Electronic contact lenses may replace reading glasses

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Electronic contact lenses can switch between different focal powers, functioning similarly to putting on and taking off reading glasses.

A leading problem facing modern optometry is correcting presbyopia, the reduction of near-visual acuity arising from the natural deterioration of the eyes’ accommodation mechanism. It affects everyone over age 45. This deterioration is thought to arise from a reduction in the crystalline lens’ flexibility that renders the aging eye unable to provide the additional focal power for near-vision tasks. The most common form of correction for presbyopia is wearing a pair of reading glasses for near-vision tasks. Contact lens correction of presbyopia is more problematic due to the fundamental restrictions caused by various forms of optical compromise associated with simultaneous vision devices. This results in reduced vision quality and user satisfaction.

Currently, correcting presbyopia with contact lenses relies on a concept known as simultaneous vision, with a single contact lens possessing multiple regions of different corrective power. Simultaneous vision contact lenses provide both focused and unfocused images on the retina. The brain’s visual system is required to select the correct image and ignore out-of-focus information. This process can result in reduced visual acuity and contrast sensitivity and is a major area of contact lens research and development. We are researching a new correction method that uses electro-active liquid-crystal lenses and avoids the visual compromises associated with current technology. Liquid-crystal lenses can be turned on and off electronically and show great promise for recreating the accommodation mechanism of the crystalline lens.

Liquid crystals are a state of matter between a solid and a liquid, and are best known for their use in flat-screen displays. Liquid crystals generally form from long, rodlike molecules that exhibit some degree of orientational order, but with no or limited positional order. The long molecules tend to point in the same direction, be it dictated by surfaces or applied electric fields. The principle behind liquid-crystal devices is the phenomenon that occurs when a voltage is applied to a liquid-crystal material, reorienting the liquid crystal. This reorientation corresponds to a change in the material’s refractive index, a property that can be exploited to form a variable-focus lens. A prototype pair of spectacle lenses using liquid-crystal lens technology was developed at the University of Arizona.

Our work on these new contact lenses is being conducted in a collaborative research project between university departments and industry. Our primary goal is to transfer liquid-crystal lens...
technology to contact lens use. Contact lenses have a unique set of requirements. First, the lens device must be able to be placed on the cornea and constructed using contact lens materials, thus deviating from the commonly used flat glass commercial devices. In terms of required optics, a contact lens device correcting for presbyopia cannot have additional optical power when it is turned off. It must also be capable of providing up to +2.00 diopters (D) of optical power when activated. Finally, the device must be thin enough to be used as a contact lens. A thickness of less than 300 microns is preferred.

Figure 1 shows our prototype device, which was designed to meet all of these criteria using a balanced optical system, with the substrates consisting of two positive meniscus polymethyl methacrylate contact lenses. The interior curvatures of the substrates were designed to produce a cavity shaped like a negative meniscus lens so it can be filled with a liquid crystal. The general principle of action is the change of refractive index of the liquid-crystal layer with the applied voltage across the cavity. In the electrically inactive state, the optical power from the lens substrates and the liquid-crystal layer are opposite and equal, resulting in a net optical power of zero. When a sufficiently high voltage is applied to the lens device, the refractive index of the liquid-crystal layer is reduced, converging optical power from the substrates dominating the system and inducing a positive net optical power for the device. We designed the device to provide a change of +2.00 D in optical power when activated, perfect for correcting most forms of presbyopia, though higher optical powers are readily achievable if needed.

We fabricated the substrates using standard contact lens manufacturing techniques, with a conductive transparent coating of indium tin oxide sputtered onto the interior surfaces of the lens device. We also treated the interior surfaces with an alignment agent and then filled the cavity containing the liquid crystal. The potential change in refractive index is 0.18, a level that is typical for commonly used liquid-crystal materials employed in displays. Upon applying a voltage above the threshold voltage of the liquid crystal, the optical power could change significantly. An additional +2.00 D can be induced (see Figure 2). In terms of the device’s optical quality, the point spread function and modulation transfer function (MTF) indicate that the optical quality of empty devices and those filled with liquid crystal are similar (typically MTF50, a standard measure of the lens’ resolving power, which is the cut-off spatial frequency at 50% modulation and relevant to vision correction). Values can vary between 60 and 70% of the diffraction limit in these devices.

Figure 3 shows the intermediate transient state before the filament is brought into sharp focus.
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Harry Milton, PhD, is a research associate who has spent over five years designing and building new electronically controlled contact lenses and fabricating optical liquid-crystal devices.

References