OPTOMETRIC CLINICAL PRACTICE GUIDELINE

Care of the

Contact Lens

Patient

American Optometric Association®

OPTOMETRY: THE PRIMARY EYE CARE PROFESSION

Doctors of optometry are independent primary health care providers who examine, diagnose, treat, and manage diseases and disorders of the visual system, the eye, and associated structures as well as diagnose related systemic conditions.

Optometrists provide more than two-thirds of the primary eye care services in the United States. They are more widely distributed geographically than other eye care providers and are readily accessible for the delivery of eye and vision care services. There are approximately 35,000 full-time equivalent doctors of optometry currently in practice in the United States. Optometrists practice in more than 6,500 communities across the United States, serving as the sole primary eye care provider in more than 3,500 communities.

The mission of the profession of optometry is to fulfill the vision and eye care needs of the public through clinical care, research, and education, all of which enhance the quality of life.

Healthy People 2010 Vision®

American Optometric Association

OPTOMETRIC CLINICAL PRACTICE GUIDELINE
CARE OF THE CONTACT LENS PATIENT
2nd Edition

Reference Guide for Clinicians

First Edition Originally Prepared and Second Edition Reviewed by the American Optometric Association Consensus Panel on Care of the Contact Lens Patient:

Barry A. Weissman, O.D., Ph.D., Principal Author
Joseph T. Barr, O.D.
Michael G. Harris, O.D., J.D.
Rodger T. Kame, O.D. (1st Edition only)
Timothy T. McMahon, O.D.
Majorie Rah, O.D., Ph.D. (2nd Edition only)
Glenda B. Secor, O.D.
Jeffrey Sonsino, O.D. (2nd Edition only)

Reviewed by the AOA Clinical Guidelines Coordinating Committee:

David A. Heath, O.D., Ed.M., Chair (2nd Edition)
John F. Amos, O.D., M.S. (1st and 2nd Edition)
Thomas L. Lewis, O.D., Ph.D. (1st Edition)
Stephen C. Miller, O.D. (1st and 2nd Edition)

Approved by the AOA Board of Trustees: April 26, 2000, (1st Edition), and June 21, 2006, (2nd Edition)

243 N. Lindbergh Blvd., St. Louis, MO 63141-7881

Printed in U.S.A.

NOTE: Clinicians should not rely on the Clinical Guideline alone for patient care and management, since evidence-based clinical care, consensus recommendations, and technologic innovations will continue to evolve. Referral to the listed references and other sources should be made for a more detailed analysis and discussion of research and patient care information. The information in the Guideline is current as of the date of publication. It will be reviewed periodically and revised as needed.

TABLE OF CONTENTS

INTRODUCTION

Optometrists, through their clinical education, training, experience, and broad geographic distribution, have the means to provide effective primary eye and vision care services, including contact lens prescription and fitting, vision rehabilitation, and disease management, to children and adults in the United States.

This Optometric Clinical Practice Guideline for Care of the Contact Lens Patient describes appropriate examination and treatment procedures for the evaluation and treatment of patients wearing contact lenses (CLs). It contains recommendations for timely diagnosis, management, and, when needed, referral for consultation with or treatment by another health care provider. This Guideline will assist optometrists in achieving the following goals:

- Identify patients who might benefit from contact lens wear
- Evaluate patients who wear, or who desire to wear, contact lenses
- Maintain and improve the care of patients wearing contact lenses
- Manage complications encountered during contact lens wear
- Inform and educate other health care practitioners as well as the lay public about contact lens care
- Assist in the professional care of patients wearing contact lenses.

I. STATEMENT OF THE PROBLEM

A. History and Epidemiology of the Use of Contact Lenses

The most common reason patients seek ophthalmic care is to optimize visual acuity. Estimates suggest that about 50 percent of the U.S. population utilize some form of refractive correction,[1] and the natural history of presbyopia indicates that virtually everyone who lives long enough will benefit from optical correction.

Contact lenses have been used, primarily to neutralize refractive errors, for more than 100 years, but they have achieved reasonable clinical success only in the last several decades. The original CLs were almost exclusively of large scleral or haptic design, and all were made from glass. Feinbloom made a scleral CL with glass optics and a plastic carrier in the late 1930s, but the first practical plastic (polymethylmethacrylate or PMMA) corneal CL was developed by Tuohy in the late 1940s. Hydrogel CLs were invented by Wichterle in Czechoslovakia in the late 1950s. In the 1970s, after recognition of the role of corneal oxygenation in achieving physiological tolerance, both hydrogel and rigid gas permeable CLs gained widespread acceptance and replaced PMMA CLs. Soft silicone hydrogel lenses became available in the late 1990s. These advances and other improvements in both materials and designs have resulted in CLs that are applicable for most forms of refractive correction and are safe and effective for most patients.[2]

Of the approximately 36 million Americans—perhaps 75 million people worldwide—who use CLs, the vast majority (about 87 percent) wear hydrogel CLs. Consumers incur the costs of CLs and associated professional care in addition to other eye care costs (e.g., comprehensive eye examinations, spectacles, sunglasses). The solutions used to care for the eyes and lenses represent additional cost.[3]

B. General Considerations

The majority of complications encountered with daily wear CLs are manageable by discontinuing their use. Inconvenience, minor physiological and allergy problems, and interruptions in wear are common. More severe (i.e., vision-threatening) complications are less common; they include corneal microbial keratitis (MK)[4] and extreme forms of corneal neovascularization (NV),[5] which can lead to opacification of the cornea in the area of the visual axis. The incidence of MK is about 1 in 2,500 wearers per year with daily wear.[6-8] Extending CL wear through one or more sleep cycles appears to increase both the prevalence and severity of all complications[9,10] and increases the incidence of MK to about 20 in 10,000 wearers per year.

An increase in complications is especially likely for patients wearing CLs made of materials having low, medium, and even what was formerly considered high oxygen permeability (less than approximately 35 Fatt Dk units). Identified by terms from the engineering literature, oxygen permeability (Dk, from D for diffusion and k for solubility) is a function of the CL material, while oxygen transmissibility (Dk/t; formerly Dk/L) is a characteristic of a lens of a certain thickness (t). The units of oxygen permeability (Dk) and transmissibility (Dk/t) have been simplified by the American National Standards Institute (ANSI). For oxygen permeability, one (1) Fatt Dk unit is 1×10^{-11} (cm^2/sec) (ml O_2)/(ml mmHg); for oxygen transmissibility, one (1) Fatt Dk/t unit is 1×10^{-9} (cm/sec) (ml O_2)/(ml mmHg).[11]

Silicone-hydrogel and some gas permeable (GP) materials fall into the "super-Dk" and "hyper-Dk" categories (Dk values greater than 60 units).[12] Hypoxic complications of these new polymers, if any, are probably minimal, at least with daily wear.

[redacted]

[redacted]

II. CARE PROCESS

A. Pre-Fitting Considerations

Many factors help determine whether a patient is a good candidate for CLs. Primary among these is motivation to be a successful CL wearer. There is no individual test or battery of tests that can predict success in wearing CLs.

1. Indications

Some factors that suggest whether a patient is a good candidate for CL wear include optical, physiologic, and cosmetic considerations. Indications that should be considered in the evaluation of a patient's potential for successful CL use are shown in Table 1.

a. Optical Factors

Contact lenses improve visual function by neutralizing ametropia, or minimizing distortion, especially when the patient suffers from more than a modest spherical refractive error or astigmatism, whether regular or irregular. Myopic patients benefit from the increased magnification provided by CLs, compared with their spectacle corrections. The reverse is true for both hyperopic and aphakic patients; however, such patients benefit from enhanced fields of vision with CLs.[13] For anisometropic patients, CL wear can reduce or eliminate aniseikonia and prismatic effects.

b. Presbyopia

Although many patients with presbyopia wear CLs, presbyopia is not specifically an indication for CL correction. Presbyopic patients may wear distance CLs and use additional reading spectacles of various types to address their presbyopia. Alternatively, patients with presbyopia (especially those with emerging presbyopia) often successfully use "monovision" correction, in which one eye wears a CL to correct for

distance vision and the other wears a CL to correct for near vision. Various bifocal CLs are available in either GP or hydrogel materials.

c. Therapeutic Potential

Contact lenses have been used to manage both aphakia and binocular vision problems, especially accommodative esotropia and convergence excess.[14,15] Contact lenses, particularly rigid CLs, can optically smooth an anterior corneal surface made irregular by disease (e.g., keratoconus or corneal microbial infection), trauma, or surgery (e.g., penetrating keratoplasty or ineffective refractive surgery). Hydrogel lenses are used as ophthalmic bandages[16] following corneal trauma or refractive corneal surgery. Rigid CLs also have been used to manage[17] or reduce[18,19] myopia. Both clear and tinted rigid and soft CLs have also been used for treatment by occlusion in cases of diplopia or amblyopia.[20]

d. Cosmetic Effect

Correcting ametropia by placing a lens directly on the corneal surface improves cosmesis by eliminating the need for spectacles. Some patients elect to wear colored CLs simply to change the appearance of their eyes. Opaque CLs also may be used for their prosthetic effect (e.g., masking an unattractive corneal scar or damaged iris or providing an artificial pupil in the treatment of aniridia).[21]

Table 1
Indications for Prescribing Contact Lenses

Cosmetic
Refractive error: anisometropia, myopia, hyperopia, regular astigmatism
Prosthetic use
Therapeutic
Myopia management
Reduction (i.e., orthokeratology)
Maintenance
Aphakia
Keratoconus
Corneal irregularity secondary to trauma, disease, surgery
Bandage
Occlusion
Treatment of accommodative esotropia or convergence excess

2. Cautions

Any patient whose clinical situation suggests increased risk for ocular infection or inflammation, but who insists on cosmetic CL fitting, should give formal informed consent before the clinician provides CLs.[22] Several factors could limit a patient's suitability for CL wear, as discussed below (see Table 2).

[redacted]

a. Ocular Considerations

The prescription of contact lenses, especially for cosmetic purposes, should be approached cautiously in treating patients who present with any active anterior segment disease, especially ocular (or adnexal) inflammation, infection, or severe dry eye conditions, because of the possible increased risk for complications, in particular corneal NV or MK. Such diseases include acne rosacea, Sjögren syndrome, atopic dermatitis, corneal exposure, severe blepharitis, conjunctival cicatrizing disorders, neurotrophic keratitis, dacryocystitis, and patent filtering blebs. Therapeutic CLs are occasionally used as bandages in these and other anterior ocular diseases.

Placing a CL directly in the precorneal tear film increases the risk of compromising the tissue. The approach to prescribing CLs for the monocular patient should be cautious, because of risk to the patient's only useful eye. Exercising similar caution when prescribing CLs for patients who are engaged in vocations or avocations involving exposure to a particularly dirty or dry environment, the clinician may advise them to wear non-prescription protective spectacles over their CLs.

An abnormal tear layer, whether insufficient in volume or of poor quality, decreases the likelihood of successful and asymptomatic CL wear, but CLs should be considered within the context of patient motivation and other relevant indications. Some abnormalities of the tear layer can be treated with supplemental artificial tear drops or ointments, mechanical or thermal occlusion of the nasolacrimal punctae, and pharmaceutical agents.[*]

b. Systemic Considerations

Other indications for caution include a patient's inability to manipulate and care for CLs appropriately or to return for appropriate professional supervision. Prescribing CL wear should be approached cautiously with the patient who has an active immunosuppressive condition (e.g., AIDS, cancer treatment, rheumatoid arthritis, diabetes), which may lead to insufficient lacrimation or increased risk for both corneal NV and MK.[23,24]

[redacted]

c. Noncompliant Patients

Clinicians should exercise caution when considering CL fitting for patients known or suspected to be so noncompliant with appropriate CL care and general hygiene that they place themselves at increased risk for severe complications.

Table 2
Reasons for Caution with Contact Lenses

Ocular (local)
Active anterior segment disease, especially infection (e.g., severe blepharitis or dacryocystitis)
Dry eye* possibly associated with Sjögren syndrome secondary to rheumatoid arthritis, lupus, thryroid disease
Acne rosacea
Atopic dermatitis
Active filtering blebs
Decreased corneal sensitivity (e.g., neurotrophic)
Systemic
The presence of only one visually useful eye
Diabetes
Immunosuppression
Inability to care for CLs or to present periodically for professional care

* Mild dry eye is a relative contraindication, which appears to increase the risk of CL failure or intolerance, but severe dry eye increases risk of secondary tissue compromise such as infection or NV.

3. Types of Contact Lenses

The majority of CLs fall into one of two main categories: hydrogel or rigid. These CLs are available in a wide variety of parameters for both spherical and spherocylindrical corrections. There are also several "hybrid" CL designs and materials.

a. Hydrogel Lenses

Spherical hydrogel CLs are indicated for the correction of myopia and hyperopia when astigmatism is limited to less than 1.00 diopter (D)[25,26] and tears are sufficient. Stock optical powers are commonly available between +6.00 D and -20.00 D; custom CLs with higher powers are also available (e.g., for cases of aphakia). Some hydrogel CLs, depending on their power and thickness profiles, may be difficult for some patients to insert and remove.

The U.S. Food and Drug Administration (FDA) has classified all hydrogel materials into four groups[27] that are believed to behave the same chemically (Table 3a). Oxygen permeability (Dk) of traditional hydrogel materials in all groups increases with water content (WC).[28] Another newer class of available hydrogel CL materials**,** "silicon hydrogel," is a blend of silicone (to enhance Dk) with hydrogel materials (for comfort).[29] Silicone hydrogel materials have Dk values far in excess of the Dk achievable with hydrogels. Increasing WC in silicone hydrogels decreases Dk because more oxygen permeable silicone is replaced with less oxygen permeable water (Table 3b). Oxygen transmissibility (Dk/t), which is lens specific for all CLs, is directly dependent on both the Dk of the CL material and the reciprocal of its individual thickness (t) profile.[30-33]

Table 3a
Some Examples of Hydrogel materials, by Water Content

Group 1 **Low Water Content** **Nonionic**	**Group 2** **High Water Content** **Nonionic**	**Group 3** **Low Water Content** **Ionic**	**Group 4** **High Water Content** **Ionic**
Crofilcon	Alphafilcon A	Balafilcon A	Bufilcon A
Dimefilcon A	Altrafilcon	Bufilcon A	Etafilcon A
Genfilcon A	Ofilcon A	Deltafilcon A	Focofilcon A
Hefilcon A & B	Omafilcon A	Droxifilcon A	Methafilcon A, B
Hioxifilcon B	Scafilcon A	Etafilcon A	Ocufilcon B
Iotrafilcon A	Surfilcon A	Ocufilcon A	Ocufilcon C
Isofilcon	Vasurfilcon A	Phemfilcon A	Ocufilcon D
Mafilcon	Xylofilcon A		Ocufilcon E
Polymacon			Perfilcon A
Tefilcon			Phemfilcon A
Tetrafilcon A			Tetrafilcon B
			Vifilcon A

Source:

Source: Food and Drug Administration. Four lens groups. In: Thompson TT. Tyler's Quarterly Soft Contact Lens Parameter Guide. Little Rock, AR: Tyler's Quarterly Inc., 1999; 16:1(index).

Table 3b
Silicone Hydrogel Contact Lens Materials
(in Ascending Order of Dk)

Trade Name	Material	Manufacturer	Water Content (%)	Dk (Fatt Units)
Acuvue Advance	Galyfilcon A	Vistakon	40	60
Acuvue Oasys	Senofilcon A	Vistakon	38	86
Purevision	Balafilcon A	Bausch & Lomb	36	99
O_2Optix	Lotrifilcon B	CibaVision	33	140
Focus Night&Day	Lotrifilcon A	CibaVision	24	170

Toric hydrogel lenses[34-36] are indicated for patients who are otherwise good candidates for hydrogel CLs and who wish to use CLs for cosmetic correction of refractive errors that include visually significant astigmatism (usually >0.75 D). Standard designs frequently correct astigmatism up to about 2.50 D; some custom hydrogel CL designs are available to correct up to about 8.00 D of astigmatism. Toric hydrogel lenses are more expensive than the spherical designs, and they may not provide universally stable visual results.[37] (Aspheric hydrogel lenses may mask modest astigmatism as well.)

Patients who have insufficient tears may have variable optical results and comfort levels with any type of hydrogel CL, especially toric lenses. On the other hand, previous severe limbal desiccation at the 3 o'clock and 9 o'clock positions ("3/9" staining) from the use of rigid CLs, with or without subsequent superficial NV, is an indication for fitting both spherical and toric hydrogel CLs in the patient with adequate tears.[38]

b. Rigid Lenses

Rigid corneal CLs usually provide better visual results than hydrogel CLs in eyes that have either regular or irregular astigmatism of the corneal surface. Insufficient tears usually do not affect the optics of rigid CLs, but this condition does increase the likelihood of both intolerance and some physiological complications. Rigid CL materials (Table 4) are available in a wide range of optical power, oxygen permeability,[39] modulus (plastic hardness), wettability, and specific gravity, all of which affect lens design and positioning.[40] Usually, the more oxygen permeable the plastic, the more fragile the finished CL. PMMA CLs may still be useful on rare occasions, but the clinician must recognize, when prescribing CLs made of this material, that it has virtually no oxygen permeability, and that corneal metabolism will be completely dependent on tear exchange. Concern about hypoxia in patients with corneal grafts or previous superficial pannus, possibly from the use of hydrogel CLs of optical powers in excess of -10.00 D,[41] is an indication for the use of higher Dk GP CLs. Clinicians should note that the use of rigid CLs might be less successful in dusty environments.

Scleral or haptic high-Dk GP (or even PMMA) CLs can be used in the management of keratoconus or in other therapeutic cases, such as ocular cicatricial pemphigoid or Stevens-Johnson Syndrome.

Table 4
Some Examples of GP Material Properties

Material	Optical Index	Specific Gravity	Oxygen Dk (Fatt Units)
Advent	1.39	1.60	78
Airlens	1.54	0.99	20
Boston ES	1.443	1.22	18
Boston EO	1.43	1.23	58
Boston XO	1.42	1.27	100
Boston II	1.47	1.13	20
CAB	1.48	1.20	8
Equalens	1.44	1.19	48
Fluoroperm 30	1.46	1.12	28
Fluoroperm 151	1.442	1.10	151
Fluorex 300	1.465	1.113	30
Fluorex 500	1.460	1.105	50
Fluorex 700	1.457	1.097	70
Menicon Z	1.437	1.20	163
Optimum Classic	1.45	1.19	26
Optimum Comfort	1.44	1.18	65
Optimum Extra	1.43	1.16	100
Optimum Extreme	1.43	1.16	125
Paragon HDS	1.449	1.16	58
Paragon 100	1.442	1.10	100
Polycon II	1.49	1.14	12
SGP II	1.47	1.10	40

Data compiled from various sources.
CAB = cellulose acetate butyrate

c. Hybrid and Silicone Lenses

Among several CL materials or designs that combine aspects of both rigid and flexible lenses are piggyback systems in which the patient wears a GP CL over a hydrogel or silicone hydrogel CL,[42,43] non-hydrogel flexible materials (e.g., Silsoft™),[44] and hard/soft combinations (e.g., Softperm™ and Synergeyes™).[45] Though not in common use, such lenses may be extremely helpful in rare cases of regular or irregular corneal astigmatism (including keratoconus) or aphakia.

B. Contact Lens Examination and Fitting

The initial procedures in determining a CL prescription include a comprehensive eye examination to arrive at optimum refractive correction and the elimination of concerns about concurrent ocular and systemic disease.* The clinician should obtain a baseline quantification of corneal curvature ("K" values from keratometry or videokeratography/topography measurements, "on K" refers to the value of the flat corneal meridian). The procedures should include careful evaluation of the anterior segment and tear layer and documentation of all pre-fitting abnormalities of the ocular and lid surfaces (e.g., corneal scars and NV, blepharitis or meibomian gland dysfunction, and palpebral conjunctival follicles or papillae) which must be considered and treated when appropriate.

1. Fitting Different Types of Contact Lenses

The clinician's goal is to prescribe a CL from a physiologically adequate material that will have minimal mechanical impact on the corneal surface while providing the required optical correction.

Although not all clinicians always use a diagnostic evaluation of trial lenses prior to ordering the CL, such a process, though somewhat labor- and time-intensive, allows clinicians and patients to gain a better

* Refer to the Optometric Clinical Practice Guideline on Comprehensive Adult Eye and Vision Examination.

perspective of the anticipated performance, including both optical and physical/physiological tolerance, of the CLs ordered. Some clinicians employ topical corneal anesthesia to ease initial GP fitting in the office.[46] Carefully applied, this technique may be useful during the initial fitting or instruction phase of CL care, without giving the patient a false sense of tolerance. To avoid complications of abuse,[47] the clinician should never prescribe or dispense topical anesthetics to a patient.

a. Spherical Hydrogel Lenses

Manufacturers commonly supply spherical hydrogel and silicone hydrogel CLs in single or multiple "base curves" or posterior curvature radii (also called back central optical radius or BCOR) and one or two overall diameters (OADs), both of which are usually measured in millimeters. The appropriate base curve and OAD of a lens is determined by clinical observation of a diagnostic lens on the patient's eye. The recommended parameters from the manufacturer's fitting guide can aid the clinician in the initial selection of a diagnostic lens. Alternatively, most patients can be fitted with a lens having a BCOR about 1 mm flatter than the mean keratometry value and an OAD of about 14.0 mm.[48-51] A steeper or flatter than normal corneal curvature, or a larger or smaller than normal horizontal visible iris diameter (HVID), should alert the clinician to observe more carefully the *in situ* mechanics of a diagnostic CL to rule out the need for alternative parameters.

Observation should occur after a minimum of 5-15 minutes' wear for "equilibration" of the lens material to the specific patient's ocular environment. The ideal hydrogel CL rides concentric with the limbus and freely glides over the corneal surface, with some displacement by blinking or gentle manipulation of the lid margins. Perfect centration is not necessary as long as full corneal coverage (to avoid corneal desiccation or edge chafing) is achieved.[52] Soft lenses that are too "tight" move poorly, if at all, and may induce conjunctival injection. On the other hand, soft lenses that are too "loose" move excessively, are uncomfortable, and often show an area of wrinkling or "fluting" at their edges.

Regardless of the theoretical BCOR/K relationship, when adequate mechanical fit is not achievable with the lens supplied by one manufacturer, an alternative with different parameters may be considered. Several generic CL parameter guides, all updated periodically, are available to keep the clinician abreast of the options. A change in BCOR usually does not affect the optical power of a thin low-minus hydrogel, provided the back surface still drapes the anterior eye, but such a change might decrease the effective power of a plus-powered hydrogel lens.[53-55]

b. Toric Hydrogel Lenses

Toric hydrogel and silicone hydrogel lenses are available in both stock (limited parameters) and custom prescriptions from many manufacturers. The clinician should first achieve a good physical fit by selection of the appropriate base curve and OAD. The refractive astigmatic axis is stabilized by prism, truncation, superior/inferior thin zones, or a combination of methods.[34-36] The astigmatic axis of the CL cylinder should be prescribed to match as closely as possible the patient's astigmatic axis, after accounting for the estimated rotation of the lens on the eye.[37,56] The optical power of the patient's astigmatism can often be undercorrected without compromise to visual acuity, which may result in less visual disturbance caused by any alignment variability or misrotation.[35]

c. Spherical Rigid Lenses

Gas permeable CLs are available in both custom and stock designs. Clinicians usually use sodium fluorescein dye to establish a GP BCOR that shows alignment with the corneal surface[57] at an OAD that will either position the CL under the upper lid ("lid attachment" fit)[58] or cause it to ride within the palpebral aperture ("interpalpebral" fit). Such positioning is thought to minimize 3/9 corneal staining[38] and lens flexure,[57] while enhancing tolerance and enabling realization of the optical benefits of a large optical zone. (Clinicians seldom provide non-GP PMMA rigid CLs to new wearers, because of the overwhelming scientific documentation supporting the cornea's physiological requirement for anterior surface oxygenation.[59-63])

When selecting the initial diagnostic GP lens BCOR, the clinician should begin with previously measured corneal curvature values as a guide. With regard to achieving a physically aligned fit in many patients' eyes, the more spherical the K values, the more likely it is that the optimum GP CL BCOR is slightly flatter than the flat K values. The more astigmatic the K values, the more likely it is that the appropriate base curve will be close to the mean K. Alternatively, some clinicians elect to achieve a slight apical vault by selection of BCOR/OAD, especially when fitting keratoconic eyes.[64] Changes in the BCOR of GP CLs directly affect the optical power of the CL/eye system and require direct optical power compensation.

In general, the flatter, more myopic, or more astigmatic the cornea, the larger the OAD required to achieve an optimum CL/cornea relationship, and vice-versa. An OAD of approximately 9.0-9.4 mm is a good starting point for most modern GP CL designs, but clinicians effectively prescribe GPs with OADs ranging from less than 8.0 mm to more than 11.0 mm. An optic zone that approximates the same value as the BCOR (about 1.2 mm smaller than the OAD) is common.

Gas permeable CLs that ride low on the patient's cornea and move minimally should be avoided. Adequate GP CL position and movement encourage the exchange of tears, which pumps fresh oxygen from the air under the lens and washes out debris and metabolic waste. Appropriate position and adequate movement of the GP CL also minimize lens binding, in which adherence to the underlying corneal surface leaves a physical impression of the lens edge in the tissue. Lens binding may lead to 3/9 corneal desiccation staining, which in turn can result in hypertrophy, vascularization, dellen formation, or even microbial infection of the peripheral corneal epithelium.[38,65-69]

The posterior peripheral curve system should be designed to lift the edge of the GP CL gently off the corneal surface to provide a reservoir of tears for exchange that maintains CL movement. This prevents chafing due to low edge lift, or drying of the peripheral cornea due to high edge lift.[70] The edge should also be well shaped and smooth.

d. Toric GP Lenses

Toric GP CL designs are also available, but their application often requires considerable experience and fitting expertise. Bitoric RGPs of either spherical or cylindrical power design are extremely useful in optimizing vision and mechanical fit, primarily in cases of significant regular or occasionally irregular corneal astigmatism.[71,72]

Front-surface toric (spherical base curve) GPs are also occasionally prescribed for residual astigmatism but clinically have a more limited role. BCOR/OAD/peripheral curve systems should be chosen for proper mechanical fit. Optics should be prescribed with the astigmatic axis stabilized by the use of prism and/or truncation(s). Occasionally, the prescription of back-surface toric designs may be appropriate. Many manufacturing laboratories offer consultation in fitting more complicated cases such as these.

e. Orthokeratology

Orthokeratology[73] is the application of rigid (usually GP) CLs designed to reshape the corneal surface temporarily to reduce myopic refractions.[17-19] As with toric designs, this application of rigid CLs often requires that the clinician have more than average experience and expertise. Manufacturers' fitting guidelines are available for most designs, and the FDA requires practitioner certification through the CL manufacturer prior to fitting the lenses.

Although many orthokeratology CL designs exist, their basic fitting strategies are similar. The GP lenses used for orthokeratology are typically "reverse geometry" designs (the BCOR is flatter than the secondary curve radius). Simulated keratometry values from the topography data are often used in the initial fitting process. Manual keratometry values can be used for the initial fitting, but the use of manual keratometry in lieu of corneal topography throughout treatment and follow-up is not recommended.

The cornea-to-CL fitting relationship is dependent on the peripheral curve system. During design of the initial lens, determination of the

peripheral curves can involve empirical use of refraction and curvature data or a diagnostic fitting. The initial selection of a diagnostic lens is typically guided by the recommended parameters from the manufacturer's fitting guide. When an adequate fit is obtained, a central bearing area approximately 4 mm in diameter will be visible on fluorescein evaluation. It is critical that this treatment zone be well centered over the pupil. When the lens is not well centered, the clinician adjusts the peripheral curves to improve the lens fit. No changes should be made in the BCOR as a means of improving lens position on the cornea.

As with traditional GP lens designs, adequate movement of the orthokeratology CL is necessary to promote tear exchange and minimize binding. This is especially important with orthokeratology, because these CLs are worn during sleep and therefore are more likely to result in lens binding in the absence of adequate tear exchange.. Likewise, the peripheral curve system should allow adequate edge clearance, while maintaining a well-centered position on the cornea.

In most orthokeratology CL designs, OAD is usually 90% of the horizontal visible iris diameter (10.0 -11.0 mm). The lens power, which depends upon the BCOR adjustment to allow for regression, typically ranges from +0.50 D to +1.00 D. Lens materials with high oxygen permeability (Dk) are recommended (see Table 4) because orthokeratology lenses are typically worn during sleep and removed upon awakening.

2. Determination of Optical Power

Consideration of over-refraction of diagnostic or initial GP or hydrogel CLs *in situ,* and of binocular vision requirements, enables the clinician to optimize CL optical power. Vertex distance must be considered if the over-refraction suggests the need for change greater than +/-4.00 D. Caution should be exercised in prescribing CLs for prepresbyopic myopic patients, because the change in vertex distance results in a need for increased accommodation and convergence for near vision, and that often results in blurred vision or ocular discomfort. The opposite effect

(i.e., decreased need for accommodation and convergence) may be anticipated in fitting prepresbyopic hyperopic patients with CLs.[13] Another way to calculate contact lens power without an over-refraction takes into account both the vertex distance of the manifest refraction and potential lacrimal lens power.

3. Special Design Features

Additional design features that may be required to optimize CL fit include lenticular edge modification, prism and truncation, fenestrations, and blending.

a. Lenticular Edge Modification

When GP CL optical power exceeds approximately +1.00 or -6.00 D, lenticular design of the anterior CL surface may improve edge profile and decrease lens thickness and weight, thereby improving lens tolerance and centration.[74] Occasionally, patients requiring very low plus or low minus power GP lenses will also benefit from a lenticular design (or construction). Manufacturers routinely provide lenticular-construction hydrogel CLs because of their large total diameters.

b. Prism and Truncation

Very rarely used to address problems of binocular vision (e.g., vertical phoria), prism is prescribed in CLs primarily for lens orientation.. Only vertical, base-down prism can be used in CLs. Base-down prism helps orient some bifocal and front-surface toric CL designs, both GP and hydrogel. Prism also can be used successfully to assist in lens positioning.[75,76]

A truncation is a zone of the circumference of a previously circular CL that has been flattened by removal of material. Similar to the effect of prism in decreasing CL rotation, truncation is most often helpful with the application of bifocal or front-surface toric CLs.

c. Fenestrations

Small holes drilled through a CL are called fenestrations. Almost exclusively used in rigid CLs (PMMA and GP), fenestrations' purpose is to improve oxygenation, either directly or by encouraging tear exchange.[77]

d. Blending

Smoothing or blending the junctions between curvatures on the posterior surface of the CL may reduce corneal chafing or trauma and enhance comfort. Blending is most often performed on GP lenses.

4. Special Concerns

Some issues deserve additional discussion, especially the use of CLs in presbyopia correction, in patients who report symptoms of dry eye, and in extended or continuous CL wear.

a. Presbyopia

Bifocal CLs for presbyopia are optically complex. Successful use is subject to many patient-specific factors and the doctor's experience, skill, and willingness to persist through fitting challenges.

Two design philosophies guide distance and near correction with bifocal CLs. “Simultaneous vision” bifocal (or multifocal) CLs typically require consistent optimal positioning over the patient’s pupils. In contrast, “alternating vision” lenses are intended to optimize distance vision while the patient’s eyes are in the primary position, then reliably “translate” or move on the corneal surface so that a large portion of the near-vision optical zone covers the pupil in downgaze.

Another successful form of CL correction for presbyopia is "monovision," in which one eye is optimally corrected for distance acuity and the other is corrected for near vision.[78-82] Use of the monovision technique has some limitations. It is most effective in cases of emerging presbyopia (usually additions of +1.75 D or less) in which patients

demonstrate adequate distance visual acuities in both eyes. There are many ways to decide which eye to correct in which manner. The most common is to select the dominant eye for distance correction, and if difficulties arise, to reverse the distance/near CL fit.

Modified monovision involves fitting one eye with a single-vision "distance" correction and the other ("near" eye) with a bifocal CL, to achieve acceptable near (reading) vision while providing some intermediate vision (and maintaining distance vision at about the 20/40 level). Modified monovision may prove to be a good alternative for some patients, particularly when they require more than a +1.75 D addition for adequate near vision.[79]

Although monovision has very little effect on binocular fusion and visual fields, it can cause subjective visual difficulties. Specifically, it can decrease both stereopsis and contrast sensitivity, the latter, in particular, with higher-power additions.[80] Overspectacles are often prescribed to optimize binocular vision for critical tasks, such as operating machinery or driving a motor vehicle.[81] Some practitioners believe that patients should give formal informed consent for the prescription of monovision CLs, indicating their full awareness of the risks, benefits, and visual limitations of this form of correction.[82]

b. Dry Eye

Depending on individual tolerance and the severity of the condition, many patients with mild dry eyes may tolerate CLs.[83] Both systemic and ocular aspects of the dry eye condition should be managed prior to and during CL wear. Two treatments that are often helpful are instruction in lid hygiene and the prescription of artificial tear drops, particularly unpreserved unit doses. There is some evidence that CL wear can cause or aggravate dry eye,[84-86] which increases the importance of close professional follow-up care in such patients.

The choice of CL material may also be important, although there is no accepted standard approach in dry eye patients. Some clinicians believe that patients often tolerate GP CLs better than hydrogel lenses over the

long term. This tolerance is primarily attributable to GP CLs' better maintenance of optics and fit, compared with that of hydrogel lenses, especially toric hydrogel lenses, which can undergo physical changes with dehydration. Some clinicians believe that thick (perhaps prism-ballasted) hydrogel CLs are associated with fewer dry eye signs and symptoms (secondary to decreased dehydration). Moreover, several of the silicone hydrogels appear to decrease dry eye signs and symptoms.[87]

Mechanical or thermal occlusion of the nasolacrimal punctae may provide significant improvement for many patients suffering from clinically significant mild to moderate dry eye.[88]

Low-grade subclinical inflammation is believed to contribute to some forms of dry eye. Recent research has suggested a role for immunomodulating pharmaceuticals in the treatment of at least some forms of dry eye, with or without concomitant CL care. Cautious use of cyclosporine A drops, and perhaps topical steroids, may be helpful in managing particular cases.[89,90]

c. Extended Wear

Overnight use of CLs has been in practice for many years. Both the prevalence and severity of all complications, especially microbial infection,[6-10] increase when CL wear is extended through one or more sleep cycles. FDA guidelines limit extended wear of approved hydrogel CLs to no more than 6 nights in succession,[91] but some silicone hydrogels, and high-Dk GPs, have gained FDA approval for up to 1 month of continuous wear.[92] The most recent study suggests, however, that even silicone hydrogel soft CLs with very high oxygen permeability, when used for extended wear, maintain the risk for subsequent corneal infection associated with previous CL designs used for this type of wear.[93]

Because of the increased risk for complications in patients who elect to sleep wearing their CLs, clinicians should fully educate them and obtain their signed informed consent to document their understanding of the potential risks. More stringent professional monitoring and follow-up care are also indicated for such patients.

C. Dispensing Lenses and Patient Education

Contact lenses should be free from defects (e.g., scratches, chips, or tears). Prior to initial dispensing of CLs, the clinician should verify that all parameters of the lenses are as ordered and that they meet established (e.g., ANSI) standards. The clinician or staff should also confirm the performance of the CLs on the patient's eyes, optically, mechanically, and physiologically. Therefore, a CL prescription is never complete until the clinician observes the CL on the patient's eye after adaptation.

The patient, or a parent or guardian, should be trained in lens care, maintenance, and handling. Clinicians should stress the importance of proper hygiene, compliance with CL care techniques, and appropriate follow-up care under professional supervision. Patient information booklets containing warnings, precautions, and directions for use of CLs are available on request from many CL manufacturers. Package inserts or professional fitting guides provide information directed to the eye care practitioner. Other available literature on the proper care of CLs is extensive.

Clinicians should teach patients to perform the following steps in the care and handling of a CL:

- Wash hands.
- Clean each CL with an appropriate solution, according to the manufacturer's recommended instructions. Rubbing and rinsing the surface of the CL may enhance cleaning even for "no rub" solutions.
- Store and disinfect CLs in fresh appropriate solution for an appropriate time interval in a clean case until reinsertion in the eyes.
- Reclean and resoak CLs periodically. If for any reason CL wear has been interrupted, repeat these procedures before reinserting CLs.

Discussion of these procedures and warnings should be provided in writing and documented in the patient's record. Professional follow-up care should be scheduled.

D. Progress Evaluations

Follow-up visits are important for proper management of the patient with CLs. Planned evaluation should occur during the initial weeks and months of CL wear, to allow any necessary mechanical or optical refinements in lens prescription(s), to monitor adaptation and minimize ocular complications, and to reinforce appropriate CL care. Subsequent evaluations are usually indicated at 6- to 12-month intervals for healthy patients wearing cosmetic CLs.[94,95]

More frequent visits are advised for patients who may be at additional risk for ocular compromise during CL wear. Such patients include those using CLs for one or more sleep cycles, those wearing CLs for treatment of eye disease (e.g., keratoconus) or following corneal trauma or surgery, and children wearing CLs to prevent or treat myopia[17] or to correct aphakia.[96]

The initial follow-up schedule is more rigorous for patients undergoing orthokeratology treatment, who most often wear CLs during sleep and remove them in the morning upon awakening. These patients need to be evaluated following the initial dispensing visit, on the first morning after lens wear. This visit allows the practitioner to evaluate the changes in corneal topography, to make certain the treatment zone is well centered, and to monitor visual acuity and corneal physiology. Followup visits are suggested after 1 week and 1 month of lens wear. Additional visits may be needed to refine the treatment or lens fit. Once full treatment has been achieved and both vision and corneal topography are stable, follow-up visits are recommended at 6-month intervals.[73]

The clinician should recommend additional visits whenever the CL patient experiences an unexpected problem in vision or ocular condition. Emergency services should always be available through the eye care practitioner's office or through emergency room facilities.

In conducting each progress evaluation, planned or unplanned, the clinician should follow the "SOAP" format:

1. Obtain a **S**ubjective history of both CL wear and other concerns.
2. Evaluate **O**bjective clinical findings, such as visual acuity and over refraction results. The evaluation should include appropriate confrontation tests and gross observation of the eyes and adnexa, followed by biomicroscopic evaluation of the lenses on the eyes and of the patient's anterior ocular segments, with the assistance of diagnostic dyes if needed. The clinician should periodically evaluate the corneal surface by keratometry or videokeratography/topography. Additional examinations and investigations may also be indicated. In cases of reduced vision that cannot be attributed to lens power or CL optical quality, ocular media and retinal assessments are indicated.
3. **A**ssess the situation.
4. **P**lan appropriate management steps. The clinician should monitor refraction and general ophthalmic health on a routine schedule appropriate for the patient.

Progress evaluations of GP wearers should include periodic verification of the prescribed parameters of the CLs and reconditioning (polishing) of the lenses to reduce both soilage and scratches, as well as lens replacement when necessary. When CLs have been damaged by cracks or edge chips, or changed during use (e.g., any substantial flattening/steepening of BCORs[97]), CL replacement is advised. Although it is often difficult to verify the parameters of hydrogel and hybrid CLs, they also can be inspected frequently for damage.

E. Management of Complications Associated with Contact Lens Wear

Fortunately, CL wearers rarely experience vision-threatening complications directly associated with wearing CLs. Because full discussion of the complications that have been associated with wearing CLs is beyond the scope of this Guideline, clinicians should consult standard textbooks and the research literature for more in-depth information.[98]

The first step in proper management of the CL wearer who experiences complications is correct diagnosis. The second step is clinical grading of

the severity of an observed complication or response to CL use (Table 5).[99] After accurate diagnosis and grading, the clinician can provide appropriate management and clinical supervision.

Table 5
Clinical Grading of Response to CL Wear:
Proposed Interpretation and Clinical Approach

Grade*	Interpretation	Clinical Approach Advised
0	Normal: no tissue changes observed	No action required; routine clinical progress evaluation suggested.
1 (minimal)	Trace: minimal if any tissue changes	Minimal, if any, change in CL wear/care suggested; observation encouraged.
2 (mild)	Definite tissue changes observed	Initiate clinical measures to address complication; observe clinical response.
3 (moderate)	Modest tissue changes observed; ocular damage possible	Decrease or discontinue CL wear and treat complication; restart CL wear with appropriate changes in wear/care when complication successfully reversed. Provide professional supervision.
4 (severe)	Ocular damage probable	Discontinue CL wear and treat complication appropriately; consider risk/benefit ratio of restarting CL wear in the future.

Based on:
Efron N. Grading scales for contact lens complications. Ophthal Physiol Opt 1998; 18:182-6.
Note: this is an ordinal and not integer scale.
* Ordinal scaling implies that a Grade 3 response is greater than a Grade 2; however, the interval between Grades 1 and 2 may not be the same as the interval between Grades 2 and 3.

1. General Considerations

The most effective way to address the complications of CL wear is to prevent them from occurring. One method of precluding many complications is to maintain CL care and hygiene, consistent with both common sense and FDA-approved manufacturers' guidelines. However, achieving and maintaining total patient compliance with recommended CL care is often difficult.[100-103]

Contact lens soilage or solution reactions, and their secondary complications, can be reduced by the use of "disposable" CLs.[104] Their manufacture through molding technology that maintains high-quality design standards has reduced the cost of these hydrogel lenses to the extent that daily replacement of lenses has become a practical option for some patients. Prescribing disposable CLs has the advantage of maximizing patient convenience while minimizing the possibility of solution reactions and certain other CL complications. Gas permeable CLs can usually be reconditioned by polishing and cleaning, but they sometimes become so warped, scratched, or soiled that they should be replaced.

Most complications of CL wear increase in both prevalence and severity when patients wear the CLs on an extended or continuous basis.[9,10] Restricting CL use to daily wear whenever possible is therefore a means of reducing the occurrence of these complications.

Lid diseases such as blepharitis, meibomian gland dysfunction, and dry eye accompany, and, in some cases partially cause, many of the complications of CL wear. Treatment of underlying lid disease and dry eye—by improving lid hygiene,[105] the use of artificial tear drops (often in unpreserved unit doses), punctal occlusion, and appropriate therapeutic management (e.g., antibiotics, immunomodulators, either topically or systemically)—is helpful in minimizing many of the complications of CL wear.

Many complications of wearing CLs can be treated effectively by temporarily discontinuing their use. Reversal of inflammatory lid and conjunctival reactions and solution sensitivities, collapse of mild forms

of corneal NV, and healing of corneal epitheliopathies often occur without additional treatment. The clinician may consider using adjunctive medical therapy consisting of artificial tears and immunomodulators, such as nonsteroidal anti-inflammatory drugs (NSAIDs[106]), antihistamines, mast cell stabilizers, cyclosporine, antibiotics, and steroid drops.

Special precautions should be taken to avoid the spread of infection. These measures should include diagnostic lens cleaning/disinfection and appropriate hygiene during CL-handling procedures. Disinfection procedures must adhere to a method approved by the U.S. Centers for Disease Control and Prevention (CDC).

2. Noninfectious Complications

The most prevalent complications of CL wear are associated with improper and incompatible lens care and solutions, and CL spoilage, particularly in the case of hydrogel lenses (Table 6).[107-111]

Table 6
Noninfectious Complications of Contact Lens Wear*

Tissue	Complication	Comments
Lids	Toxicity	Usually a solution reaction
	Allergy	Usually a solution reaction (type IV Gell-Coombs hypersensitivity)
	GPC	Type I Gell-Coombs hypersensitivity, related to CL deposits/edge.
	Ptosis	Associated with GPC or RGP wear.
	Blepharitis	Lid inflammation, related to bacterial or noninfectious etiology; not CL-caused but can complicate care and lead to dry eye symptoms, soiled CLs, lid and eye infections.
Bulbar conjunctiva	Injection	Usually a solution reaction; toxicity or allergy; possibly CL hypoxia, dry eye.
	Edema	Usually a solution reaction; toxicity or allergy.
	Staining	From lens edge, desiccation.

Table 6 (Continued)

Tissue	Complication	Comments
Corneal epithelium	3/9 stain	Primarily associated with low-riding RGPs; also evaluate edge lift, shape, position, tears, and lids; possibly leads to dellen, NV, VLK-pseudopterygium.
	Pancorneal stain	Medicamentosa, dirty CL, solution toxicity or sensitivity; consider viral infection.
	Superior epithelial arcuate lesion (SEAL)	Always in association with hydrogel CLs; possibly dirty or tight CL (also called epithelial splitting).
	Inferior arcuate stain	Dehydration through hydrogel lens.
	Foreign body track	Foreign body between CL and cornea or under upper lid.
	Cluster overwear stain	Central corneal hypoxia and secondary stain from nonpermeable HCL wear.
	Inferior band stain	Corneal exposure or blepharitis (non-CL wear).
	Abrasion	Deep or coalesced epithelial defect, usually with symptoms (pain, foreign body sensation) but without infiltrate.
	Dimple veil	Saucer-shaped depressions in epithelium from bubbles trapped between CL and cornea.

Table 6 (Continued)

Tissue	Complication	Comments
	Infiltration	First consider infection; also consider solution sensitivity, herpes simplex keratitis (HSK), Thygeson disease, etc.
	Edema	CL hypoxia causing CCC, ECF, microcysts, microcystic edema.
Corneal stroma	Edema	Deep stromal striae, similar to keratoconus; Vogt's striae at ~4-6% swelling; striae keratopathy at Descemet's membrane at ~10% swelling; also consider endothelial cell dysfunction (e.g., Fuchs corneal dystrophy) or glaucoma.
	Neovascularization	Pseudopterygium at 3/9 stain, associated with RGP (NV) wear; pannus (associated with hypoxia from hydrogel wear); possibly deep stromal NV.
	Infiltration	First consider bacterial, amoebic, or fungal infection; rule out solution reaction, HSK, adenoviris, *Chlamydia*, Epstein-Barr virus, Lyme disease, etc.
	Scar	Deformation in endothelial cells associated with acute hypoxia
Corneal endothelium	Blebs	Deformation in endothelial cells associated with acute hypoxia.
	Polymegethism	Change in endothelial cell size or shape associated with chronic hypoxia.

* Always consider masquerade syndromes

Another potential complication of CL wear is hypoxia, which induces changes in all layers of the cornea. These changes include microcysts and microcystic edema (MCE); central circular clouding (CCC); pseudodendritic edematous corneal formations (ECF); decreased epithelial mitosis, sensitivity and adhesion;[112-118] changes in stromal thickness, acidosis, and striae;[60,61,119-122] and endothelial blebs and polymegethism.[123-125] In a postulated corneal exhaustion syndrome (CES), previously successful long-term CL wearers suddenly become unable to tolerate CLs.[126]
Superficial corneal pannus can be associated with either chronic hypoxia[41,127] or chronic 3/9 epithelial desiccation (in the case of rigid CLs).[67,68] Secondary intracorneal hemorrhages can also occur.[128] Deep stromal NV is a very rare complication.[5]

CL wear can lead to distortion and warpage of the corneal surface,[129-133] which results in "spectacle blur" or a reversible loss of good spectacle acuity immediately following CL wear. Clinicians also may observe "dimple veil" epithelial depressions from bubbles of air, or even rolled up balls of mucin,[134] trapped between CLs and the ocular surface.

True epithelial "staining" represents some disruption of the epithelial cell layer, which occasionally progresses to erosions[52,135-138] and even abrasions.[139,140] Potential etiologic factors include chemical trauma (e.g., solution reactions[141]), mechanical trauma (e.g., damaged CLs, foreign bodies trapped between the CL and the eye), or superior epithelial arcuate lesion[136] (SEAL or "epithelial splitting").

Clinicians should consider either keratoconus[140] or Cogan's microcystic map-dot-fingerprint dystrophy in any patient who presents with an abrasion without a clear-cut historical etiology (see Appendix Figure 1).

Corneal infiltrates, both round and dendritic, may be signs of solution sensitivity, true corneal microbial infection, or even unrelated complications.[6-10,142-145] The clinician should always be alert to the possibility of herpetic or *Acanthamoeba* infection, masquerading as a more benign CL complication (see Appendix Figure 2).

Documented lid reactions include allergic responses such as giant papillary conjunctivitis (GPC)[100,146,147] or ptosis.[148-152] The conjunctiva is subject to many types of toxic and allergic reactions, some totally and others partially, due to the use of CLs and CL care solutions.[141-145,153-158] The clinician should always be careful to consider masquerade syndromes (e.g., drug abuse or herpetic disease).[47,144,145]

Often the clinical challenge is to maintain CL wear in the face of five specific types of noninfectious complications: solution reactions, hypoxia, 3/9 staining, corneal abrasion, and giant papillary conjunctivitis.

a. Solution Reactions

The majority of care product and solution problems are cell-mediated (Gell-Coombs type IV) reactions to preservatives.[143-145] The anterior segment signs are often nonspecific. Solution reactions may present with fine corneal staining, with or without infiltrates, conjunctival injection, and/or edema. When the clinician suspects such a reaction, CL wear should be discontinued, and appropriate treatment and professional observation should be initiated. After reversal of the reaction, the clinician may initiate a different care regimen. When such a measure is unsuccessful, the clinician may fit the hydrogel CL wearer with single-use (daily disposable) CLs, to eliminate all solution issues. Gas permeable CL wearers should use preservative-free saline to rinse their lenses copiously prior to insertion. To reduce the risk for *Acanthamoeba* infection, the clinician should instruct patients to avoid the use of tap water or fresh water rinses (see Appendix Figure 3.)

b. Hypoxia

In the mid-1970s, all rigid CLs were made of non-oxygen-permeable PMMA, and early hydrogel lenses all had modest oxygen transmissibility. Hypoxia was a common complication of CL wear.[57-59,112-122] It is now clear that anterior corneal oxygen tension of about 100 mmHg will preclude physiological hypoxia, although various studies have placed this value between about 20 and 125 mmHg.[58,59,159-161]

Most of the GP and hydrogel CLs now available—particularly silicone hydrogel and GP lenses manufactured using materials with oxygen transmissibility of at least 100 Dk units (see Section I.B, General Considerations)—generally do not cause corneal hypoxia under daily wear conditions. Lenses made from these very-high-Dk materials also appear to provide adequate corneal oxygenation when used on an extended wear basis, even though the level of CL oxygen permeability necessary to preclude hypoxia under such conditions has not been established.[92,161] When there is clear evidence of hypoxic corneal changes (e.g., epithelial or stromal edema, corneal pannus[41] greater than approximately 2 mm, unrelated to 3/9 stain), conjunctival changes,[162] or suspected CES,[126] the clinician should adjust the CL wear schedule or change the CL material or design to enhance the availability of oxygen to the anterior corneal surface (see Appendix Figure 4).

c. Three O'clock and Nine O'clock Staining

Perhaps the most common complication of rigid CL wear is 3/9 staining. Even moderate to severe 3/9 staining deserves attention to decrease the potential for this complication to advance to infection, dellen, or pseudopterygium/vascularized limbal keratitis (VLK).[67,68] The principal cause of 3/9 staining is low-riding rigid CLs, resulting in inadequate lid closure and localized corneal desiccation. Therefore, the clinician should make an effort to optimize the position of the CL, by increasing its OAD and/or flattening its BCOR. In cases of substantial corneal astigmatism, bitoric rigid designs may be appropriate. When the CL centers well, the clinician should consider modifying the edge lift associated with the peripheral curve design, the edge thickness, and/or the OAD.[38,163] The clinician should also consider whether CL binding plays a role in development of the corneal epitheliopathy.

The condition of the patient's lids/meibomian glands and tear layers can often contribute to 3/9 staining and should also be addressed.[105] Lens position and wearing time should be managed if necessary. If all attempts to remedy the problem of 3/9 staining are unsuccessful, the clinician may consider prescribing hydrogel CLs, provided there are no contraindications[38] (see Appendix Figure 5).

d. Corneal Abrasion

Corneal epithelial abrasion is a potential complication of all CL wear. The clinician can expect to spend approximately 1 percent of CL-related office visits treating abrasions, more when the practice has numerous keratoconic patients.[140] The clinician should first rule out infection, and the patient should temporarily discontinue CL wear. Some clinicians believe in prophylactic antibiotic treatment, while others prefer to withhold antibiotics unless infection is suspected or proven. To decrease the risk of precipitating or enhancing a microbial corneal infection, the clinician initially should refrain from patching the eye and should withhold topical steroids (see section II.E.3.a., Bacterial Infections).[164] However, topical nonsteroidal anti-inflammatory topical agents may be helpful in moderating pain during the healing process [106,165]

Close professional supervision is prudent until an epithelial defect has closed. The etiology of the abrasion should be considered before the patient resumes CL wear. For example, when the abrasion appears to be due to the patient's inability to insert or remove the CLs properly, reinstruction in these procedures should precede redispensing the CLs. Management of the patient with repeated apical corneal abrasions, in particular the patient with keratoconus, may require refitting of the CLs with steeper BCORs or the use of a piggyback CL system[43,166] (see Appendix Figure 6).

e. Giant Papillary Conjunctivitis

Giant papillary conjunctivitis (GPC) is a Gell-Coombs type I hypersensitivity reaction. In type I reactions, a second-antigen presentation activates conjunctival mast cells that have been presensitized by immunoglobulin E (IgE) generated during a previous encounter. Though never identified, the GPC antigen is understood to be related to biological debris adhering to the surface of a CL or, perhaps, to mechanical conjunctival irritation from the edge of the CL itself.

If possible, the patient diagnosed with GPC should first discontinue CL wear until he or she is asymptomatic and the signs (mucus, inflammatory tarsal conjunctival papillae) subside. The patient may then resume CL

wear, cautiously, with improved CL cleaning (e.g., more frequent, increased use of enzyme cleaner) and/or more frequent CL replacement. The use of peroxide disinfection or single-use CLs is helpful for hydrogel wearers. Often it is also helpful to change the CL design from hydrogel to GP, or vice-versa. In some instances, modification of CL edge design is sufficient to preclude the reoccurrence of GPC. For those patients in whom conservative (non-medical) treatment has not been sufficient, the clinician may prescribe adjunctive topical mast cell-stabilizing agents, NSAIDs, antihistamines, and occasionally steroids (with caution, to minimize the risk of secondary ocular infection, glaucoma, or cataract; see Appendix Figure 7).[167-171]

3. Infectious Complications

Microbial keratitis (MK) has an annual incidence of about 20 per 10,000 people who use CLs for extended wear and about 4 per 10,000 people who use CLs for daily-wear.[6-8] MK is probably the CL-associated complication of most concern to both patients and practitioners.[172] The symptoms of microbial infections of the cornea include ocular pain (frequently of sudden onset), photophobia, "red" eye, and discharge. Observable clinical signs include a corneal epithelial/stromal defect with associated inflammatory response (corneal infiltration). MK is often accompanied by anterior chamber reaction (including hypopyon in some cases), conjunctival discharge, lid swelling, and conjunctival injection.[173-176]

Corneal infection is a sight-threatening disease, but, fortunately, it is infrequent when patients are compliant with good CL care and hygiene. Extended wear of hydrogel CLs increases the risk for MK.[6-8] When MK is suspected or diagnosed in a CL wearer, lesions should be assumed to be infectious in nature and treated accordingly. Whenever any of the signs or symptoms of corneal infection occur, CL wear should be immediately discontinued in both eyes to decrease the potential for bilateral disease.

a. Bacterial Infections

Bacterial corneal infections associated with CL wear are usually attributable to Gram-negative *Pseudomonas aeruginosa*, but also to Gram-positive *Staphylococcus aureus* and *Staphylococcus epidermidis*. Other bacteria are also occasionally cultured from such lesions. Bacterial corneal infection has been primarily associated with extended or continuous wear of rigid or hydrogel CLs, which have limited oxygen transmissibility, through one or more sleep cycles.[4,6-8,173-176]

Poor compliance with CL care procedures also appears to be a major risk factor for microbial infection.[177]

Traditional management of corneal ulcers and severe infections begins with the acquisition of cultures on blood and chocolate agars, on heart and blood infusion (HBI, for fungi), or on thioglycolate medium or Eugenic broth (for anaerobes), with Gram-staining of smears for microscopic evaluation. A sterilized Kimura spatula is used to acquire material for these laboratory investigations by scraping the base and leading edge of the corneal ulcer.[178,179]

Clinicians should recognize that the diagnosis and management of corneal infection continues to evolve. For example, community doctors tend to treat empirically, without initially collecting cultures and smears/staining, whereas such laboratory investigations prior to treatment remain the standard of care at hospitals and university medical centers. In general, the trend is toward treating peripheral and small, suspected corneal infections without laboratory investigation, while central and large corneal lesions are almost universally cultured prior to treatment.[180-183]

Topical fluoroquinolone antibiotics were introduced to ophthalmic care in the early 1990s,[184] replacing several earlier antibiotics. Several studies discussed the clinically successful use of 0.3% commercial-strength topical fluoroquinolone antibiotics (e.g., Ciloxan) as monotherapy for suspected bacterial corneal infections, without cultures, especially when the lesions were relatively small (<2 mm), and neither central nor deep.[184-186] Many clinicians found fluoroquinolone

monotherapy as effective as previous dual therapy with "fortified" aminoglycosides (e.g., gentamicin, tobramycin, amikacin) and cephalosporins (see below), and they believed that initial cultures were unnecessary in many cases. With emerging resistance to the fluoroquinolone antibiotics,[187] some clinicians have discussed a new form of dual therapy, utilizing both fluoroquinolone and cephalosporin agents.[188]

It now appears that small, peripheral, suspected bacterial corneal infections are often treated by a third- or fourth-generation topical fluoroquinolone antibiotic agent as monotherapy. An initial "loading" dose is established, using one drop every 15 minutes for the first hour of treatment. It is followed by one additional drop every 1-2 hours while the patient is awake. Professional supervision should be frequent, often at 24-hour intervals if not more often. Although a loading dose may not be needed for fourth-generation fluoroquinolones, which have excellent penetration characteristics, clinicians often use it.

The treatment of central corneal ulcers is more aggressive. After scraping, obtaining a Gram or Giemsa stain, and culturing the material, aggressive topical treatment should begin with dual therapy consisting of specially fortified topical aminoglycosides (e.g., gentamicin, tobramycin, amikacin) to attack Gram-negative bacteria and cephalosporins (e.g., cefazolin) or vancomycin to destroy Gram-positive bacteria.[178] The clinician may modify the treatment after observation of the patient's clinical course and laboratory identification of likely microorganisms and their antibiotic sensitivities.[178] Adjunctive patching should be avoided.[164]

Early use of topical steroids is usually contraindicated, but some clinicians intervene with steroids early, with the intention of limiting scar formation from stromal infiltration. However, this using this treatment runs the risk of allowing inadequately controlled microbial infections (e.g., *Pseudomonas* sp., herpes, and *Acanthamoeba*) to escape therapy.

Proper treatment of bacterial corneal infection therefore remains an area of much debate and concern. Clinicians are advised to keep abreast of the latest clinical recommendations and research regarding this evolving topic.

b. Acanthamoeba Infections

In any CL-related keratitis, the clinician should always (especially in cases of chronic disease) consider the possibility of infection by the *Acanthamoeba* species, in which cultures are initially negative and the patient fails to respond to antibiotic therapy. Clinical suspicion should increase when the patient reports extreme ocular pain and/or a history of exposing the CLs to non-sterile water, or when an unusual epitheliopathy (reminiscent of herpetic epithelial disease) or peripheral corneal radial neuropathy is observed.[177,189-191] Special culture techniques are available for *Acanthamoeba* infections, but tissue biopsy is often necessary. Confocal microscopy is often helpful in the diagnosis of *Acanthamoeba* MK[192,193] but, unfortunately, very few confocal microscopes are readily available to clinicians in the United States, so cultures and biopsies remain the common diagnostic tests.

Combinations of the following four types of pharmacological agents have been used successfully for medical treatment of *Acanthamoeba* keratitis:[194,195]

- **Antibiotic/aminoglycoside**: paromomycin, neomycin
- **Antifungal**: clotrimazole, ketoconazole, itraconazole, miconozole, fluconazole
- **Antiparasitic/aromatic diamidine**: propamidine isethionate, hydroxystibamidine, hexamidine di-isethionate
- **Biocide/cationic antiseptic**: polyhexamethylene biguanide, chlorhexidine gluconate, povidone-iodine.

Misdiagnosis and medical failures in the treatment of *Acanthamoeba* infections are common.

c. Fungal Infections

Fungal infections of the cornea have been extremely rare among cosmetic CL wearers. Most cases reported in the literature have involved the use of bandage CLs or chronic treatment with topical steroids in patients suffering from concurrent ocular disease (e.g., neurotrophic epithelial defects, diabetes, trauma).[196,197] Fungal infections have been associated with the use of one specific brand of soft CL care solution.

The practitioner's vigilance is necessary, because fungal infections are often confused with easily mistaken for bacterial (including mycobacterial), herpetic, or amoebal infections, and the treatments are very different. Both commercial and custom-made antifungal pharmaceutical agents are available, but medical treatment is often quite difficult and complications may result in the need for corneal transplantation.

d. Viral Infections

Adenoviral and herpes viral corneal infections can occur during CL wear. No causative association has been uncovered for such viral infections. CL wear should be discontinued during viral infections, unless the CL is being used in a treatment protocol. Successful management of adenovirus infection usually includes supportive therapy, such as tear supplements and topical decongestants, or steroid therapy. Effective antiviral agents are available for the treatment of herpetic eye disease. The clinician who observes apparent herpetic keratitis in association with CL use should always consider the possibility of *Acanthamoeba* as the source of the infection.

It is prudent to consider discarding CLs that have been worn during an active viral infection and dispensing new CLs once the infection has resolved.

In summary, microbial keratitis associated with CL wear, while rare, remains an issue of concern,[198,199] and its management is complex. Regardless of culture results, aggressive medical treatment—including subconjunctival injections and/or systemic antibiotic treatment with hospitalization, and perhaps corneal transplantation—may be necessary, especially in cases of indolent, refractory, or non-bacterial corneal infections. The hallmarks of successful treatment and healing include improved patient comfort (decreased pain), reduced inflammatory signs, and closure of epithelial defects. For the patient who has severe or refractory inflammatory or infectious ocular disease, referral to a corneal and external eye disease specialist is prudent.

CONCLUSION

Patients with refractive error seek improved visual acuity to enhance their perception and enjoyment of the world. Alternatives for vision correction include spectacles, contact lenses, orthokeratology, and refractive surgery. Modern CLs are occasionally used to provide therapeutic benefit as well as to correct vision and enhance cosmesis. New and improved materials and designs have made CLs a practical option for the majority of motivated patients. Because these lenses float within the tear layer, in intimate contact with the anterior ocular surface, clinicians should take great care in the prescription and application of CLs, and in the supervision of patients who wear them.

Fortunately, complications that can threaten vision and persist after CL removal, such as severe MK and deep stromal NV, are rare. When accompanied by reasonable prescribed wear schedules, adequate professional supervision, and patient compliance with both the principles of good personal hygiene and the published recommendations of CL and solution manufacturers, the prescription of CLs with adequate Dk/t should result in safe and effective CL wear.

III. REFERENCES

1. Bennett I, Aron F. State of the profession —1993. Optom Econ 1993; 3:8-14.

2. Barr JT. History and development of contact lenses. In: Bennett ES, Weissman BA, eds. Clinical contact lens practice, 2nd ed. Philadelphia: JB Lippincott, 2005:1-10.

3. Barr J. Contact lenses annual report: 2005. Contact Lens Spectrum 2006;21:26-34.

4. Krachmer JH, Purcell JJ. Bacterial corneal ulcers in cosmetic soft contact lens wearers. Arch Ophthalmol 1978; 96:57-61.

5. Rozenman Y, Donnenfeld ED, Cohen EJ, et al. Contact lens-related deep stromal neovascularization. Am J Ophthalmol 1989; 107:27-32.

6. Schein OD, Glynn RJ, Poggio ED, et al. The relative risk of ulcerative keratitis among users of daily wear and extended wear soft contact lenses. New Engl J Med 1989; 321:773-8

7. Poggio ED, Glynn RJ, Schein OD, et al. The incidence of ulcerative keratitis among users of daily wear and extended wear soft contact lenses. New Engl J Med 1989; 321:779-83.

8. Cheng KH, Leung SL, Hoekman HW, et al. Incidence of contact lens associated microbial keratitis and its related morbidity. Lancet 1999; 354(9174):181-5.

9. Keech PM, Ichikawa L, Barlow W. A prospective study of contact lens complications in a managed care setting. Optom Vis Sci 1996; 73:653-8.

10. Levy B, McNamara N, Corzine J, et al. Prospective trial of daily and extended wear disposable contact lenses. Cornea 1997; 16:274-6.

11. ANSI Z80.20-2004: American national standard for ophthalmics—contact lenses. Standard terminology, tolerances, measurements, and physicochemical properties. Merrifield, VA: Optical Laboratories Association, 2004.

12. Benjamin WJ. EOP and Dk/L: the quest for hyper transmissibility. J Am Optom Assoc 1993; 64:196-200.

13. Westheimer G. The visual world of the new contact lens wearer. J Am Optom Assoc 1962; 34:135-8.

14. Robertson DM, Ogle KN, Dyer JA. Influence of contact lenses on accommodation. Am J Ophthalmol 1967; 64:860-71.

15. Paugh JR, Matoba R, Matoba ENY. Plus acceptance in hard contact lens wearers. Am J Optom Physiol Opt 1987; 64:703-7.

16. Gassett AR, Kaufman HE. Therapeutic uses of hydrophilic contact lenses. Am J Ophthalmol 1970; 69:252-9.

17. Grosvenor T, Perrigin J, Perrigin D, et al. Silicone acrylate contact lenses for myopia control: 3-year results. Optom Vis Sci 1990; 67:764-9.

18. Polse KA, Brand RJ, Vastine DW, et al. Corneal change accompanying orthokeratology. Plastic or elastic? Results of a randomized clinical trial. Arch Ophthalmol 1983; 101:1873-8.

19. Barr JT, Rah MJ, Jackson JM, et al. Orthokeratology and corneal refractive therapy: a review of recent findings. Eye Contact Lens, 2003; 29(1 suppl):S49-53.

20. Lee JR, Refojo MF, Leong FL. Tinted hydrogel lenses for cosmetic and optical problems. Cont Lens Intraocul Med J 1977; 3:22-6.

21. McMahon TT, Krefman RA. A four-year retrospective study of prosthetic hydrogel lens use. Int Contact Lens Clin 1989; 11:149-55.

22. Classe JG, Snyder C, Benjamin WJ. Documenting informed consent for patients wearing disposable lenses. J Am Optom Assoc 1989; 60:215-20.

23. Eichenbaum JW, Feldstein M, Podos SM. Extended wear aphakic soft contact lenses and corneal ulcers. Br J Ophthalmol 1982; 66:663-6.

24. Maguen E, Salz JJ, Nesburn AB. Pseudomonas corneal ulcer associated with rigid, gas permeable, daily wear contact lenses in a patient infected with human immunodeficiency virus. Am J Ophthalmol 1992; 113:336-7.

25. Sarver MD. Vision with hydrophilic contact lenses. J Am Optom Assoc 1972; 43:316-20.

26. Snyder C, Talley DK. Masking of astigmatism with selected spherical soft contact lenses. J Am Optom Assoc 1989; 60:728-31.

27. Thompson, TT. FDA four lens groups. Tyler's quarterly soft contact lens parameter guide. Little Rock, AR: Tyler's Quarterly Inc., 1999; 16:1(index).

28. Brennan NA, Efron N, Weissman BA, et al. Clinical application of oxygen transmissibility of powered contact lenses. CLAO J 1991; 17:169-72.

29. Alvord L, Court J, Davis T, et al. Oxygen permeability of a new type of high Dk soft contact lens material. Optom Vis Sci 1998; 75:30-6.

30. Fatt I, St Helen R. Oxygen tension under an oxygen-permeable contact lens. Am J Optom Arch Am Acad Optom 1971; 48:545-55.

31. Fatt I. Gas transmission properties of soft contact lenses. In: Ruben M, ed. Soft contact lenses. New York: John Wiley & Sons, 1978:83-110.

32. Fatt I, Neumann S. The average oxygen transmissibility of contact lenses: application of the concept to laboratory measurements, clinical performance and marketing. Neue Optickerjournal 1989; 31:55-8.

33. Weissman BA, Phan C. The L in Dk/L. Optom Vis Sci 1992; 69:639-44.

34. Holden BA. The principles and practice of correcting astigmatism with soft contact lenses. Aust J Optom 1975; 58:279-99.

35. Weissman BA. Theoretical optics of toric hydrogel contact lenses. Am J Optom Physiol Opt 1986; 63:536-8.

36. Hanks AJ, Weisbarth RE, McNally JJ. Clinical performance comparisons of toric soft contact lens designs. Int Contact Lens Clin 1987; 14:16-21.

37. Snyder C. A review and discussion of crossed cylinder effects and over-refractions with toric soft contact lenses. Int Contact Lens Clin 1989; 16:113-8.

38. Businger U, Treiber A, Flury C. The etiology and management of three and nine o'clock staining. Int Contact Lens Clin 1989; 16:136-9.

39. Refojo MF. The siloxane bond in contact lens materials: effect of methyl and phenyl content on oxygen permeability of silicone lenses. Int Contact Lens Clin 1984; 11:83-6.

40. Weissman BA. Mass of rigid contact lenses. Am J Optom Physiol Opt 1985; 62:322-8.

41. Chan WK, Weissman BA. Corneal pannus associated with contact lens wear. Am J Ophthalmol 1996; 121:540-6.

42. Baldone JA, Clark WB. Contact lens in the aphakic child. Contact Lens Med Bull 1970; 3:25-7.

43. Yeung K, Eghbali F, Weissman BA. Clinical experience with piggyback contact lens systems on keratoconic eyes. J Am Optom Assoc 1995; 66:539-43.

44. Nelson LB, Cutler SI, Calhoun JH, et al. Silsoft extended wear contact lenses in pediatric aphakia. Ophthalmology 1985; 92:1529-31.

45. Maguen E, Martinez M, Rosner IR, et al. The use of Saturn II lens in keratoconus. CLAO J 1991; 17:41-3.

46. Bennett ES, Smythe J, Henry VA**,** et al. Effect of topical anesthetic use on initial patient satisfaction and overall success with rigid gas permeable contact lenses. Optom Vis Sci 1998; 75:800-5.

47. Varga JH, Rubinfeld RS, Wolf TC, et al. Topical anesthetic abuse ring keratitis. Report of four cases. Cornea 1997; 16:424-9.

48. Olson M, Sarver MD. Apical bearing and success with the Bausch & Lomb Soflens (polymacon) contact lens. Am J Optom Physiol Opt 1976; 53:173-6.

49. Bibby MM. Sagittal depth considerations in the selection of the base curve radius of a soft contact lens. Am J Optom Physiol Opt 1979; 56:407-13.

50. Lowther GE, Tomlinson A. Critical base curve and diameter interval in the fitting of spherical soft contact lenses. Am J Optom Physiol Opt 1981; 58:355-60.

51. Roseman MJ, Frost A, Lawley ME. Effects of base curve on the fit of thin, mid-water contact lenses. Int Contact Lens Clin 1993; 20:95-101.

52. Kline L, DeLuca TJ. An analysis of arcuate staining with the Bausch & Lomb Soflens. J Am Optom Assoc 1975; 46:1126-32.

53. Sarver MD, Ashley D, Van Every J. Supplemental power effect of Bausch & Lomb Soflens contact lenses. Int Cont Lens Clinic 1974; 1:3-9.

54. Weissman BA. A general relationship between changing surface radii of flexing soft contact lenses. Am J Optom Physiol Opt 1984; 60:651-3.

55. Weissman BA. Loss of power with flexure of hydrogel plus lenses. Am J Optom Physiol Opt 1986; 63:166-9.

56. Snyder C, Daum KM. Rotational position of toric soft contact lenses on the eye—clinical judgments. Int Contact Lens Clin 1989; 16:146-51.

57. Herman JP. Flexure of rigid lenses on toric corneas as a function of base curve fitting relationship. J Am Optom Assoc 1983; 54:209-13.

58. Korb DR, Korb JE. A new concept in contact lens design—Part I and Part II. J Am Optom Assoc 1970; 41:1023-32.

59. Smelser G, Ozanics V. Importance of atmospheric oxygen for maintenance of optical properties of the human cornea. Science 1952; 115:140. [Beginning here and continuing to REF 63, check order in text, as they had apparently been revised.

60. Holden BA, Sweeney DF, Sanderson G. The minimum precorneal oxygen tension to avoid corneal edema. Invest Ophthalmol Vis Sci 1984; 25:476-80.

61. Holden BA, Mertz GW. Critical oxygen levels to avoid corneal edema for daily and extended wear contact lenses. Invest Ophthalmol Vis Sci 1984; 25:1161-7.

62. Klyce SD. Stromal lactate accumulation can account for corneal edema osmotically following epithelial hypoxia in the rabbit. J Physiol 1981; 321:49-64.

63. Bonnano JA, Polse KA. Corneal acidosis during contact lens wear: effects of hypoxia and CO_2. Invest Ophthalmol Vis Sci 1987; 28:1514-20.

64. Korb DR, Finnemore VM, Herman JP. Apical changes and scarring in keratoconus as related to contact lens fitting techniques. J Am Optom Assoc 1982; 53:199-205.

65. Steele E. Observations on the fitting of corneal contact lenses. Am J Optom Arch Am Acad Optom 1959; 36:194-9.

66. Sarver MD, Nelson JL, Polse KA. Peripheral corneal staining accompanying contact lens wear. J Am Optom Assoc 1969; 40:310-3.

67. Stainer GA, Brightbill FS, Holm P, et al. The development of pseudopterygia in hard contact lens wearers. Contact Intraocul Lens Med J 1981; 7:1-4.

68. Grohe RM, Lebow KA. Vascularized limbal keratitis. Int Contact Lens Clin 1989; 16:197-208.

69. Swarbrick HA, Holden BA. Rigid gas permeable lens adherence: a patient dependent phenomenon. Optom Vis Sci 1989; 66:269-75.

70. Bibby MM. Factors affecting peripheral curve design. Am J Optom Physiol Opt 1979; 56:2-9.

71. Sarver MD. A toric base curve corneal contact lens with spherical power effect. J Am Optom Assoc 1963; 34:1136-7.

72. Weissman BA, Chun MW. The use of spherical power effect bitoric rigid contact lenses in hospital practice. J Am Optom Assoc 1987; 58:626-30.

73. Rah MJ, Jackson JM. Contact lens corneal reshaping. In: Bennett ES, Weissman BA, eds. Clinical contact lens practice. Philadelphia: Lippincott, Williams & Wilkins, 2005:577-94.

74. Nelson G, Mandell RB. The relationship between minus carrier design and performance. Int Contact Lens Clin 1975; 2:75-81.

75. Bailey NJ. Special contact lenses and their applications—prism contact lenses. Opt J Rev Optom 1960; 97:54-6.

76. Knoll HA. On the stability of the shape of the human cornea. Am J Optom Physiol Opt 1976; 53:359-61.

77. Korb DR. Application of multiple microholes. J Am Optom Assoc 1961; 32:891-2.

78. Back AP, Holden BA, Hine NA. Correction of presbyopia with contact lenses: comparative success rates with three systems. Optom Vis Sci 1989; 66:518-25.

79. Situ P, Du Toit R, Fonn D, et al. Successful monovision contact lens wearers refitted with bifocal contact lenses. Eye Contact Lens 2003; 29:181-4.

80. Loshin DS, Loshin MS, Comer G. Binocular summations with monovision contact lens correction for presbyopic patients. Int Contact Lens Clin 1982; 9:161-5.

81. Josephson JE, Erickson P, Back A, et al. Monovision. J Am Optom Assoc 1990; 61:820-5.

82. Harris MG. Informed consent for presbyopic contact lens patients. J Am Optom Assoc 1990; 60:717-23.

83. Lowther GE. Dryness, tears, and contact lens wear: Clinical practice in contact lenses. Boston: Butterworth-Heinemann, 1997.

84. Farris RL. The dry eye: its mechanism and treatment; evidence that contact lenses are a cause. CLAO J 1986; 12:234-60.

85. Cedarstaff TH, Tomlinson A. A comparative study of tear evaporation rates and water content of soft contact lenses. Am J Optom Physiol Opt 1983; 60:167-74.

86. Orsborn G, Robby M. Hydrogel contact lenses and dry eye symptoms. J Br Contact Lens Assoc 1989; 6:37-8.

87. Dillehay S, Long W, Barr J, et al. Changes in biomicroscopy signs and symptoms for low Dk daily wear and extended wear soft contact lens wearers refitted in high Dk Lotrafilcon A contact lenses. Optom Vis Sci 2003;80(12 suppl):246.

88. Giovagnoli D, Graham SJ. Inferior punctal occlusion with removable silicone punctal plugs and the treatment of dry eye-related contact lens discomfort. J Am Optom Assoc 1992; 63:481-5.

89. Pflugfelder SC. Antiinflammatory therapy for dry eye. Am J Ophthalmol 2004;137:337-42.

90. Perry HD, Donnenfeld ED. Topical 0.05% cyclosporin in the treatment of dry eye. Expert Opin Pharmacother 2004; 5:2099-107.

91. Tolbert M, Lippman RE. Contact lenses: the better the care the safer the wear. In: FDA Consumer Magazine (DHHS Pub. no. [FDA] 91-4220): revised April 1991.

92. Nilsson SE. Seven-day extended wear and 30-day continuous wear of high oxygen transmissibility soft silicone hydrogel contact lenses: a randomized 1-year study of 504 patients. CLAO J 2001;27(3):125-36.

93. Schein OD, McNally JJ, Katz J, Chalmers, et al. The incidence of microbial keratitis among wearers of a 30-day silicone hydrogel extended wear contact lens. Ophthalmology 2005;112:2172-9.

94. Rosenwasser HM. Malpractice and contact lenses. Philadelphia: Gilman-Marcuse, 1988:31.

95. Gruber E. Post-fitting care of soft lenses. In: Dabezies OH, ed. Contact lenses: CLAO guide to basic science and clinical practice. Orlando: Grune & Stratton, 1984:41.1-41.2.

96. Neumann D, Weissman BA, Isenberg S, et al. The effectiveness of daily wear contact lenses for the correction of infantile aphakia. Arch Ophthalmol 1993; 111:927-30.

97. Mandell RB. Contact lens practice, 3rd ed. Springfield: Thomas, 1981:349.

98. Efron N. Contact lens complications, 2nd ed. Oxford: Butterworth-Heinemann, 2004.

99. Efron N. Grading scales for contact lens complications. Ophthalmic Physiol Opt 1998; 18:182-6.

100. Herman J. Clinical management of GPC. Contact Lens Spectrum 1987; 2:24-36.

101. Chun MW, Weissman BA. Compliance in contact lens care. Am J Optom Physiol Opt 1987; 64:274-6.

102. Collins MJ, Carney LG. Patient compliance and its influence on contact lens wearing problems. Am J Optom Physiol Opt 1986; 63:952-6.

103. Donzis PB, Mondino BJ, Weissman BA, et al. Microbial contamination of contact lens care systems. Am J Ophthalmol 1987; 104:325-33.

104. Donshik P, Weinstock FJ, Wechsler S, et al. Disposable hydrogel contact lenses for extended wear. CLAO J 1988; 14:191-4.

105. Korb DR, Henriquez AR. Meibomian gland dysfunction and contact lens intolerance. J Am Optom Assoc 1980; 51:243-51.

106. Goyal R. Shankar J, Fone DL, et al. Randomized controlled trial of ketorolac in the management of corneal abrasions. Acta Ophthalmol Scand. 2001;79:177-179.

107. Refojo M. Tear protein absorption on hydrogels: a possible cause of soft contact lens allergy. Contact Intraocul Lens Med J 1977; 3:23-35.

108. Kleist FD. Appearance and nature of hydrophilic contact lens deposits. Int Contact Lens Clin 1979; 6:120-30, 177-86.

109. Tripathi RC, Tripathi BJ, Ruben M. The pathology of soft contact lens soilage. Ophthalmology 1980; 187:365-80.

110. Gellatly KW, Brennan NA, Efron N. Visual decrement with deposit accumulation on HEMA contact lenses. Am J Optom Physiol Opt 1988; 65:937-41.

111. Snyder C. Infiltrative keratitis with contact lens wear—a review. J Am Optom Assoc 1995; 66:160-7.

112. Korb DR, Exford JM. The phenomenon of central circular clouding. J Am Optom Assoc 1968; 39:223-30.

113. Korb DR. Edematous corneal formations. J Am Optom Assoc 1973; 44:246-53.

114. Zantos S, Holden B. Ocular changes associated with continuous wear of contact lenses. Aust J Optom 1978; 61:418-26.

115. Millodot M, O'Leary DJ. Effect of oxygen deprivation on corneal sensitivity. Acta Ophthalmol 1980; 58:434-9.

116. Hamano H, Hori M, Hamano T, et al. Effects of contact lens wear on the mitosis of corneal epithelium and lactate content in the aqueous humor of rabbits. Jpn J Ophthalmol 1983; 27:451-8.

117. Bergmanson JPG, Ruben CM, Chu LWF. Epithelial morphological response to soft hydrogel contact lenses. Br J Ophthalmol 1985; 69:373-9.

118. Madigan MC, Holden BA, Kwok LS. Extended wear of contact lenses can compromise corneal epithelial adhesion. Curr Eye Res 1987; 6:1257-60.

119. Polse KA, Mandell RB. Hyperbaric oxygen effect on corneal edema caused by a contact lens. Am J Optom Arch Am Acad Optom 1971; 48:197-200.

120. Sarver MD. Striate corneal lines among patients wearing hydrophilic contact lenses. Am J Optom Physiol Opt 1971; 48:762-3.

121. Polse KA, Mandell RB. Etiology of corneal striae accompanying hydrogel lens wear. Invest Ophthalmol Vis Sci 1976; 15:553-6.

122. Hirji NK, Larke JR. Corneal thickness in extended wear of soft contact lenses. Br J Ophthalmol 1979; 63:274-6.

123. Zantos SG, Holden BA. Transient endothelial changes soon after wearing soft contact lenses. Am J Optom Physiol Opt 1977; 54:856-8.

124. Schoessler JP, Woloschak MJ. Corneal endothelium in veteran PMMA contact lens wearers. Int Contact Lens Clin 1981; 8:19-25.

125. Holden BA, Sweeney DF, Vannus A, et al. Effects of long-term extended contact lens wear on the human cornea. Invest Ophthalmol Vis Sci 1985; 26:1489-501.

126. Sweeney DR. Corneal exhaustion syndrome with long-term wear of contact lenses. Optom Vis Sci 1992; 60:601-8.

127. Dixon JM, Lawaczeck E. Corneal vascularization due to contact lenses. Arch Ophthalmol 1963; 69:106-9.

128. Hurwitz BS. Spontaneous intracorneal hemorrhage caused by aphakic contact lens wear. Ann Ophthalmol 1981; 13:57-9.

129. Rengstorff RH. The Fort Dix report—a longitudinal study of the effects of contact lenses. Am J Optom Arch Am Acad Optom 1965; 42:153-63.

130. Grosvenor T. Changes in corneal curvature and subjective refraction of soft contact lens wearers. Am J Optom Physiol Opt 1975; 52:405-13.

131. Wilson SE, Lin DTC, Klyce SD, et al. Topographic changes in contact lens induced corneal warpage. Ophthalmology 1980; 97:734-44.

132. Mobilia EF, Yamamoto GK, Dohlman CH. Corneal wrinkling induced by ultrathin soft contact lenses. Ann Ophthalmol 1980; 12:371-5.

133. Schanzer MC, Mehta RS, Arnold TP, et al. Irregular astigmatism induced by annular tinted contact lenses. CLAO J 1989; 15:207-11.

134. Tan J, Keay L, Jalbert I, et al. Mucin balls with wear of conventional and silicone hydrogel contact lenses. Optom Vis Sci 2003; 80:291-7.

135. Kline LN, DeLuca TI. Pitting stain with soft contact lenses. J Am Optom Assoc 1977; 48:372-6.

136. Malinovsky V, Pole J, Pence NA. Epithelial splits of the superior cornea in hydrogel contact lens patients. Int Contact Lens Clin 1989; 16:252-5.

137. Zadnik K, Mutti DO. Inferior arcuate corneal staining in soft contact lens wearers. Int Contact Lens Clin 1985; 12:110-5.

138. Orsborn GN, Zantos SG. Corneal desiccation staining with thin high water content contact lenses. CLAO J 1988; 14:81-5.

139. Lansche RK, Lee RC. Acute complications from present day corneal contact lenses. Arch Ophthalmol 1960; 64:275-85.

140. Weissman BA, Chun MW, Barnhart LA. Corneal abrasion associated with contact lens correction of keratoconus - a retrospective study. Optom Vis Sci 1994; 71:677-81.

141. Jones L, Macdougall N, Sorbara LG. Asymptomatic corneal staining associated with the use of Balafilcon silicone hydrogel contact lenses disinfected with a polyaminopropyl biguanide-preserved care regimen. Optom Vis Sci 2002; 79:753-61.

142. Stein RM, Clinch TE, Cohen EJ, et al. Infected vs sterile corneal infiltrates in contact lens wearers. Am J Ophthalmol 1988; 105:632-6.

143. Josephson JE, Caffrey BE. Infiltrative keratitis in hydrogel lens wearers. Int Contact Lens Clin 1979; 6:47-70.

144. Mondino BJ, Groden LR. Conjunctival hyperemia and corneal infiltrates with chemically disinfected soft contact lenses. Arch Ophthalmol 1980; 98:1767-70.

145. Margulies LJ, Mannis MJ. Dendritic corneal lesions associated with soft contact lens wear. Arch Ophthalmol 1983; 101:1551-3.

146. Spring TF. Reaction to hydrophilic lenses. Med J Aust 1974; 1:449-50.

147. Allansmith MR, Korb DR, Greiner JV, et al. Giant papillary conjunctivitis in contact lens wearers. Am J Ophthalmol 1977; 83:697-708.

148. Michaels DD, Zugsmith GS. An unusual contact lens complication. Am J Ophthalmol 1963; 55:1057-8.

149. Sheldon L, Biedner B, Geltman C, et al. Giant papillary conjunctivitis and ptosis in a contact lens wearer. J Paediatr Ophthalmol Strabismus 1979; 16:136-7.

150. Epstein G, Putterman AM. Acquired blepharoptosis secondary to contact-lens wear. Am J Ophthalmol 1981; 91:634-9.

151. Fonn D, Holden BA. Extended wear of hard gas permeable contact lenses can induce ptosis. CLAO J 1986; 12:93-4.

152. Mutti DO, Seger RG. Eyelid asymmetry in unilateral hydrogel contact lens wear. Int Contact Lens Clin 1988; 15:252-5.

153. Bernstein HN, Lemp MA. An unusual keratoconjunctivitis occurring after long time wearing of AO Softcon (formerly Griffin or Bionite) hydrophilic contact lens. Ann Ophthalmol 1975; 7:97-106.

154. McMonnies CW, Chapman-Davies A, Holden BA. The vascular response to contact lens wear. Am J Optom Physiol Opt 1982; 59:795-9.

155. Stenson S. Superior limbic keratoconjunctivitis associated with soft contact lens wear. Arch Ophthalmol 1983; 101:402-4.

156. Knopf HL. Reaction to hydrogen peroxide in a contact-lens wearer. Am J Ophthalmol 1984; 97:796.

157. Bernstein DI, Gallagher JS, Grad M, et al. Local ocular anaphylaxis to papain enzyme contained in a contact lens cleaning solution. J Allerg Clin Immunol 1984; 74:258-60.

158. Begley C, Wierich B, Benak J, et al. Effects of rigid gas permeable contact lens solutions on the human epithelium. Optom Vis Sci 1992; 69:347-53.

159. Polse K, Mandell RB. Critical oxygen tension at the corneal surface. Arch Ophthalmol. 1971; 84:505-8.

160. Harvitt DM, Bonnano JA: Re-evaluation of the oxygen diffusion model for predicting minimum contact lens Dk/t values needed to avoid corneal anoxia. Optom Vis Sci 1999;76:712-719.

161. Brennan NA, Efron N. Corneal oxygen consumption and hypoxia. In: Bennett ES, Weissman BA, eds. Clinical contact lens practice, 2nd ed., Philadelphia: Lippincott, Williams 7Wilkins, 2005.

162. Papas EB, Vajdic CM, Austen R, et al. High oxygen transmissibility soft contact lenses do not induce limbal hyperemia. Curr Eye Res 1997; 16:942-8.

163. Schnider CM, Terry RL, Holden BA. Effect of lens design on peripheral corneal desiccation. J Am Optom Assoc 1997; 68:163-70.

164. Clemons CS, Cohen EJ, Arentsen JJ, et al. Pseudomonas ulcers following patching of corneal abrasions associated with contact lens wear. CLAO J 1987; 13:161-4.

165. Weaver CS, Terrell KM. Evidence-based emergency medicine. Update: do ophthalmic nonsteroidal anti-inflammatory drugs reduce pain associated with simple corneal abrasion without delaying healing? Ann Emerg Med 2003; 41:134-40.

166. Korb DR, Finnemore VM, Herman JP. Apical changes and scarring in keratoconus as related to contact lens fitting techniques. J Am Optom Assoc 1982; 53:199-205.

167. Meisler DM, Berzins UJ, Krachmer JH, et al. Cromolyn treatment of giant papillary conjunctivitis. Arch Ophthalmol 1982; 100:1608-10.

168. Korb DR, Greiner JV, Finnemore VM, Allansmith MR. Treatment of contact lenses with papain. Increase in wearing time in keratoconic patients with papillary conjunctivitis. Arch Ophthalmol 1983; 101:48-50.

169. Donshik PC, Ballow M, Luistro A, et al. Treatment of contact lens-induced giant papillary conjunctivitis. CLAO J 1984; 10:346-50.

170. Bucci FA, Lopatynsky MO, Jenkins PL, et al. Comparison of the clinical performance of the Acuvue disposable contact lens and CSI lens in patients with giant papillary conjunctivitis. Am J Ophthalmol 1993; 115:454-9.

171. Friedlaender MH, Howes J. A double masked placebo-controlled evaluation of the efficacy and safety of loteprednol etabonate in the treatment of giant papillary conjunctivitis. The Loteprednol Etabonate Giant Papillary Conjunctivitis Study Group I. Am J Ophthalmol 1997; 123:455-64.

172. Dixon JM, Young CA, Baldone JA, et al. Complications associated with the wearing of contact lenses. JAMA 1966; 195:901-3.

173. Cooper RL, Constable IJ. Infective keratitis in soft contact lens wearers. Br J Ophthalmol 1977; 61:250-4.

174. Wilson LA, Schlitzer RL, Ahearn DG. Pseudomonas corneal ulcers associated with soft contact lenses. Am J Ophthalmol 1981; 92:546-54.

175. Weissman BA, Mondino BJ, Pettit TH, et al. Corneal ulcers associated with extended wear soft contact lenses. Am J Ophthalmol 1984; 97:476-81.

176. Mondino BJ, Weissman BA, Farb MD, et al. Corneal ulcers associated with daily wear and extended wear contact lenses. Am J Ophthalmol 1986; 102:58-65.

177. Moore MB, McCulley JP, Luckenbach M, et al. Acanthamoeba keratitis associated with soft contact lenses. Am J Ophthalmol 1985; 100:396-403.

178. Baum JL, Jones DB. Initial therapy of suspected microbial corneal ulcers. Surv Ophthalmol 1979; 24:97-116.

179. Levey SB, Katz HR, Abrams DA, et al. The role of cultures in the management of ulcerative keratitis. Cornea 1997; 16:383-6.

180. McDonnell PJ, Nobe J, Gauderman WJ, et al. Community care of corneal ulcers. Am J Ophthalmol 1992; 114:531-8.

181. O'Brien TP, Maguire MG, Fink NE, et al. Efficacy of ofloxacin vs cefazolin and tobramycin in the therapy of bacterial keratitis. Arch Ophthalmol 1995; 113:1257-65.

182. McLeod SD, Kolahdouz-Isfahani A, Rostamian K, et al. The role of smears, cultures and antibiotic sensitivity testing in the management of suspected infectious keratitis. Ophthalmology 1996; 103:23-8.

183. The Ofloxacin Study Group. Ofloxacin monotherapy for the primary treatment of microbial keratitis: a double-masked, randomized, controlled trial with conventional dual therapy. Ophthalmology 1997; 104:1902-9.

184. Hyndiuk RA, Eiferman RA, Caldwell DR, et al. Comparison of ciprofloxacin ophthalmic solutions 0.3% to fortified tobramycin-cefazolin in treating bacterial corneal ulcers. Ciprofloxacin Bacterial Keratitis Study Group. Ophthalmology 1996; 103:1854-62

185. McLeod SD, DeBacker CM, Viana MA. Differential care of corneal ulcers in the community based on apparent severity. Ophthalmology 1996;103:479-84.

186. Leibowitz H. The role of ciprofloxacin in the antibacterial therapy of bacterial keratitis and bacterial conjunctivitis. Am J Ophthalmol 1991; 112 (suppl):1S-48S.

187. Kunimoto DY, Sharma S, Garg P, et al. In vitro susceptibility of bacterial keratitis pathogens to ciprofloxacin. Emerging resistance. Ophthalmology 1999; 106:80-5.

188. Bower KS, Kowalski RP, Gordon YJ. Fluoroquinolones in the treatment of bacterial keratitis. Am J Ophthalmol 1996; 121:712-5.

189. Koenig SB, Solomon JM, Hyndiuk RA, et al. Acanthamoeba keratitis associated with gas-permeable contact lens wear. Am J Ophthalmol 1987; 103:832.

190. Moore MB, McCulley JP, Newton C, et al. Acanthamoeba keratitis. A growing problem in soft and hard contact lens wearers. Ophthalmology 1987; 94:1654-61.

191. Stehr-Green JK, Bailey TM, Visvesvara GS. The epidemiology of Acanthamoeba keratitis in the United States. Am J Ophthalmol 1989; 107:331-6.

192. Nakano E, Oliveira M, Portellinha W, et al. Confocal microscopy in early diagnosis of Acanthamoeba keratitis. J Refract Surg 2004; 20:S737-740.

193. Mathers WD, Nelson SE, Lane JL, et al. Confirmation of confocal microscopy diagnosis of Acanthamoeba keratitis using polymerase chain reaction analysis. Arch Ophthalmol 2000; 118:178-83.

194. Berger ST, Mondino BJ, Hoft RH, et al. Successful medical management of Acanthamoeba keratitis. Am J Ophthalmol 1990; 110:395-403.

195. D'Aversa G, Stern GA, Driebe WT. Diagnosis and successful treatment of Acanthamoeba keratitis. Arch Ophthalmol 1995; 113:1120-3.

196. Wilson LA, Ahearn DG. Association of fungi with extended wear soft contact lenses. Am J Ophthalmol 1986; 101:434-6.

197. Kent HD, Cohen EJ, Laibson PR, et al. Microbial keratitis and corneal ulceration associated with therapeutic soft contact lenses. CLAO J 1990; 16:49-52.

198. Mah-Sadorra JH, Yavuz SG, Najjar DM, et al. Trends in contact lens-related corneal ulcers. Cornea 2005; 24:51-8.

199. Holden BA, Sankaridurg PR, Sweeney DF, et al. Microbial keratitis in prospective studies of extended wear with disposable hydrogel contact lenses. Cornea 2005; 24:156-61.

Figure 1
Corneal Stain

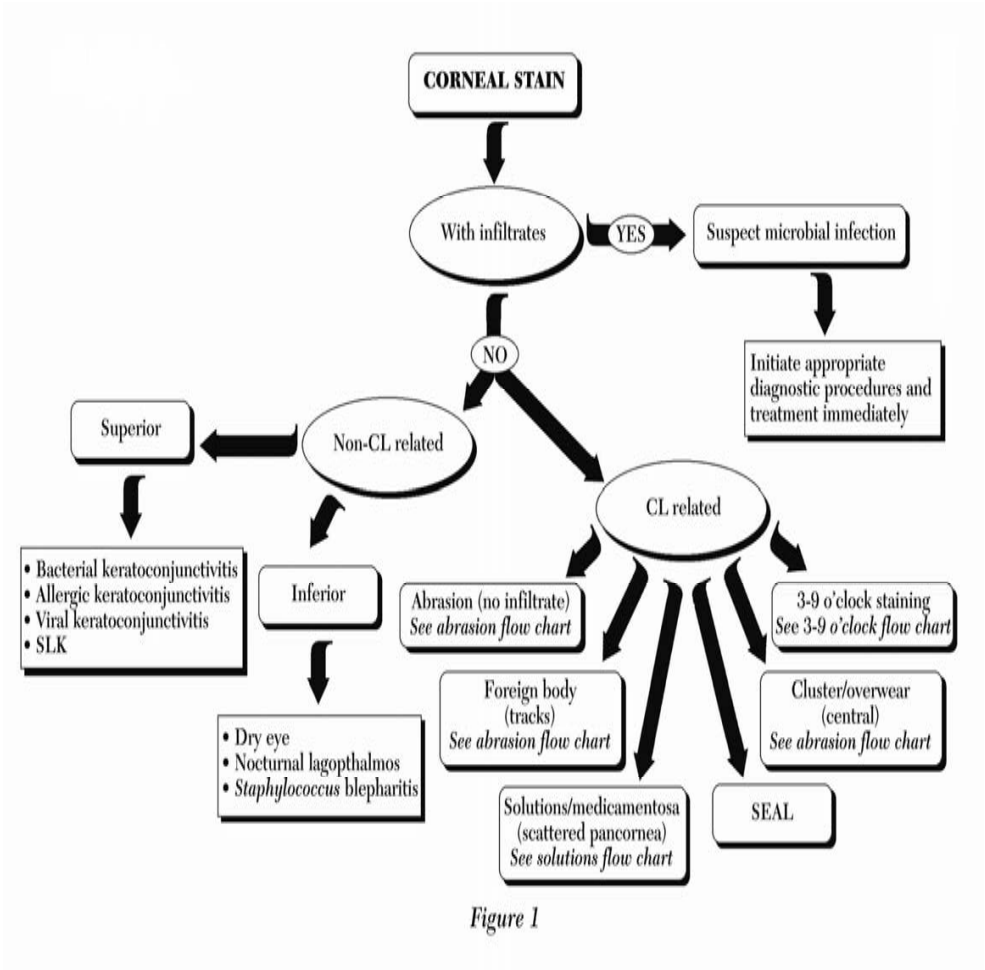

Figure 1

Figure 2
Corneal Infiltrates

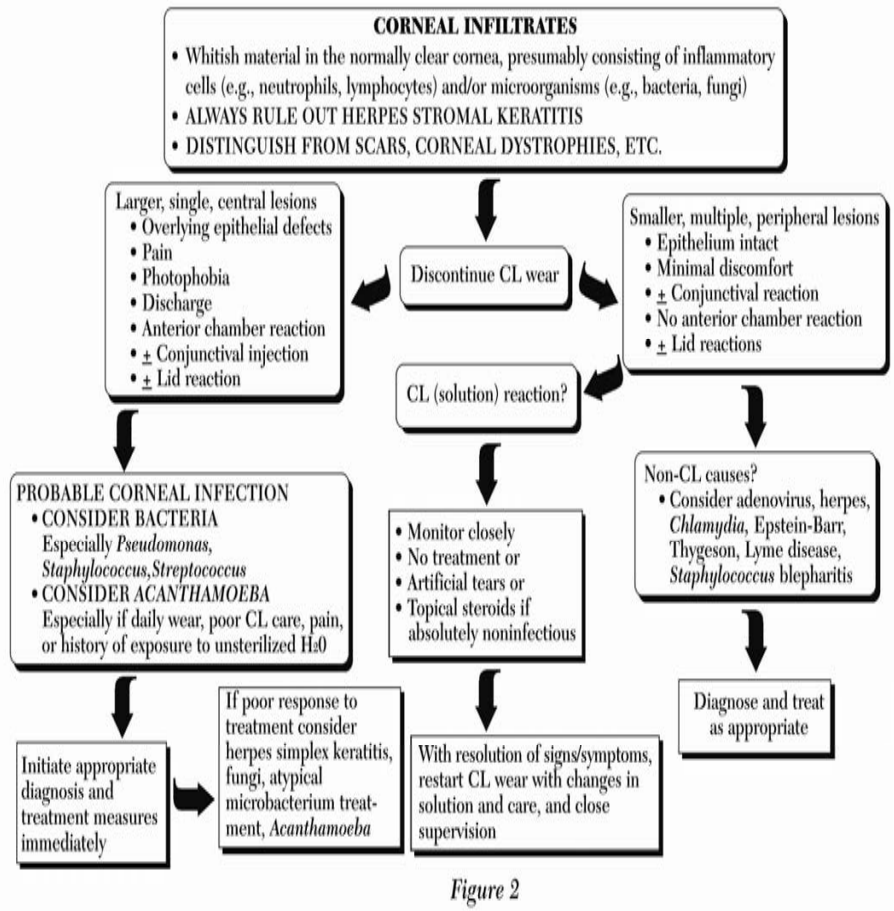

Figure 2

Figure 3
Conjunctival Injection (Conjunctivitis)

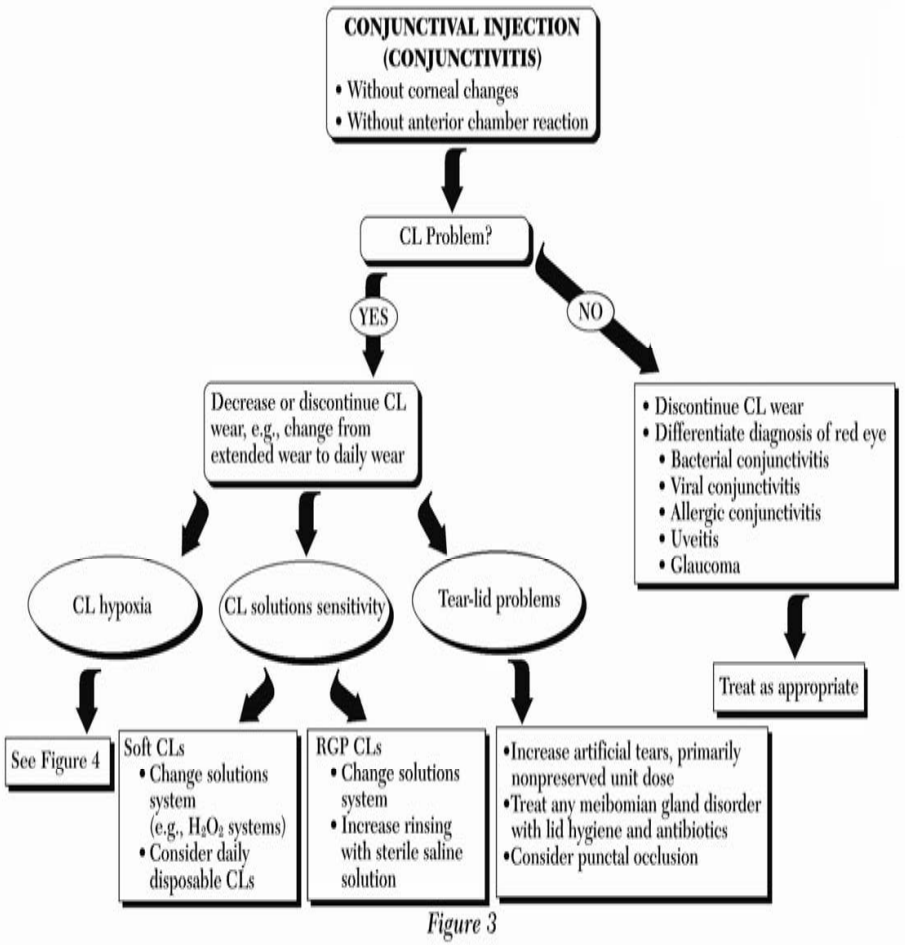

Figure 3

Figure 4
Contact lens induced Corneal Hypoxia

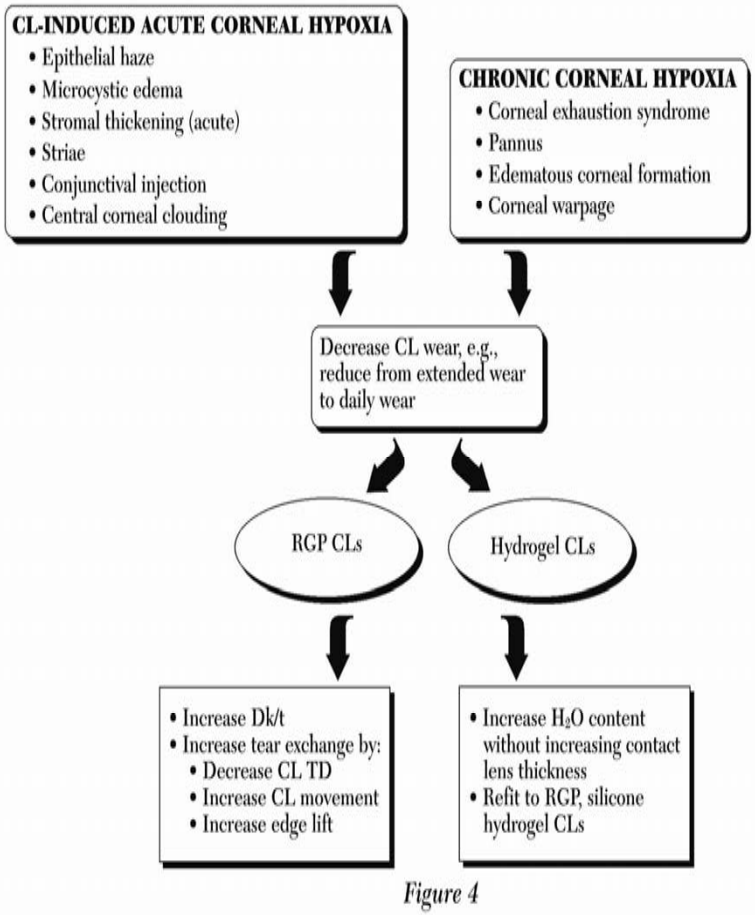

Figure 4

Figure 5
"3/9" or Juxtaposition Corneal Stain

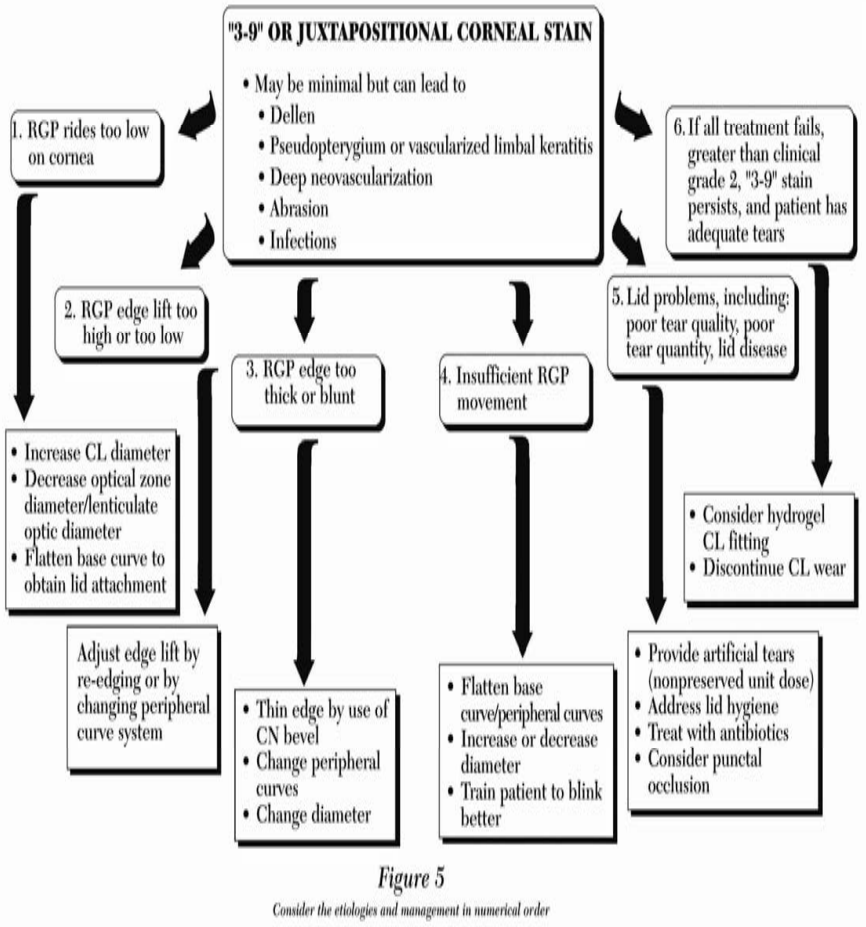

Figure 5

Consider the etiologies and management in numerical order

Figure 6
Corneal Abrasion

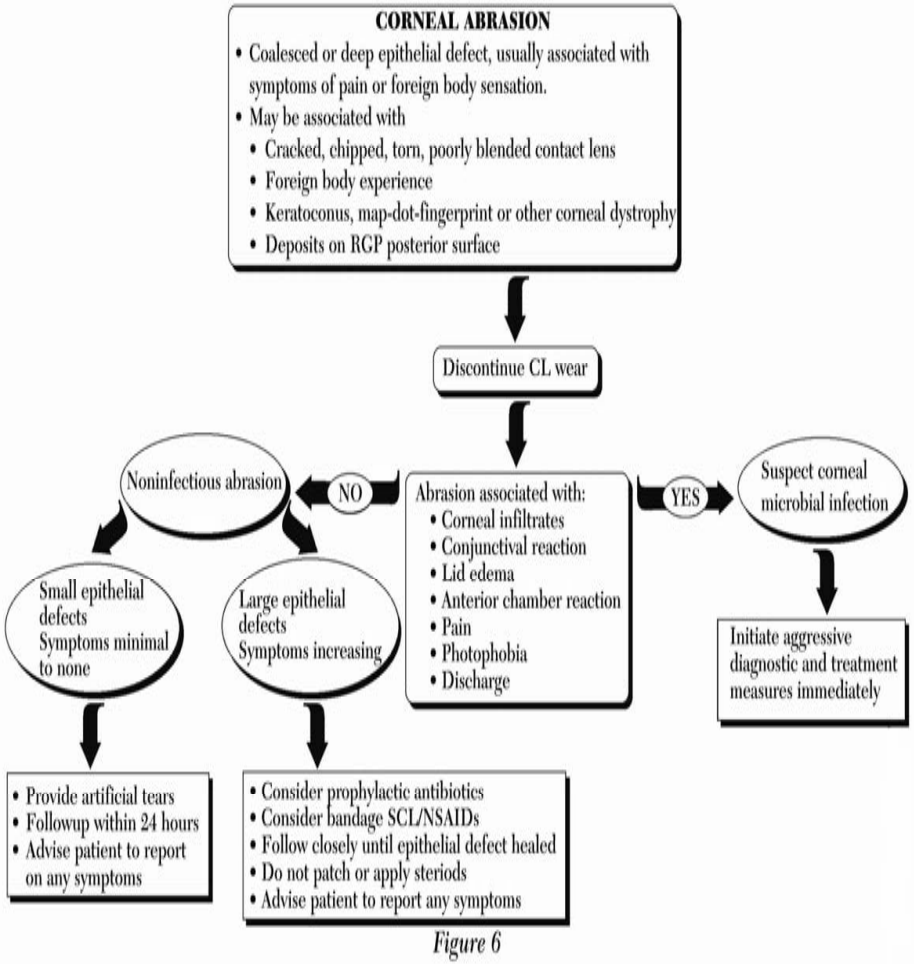

Figure 6

Figure 7
Giant Papillary Conjunctivitis

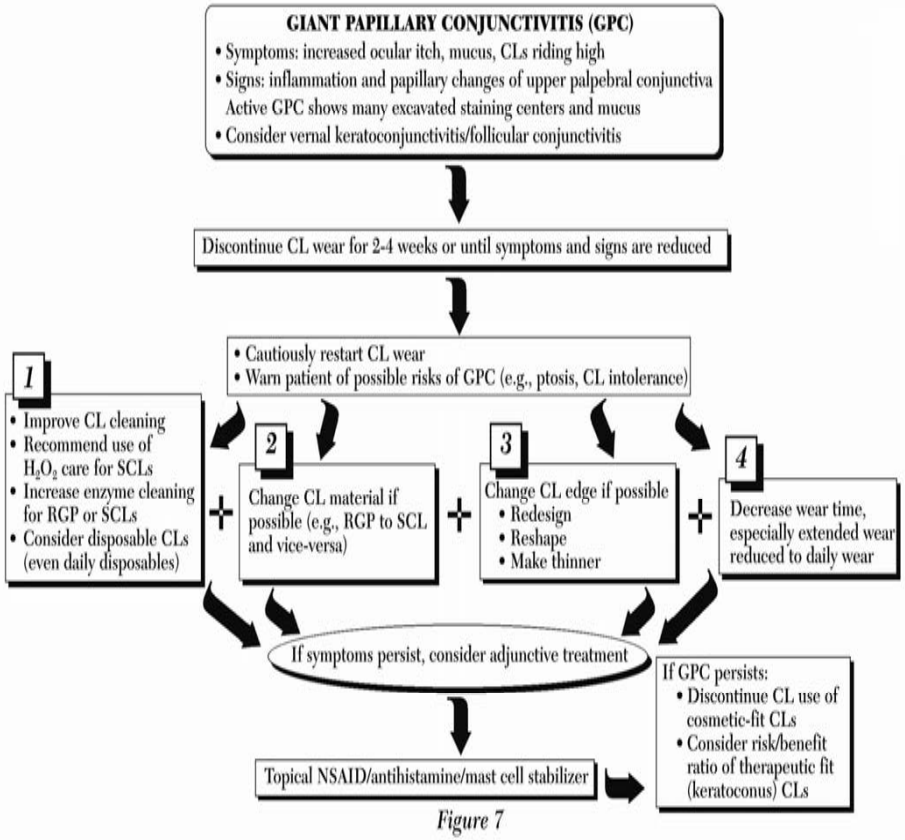

Figure 7

Figure 8
ICD-9-CM CODES

Degenerations of iris and ciliary body	**364.5**
Essential or progressive iris atrophy	**364.51**
Pigmentary iris degeneration	**364.53**
Acquired heterchromia of iris	
Pigment dispersion syndrome of iris	
Translucency of iris	
Degeneration of pupillary margin	**364.54**
Atrophy of sphincter of iris	
Ectropion of pigment epithelium of iris	
Other iris atrophy	**364.59**
Iris atrophy (generalized) (sector shaped)	
Disorders of refraction and accommodation	**367**
Hypermetropia	**367.0**
Far-sightedness Hyperopia	
Myopia	**367.1**
Near-sightedness	
Astigmatism	**367.2**
Astigmatism, unspecified	**367.20**
Regular astigmatism	**367.21**
Irregular astigmatism	**367.22**

[redacted]

[redacted]

Anisometropia and aniseikonia **367.3**

Anisometropia **367.31**

Aniseikonia **367.32**

Presbyopia **367.4**

Visual disturbances **368**

Amblyopia ex anopsia **368.0**

Amblyopia, unspecified **368.00**

Strabismic amblyopia **368.01**
Suppression amblyopia

Deprivation amblyopia **368.02**

Refractive amblyopia **368.03**

Corneal opacity and other disorders of cornea **371**

Corneal scars and opacities **371.0**
Excludes: that due to vitamin A deficiency (264.6)

Corneal opacity, unspecified **371.00**
Corneal scar NOS

Minor opacity of cornea **371.01**
Corneal nebula

Peripheral opacity of cornea **371.02**
Corneal macula not interfering with central vision

Central opacity of cornea **371.03**
Corneal:
leucoma interfering with central vision
macula interfering with central vision

Adherent leucoma **371.04**

Phthisical cornea **371.05**
Code first underlying tuberculosis (017.3)

Keratoconus **371.6**

Keratoconus, unspecified **371.60**

Keratoconus, stable condition **371.61**

Keratoconus, acute hydrops **371.62**

Other corneal deformities **371.7**

Corneal deformity, unspecified **371.70**

Corneal ectasia **371.71**

Descemetocele **371.72**

Corneal staphyloma **371.73**

Unspecified corneal disorder **371.9**

Aphakia and other disorders of lens **379.3**
Excludes: after-cataract (366.50-366.53)

Aphakia **379.31**

[redacted]

[redacted]

Nystagmus and other irregular eye movements **379.5**

Nystagmus, unspecified **379.50**

Congenital nystagmus **379.51**

Superficial injury of eye and adnexa **918**
Excludes: Burn (940.0-940.9)
Foreign body on external eye (930.0-930.9)

Cornea **918.1**
Corneal abrasion
Superficial laceration

Excludes: Corneal injury due to contact lens (371.82)

Abbreviations of Commonly Used Terms

AEL	Axial edge lift
ANSI	American National Standards Institute
BCOR	Back central optical radius
CCC	Central circular clouding; also central corneal clouding
CDC	Centers for Disease Control and Prevention
CES	Corneal exhaustion syndrome
CL(s)	Contact lens(es)
D	Diopter(s) of optical power; diffusion coefficient
Dk	Oxygen permeability
Dk/t	Oxygen transmissibility
ECF	Edematous corneal formation
FDA	U.S. Food and Drug Administration
FST	Front surface toric lens
GP	Gas permeable
GPC	Giant papillary conjunctivitis
HCL	Hydrogel contact lens
HEMA	Hydroxyethylmethacrylate
HSK	Herpes simplex keratitis

HVID	Horizontal visible iris diameter
IgE	Immunoglobulin E
K	Quantification value of corneal curvature, by keratometry or videotopography
MCE	Microcystic edema
MK	Microbial keratitis
NSAIDs	Nonsteroidal anti-inflammatory drops
NV	Neovascularization
OAD	Overall diameter
On K	Flat keratometry measurement
PKP	Penetrating keratoplasty
PMMA	"Hard" polymethylmethacrylate
REL	Radial edge lift
RGP	Rigid gas permeable lens
SEAL	Superior epithelial arcuate lesion
SOAP	Subjective, objective, assess, plan
t	Thickness of individual CL, often at the center
VLK	Vascularized limbal keratitis
WC	Water content

GLOSSARY

Abrasion A defect in the corneal epithelium, usually accompanied by subjective pain or foreign body symptoms, but not infiltrates.

Acne rosacea A chronic inflammatory skin condition of the face, involving mild to persistent erythema and extensive hyperplasia of the sebaceous glands (with deep papules and pustules) accompanied by telangiectasia.

Aphakia Absence, usually postsurgical, of the crystalline lens of the eye.

Artificial tears Lubricating drops prepared to supplement the normal tear layer**,** often containing chemicals to adjust pH, viscosity, and other nutritional constituents to mimic the normal tear layer. Can be non-preserved (sterility achieved by the use of unit dosage) or preserved with a variety of agents.

Aspheric Non-spherical surface, usually symmetrical about its axis of rotation and derived from conic sections (therefore having both apical radius and eccentricity); possibly front, back, or peripheral surfaces of a contact lens.

Astigmatism Refractive anomaly due to unequal refraction of light in different meridians of the eye, generally caused by a toroidal anterior surface of the cornea.

Atopic dermatitis Allergic inflammation of the skin.

Back optical diameter (or zone) The central optical posterior surface of the contact lens.

Back toric lens A contact lens which has a back surface cylinder and spherical front surface for toric cornea fitting.

Base curve, or back central optic radius (r or BCOR) The radius of curvature of the posterior central optical portion, in the area corresponding to the optical zone, of a contact lens, usually measured in millimeters.

Bifocal Pertaining to a lens system having two focal lengths.

Binding A condition in which contact lenses (particularly rigid CLs which position inferiorly) occasionally cease to move and become adherent to the underlying cornea; removal of the CLs reveals areas where the back surface (optic zone and edge) of the contact lens has become compressed into the underlying tissues**,** leaving a mold of its shape.

Bitoric lens A rigid contact lens with astigmatic (toric or cylindrical) anterior and posterior surfaces.

Blepharitis An inflammatory process affecting the lid margins, the lash follicles, or the openings of the meibomian glands.

Carrier A radially symmetrical portion of a lenticular design contact lens, peripheral to the optical cap. The carrier may be negative (edge thickness greater than the junction thickness), positive (edge thickness less than that of the junction), or parallel in cross-section.

Central circular clouding (CCC) A superficial diffuse edema of the cornea, usually circular, associated with wearing contact lenses that either bear on the central epithelium or entrap tear fluid in this area; central corneal clouding.

CN bevel Slanted thinning of a contact lens edge on its anterior surface, to reduce edge thickness.

Contact lens (CL) A small, shell-like, bowl-shaped glass or plastic lens that rests directly on the eye, in contact with the cornea or the sclera or both, serving as a new anterior surface of the eye and/or as a retainer for fluid between the cornea and the contact lens, ordinarily to correct for refractive errors of the eyes.

Continuous wear Wearing a contact lens constantly, only removing it when a complication is encountered.

Corneal CL A contact lens worn on the cornea, typically 7.5-11.5 mm in total diameter.

Corneal exhaustion syndrome (CES) An acute intolerance to contact lens wear in previously successful wearers, usually believed to be associated with corneal swelling (edema), changes in endothelial cell morphology, and visual difficulties.

Daily wear lens A contact lens requiring daily or more frequent removal for cleaning and other purposes.

Dellen Transient ellipsoid depressions in the cornea caused by localized severe dehydration, usually involving acute shrinkage of the stroma without any loss of epithelium.

Dendrite A branch-like formation in the corneal epithelium, usually seen with the aid of sodium fluorescein solution; the hallmark of herpetic keratitis.

Diffusion coefficient (D) From the engineering literature, (see Dk and Dk/t.

Dimple veil stain Depressions in corneal epithelial surface from bubbles trapped between a contact lens and the corneal surface; usually associated with a somewhat “tight” or “steep” RGP or HCL, or to a related corneal depression (e.g., in keratoconus or associated with a scarred cornea).

Diopter (D) A unit of optical power.

Edematous corneal formation (ECF) Epithelial dendritic figure related to rigid (especially PMMA) contact lens-generated edema of the corneal epithelium.

Edge lift The distance between an extension of the BCOR and the absolute edge of the lens; when measured parallel to the optical axis, axial edge lift (AEL**)**; when measured along the radius, radial edge lift (REL).

Equilibration The period during which a contact lens approaches steady state with regard to the properties of the patient's tear layer (e.g., tonicity, pH).

Extended wear lens A contact lens designed to have oxygen permeability, thickness, and periodic cleaning requirements that permit continuous wear for more than a day by a person with compatible physiological characteristics.

Fenestration A perforation to allow transfer of air and/or tears between the contact lens and cornea.

Filtering bleb A conjunctival vesicle with a scleral channel that allows direct communication of fluid from the inside of the eye, either planned (e.g., for treatment of glaucoma) or unplanned, (e.g., following cataract extraction).

Follicle Conjunctival nodule of lymphatic origin, lacking a central vascular core; seen in viral, chlamydial, allergic conjunctivitis.

Front optic diameter (or zone) The anterior optical surface of a contact lens.

Front surface toric lens (FST) Contact lens with toric optics on only its front surface and a spherical base curve , intended to correct residual astigmatism.

Gas permeable (GP) lens Any of a family of rigid oxygen-permeable plastics that retain their form without support, under normal conditions; these plastics have been prepared for the contact lens industry to allow oxygen diffusion at clinically significant levels; also called hard gas permeable (HGP), rigid gas permeable (RGP) and "semi-soft lens."

Giant papillary conjunctivitis (GPC) Type I atopic response in the palpebral conjunctiva, in which the breakdown of septae between many small papillae create giant (>1 mm) papillae.

Haptic CL Any contact lens having a section designed to rest on the sclera.

Horizontal visible iris diameter (HVID) The horizontal diameter of the cornea across the visible limbus, usually measured in millimeters.

Hydrogel Any of a family of water-absorbing (hydrophilic) plastics used for contact lenses; also called soft lenses. Silicone hydrogels are plastic lens materials that incorporate silicone to enhance oxygen permeability.

Hydroxyethylmethacrylate (HEMA) The first plastic used for a hydrogel lens, invented by Otto Wichterle.

Hypermetropia (hyperopia) A refractive condition in which the light entering the non-accommodated eye is focused behind the retina; farsightedness.

Infiltrates White or gray material in the normally transparent cornea, usually composed of either inflammatory leukocytes or invading microorganisms, or both.

K Symbol for the central corneal curvature of longest radius, as measured by a keratometer.

k Solubility (of oxygen) in a material (e.g., plastic), from the engineering literature (see Dk and Dk/t)

Keratoconus A developmental or dystrophic deformity of the cornea in which it becomes cone-shaped, due to a thinning and stretching of the tissue in its central area. It usually manifests itself during puberty and is usually bilateral but asymmetric.

Keratometry Measurement of the anterior curve of the cornea.

Lenticular design A (contact) lens design with a front optic diameter smaller than the total diameter of the lens, creating an optical "cap" and a peripheral carrier portion.

Microcystic edema (MCE) Very small fluid cysts in the corneal epithelium.

Microbial keratitis (MK). Corneal infection due to bacteria (primarily) but also other microbes including viruses, fungi, and amoebae (specifically *Acanthamoeba* sp.), characterized by symptoms of sudden onset ocular pain (or persistent foreign body sensation), discharge, and redness, and signs of a corneal epithelial/stromal defect with associated inflammation (corneal infiltrate, conjunctival injection, anterior chamber reaction, lid edema).

Monovision A technique for the optical correction of presbyopia, by which a binocular patient is deliberately provided with one contact lens prescribed for distance vision and the other for near vision.

Myopia Refractive condition in which the light entering the non-accommodated eye is focused in front of the retina; nearsightedness.

Neovascularization (NV) Growth of abnormal new blood vessels.

Neurotrophic keratitis Corneal epitheliopathy due to damaged innervation.

Nonsteroidal anti-inflammatory drug (NSAID) Any of several classes of pharmaceutical agents, excluding steroids, that act to suppress the inflammatory response.

Ocular rosacea Acne rosacea involving the eye or its adnexa, that may include any or all of these chronic eye signs: blepharitis, meibomitis, telangiectasia of the lids; insufficient tears; bulbar and corneal epitheliopathies, corneal scarring and melting.

Optic cap See lenticular design.

Orthokeratology The science or program of therapeutic application of contact lenses to alter the curvature of the cornea, especially to reduce myopia.

Overall diameter (OAD) The chord diameter of a contact lens, measured from one absolute edge to the other in millimeters.

Pannus An abnormal, superficial vascularization of the cornea associated with a membranous infiltration of granulation tissue

Papilla Allergically induced conjunctival nodule with a central vascular core; collection of mast cells, basophils, and eosinophils, and subsequent other inflammatory cells. See giant papillary conjunctivitis.

Penetrating keratoplasty (PKP) A surgical procedure in which a section of the entire thickness of an opaque cornea is removed and replaced by transparent cornea.

Permeability Oxygen permeability of a plastic, called "Dk" in the engineering literature.

Peripheral curves Non-optical curves of set chord lengths and curvatures on both anterior and posterior peripheral surfaces of contact lenses.

Piggyback A contact lens system in which a soft CL is used underneath a rigid CL on the same eye.

Polymegethism Marked pleomorphism (cell size variation) in the corneal endothelial layer.

Polymethylmethacrylate (PMMA) A lightweight, transparent, essentially non-oxygen-permeable thermoplastic commonly used in the manufacture of hard contact lenses between 1950 and 1980, now almost outdated; lucite or plexiglas

Posterior apical radius of curvature (PAR) The radius of curvature over a small area surrounding the apex of the posterior surface of an aspheric contact lens.

Presbyopia A reduction in accommodative ability that occurs normally with age and necessitates a plus lens addition for satisfactory near vision.

Prism A triangular refracting body that optically deflects light toward its base while separating wavelengths; Due to its shape, one side is therefore of greater thickness and mass than the other.

Prosthetic device Artificial body part.

Pseudodendrite Epithelial branch-like formation not associated with herpetic keratitis; usually a contact lens solution-related hypersensitivity or hypoxic response.

Pterygium A horizontal, triangular growth of the bulbar conjunctiva occupying the intrapalpebral fissure, with the apex extending onto the cornea.

Ptosis Drooping of the upper eyelid below its normal position.

Reverse geometry A contact lens design in which the base curve radius (BCOR) of the CL is flatter than the secondary curve radius of the CL peripheral curve system.

Rigid contact lenses See gas permeable (GP) contact lenses.
Scleral (or haptic) contact lens A large contact lens, covering most of the front of the eye, including the bulbar conjunctiva as well as the cornea.

Silicone hydrogel A family of hydrogel plastics that incorporate some form of silicone to enhance oxygen permeability (Dk).

Soft lenses Contact lenses made of a water-absorbing substance that when worn are soft and flexible.

Spherical Round; non-astigmatic; non-aspheric.

Stromal striae Fine parallel lines seen in the deep stroma during corneal swelling from contact lens-associated hypoxia, early Fuchs dystrophy, or keratoconus. (Deeper frank folds in Descemet's membrane usually are not related to contact lens wear and are called "striate keratopathy.")

Superior epithelial arcuate lesion (SEAL) Lesion of unknown etiology that occurs occasionally during hydrogel contact lens wear; also called "epithelial splitting." The eye is asymptomatic, or mildly symptomatic, and an arc of corneal epithelial disruption approximately 1 mm below and parallel to the superior limbus is evident.

Thickness (t) Thickness of a contact lens, usually in millimeters and usually measured at the center of the lens.

Toric lens A lens that has one surface with two meridians of curvature(least and greatest curvatures) located at right angles to each other; astigmatism.

Transmissibility (Dk/t) The ability of a contact lens material to diffuse oxygen; oxygen permeability divided by thickness.

Truncation Deliberate removal and polishing of a portion of a circular contact lens circumference, to affect lens rotation and positioning.

Vascularized limbal keratitis (VLK) Inflammation at the lateral borders of the cornea, initiated by desiccation from rigid contact lens wear, resulting in a pseudopterygium.

Water content (WC) Percentage of water in a hydrogel material.

"3/9" staining Corneal epithelial erosions at the lateral borders of the cornea, initiated by desiccation from rigid contact lens wear, close to the positions occupied by 3 o'clock and 9 o'clock on an analog dial.

Sources:

Cline D, Hoffstetter HW, Griffin JR. Dictionary of visual science, 4th ed. Philadelpha: Chilton, 1989.

Mandell RB. Contact lens practice, 3rd ed. Springfield, IL: Thomas, 1981:349.

Silbert JA, ed. Anterior segment complications of contact lens wear, 2nd ed. New York: Butterworth-Heinemann, , 2000.

Bennett E, Weissman BA, eds.. Clinical contact lens practice, 2nd ed. Philadelphia: Lippincott, Williams & Wilkins, 2005.