CCLR

Centre for Contact Lens Research

25 (1988-2013)

25 Years of Ocular Research

WATERLOO OPTOMETRY & VISION SCIENCE

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Ocular Research

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We are **professors,** **clinicians,** **microbiologists,** **engineers** and **social scientists.**

Our work is driven by a **passion for research and scientific rigor,** a **commitment to objectivity** and an appreciation for **inter-disciplinary collaboration.**

The CCLR is a world class research facility specializing in the integration of clinical, laboratory and socio-behavioural research centering on the eye.

The CCLR was established in 1988 at the University of Waterloo's School of Optometry and Vision Science.

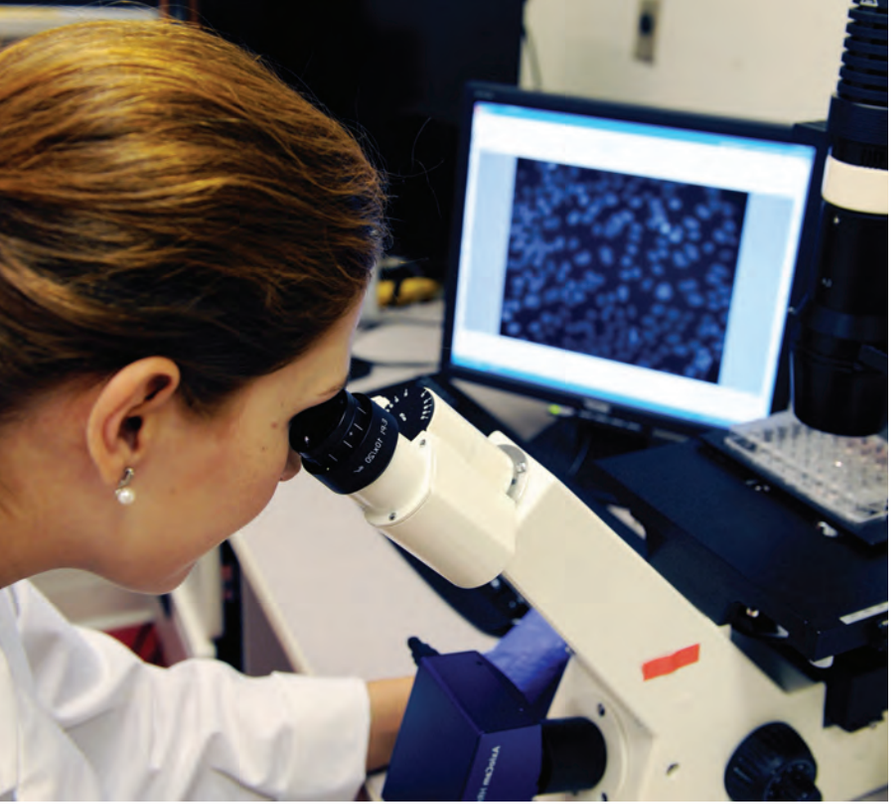
It was designed to meet a need for objective, academically-grounded research to support a growing contact lens industry. Over the next two decades, founding director Desmond Fonn developed the organization from a three-person operation into a thriving hub of basic and applied research.

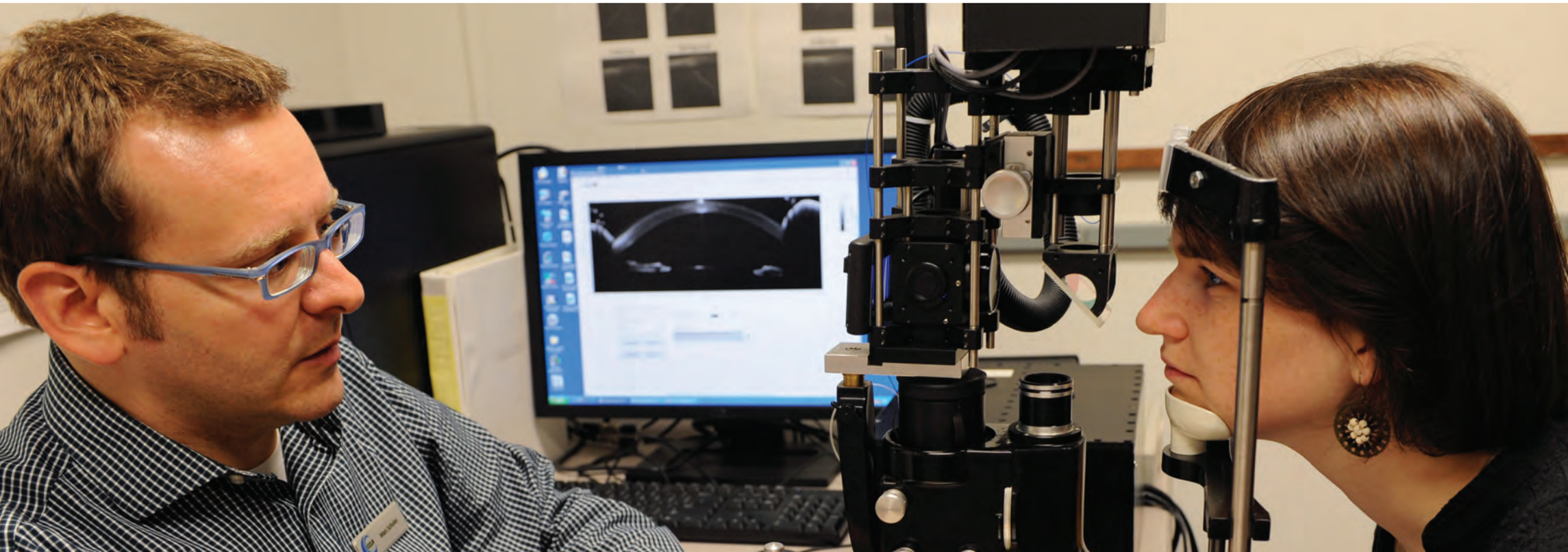
Our roots are in contact lens research.

We played a significant role in the early development and testing of silicone hydrogel lenses and the role of oxygen in corneal health and continue to play a significant role in the development of new contact lens materials, designs and care systems.

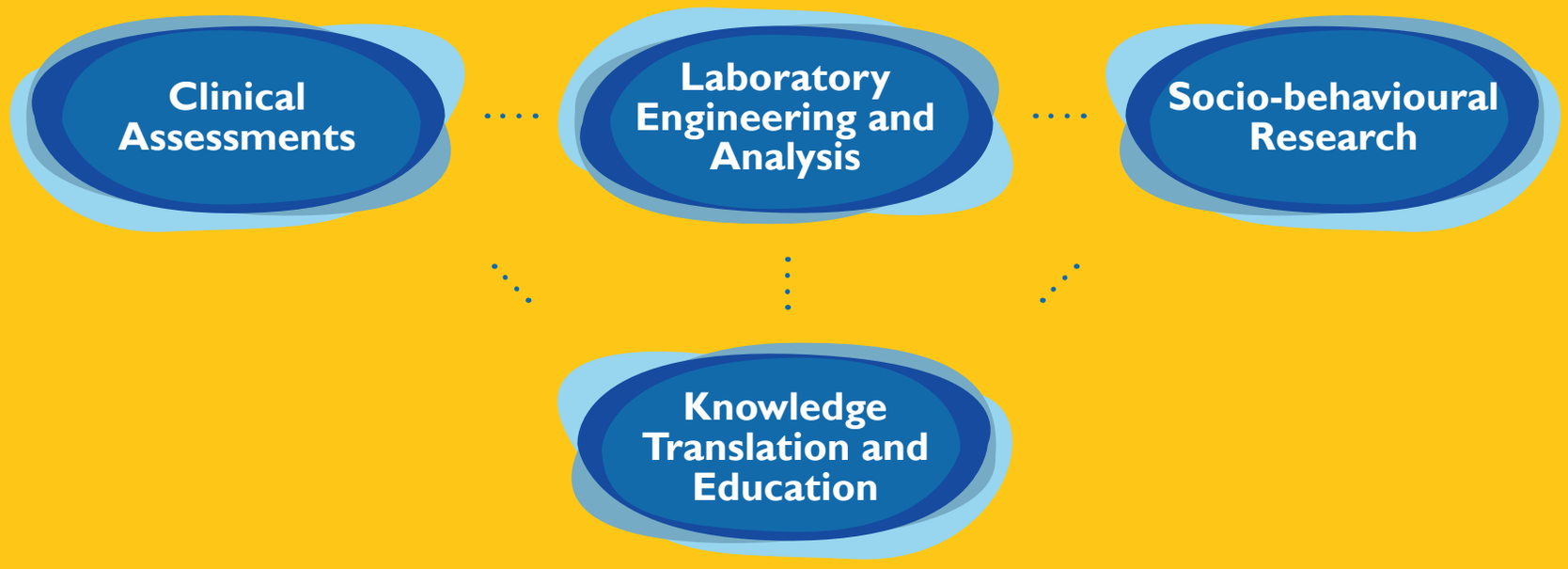
Our research vision has broadened significantly over 25 years.

Lyndon Jones was appointed director in 2011. His vision has continued to inspire our evolution as an integrated site for ocular research and education, combining clinical, laboratory and socio-behavioural methodologies and packaging results in a way that facilitates evidence-based clinical practice.





We have an integrated approach to research, combining clinical, laboratory and socio-behavioural strategies, and packaging results in a way that facilitates evidence-based clinical practice.



Our interests are wide-reaching.

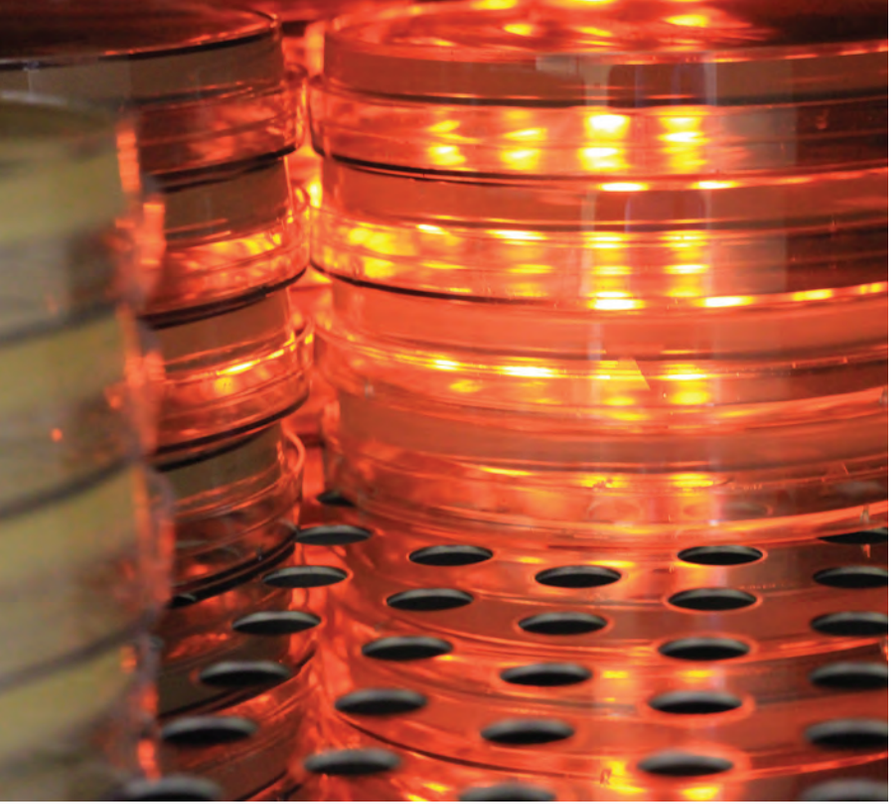
- Biomaterial engineering
- Contact lens materials
- Contact lens care products
- Corneal and conjunctival physiology
- Microbiology and toxicology
- Ocular surface sensitivity and symptoms
- Practitioner, patient and consumer perspectives
- Refractive error correction and control
- Tear film and dry eye
- Visual performance

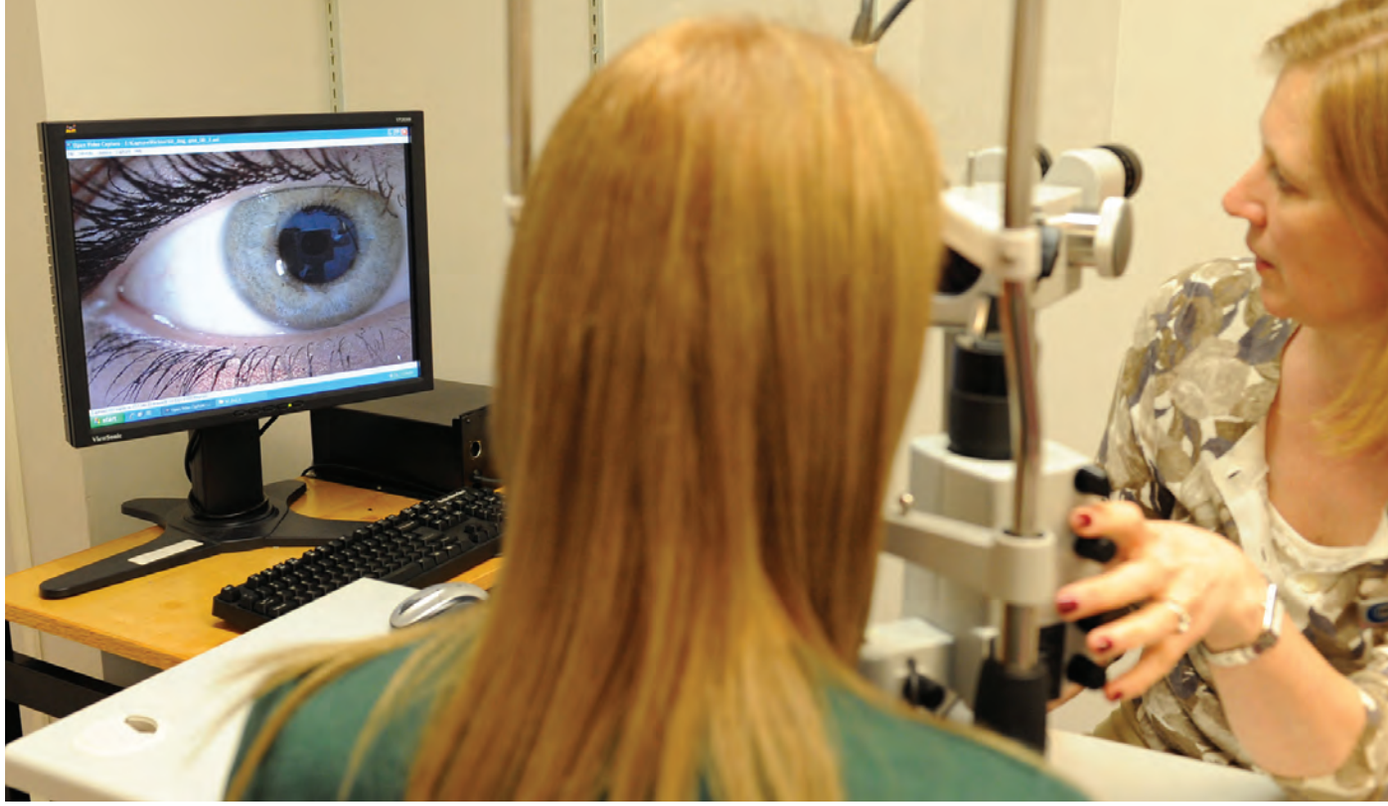
We engage in research on a variety of levels.

- Conception and development
- Execution and analysis
- Conference presentations and manuscript writing
- Graduate and post-doctoral student training
- Knowledge translation
- Provision of continuing education

Our performance is supported by an extensive network of tools, techniques and strategies.

- Advanced research methodologies
- State-of-the-art clinical technology
- Comprehensive laboratory equipment and techniques
- Interdisciplinary collaboration
- Precision imaging innovations





Our Research Facilities

Our facilities are located within the School of Optometry and Vision Science at the University of Waterloo.

- Nine clinical consulting rooms
- Five wet laboratories
- Facilities for overnight clinical studies
- A private video-conference meeting room
- A database of 6000 potential study participants, which can be filtered by:
  - » demographics
  - » lens wear
  - » ocular conditions
  - » custom visual needs

We also have the capacity to collect a variety of biological samples for analysis:

- Blood
- Corneal cells
- Conjunctival cells
- Meibum
- Tear film neurophils
- Tears

Key Publications

Boone A, et al. Uptake and release of dexamethasone phosphate from silicone hydrogel and FDA group I, II, and IV hydrogel contact lenses. *Eye Contact Lens* 2009;35(5): 260-267.

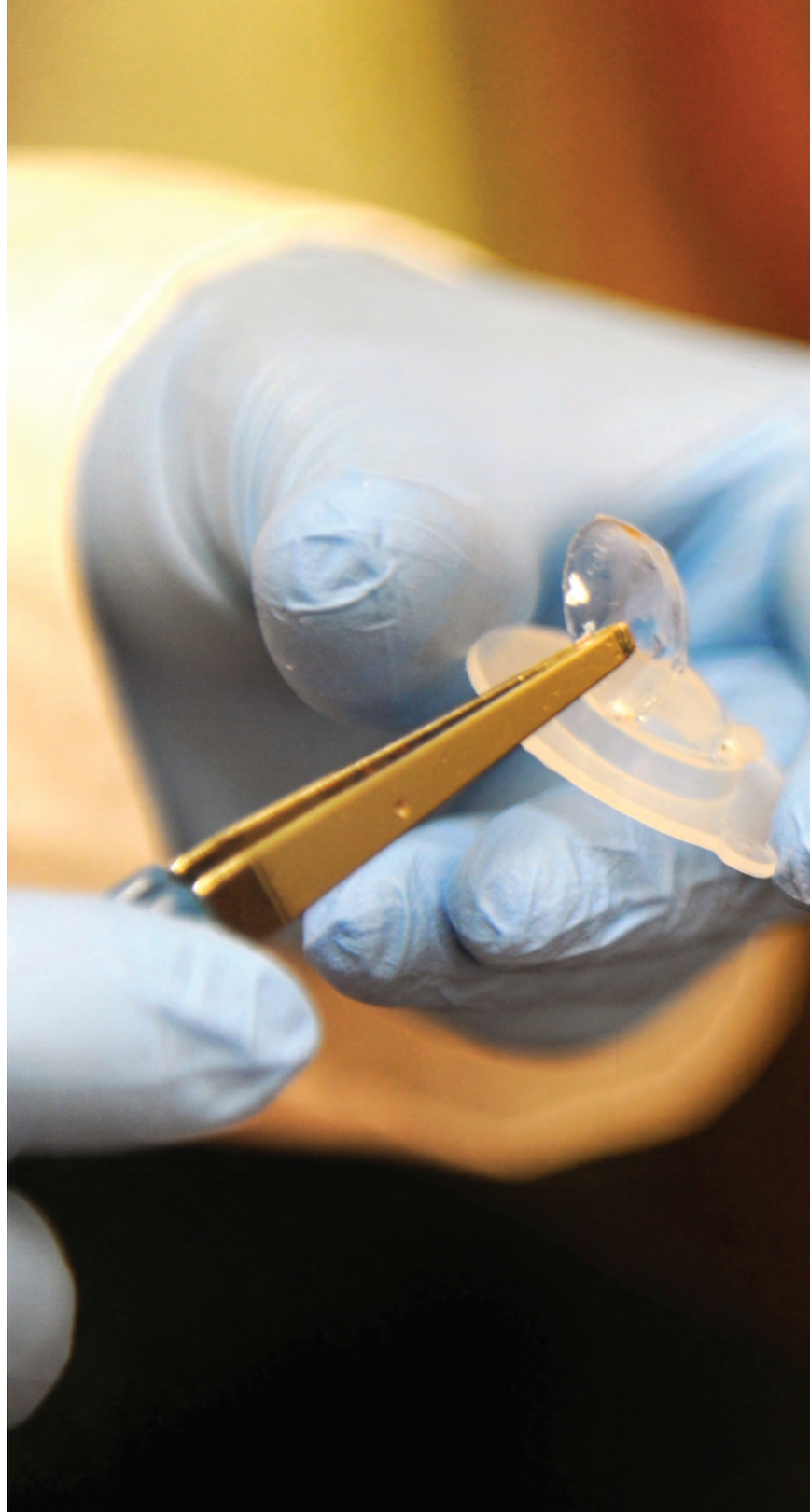
Hui A, et al. Acetic and acrylic acid molecular imprinted model silicone hydrogel materials for ciprofloxacin-HCL delivery. *Materials* 2012;5(1):85-107.

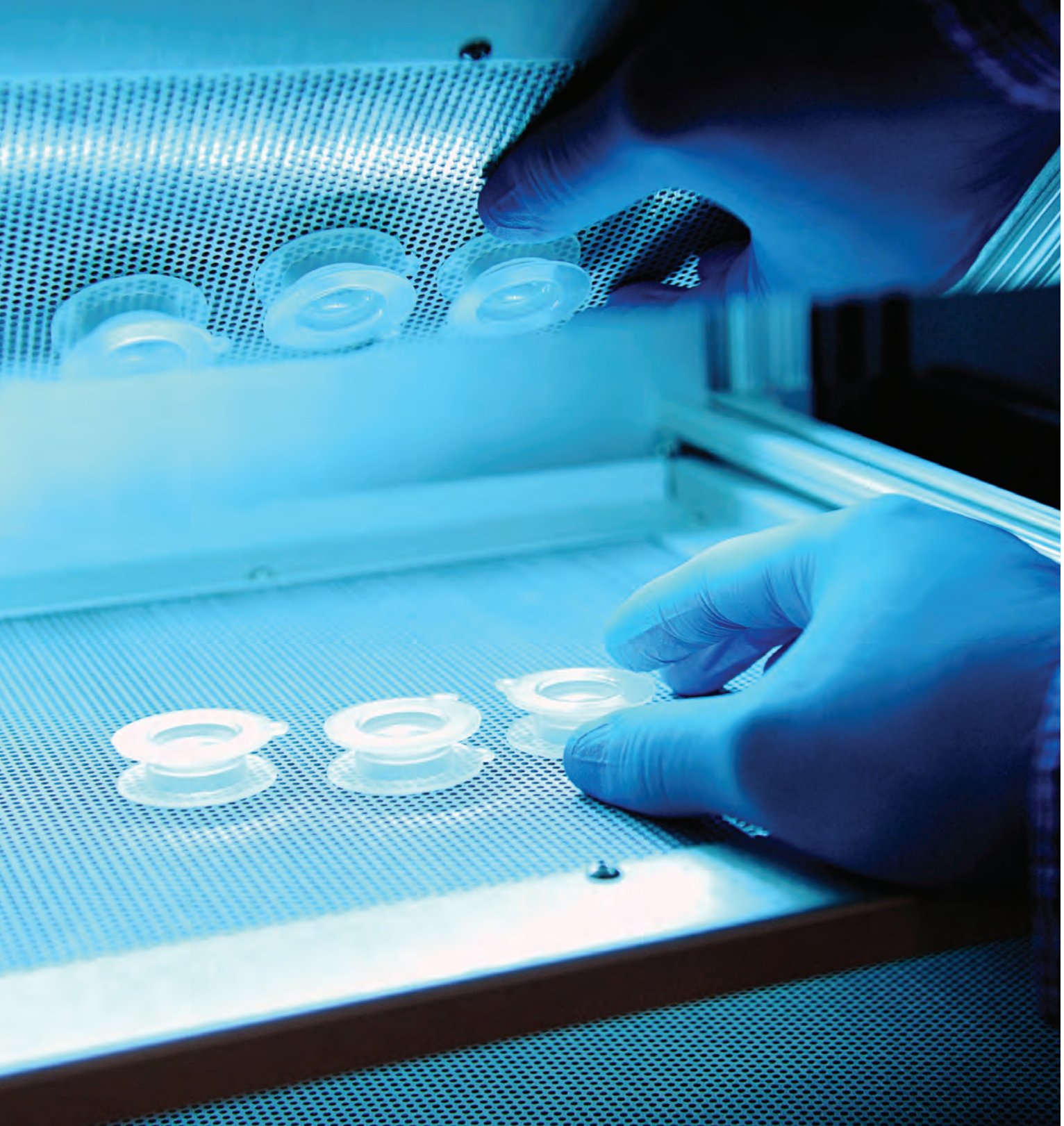
Phan C, et al. *In vitro* uptake and release of natamycin Dex-b-PLA nanoparticles from silicone hydrogel contact lens materials. *Invest Ophthalmol Vis Sci* 2013: e-abstract 501.

Soluri A, et al. Ocular delivery of ketotifen fumarate by commercial contact lens materials. *Optom Vis Sci* 2012;89(8): 1140-1149.

Weeks A, et al. Photocrosslinkable hyaluronic acid as an internal wetting agent in model conventional and silicone hydrogel contact lenses. *J Biomedical Mat Res* 2012;100(8): 1972-1982.

Weeks A, et al. The competing effects of hyaluronic and methacrylic acid in model contact lenses. *J Biomaterials Sci* 2012;23(8): 1021-1038.





Biomaterial Engineering

Our interests and expertise:

- Development of model conventional and silicone hydrogel lens materials
- Engineering of contact lens materials for ocular drug delivery
- Incorporation of novel substances to enhance properties of model lens materials

Laboratory Capabilities

- Characterization and quantification of protein and lipid deposition
- Contact angle analysis
- Nanoparticles and molecular imprinting
- Optical transparency
- Water content analysis

Key Publications

Heynen M, et al. Quantification of non-polar lipid deposits on senofilcon A contact lenses. *Optom Vis Sci* 2011;88(10): 1172-1179.

Lorentz H, et al. The impact of intermittent air exposure on lipid deposition. *Optom Vis Sci* 2012;89(11): 1574-1581.

Luensmann D, et al. Localization of lysozyme sorption to conventional and silicone hydrogel contact lenses using confocal microscopy. *Curr Eye Res* 2009;34(8): 683-697.

Menzies K, et al. The impact of contact angle on the biocompatibility of biomaterials. *Optom Vis Sci* 2010;87(6): 387-399.

Ng A, et al. Impact of tear film components on lysozyme deposition to contact lenses. *Optom Vis Sci* 2012;89(4): 392-400.

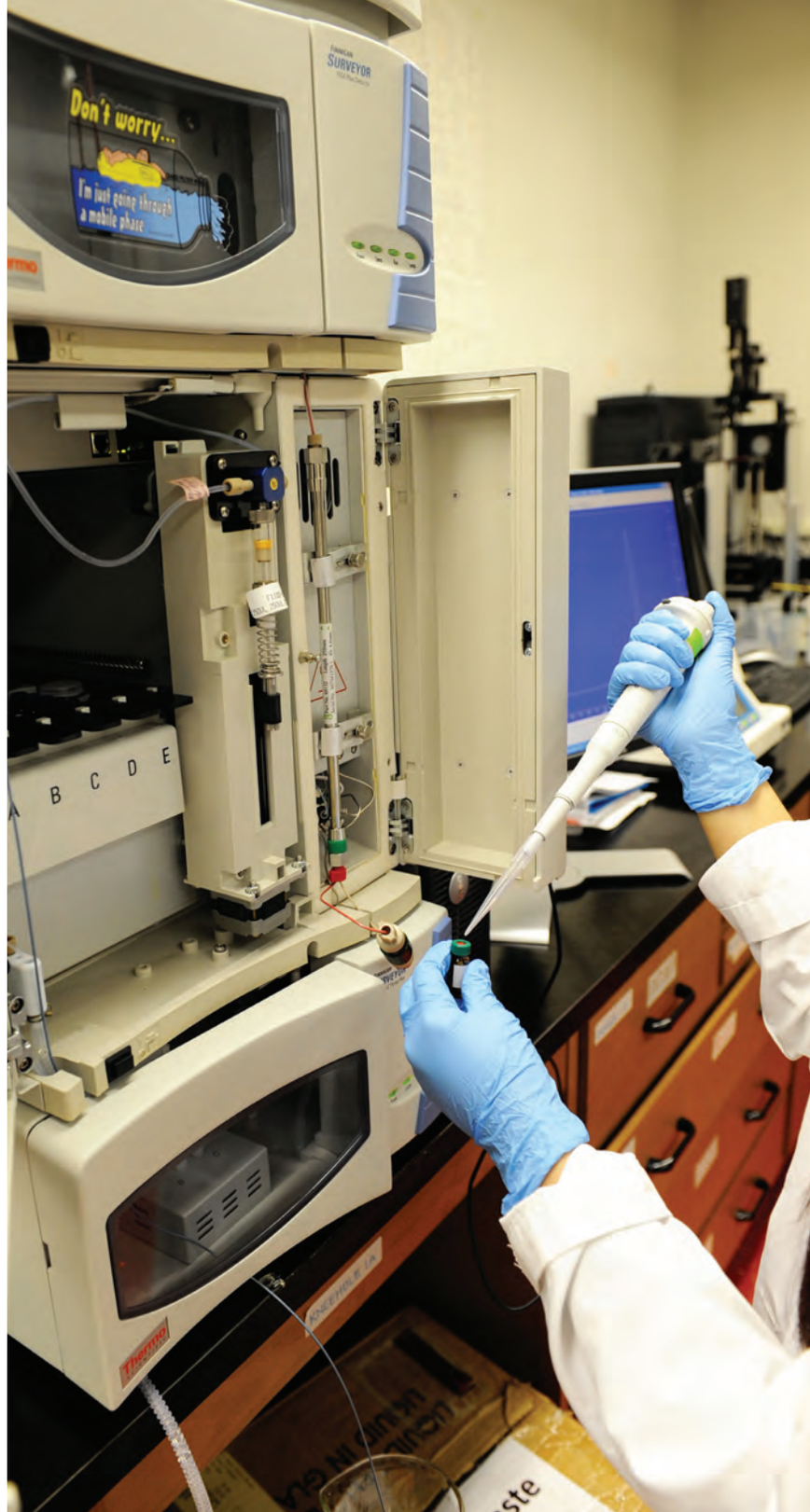
Ng A, et al. Optimization of a fluorescence-based lysozyme activity assay for contact lens studies. *Curr Eye Res* 2013;39(2): 252-259.

Subbaraman L, et al. Kinetics of *in vitro* lysozyme deposition on silicone hydrogel, PMMA, and FDA groups I, II, and IV contact lens materials. *Curr Eye Res* 2006;31(10): 787-796.

Subbaraman LN, et al. Protein deposition and clinical symptoms in daily wear of etafilcon lenses. *Optom Vis Sci* 2012;89(10): 1450-1459.

Teichroeb JH, et al. Imaging protein deposits on contact lens materials. *Optom Vis Sci* 2008;85(12): 1151-64.

Walther H, et al. Factors that influence *in vitro* cholesterol desposition on conventional and silicone hydrogel contact lens materials. *Optom Vis Sci* 2013. In press.



Contact Lens Materials

Our interests and expertise:

- Adherence of cosmetics to lens materials
- Characterization of the surface and bulk properties of contact lens materials
- Clinical correlates of biomaterial properties
- Distribution of tear film deposits within contact lens materials
- Efficacy of ultraviolet ocular protection
- Quantification and characterization of tear film deposits

Laboratory Capabilities

- Atomic force microscopy of topographic features of biomaterials
- Characterization and quantification of protein and lipid deposition
- Confocal microscopy for determination of location of deposits
- Contact angle analysis
- High performance liquid chromatography
- Gas chromatography
- Interferometry to determine water break-up time
- Modeling of *in vitro* blink simulation
- Measurement of physical dimensions
- Nanoparticles and molecular imprinting
- Optical profiling
- Radiolabeling
- Spectroscopy (ultraviolet and fluorescence)
- Surface analysis
- Water content analysis

Clinical Capabilities

- Determination of clinical correlates of biomaterial properties
- Collection of subjective symptoms associated with tear film deposition
- Collection of worn contact lenses for *ex vivo* deposition analysis

Socio-Behavioural Capabilities

- Focus groups
- Interviews

Key Publications

Dalton K, et al. Physical properties of soft contact lens solutions. *Optom Vis Sci* 2008;85(2): 122-128.

Gorbet MB, et al. Effect of contact lens material on cytotoxicity potential of multipurpose solutions using human corneal epithelial cells. *Mol Vis* 2011;17: 3458-3467.

Jones L, et al. 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(12): 753-761.

Lorentz H, et al. Using an *in vitro* model of lipid deposition to assess the efficiency of hydrogen peroxide solutions to remove lipid from various contact lens materials. *Curr Eye Res* 2012;37(9): 777-786.

Luensmann D, et al. The efficiency of contact lens care regimens on protein removal from hydrogel and silicone hydrogel lenses. *Mol Vis* 2010;16: 79-92.

McCanna D, et al. Membrane permeability of *Staphylococcus aureus* aggregates exposed to contact lens care solutions. *Invest Ophthalmol Vis Sci* 2012;53: e-abstract 6089.

Subbaraman LN, et al. Rewetting drops containing surface active agents improve the clinical performance of silicone hydrogel contact lenses. *Optom Vis Sci* 2006;83(3): 143-151.

Woods J, et al. Solution-induced corneal staining (SICS): symptoms and staining patterns. *Optom Vis Sci* 2012;89: e-abstract 125625.

Contact Lens Care Products

Clinical Capabilities

- Biomicroscopic grading with photo and video documentation
- Confocal microscopy (*in vivo*)
- Fluorophotometry
- Hyperemia assessment
- Use of diagnostic stains

Our interests and expertise:

- Antimicrobial efficacy
- Cleaning efficacy
- Cytotoxicity
- Efficacy of rewetting drops
- Physical properties
- Uptake/release of biocides

Laboratory Capabilities

- Viability of ocular surface cells
- High performance liquid chromatography
- Radiolabeling to determine cleaning efficacy
- Viability of microorganisms, including bacteria and fungi
- Viscosity measurement
- Surface tension measurement
- pH measurement
- Osmolality measurement

Socio-Behavioural Capabilities

- Collection of real-world data via custom smartphone technology
- Focus groups
- Interviews
- Questionnaires

Key Publications

Duench S, et al. Impact of silicone hydrogel lenses and solutions on corneal epithelial permeability. *Optom Vis Sci* 2013;90(6): 546-556.

Duench S, et al. Assessment of variation in bulbar conjunctival redness, temperature, and blood flow. *Optom Vis Sci* 2007;84(6): 511-516.

Fonn D, et al. Sympathetic swelling response of the control eye to soft lenses in the other eye. *Invest Ophthalmol Vis Sci* 1999;40(13): 3116-3121.

Moezzi AM, et al. Distribution of overnight corneal swelling across subjects with four different silicone hydrogel lenses. *Eye Contact Lens* 2011;37(2): 61-65.

Schulze M, et al. The development of validated bulbar redness grading scales. *Optom Vis Sci* 2007;84(10): 976-983.

Woods J, et al. Use of a photographic manipulation tool to assess corneal vascular response. *Optom Vis Sci* 2012;89(2): 215-220.

Corneal and Conjunctival Physiology

Clinical Capabilities

- Biomicroscopic grading with photo and video documentation
- Confocal microscopy (*in vivo*)
- Corneal and epithelial thickness
- Corneal permeability
- Corneal topography
- Development of subjective tools and rating scales
- Hyperemia assessment
- Ocular biometry

Our interests and expertise:

- Development of *in vitro* models
- Dry eye disease
- Live imaging of cell morphology
- Ocular response to contact lens wear
- Physical and chemical characterization of the tear film
- Tissue assessment: meibomian glands, lid wiper

Laboratory Capabilities

- Cell culture and analysis
- Cell identification, quantification and viability
- Confocal microscopy
- Cytology and immunohistochemistry
- High-sensitivity radioactive biochemical assays

Key Publications

Gorbet M, et al. The impact of silicone hydrogel-solution combinations on corneal epithelial cells. *Eye Contact Lens* 2013;39(1): 42-47.

Gorbet M, et al. Effect of contact lens material on cytotoxicity potential of multipurpose solutions using human corneal epithelial cells. *Mol Vis* 2011;17: 3458-3467.

Kao ECY, et al. Utilization of *in vitro* methods to determine the biocompatibility of intraocular lens materials. *Toxicol in Vitro* 2011;25(8): 1906-1911.

McCanna D, et al. Efficacy of contact lens solutions against *Achromobacter xylosoxidans* biofilms using confocal microscopy. *Invest Ophthalmol Vis Sci* 2012;54: e-abstract 523.

Subbaraman LN, et al. Influence of protein deposition on bacterial adhesion to contact lenses. *Optom Vis Sci* 2011;88(8): 959-966.

Youn H, et al. *In vitro* ultraviolet-induced damage in human corneal, lens, and retinal pigment epithelial cells. *Molecular Vision* 2011;17: 237-246.

Microbiology and Toxicology

Our interests and expertise:

- Bacterial binding to contact lenses
- Biofilm formation on lens cases and contact lenses
- Efficacy of biomaterials in blocking ultraviolet radiation
- Ocular surface cell response to adverse conditions

Laboratory Capabilities

- Cytotoxicity evaluation
- Enumeration of bacterial/fungal colony forming units
- Flow cytometry
- Identification of Gram positive and Gram negative bacteria
- *In vitro* testing of UV-absorbing ophthalmic products
- Microbial growth under aerobic, anaerobic and CO_2 conditions
- Radiolabeling of bacteria
- Viability of ocular surface cells

Key Publications

Dumbleton KA, et al. Comfort and adaptation to silicone hydrogel lenses for daily wear. *Eye Contact Lens* 2008;34(4): 215-223.

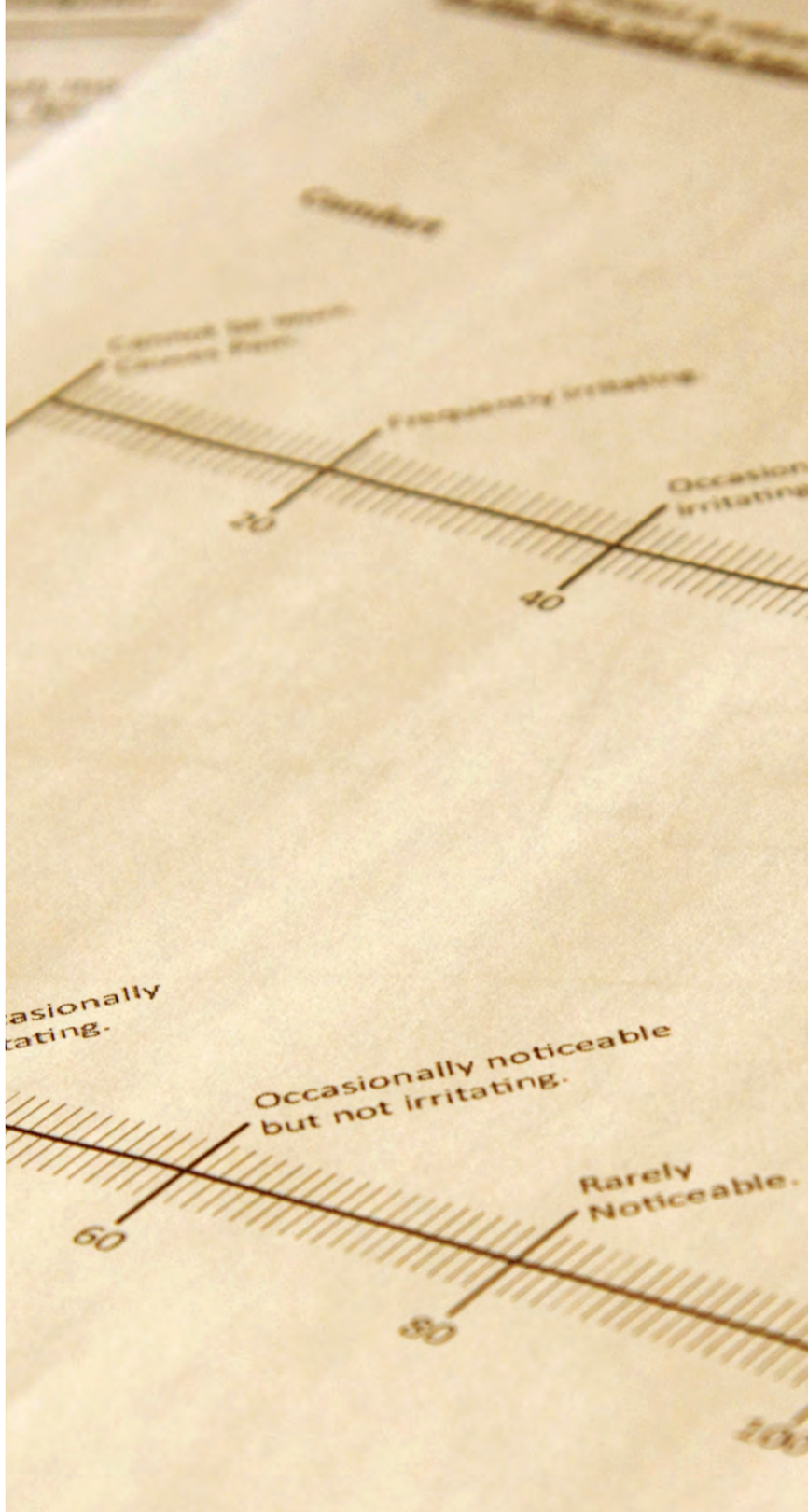
Keir N, et al. End-of-day comfort interpreted using a novel cumulative comfort score. *Invest Ophthalmol Vis Sci* 2012;53: e-abstract 4728.

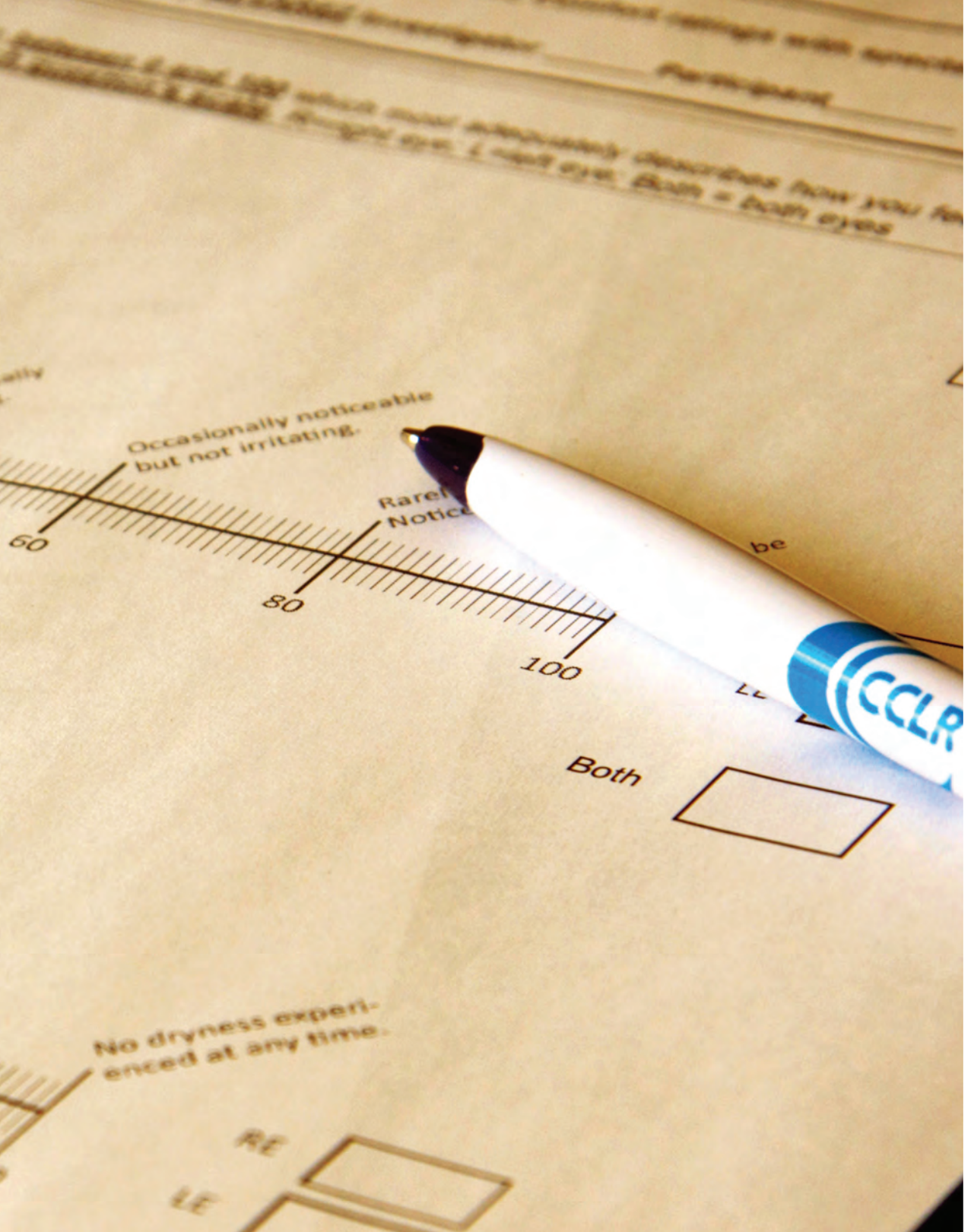
Simpson TL, et al. Dry eye symptoms assessed by four questionnaires. *Optom Vis Sci* 2008;85(8): E692-E699.

Situ P, et al. Interaction of corneal nociceptive stimulation and lacrimal secretion. *Invest Ophthalmol Vis Sci* 2010;51(11): 5640-5645.

Situ P, et al. Effects of silicone hydrogel contact lens wear on ocular surface sensitivity to tactile, pneumatic mechanical, and chemical stimulation. *Invest Ophthalmol Vis Sci* 2010;51(12): 6111-6117.

Srinivasan S, et al. Clinical signs and symptoms in post-menopausal females with symptoms of dry eye. *Ophthalmic Phys Opt* 2008;28(4): 365-372.





Ocular Surface Sensitivity and Symptoms

Our interests and expertise:

- Comfort
- Corneal and conjunctival sensitivity
- Correlation between signs, symptoms and tear film deposition
- Development of subjective rating scales

Clinical Capabilities

- Response to pneumatic, tactile, mechanical and chemical stimulation
- Simultaneous measurements of ocular redness and discomfort

Socio-Behavioural Capabilities

- Collection of real-world subjective data via custom smart phone technology
- Development of subjective tools and rating scales
- Focus groups
- Interviews
- Web-based questionnaires

Key Publications

Dumbleton KA, et al. Exploring compliance: A mixed-methods study of contact lens wearer perspectives. *Optom Vis Sci* 2013;90(8): 898-908.

Dumbleton KA, et al. The relationship between compliance with lens replacement and contact lens-related problems in silicone hydrogel wearers. *Contact Lens Ant Eye* 2011;34(5): 216-222.

Dumbleton K, et al. Comfort and vision with silicone hydrogel lenses: Effect of compliance. *Optom Vis Sci* 2010;87(6): 421-425.

Dumbleton KA, et al. Ability of patients to recall habitual contact lens products and enhancement of recall using photographic aids. *Contact Lens Ant Eye* 2011;34(5): 236-240.

Richter D, et al. Patient and practitioner compliance with silicone hydrogel and daily disposable lens replacement in Canada. *Can J Optom* 2010;72(1): 10-19.

Woods CA, et al. Patient use of smartphones to communicate subjective data in clinical trials. *Optom Vis Sci* 2011;88(2): 290-294.

Practitioner, Patient and Consumer Perspectives

Our interests and expertise:

- Comfort with contact lens products
- Compliance with recommended lens care hygiene and lens replacement schedules
- Development of subjective tools
- Pursuit of qualitative input to shape and answer clinical questions and challenges
- Real-world responses to product performance
- Web-based surveys

Socio-Behavioural Capabilities

- Collection of real-world data via custom smartphone technology
- Cross-disciplinary teams
- Focus groups
- Interviews
- Web-based questionnaires

Key Publications

Lu F, et al. Malleability of the ocular surface in response to mechanical stress induced by orthokeratology contact lenses. *Cornea* 2008;27(2): 133-141.

Sorbara L, et al. Reduction of myopia from corneal refractive therapy. *Optom Vis Sci* 2005;82(6): 512-518.

Paquette L, et al. Ease of contact lens fitting and training in a child and youth population. *Optom Vis Sci* 2011;88: e-abstract 115833.

Woods J, et al. Inhibition of defocus-induced myopia in chickens. *Invest Ophthalmol Vis Sci* 2013;54(4): 2662-2668.

Refractive Error Correction and Control

Our interests and expertise:

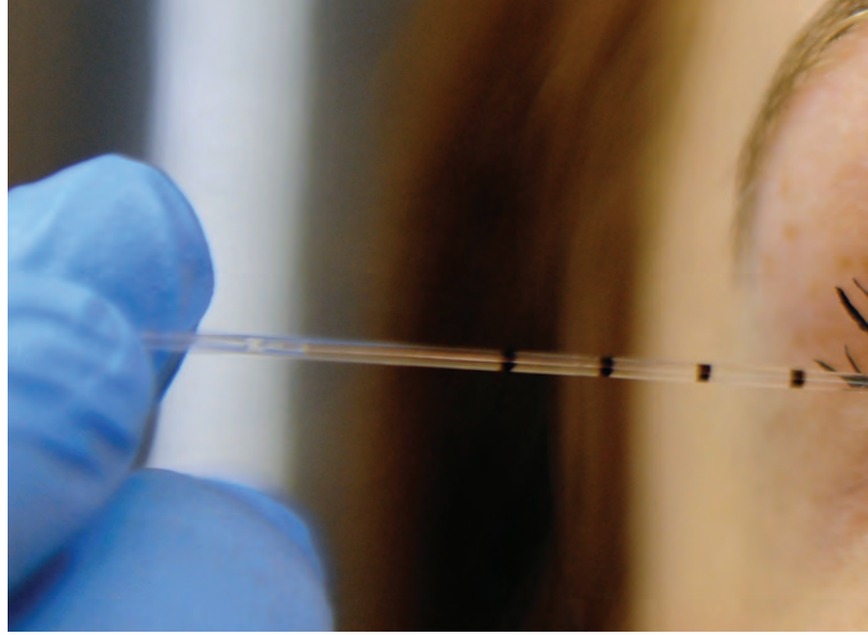
- Myopia prevalence
- Myopia progression in children
- Orthokeratology
- Post-Lasik evaluations
- Prevalence of uncorrected refractive error
- Spectacle studies

Clinical Capabilities

- Aberrometry
- Cycloplegic refraction
- Pediatric studies

Laboratory Capabilities

- Animal models



Key Publications

Keech A, et al. Impact of time between collection and collection method on human tear fluid osmolarity. *Curr Eye Res* 2013;38(4): 428-436.

Keech A, et al. Tear meniscus height determination using the OCT2 and the RTVue-100. *Optom Vis Sci* 2009;86(10): 1154-1159.

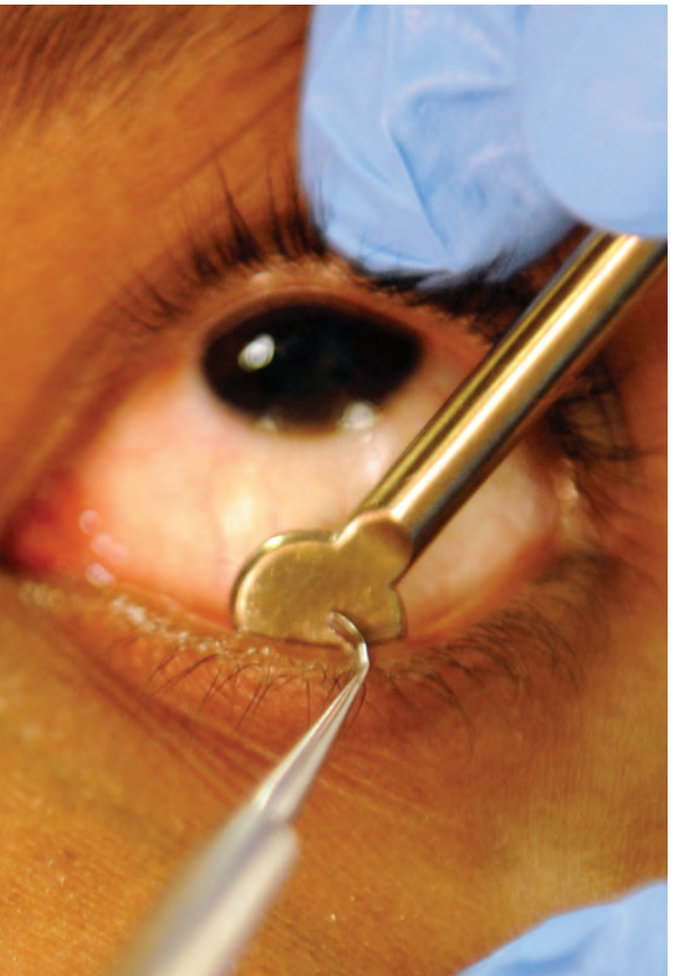
Srinivasan S, et al. Quantification of MUCIN 1, cell surface associated and MUCIN16, cell surface associated proteins in tears and conjunctival epithelial cells collected from postmenopausal women. *Mol Vis* 2013;6(19): 970-979.

Srinivasan S, et al. Infrared imaging of meibomian gland structure using a novel keratograph. *Optom Vision Sci* 2012;89(5): 788–794.

Srinivasan S, et al. Tear osmolality and ferning patterns in postmenopausal women. *Optom Vis Sci* 2007;84(7): 588-592.

Subbaraman L, et al. Tear film cytokine analyses using a novel electrochemiluminescent array technique. *Invest Ophthalmol Vis Sci* 2013;54: e-abstract 1610524.

Varikooty J, et al.. Estimating tear film spread and stability through tear hydrodynamics. *Optom Vis Sci* 2012;89(8): 1119-1124.



Tear Film and Dry Eye

Clinical Capabilities

- Assessment of lid wiper epitheliopathy
- Biomicroscopic grading with photo and video documentation
- Confocal microscopy (*in vivo*)
- Development of subjective tools and rating scales
- Interferometry
- Measurement of lipid layer appearance and thickness
- Meibography
- Tear film break-up time, drainage kinetics, meniscus height, volumetric analysis
- Use of diagnostic stains

Laboratory Capabilities

- Analysis of inflammatory markers
- Cell culture
- Cell identification, quantification and viability
- Characterization of tear film neutrophil phenotypes
- Confocal microscopy
- Cytology and immunohistochemistry
- High-sensitivity radioactive biochemical assays
- Meibum analysis
- Osmolality
- Quantification and characterization of proteins and lipids
- Tear ferning
- Tear film stability

Our interests and expertise:

- Development of *in vitro* models
- Dry eye disease
- Live imaging of cell morphology
- Ocular response to contact lens wear
- Tear film characterization (physical and chemical)
- Tissue assessment, including the meibomian glands and lid wiper

Key Publications

Keir NJ, et al. Outcomes of wavefront-guided laser *in situ* keratomileusis for hyperopia. *J Cataract Ref Surg* 2011;37(5): 886-893.

Keir NJ, et al. Wavefront-guided LASIK for myopia: Effect on visual acuity, contrast sensitivity, and higher order aberrations. *J Ref Surg* 2009;25(6): 524-533.

Woods J, et al. Early symptomatic presbyopes - What correction modality works best? *Eye and Contact Lens* 2009;35(5): 221-226.

Woods J, et al. Using objective tests and novel subjective rating assessments to compare the performance of a new silicone hydrogel multifocal lens design to monovision. *Contact Lens Ant Eye* 2009;32(5): 232.

Woods J, et al. Comparison of the simplicity of completing an initial fit of symptomatic early presbyopes with monovision and an aspheric multifocal silicone hydrogel. *Optom Vis Sci* 2008;85: e-abstract 80089.

Visual Performance

Our interests and expertise:

- Monovision and multifocal lenses
- Spectacle lenses
- Toric contact lenses
- Use of objective vision assessments to predict subjective satisfaction

Clinical Capabilities

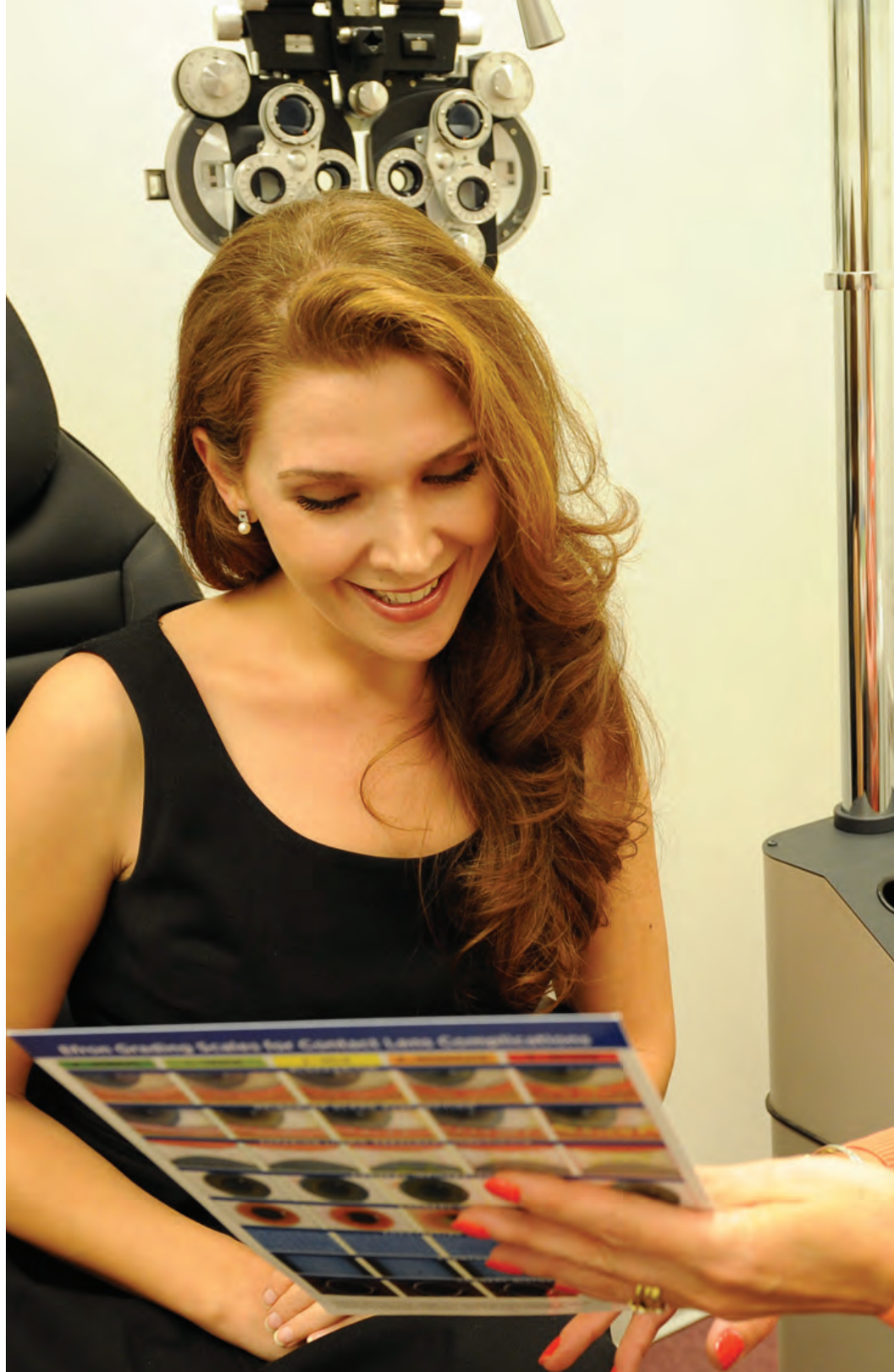
- Aberrometry
- Computerized vision charts
- Contrast sensitivity
- Convergence, phoria and amplitude of accommodation assessments
- Glare/halo evaluation
- Peripheral refraction
- Stereoacuity
- Visual acuity

Socio-Behavioural Capabilities

- Collection of real-world data via custom smartphone technology
- Focus groups
- Interviews

Key Educational Projects

- www.contactlenscompendium.com: A guide to contact lenses in Canada
- www.contactlensupdate.com: Clinical insights grounded in current research
- *All About Meibomian Gland Dysfunction: A guide for patients*
- *Can Kids Wear Contact Lenses? A guide for parents*
- *Correction of Presbyopia with GP Contact Lenses: a practitioner manual*
- *Correction of Keratoconus with GP Contact Lenses: a practitioner manual*
- *Research-in-Brief: Let's Talk About SICS: A guide for practitioners*



Knowledge Translation

The CCLR is dedicated to providing eye care professionals and the general public with information and educational tools in a variety of accessible formats. Please contact us for help transforming your information into evidence-based educational materials.

For eye care professionals

We are committed to sharing global research outcomes with eye care professionals, to support and facilitate their capacity to provide evidence-based patient care.

- Articles published in professional journals
- Clinical conference presentations and workshops
- Conference reporting
- Educational websites
- Information resources
- Manuals and fitting guides
- Video modules and podcasts

For the research community

We regularly share our research results and collaborate with other international research groups.

- Articles published in peer-reviewed journals
- Membership in research organizations
- Paper and poster presentations at scientific conferences and meetings

For the general public

We provide accessible information about ocular physiology, ocular conditions and eye care in plain language for the general public.

- Educational websites
- Fact sheets
- Interactive, informal lectures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Regulatory Compliance

Clinical studies conducted at the CCLR are designed to comply with the following guidelines:

- The ethical principles outlined in the Declaration of Helsinki
- The Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (2nd edition).
- The University of Waterloo's guidelines for research with human participants
- The International Conference on Harmonisation guidelines for good clinical practice

Clinical study protocols require clearance from the Clinical Research Ethics Committee at the University of Waterloo. Health Canada approval is further required for studies using investigational medical devices or drugs.

Animal study protocols require clearance from the Animal Care Committee at the University of Waterloo.

Data security and integrity

We care about the security and integrity of our data, and have the capacity to provide a variety of data management solutions:

- Paper or electronic data entry
- Standard or FDA-compliant databases
- Double data entry

Graduate and Post-Doctoral Training

The strength and diversity of the CCLR's clinical and laboratory-based research has attracted graduate students and post-doctoral fellows from a wide range of countries and with a variety of educational backgrounds, including biomedical science, chemistry, engineering, optometry and microbiology.

Graduate and post-doctoral work is integrated seamlessly into the CCLR's overall research agenda. Students and fellows are encouraged to contribute ideas and share their expertise in addition to presenting their own work at international conferences and interacting with the wider research community.

Contributions to Professional Development

Our researchers are available to speak on a variety of special topics. Most recently, our lectures have included the following subjects:

Emerging trends and technologies

- Myopia: A world-wide epidemic
- Myopia control in a pediatric population
- New animal research in myopia

Needs of specific populations

- Contact lenses for the emerging presbyope
- Keratoconus fitting
- Kids and contact lenses
- Multifocal contact lens wear
- Presbyopic contact lens fitting
- Impact of compliance: safety/lens performance

Comfort and dryness symptoms

- Comfortable contact lenses - a realistic dream?
- Dry eye disease vs. contact lens dry eye
- Nutrition and dry eye

Technology and techniques

- Corneal imaging techniques
- Extraction of mucin from hydrogel contact lenses
- Ocular surface sampling techniques
- Ocular tear film assessment

Physiological effects of contact lens wear

- Conjunctival response to soft contact lens wear
- Corneal staining and contact lens wear
- Critical oxygen transmissibility
- Infiltrates and contact lens wear
- Meibomian gland dysfunction
- Physiological benefits of silicone hydrogel lenses
- Red eyes and contact lenses

Lens and solution updates

- Disinfecting solutions
- Future of contact lenses and care products
- Specialty contact lenses
- Novel contact lens materials for drug delivery
- *In vitro* dehydration rates of lens materials
- Soft contact lens wettability and comfort

Biocompatibility, deposition and interactions

- Lens solutions and the tear film/ocular surface
- Corneal sensitivity and sensation
- Impact of tear film components on *in vitro* lipid uptake to contact lens materials
- Lipid deposition on silicone hydrogel lenses

Study Capacity

In addition to pursuing the answers to fundamental scientific questions, we have the capacity to conduct the following types of studies, as recommended by Health Canada and the United States Food and Drug Administration (FDA):

Pre-clinical studies determine the *in vitro* toxicity and/or evaluate the anti-microbial efficacy of products.

PHASE II clinical trials evaluate the effectiveness of a product for a particular indication, and determine short-term side effects and risks.

PHASE III clinical trials gather additional information to evaluate a product's overall benefit-risk relationship after preliminary evidence has been obtained.

PHASE IV clinical trials (post-marketing studies) gather additional information, including a product's risks, benefits and optimal use.

Local Resources

Study participants

The Region of Waterloo has a young, growing and diverse population, representing a large demographic cross-section[1]. It comprises:

- One of Canada's fastest growing populations
- Two universities and one community college
- A thriving high-tech industry within a prosperous rural region
- A median age of 38 years[1]
  - » 12% aged 5-14
  - » 35% aged 15-39
  - » 38% aged 40-65
- A wide range of ethnic diversity, with ties to South and Southeast Asia; the Caribbean; Latin, Central and South America; Africa; the Middle East and Europe.[2]

Community outreach

We establish connections with local residents by attending community events, providing eye care information for the public, and carrying out promotional activities.

Partnerships with local eye care professionals

We continue to build a mutually beneficial relationship with local optometrists, ophthalmologists and opticians, providing them with information and resources in return for assistance with participant recruitment.

[1] Population by selected ethnic origins, Kitchener-Cambridge-Waterloo. 2006 Census, Statistics Canada.
[2] Region of Waterloo Census Bulletin, 2006.

Laboratory Technologies

Measurement	Techniques and Instruments
Tear Film Analysis	
Cytokine analysis	Enzyme linked immunosorbent assay (ELISA)
Ferning	Axiovert 40CFL microscope (Zeiss)
Lipid analysis	Surveyor High Performance Liquid Chromatography System (Thermo Finnigan) Thin layer chromatography TRACE GC Ultra Gas Chromatograph (Thermo Scientific Inc.) Colourimetrics
Protein analysis and quantification	Enzyme linked immunosorbent assay (ELISA) Vertical and horizontal electrophoresis and immunoblotting: Phast System™ and SE 600 Ruby Standard Dual Cooled Vertical Unit (GE Biosciences), Midi Gel system (Novex®), Mini-systems (Bio-Rad Laboratories, Inc.), Storm 840 (Molecular Dynamics) Surveyor High Performance Liquid Chromatography System (Thermo Finnigan)
Osmolality	Osmometer (Vapro 5520)
Meibum Analysis	
Lipid analysis	Surveyor High Performance Liquid Chromatography System (Thermo Finnigan) Thin layer chromatography Nuclear magnetic resonance (NMR), Bruker 500 and 600 MHz high resolution with solid capabilities (in collaboration with the Department of Chemistry, University of Waterloo) TRACE GC Ultra Gas Chromatograph (Thermo Scientific Inc.)
Corneal Cell Collection and Analysis	
Cell identification / phenotype	FACScan flow cytometer (Becton Dickinson and Company), in collaboration with the Department of Systems Design Engineering, University of Waterloo Immunohistochemistry Cytology - microscopic evaluation Eclipse TE2000-S (Nikon Instruments, Inc.) with motorized stage (Applied Scientific Instrumentation) Axiovert 40CFL microscope (Zeiss)

Laboratory Technologies

Measurement	Techniques and Instruments
Cytotoxicity – *in vitro*	Metabolic assays Confocal microscope (Zeiss LSM 510 Meta, Axiovert) UV/vis/fluorescence microscopy (Eclipse TE2000-S (Nikon Instruments, Inc.) with motorized stage (Applied Scientific Instrumentation) Axiovert 40CFL microscope (Zeiss)
Conjunctival Analysis	
Cytology	Eclipse TE2000-S (Nikon Instruments, Inc.) Axiovert 40CFL microscope (Zeiss)
Protein analysis	Enzyme linked immunosorbent assay (ELISA) Plate Readers: Multiskan (Thermo Lab Systems) Spectramax M5e (Molecular Devices) Vertical and horizontal electrophoresis and immunoblotting: Phast System and SE600 systems (GE Biosciences) Midi systems (Novex®) Mini systems (Bio-Rad Laboratories, Inc.) Storm 840 (Molecular Dynamics)
RNA regulation	RNA isolation - PCR (in collaboration with the Department of Biology, University of Waterloo)
Contact Lens Materials	
Defects	Bright/dark field microscopy: STEMI SR (Zeiss)
Diameter	Wet cell analysis: Chiltern (Optimec Limited)
Effect of air exposure	*In vitro* model blink cell (custom)
Inflammatory markers	Enzyme linked immunosorbent assay (ELISA)

Laboratory Technologies

Measurement	Techniques and Instruments
Lipid deposits	Surveyor High Performance Liquid Chromatography System (Thermo Finnigan) Thin layer chromatography *In vitro* radiolabeling: Savant SpeedVac® (Thermo Fisher Scientific, Inc.), 1470 Wallac Wizard (PerkinElmer, Inc.), LSC6200 (Beckman Coulter, Inc.) Thermo Trace GC Ultra gas chromatograph (Thermo Fisher Scientific, Inc.) Colourimetric kits
Moisture analysis	Moisture analyzer (MA100, Sartorius)
Power profile	Contest Plus (ROTLEX)
Protein deposits	Enzyme linked immunosorbent assay (ELISA) Vertical and horizontal electrophoresis and immunoblotting: Phast System and SE600 systems (GE Healthcare Life Sciences), Midi systems (Novex®) Mini systems (Biorad Laboratories, Inc.), Storm 840 (Molecular Dynamics) Surveyor High Performance Liquid Chromatography System (Thermo Finnigan) *In vitro* radiolabeling tracer studies: Savant SpeedVac® (Thermo Fisher Scientific Inc.), 1470 Wallac Wizard (PerkinElmer, Inc.), LSC6200 (Beckman Coulter, Inc.) *In vitro* colourimetric analysis: UV/Vis and Fluorescence spectrophotometers Spectramax M5e Multi-Mode Microplate Reader (Molecular Devices, LLC) MultiSkan® Spectrum (Thermo Fisher Scientific, Inc.)
Radius	Radiuscope (Reichert, Inc.)
Surface wettability	Contact angle analysis (Contact Angle System OCA)
Thickness	Digital thickness gauge (Rehder)
Topography	Nanowizard® II atomic force microscope (JPK Instruments), in collaboration with the Department of Physics, University of Waterloo)
Water content analysis	Moisture analyzer (Sartorius)
Water break-up	CA-100F Corneal Analyser (Topcon)

Laboratory Technologies

Measurement	Techniques and Instruments
Lens Care Systems	
Cleaning efficacy (proteins and lipids)	*In vitro* Radiolabeling tracer studies: Savant SpeedVac® (Thermo Fisher Scientific Inc.) 1470 Wallac Wizard (PerkinElmer, Inc.) LSC6200 (Beckman Coulter, Inc.)
Cleaning efficacy (proteins and lipids)	*In vitro* colourimetric analysis: UV/Vis and Fluorescence spectrophotometers Spectramax M5e (Molecular Devices) MultiSkan® Spectrum (Thermo Fisher Scientific, Inc.)
Physical characteristics	Viscometer (ViscoLab 300) pH meter (Symphony SB20, VWR) Osmometer (Vapro 5520)
Microbiology and Toxicology	
Anti-microbial efficacy of lens care systems	Culture growth, inoculum preparation
Bacterial adhesion	Inoculum preparation: Radio-labelling, plate count method
Bacterial growth	Inoculum preparation: MTT assay
Biofilm assay	Culture growth, inoculum preparation: Crystal violet staining
Biofilm testing	Fluorescent viability dyes: Zeiss LSM 510 Meta, Axiovert 40CFL microscope (Zeiss)
Microbial contamination	Plate count method
Microbial identification	Culture growth

Laboratory Technologies

Measurement	Techniques and Instruments
Biomaterial Engineering	
Molecular imprinting	UV oven, model 2000 flood light curing system (Dymax®)
Uptake and release of drugs for delivery to eye	Surveyor High Performance Liquid Chromatography System (Thermo Finnigan) UV/Vis/Fluorescence spectroscopy (Spectramax M5e (Molecular Devices), MultiSkan® Spectrum (Thermo Fisher Scientific, Inc.), Fluorimeter, (F4500, Hitachi, Ltd.)
Toxicology	
Cytotoxicity	Alamar Blue, MTT assay
In vitro cell culture	Biological safety cabinet (Forma Scientific) CO_2, water-jacketed incubators (Sanyo MCO-20A1C and Forma 3110)
Immunohistochemistry	Eclipse TE2000-S (Nikon Instruments, Inc.) with motorized stage (Applied Scientific Instrumentation) Axiovert 40CFL microscope (Zeiss) FACScan flow cytometer (Becton Dickinson and Company), in collaboration with the department of Systems Design Engineering, University of Waterloo Confocal microscope LSM 510 Meta, Axiovert (Zeiss)

Clinical Technologies

Measurement	Clinical Techniques and Instruments
Aberrometry	
Ocular aberrations	COAS™ Precision Aberrometer (AMO WaveFront Sciences, Inc.) LADARWave™ (Alcon)
Surface aberrations	CA-100F/CA-200F Corneal Analyser (Topcon Medical Systems, Inc.)
Clinical Assessment	
Automated redness (bulbar & limbal)	Keratograph 5M (OCULUS, Inc.) PR-650 SpectraScan® spectrophotometer (Photo Research, Inc.)
Biomicroscopy	Biomicroscopic grading with photo and video documentation
Contrast sensitivity	Rabin, MARS, FACT vision charts
Corneal cell imaging	Heidelberg Retinal Tomograph 3 with Rostock Corneal Module (Heidelberg Engineering, Inc.) Confoscan 3 (Nidek Technologies)
Corneal curvature	KR-8800 Auto-Refractor (Topcon Medical Systems, Inc.)
Meibography	Keratograph 5M (OCULUS, Inc.)
Fixation disparity	Mallet box
Objective refraction	KR-8800 Auto-Refractor (Topcon Medical Systems, Inc.)
Phoria	Phoropter
Stereoacuity	Stereo Butterfly SO-005 Random Dot Stereotest (Stereo Optical Co., Inc.)
Visual acuity assessment (high and low contrast)	Computerized vision charts (Custom)
Comfort and Sensitivity	
Comfort and redness (simultaneous)	Comfort-scope (Custom)
Corneal sensitivity (response to pneumatic, tactile, mechanical and chemical stimuli)	Adapted Belmonte esthesiometer (Custom) Cochet-Bonnet esthesiometer

Clinical Technologies

Measurement	Clinical Techniques and Instruments
Contact Lens Performance	
Lens movement & centration (automated)	High-speed video slit lamp (Custom)
Deposits	Biomicroscopic photo and video documentation
Clearance on eye (gas permeable or scleral lenses)	Ultra-long OCT (Custom) Visante OCT (Zeiss)
Multifocal lens centration & power profile (on eye)	E300 Corneal Topographer (Medmont) High-speed video camera
Wettability (on eye)	Biomicroscopic grading with photo and video documentation
Tear Film Assessment	
Dynamics (particle tracking)	Slit lamp with high speed video Keratograph 5M (OCULUS, Inc.)
Lipid layer quality	Keratograph 5M (OCULUS, Inc.) TearScope (Keeler Ophthalmic Instruments)
Lipid layer thickness	LipiView® (Tear Science®)
Meniscus height	Ultra-long OCT (Custom) RT-Vue 100 OCT (Optovue, Inc.) Keratograph 5M (OCULUS, Inc.)
Meniscus area	Ultra-long OCT (Custom)
Non-invasive break-up time (automated)	Keratograph 5M (OCULUS, Inc.)
Non-invasive break-up time (manual)	Tearscope PLUS (Keeler Ophthalmic Instruments) Atlas™ Corneal Topographer (Zeiss) E300 Corneal Topographer (Medmont)
Osmolarity	Osmometer (TearLab™)
Turnover rate	Fluorotron™ Master Ocular Fluorophotometer (OcuMetrics, Inc.)

Clinical Technologies

Measurement	Clinical Techniques and Instruments
Ocular Biometry	
Axial length	Lenstar LS 900® (Haag Streit Diagnostics) IOL Master (Zeiss)
Anterior chamber depth	Visante optical coherence tomographer (Zeiss) IOL Master (Zeiss) Pentacam® HR (OCULUS, Inc.)
Corneal diameter (white-to-white)	Pentacam® HR (OCULUS, Inc.) Lenstar LS 900 (Haag Streit Diagnostics)
Corneal thickness	Digital optical pachymeter (Custom software) mounted on 30 SL-M slit lamp (Zeiss) Ultra-long OCT (Custom) Visante OCT (Zeiss) Pentacam HR (OCULUS, Inc.) Heidelberg Retinal Tomographer 3 with Rostock Corneal Module (Heidelberg Engineering, Inc.)
Corneo-scleral junction angle	Ultra-long OCT (Custom)
Corneal topography	Keratograph 5M (OCULUS, Inc.) Medmont E300 (Medmont)
Endothelial cell analysis	Heidelberg Retinal Tomographer 3 with Rostock Corneal Module (Heidelberg Engineering, Inc.)
Ocular shape	Ultra-long OCT (Custom)
Peripheral refraction	WAM 5500 Autorefractor/Keratometer (Grand Seiko Co., Ltd.)
Tissue Collection	
Blood	Venipuncture
Conjunctival cells	Impression cytology
Corneal cells	Saline irrigation via Ocular Surface Cell Collection Apparatus (Custom)
Tears	Capillary tubes Eyewash

General Inquiries

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