Optical Simulation of Myopia for Vision Correction

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Abstract: With the current trends in surgical development, the traditional surgical knife is being replaced by laser scalpel. In addition, traditional surgery, which is risky, is being replaced by minimally risky surgery. Assessing vision correction before laser scalpel surgery is important. This study aims to simulate image formation of the retina by using an application-specific automation processor. The results show that the image diffused with the development of myopia on the retina.

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1. Introduction

Various options are available for people who wear glasses or contact lenses to reduce or eliminate their dependence on their corrective lenses. Vision correction surgery such as LASIK is effective in most cases. The advantages of LASIK include safety, high precision, high stability, short surgery duration, and easier recovery. Precise assessment of vision correction is important before laser scalpel surgery.

This article uses application-specific automation processor (ASAP) optical simulation software to simulate images of myopia on the retina. The results show that image size increases gradually with increasing diopter.

2. Model of an Eyeball

The structure of an eyeball is illustrated in Fig. 1. The outermost layer of an eyeball consists of the transparent layer of the cornea and the white layer of the sclera. The cornea sends reflections of light into the pupil; this is the first step in vision creation. The sclera, which is known as the white of the eye, protects the inside of the eyeball and maintains its shape. The middle layer in the anterior chamber is the iris, which has a small hole in its center. This hole is the pupil, the size of which adjusts according to the intensity of light. The choroid is located in the posterior chamber of the eyeball. The ciliary muscle is between the choroid and the iris. Behind the iris is the crystalline lens, which should always be clear and transparent to allow light to pass through. The vitreous body is behind the crystalline lens, followed by the retina, which has sensor cells and nerves. The light that enters the eyeball through the pupil is reflected by the crystalline lens and then focused on the retina to create a clear image; this process enables us to see objects. The optic nerves transmit the image to the cerebral cortex to produce vision.

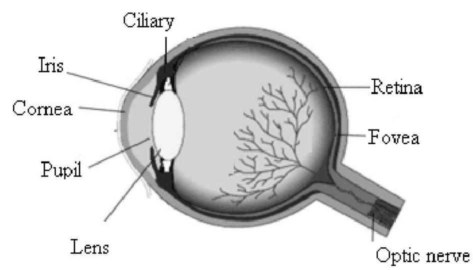

Fig. 1 Structure of an eyeball

In a normal eye, light is focused on the retina to create a clear image, as shown in Fig. 2. Myopia may be caused by a visual axis that is too long or a focal distance (of the cornea and the crystalline lens) that is too far, which causes the light to be focused in front of the retina. Therefore, a myopic person can see nearby objects, but not objects that are farther away. Hyperopia may be caused by a visual axis or a focal distance (of the cornea and the crystalline lens) that is too short, which causes light to be focused behind the retina. Therefore, a person with hyperopia cannot see nearby objects.

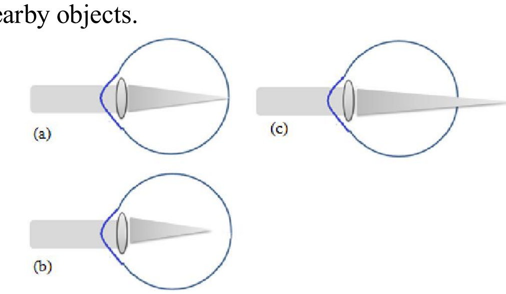

Fig. 2 (a) Normal eye; (b) myopia; and (c) hyperopia

Corneal Equations

The change in the corneal surface, which was achieved by the LASIK treatment, is shown in Equation 1, which uses Munnerlyn's equation.

$$f_{mun}(\rho)=\sqrt{R_1^2-\rho^2}-\sqrt{\frac{R_1(n-1)}{n-1+R_1 s}-\rho^2}$$

$$-\sqrt{R_1-\frac{\phi^2}{4}}+\sqrt{\frac{R_1(n-1)}{n-1+R_1 s}-\frac{\phi^2}{4}}+f_0^{TZ} \quad (1)$$

where ρ refers to the length of the optical axis; R_1 indicates the initial radius of curvature of the cornea; *n* signifies the refractive index of the cornea with a value of 1.377; S represents the corrected refractive errors; and Φ indicates the radius of the optical area. This equation is further simplified by a Taylor series, which obtained the parabolic Equation 2 after eliminating higher-order terms.

$$f(\rho)=\frac{4s\rho^2}{3}-\frac{s\varphi}{3}-f_0^{TZ} \quad (2)$$

The corneal equation after the treatment can be derived as shown in Equation 3

$$g(\rho)-f(\rho)=\frac{ch^2}{1+\sqrt{1-(1+K)^2c^2h^2}}-\frac{4s\rho^2}{3}+\frac{s\varphi}{3}-f_0^{TZ} \quad (3)$$

where g(ρ) is the original cornea, and f(ρ) is the change in the cornea achieved by the LASIK treatment.

3. Optical Simulation of Myopia

Figure 3 presents the image formation on the retina with various degrees of myopia, namely, 100°, 300°, 500°, and 700°, which correspond to (a), (b), (c), and (d). The distance between the retina and the object is 1 m. The horizontal axis is the image size in the x direction, while the vertical axis is the image size in the y direction (measured in μm). The upper right corner of 3(a) is the image formation on a normal retina. In a normal vision, the object is focused on one point. In myopia, the image diffuses with the development of myopia on the retina in a Gaussian distribution because the focal point is in front of the retina. Thus, patients with myopia cannot clearly see objects at a distance.

Figure 4 shows the image size on the retina of various diopters, where the distance between the retina and the object is 1 m. In a normal eye, the image is about 0.03 mm. The image size continues to increase gradually with increasing diopter. The maximum size of the image is around 0.033 of D= −7, which indicates myopia of 700°. The image becomes larger with increasing diopter of myopia, and the image becomes more blurred.

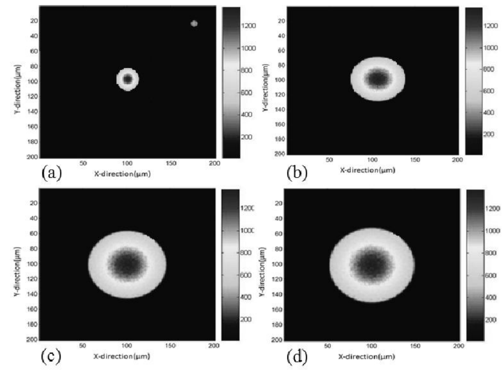

Fig. 3 Image formation on the retina with various degrees of myopia: 100°, 300°, 500°, and 700°, which correspond to (a), (b), (c), and (d).

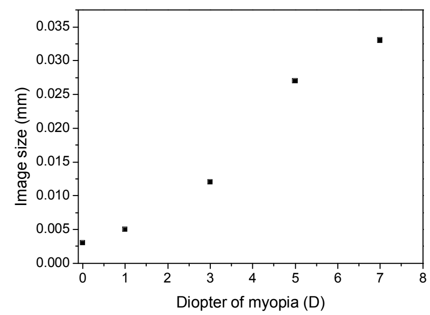

Fig. 4 Image size on the retina of various diopters

Conclusions

ASAP optical simulation software was used to simulate images of myopia on the retina. The image size on the retina increases gradually with increasing diopter. The maximum size of the image is around 0.033 of D = −7, and the image is more blurred.

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