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A Pictorial Study of How Spherical Aberration Affects Image Quality after LASIK

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Introduction

Spherical aberrations are known to increase after LASIK surgery. This can cause problems with the vision at night when the pupil size increases to adjust for the darkness. The purpose of this paper is to show through photographs how spherical aberrations affect image quality. The first step in this process is to find a way to generate spherical aberrations. The optical literature is filled with many different and complex devices that do this i.e. see bibliography. What is needed is a simple device that can record an image and that allows varying amounts of spherical aberration to be introduced so that its affect on image quality can be determined. Thus, for this study a modified film camera is used.

Spherical aberrations are produced when the peripheral part of the lens refracts the light more than near its optical center. Consider what happens when a +2.00 lens with a 5 mm hole in its optical center is attached to a 50 mm lens. When the lens aperture is smaller than 5 mm only light that passes through the hole reaches the film plane to produce a central image. Light from the +2.00 lens is blocked. However, if the lens aperture is larger than 5 mm some of the light from the +2.00 lens will reach the film plane. This light is over refracted and will produce spherical aberrations in the central image. As the lens aperture is increased more light from the +2.00 lens reaches the film plane to produce more aberrations.

To perform this study the UV glass of a UV lens filter is replaced with a +2.00 lens with a 5 mm hole in its optical center and is attached to the 50 mm lens in the usual manner. As described above this modification makes the 50 mm lens a spherical aberration generator. Two sets of photographs, one with the lens modified the other unmodified, are taken of a static object for apertures F/4 through F/16.

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Figure 1: Photograph taken with the unmodified lens at F/4. It has uniformly good resolution and contrast.

Figure 2: The photograph in Figure 2 was taken with the modified lens at F/4. Note that all detail is lost in the center and only the general shape of the central object remains.

Figure 3: Photograph with the modified lens at F/5.6. It has good image quality.

Figure 4: Photograph taken with the modified lens at F/5.6. Note the central image is still poor but improved from Figure 2. This is because the lens aperture is smaller at F/5.6 than at F/4 and allows less over refracted light to enter the film plane.

Figure 5: photograph taken with the modified lens at F/8. It has good image quality.

Figure 6: Photograph with the modified lens at F/8. At this F-stop the diameter of the lens aperture is 6.25mm and a fairly large amount of over refracted light still reaches the film plane. Note that the central image has improved enough to make the letters of the license plate almost distinguishable.

Figure 7: Photograph with the unmodified lens at F/11. The image quality is good.

Figure 8: Shows a photograph with the modified lens at F/11. The lens aperture is 4.55mm and a good central image is produced because most of the over refracted light is blocked.

Figure 9: Photograph with the unmodified lens at F/16. It has great image quality.

Figure 10: Photograph with the modified lens at F/16 and has a central image quality that is on par with that of Figure 9.

Discussion

The study described herein takes two sets of photographs of a static object for lens apertures F/4 to F/16 in order to gauge the affects of spherical aberrations on image quality. All of the photographs with the unmodified lens show good image quality over the full range of apertures. This is because there is minimal spherical aberration generated when the aperture is changed. However, the same is not true for the unmodified lens. When the aperture is small, at F/16, the image quality is good. But as the aperture size is increased the image quality decreases until at F/4 it is terrible. The take away from this study is that the image quality after LASIK may change significantly depending on the size of the pupil. For example on a bright sunny day the vision might be great because the pupil is small, just like in the modified lens at F/16, and the effects of spherical aberrations are small. However, in the evening or at night the pupil will adjust to less light and become larger. A larger pupil will allow more over refracted light to enter the eye. This will generate greater amounts of spherical aberrations that damage image quality. If the spherical aberration is high enough the vision can be severely limited as shown in Figure 2. The conclusions of this paper are applicable in a general sense.

They are a guide to show the limitations of LASIK. However, LASIK is not a one size fits all. Every patient's treatment must be individualized and the issues raised in this paper must be discussed in detail with the operating surgeon.

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