Abstract

The eye is a complex optical system that, like other organs, may become injured due to disease or injury. As such, various prosthetics have been designed to allow such people to regain their sight and enjoy a full life. This paper mostly covers the cornea, but it also covers the iris and the lens. Since someone else was researching artificial retinas, that will not be covered. The truth is, I really wanted to cover that, since there are many advances in that field, while still being in its infancy.

Introduction

The eye consists of many parts.

- Sclera: The majority of the eye, it forms the white shell and the basic shape of the eyeball.
- Cornea: The frontal 1/6 of the eye’s surface area, it also serves as the main curvature of the eye. It has an index of refraction of 1.376.
- Aqueous humor: The fluid that separates the cornea from the lens. Has an index of refraction of 1.336.
• Lens: Along with the iris, it forms an aperture stop for the eye, which it adjusts by dilating and contracting. Has an index of refraction ranging from 1.386 to 1.406.
• Iris: Along with the lens, it forms an aperture stop for the eye. Opaque.
• Vitreous body: The fluid that fills the space inside the sclera. It has an index of refraction of 1.337.
• Retina: At the rear of the eye, it changes the images focused from the other elements into electrical signals, which are sent to the brain.

If you are wondering why the various indexes of refraction are roughly the same as water, don’t forget that the human body is made of 70% water (and the various bodily fluids have a higher percentage of their mass as water).

The Cornea

The cornea is located at the front of the eye and serves as the main curvature. It has an index of refraction of 1.376 and consists of three layers. On the outside is the epithelium, which acts like the epidermis of the eye. Behind the epithelium lies the stroma, which is essentially highly organized collagen. Behind the stroma lies the endothelium, which helps maintain water balance and transparency. The cornea may be damaged either through physical injury, or by a disease that affects 10 million people worldwide. In most cases, the problem is solved by implanting a donor’s cornea. Unfortunately, some patients may either not have an available donor, or tend to reject donor corneas. An artificial cornea may succeed in these cases where donor corneas fail.
The most prominent of these is called AlphaCor, which is developed by Argus Biomedical Pty Ltd., which is located in Perth, Australia. AlphaCor has been under clinical investigation since 1998 and was FDA-approved in August 2002. It is made from a hydrogel called PHEMA (poly [2-hydroxyethyl methacrylate].) Hydrogels are the same type of material used in making soft contact lenses. The benefits of this material are that it is wear-resistant, fracture-resistant, optically clear, and glucose-permeable. The total diameter of the device is 7.0 mm and is 600µm thick. The edge of the device (called the skirt) is spongy, porous, and opaque, which allows existing corneal tissue to grow in it and hold it in place. The inside of the device is transparent with an index of refraction of 1.43.

Surgery for AlphaCor is nearly identical to the operation of inserting a regular transplant. First, open up a Gunderson flap that will go over the implant. Next, dissect enough corneal tissue to form a lamellar corneal pocket. Then, insert the implant into the pocket. Next, sew a mattress suture to prevent the implant from riding up. Then, close the pocket with nylon sutures. After 12 weeks, remove the Gunderson flap and expose the artificial cornea.
However, artificial corneas are not without their problems either. The two main complications with prosthetics like AlphaCor are stromal melting and optic deposits (such as calcium phosphate) gathering on the device. Stromal melting is where the patient’s stroma loses its structural integrity, and thus “melts”. This occurs in 30% of patients tested and may blind that eye permanently if unchecked. Optic deposits are far less common, but are less of a threat to the patient’s eyesight.

In the future, Argus Biomedical plans for AlphaCor to have a larger optical area, as well as colored skirts to match the patient’s iris color. Stanford University has also experimented with making artificial corneas with double network hydrogels, which possess 20 times greater tensile strength than its single components. However, they have yet to test cellular response with these hydrogels, or make a transplantable device prototype.

**The Iris**

The iris acts as the aperture stop of the eye, controlling the amount of light that passes through to the retina. The iris is also unique enough to be used for personal identification. Some people are born without an iris (aniridia, only affects 1 out of 50,000 people), while others may lose iris functionality by physical injury.
One of the first artificial irises made is the Morcher Iris Diaphragm Ring, developed by Dr. Kenneth J. Rosenthal and Dr. Volker Rasch in 1996. Dr. Rosenthal also did the first surgery with the device in 1997. As you can see, while this picture is not the actual device, it does not appear realistic. However, it is quite possible to design a more realistic-looking prosthetic iris design by rendering it using 30 textured CG layers.

**The Lens**

The lens is located roughly in the center of the eye. By varying its curvature, the focal point of the eye can be adjusted (to certain limits). The index of refraction of the lens varies in the eye, which starts at 1.386 on the outside to 1.406 in the center. The lens is usually damaged through cataracts, and is replaced with a simple prosthetic made from plastic, silicone, or acrylic. Since the aqueous humor and the vitreous body have indexes of refraction close to that of the lens, the shape of the lens does not need to be very fine. Because of this, there is little scientific progress (or need of progress) in human lenses.
Conclusions

Before researching this topic, I did not know about the various prosthetic devices on the market (except for Doelle which I heard about on the news one day). What I learned about the eye while doing this project is just how much progress they have done (or needed to be done) on the iris and the lens, how complicated replacing corneas can be, and how little progress we have made on artificial retinas. While I haven’t covered the last one in this paper (since another student is focusing solely on that aspect), it is what drew me into doing this topic.

References


