Optical Prosthetics

Technology Mimicking the Eye
The parts of the eye we are covering are:

- The Cornea
- The Iris
- The Lens
Index of Refraction of the Eye

- To be used as a reference.
  - Cornea—1.376
  - Aqueous humor—1.336
  - Lens—Ranges from 1.386 in the outer layers to 1.406 at the center.
  - Vitreous body—1.337
The Cornea and its Functions

- The cornea is the outermost layer of the eye and provides the main curvature.

Properties of the cornea

- Index of Refraction of 1.376
- Consists of three layers:
  - Epithelium—Similar to the epidermis of our skin.
  - Stroma—Highly organized collagen.
  - Endothelium—Maintains water balance and transparency.
How the Cornea is Lost

- Two main ways a person can lose their cornea.
  - Damage caused by disease (affects 10 million people worldwide).
  - Physical injury.
- Currently today, most cases are solved by surgically implanting a donor’s cornea.
- However, there are some cases where implants are rejected and won’t suffice...
In 2003, the University of Ottawa managed to grow a pig’s cornea in partially blind pigs by implanting a “scaffold” of plastic and protein where the cornea will grow.
Artificial Corneas

- Rather than abusing pig eyes, artificial corneas are being developed from hydrogels, polymers that consist of ~70% water.
- Desirable properties of hydrogels:
  - Wear resistant
  - Fracture resistant
  - Optically clear
  - Glucose-permeable
The current product on the market is an artificial cornea called AlphaCor. It is developed by Argus Biomedical Pty Ltd in Perth, Australia.
Details on AlphaCor

- Under clinical investigation since 1998.
- FDA-approved in 2002.
- AlphaCor is made from a hydrogel called PHEMA (poly 2[hydroxyethyl methacrylate]).
- Its diameter is 7.0 mm, its width is 600 µm.
The Two Layers

- **Outer skirt**
  - Spongy, porous, and opaque, allowing natural corneal tissue to grow and help hold the implant in place.

- **Inner Layer**
  - Transparent with an index of refraction of 1.43.
Implanting an Artificial Cornea

- Surgery is nearly identical to that of a regular cornea.
  - Open up a Gunderson’s flap that the implant will go under.
  - Dissect enough corneal tissue to form a lamellar corneal pocket.
  - Insert the implant into the pocket.
(continued from above)

- Sew a mattress suture to prevent the implant from riding up.
- Close the pocket with nylon sutures.
- After 12 weeks, remove the Gunderson’s flap to expose the corneal implant.
There are two things that can go wrong with implanting an artificial cornea like AlphaCor.

- Stromal melting is a fairly common side effect occurring in 30% of patients, where the patient’s stroma layer loses structural integrity.
- Optic deposits (i.e. calcium phosphate) may form on the center of the device.
Future Plans for AlphaCor

- Enhance the optical zone (the transparent part).
- Color the outer skirt to match the patient’s iris color.
Double Network Hydrogels

- Currently being developed by the University of Stanford.
- Tensile strength is 20 times greater than its single hydrogel components.
- However...
  - Working prototypes still need to be developed.
  - Cellular response still needs to be tested.
The Iris and its Functions

- By contracting and dilating, it determines the f/# number of the eye.
- Can either be born without one (aniridia, affects 1 out of 50,000 people), or lose function by physical injury.
- In addition, iris patterns are unique enough to be used for personal identification.
Artificial Irides

- Most notable of artificial irises is the Morcher Iris Diaphragm Ring.
  - Invented by Dr. Volker Rasch from Potsdam, Germany and Dr. Kenneth J. Rosenthal in 1996.
  - In addition, Dr. Rosenthal also performed the first surgery with the device in 1997.
Picture of Artificial Iris
Realistic-looking Artificial Irises

- It is possible to make very realistic looking irises by using computer rendering with 30 textured layers.
- In addition to CG, can also be used in prosthetic design.
The Lens and its Function

- By adjusting its angle of curvature, the focal length of the eye can be adjusted (to certain limits).
- The index of refraction varies in the lens from 1.386 at the outer layers to 1.406 at the inner layers.
- Due to its position, shape of lens less a factor than that of the cornea.
Losing the Lens

- Generally, lenses need to be replaced after cataract surgery.
- Most artificial lenses are made from plastic, silicone, or acrylic and last for life.
- Sorry, not the place of the eye with great advances in science.
References


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