# Fast Forward to the Future

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### Financial Disclosures

***Over the past three years, CORE has received research funding and/or honoraria from the following 22 companies:***

- Alcon
- Allergan
- Allied Innovations
- Aurinia Pharma
- Azura Ophthalmics
- Bausch Health Canada
- BHVI
- CooperVision
- GL Chemtec
- i-Med Pharma
- Johnson & Johnson Vision
- Lubris
- Menicon
- Nature's Way
- Novartis
- Ophtecs
- Oté Pharma
- PS Therapy
- Santen
- SightGlass
- SightSage
- Visioneering Tech Inc

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# CLEAR: Contact lens technologies of the future

- Diagnosis & screening for systemic disease
- Diagnosis & screening for ocular disease
- Treatment of ocular conditions
- Drug delivery to the ocular surface
- Antimicrobial lenses
- Theranostics
- Optical enhancements
- Contact lens packaging
- Storage cases


Contact Lens and Anterior Eye

CLEAR - Contact lens technologies of the future

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Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430.

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# Available Now!

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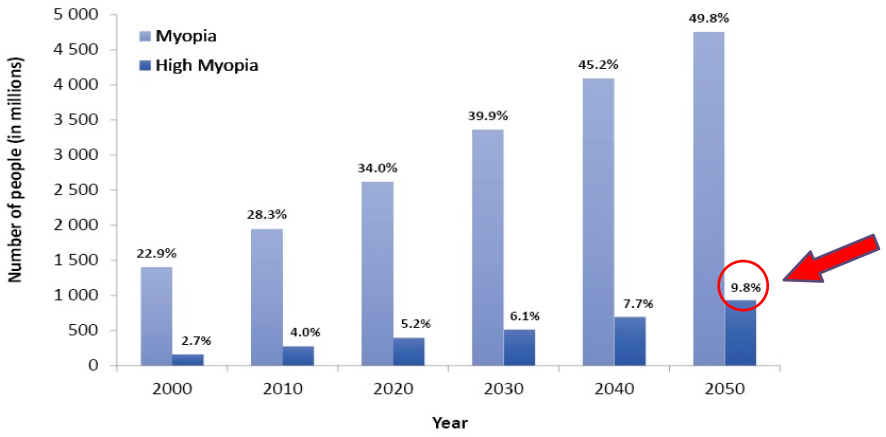
# Increase in high myopia

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Holden et al.: Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology 2016; 123;5: 1036-42.

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# Myopia - what are the risks

| Emmetropia = 1x | Cataract (PSCC) | Retinal Detachment | Myopic Maculopathy |
|---|---|---|---|
| -1.00 to -3.00 | 2.1 | 3.1 | 2.2 |
| -3.00 to -6.00 | 3.1 | 9.0 | 9.7 |
| -6.00 or greater | 5.5 | 21.5 | 40.6 |

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Flitcroft. The complex interactions of retinal, optical and environmental factors in myopia aetiology. *Prog Retin Eye Res*. 2012;31:622-60

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# Myopia Management Products Available



IMI – Myopia Control Reports Overview and Introduction



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# Contact lens innovation

- ACUVUE® OASYS with Transitions™
- Launched in US & Canada, April 2019
- First-of-its-kind photochromic contact lens
- Filters light both outdoors and indoors


https://www.jnj.com/latest-news/acuvue-oasys-with-transitions-contact-lenses-make-2018-times-best-inventions-list
https://www.jnjvisionpro.com/acuvue-transitions

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# Diagnosis & Screening for Systemic Disease

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## Wearable Sensor Market

- Market for wearable technology is expected to reach $US 31.27 Billion by 2025, at annual growth rate of 17.8%
  - smartwatches
  - wristbands
- Major players
  - Adidas; Apple; Fitbit; Garmin; Google; Nike; Samsung; Sony


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# Wearable Sensor Market


sensors — MDPI

*Review*

**Wearable Health Devices—Vital Sign Monitoring, Systems and Technologies**

**Duarte Dias [1,*] and João Paulo Silva Cunha [1,2]**

1 Biomedical Research and INnovation (BRAIN), Centre for Biomedical Engineering Research (C-BER), INESC Technology and Science, Porto 4200-465, Portugal; jpcunha@fe.up.pt
2 Faculty of Engineering, University of Porto, Porto 4200-465, Portugal
* Correspondence: duarte.f.dias@inesctec.pt; Tel.: +351-91-918-2933

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**Abstract:** Wearable Health Devices (WHDs) are increasingly helping people to better monitor their health status both at an activity/fitness level for self-health tracking and at a medical level providing more data to clinicians with a potential for earlier diagnostic and guidance of treatment. The technology revolution in the miniaturization of electronic devices is enabling to design more reliable and adaptable wearables, contributing for a world-wide change in the health monitoring approach. In this paper we review important aspects in the WHDs area, listing the state-of-the-art of wearable vital signs sensing technologies plus their system architectures and specifications. A focus on vital signs acquired by WHDs is made: first a discussion about the most important vital signs for health assessment using WHDs is presented and then for each vital sign a description is made concerning its origin and effect on heath, monitoring needs, acquisition methods and WHDs and recent scientific developments on the area (electrocardiogram, heart rate, blood pressure, respiration rate, blood oxygen saturation, blood glucose, skin perspiration, capnography, body

The Economist — Menu — Weekly edition — Search

Wearable technology promises to revolutionise health care

Do not let bureaucracy delay matters

IT IS A stealthy killer. When the heart's chambers beat out of sync, blood pools and clots may form. Atrial fibrillation causes a quarter of more than 100,000 strokes in Britain each year. Most of those would never happen if the heart arrhythmia were treated, but first it has to be found. Tests are costly and inaccurate, but Apple Watches, and soon Fitbits, can detect it, are far cheaper and can save those whose lives are in danger.

Dias & Cunha. Wearable Health Devices-Vital Sign Monitoring, Systems and Technologies. Sensors (Basel) 2018; 18;8: 2414.

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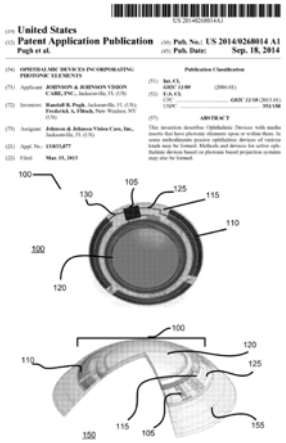
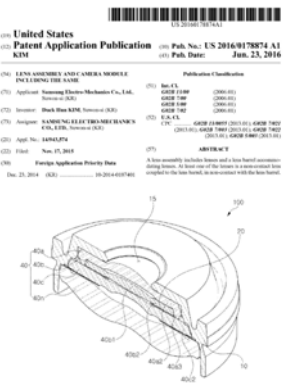
# Patents: Samsung; Sony; J&J; Medella Health



(19) **United States**
(12) **Patent Application Publication**
**Pugh et al.**
(10) **Pub. No.: US 2014/0268014 A1**
(43) **Pub. Date: Sep. 18, 2014**



(19) **United States**
(12) **Patent Application Publication**
**KIM**
(10) **Pub. No.: US 2016/0178874 A1**
(43) **Pub. Date: Jun. 23, 2016**

**>250 patents since 2012**

US 20170042480A1

(19) **United States**
(12) **Patent Application Publication**
**Gandhi et al.**
(10) **Pub. No.: US 2017/0042480 A1**
(43) **Pub. Date: Feb. 16, 2017**

(54) **FUNCTIONAL CONTACT LENS AND RELATED SYSTEMS AND METHODS**

(71) Applicant: **Medella Health Inc.**, Kitchener (CA)

(72) Inventors: **Harry Gandhi**, Kitchener (CA); **Huayi Gao**, Kitchener (CA); **Maarij Baig**, Kitchener (CA); **Ray Chen**, Kitchener (CA)

(73) Assignee: **Medella Health Inc.**, Kitchener, ON (CA)

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*A61B 3/10* (2006.01)
*A61B 5/053* (2006.01)
*A61B 5/145* (2006.01)
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(52) **U.S. Cl.**
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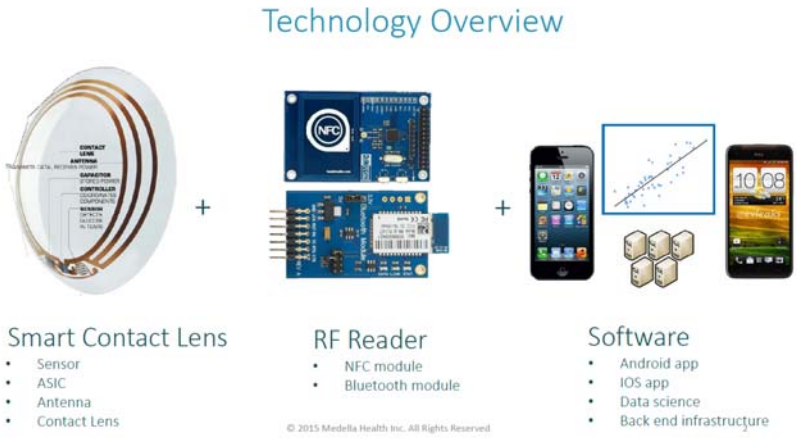
# "Smart" CL System

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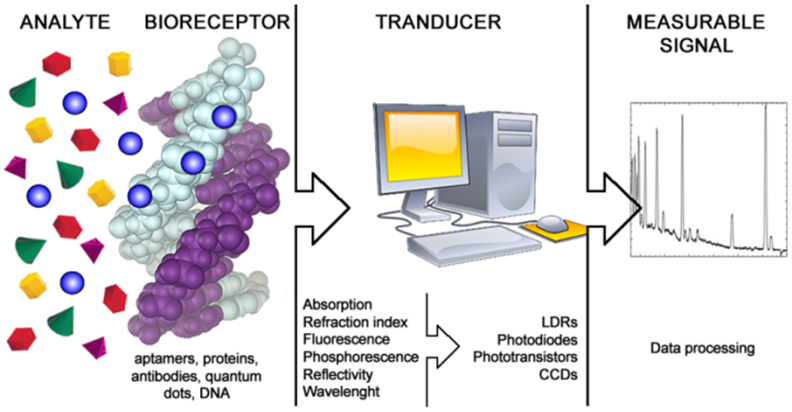
# Biosensing Contacts

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# Systemic Disease Biomarkers

**Table 1**
Systemic disease biomarkers found within the tear film.

| Disease | Potential tear biomarkers |
|---|---|
| Alzheimer's disease | Increased levels of dermcidin, lacritin, lipocalin-1 and lysozyme-C [2] |
| Cancer | Increased levels of lacryglobin [3,4], changes in combination of specific proteins [5] |
| Cystic fibrosis | IL-8 and IFN-γ [6], MIP-1α [7] and MIP-1β [8] |
| Diabetes | Increased levels of glucose [9], advanced glycation end products [10], cytokine changes [11] |
| Multiple sclerosis | Oligoclonal bands of IgG [12,13] and α-1-antichymotrypsin [14] |
| Parkinson's disease | TNF-α [15] and oligomeric alpha-synuclein [16] |
| Thyroid disease | IL-1β, IL-6, IL-17, TNF-α [17] and IL-7 [18] |

IL – Interleukin; IFN – Interferon; MIP – Macrophage inflammatory protein; TNF – tumor necrosis factor; IgG – Immunoglobulin G.

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Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430.

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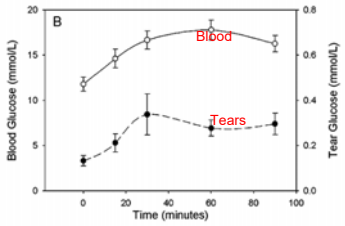
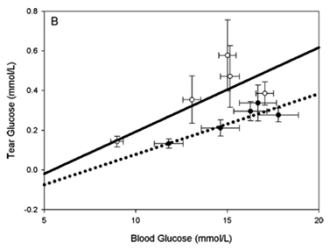
# Blood vs Tear Glucose

- 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 that time due to technical limitations

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

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# Glucose Biosensors for CL

Table 2
Examples of glucose biosensors developed for contact lenses.

| Mode of detection | Glucose sensor | Reader |
|---|---|---|
| Fluorescence [60] | Boronic acid, Concanavalin A | External detector |
| Colourimetric [47] | Boronic acid | Colour chart |
| Fluorescence [61] | Boronic acid | Photodetector |
| Fluorescence, colourimetric [62] | Boronic acid, Concanavalin A | External detector |
| Fluorescence, colourimetric [63] | Boronic acid, Concanavalin A | Photodetector |
| Fluorescence [64] | Boronic acid, Concanavalin A | External detector |
| Light emitted [65] | Boronic acid | Photodetector |
| Electrochemical [45] | Boronic acid | Electrode |
| Fluorescence, luminescence [66] | Boronic acid | External reader |
| Light emitted [31] | Boronic acid | Smart phone |
| Optical [33] | Boronic acid | External reader |
| Absorbance [50] | Concanavalin A | Spectrophotomer |
| Fluorescence [49] | Concanavalin A | Handheld photofluorometer |
| Fluorescence [32] | Concanavalin A | Handheld photofluorometer |
| Electrochemical [46] | Glucose oxidase | Electrode |
| Electrochemical [29] | Glucose oxidase | Smart phone |
| Electrochemical [30] | Glucose oxidase | Handheld reader or smart phone |
| Electrochemical [67] | Glucose oxidase | External receiver |
| Electrochemical [38] | Glucose oxidase | On lens display |
| Electrochemical [68] | Metal oxides | External receiver |


Verily (Google Life Sciences): 2013 - 2018


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Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430.

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# TF Substance P: Marker for Diabetic Peripheral Neuropathy?


**Conclusion**
Tear film Substance P may provide a potential non-invasive biomarker for assessing neuropathy in Type 1 Diabetes

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Tummanapalli et al. Tear film substance P: A potential biomarker for diabetic peripheral neuropathy. Ocul Surf 2019; 17;4: 690-698

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# Diagnosis & Screening for Ocular Disease

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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. Mansouri & Weinreb (2012). Continuous 24-hour intraocular pressure monitoring for glaucoma--time for a paradigm change. Swiss Med Wkly, 142, w13545.
2. Mansouri & Weinreb (2012). Meeting an unmet need in glaucoma: continuous 24-h monitoring of intraocular pressure. Expert Rev Med Devices, 9(3), 225-231
3. Lorenz, et al. (2013). Tolerability of 24-hour intraocular pressure monitoring of a pressure-sensitive contact lens. J Glaucoma, 22(4), 311-316.
4. Mansouri et al (2015). Efficacy of a contact lens sensor for monitoring 24-h intraocular pressure related patterns. PLoS One, 10(5), e0125530.


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## CL Monitoring Devices: Other Opportunities

- Dry eye diagnosis and monitoring
  - osmolarity [1]
  - inflammatory cytokines [2]
    - TNF-α, IL-6, IL-17a and IL-8
- Blink monitoring [3]
- Ocular surface temperature [4]
- Ocular surface vasculature responses [5]

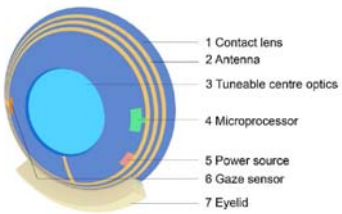


**Fig. 3.** Schematic design of an electronic presbyopic contact lens [425]. The sensor monitors (6) the gaze and sends the information to a microprocessor (4), which controls the tuneable centre optics (3). The optics can be tuned using a responsive polymer [435] or liquid crystals [424,425,436]. The entire system is supported by a power source (5) and an antenna (2).

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1. Chiou JC: The Development of Smart Contact Lens System: Taking Dry Eye Syndrome Diagnosis as an Example. Future Tech Expo 2019 2019; https://www.futuretech.org.tw/futuretech/index.php?action=product_detail&prod_no=P0008700001856&web_lang=en-us.
2. Roy et al.: The Growing Need for Validated Biomarkers and Endpoints for Dry Eye Clinical Research. Invest Ophthalmol Vis Sci 2017; 58;6: BIO1-BIO19.
3. Pugh et al.: Blink detection system for electronic ophthalmic lens, U.P. Office, Editor. 2015, Johnson and Johnson Vision Care Inc.
4. Moreddu et al.: Contact lenses for continuous corneal temperature monitoring. RSC Advances 2019; 9;20: 11433-11442.
5. Ho & Amirparviz: Contact lens with intergrated pulse oximeter, U.P. Office, Editor. 2015, Google Inc. p. 25.

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# Treatment of Ocular Conditions

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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 as a delivery vehicle?

- 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 CL [3]
- Clinical success depends on
  - drug loading
  - drug release

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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. Karlgard *et al.* Survey of bandage lens use in North America, October-December 2002. Eye Contact Lens 2004; 30;1: 25-30.


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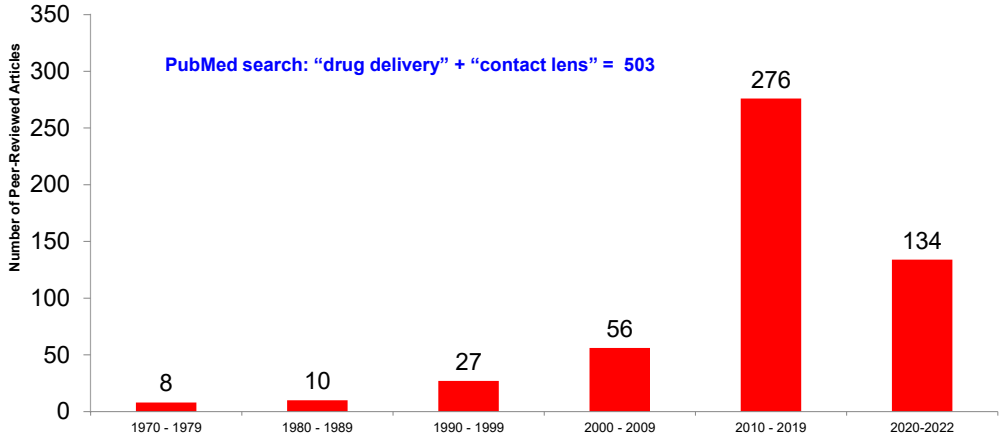
# Plenty of academic interest…

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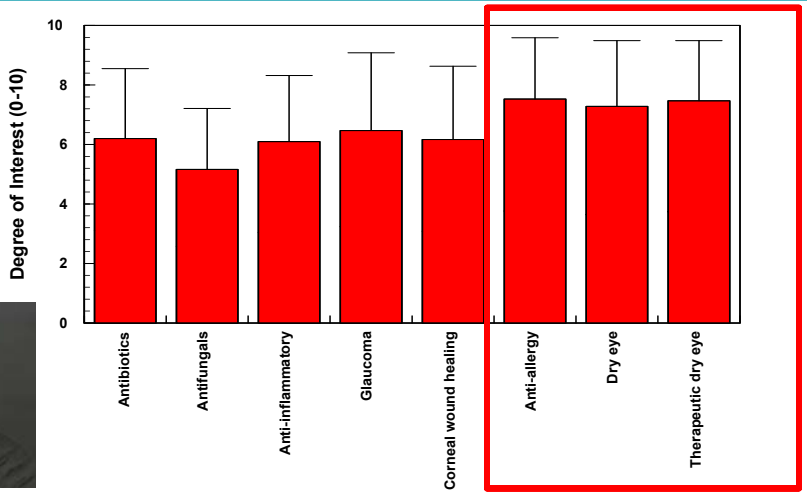
# Practitioner Interest?

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N – 316 optometrists at CE meetings

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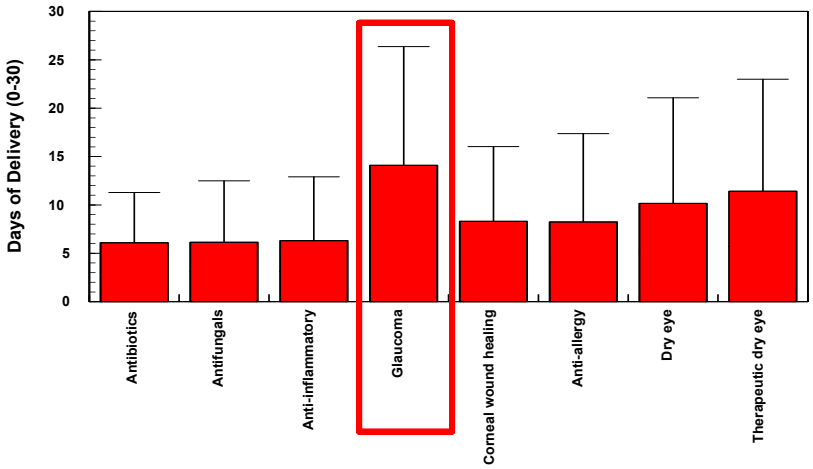
## Days of Continuous Delivery?

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N – 316 optometrists at CE meetings

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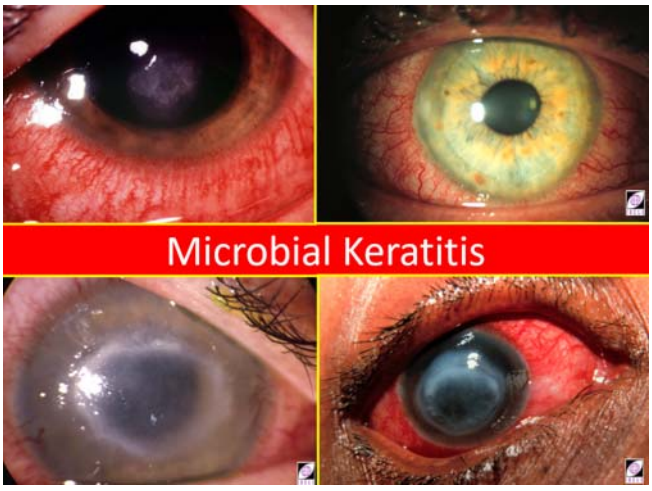
## Relevant diseases: short-term therapy





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## Severe corneal abrasions


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## Relevant diseases: long-term therapy

- Ocular allergy
- Glaucoma

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# Why not just use existing commercial lenses?

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## Interactions between topical drugs & CL materials: Many publications…

Ciprofloxacin Interaction with Silicon-Based and Conventional Hydrogel Contact Lenses

In vitro uptake and release studies of ocular pharmaceutical agents by silicon-containing and p-HEMA hydrogel contact lens materials

Uptake and Release of Ciprofloxacin-HCl From Conventional and Silicone Hydrogel Contact Lens Materials

Uptake and Release of Dexamethasone Phosphate From Silicone Hydrogel and Group I, II, and IV Hydrogel Contact Lenses

Delivery of Ketotifen Fumarate by Commercial Contact Lens Materials

In Vitro Uptake and Release of Natamycin From Conventional and Silicone Hydrogel Contact Lens Materials

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CORE – published >30 papers on this topic

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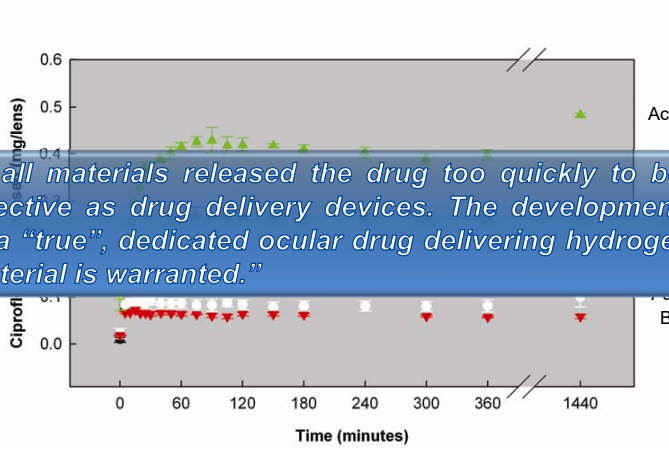
## Release Rates




*"...all materials released the drug too quickly to be effective as drug delivery devices. The development of a "true", dedicated ocular drug delivering hydrogel material is warranted."*

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

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# What slow release technologies have been investigated?

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# CL as Drug Delivery Devices

- 144 review papers!
  - 1982-2022
    - 7 already this year


1. White & Byrne: Molecularly imprinted therapeutic contact lenses. Expert Opin Drug Deliv 2010; 7:6: 765-80.; 2. Bengani et al.: Contact lenses as a platform for ocular drug delivery. Expert Opin Drug Deliv 2013; 10;11: 1483-96; 3. Hsu et al.: Review of ophthalmic drug delivery by contact lenses. J Drug Del Sci Tech 2014; 4;2: 123-135; 4. Phan et al.: Contact lenses for antifungal ocular drug delivery: a review. Expert Opin Drug Deliv 2014; 11;4: 537-46; 5. White et al.: Bringing comfort to the masses: a novel evaluation of comfort agent solution properties. Cont Lens Anterior Eye 2014; 37:2: 81-91; 6. Gause et al.: Mechanistic modeling of ophthalmic drug delivery to the anterior chamber by eye drops and contact lenses. Adv Colloid Interface Sci 2016; 233 139-154 ; 7. Alvarez-Lorenzo et al.: Bioinspired hydrogels for drug-eluting contact lenses. Acta Biomater 2019; 84 49-62; 8. Lanier et al.: Commercialization challenges for drug eluting contact lenses. Expert Opin Drug Deliv 2020; 17;8: 1133-1149; 9. Garcia Del Valle & Alvarez-Lorenzo. Atropine in topical formulations for the management of anterior and posterior segment ocular diseases. Expert Opin Drug Deliv 2021; 18;9: 1245-1260; 10. Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430. 11. Pereira-da-Mota et al.: Testing drug release from medicated contact lenses: The missing link to predict in vivo performance. J Control Release 2022; 343 672-702.

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# CL Slow-Release Drug Delivering Concepts

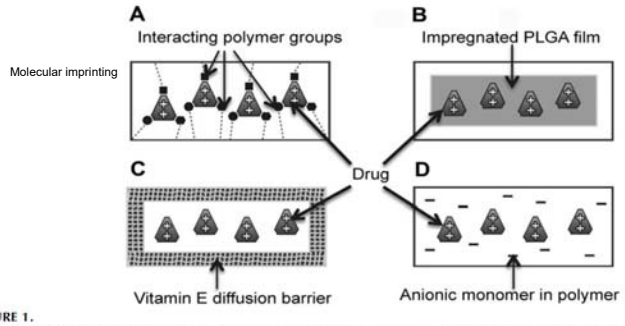


**FIGURE 1.**
Schematic representation of different strategies used to modify drug release from contact lens materials. Researchers have investigated (A) molecular imprinting to create noncovalent interactions between a drug and polymer groups, (B) incorporation of drug-impregnated PLGA films to serve as a drug reservoir within the center of the lens, (C) the addition of diffusion barriers to slow down the diffusion of drugs from the contact lens matrix, and (D) cationic/anionic monomer incorporation to generate an overall net charge within the material to interact with charged drug molecules, all in the hopes of modifying drug release kinetics and the amount of drug released.

1. Hui & Willcox. In Vivo Studies Evaluating the Use of Contact Lenses for Drug Delivery. Optom Vis Sci 2016;93:367-76.
2. Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430.

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# Nanoparticle Technologies

**Table 3**
Examples of nanoparticle technologies for contact lens drug delivery.

| Drug | Nanoparticle | Synthesis method | Loading method | Average size (nm) | Release Duration |
|---|---|---|---|---|---|
| Ciprofloxacin [249] | Pullulan-PCL *micelles* | Dropwise addition of water to DMSO | Dispersion in pre-polymer solution and soaking | 142 ± 12 | 3–4 days |
| Cyclosporine [250] | Brij surfactants *micelles* | Dissolution in water | Dispersion in pre-polymer solution | <40 | >15 days |
| Cyclosporine [243] | C-HA *micelles* | Dissolution in water and DMSO | Dispersion in pre-polymer solution | 300 | 12 days |
| Ketotifen [242] | silica shell | Microemulsion | Dispersed in pre-polymer solution | 104.2–126.54 | 10 days |
| Lidocaine [221] | DMPC *liposomes* | Microemulsion | Dispersed in pre-polymer solution | 20 | 8 days |
| Loteprednol etabonate [251] | PCL/HEMA/PEG-DA | Surfactant-free mini-emulsion polymerisation | Dispersed in pre-polymer solution | 52.3–83.4 | 12 days |
| Natamycin [252] | Dex-*b*-PLA *micelles* | Nanoprecipitation (DMSO to water) | Soaking | 26.1–26.6 | 12–24 h |
| Prednisolone [253] | PLGA | Emulsion-solvent evaporation | Dispersed in pre-polymer solution | 294.5 ± 1.8 | 24 h |
| Timolol [254] | PVP-PNIPAAM | Electrohydro-dynamic atomisation | Dissolved in polymeric solution | 52 % of nano-structures < 200 | 24 h |
| Timolol [241] | EC | Double emulsion | Dispersed in pre-polymer solution | 261–340 | 168 h |

C-HA, cholesterol-hyaluronic acid; DA, diacrylate; EC, ethyl cellulose; Dex, Dextran; DMPC, dimyristoylphosphatidylcholine; DMSO, dimethylsulfoxide; HEMA, poly (2-hydroxyethyl methacrylate); PEG, polyethylene glycol; PCL, polycaprolactone; PLA, polylactic acid; PLGA, poly (lactic-co-glycolic acid); PNIPAAM, poly (N-iso-propylacrylamide); PVP, poly(vinylpyrrolidone).

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Jones et al.: CLEAR - Contact lens technologies of the future. Cont Lens Anterior Eye 2021; 44;2: 398-430.

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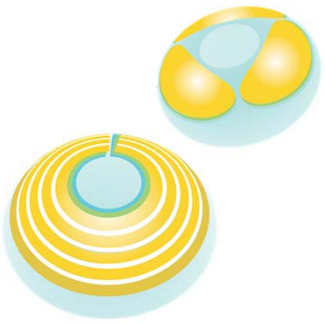
# Drug "Printing" Concept

- MediPrint™ Ophthalmics
- A proprietary process allows for printing of drug and barrier layers on the contact lens surface to control drug diffusion release kinetics
- Early phase study on LL-BMT1
  - drug-eluting CL for glaucoma treatment using bimatoprost



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# *In vitro* vs *In vivo*?

Journal of Controlled Release 343 (2022) 672–702

Contents lists available at ScienceDirect

Journal of Controlled Release

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

Review article

Testing drug release from medicated contact lenses: The missing link to predict *in vivo* performance

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*in vitro-in vivo* correlations

ABSTRACT

Contact lenses (CLs) offer a wide variety of advantages as ocular drug-releasing platforms, but the feasibility of medicated CL development is constrained by numerous scientific, technological, and regulatory challenges. One main difficulty is the setting of release rate specifications for each drug, since at present there are no standardized *in vitro* release models that can appropriately predict the performance of drug-eluting CLs once placed onto the eye. CL-adapted release tests may provide knowledge on how the drug release pattern should perform *in vivo* to trigger and maintain the therapeutic effects for both anterior and posterior ocular tissues. Moreover, *in vitro* release tests are valuable tools for quality assessment during production and to investigate the effect of a change in composition or process variables. This review aims to shed light on biorelevant ways of evaluating *in vitro* drug

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Pereira-da-Mota et al.: Testing drug release from medicated contact lenses: The missing link to predict in vivo performance. J Control Release 2022; 343 672-702.

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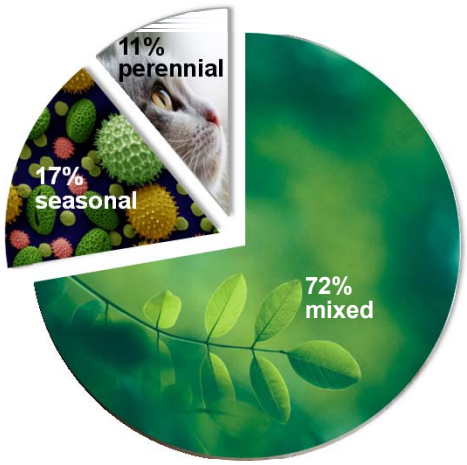
# Allergic Rhino-Conjunctivitis (Hay Fever)

**Classification by Sensitization*[1]**

- **Seasonal 17% (airborne pollens)**
  - Symptoms more irritative, more conjunctivitis (64.9%)
  - Peak suffering March - September
- **Perennial 11% (mites, pets)**
  - Symptoms more obstructive
  - Peak suffering October - February
- **Mixed 72% (indoor & pollen)**
  - Both irritative & obstructive symptoms
  - Suffering year round

**12% *overall* but rising year over year**




*19,475 consecutive subjects

1. Ciprandi G, Cirillo L, Vizzaccaro A et al. Season and perennial allergic rhinitis: is this classification adherent to real life? Allergy 2005; 60:882-887.

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# Contact Lens Patients with Allergies


ocular allergy patients are contact lens wearers[1]


of allergy days result in symptoms that might require drops[1]


contact lens wearers switch to glasses during allergy season[1]

***Disruptive and Frustrating!***

1. JJV Data on File 2019. JJV US & Canada Ocular Allergy Key Insights Review, March 2019

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## Licensed in Japan & Canada May 2021; USA Mar 2022

- J&J Acuvue Theravision with Ketotifen
  - topical antihistamine
- "Itchy eye relief"
  - allergic conjunctivitis
- Daily disposable platform
  - etafilcon A
  - hydrogel; 58% water content
  - preservative free
  - releases product over 5 hrs
  - provides up to 12 hr relief

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1. Pall et al.: Management of Ocular Allergy Itch With an Antihistamine-Releasing Contact Lens. Cornea 2019; 38;6: 713-717.
2. Pall & Sun: Evaluation of corneal staining with an antihistamine-releasing contact lens. Clin Exp Optom 2022 1-6.
3. https://contactlensupdate.com/2021/04/28/the-ex-vivo-drug-amount-of-an-antihistamine-releasing-contact-lens/


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# Antimicrobial Lenses



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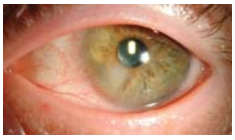
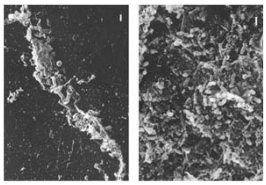
## Antimicrobial lenses

- Microbial adhesion to CL is a risk factor for developing MK, CLARE & CLPU [1]
  - reduction in bacterial adhesion to CL using antimicrobial coatings/treatments could thus be a viable means of reducing these potentially sight threatening complications
- Technologies investigated include
  - silver [2]
  - antimicrobial peptides melimine, Mel4 and Esculentin-1a [3]
  - fimbrolides (furanones) [4]





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1. Willcox: Microbial adhesion to silicone hydrogel lenses: a review. Eye Contact Lens 2013; 39;1: 61-6.
2. Willcox et al.: Ability of silver-impregnated contact lenses to control microbial growth and colonisation. Journal of Optometry 2010; 3;3: 143-148.
3. Dutta et al.: Biocompatibility of antimicrobial melimine lenses: rabbit and human studies. Optom Vis Sci 2014; 91;5: 570-81.
4. Zhu et al.: Fimbrolide-Coated Antimicrobial Lenses: Their In Vitro and In Vivo Effects. Optometry and Vision Science 2008; 85;5: 292-300.


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# Storage Cases



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## CL Storage Cases

- Implicated in MK
  - can be contaminated in as little as 7 days [1]
  - 80% contamination possible in 14 days [2]
  - mature biofilms by 30 days [1]
- Overcome by
  - in-built reminders to replace [3]
  - controlled obsolescence [4]
  - silver or selenium containing cases [5,6]
  - in-built colorimetric biofilm sensors [7,8]

Fig. 4. Microbiosensor in a contact lens case with the bottom blue colour indicating microbial contamination [525].

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1. Lakkis et al.: Time course of the development of contact lens case and contact lens contamination. Invest.Ophthalmol. Vis. Sci. 2009; 50;13: 6352 (abstract).
2. Dantam et al.: Microbial Contamination of Contact Lens Storage Cases During Daily Wear Use. Optom Vis Sci 2016; 93;8: 925-32.
3. O'Hara et al.: Countdown timer contact lens case. Patent # US7628269B2, 2009.
4. Josephson et al.: Limited use, self-destructive contact lens case. Patent # US20110180429A1, 2011.
5. Amos & George: Clinical and laboratory testing of a silver-impregnated lens case. Cont Lens Anterior Eye 2006; 29;5: 247-55.
6. Tran et al.: Organoselenium Polymer Inhibits Biofilm Formation in Polypropylene Contact Lens Case Material. Eye Contact Lens 2017; 43;2: 110-115.
7. Govindji-Bhatt & Dobson: Contact lens case changes color to signal bacterial contamination, in Interscience Conference on Antimicrobial Agents and Chemotherapy. 2015: San Diego.
8. LeBlanc et al.: Detecting bacteria colorimetrically on contact lens cases using immobilized gold nanoparticles. Investigative Ophthalmology & Visual Science 2015; 56;7: e-Abstract 2268.


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# Optical Enhancements

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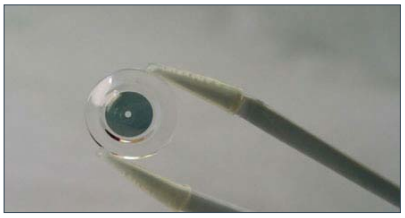
## Visual Augmentation

- Six Million Dollar Man (1974-78)
  - "bionic" eye
    - 20x zoom lens
    - camera
    - IR filter (night vision & heat detection)
- Contact lens is a key component of any such modern-day concept
  - permits focus on content close to the eye
  - or carries the information display

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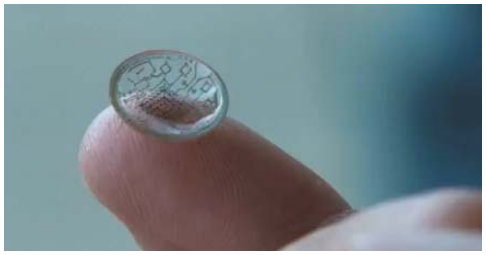
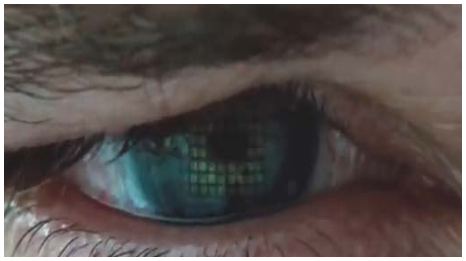
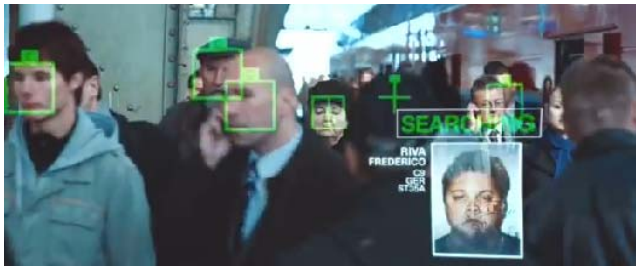
## Mission Impossible: Ghost Protocol (2011)





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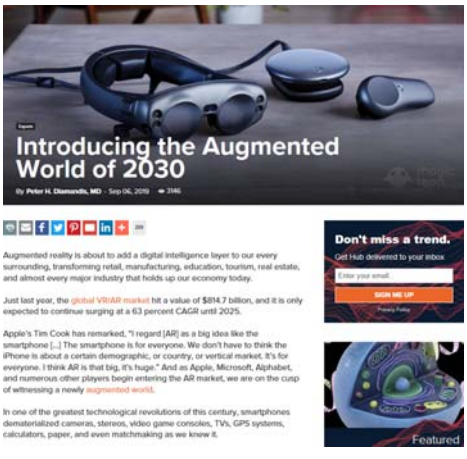
## Augmented & Virtual Reality

- VR - completely immerses users in digital realities
- AR - allows users to remain engaged with their physical surroundings, serving as a visual enhancement rather than replacement
- In 2018 the global VR/AR market hit a value of $814.7 billion
  - expected to continue surging at a 63% annual growth until 2025

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## AR & VR "Players"

- Well-known players
  - Microsoft, Apple, Alphabet, Intel have made tremendous strides
  - Samsung
    - recently granted US patent to develop smart lenses capable of streaming text, capturing videos, and even beaming images directly into a wearer's eyes
    - contacts are designed to include a motion sensor (for eye movement tracking), hidden camera, and display unit
  - Start-ups remain competitive (>1800)
    - Magic Leap - raised a total of $2.6 billion since its founding in 2010
      - head-mounted virtual retinal display, Magic Leap projects a digital light field into users' eyes to superimpose 3D computer-generated imagery over set environments
    - Mojo Vision - raised ~$150 million in its efforts to develop and produce an AR contact lens

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# Approaches: Electronic and Optical

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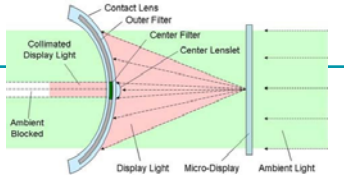
# Innovega

- No electronics in the lens
- Uses a two-state linear polarizer to separate a display path and a non display normal vision path
- Filters coupled with a very high-power 1mm center add (+65 to +85 D) allows the ability to see a display in the spectacle plane and see the real world with normal contact lens refractive correction
- Display eyewear may then be directly viewed with no additional optics and may have transparent displays for AR or occluded displays for VR





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http://innovega-inc.com

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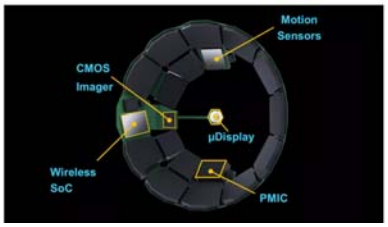
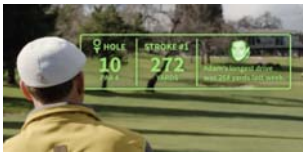
# Mojo Vision

- Scleral lens containing electronics
- The Mojo Lens centerpiece is a hexagonal display less than half a millimeter wide
  - a "femtoprojector" expands the imagery optically and beams it to a central patch of the retina
- Mojo is developing its lenses with Japanese contact lens maker Menicon

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https://www.mojo.vision/

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# Contact Lens "Zooming" Under Ocular Control

News

## Robotic lens zooms-in with blink of an eye

Movements of soft robotic lens are controlled by the eyes

September 6, 2019
by Liezel Labios, UC San Diego

Topics

Electronics

Tags

contact lens

**A research team led by the University of California San Diego has developed a soft robotic lens whose movements are controlled by the eyes — blink twice and the lens zooms in and out; look left, right, up or down and the lens will follow.**

The lens is the first example of an interface between humans and soft machines. "The human-machine interface, as we know it, features classical machines: computers, wheelchairs, and rigid robotics, for example. The innovation here is the interface with soft robotics. This can really open up new opportunities in the field," said Shengqiang Cai, a professor of mechanical and aerospace engineering at UC San Diego who led the research.

Potential applications of the system include visual prostheses, adjustable glasses, VR, and soft robots that can see.

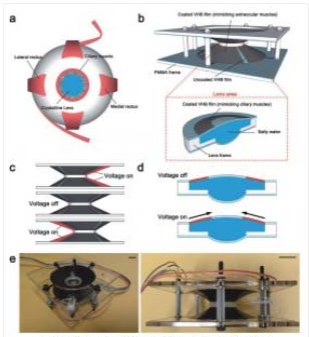


Illustration and photos of the soft robotic lens.
Courtesy of Cai lab/Advanced Functional Materials

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Li et al. A Biomimetic Soft Lens Controlled by Electrooculographic Signal. Advanced Functional Materials 2019; 29: 1903762.

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# Augmented Reality for Education

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# Augmented Reality for Training

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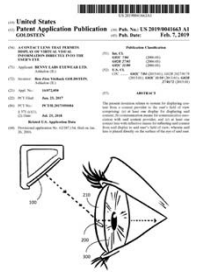
# Unique Optical Opportunities

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



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# Summary

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## Summary

- Incredible diversity of new technologies under development that will shape the future for CL
- Rapid growth in novel biomaterials and the development of powered CL through advancements in nanotechnology will enable the commercialisation of lenses that can both detect and treat ocular and systemic disease
- Novel optical designs will provide enhanced vision for patients with low vision and a wide variety of other optical considerations
  - head-up displays etc
- Contact lenses have been around for over 100 years - and their future remains bright

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# THANK YOU

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