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Electro-Optic Designing and Construction to test the Tilting and the Decentering

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Abstract

As a result of existence of optical defects at the center of radius of curvature such as tilting and decentering because of non accuracy of processing after polishing and cementing operations. Theoretical and analytical studies depending on Liou and Brennan model (LBME) was done in addition to design and construct a system to test the effect of tilting and decentering on the MTF of the system with pupil diameter of 3 and 4.5 measured in (mm). Decentration and Tilt findings demonstrated high imaging quality corruption in the aberration corrective lens.

Keywords: Optical Tilt: Decentering: MTF: Sagittal MTF: Tangential MTF: Image analysis.

Introduction

Aspheric lenses have been used in optical and medical devices for several years to improve the vision images. Several methodologies have been described to design the aspheric elements [1-3]. Most of intraocular lens (IOL) designs are optimized depending on the eye, models. Liou and Brennan model eye (LBME) is the more accurate model [4]. It is very necessary to evaluate the tilt and the decentration alteration effect on Aspheric IOL behavior, because the correction of any wavefront depends on the involved optical element exact alignment. In the past decades, several clinical studies have measured the IOL mean decentration (0.3mm) ranging from 0 to 1.0 mm and mean tilt (2.62) degrees ranging from 0.2 to 8.17 degrees after cataract surgery [5-6]. Roughly, these researches provide an absolute decentration and tilt values of IOL with no indication of sign or direction.

Modulation transfer function (MTF) calculations to evaluate of imaging quality were performed with the ZEMAX optical design software. The LBME was simulated (parameters of design in Table 1) and then the crystal lens (surfaces 8 and 9) was replaced with the IOLs of refractive index (1.107461) and center thickness was thickness of 1.107 and the diameter of 6.0 mm.

Table 1. Optical design data of the LBME [4]

Surf	Type	Comment	Radius	Thickness	Glass	Semi-diameter	Conic factor
OBJ	Standard	Object	Infinity	Infinity	-	92	0
3	Standard	Cl- Back	7.8	7.8	Water	4	0
4	Coo.Breaker	-	-	-7.8	-	0	-
5	Standard	Cornea	7.77	0.55	1.38,50.2	5	-0.18
6	Standard	Aqueous	6.4	3.16	1.34,50.2	5	-0.6
STO#	Standard	Pupil	Infinity	0.0	1.34,50.2	1.25	0
8 +	Gradient 3	Lens-Front	12.4	1.59	-	5	0
9 +	Gradient 3	Lens-Back	Infinity	2.43	-	5	0
10	Standard	Vitreous	-8.09998	16.2388	1.34,50.2	5	0.96
IMG	Standard	Retina	-12	-	-	5	0

Materials and methods

Figure 1 is a diagram for the setup to calculate the lens tilt and decenter. It consists of a laser source, a chopper, a precise three axises lens holder, CCD camera and micro controller connected to a PC computer. All these equipments are aligned on a bench. The three dimension holder is moving in x, y and z-direction and can be rotated from 90 to 90 degrees.

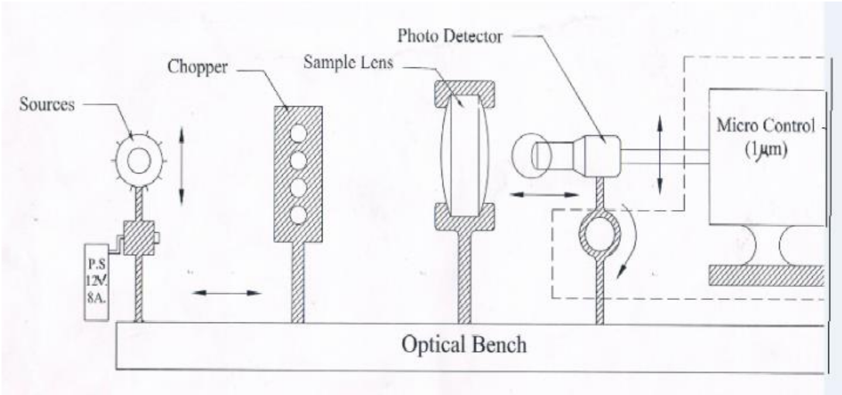

Figure 1. Setup to measure lenses tilt and decenter.

This setup is simple and can be used for any lens types (spherical, aspherical, contact lens and intraocular lens IOL). The tilt is calculated by using the following equation [7]

$$Tilt = \frac{y_1 - y_2}{R_1 - R_2 - C_T} \qquad \ldots(1)$$

Where y1, y2 is the position of the source image from 1st and 2nd lens surface, respectively: R1, R2 is the radius of curvature for the 1st and 2nd lens surface respectively: CT is the thickness at the lens center and can be calculated from.

$$C_T = \frac{R_2 - R_1}{n^2 - 1} n^2 \qquad \ldots(2)$$

Where n is the lens material refractive index. The decenter is measured from the following equation [3]

$$Decenter = \frac{(y_1 \mp y_2)}{2} \qquad \ldots(3)$$

The system can be improved to measure the modulation transfer function MTF for any lens and compare the results with the simulated results obtained from ZEMAX program for IOL lens. The IOL performance was simulated using the more physiologically accurate model LBME [4] construction and applied in ZEMAX optical design software, 2005. LBME replaced the crystalline lens (gradient index) by the applied IOL.

Specifications of this model: aspherical cornea, the crystalline lens, pupil aperture (iris), the pupil is nasally decentered by 0.5 mm and the vision axis (tilted relative to the optical axis by 5 degrees) [4]. The pupil diameter (PD) from corneal anterior vertex was 3.1 mm and its center has displaced 0.59 mm nasally. The complete model was rotated by 5 degrees around the pupil center to simulate the retinal image. LBME was designed mainly for the on axis imaging so they didn't provide a retinal curvature value. The retinal surface radius was set at 12 mm; the same value was employed by Atchison and smith [8] with LBME for optical simulation.

Other eye models use slightly different retinal curvature values. Spherical and chromatic aberrations were not significant in the current simulation because the image fineness was considered for the green light 555 nm (monochromatic light). Also It has been shown the Stiles Crawford influence is negligible at small values [9-10]. Calculations of image quality were evaluated for the eye model visual axis depending on MTF which performed with ZEMAX software. LBME was simulated as illustrated in Table 1, and replacement of IOL design data has explained in Table 2. The design data for Tecnis Z9000 IOL were taken the published patent [11]. The refractive index (RI) was assumed to be 1.461 and 0.3 mm thickness at 6 mm full diameter which resulted in 1.107 mm central thickness.

Table 2. Tested IOL design parameters and their optical properties.

Product	Power(D)	Lens shape	Anterior surface	Radius (mm)	Conic constant k	2nd order coff	4Th order coefficient.	6th order cofficient	Poster surface	Radius (mm)	2nd order coefficient	Center thickness (mm)	Refractive index	Optical material	2nd order coefficient
Tecnis Z9000	22	Equiconvex	6th order asphere	11.043	-1.03613	0	-.000944	-0.0000137	Sphere	-11.043	0	1.164	1.458	Silicone	0

Continue

After optimization, tangential and sagittal MTF features were calculated through the spatial frequency (v) in cycles/millimeter by ZEMAX optical design software. The IOL displacement was performed as seen in Figure 1. The IOL was decentered from -1 mm temporal to + 1 mm nasally in 0.25 mm steps relative to the pupil center to evaluate the decentration impact. Values of respective MTF were recorded for each decenter step with 3 and 4.5 mm

PDs. To evaluate the tilt effect on MTF, IOL was tilted from -5 to +5 degrees in step of 1 degree relative to the line of sight (see Figure 1).

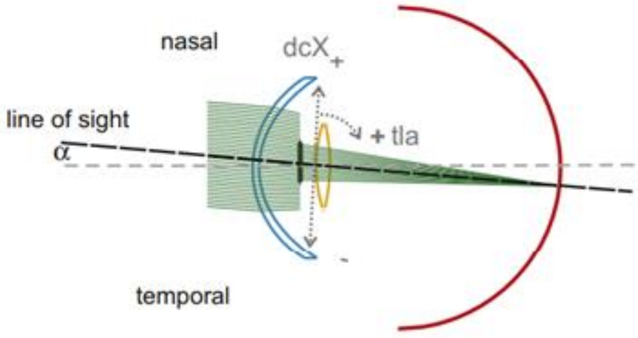

Figure 1. LBME layout after implanting the IOL. (dcX) refers to decentration relative to pupil center and the dashed line represents the angle of tilt (tla). The reference axis (α) acts the line of sight for IOL tilt and image quality.

Results

Figure 2 shows the MTF plots with a 3.0 mm and 4.5 mm pupil diameters. The Tangential MTF (dashed line----) are nearly equal each other, While the differences is observed in Tangential MTF. This difference happened by the aspherical surface of the lens.. With the 3.0 mm pupil size, the MTF had similar behavior to the aberration-free MTF were nearly insensitive to decentration. Figure 2 shows that the 4.5 mm pupil diameter led to poor MTF. Negative spherical aberration (SA) amount at 4.5mm pupil diameter and the design parameters of the used IOL in term of position and the order of aspherical surface have a manifest influence on the sensitivity of decentration. Predominant focus errors induced by the decision was horizontal coma followed by astigmatism and defocus.

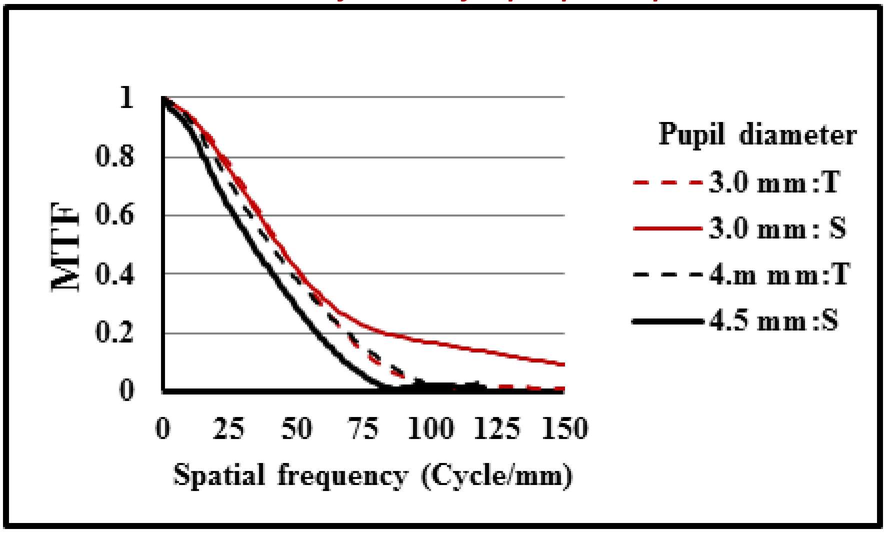

Figure 2. The Sagital MTF (dashed lines) and Tangintial MTF (solid line) of LBME with a 3.0 mm and 4.5 mm pupil diameter.

Figure 3 indicates the Tangintial MTF for lens decenteration (0.5, 1 ,2 ,3 ,4,5 mm). It is shown that as the decenter increase the MTF decrease.

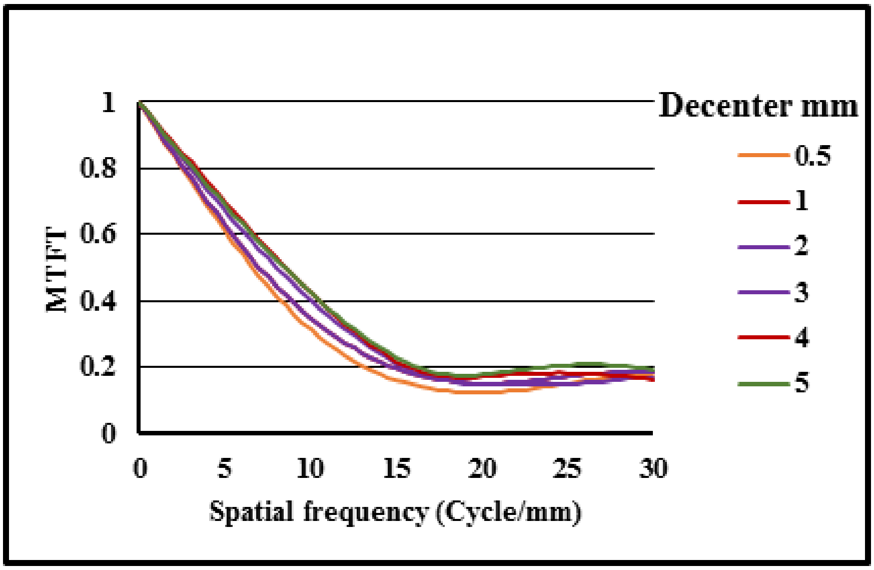

Figure 3. Tangential MTF as a function of positive decenter for lens with 3.0 mm pupil diameter.

The effect of lens decenter between (-1 to +1 mm) and zero tilt on the image spot size is shown in Figure 4. It is clear that the spot size is increased as the decenter increased in the positive and negative direction of decenter axies.

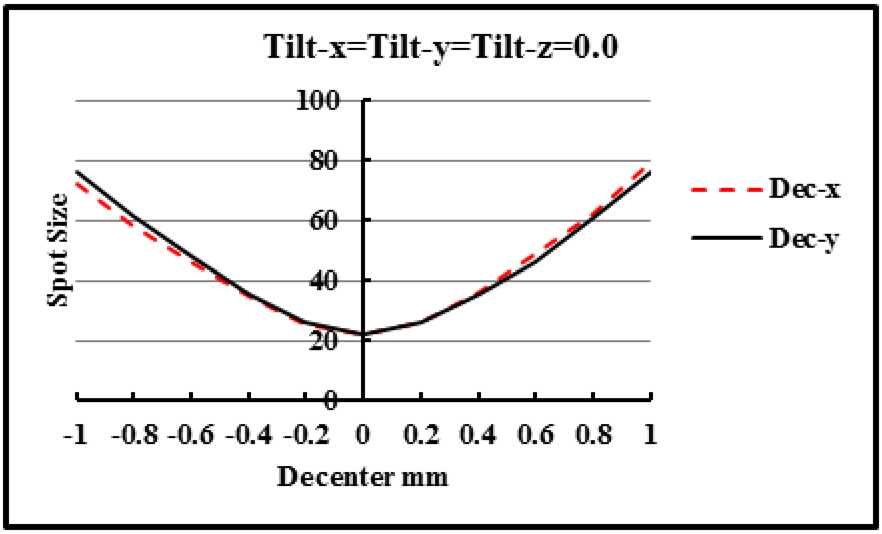

Figure 4. Spot size as a function of lens decenter.

In Figure 5, MTF of testing lens as a function of negative decenter about x-axis at 3 mm PD. The solid line represents the sagittal MTF while (dotted line) represents tangential MTF (red dashed line). The MTF's degradation as the spatial frequency is increased. The TMTF performance is better than the SMTF. This means that SMTS is more sensitive than TMTF to the lens decenter.

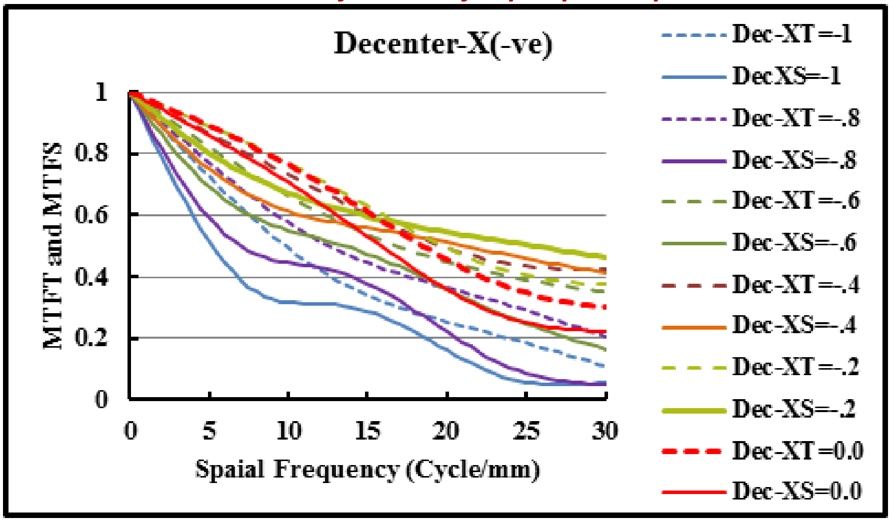

Figure 5. MTF of testing lens as a function of decentration at 3 mm pupil diameter.

From Figure 6, it is clear that the MTFT response changes as the spatial frequency beyond 15 cycle/mm. The effect of tilt on the MTF was not as distinct as the effect of decentration. The MTF analysis for both decenter and tilt is very complicated.

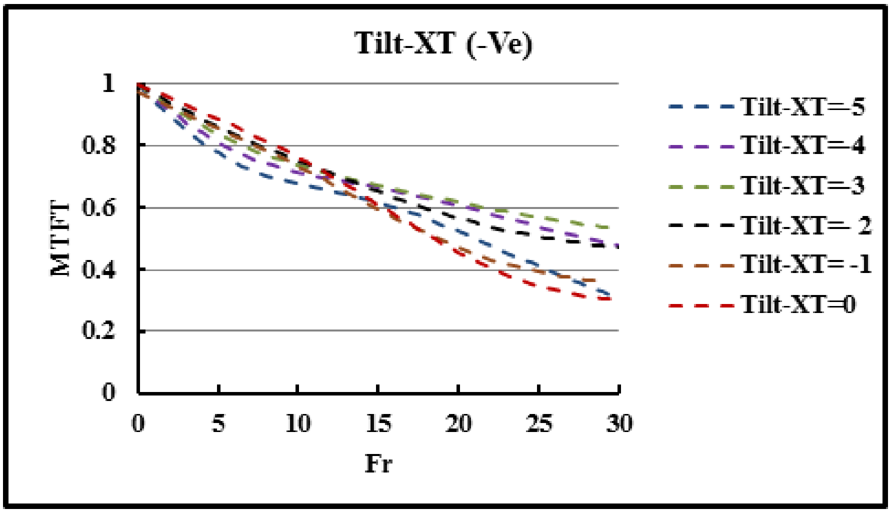

Figure 6. MTFT imaging quality of the lens as a function of lens tilt (from 0 to 5 degrees).

Discussion

A typical and valuable technique for structuring and hypothetically testing optical parts namely ray tracing. We utilized an optical plan programming bundle to follow a heap of beams through the generally acknowledged LBME which contains aspheric and angle list components just as a decentered understudy, as is found in numerous human eyes. Figurings were outright with 555nm monochromatic light. Then we has decentered the implanted lens element from -1.00 mm (transient) to +1.00 mm (nasal) and determined tangential, sagittal. The results of decenteration has demonstrated an improved imaging quality corruption in aberration corrective lens. Taking everything into account, aspheric lenses gave preferred imaging quality over spherical IOLs; in any case, image quality might be touchy to decentration or tilt contingent upon an aberration correction idea of the lens plan. On the off chance that the mean decentration can be restricted to +0.3 mm, the aberration amending IOL idea gives, pretty much, diffraction-limited image quality.

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تصميم وبناء كهروبصري لفحص الأنحراف وعدم التمركز

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الملخص:

نتيجة لوجود عيوب بصرية في مركز نصف قطر التكور مثل الأنحراف واللاتمركز والناتجه بسبب عدم دقة المعالجة بعد عمليات التنعيم واللصق . أجريت دراسة تحليلية نظرية اعتمادًا على نموذج تأثيركل من الانحراف وعدم التمركز للعدسات معتمدا على نموذج ليو للعين البشريه ذات فتحه بؤبؤ ٣ و ٤,٥ ملم. أظهرت النتائج تاثير واضح لهذه العوامل غلى جودة الصوره وكان الانحراف اقل وضوحا من عن تأثير اللاتمركز.

الكلمات المفتاحية: الأنحراف البصري, داله التضمين البصري, اللاتمركز, داله التضمين المماسيه , داله التضمين السهمي و تحليل الصوره .