aggressively studied disease. The lack of obvious clinical signs in many symptomatic patients has encouraged much research into why symptoms occur and what treatments and interventions can alleviate them. This study was the first to investigate a relationship between symptomatic CLIDE and binocular vision disorders. Observations from this sample suggest patients who are significantly symptomatic for dry eye also frequently have binocular vision symptoms and signs. In addition, those with no or few dry eye signs had a high prevalence of symptomatic CI with significant clinical signs.

A future study with a larger sample size is needed to confirm this relationship. Still, these findings are sufficiently compelling to encourage CLIDE researchers to add basic BV testing to their subject evaluation and exclusion criteria. Potential dry eye study subjects should be screened for binocular vision anomalies. Symptoms assumed to be caused by CLIDE may actually be caused by a BV disorder. Because the symptomology is similar between the two disorders, a thorough CLIDE study should include basic BV testing (cover test, NPC, etc.) in order to exclude subjects who may be experiencing a binocular vision disorder.
These study findings can be used by clinicians to better address CLIDE-like symptoms. Basic BV testing may reveal a binocular vision disorder that is causing or contributing to symptoms of CLIDE. According to the results of this study, this type of testing would be especially useful for patients with no or few dry eye signs. Without screening assumed CLIDE patients for BV disorders, clinicians risk prescribing a treatment regime that will not alleviate symptoms. Basic BV screening of symptomatic contact lens wearers will aid in eliminating unnecessary dry eye treatment and contact lens discontinuation.

Soft contact lenses cause dry eye-like symptoms that lead to decrease or discontinuation of contact lens wear. CLIDE commonly presents with distinct symptoms and few clinical signs. CLIDE symptoms overlap with symptoms of basic binocular vision disorders. This study found a large proportion of subjects with significant dry eye symptoms also had concurrent binocular vision signs. Subjects with few or no dry eye signs were even more likely to have a binocular vision disorder. These findings indicate the need for basic BV screening when studying dry eye and when treating dry eye symptoms. Future investigations with a larger, more diverse sample size will aid in further describing the relationship between clinically insignificant, symptomatic CLIDE and binocular vision disorders.
References


Appendix A: The Ocular Surface Disease Index (OSDI)

**Ocular Surface Disease Index® (OSDI®)**

Ask your patient the following 12 questions, and circle the number in the box that best represents each answer. Then, fill in boxes A, B, C, D, and E according to the instructions beside each.

### Have you experienced any of the following during the last week:

<table>
<thead>
<tr>
<th>Question</th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Half of the time</th>
<th>Some of the time</th>
<th>None of the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Eyes that are sensitive to light?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2. Eyes that feel gritty?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3. Painful or sore eyes?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4. Blurred vision?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5. Poor vision?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Subtotal score for answers 1 to 5 *(A)*

### Have problems with your eyes limited you in performing any of the following during the last week:

<table>
<thead>
<tr>
<th>Activity</th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Half of the time</th>
<th>Some of the time</th>
<th>None of the time</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Reading?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>7. Driving at night?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>8. Working with a computer or bank machine (ATM)?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>9. Watching TV?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Subtotal score for answers 6 to 9 *(B)*

### Have your eyes felt uncomfortable in any of the following situations during the last week:

<table>
<thead>
<tr>
<th>Situation</th>
<th>All of the time</th>
<th>Most of the time</th>
<th>Half of the time</th>
<th>Some of the time</th>
<th>None of the time</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Windy conditions?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>11. Places or areas with low humidity (very dry)?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>12. Areas that are air conditioned?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Subtotal score for answers 10 to 12 *(C)*

**Add subtotals A, B, and C to obtain D** *(D)*

**Total number of questions answered (do not include questions answered N/A)** *(E)*

Please turn over the questionnaire to calculate the patient’s final OSDI® score.
## Appendix B: Contact Lens Dry Eye Questionnaire-8 (CLDEQ-8)

**CONTACT LENS QUESTIONNAIRE-8 (CLDEQ-8)**

1. **Questions about EYE DISCOMFORT:**
   a. During a typical day in the past 2 weeks, how often did your eyes feel discomfort while wearing your contact lenses?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Frequently</td>
<td>Constantly</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

When your eyes felt discomfort with your contact lenses, how intense was this feeling of discomfort…

b. At the end of your wearing time?

<table>
<thead>
<tr>
<th></th>
<th>Never have it</th>
<th>Not at All Intense</th>
<th>Very Intense</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Questions about EYE DRYNESS:**
   a. During a typical day in the past 2 weeks, how often did your eyes feel dry?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Frequently</td>
<td>Constantly</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

When your eyes felt dry, how intense was this feeling of dryness…

b. At the end of your wearing time?

<table>
<thead>
<tr>
<th></th>
<th>Never have it</th>
<th>Not at All Intense</th>
<th>Very Intense</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Questions about CHANGEABLE, BLURRY VISION:**
   a. During a typical day in the past 2 weeks, how often did your vision change between clear and blurry or foggy while wearing your contact lenses?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Frequently</td>
<td>Constantly</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

When your vision was blurry, how noticeable was the changeable, blurry, or foggy vision …

b. At the end of your wearing time?

<table>
<thead>
<tr>
<th></th>
<th>Never have it</th>
<th>Not at All Intense</th>
<th>Very Intense</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **Question about CLOSING YOUR EYES:**
   During a typical day in the past 2 weeks, how often did your eyes bother you so much that you wanted to close them?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Frequently</td>
<td>Constantly</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

5. **Question about REMOVING YOUR LENSES:**
   How often during the past 2 weeks, did your eyes bother you so much while wearing your contact lenses that you felt as if you needed to stop whatever you were doing and take out your contact lenses?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>Less than once a week</td>
<td>Weekly</td>
<td>Several times a week</td>
<td>Daily</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

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## Appendix C: Convergence Insufficiency Symptom Survey (CISS)

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>(not very often) Infrequently</th>
<th>Sometimes</th>
<th>Fairly often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do your eyes feel tired when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do your eyes feel uncomfortable when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Do you have headaches when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Do you feel sleepy when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Do you lose concentration when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Do you have trouble remembering what you have read?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Do you have double vision when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Do you feel like you read slowly?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Do your eyes ever hurt when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Do your eyes ever feel sore when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Do you feel a “pulling” feeling around your eyes when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Do you notice the words blurring or coming in and out of focus when reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Do you lose your place while reading or doing close work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Do you have to re-read the same line of words when reading?</td>
<td>x 0</td>
<td>x 1</td>
<td>x 2</td>
<td>x 3</td>
<td>x 4</td>
</tr>
</tbody>
</table>

Total Score: ___
Appendix D: Oxford Grading Scheme

<table>
<thead>
<tr>
<th>PANEL</th>
<th>GRADE</th>
<th>CRITERIA</th>
<th>DOT COUNT</th>
<th>LOG</th>
<th>VERBAL DESCRIPTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>Equal to or less than panel A</td>
<td>1</td>
<td>0</td>
<td>Absent</td>
</tr>
<tr>
<td>B</td>
<td>I</td>
<td>Equal to or less than panel B, greater than A</td>
<td>10</td>
<td>1.0</td>
<td>Minimal</td>
</tr>
<tr>
<td>C</td>
<td>II</td>
<td>Equal to or less than panel C, greater than B</td>
<td>32</td>
<td>1.5</td>
<td>Mild</td>
</tr>
<tr>
<td>D</td>
<td>III</td>
<td>Equal to or less than panel D, greater than C</td>
<td>100</td>
<td>2.0</td>
<td>Moderate</td>
</tr>
<tr>
<td>E</td>
<td>IV</td>
<td>Equal to or less than panel E, greater than D</td>
<td>316</td>
<td>2.5</td>
<td>Marked</td>
</tr>
<tr>
<td>&gt;E</td>
<td>V</td>
<td>Greater than panel E</td>
<td>&gt;316</td>
<td>&gt;2.5</td>
<td>Severe</td>
</tr>
</tbody>
</table>