

# Comparison of Three Phakic Intraocular Lenses for Correction of Myopia

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## Abstract

**Purpose:** To compare the visual outcomes and complications of three different types of phakic intraocular lenses (PIOLs), for correction of moderate to high myopia.

**Methods:** We reviewed 112 myopic eyes undergoing PIOL implantation using Artisan (40 eyes), Artiflex (36 eyes), and implantable collamer lens (ICL, 36 eyes). Best corrected visual acuity (BCVA), intraocular pressure (IOP), pachymetry, corneal endothelial cell (CEC) loss, and higher order aberrations (HOA) were compared.

**Results:** Mean follow-up period was  $30 \pm 11$  months. Preoperatively, spherical equivalent (SE) refractive error was  $-11.6 \pm 3.7$ ,  $-9.59 \pm 1.97$ , and  $-12.3 \pm 4.8$  D in the Artisan, Artiflex and ICL groups, respectively. SE was comparable among the study groups at final follow-up ( $P = 0.237$ ). Mean astigmatic reduction was  $0.31 \pm 0.72$ ,  $0.45 \pm 0.62$ , and  $0.0 \pm 0.57$  in the Artisan, Artiflex and ICL groups, respectively ( $P = 0.007$ ). Emmetropia ( $\pm 1$  D) was achieved in 60%, 91.7% and 77.8% of eyes in the Artisan, Artiflex and ICL groups, respectively, the difference was significant between the Artisan and Artiflex groups ( $P = 0.017$ ). BCVA improvement more than one line occurred in 25%, 19.4% and 38.9% of eyes ( $P = 0.158$ ); pachymetric changes were minimal with no difference among the three groups ( $P = 0.754$ ), and mean CEC loss was  $10 \pm 9\%$ ,  $9 \pm 6\%$  and  $9 \pm 10\%$  in the Artisan, Artiflex and ICL groups, respectively ( $P = 0.694$ ). HOAs ( $P = 0.039$ ), vertical trefoil ( $P = 0.032$ ) and spherical aberration ( $P = 0.001$ ) were higher with Artisan group as compared to ICL. Total aberrations ( $P = 0.028$ ) and spherical aberration ( $P = 0.001$ ) was also higher with Artisan group as compared to Artiflex.

**Conclusion:** Visual and refractive outcomes were comparable with Artisan, Artiflex and ICL. In terms of HOAs and quality of vision, ICL and Artiflex seem to be better choices in highly myopic eyes.

**Keywords:** Artiflex; Artisan; Implantable Collamer Lens; Phakic Intraocular Lens

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## INTRODUCTION

Limitations exist for corneal refractive surgeries such as laser *in situ* keratomileusis (LASIK) and photorefractive keratectomy (PRK) for correction of high myopic refractive errors.<sup>[1,2]</sup> These limitations include biomechanical changes and irregular corneal healing

which can result in corneal thinning and post-LASIK ectasia, less predictable results, prolonged recovery time, refractive instability and even the potential for visual loss due to induced astigmatism or corneal ulcers. On the other hand, intraocular refractive procedures entail advantages such as the ability to correct a wider

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range of refractive errors, shorter visual recovery times, more stable refractive outcomes and superior quality of vision.<sup>[3,4]</sup>

Compared to other refractive surgeries, implantation of phakic intraocular lenses (PIOLs) have more desirable results and are potentially reversible procedures due to the possibility of explanting these lenses.<sup>[5]</sup> These methods usually do not require expensive or special surgical equipment and most ophthalmologists are able to perform these procedures; however disabilities resulting from PIOLs are more severe compared to corneal refractive surgery.<sup>[6]</sup>

Due to the potential risk of damage to anterior segment structures, especially corneal endothelial cell loss, PIOL implantation is subject to debate. Complications of PIOL implantation include glaucoma, iridocorneal angle damage, synechiae formation, cataract, corneal decompensation, pupil ovalization, uveitis and endophthamitis.<sup>[7]</sup>

Initially angle-supported PIOLs were introduced; these implants had long term complications and were therefore substituted with iris-fixated PIOLs which entail fewer complications. As time passed, posterior chamber lenses such as the implantable collamer lens (ICL) were developed which were better compatible with delicate eye structures and induced fewer complications such as cataracts.<sup>[8]</sup> Currently, three types of PIOLs including the Artisan (Ophtec, Groningen, Netherlands), Artiflex (Ophtec, Groningen, Netherlands) and ICL (Staar Surgical, Monrovia, CA, USA) are the most popular PIOLs used for correction of refractive errors.

The current study was performed to compare Artisan, Artiflex and ICL in terms of visual and refractive outcomes, quality of vision and complications, especially changes in corneal endothelial cell density, as well as intra-and postoperative safety and efficacy in myopic eyes.

## METHODS

In this historical cohort study, all highly myopic patients who had undergone PIOL implantation from 2006 to 2010 at Labbafinejad Medical Center or Rassoul Akram Hospital, Tehran-Iran were recalled for evaluation. Based on the type of PIOL, the patients were divided into three groups: Artisan, Artiflex and ICL. All patients underwent a complete ophthalmologic examination including refraction, determination of uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), intraocular pressure (IOP) measurement, presence of corneal edema, corneal clarity and cataracts. Central corneal thickness (CCT) was measured (UP-1000 Pachymeter, Nidek, Gamagori, Japan), and central corneal endothelial cell count was evaluated (Specular Microscope SP-2000P, Topcon, Tokyo, Japan). The results were compared with corresponding preoperative values.

Optical aberrations were also measured at the recall examination (Zywave II Aberrometer, Bausch and Lomb, Technolas Perfect Vision, Munich, Germany). Intra-and postoperative complications such as inflammation or infection were assessed based on hospital records.

Age at the time of operation was 21 years or more. Exclusion criteria were as follows: Corrected anterior chamber depth (from the endothelium) less than 3 mm, central endothelial cell density less than 2500/mm<sup>2</sup>, keratoconus, corneal astigmatism higher than 2 diopters (D), previous cataract surgery, glaucoma, uveitis, and any history of significant retinal pathology or detachment. All procedures were performed by three expert anterior segment surgeons (FK, SJH and ARBR). To reduce astigmatism based on preoperative keratometry, incisions were made on the steep corneal meridian. The Artisan and Artiflex Lens powers were calculated based on the Van der Heijd formula, as recommended by the manufacturer.

### Artisan Lens

The myopic model 206 was used for myopia less than -15.5 D and model 204 was used for higher myopia. Under general anesthesia and based on the optic diameter of the lens, an incision 5.5–6.5 mm in length was made on the cornea at 12 o' clock position together with two 1.5 mm stab incisions at 2 and 10 o' clock positions. Acetylcholine was injected intracamerally and then the anterior chamber was filled with sodium hyaluronate 1% (Microvisc, Bohus, BioTechAB, Strömstad, Sweden). The Artisan lens was introduced inside the eye through the 12 o' clock incision and was rotated into horizontal position. After grasping the lens by a special fixation forceps, the lens haptics were enclavated to the mid-peripheral iris stroma at 3 and 9 o' clock positions. Finally, a peripheral iridotomy was performed at 12 o' clock. The viscoelastic material was washed out and the incision was sutured using 10–0 nylon suture.

### Artiflex Lens

The procedure was similar to that of the Artisan lens. A 3.2 mm clear corneal incision at 12 o' clock and two lateral stab incisions at 2 and 10 o' clock positions were made. After filling the anterior chamber with viscoelastic material, the lens was inserted into the anterior chamber after being loaded onto the special spatula. After positioning the lens in the proper location, its haptics were enclavated, peripheral iridotomy was performed and the viscoelastic material was irrigated.

### ICL

Type V<sub>4</sub> ICL was employed in all subjects. The sulcus-to-sulcus diameter was determined by ultrasonic

biomicroscopy (Sonomed, Lake Success, NY, USA) for ICL sizing. Two peripheral iridotomies using Nd-YAG laser were performed 2 weeks before surgery. For complete mydriasis, topical tropicamide 1% and phenylephrine 2.5% eye drops were used 1 hour preoperatively. Using a 3.2 mm keratome, one incision was made on the temporal side of cornea and another 1.0 mm one at 12 o'clock position. Methylcellulose was injected into the anterior chamber followed by introduction of the lens, loaded on its special cartridge, into the eye. A blunt tipped manipulator was used to place the lens haptics under the iris. Acetylcholine 1% was injected thereafter and the viscoelastic material was irrigated completely. The corneal incisions were then closed by stromal hydration.

At the conclusion of all procedures, subconjunctival injection of 4 mg betamethasone and 100 mg cephazolin was performed. Topical 0.1% betamethasone and 0.5% ciprofloxacin (Sina-Darou, Tehran, Iran) eye drops were prescribed every 4 hours for 1-week and later the steroid drops were tapered off gradually over 1-month.

We used safety and efficacy indices to consider differences in preoperative BCVA among the 3 groups; "efficacy index" was the ratio of postoperative UCVA to preoperative BCVA and "safety index" was the ratio of post- to pre-operative BCVA.

Statistical analysis was performed using SPSS software version 17.0 (SPSS Inc., Chicago, IL, USA). In order to compare data among the study groups, considering the fact that the operations were performed bilaterally and considering baseline values, generalized estimating equation (GEE) analysis was used. Dual comparisons using the Bonferoni method was also used to find the differences between the groups when the group effect was statistically significant. *P* values less than 5% were considered as statistically significant.

## RESULTS

Of 74 recalled patients, 61 (including 36 female and 25 male) subjects were enrolled; a total of 112 eyes including 40 eyes in the Artisan group, 36 eyes in the Artiflex group and 36 eyes in the ICL group were evaluated and analyzed. Mean age was  $28 \pm 5$  (range, 20–42) years and mean follow-up duration was  $30 \pm 11$  (range, 12–56) months. There were statistically significant differences in terms of age and follow-up period among the groups, but these differences were not clinically significant [Table 1].

### Visual Acuity

Mean preoperative BCVA was  $0.16 \pm 0.2$ ,  $0.08 \pm 0.11$  and  $0.27 \pm 0.34$  LogMAR in the Artisan, Artiflex and ICL groups (equivalent to 20/30, 20/50 and 20/40 Snellen acuity, respectively, *P* = 0.037). Mean postoperative

UCVA was  $0.22 \pm 0.21$ ,  $0.07 \pm 0.14$ , and  $0.24 \pm 0.25$  LogMAR (equivalent to 20/33, 20/22 and 20/35 Snellen acuity) in the Artisan, Artiflex and ICL groups, respectively. The difference between the ICL group and two others groups was statistically significant (*P* = 0.039). Mean postoperative BCVA values were  $0.07 \pm 0.13$ ,  $0.02 \pm 0.06$  and  $0.17 \pm 0.25$  LogMAR in the Artisan, Artiflex and ICL groups, respectively. The difference between the Artisan and ICL groups was statistically significant (*P* = 0.009). BCVA better than 20/40 was seen in 90%, 97.2% and 75% of eyes in the Artisan, Artiflex and ICL groups, respectively and the difference between the Artiflex and ICL groups was statistically significant (*P* = 0.049). Safety and Efficacy indices in these three groups are compared in Table 2 showing no significant difference among the three study groups.

The rate of at least one line improvement in BCVA postoperatively was 75%, 80.6% and 61.1% in the Artisan, Artiflex and ICL groups, respectively. Also, more than one line of improvement occurred in 25%, 19.4% and 38.9% of the above mentioned groups, respectively (*P* = 0.158). In the Artisan group, 3 eyes (7.5%) experienced more than one Snellen line decrease in BCVA and one eye (2.5%) demonstrated more than 2 lines of decreased vision. None of the eyes in the other study groups developed more than one line of decreased vision.

### Refractive Errors

No significant difference was noted among the 3 groups in terms of spherical equivalent (SE) and astigmatism preoperatively [Table 3]. After surgery, 24 eyes (60%) in the Artisan group, 33 eyes (91.7%) in the Artiflex group and 28 eyes (77.8%) in the ICL group were within 1D of emmetropia. The difference between the Artisan and Artiflex groups was statistically significant (*P* = 0.017).

**Table 1. Mean age and follow-up duration in the study subgroups**

Groups	Artisan (1)	Artiflex (2)	ICL (3)	<i>P</i>
Age (year)				
SD±mean	27±3	30±5	27±6	0.018 (1 and 2)
Follow-up (month)				
SD±mean	29±13	31±9	29±11	0.013 (2 and 3)

SD, standard deviation; ICL, implantable collamer lens

**Table 2. Efficacy and safety indices among the study groups**

	SD±mean			<i>P</i> *
	Artisan	Artiflex	ICL	
Efficacy index	1.09±0.56	1.19±0.55	1.21±0.52	0.38
Safety index	1.2±0.54	1.3±0.42	1.23±0.40	0.68

\*Based on GEE analysis. SD, standard deviation; ICL, implantable collamer lens; GEE, generalized estimating equation

### Complications

No significant complication was noted in any group during or after surgery. No case of severe uveitis leading to prolongation of steroid usage, fibrin formation or precipitation on phakic lenses was found in any of the patients. Two eyes (5.6%) in the ICL group showed transient IOP rise which were controlled with one anti-glaucoma medication. No case of prolonged increase in IOP was noted in any of the two other groups. Table 4 shows IOP changes in these three groups. Although IOP changes in the ICL group were significantly lower than the other groups, this difference was clinically negligible. Permanent IOP changes and development of glaucoma requiring medical or non-medical treatment did not occur in any group.

Regarding corneal complications, there were no significant differences in endothelial cell changes, and corneal thickness between the three groups [Table 5].

Two eyes (5.6%) in the ICL group developed nuclear cataracts, but this problem did not cause any change in visual acuity during the follow-up period. Four eyes (11.1%) in the Artiflex group and 2 eyes (5%) in the Artisan group manifested local iris atrophy at the site of haptic enclavation to the iris.

Twelve eyes (33.3%) in the Artiflex group, 4 eyes (10%) in the Artisan group and 2 eyes (5.6%) in the ICL group complained of glare non-related to cataracts. Although, initial analysis showed that the difference is significant, a second evaluation considering both

**Table 3. Changes in SE and astigmatism in the study groups**

	SD±mean			Total P*	Compared groups**	Adjusted P used as base value
	Artisan (1)	Artiflex (2)	ICL (3)			
SE (diopter)						
Presurgery	-11.6±3.7	-9.59±1.97	-12.3±4.8	0.005	(2 and 3)	0.237
Postsurgery	-0.76±0.55	-0.38±0.36	-0.57±1	0.008	(2 and 3)	
Changes	-10.86±3.7	-9.21±2	-11.8±4.3	0.013	(1 and 3)	
Astigmatism (diopter)						
Presurgery	1.45±0.57	1.13±0.58	0.86±0.7	0.003	(1 and 3)	0.07
Postsurgery	1.14±0.6	0.67±0.55	0.87±0.54	0.009	(1 and 2)	
Changes	0.31±0.72	0.45±0.62	0±0.57	0.008	(2 and 3)	

\*Based on GEE analysis; \*\*Based on Bonferoni method. GEE, generalized estimating equation; SE, spherical equivalent; ICL, implantable collamer lens; SD, standard deviation

**Table 4. Pre and postoperative intraocular pressure in the study groups**

	SD±mean			Total P*	Comparing couples**	Adjusted P used as a base value
	Artisan (1)	Artiflex (2)	ICL (3)			
Intraocular pressure (mmHg)						
Presurgery	12±3	13±2	13±2	0.007	(1 and 3)	0.042
Postsurgery	13±2	14±2	13±2	0.317		
Changes	-1.7±3.2	-1.1±2.2	0.4±1.7	0.001	(1 and 3) (2 and 3)	

\*Based on GEE analysis; \*\*Based on Bonferoni method. SD, standard deviation; ICL, implantable collamer lens; GEE, generalized estimating equation

**Table 5. Changes in corneal endothelial cell counts and corneal thickness**

	SD±mean			Total P*	Adjusted P used as a base value*
	Artisan (1)	Artiflex (2)	ICL (3)		
CEC (mm <sup>2</sup> )					
Presurgery	2825±359	2813±364	2848±325	0.926	0.694
Postsurgery	2541±319	2573±366	2589±295	0.846	
Changes	283±276	241±176	258±279	0.703	
Change %	10±9	9±6	9±10	0.95	
CCT (microns)					
Presurgery	516±44	503±41	507±32	0.58	0.754
Postsurgery	521±46	506±40	510±35	0.48	
Changes	-5±25	-3±0.13	-3±0.22	0.91	
Change %	-1±5	0±3	0±4	0.90	

\*Based on GEE analysis. CCT, central corneal thickness; SD, standard deviation; ICL, implantable collamer lens; GEE, generalized estimating equation; CEC, corneal endothelial cell

eyes of each patient revealed the difference to be not significant ( $P = 0.084$ ).

### Higher Order Aberrations

Total and higher order optical aberrations after surgery for each study group are shown in Table 6. These values were measured for a 6 mm pupil. HOA's between three groups were least in ICL group ( $P = 0.039$ ). Vertical trefoil was highest in Artisan group which can be explained by incision position at 12 o'clock position. Spherical aberration was also highest in Artisan group, which may be due to different composition of this lens (i.e. PMMA) in comparison to other two lenses.

## DISCUSSION

This retrospective comparative study included 112 eyes undergoing implantation of 3 popular types of PIOLs including Artisan, Artiflex and ICL for the correction of moderate to high myopia. Mean follow-up period was 30 months and mean myopic refraction before surgery was  $-11.2$  D. The degree of myopia was significantly higher in the ICL group as compared to Artiflex implanted eyes.

The number of surgeons in this study was similar to the study by Coulet et al<sup>[7]</sup> who evaluated the results of 3 contributing surgeons. Menezo et al<sup>[6]</sup> recalled all implanted cases between 1992 and 2001 in their center, but did not mention the number of surgeons. While the contribution of 3 surgeons increases the external validity of the study, it may decrease its internal validity.

In a prospective study by Coulet et al<sup>[7]</sup> on 31 patients, the patients were followed for 12 months after implantation of Artisan in one eye and Artiflex in the other eye. Mean refraction was  $-10.3$  D and  $-9.5$  D in the Artisan and Artiflex groups, respectively. In another research Menezo et al<sup>[6]</sup> retrospectively compared the results of implantation of Artisan, ICL and Adatomed PIOLs. In the Artisan and ICL groups, mean values of refractive error were  $-16.2$  and  $-16$  D and mean follow-up period was 96 and 18 months, respectively. Our study is comparable to previous studies regarding the magnitude of refractive error and follow-up duration.

In the present study, BCVA improved in all three PIOL groups to a similar extent and there was no significant difference among them in terms of efficacy index ( $P = 0.687$ ). Improvement in visual acuity, after PIOL implantation has been reported in other studies.<sup>[8-10]</sup> This can be due to neutralization of the minification effect of the concave spectacle lenses in high myopic subjects.<sup>[9,10]</sup>

In our study, postoperative SE within 1D of emmetropia was achieved in 60%, 91.7% and 77.8% of cases in the Artisan, Artiflex and ICL groups, respectively. The difference was statistically significant between the Artisan and Artiflex groups ( $P = 0.017$ ). The higher rate in the Artiflex group can be due to differences in surgical technique with these two lenses. Comparison of visual acuity did not show any significant difference between the groups; in other words efficacy index was comparable ( $P = 0.380$ ). Improvement of more than one Snellen line in BCVA in all three groups was comparable ( $P = 0.158$ ). Corneal astigmatism decreased postoperatively in a similar magnitude in all three groups ( $P = 0.07$ ). Coulet et al<sup>[7]</sup> reported that 83.9% of eyes with Artiflex and 58% of eyes with Artisan lenses were within 1D of emmetropia which are similar to findings in our study. They suggested that this outcome seems to be due to the fact that Artiflex power can be calculated with more accuracy and predictability. They also believed that this difference cannot be explained upon different incision techniques for surgery. Due to corneal coupling effect, changes in corneal curvature in the incision meridian and the axis perpendicular to it do not lead to significant change in SE in their study, similar to the present study, no statistically significant difference was observed between the safety indices of these two lenses. In the present study, it seems that residual refraction in the Artisan group was a result of inadequate accuracy of lens power calculation via the formula recommended by the manufacturer.

The safety and efficacy of toric ICL to correct a wide range of astigmatism along with myopia have been studied.<sup>[9]</sup> Toric ICL was not available in our region at

**Table 6. Postoperative total and higher order aberrations in the study groups**

	SD±mean			Total P*	Compared groups**
	Artisan (1)	Artiflex (2)	ICL (3)		
General results	1.79±0.74	1.41±0.51	1.31±0.91	0.028	(1 and 2)
Higher order aberrations	0.45±0.22	0.45±0.23	0.33±0.15	0.039	(1 and 3) (2 and 3)
Vertical trefoil	0.15±0.28	-0.09±0.37	0.04±0.22	0.32	(1 and 3)
Vertical coma	-0.12±0.38	0.07±0.33	0.05±0.24	0.08	-
Horizontal coma	0.02±0.23	-0.07±0.18	-0.006±0.19	0.094	-
Horizontal trefoil	0.07±0.28	0.16±0.33	0.01±0.25	0.07	-
Spherical aberration	-0.25±0.28	0.01±0.35	0±0.19	0.001	(1 and 2) (1 and 3)

\*Based on GEE analysis; \*\*Based on Bonferoni method. SD, standard deviation; ICL, implantable collamer lens; GEE, generalized estimating equation

the time of the study. In the current series, the change in astigmatism was nil in the ICL group as compared to the two other groups. The length of the main incision for ICL was only 3.2 mm, therefore astigmatic change is negligible. The incision was longer in two other groups and greater astigmatic change was expected.

In our study, similar to studies by Coulet et al<sup>[7]</sup> and Menezo et al<sup>[6,8]</sup> no important intraoperative complication was noted. One of the major long-term concerns after implantation of PIOLs, specifically posterior chamber lenses (i.e. ICL) is the development of cataracts.<sup>[10]</sup> In a meta-analysis including 6,338 eyes undergoing ICL implantation, the risk of developing cataracts was reported to be as high as 9.6%.<sup>[11]</sup> Uusitolo et al<sup>[12]</sup> observed lens opacities in 2.6% of ICL cases. Menezo et al<sup>[6]</sup> reported a rate of 17% for cataract formation in the ICL group. They believed that this high rate was due to using the V3 model (Version 3) in their study which is an old model. Compared to the V4 model, the V3 ICL had a smaller vault (the distance between the ICL and the anterior lens capsule) resulting in more contact between the ICL and the crystalline lens. Only two eyes (5.6%) in the ICL group in our study developed nuclear cataracts. This low rate may be due to the limited follow-up period in our study but may increase with longer follow-up. One important risk factor for cataract formation is the area of contact between the anterior lens capsule and the ICL; the greater the contact area, the higher the risk of cataract development.<sup>[13,14]</sup> All ICL cases in our study had adequate vaulting as recommended by manufacturer and no ICL was explanted or exchanged due to size measurement errors. This can probably be the other explanation for the lower rate of cataract formation. Appropriate lens vault decreases the risk of cataract formation, but excessive vaulting on the other hand can cause contact with the iris pigment epithelium leading to release of iris pigment together with anterior chamber shallowing and occlusion of the iridocorneal angle. At the present time, in order to precisely choose the posterior chamber PIOL diameter, sulcus-to-sulcus distance measurement by ultrasound biomicroscopy is recommended.

In terms of corneal complications such as decreased endothelial cell counts and changes in corneal thickness, no significant difference was observed among the study groups in our series. At the end of the follow-up period, the level of decrease in endothelial cell counts was 10%, 9% and 9% in the Artisan, Artiflex and ICL groups, respectively. Similarly, Coulet et al<sup>[7]</sup> reported a decrease of 9.4% and 9% in endothelial cell counts following Artisan and Artiflex implantation after 1-year, respectively. In our study, endothelial cell counts in the superior corneal quadrants were similar in the Artisan and Artiflex groups indicating no significant contact between the Artiflex lenses and the superior corneal endothelium where the lens is unfolded inside the eye

during implantation. In a prospective study, Ruhsurm et al<sup>[15]</sup> reported 34 cases of ICL implantation. Endothelial cell counts decreased about 7.9% and 12.9% after 2 and 3 years, respectively. Their rate is higher than the corresponding rate in our series. They linked this high rate of endothelial cell loss to the first experiences of this surgery in their center and to the effect of learning curve in addition to duration and method of surgery. PIOL may also cause chronic loss of endothelial cell by developing uveitis. The presence of iris tissue between the ICL and endothelium may decrease the rate of endothelial cell loss in a protective way, but according to Edelhauser et al<sup>[16]</sup> the most acceptable theory for endothelial cell loss 1–3 years after the surgery is intraoperative trauma and subsequent endothelial cell remodeling.

Subclinical chronic inflammation due to the PIOL itself has also been observed.<sup>[17,18]</sup> Ghoreishi et al<sup>[18]</sup> reported more flare in the anterior chamber with Artiflex which is discordant with our findings; no case of subclinical inflammation and chronic flare was observed in our series during follow-up.

IOP averagely increased 1 mmHg in the Artisan and Artiflex groups without any increase in the ICL group. Despite the difference being statistically significant, it is not clinically significant. Other studies found no change in IOP following Artisan, ICL or Adatomed lenses.<sup>[6,7]</sup> We performed peripheral iridectomy in all patients pre-or intraoperatively and no case developed an acute rise in IOP; therefore, we highly recommend peripheral iridectomy.

Similar to Coulet et al<sup>[7]</sup> we found no statistically significant difference among the study groups in terms of glare ( $P = 0.084$ ). To evaluate quality of vision after implantation of these 3 types of PIOL, we measured postoperative higher order aberrations and found that total higher order aberration was lower in the ICL group ( $P = 0.039$ ), spherical aberration was higher in the Artisan group ( $P = 0.001$ ), and also vertical trefoil was higher in the Artisan group ( $P = 0.032$ ) as compared to the other study groups. Visual system aberrations were not available preoperatively but the study groups were comparable in terms of age and severity of myopia and astigmatism. Therefore, postoperative comparison of the aberrations seems appropriate. Tahzib et al<sup>[19]</sup> compared higher order aberrations before and after surgery in 27 eyes with Artiflex and 22 eyes with Artisan. They concluded that Artiflex PIOL decreases while Artisan PIOL increases spherical aberrations. They believed that these effects are due to differences in optical design of these two PIOLs. Also, vertical trefoil was increased in both groups which was attributed to the different length of corneal incisions. Ghoreishi et al<sup>[17]</sup> compared Artiflex with ICL in terms of visual outcomes and contrast sensitivity and reported comparable results. Sarver et al<sup>[5]</sup> evaluated quality of vision in myopic eyes corrected by ICL implantation or LASIK by

comparing higher order aberrations postoperatively. They concluded that spherical aberrations and coma were lower after ICL implantation. Our study showed that ICL and Artiflex implantation resulted in lower aberrations as compared to Artisan PIOL. It seems that myopic patients benefit from better quality of vision after implantation of PIOLs.

We believe that the present study is the first independent, unsponsored study comparing the results and complications of implanting these three types of PIOL. Many of the previous studies were financial supported by PIOL manufacturers, or only compared two types of PIOLs. Considering the final visual outcomes and complications, no obvious superiority was noted among these lenses in our study. The Artisan group showed greater higher order aberrations and a higher rate of problems regarding quality of vision as compared to the other two groups. Drawbacks to our study include its retrospective nature, lack of randomization, limited number of cases and not measuring preoperative higher order aberrations.

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