



## Original research

# Ocular higher-order aberrations (HOAs) changes after implantable collamer lens implantation for high myopic astigmatism

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## Abstract

**Purpose:** To investigate the changes in higher-order aberrations (HOAs) induced by the implantation of implantable collamer lenses (ICLs) and Toric ICL (TICL) in eyes with high myopia and high myopic astigmatism.

**Methods:** We investigated 33 eyes of 18 consecutive patients (in a prospective, interventional case series study), with spherical equivalent errors of  $-6.00$  to  $-21.09$  diopters (D) and cylindrical errors of  $-0.5$  to  $-4.75$  D, who underwent ICL and TICL implantation. Before and after 5 days, 2 and 6 months of surgery, the uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), defocus and adverse events of the surgery were assessed. Ocular HOAs were also evaluated by Hartmann-Shack aberrometry (Technolas PV, Rochester, New York, USA) before and after 6 months of surgery.

**Results:** At 6.0 months after surgery, the UCVA and BCVA in 40 and 66.7% of eyes were 20/20, respectively. Mean defocus refraction and astigmatism was reduced to  $-0.66$  and  $0.65$  D from  $-12.79$  and  $2.18$  at baseline, respectively. For a 6 mm pupil, HOAs were not significantly changed, merely from  $0.417 \pm 0.162 \mu$  before surgery to  $0.393 \pm 0.119 \mu$  after surgery ( $P = 0.45$ ). Spherical aberration (Z400) increased significantly ( $P = 0.00$ ). Surgical induced astigmatism was lower than  $0.25$  D, and there were no changes in trefoils and coma aberration. No vision-threatening complications occurred during the observation period.

**Conclusion:** This study shows that the ICL and TICL performed well in correcting high myopic astigmatism without significant changes in HOAs during a 6-month observation period, although the spherical aberration (Z400) increased significantly.

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**Keywords:** Implantable collamer lens; Higher-order aberrations; Phakic intraocular lens; Myopic astigmatism

## Introduction

There are various ways to correct refractive errors. Two main surgical treatments are corneal refractive surgery and intraocular lens (IOL) implantation or phakic IOLs. Kerato-refractive surgery like laser-assisted in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) have been utilized more successfully for correcting mild and moderate than high myopia and astigmatism.<sup>1–4</sup> On the other hand, limit ablation in laser refractive surgeries makes them improper for correcting high myopia owing to possible postoperative

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corneal ectasia and haziness. Another problem of this approach for high myopia is possible postoperative higher-order aberrations (HOAs) most common of which is spherical aberration.<sup>5,6</sup> FDA has accepted implantable collamer lenses (ICLs) for moderate and high myopia correction. These are also employed for astigmatism and hyperopia correction.<sup>7–9</sup> According to some studies, using these lenses is more appropriate than laser surgeries from safety and efficiency view point.<sup>10,11</sup> Since cornea remains prolate in IOL implantation and it becomes oblate in laser surgeries (LASIK & PRK), there are more possibilities of HOAs in cornea laser surgeries as compared to IOL implantation.<sup>12</sup> Despite several advances in laser surgeries and wave front-guided ablation or wave front-optimized ablation for myopia correction without HOA thereafter, some factors such as preoperative HOAs or cyclotorsional misalignment can affect the laser surgery results.<sup>13</sup> Phakic IOLs owing to their optic properties as well as corneal incisions made during the surgery also create HOAs.<sup>14</sup> Thus, although studies have shown less possibility of HOAs in phakic IOL implantation as compared to laser surgeries, there are few studies on extent of HOAs which resulted merely from phakic IOLs (including ICL). Only in CariPrez Vives' study, the effects of ICL on HOA were examined, and results demonstrated negative spherical aberration. In addition, simultaneous effects of ICL and corneal incision on HOA were studied by Sun Woong Kim's study, and results indicated both changes in spherical aberration due to ICL and changes in coma caused by different corneal incision. The aim of this study is to re-examine the effects of ICL and Toric ICL (TICL) on HOA.

## Methods

This study is a prospective, interventional case series. We evaluated 33 eyes of 18 patients being operated from the years 2010–2011 in Rassoul Akram Hospital, Iran University of Medical Sciences, Tehran and Iranian Eye Clinic. This study was approved by the Ethics Committee of Iran University Eye Research Center. After explaining the advantages and disadvantages of surgery, all patients agreed to be operated and filled informed consent.

The subjects include 18 (54.4%) women and 15 (45.5%) men. The average age was  $24.22 \pm 3.21$  years ranging from 20 to 34 years old. Myopia and astigmatism among the patients ranges from  $-6$  to  $-21.09$  and  $-0.5$  to  $-4.75$  diopters (D), respectively.

All patients underwent full ophthalmic examination. This examination includes: best corrected visual acuity (BCVA) in 12 mm vertex distance, uncorrected visual acuity (UCVA), manifest and cycloplegic refraction, slit-lamp examination and funduscopy with dilated pupil, Goldmann tonometry.

Anterior chamber depth (ACD) was measured by Orbscan (Orbscan II Z; Bausch & Lomb, Rochester, New York, USA) from endothelium to anterior surface of crystalline lens. Keratometry was performed via automated keratometry by Topcon Kr 8000.

Aberrometry and pupil measurement in mesopic condition was performed for all patients using Hartmashack method by advanced personalized technology (APT, pv. Rochester, New York, USA). Placido disc topography (Eye sys 2000 version 4.2 Irvin USA) and endothelial cell count (non-contact specular microscope: Konan Medical Inc. Nishinomiya, Japan) was conducted for all patients.

All patients were examined on the 5th day, 2nd and 6th month after operation from BCVA and UCVA, and complete ocular examination point of view. Aberrometry of all patients was performed at 6 months postoperation.

Inclusion criteria include: white-to-white  $>11$  mm, ACD  $> 2.8$  mm, iridocorneal angle  $>30^\circ$ , corneal endothelial cells in 20- to 30-year-old patients was at least 2500 cells/mm<sup>2</sup> and in 30- and 40-year-old patients was at least 2000 cells/mm<sup>2</sup>.

Exclusion criteria were symptoms and history of uveitis, glaucoma, ocular hypertension, maculopathy, cataract, diabetes, progressing diseases except myopia, iris pigment defect, previous experience of ocular surgery, pregnancy scotopic pupil exceeding 7.5 mm, and less than 2 months or two times postoperative examinations.

Alignment of the TICL was evaluated by slit-lamp examination at all visits postoperatively. Vector analysis of keratometric astigmatism was conducted pre-operation and 6 months postoperation.

### *Implantable collamer lens sizing method*

ICL sizing was made based on white-to-white measurement by caliper and slit-lamp, and also confirmed by Orbscan II. Direct measurement of sulcus to sulcus was made by UBM as described below.

### *UBM ciliary sulcus measurement*

Topical tetracaine 0.5% (Sinadarou, Tehran, Iran) was instilled to anesthetize the cornea prior to measurement. One of the 3 differently sized eyecups (18, 20, and 22 mm) was inserted depending on the ocular aperture size. An eyecup was filled with sterile normal saline, and the subject was asked to fixate on a ceiling target with the fellow eye to maintain accommodation and fixation. Diameters of the ciliary sulcus were measured via a VuMax-II UBM (Sonomed, Inc. USA) equipped with a 35-MHz transducer. Cross-sectional images were obtained on the horizontal meridians: ( $180^\circ$ ), sulcus and anterior chamber (AC) diameters were measured in captured images using the zoom function to enhance the accuracy of angle and sulcus measurements.

All measurements were carried out under usual room light condition, and after capturing a video clip of the eye, the clip was reevaluated and the best-captured image was selected.

### *Surgical methods*

In this study, the V4 ICL design (STAAR Surgical, Nidau, Switzerland) was implanted. All patients in this study were

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