CONTACT LENSES: FROM THE PAST TO THE FUTURE

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THE HISTORY OF CONTACT LENSES
INITIAL CONCEPTS

• Leonardo Da Vinci: first person to neutralize the cornea by substituting a new refracting surface. About 1508, he described several forms of CLs to accomplish this.

• Rene Descartes: first to suggest placing a CL directly upon cornea with scleral lens (about 1632); demonstrated cornea’s role in astigmatism with hydrodiascope-like device

Leonardo da Vinci (about 1508)
1452-1519

Often cited as being the first to conceive a contact lens... based on his sketches that appear to illustrate a head plunged into a bowl of water.

RENE DESCARTES 1637
When the eye is immersed in water corneal refraction (later known as astigmatism) was neutralized

Rene Descartes
1596-1650
French Philosopher and Mathematician

His early sketches were misinterpreted as being a contact lens. They were actually describing the optics of a telescope

Frederick a Muller-Sohne
1886 or 1887
Wiesbaden, Germany

Master glass blower and maker of artificial eyes. Fabricated a protective glass shell for a patient with severe exposure following removal of a malignant lid tumor. The patient continued to wear the shell for 21 years until his death in 1907.
The Birth of Contact Lenses

In 1888-1889 three individuals independently developed the first contact lenses.

Adolph Eugen Fick  Zurich Switzerland
Eugene Kalt  Paris France
August Muller  Kiel Germany

Adolph Eugene Fick

1888 ZURICH, SWITZERLAND

“Eine Contactbrille”
“A Contact Spectacle”

• First published clinical work on contact lenses.
• Reported how he had fitted contact lenses to irregularly shaped corneas.

Eugene Kalt MD

1888 PARIS, FRANCE

Developed the first contact lens for the correction of keratoconus.
“Designed with a radius similar to that of a normal eye to apply pressure onto the corneal apex”.

First to base his lens fitting from keratometric measurements from the Javal/Schiotz
August Muller
1887 Kiel, Germany

He eventually abandoned the cocaine and was able to wear the shell for increasingly long periods.

Otto Himmler (Berlin) scleral Lens:
BC 8.00, Diameter 16.5 mm, Scleral Radius 12.00 mm

1912 to 1936 ... The Period of Renewed Interest (fluidless glass sclerals)

Blown Glass
Scleral Lenses
F.A. Muller Company
Wiesbaden, Germany

Ground Glass
Scleral Lenses
Carl Zeiss Company
Jena, Germany

FLUIDLESS GLASS SCLERAL

• Josef Dallos (Budapest): 1929: fluidless glass scleral lenses (large) using eye molds; corneal section optics; more secure, controllable and comfortable fit
• Fenestrations minimized adhesion and enhanced lacrimal exchange

FLUIDLESS GLASS SCLERAL

• Adolf Mueller-Welt (Stuttgart, Germany): produced fluidless glass scleral lenses, beginning in 1927.
• He designed lenses to allow lacrimal fluid to circulate between lens and cornea
• First to develop large trial sets & inventories & (with Joe Breger), initiated one of the first CL labs in the U.S.
**MUELLER-WELT**

Two blown-glass, fluidless Mueller-Welt scleral lenses.

**JOSEPH DALLOS 1930**

**BRITISH OPHTHALMOLOGIST**

First to make impressions of living eyes
The casts of which were used to produce molded glass lenses.

**Cast Molding Kit**

**SCLERAL PMMA**

- PMMA served as the primary CL material from the late 1930’s to the late 1970’s due to:
  - Lower specific gravity
  - Better & faster reproducibility
  - Thinner
  - Could be fenestrated
  - Difficult to break

**SCLERAL PMMA**

- Feinbloom (1936): combined glass corneal section with a plastic section contact lens
- First All PMMA Lenses (1938 - 1940): via numerous manufacturers
  - Still taking molds
  - Obrig Lab
  - Role of Sol Braff

**FEINBLOOM**
Kevin Tuohy 1948

California optician given credit for (accidentally) introducing the corneal PMMA lens

Patented the first plastic corneal contact lens in 1948, an 11.0 diameter lens with a CT of .40 mm.

George Butterfield 1951

Designed the first multicurve lenses to better contour the true shape of the cornea.

CORNEAL PMMA (1948)

- Monocurve design
- Fitted flat
- Thick with blunt edges

Newton Wesley

- The individual most responsible for contact lenses going mainstream
- Attended (now Pacific University College of Optometry); graduated & at age 22 he bought it
- In WWII(1942) he & family forced to live in Relocation Center
- After leaving, he taught at ICO, met a brilliant student (George Jessen) who corrected his keratoconus with PMMA contact lenses: worked out of basement of mom’s rooming house

- They proceeded to establish the Plastic CL Company in 1946 (so people would not think glass)
- At that time (late 1940s) CLs were practically unheard; Dr. Wesley wanted to make them mainstream
- He and Dr. Jessen traveled nationwide to train ODs to fit the lenses as well as providing sessions in Chicago office. They trained thousands
- He also invested 500K annually for a PR campaign, including television
- By 1956, they had 85% of the market and CLs were in the dictionary
- Without him, would contact lens have gone mainstream?
Oh . . . and he also

- Co-invented bifocal contact lenses
- Co-invented orthokeratology
- Developed contact lens correction of keratoconus
- Developed the first corneal topographer (PEK)
- Established the World CL Congress (1200 attendees) in 1959
- Dissipated rumors that CLs caused cancer; plastic was toxic to eyes
- Responsible for schools becoming accredited and the doctor degree recognized

Modified PMMA Channel Designs

HYDROGEL LENSES

- Historical Development
  - Wichterle
  - Hornstein
  - National Patent Development Corporation
  - Morrison
  - Isen
HISTORICAL DEVELOPMENT

- In late 50s & early 60s, Dr. Otto Wichterle, Czechoslovakian polymer chemist developed a hydrophilic plastic compound (hydroxyethylmethacrylate or HEMA)
- A child’s erector set was used to develop a spin-casting technique for shaping HEMA into contact lenses

HISTORICAL DEVELOPMENT

- National Patent Development Corporation: Martin Pollak (NPDC attorney) visited Dr. Wichterle in Prague (1964)
- Applications were discussed and Dr. Bob Morrison was selected to assist
- NPDC established Flexible CL Company
- October, 1966 B & L signed a licensing agreement with NPDC
- FDA classified soft lens as drug; delayed product launch until 1971

HISTORICAL DEVELOPMENTS

- Robert Morrison: Rochet (French OD) told him of Wichterle; he visited Prague 10 times and brought back materials
- First American to fit soft lenses
- Czechs almost signed over patents until Pollak called
- Signed “napkin” agreement with Pollak
- Gave up 50% control of Flexible CL Co.

BAUSCH & LOMB

1971
First Hydrogel lens approved by the FDA for the US market.

Dr. Robert Koetting

- First to establish contact lens only specialty practice
- First to popularize the contact lens fitting of the presbyope
- Initiated the perception of St. Louis representing the contact lens capital of the United States

The B & L “C” Series

25 F , 80 C, 80 N
RIGID GAS PERMEABLE/Gas Permeable or GP

Modified PMMA Designs (1970’s)
Ultrathin, low wetting angle

• Cellulose Acetate Butyrate: 1978 became the first approved RGP; very low O2 permeability and unstable
• Silicone/acrylate (Polycon I): approved January, 1979; Gaylord patent of 1974; Seidner - Syntex - Sola-Barnes-Hind - Sola - WJ - Ciba
• Fluoro-Silicone/acrylate: Boston Equalens (1986)

SILICONE ELASTOMER

• Becker (1956) developed silicone elastomer; advantages = O2 and flexibility; disadvantages = wettability & adherence
• Breger worked on it from 1959 - 1972
• Dow Corning introduced it in the 1970s (Silsoft); sold it in 1984
• B + L has been working with it for almost 20 years (PureVision); Ciba sued (Focus Night and Day) = No PureVision for a few years

OTHER DEVELOPMENTS

• Extended Wear (1979): first 30 day aphakic and then myopic; high water thick lenses
• Soft Torics: approximately 1980; initial lenses (WJ) were fine except for discomfort, poor vision and edema
• Disposable Lenses: 1987 (Acuvue from Vistakon)
• Opaque tints (late 1980s) (WJ)
• Daily disposable: 1996
• Silicone-Hydrogel: 1998 (Bausch + Lomb Purevision)

CARE SYSTEMS

• GP: little change from PMMA except consolidation of wetting and soaking; use of liquid enzyme
• Soft: Started with liquid heat units and then dry heat units (good disinfection; short lens life); in late 70s chemical disinfection was introduced (borderline disinfection; preservative RxS & GPC); H2O2 in mid 1980s; effective chemical disinfection (ReNu/Optifree) in late 1980s
Decline in CL options; increase in surgery-mediated options

THE FUTURE OF CONTACT LENSES

• Myopia Control
• Transitional Contact Lenses
• Presbyopia
• Drug Delivery
• Diabetic Monitoring
• IOP Monitoring
• Stem Cell Coated Contact Lenses
• Augmented Reality/Virtual Reality/Nanotechnology in Contact Lenses

MYOPIA RISK (Kate Gifford, Jan., 2017, GSLS)

Control, by how much? (Walline, Oct., 2012, CL Spectrum)

Reduction in myopia progression of 50% is clinically meaningful to patients.

-1.00 D at age 8 progressing at 0.5 D / year

<table>
<thead>
<tr>
<th>% Myopia Progression Reduced</th>
<th>Final myopia (at 16 years)</th>
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<tr>
<td>0</td>
<td>-5.00D</td>
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<tr>
<td>25</td>
<td>-4.00D</td>
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<tr>
<td>50</td>
<td>-3.00D</td>
</tr>
<tr>
<td>75</td>
<td>-2.00D</td>
</tr>
<tr>
<td>100</td>
<td>-1.00D</td>
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Myopia control: orthokeratology

Risk of myopia

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<tr>
<th>Caract (PSCC)</th>
<th>Retinal detachment</th>
<th>Myopic Maculopathy</th>
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<tr>
<td>-1.00 to -6.00</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>-3.00 to -6.00</td>
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<td>5.5</td>
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**The Bennett Lens**

**Soft Multifocal Contact Lenses**

- Peripheral defocus
- Peripheral hyperopia
- Peripheral myopia

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Looking Further Ahead

The Future of Contact Lenses
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Multifocal Electronics
- The age of accommodating multifocal lenses should be present within 5 – 10 years
- They will change refractive error based upon the task
- These so-called “Smart Lenses” (google/Novartis) restore eye’s ability to autofocus

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Contact Lenses for Drug Delivery
- % of ocular medication – topical
  Estimated only 1-7% of an eye drop reaches target

  Compliance:
  Higher frequency = less compliance
  Over time in compliance
  est. at 8 mos. 50% compliance

Contact Lenses for Drug Delivery
- Uses include glaucoma, dry eye, allergies, infection, inflammation
- Better compliance
- Eliminates preservatives
- Can combine with bandage lens
- Can be used in cases where drugs can’t be inserted
  (est. 1/6 of glc pts need assistance with drop insertion)
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Impact of Diabetes

- In 2010:
  - 25.8 million Americans
  - 8.3% of the population
- In 2012:
  - 29.1 million Americans
  - 9.3% of the population
- In 2015:
  - 30.3 million Americans
  - 9.4% of the population

Impact of Diabetes

- Daily pills
  - Blood sugar
  - Blood pressure
  - Cholesterol
- Injections?
- Diet control
- Finger prick readings

Impact of Diabetes

- “Between 10% and 18% of patients reported that they would be willing to give up eight to 10 years of life in good health to avoid life with treatment”

Diabetic Monitoring

Google

Diabetic Monitoring

Google’s “smart” contact lens

Note: 20 minutes between change in blood glucose and tear glucose

Huang ES. Diabetes Care. 2007 Oct;30(10):2478-83
Future Holds Myriad Uses for Contact Lenses

- In the near future, contact lenses will be used to measure glucose in diabetic patients.
- Human tears contain glucose, and contact lenses could be fitted with a photonic crystal glucose-sensing component. Recording of results will be fairly straightforward using this type of system.
- Results can be read either on the contact lens itself through a color coding system or through a handheld device.

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Digital applications

- IOP monitoring
  - Triggerfish (Sensimed)
  - US Approval: March 2016
  - Specifications:
    - Silicone hydrogel
    - 14.1 mm diameter
    - 585 microns center thickness (vs 70-80 microns)
    - BC: 8.4, 8.7, 9.0 mm

Digital applications

- IOP monitoring
  - Triggerfish (Sensimed)
    - detects tiny changes or fluctuations in the eye's volume
    - 1-7% change in volume with IOP changes

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Health of cornea relies on limbal stem cells to replace epithelial cells

Reduction in # of stem cells can result in Limbal Stem Cell Deficiency (LSCD)

Reconstituting the ocular surface complicated by use of synthetic or animal products that may create an immune response
STEM CELL COATED CL (Univ New South Wales)

New process developed using contact lenses
- superior limbal or conjunctival stem cells removed
- cultured on the concave surface of a FDA approved SiHy lens for 10 days (Focus Night and Day) to allow time to revert and colonize
- epithelial growth and migration noted in 2 – 3 days, to lens margin in 9 – 10 days
- cl placed on eye

* 3 patients legally blind in one eye
* 2 patients damaged corneas 2º to surgery to remove cancerous growths
* small sample of limbal cells (1mm) removed from cornea of ‘good’ eye
* 1 patient congenital problem in both eyes - aniridia
small sample of tissue (1mm) removed from conjunctiva

Results (patients followed from 8 – 13 months):
• A stable transparent corneal epithelium was restored in each patient.
• There was no recurrence of conjunctivalization or corneal vascularization
• Best-corrected visual acuity was increased in all eyes after the procedure.

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Augmented & Virtual Reality

• Virtual Reality (VR)
  • an artificial, computer-generated simulation or recreation of a real life environment or situation. It immerses the user by making them feel like they are experiencing the simulated reality firsthand, primarily by stimulating their vision and hearing.
  • Uses:
    • Video and computer games
    • 3D movies
    • Enhanced training (Flight simulators)
Augmented & Virtual Reality

- **Augmented Reality (AR)**
  - a technology that layers computer-generated enhancements atop an existing reality in order to make it more meaningful through the ability to interact with it.
  - Uses:
    - Telecasted sports games
    - Pop out 3D emails
    - Mobile device photos or texts
    - Medicine

Virtual Reality

https://www.youtube.com/watch?v=dhUs9U1k

Augmented Reality

https://www.youtube.com/watch?v=kC7OlweCJ8I

Augmented & Virtual Reality

- Major Applications:
  - Gaming
  - Medical
  - Aerospace and Defense
  - Commercial
  - Others

Augmented & Virtual Reality

- Benefits of CL over Spectacles
  - Eye tracking important feature
  - CLs do no interfere
  - Allows for less bulk and lighter headsets

Nanotechnology Contact Lens
Being developed by engineers at the U. of Washington
Combines RGP lens with imprinted electronic circuits and lights.

Rationale for development:
Miniaturization of computers, cell phones, etc. are limited by the size of the display screen.
- miniature projectors not small enough, affords no privacy and are not commercially available
- externally worn ‘heads up’ displays too costly and cumbersome

AUGMENTED REALITY
Many potential uses
Can add camera, etc. (outside of OZ) used with wearable computer (zoom in/out, record, etc.) Will have wireless connection

Power Source - Radio Frequency and Solar Cell placed on lens
Prototype lens containing an electric circuit and red light-emitting diodes for a display, has been tested on rabbits with no adverse effects.

Maybe?
Captures everything you see in the course of a day, saving the video to a USB thumb drive in your pocket. Just plug it into your PC or stream wirelessly via Bluetooth or Wi-Fi, and you can check out everything you saw, along with audio recorded via the drive's built-in microphone.