Fascinating Physics of Contact Lenses

Contact lenses have been an option for people who need vision correction for over one hundred years. Since then they have been changed and perfected so that many different people can wear them. People spend a great deal of money each year on contacts and solutions. The science behind this wonderful form of vision correction is very intriguing. This paper is about how they work and how they are made. The objective is to inform consumers about what makes up the product and how it bends the light in different ways for far and near sighted people.

How Contact Lenses Work

There are four basic kinds of vision problems: myopia, hyperopia or hypermetropia, astigmatism, and presbyopia ("Refractive Error and Presbyopia"). Each type of vision problem results in a different refractive error. "Refractive error" is "when light does not focus" properly on the retina ("Refractive Error and Presbyopia"). Most people have refractive error to a certain degree even if they don't know it ("Refractive Error and Presbyopia"). All four effect vision in different ways.

Myopia

Myopia is the technical term for near-sightedness. Myopia is when parallel rays are focused in front of the retina causing objects to appear more blurry the farther away they are (see figure 1). It tends to run in families, but the precise cause is unknown. Myopia affects more than 25% of the general population and is the most common eye problem throughout the entire United States (Fekrat, Weizer, and Lee 18-20). Myopia is corrected using a negative power (concave) lens. Concave lenses change the angle of refraction for light rays so they converge farther back and on to the retina.

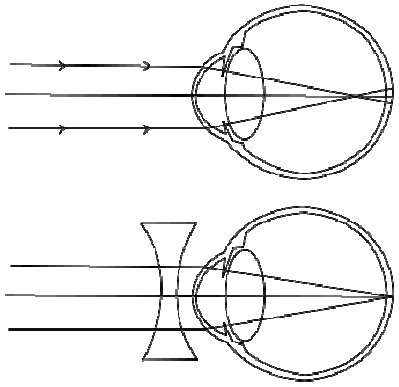

Figure 1: This picture shows how myopia affects vision and where it focuses the parallel rays and how a concave lens corrects this ("Images:Myopia").

Hyperopia

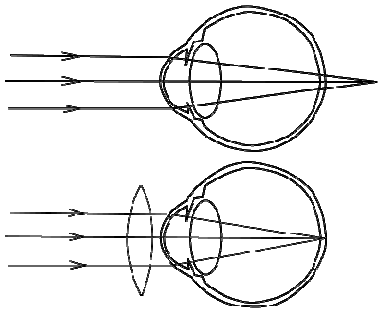

Figure 2: This picture illustrates how hyperopia affects vision, where it focuses the parallel rays and how a concave lens corrects this

Hyperopia or hypermetropia is when parallel rays are focused behind the retina causing objects to appear more blurry the closer they are (see figure 2). Many babies are born with hyperopia, but out grow it by the time they become teenagers (Fekrat, Weizer, and Lee 13-14). "Children and young adults with mild or moderate hyperopia are often able to see clearly because their natural lens can change its shape, or accommodate, to focus on near objects" (Fekrat, Weizer, and Lee 20-21).Hyperopia is corrected with a positive power (convex) lens. These lenses bring the focal point closer and on to the retina (Mayo Clinic on Vision 13-14).

Astigmatism

Astigmatism is when parallel rays of light do not converge on a single focal point on the retina (see figure 3). This results in vision being distorted in all directions and all distances. People with astigmatism are usually born with it and it gets worse with age (VisionRx). Astigmatism can be coupled with myopia or hyperopia and is most often caused by an irregularly shaped cornea (Lee and Bailey). The lens will have refractions in two different directions and be concave or convex depending on whether a person also has myopia or hyperopia (Hughes).

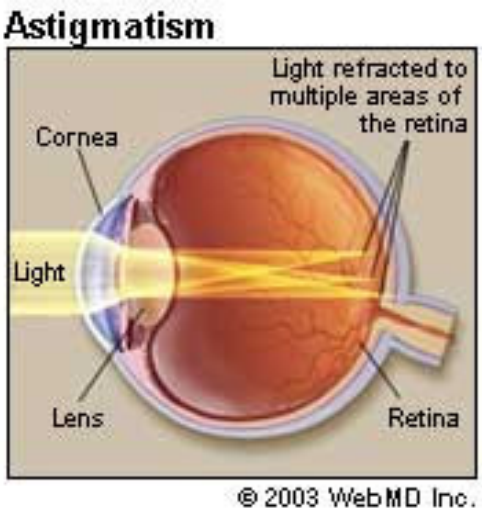

Figure 3: This picture illustrates how astigmatism causes the light rays to not end up on just one point on the eye, but rather many points.

Presbyopia

Presbyopia is a common vision problem caused by aging and affects the eye's ability to adjust. It is often confused with hyperopia. Presbyopia affects all people once they reach their forties ("Refractive Error and Presbyopia"). According to RefractiveSource, "one of the best ways to understand presbyopia is to consider

what one's vision is like when the eyes are dilated at the doctor's office. The dilating drops simulate presbyopia by relaxing the eyes' ability to focus (besides making the pupil large)."

How Contact Lenses Are Made

History and Progression

Leonardo da Vinci was the first person to come up with the basic idea of contact lenses ("Contact lenses"). He however, was not interested in vision correction, but rather in mechanisms of accommodation of the eye ("Contact lenses"). In 1636, René Descartes came up with a glass tube filled with liquid and placed in direct contact with the cornea; however this would make blinking impossible, so that idea was out ("Contact Lenses"). In 1801, Thomas Young constructed a liquid-filled "eyecup", but like with da Vinci, it was created with mechanisms of accommodation, and not for vision correction ("Contact Lenses"). "The first ever eye covering to be seen through and tolerated" was produced by a glassblower named F. E. Muller ("Contact lenses"). A hundred years ago contacts were made of glass, making them uncomfortable, heavy, and "not able to be worn for" long "periods of time" (Woodward). Plastic "corneal" lenses were worn from the 1930's to the 60's, but caused discomfort due to lack of oxygen getting into the eye. In 1971, polymers were discovered to be more comfortable due to the ability of oxygen to reach the eye (oxygen permeability). Some contact lenses today have silicone hydrogels to improve gas permeability ("Soft Contact Lenses").

Materials

There are three different types of contact lenses (Serge). These are: soft lenses, hard lenses, and GP (gas permeable) or RGP (rigid gas permeable) lenses. Contact lenses are made of different materials depending on what type they are.

"Hard lenses are made from PMMA," which is "also known as" Lucite or Plexiglas (Serge). Hard lenses are almost entirely "obsolete and rarely used" (Serge). According to Serge, "Soft lenses are made from gel-like, water-containing plastics, and are most common. They're a bit larger in size than an iris (the colored part of the eye)." Serge also says that, "GP lenses, also know as RGP or "oxygen permeable" lenses, are made from rigid, waterless plastics and are especially good for presbyopia and high astigmatism. These lenses are usually about eight millimeters in diameter, which is smaller than the iris" (Serge).

Process

There are two possible methods, and four steps in making contact lenses. They can be made by a molding process, or by cutting blank on a lathe ("Contact Lens"). The lens formation involves shaping the plastic into certain curvatures ("Contact Lens"). According to "Contact Lens", "The major curves of the lens are named the *central anterior curve* (CAC) and the *central posterior curve* (CPC). The CAC refers to the overall curve of the side of the lens that faces out. This contour produces the correct refractive change to fit the patient's visual needs. The CPC is the concave inner side of the lens. This conforms to the measurements of the patient's eye." Generally "these two curves are" made first, and then the lens is deemed "semi-finished" ("Contact Lens"). It "is finished when intermediate curves are formed, and the edge is shaped" ("Contact Lens").

One method for making lenses is molding (see figure 4). This can be done many different ways. The type of lenses that were first developed in Prague were spin-cast lenses ("Contact Lens"). Injection molding however, is a more reliable method for mass-production ("Contact Lens"). With injection molding, liquefied plastic is injected into the mold under a certain amount of pressure. "The lens is removed from the mold", cooled, and then finished on a lathe ("Contact Lens"). Recent development has removed the need for a lathe, so it can be done entirely with molding ("Contact Lens").

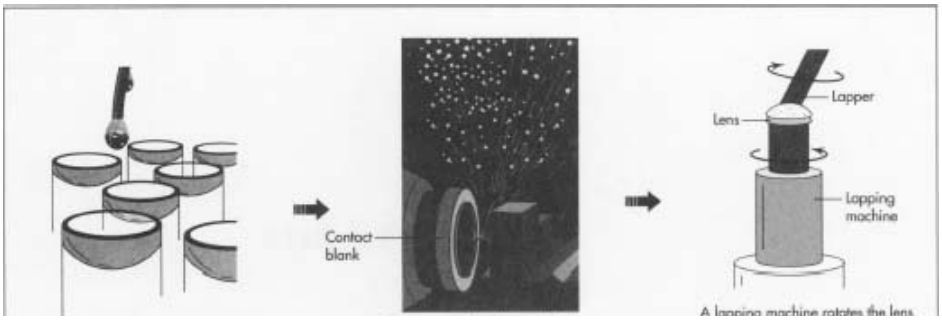

Figure 4: This picture shows some of the methods for making contact lenses, including molding and lathe cut.

Another method for making contact lenses is the lathe process (Woodward). "The initial forming of the lens" is lathe cutting in this method (Woodward). "First a blank is made. The blank is a circle only slightly larger than the size of the finished lens. This can be cut from a plastic rod, or stamped from a plastic sheet. Next the blank is fastened to a steel button with a drop of molten wax. The button is centered on a lather, which begins to spin at a high speed" (Woodward) ("Contact Lens"). ("Concave cuts in the blank" that "form the CPC" are made by "a cutting

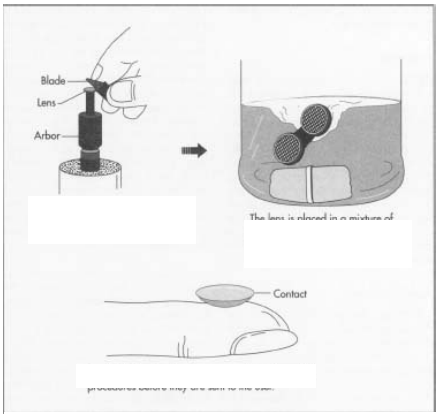

Figure 5: This picture shows the final steps in the lathe cut process.

tool, which" is typically either "a diamond, or a laser" ("Contact Lens"). According to "Contact Lens", "The button holding the blank is next moved to a lapping machine. The lapping machine holds the blank against a lapper, which is a revolving disk coated with an abrasive compound. The shape of the lapper matches the CPC of the lens. The lapping machine spins the blank in one direction, and the lapper in the other." The blank is also moved in a tiny figure eight type motion ("Contact Lens"). Once the lens is polished, the final cuts are made on a steel shaft called an arbor (see figure 5) ("Contact Lens"). Then several more curves are made to finish it, the quality of the lens is checked and then they are sterilized, soaked for several hours and packaged ("Contact Lens").

In conclusion, contact lenses have been around for over a century. Since they were first conceptualized, they have been honed and perfected so that they can be worn all day, and by many different people. There are contacts for people with myopia, hyperopia, astigmatism, and presbyopia. There are hard, soft, and gas permeable lenses. There are also varying methods for producing contacts including lathe and molding. The physics behind this form of vision correction explains exactly how they correct the different kind of vision problems.

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