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Comparison of higher-order aberrations between implantations of AcrySof and AcrySof ReStor multifocal aspherical intraocular lens

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Abstract

• AIM: To compare the higher-order aberrations between implantations of AcrySof and AcrySof ReStor multifocal aspherical intraocular lens (IOL) with various pupil diameters.

• METHODS: Fifty-four patients (62 eyes) with bilateral senile cataracts were retrospectively selected. Patients were operated with phacoemulsification and IOL implantation. They were divided into two groups based on the IOL implantation of AcrySof IQ and AcrySof ReStor. Wave front aberration: spherical aberration (C12) and the root mean square of the total higher-order aberration (RMSh) were observed 3 months after surgery.

• RESULTS: The larger the pupil was, the higher the C12 and RMSh were in the eyes ($P<0.01$). There were no statistical differences in C12 or RMSh between two groups at 5, 6 or 7mm pupil diameters ($P>0.05$).

• CONCLUSION: There are no differences between AcrySof IQ group and AcrySof ReStor group at 5, 6 or 7mm pupil diameters.

• KEYWORDS: phacoemulsification; multifocal intraocular lens; wave-front aberration; pupil diameters

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INTRODUCTION

Among people over the age of 40, the aberration has become a major factor of normal visual quality, particularly higher-order aberration has increasingly gained attention, for which can not be corrected by ordinary glasses. Traditional intraocular lens (IOL) can not only balance the positive spherical aberration of the cornea but also will increase the total aberration of the eyes, which may result in an unideal visual quality after operation. Non-spherical crystals has been widely used because its unique design can effectively reduce the higher-order aberration caused by traditional IOL[1]. Cataract surgery patients don't need to wear glasses after advent of multifocal IOL. However, there are many problems with (AcrySof ReStor), such as postoperative glare, halos and so on, which even become much more serious with the increase of pupil diameter[2]. Thus they will cause the decrease of visual quality. Research has shown a relationship between these phenomena and increasing of higher-order aberration. This article discussed the higher-order aberration of different AcrySof ReStor after early postoperative implantation and made an assessment on clinical effects of AcrySof ReStor from the aspects of higher-order aberration.

MATERIALS AND METHODS

Subjects From August 2009 to February 2010, 54 cases 62 eyes of phacoemulsification and IOP implantation were retrospectively selected, 31 cases 37 eyes were male and 23 cases 25 eyes were female. The average age of group A was 69.5±7.2 years old, and that of group B was 69.0±6.9 years old. Gender and age differences of the two groups had no statistical significances. Standards of cases selection: the simple cataract with normal activities of pupil, corneal degeneration, glaucorna, uveitis, age-related macular degeneration, corneal astigmatism ≥1.00D, highmyopia, eye surgery and trauma, diabetes and other related eyes and systemic disease, serious complications after surgery, postoperative examination can not be well coordinated and that can not be followed. All patients were informed before surgery and signed informed consent. According to the type of IOL implantation, all cases were divided into A group (AcrySof IQ group) and B group (AcrySof ReStor group).

Methods All surgeries were operated by the same physician using the same phacoemulsification instrument in routine surgical procedures under the microscope without occurring of complications like posterior capsule rupture. Hormones were started to be used as eye drops after operation, 4 times a day, withdrawal after a week. We checked the wave-front aberrations with a wave-front aberrometer (Allegro Analyzer) after a week postoperationally, then used eye drops to dilate pupil to 5, 6, 7mm and made the measured data collection of wavefront aberration. Each patient was measured at least 4 times, and among the measurements, the mean of 3 times'

measurements' results of the well-centered images, the decentration of X-axis and Y-axis <0.06 ram and the least missing light spots, were taken as the final statistics. We used Zernike polynomials to express the wavefront as 6 order, 27 items, and selected the 5,6,7mm pupil size of the spherical aberration (C12) by the Calibration apparatus and chose total higher order aberrations RMS (RMSh) Value as indicators.

Statistical Analysis The data were checked using statistical software SPSS 10.0 for statistical processing, and tested for independent samples t test, $P<0.05$ showed the difference was statistically significant.

RESULTS

C12 were increasing along with pupil diameters' increasing, which meant spherical aberration of group A increased with pupil diameters' increasing. It was found that RMSh was also increasing with pupil diameters' increasing, which also showed that total aberration of group A was also increasing with pupil diameters' increasing. C12 in three pupil diameters were increasing along with pupil diameters' increasing, which meant spherical aberration of group B increased with pupil diameters' increasing. It was found that RMSh was also increasing with pupil diameters' increasing, which also showed that total aberration of group B was also increasing with pupil diameters' increasing. The total aberration of group A and B were compared: the difference of spherical aberration (C12) and the total higher order aberrations (RMSh) between group A and B showed no statistical significances while pupil diameter was 5,6 or 7mm ($P>0.05$, Table 1).

Table 1 Wavefront aberration pupil in patients with each group ($\bar{x}\pm s$, μm)

Pupil	C12	RMS4	RMSh
5mm: A	-0.07±0.17	0.20±0.07	0.29±0.16
B	-0.02±0.07	0.20±0.09	0.35±0.22
6mm: A	0.04±0.23	0.21±0.15	0.36±0.26
B	0.01±0.16	0.23±0.11	0.40±0.21
7mm: A	0.16±0.26	0.16±0.14	0.48±0.17
B	0.08±0.12	0.18±0.14	0.46±0.17

DISCUSSION

With the improvement of life standards and the rapid development of cataract surgery technology, people's demands on visual quality of postoperation is much higher. Cataract surgery has changed from sight restoring to refractive surgery, and the ordinary monofocal IOP plays an irreplaceable role for the correction of aphakia refraction, but the spherical design allows imaging of peripheral wavefront distortion and decomposition of retinal focus light, which results in reduced retinal image quality. The emergence of non-spherical IOL improves the design flaws of traditional IOL, but as a single intraocular lens (SIOL), it still has the inevitable shortcomings that is lack of force to be adjusted. Patients still need glasses after surgery to meet different needs of working distance, thus that will cause much inconvenience to life and work. The appearance of multifocal intraocular lens (MIOL) make up for lack of SIOL in a certain extent. Distant vision of MIOL is the same as SIOL's, while near vision of MIOL is better than monofocal lens, which let patients get good whole vision after operation. Statistics showed that the naked eye after implantation of ReStor, the average visual acuity of the distant vision(5m), the intermediate vision(60cm) and close range vision (33cm) were 0.91, 0.40 and 0.6, so that patients could get rid of wearing mirror's distress[3]. In the study at home and abroad on comparison of postoperation vision between SIOL and MIOL, scholars have generally agreed that MIOL could reduce patients' dependence on glasses after implantation, but there appeared the night glare, halos, double-focus and so on[6]. In our study, 1 patient complained of night glare, 2 patients complained of halos. Some researches showed that these discomforts were caused by the wavefront aberrations after surgery, particularly due to increased higher-order aberrations. Studies in this article were about MIOL Acrysof ReStor, which belonged to progressive multifocal diffractive IOL that had 12 ladder rings in the area around the anterior surface of crystals in the central optic zone diameter of 3.6mm, while the diameter of ladder for near vision was only 0.75mm. In the case of the pupil was small (1.5-2.0mm), we could also ensure at least 3 to 4 steps Cycle on the light road[5].

Human eye is not a perfect refractive system. When the light goes through the optical system of the eye, there lies some difference between the actual wave-front and the ideal wave-front, which results in various aberrations. When the pupil diameter is greater or more than 2mm, compared with the diffraction, aberrations become the dominant factors to restrict vision. With the increasing of the pupil, the limitation of higher-order aberrations is significant, which is called aberration limited [6], for higher-order aberrations can not be offset by an ordinary lens, so the impact of its role in the visual quality is even more important. The commonly used method measuring higher order aberrations is Zernike polynomials. This method can quantitatively describe the size of the human eye aberrations in the form of the function describing the distribution of human eye aberrations. Zernike polynomial decomposes the wavefront into a stage so as to observe the size of each order aberrations. Usually Zernike polynomials is step 6 order 27 or step 7 order 35 of the Zernike coefficients, by calculating a root mean square of each wavefront aberrations (root mean square, RMS), you can get the estimated value of the whole eye wavefront (total RMS). Among them, the first-order and second-order aberrations are low ones, including tilt, defocus (myopia and hyperopia) and astigmatism of the X and Y axis. The third and above order aberrations are high ones, including coma, spherical aberration, high order astigmatism, trefoil, *etc* [7].

For spherical aberration is the most important part of higher-order aberration, it can affect the retinal image quality directly. So in our study, we used C12 which stands for spherical aberration and RMSh which stands for higher-order aberration as our indicators measuring higher order aberrations. In the optical system of human eyes, higher-order aberrations is not the only factor to affect vision quality,

contrast sensitivity, age, IOL material, regulatory changes of IOL *etc*. are the influential factors too[8]. In our study, we fully reduced the impact factors of age by the randomized grouping, and selected the same two IOL materials, which eliminated the influence of material factors. The highest quality images were got on the retina when pupil was 2-3mm; the aberrations increased with the pupil diameter increase. When the pupil was larger than 3. 5mm, the wave-front aberration was an important factor of the visual quality, especially spherical aberration played an important role in the visual quality. In our conclusions, the spherical aberration and total higher-order aberrations of two groups with IOL increased with the increase of pupil diameter, which also confirmed this view. The normal 95% confidence interval of pupil diameter was 5. 46-8. 36mm under dark. Therefore, we selected measuring higher-order aberrations when pupil diameter was 5, 6 and 7mm in order to simulate the pupil diameter of patients in the dark environment.

In the three pupil diameters we have measured, the total higher order aberrations (RMSh) between group A and B showed no statistically significance ($P > 0.05$), but our survey showed that 1 patients implanted MIOL complained night glare and 2 patients complained halo in the dark looking at lights. The three patients who were 58, 63 and 69 years old, and 2 male and 1 female among them, varied with our results. We analyzed this difference on the following aspects. From the point of contrast sensitivity, it will lead to the loss of light energy, because MIOL can assign the light into eyes to the focus near and far. From the point of theory, it will affect the contrast sensitivity and glare sensitivity, thus it will result in glare and halos, and the early report on MIOL also confirmed this point. However, clinical observations in recent years have suggested that contrast sensitivity and glare sensitivity of ReSTOR eyes after operation showed no significant difference with those of the other lens or phakic eyes reported in the literature [5]. From the psychological perspective, for the higher price of MIOL, patients' expectations of increasing in visual quality postoperative is more too. In the preoperative conversation, the doctor will also inform them about the problems like glow and glare after operation, which will make the patient pay attention to those symptoms. Of course, there will still be other factors, such as the center of the pupil, the patient's tear film and so on. We will discuss this issue in the further study.

In summary, we can conclude that Aspheric monofocal AcrySof IQ and multifocal IOLAcrySof ReStor do not differ significantly from the perspective of higher-order aberrations, some patients could suffer from MIOL AcrySof ReStor night glare, halos, double-focus, *etc*. after the implantation, but these patients can be able to adapt with them. Acrysof ReStor crystal brings patients with much better vision.

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单焦点及多焦点非球面 IOL 植入术后的高阶像差对比

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摘要

目的:比较不同瞳孔直径下单焦点 AcrySof IQ(SN60WF)及多焦点非球面人工晶状体 AcrySof ReStor +3(SN6AD1)植入术后的高阶像差。

方法:回顾性选取 2009-08/2010-04 在我院眼科行超声乳化吸出术联合人工晶状体植入术的患者 54 例 62 眼,按照植入人工晶状体的不同类型分为两组:AcrySof IQ 组及 AcrySof ReStor 组。主要观察项目为术后球差(C12)及总高阶像差的均方根(RMSh)。

结果:两组术后 3mo 应用波前像差仪(Allegro Analyzer)检查,瞳孔直径在 5,6,7mm 时,A 组球差和 B 组球差和 RMSh 均方根均随着瞳孔直径增大而增加,差异有统计学意义($P<0.01$);瞳孔直径为 5,6,7mm 时,A 组总高阶像差与 B 组相比,差异均无统计学意义($P>0.05$)。

结论:在瞳孔直径 5,6,7mm 的时候 AcrySof IQ 及 AcrySof ReStor 的高阶像差基本无差别。

关键词:超声乳化;多焦点人工晶状体;波前像差;瞳孔直径