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Original article

Corneal spherical aberration and its impact on choosing an intraocular lens for cataract surgery

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Abstract

Purpose: To analyze the post operative results of targeting zero spherical aberration by selecting the best-fit aspheric intraocular lens (IOL), based on preoperative corneal spherical aberration of patients with phacoemulsification surgery.
Setting: AlHokama Eye Specialist Center, Riyadh, Saudi Arabia.
Period: From the 1st of October 2012 until the 10th of April 2013.
Methods: Fifty-three eyes, were subjected to phacoemulsification cataract surgery and divided into two groups, 34 eyes were implanted with aspheric IOLs based on their corneal spherical aberration targeting post operative zero total spherical aberration, whereas 19 eyes were implanted with neutral aspheric IOLs regardless of their corneal spherical aberrations (CSAs). As a pre and post routine examination, patients underwent: slit lamp testing, intraocular pressure (IOP) measuring, fundus examination, best spectacle corrected visual acuity (BSCVA), manifest refraction, pupillometry, axial length, contrast sensitivity, and corneal aberration measurement using Pentacam HR (OCULUS, Germany) at the 6-mm optical zone. Post operatively, visual function questionnaire (VF-14) was asked to all patients.
Results: Fifty-three eyes of 45 patients, whose age ranged from 45 to 90 years old, were available for analysis, the selected group was implanted with: Tecnis ZA9003 or ZCB00 (Abbott Medical Optics) IOLs in 17 eyes with corneal spherical aberration of more than 0.27 μm, AcrySof IQ SN60WF (Alcon Laboratories Inc.) IOLs were implanted in 4 eyes with CSA = (0.2–0.27) μm, and Rayner 970C, 920H or 620H IOLs with spherical aberration (SA) = 0 in 13 eyes with CSA less than 0.20 μm. The other group of 19 eyes was implanted with aspheric IOLs that have zero spherical aberration (Rayner 970C or 920H) regardless of their CSA. Root mean square (RMS) of total corneal aberration positively correlates to the pupil diameter ($P = 0.0031$, $r = 0.3989$). A low negative correlation was found between the corneal spherical aberration of the fourth ordered (Z40) and the axial length ($r = -0.2009$, $P = 0.1492$). There was no significant difference between the selected and non-selected group in contrast sensitivity, best spectacle corrected visual acuity, and visual satisfaction ($P = 0.5316$, $P = 0.3919$, $P = 0.7667$).
Conclusion: Customized selection of aspheric IOLs based on the eyes' corneal spherical aberration has no significant importance comparing their results with the non-selected group.

Keywords: Spherical aberration, Z(4,0), Z(6,0), IOL, Cataract, Corneal aberration, Higher order aberration, Intraocular lens

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Introduction

Optical degradation with age is caused by the increase of the opacification of the crystalline lens that will result in visual impairment, loss of contrast, and an increase in the spherical aberration of the optical system.[1,2] In young healthy crystalline lens, the lens compensates for the cornea positive spherical aberration. With age, the crystalline lens becomes less negative (or even more positive), and the angle of refraction of the peripheral rays will be larger comparing to the paracentral rays, resulting in increasing the total optical spherical aberration of the eye.[3,4]

With the advancement of cataract eye surgery and wavefront sensors, the unquantifiable refractive measurements have been identified and the high ordered aberrations have shown their effect on high resolution imaging.[5]

Therefore, the conventional spherical intraocular lenses (IOLs) have been replaced with aspheric intraocular lenses (IOLs) that have no or negative spherical aberration to overcome the naturally occurring positive spherical aberration of the corneal surface and then achieve better results.[6–8]

Thus, this study was designed to determine whether patients with selected IOLs have better visual acuity, contrast sensitivity, and visual satisfaction outcomes than comparable patients who had no specific target of postoperative spherical aberration.

Patients and methods

Fifty-three eyes of forty-five Saudi subjects (25 men and 20 women), whose age ranged from 45 to 90 years old, with comparable spherical equivalent of their refractive errors, were subjected to routine pre cataract surgery examination of: slit lamp testing, intraocular pressure (IOP) measuring, fundus examination, best spectacle corrected visual acuity (BSCVA), manifest refraction, pupillometry, axial length, contrast sensitivity, and corneal aberration measurement using **Pentacam HR** (OCULUS, Germany) at the 6-mm optical zone.

34 eyes were implanted with IOLs according to their spherical aberration

1- Tecnis IOLs with spherical aberration (SA) of 0.27 μm were implanted in 17 eyes with corneal spherical aberration (CSA) of more than 0.27 μm.
2- IQ IOLs (SA = 0.2 μm) were implanted in 4 eyes with CSA = (0.2–0.27) μm.
3- Rayner IOLs (SA = 0) were implanted in 13 eyes with CSA less than 0.20 μm.

Whereas 19 eyes were applied with non selected IOLs (Rayner IOLs (SA = 0)) (Table.1).

One month postoperatively, patients returned to measure: the best spectacle corrected visual acuity (BSCVA), manifest refraction, contrast sensitivity, visual function questionnaire (VF-14), and corneal aberration measurement using **Pentacam HR** (OCULUS, Germany) at the 6-mm optical zone.

Patients with a history of contact lens wear, keratorefractive surgery, existing ocular or systemic pathologies were excluded. Otherwise, all patients with clear cornea, no scarring nor pigmentation were included in the study. Corneal spherical aberration root mean square (RMS), total and high order aberrations (RMS) up to 6th order of all eyes were obtained without dilatation in the dark at 6 mm optical zone.

The study was conducted according to the tenets of declarations of Helsinki in a central anterior segment referral clinic and received the approval of the institute. All the subjects signed a comprehensive written consent prior to participation in the study.

Statistical analysis

Statistical analysis of the results was done by Microsoft Excel, Graphpad prism, and Instat.

Results

Fifty-three eyes of forty-five patients underwent uneventful phacoemulsification and IOL implantation by one surgeon (Al-Saleh A.). Thirty-four eyes were implanted with IOLs based on their corneal spherical aberrations, Rayner for the eyes with a CSA less than 0.2 μm, AcrySof IQ for the CSA of [0.2–0.27] μm, and the Tecnis IOLs were implanted in the eyes with a CSA of >0.27 μm. The rest nineteen eyes have been implanted with Rayner IOLs that have zero spherical aberration, regardless of their CSA.

The mean corneal spherical aberration of the fourth order (Z_4^0) of the entire eyes = 0.3354 ± 0.1965 μm, RMS of the 6th order spherical aberration = 0.0059 ± 0.0738 μm, whereas the mean total corneal aberration was 2.867 ± 1.174 μm, while the RMS of high order aberration (HOA) = 0.8164 ± 0.3524 μm. The *P* value for the four was <0.0001, considered extremely significant (Fig. 1).

The total CSA of the fourth and sixth order ranged from −0.254 to 0.817 μm, with a mean RMS of 0.3413 ± 0.1814 μm.

The pupil diameter under mesopic condition was found to slightly positively correlate to the fourth order corneal spherical aberration and RMS of HOA ($P = 0.4677$, $r = 0.1019$) ($P = 0.2813$, $r = 0.1507$), respectively, whereas RMS of the total corneal aberration moderately to highly positively correlates to the pupil diameter ($P = 0.0031$, $r = 0.3989$) (Fig.2).

Table 1. Types of aspheric IOLs implanted after cataract surgery.

IOL type	Rayner	Tecnis	AcrySof IQ
Manufacturer	Rayner	Advanced Medical Optics	Alcon Laboratories Inc.
Code number	920H, 970C, 620H	ZA9003, ZCB00	SN60WF
Optic diameter (mm)	(5.75–6.25) mm	6.00 mm	6.00 mm
Optic material	Hydrophilic acrylic	Hydrophobic acrylic (ZA9003)	Acrylate, blue blocking
Spherical aberration	Zero	−0.27 μm	−0.2 μm
Design	Single-piece	3-piece (ZA9003), single-piece (ZCB00)	Single-piece
Refractive index	1.46	1.47	1.55
Overall length (mm)	(12.00–12.50) mm	13.00 mm	13.00 mm