

Contact Lenses in 2020 and Beyond: What Does the Future for Contacts Look Like?



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Lyndon Jones PhD, DSc, FCAHS, FCOptom, FFAO Financial Disclosures


Over the past three years, members of CORE have received research funding and/or honoraria from the following 15 companies & 3 funding agencies:

- Alcon
- Allergan
- Contamac
- CooperVision
- GL Chemtec
- Inflamx Research
- Johnson & Johnson Vision
- Menicon
- Nature's Way
- Novartis
- Safilens
- Santen
- Shire
- SightGlass
- Visioneering





The Future?

Summary





Revolutionary future uses of contact lenses. *Optom Vis Sci* April 2016




Detection of Ocular Disease

Wearable Sensor Market

- Market for wearable technology is expected to reach \$US 31.27 Billion by 2020, at annual growth rate of 17.8%
 - smartwatches
 - wristbands
- Major players
 - Adidas; Apple; Fitbit; Garmin; Google; Nike; Samsung; Sony

A MUCH More Diversified Market Than Investors Realize



Clothing?

Netflix has created 'smart' socks that sense when you fall asleep and pause the show you're watching

Patent No. US 2017042280 A1
Feb. 16, 2017

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"Smart" CL System

Technology Overview

- Smart Contact Lens**
 - Sensor
 - ASIC
 - Antenna
 - Contact Lens
- RF Reader**
 - NFC module
 - Bluetooth module
- Software**
 - Android app
 - iOS app
 - Data science
 - Back end infrastructure

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J&J; Samsung; Sony; Medella Health

>100 patents since 2012

United States Patent Application Publication
Pub. No. US 2017042280 A1
Feb. 16, 2017

INVENTOR CONTACT LENS AND RELATED SYSTEMS
Medella Health Inc., Inventor: J. J. ...
Samsung, Inventor: ...
Sony, Inventor: ...
J&J, Inventor: ...

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CL Monitoring Devices

Glaucoma

- Sensimed Triggerfish®
- "Smart" contact lens with tiny embedded strain gauge to monitor curvature of the eye over a period of 24 hours
- Looks at relative changes in IOP
 - not absolute values
- Silicone-based (Dk~350)
- Thickness ~ 600µm
 - Dk/t ~ 60
 - hypoxia with overnight wear
- Single-use only

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1. Mansour, A. & Wainwright (2012) Continuous 24-hour intraocular pressure monitoring for glaucoma-free for a paradigm change. *Retina* 32(14): 2412-2416
 2. Mansour, A. & Wainwright (2012) Meeting an unmet need in glaucoma: continuous 24-h monitoring of intraocular pressure. *Expert Rev Med Devices*, 8(5): 225-231
 3. Gopal, et al (2015) Feasibility of 24-hour intraocular pressure monitoring of a pressure-sensitive contact lens. *J Glaucoma*, 24(6): 311-316
 4. Mansour, et al (2015) Efficacy of a contact lens sensor for monitoring 24-h intraocular pressure-related patterns. *PLoS One*, 10(5): e0125530

FDA Approval: March 2016

FDA grants marketing approval for Triggerfish IOP monitoring device

The FDA approved the marketing of the Triggerfish device, a soft silicone lens with an embedded sensor that detects key changes in backscatter in the eye's vitreous, according to an agency press release.

Key Takeaways:

- The Triggerfish device is a soft silicone lens with an embedded sensor that detects key changes in backscatter in the eye's vitreous, according to an agency press release.
- The information can help determine the most critical time of day for the clinician to measure the patient's IOP.
- William H. Hargett, MD, MPH, acting director of the Office of Device Evaluation in the FDA's Center for Devices and Radiological Health, said in the release.

Features:

- Highlights from the November 2015 meeting.
- 2015 New York
- 2015 New York
- 2015 New York
- 2015 New York

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Biosensing Contacts

ANALYTE (glutamines, proteins, antibodies, quantum dots, DNA) → **BIORECEPTOR** → **TRANSDUCER** (Absorption, Refraction index, Fluorescence, Photophosphorescence, Reflectivity, Wavelength) → **MEASURABLE SIGNAL** (LDs, Photodiodes, Phototransistors, CCDs) → **Data processing**

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Contact Lenses for Detection of Diabetes?

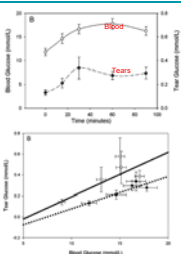
- 382 million diabetics worldwide
- Daily monitoring of blood glucose is intrusive
 - diabetic patient pricks their finger 1800 times a year
- Different body fluid such as urine, saliva or tears could be monitored
- The glucose monitoring devices market is expected to be more than **\$20 billion** by the end of 2020
- Tears are easily accessible
 - but takes **more than 10 mins** to collect enough tears in a capillary tube to test



CORE | Zhang et al. Non-invasive diagnostic devices for diabetes through measuring tear glucose. J Diabetes Sci Tech 2011;5:166-72.

Blood vs Tear Glucose

- Poor correlation between blood and tears for glucose levels in **non-diabetics**
- Excellent correlation for **diabetics** ($R^2 > 0.8$)
- Unable to develop a viable CL-based detection product at the time due to technical limitations



CORE | Lane et al. Tear glucose dynamics in diabetes mellitus. Curr Eye Res 2006;31:895-901

Verily (Google Life Sciences): 2013 - 2018


- 2013: Google announces its entry into the market.
- 2014: Partners with Novartis
- 2018: Project halted



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Potential CL Biosensor Targets

- **Ocular**
 - IOP
 - osmolarity
 - biomarkers
 - dry eye disease etc
- **Systemic**
 - diabetes
 - cancer markers
 - blood pressure
 - neurological disorders
 - heart rate
 - kidney function
 - ovulation




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Management of Ocular Disease

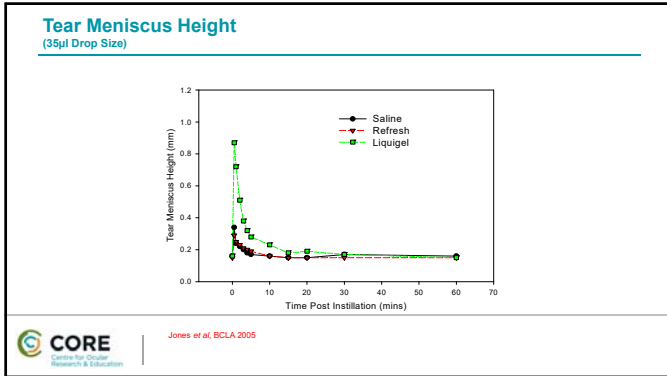
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Topical Drops

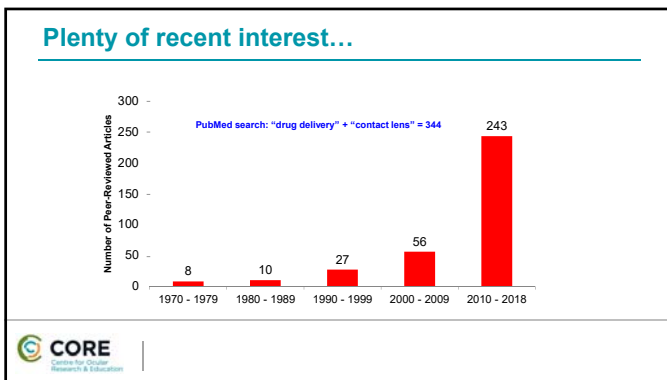
- >95% of current market for disease management
 - poor insertion technique in >50%
 - over-spill
 - poor compliance in 50%
 - rapid tear flow drainage
 - drug diluted by blinking
- Substantial systemic absorption
- **<5% of drug gets to target**



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- ### What about using CL?
- Soaked CL **should release drugs much slower**
 - First suggested in original Wichterle hydrogel patents in 1960's ¹
 - first published manuscript in 1971 ²
 - 93% of surveyed clinicians would be interested in using a drug delivering bandage CL ³
 - Clinical success depends on
 - drug loading
 - drug release
 - affinity between drug and material
- 
1. Wichterle & Lim. Cross-linked hydrophilic polymers and articles made therefrom. US patent. 3220960, 1965
 2. Morgan. A new drug delivery system for the eye. IMS Ind Med Surg 1971;40:11-3.
 3. Kargard et al. Eye Contact Lens 2004; 30:11-25:30.



A Dream?

research review
 BY L. JONES, PH.D., FRCOPTH, FRCO
Drug-Delivering Contact Lenses: A Dream Worth Chasing?
 For many years, practitioners have used hydrogel contact lenses as bandage lenses in cases of corneal disease and trauma. In many cases in which a bandage lens is required, the condition drug to achieve optimum ocular delivery concentrations for most ocular pathologies, if materials released the drug too quickly to be effective or drug delivery devices with the capacity of the drug released within the first 11 minutes.

L. Jones. Contact Lens Spectrum 2009, 24:3-18-19.

Ophthalmic Drug Delivery

Natural Sciences and Engineering Research Council of Canada
 www.nserc-trang.gc.ca

20/20: NSERC Ophthalmic Materials Network (2008 - 2014)

Challenge
 The CNR estimates the direct and indirect costs of vision loss in Canada at \$1.8 billion per year. There are more than 1.6 million Canadians living with significant vision loss that cannot be corrected using existing technology. With our aging population, this number is expected to increase dramatically over the next 25 years. Furthermore, while there are new ocular drugs in development, successful delivery of therapeutic doses of these drugs to the eye remains problematic. Therefore, the development of new ophthalmic materials and drug delivery devices is clearly needed by individual patients and society as a whole.

Goal
 A vision of perfect vision is the overarching goal of 20/20. Research by 20/20 is aimed at the development of new biomaterials - and ultimately new therapies - for treating vision disorders.

What diseases may be relevant?

Long-Term Therapy

- Glaucoma
- Allergy

Microbial Keratitis

Severe Corneal Abrasions

branch curling iron paper cut

Management of Severe Abrasions

What Drugs are Being Used with Bandage Contact Lenses?

TABLE 5. *Types of pharmaceuticals used in conjunction with bandage lenses as percentage of patients treated with pharmaceuticals*

Type	Patients treated (%)
Antibiotic	47.5
Steroid (antiinflammatory)	23
Nonsteroidal antiinflammatory	17
Cycloplegic (antiinflammatory)	2
Artificial tears	6
Antiviral	1
Glaucoma	1
Unspecified	2.5

Karlgard et al. Survey of bandage lens use in North America, October-December 2002. Eye Contact Lens 2004;30:25-30.

Why not just use existing commercial lenses?

Topical Drugs & CL Materials

CORE – published 30 papers on this topic

Release Rates

Hui et al. Uptake and release of ciprofloxacin-HCl from conventional and silicone hydrogel contact lens materials. *Eye Contact Lens* 2008;34:266-71.

Soft Lens Drug Delivering Concepts

Hui & Wilcox. In Vivo Studies Evaluating the Use of Contact Lenses for Drug Delivery. *Optom Vis Sci* 2016;93:367-76.

Molecular Imprinting

Materials 2012, 5, 85-107; doi:10.3390/ma5010085

OPEN ACCESS

materials

ISSN 1996-1944

www.mdpi.com/journal/materials

Article

Acetic and Acrylic Acid Molecular Imprinted Model Silicone Hydrogel Materials for Ciprofloxacin-HCl Delivery

Alex Hui ^{1,*}, Heather Sheardown ² and Lyndon Jones ^{1,2}

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

Clinically Relevant Amounts of Release up to 14 days

Hui A, Sheardown H, Jones L. Acetic and Acrylic Acid Molecular Imprinted Model Silicone Hydrogel Materials for Ciprofloxacin-HCl Delivery. *Materials* 2012;5:85-107.

Drugs Under Investigation

- Anti-infective
- Anti-inflammatory
- Anti-glaucoma
- Epidermal growth factor
- Anti-allergy
 - J&J have already evaluated and reported on 4 trials of a ketotifen-releasing DD lens (2007-2015)
 - antihistamine/mast cell stabilizer

Entertainment Purposes

3D Printed CL Materials



What Does 3D Printing Have To Do With Contact Lenses?

3D Printing & the Future of Contact Lenses

3D printing has the ability to create custom lenses for each individual eye. This allows for a more precise fit and better vision correction. 3D printing also allows for the creation of lenses with unique optical properties, such as those used in augmented reality (AR) and virtual reality (VR) applications.

J&J's Plans for Smart & 3D Printable Contact Lenses

Johnson & Johnson Vision Care, Inc. is developing smart contact lenses that can be 3D printed. These lenses are designed to be used in a variety of applications, including AR and VR. The company is currently in the process of testing these lenses and expects to launch them in the near future.

3D Printed CL Materials

Bionic eye: 3D printing merges contact lens and QLEDs

Quantum dots have been successfully 3D printed into a contact lens, allowing the lens to project beams of light.



Protonics's QLED 3D printer has taken the next step beyond printing quantum dot LEDs. It has merged to integrate them with a standard contact lens, creating a device that can project beams of colored light.

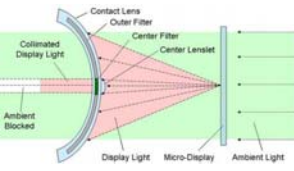
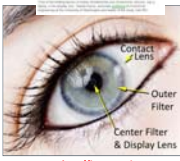
It's not wearable yet. The lens itself is made of hard plastic, which is unsuitable to be worn on the eye, and the QLEDs require an external power supply. However, it does demonstrate the feasibility of 3D-printed electronics, integrated with complex shapes to create fully realized devices.

Virtual Reality Contacts?

United States Patent
Leyman et al.

Patent No. US 8,428,816 B2
Date of Patent: Mar. 27, 2012


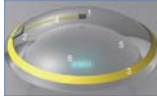
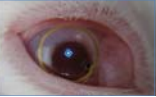


Abstract: A contact lens system for providing a user with a virtual reality experience. The system includes a contact lens with a micro-display and a display light. The contact lens is configured to project light from the micro-display onto the user's eye, creating a virtual reality image. The system also includes a center filter and an outer filter. The contact lens is configured to filter light from the display light, allowing only light from the micro-display to reach the user's eye.

<http://innovega-inc.com>

Visual Augmentation

- Contact lens is a key component
 - permits focus on content close to the eye
 - or carries the information display

(Image: Institute of Physics)

Mission Impossible: Ghost Protocol






Sept 20th 2015



Novartis to Begin Testing of Smart Lens for Presbyopes in 2016

According to reports from Reuters and other news sources, Novartis plans the first human tests next year of the contact lens for correcting presbyopia that it is developing with Google. In July, 2015, Novartis announced that its eye care division, Alcon, has entered into an agreement with a division of Google Inc. to license its "smart lens" technology for all ocular medical uses. (See <http://www.credentia.com/news/2015/07/14>) The agreement was designed to marry Google's expertise in microfluidic electronics, low power chip design and microfabrication with Alcon's expertise in physiology and visual performance of the eye, clinical development and evaluation, as well as commercialization of contact and intraocular lenses.

In a recent interview Novartis Chief Executive Joe Jimenez told Swiss newspaper Le Temps that the project is progressing well. "I had said it would take about five years to see a product on the market," Jimenez told the paper. "The calendar is on track and we are already developing a technological lens prototype (that) should be tested on humans in 2016."

Unique Optical Opportunities

- Accommodating CL
 - presbyopia
- Magnifying CL
 - low vision
- Camera in a lens
- Facial recognition
- Head-up displays



Summary

Summary

- Contact lens industry is alive and well
 - practitioners now have **MANY** excellent products to offer to patients
- Contacts will still be here in 2050!
- Development of new products with
 - extended roles in
 - health monitoring
 - health treatment
 - unique optical uses



THANK YOU

