The Novel Application of Hydrogel Technology for Human Optical Lens Replacement

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Introduction

The lens of the eye is a hard, yet flexible structure responsible for focusing light waves onto the retina in the back of the eye to produce clear visual images. The lens is capable of accommodation, or focusing of the light waves, by the action of the ciliary muscles. These muscles can pull on the lens to alter the shape and provide a more focused image.

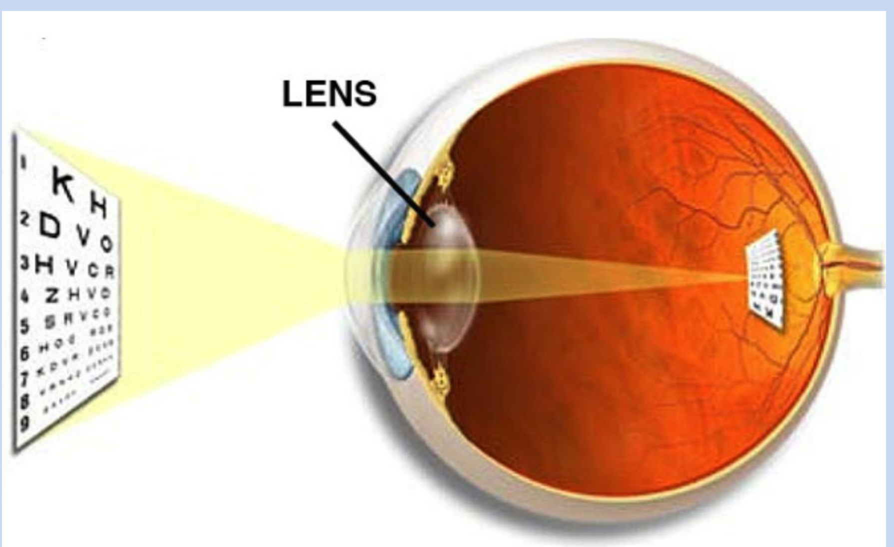
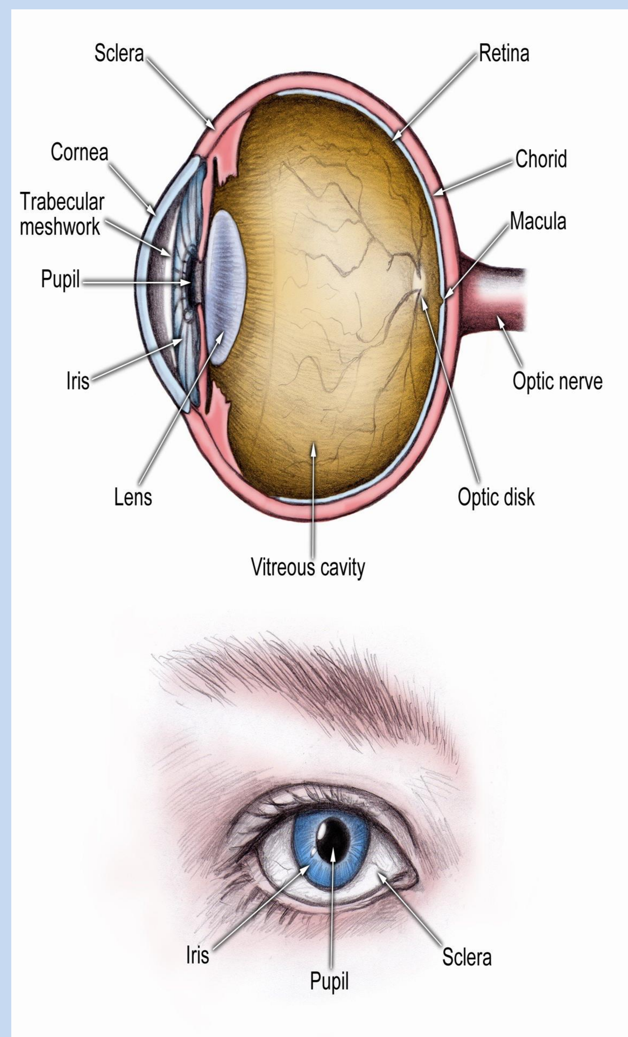


Figure 1a. A human eyeball cut in half to show the lens and the passage of light through it from the object ahead to the focus on the retina.



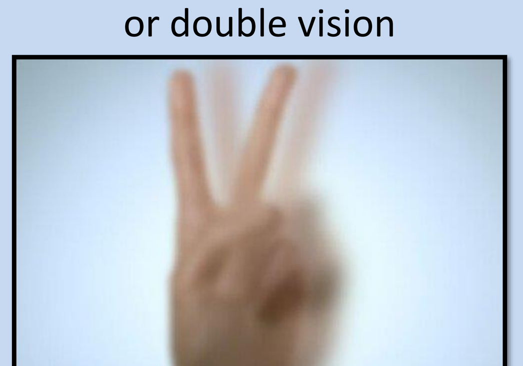
Cataracts is a clouding of the lens which causes scattering of the light waves entering the eye rather than focusing them. This causes blurred vision, visual aberrations, night glare and can result in blindness if left untreated is some cases. Cataracts are one of the most common problems associated with aging. However, cataracts can also appear in much younger individuals. Congenital cataracts account for around 200,000 cases of blindness in newborns each year according to the Journal of Cataract & Refractive Surgery.

Figure 10. Photograph of a patient's right eye with a dense mature cataract. Courtesy of James Gilmore, Photography department at the Moran Eye Center.

Symptom of cataracts: glare

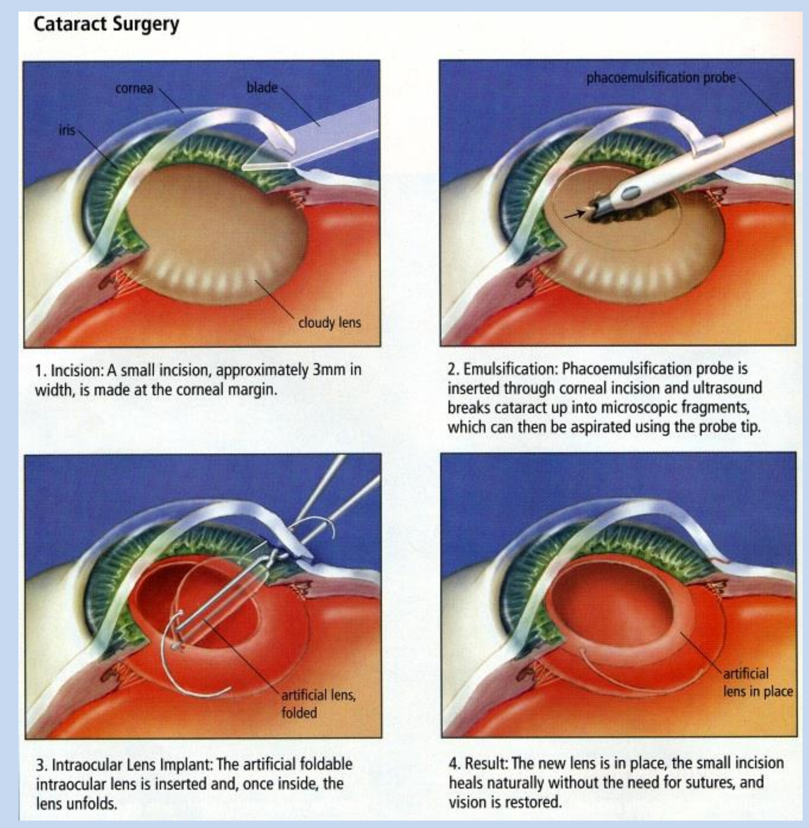
Symptom of cataracts: color changes

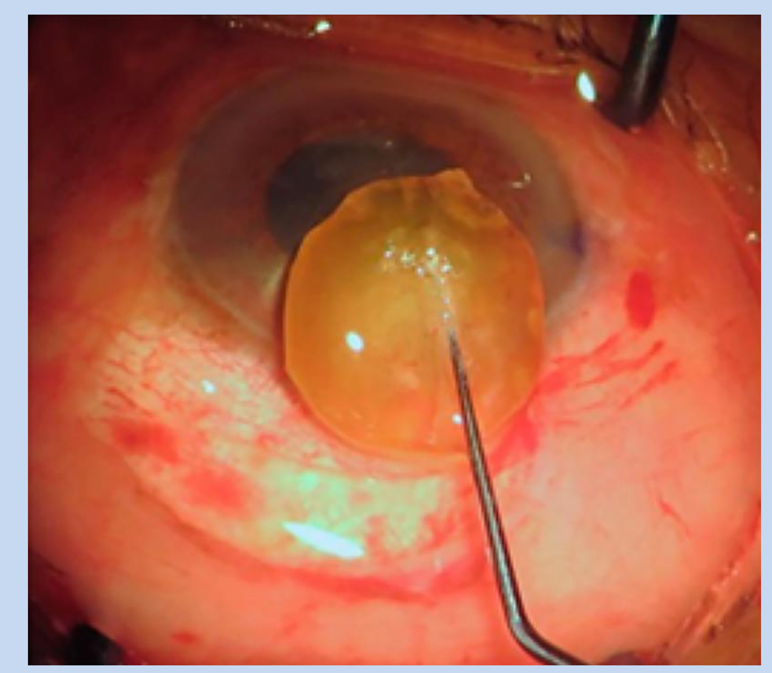
Symptom of cataracts: blurry or double vision



Objective

The current treatment for cataracts is to surgically replace the lens with an artificial lens that is clear. The eye surgeon opens the membrane surrounding the lens, removes the cloudy lens and replaces it with the artificial lens. The light waves are now able to go through the lens without scattering. However, the artificial lens does not possess the focusing ability of the natural lens so a person must use glasses after the surgery. Also, inserting a larger lens sometimes requires sutures to close the membrane after insertion of the artificial lens. The average cost of cataract surgery is several thousand dollars per eye.

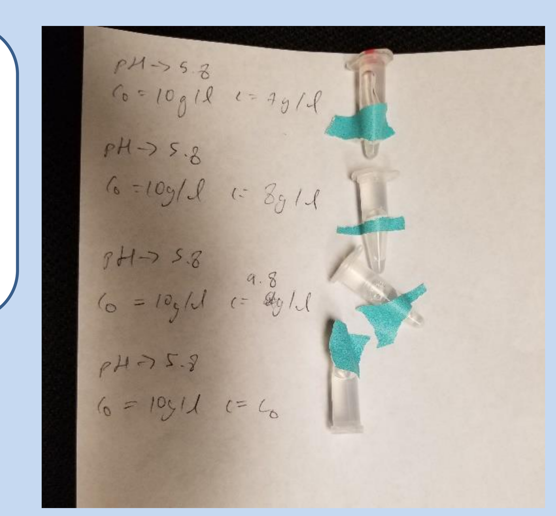




This research project centers around creating an artificial lens using a new type of hydrogel. The hydrogel can be inserted through a smaller opening in the eye and then solidify in place. It would have the correct elasticity to mimic a natural lens so that post-operative corrective lenses would not be necessary. The hydrogel materials and lessened amount of time needed for surgery would dramatically reduce the cost of removal of cataracts. This would make the procedure much more widely available.

Methods

The hydrogel under investigation was developed from new polymer formulas that were reported to have the needed elasticity index to replicate the stretch and stiffness of a natural lens. The other impetus for using this new polymer formula is that it doesn't continue to absorb water which would increase the intraocular pressure and possibly cause damage.

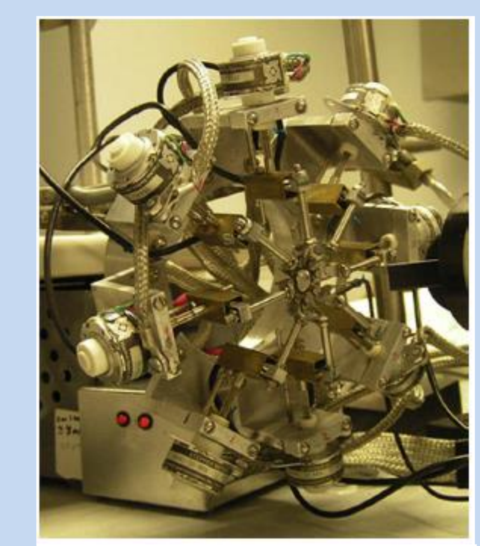


The two hydrogel formulas are mixed separately in an acidic base solution and must be done in dark, cool conditions so gelling doesn't occur at the wrong time. The solutions are then diluted and mixed in a systematic series of ratios to test for gelling consistency. The gel time also needed to take place within a ten-minute time frame to be a candidate as a possible surgical lens replacement option.

Results

Experimental preparation of the hydrogels was successfully completed. The hydrogel was then subjected to testing using a rheometer to determine the level of elasticity. It was determined that subsequent hydrogel preparations did obtain the same elasticity modulus of a natural lens.

The next stage of research involved testing the hydrogel in an actual eye to determine if the hydrogel would indeed function as a lens. The hydrogel would need to stretch and return to its original shape just as a natural lens. This must also be repeated over and over without loss of shape or elasticity. Furthermore, the refractive ability of the lens could also be determined.



Comparison of the behavior of natural and refilled porcine lenses in a robotic lens stretcher

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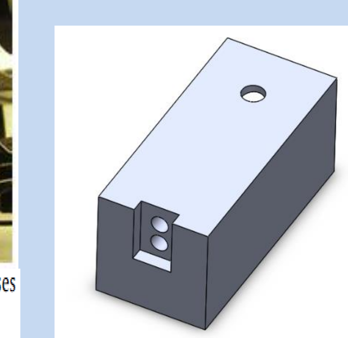
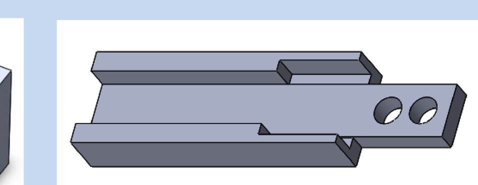
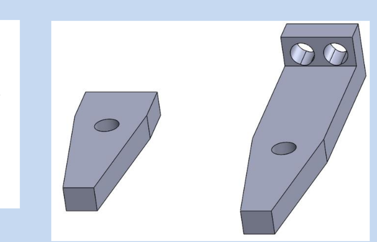
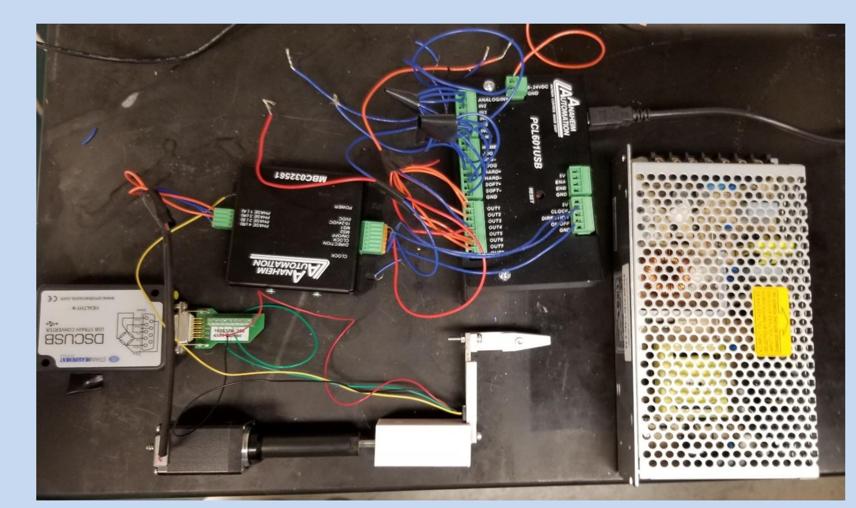
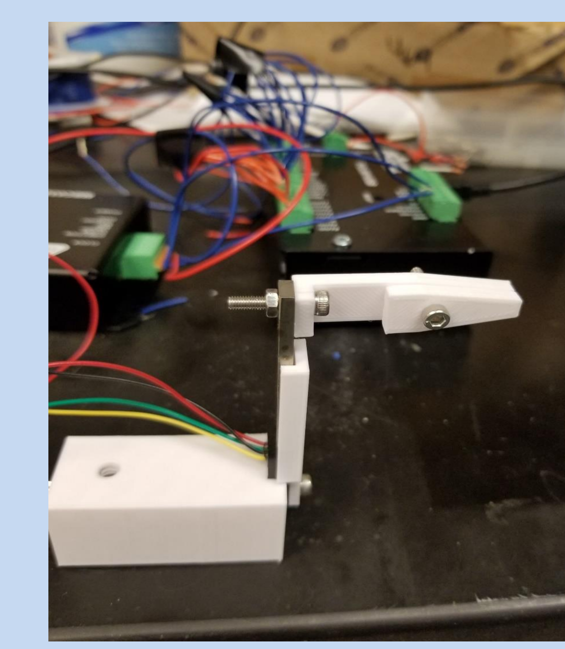
The donated eyes equipped with the new hydrogel lenses would require development of additional equipment. A lens stretcher needed to be constructed and equipped with force sensors to gauge the force of the stretch on the lens. A 3D printer was used to produce newly designed parts to replicate another model of a lens stretcher.











Discussion

After successful completion of testing in Dr. Alba's lab, the newly developed hydrogel lens will undergo medical experimental research at Baylor University for further study of its suitability as a human eye lens replacement.

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