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ORIGINAL RESEARCH

Anterior Chamber Changes After Implantable Collamer Lens Implantation in High Myopia Using Pentacam: A Prospective Study

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ABSTRACT

Introduction: The objective of this study was to evaluate the changes of the anterior chamber (AC) of the eye after implantable Collamer lens (ICL) implantation in high myopia by using the Pentacam.

Methods: The prospective study included 34 high myopic patients (34 eyes). All patients were treated with Visian implantable Collamer lens (ICL) (Staar Surgical Co.) implantation. The Pentacam (Oculus) was used for all cases preoperatively and 1, 3 and 6 months postoperatively. AC angle (ACA), AC volume (ACV), central AC depth (CACD), ICL vault, central corneal thickness (CCT), pupil diameter (PD), K readings and intraocular pressure (IOP) were recorded.

Results: Our study included 34 eyes of 34 patients, 20 females (59%) and 14 males (41%). Mean ACA was $36.93° \pm 4.75°$ preoperatively, $25.17° \pm 5.64°$ and $25.23° \pm 6.05°$ 1 and 3 months postoperatively ($p < 0.001$). Mean ACV was 191.24 ± 11.18 mm^3 preoperatively, 141.53 ± 16.77 and 142.11 ± 15.89 mm^3 1 and 3 months postoperatively ($p < 0.001$). Mean CACD was 3.59 ± 0.17 mm preoperatively, 2.83 ± 0.24 mm and 2.96 ± 0.25 mm 1 and 3 months postoperatively ($p < 0.001$). The ICL vault decreased from 0.556 ± 0.033 mm 1 month postoperatively to 0.431 ± 0.056 mm 3 months postoperatively ($p < 0.001$). There were no statistically significant differences for any of the AC parameters among measurements taken 3, 6 and 12 months postoperatively. There were no statistically significant differences between preoperative and any postoperative measurements of CCT, PD and K readings.

Conclusions: ICL implantation for correction of high myopia leads to significant changes in the anterior chamber angle, volume and depth and insignificant changes in the pupil diameter, CCT and K readings.

Keywords: Anterior chamber; Collamer, myopia; ICL; Pentacam

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INTRODUCTION

The Visian Implantable Collamer Lens (ICL, STAAR Surgical, Nidau, Switzerland), a posterior chamber phakic intraocular lens (IOL), has been widely used and accepted for the correction of high myopia [1]. It has been reported to be a safe, effective and reversible approach but patients must be aware of possible complications, such as lens opacification, endothelial

cell loss, increased intraocular pressure (IOP), inflammation and others [2, 3].

The anterior segment parameters are vital to choose the suitable refractive surgery. Central anterior chamber depth (CACD) and white to white (WTW) are important parameters for evaluating eligibility for ICL surgery and selecting the proper size of ICL [4]. A CACD value less than 2.80 mm is a contraindication to ICL surgery. The central vault, the distance between the back surface of the ICL and the front surface of the lens, is of value for estimating the safety of surgery postoperatively. An excessive vault may lead to glaucoma, and an insufficient vault increases the risk of anterior subcapsular cataracts [5]. Hence, an accurate and objective CACD and central vault assessment are both of great value for successful ICL surgery.

The Pentacam generates a three-dimensional virtual model of the anterior segment in about 2 s. Software allows evaluation and quantification of anterior segment parameters such as the central anterior chamber depth (CACD), anterior chamber volume (ACV), pupil diameter (PD) and anterior chamber angle (ACA) of cross-section photographs from 0° to 360° [6].

Previous studies have been done to evaluate the safety and efficacy of ICL as a refractive treatment [1, 2, 7], to compare different methods of anterior segment imaging postoperatively [8] and to detect changes in anterior segment parameters after surgery [9]. However, none of these studies compared the pre- and postoperative anterior segment parameters using the Pentacam. The aim of our work is to evaluate changes of the anterior chamber (AC) of the eye after ICL implantation in high myopia using the Pentacam.

METHODS

Thirty-four eyes of 34 patients (20 females, 14 males) who underwent ICL implantation for correction of high myopia at the Ophthalmology Department of Benha University Hospital between January 2015 and March 2016 were included. Patients with unrealistic expectations;

anterior chamber depth less than 2.80 mm; IOP greater than 20 mmHg; a history of ocular surgery or trauma, cataract, glaucoma, diabetes mellitus, other ocular or systemic autoimmune diseases; and age less than 18 years were excluded from the study. The study was agreed upon by the research ethics committee of the Benha Faculty of Medicine. Informed consent was signed by all participants as per the Declaration of Helsinki.

Clinical Evaluation

We did a full ophthalmic examination for all subjects before the operation and 1, 3, 6 and 12 months postoperatively. The examinations included uncorrected and corrected distance visual acuity (UDVA and CDVA) according to the Snellen chart, manifest and cycloplegic refractions, slit-lamp bio-microscopy, fundus examinations and intraocular pressure.

Imaging

Imaging of the anterior segment preoperatively and 1, 3, 6 and 12 months after surgery using a rotating Scheimpflug camera (Pentacam version 1.20, Oculus, Germany) was carried out by the same observer and under scotopic conditions, with the patient's chin placed on the chin rest and the forehead against the forehead strap. The patient was asked to fixate on the fixation target. Once alignment was perfect, 25 Scheimpflug images were automatically recorded within 2 s. Image quality was checked using the quality factor value for each eye. The AC angle (ACA) was measured superiorly, inferiorly, nasally and temporally, and then a mean ACA was calculated; the AC volume (ACV), central AC depth (CACD) and peripheral AC depth (PACD) were measured 4 mm from the center superiorly, inferiorly, nasally and temporally. Then, a mean PACD was calculated, and central corneal thickness (CCT), pupil diameter (PD) and K readings were recorded. The central vault of the ICL was measured 1, 3, 6 and 12 months after surgery using the image analysis program accompanying the device.

Implantable Collamer Lens Calculation

The ICL is 6.0 mm wide, and four sizes are available (11.5, 12.0, 12.5 and 13.0 mm in from −3.00 to −23.00 DS). Calculations of ICL power and size were done by the manufacturer. A modified vertex formula was used in power calculations. The variables in the formula are preoperative manifest and cycloplegic refractions, K readings, CCT and central ACD. The size of the ICL was determined by the STAAR sizing formula based on the WTW and CACD obtained by the Pentacam. For CACD of 2.80–3.00 mm, ICL length = WTW + 0.2–0.4 mm; for CACD of 3.00–3.50 mm, ICL length = WTW + 0.4–0.6 mm; for CACD of 3.50–3.70 mm, ICL length = WTW + 0.6–0.8 mm.

Surgical Procedure

Two YAG peripheral iridectomies were done at two different sites 2 weeks before surgery. Mydriatic agents were instilled four times at 10-min intervals before surgery. After topical anesthesia, a 3-mm temporal corneal incision was created. Viscoelastic material was injected in the AC. An injector cartridge (STAAR Surgical) was used to insert the ICL V4 without hole. The four footplates of the ICL were placed on the ciliary sulcus along the 180° axis. Viscoelastic material was completely removed using buffered salt solution. No astigmatic keratotomy or limbal relaxing incision was made. Postoperatively, tobramycin 0.3%-dexamethasone 0.1% (Tobradex) and moxifloxacin 0.5% (Vigamox) eye drops were administered topically three times daily for 2 weeks.

Statistical Analysis

Statistical analysis was done using SPSS version 20.0 (SPSS Inc., IBM, USA), and the results are expressed as mean ± standard deviation (SD). The Kolmogorov-Smirnov test was employed to assure the normal distribution of the data. Comparison between pre- and postoperative measurements was done using independent t tests. A p value ≤0.05 was considered statistically significant. Spearman's rho test was used to measure the strength of association between variables.

RESULTS

This study included 34 eyes of 34 patients, 20 females (59%) and 8 males (41%). Mean age was 24.76 ± 5.14 (range, 19–37) years. Mean spherical equivalent (SE) of refractive error was −16.91 ± 2.37 D before surgery. One month after surgery, SE was −0.46 ± 0.37 D, and 3 months postoperatively SE became −0.51 ± 0.32 D ($p = 0.553$) (Table 1). No intra- or postoperative complications occurred except for increased IOP (>21 mmHg) in five eyes, which was managed by medical treatment with no need for surgical intervention.

One month after surgery, ACV, ACA, CACD and PACD decreased significantly ($p < 0.001$). On the other hand, PD, CCT, keratometric values ($K1$ and $K2$) and IOP showed insignificant change with p values of 0.062 (PD was near to significance), 0.436, 0.145, 0.477 and 0.207, respectively, as shown in Table 2.

Table 1 Patient demographics: selected pre- and postoperative characteristics

Gender	20 females (59%)	
	14 males (41%)	
Age in years	24.76 ± 5.14	
Preoperative SE (D)	−16.91 ± 2.37	
1 month postoperatively SE (D)	−0.46 ± 0.37	$t = 0.596$
		$p = 0.553$
3 months postoperatively SE (D)	−0.51 ± 0.32	
6 months postoperatively SE (D)	−0.55 ± 0.22	
12 months postoperatively SE (D)	−0.53 ± 0.28	

Data are mean ± SD of 34 eyes of 20 patients preoperatively, 1, 3, 6 and 12 months after ICL implantation
SE spherical equivalent

Table 2 Changes in anterior chamber parameters 1 month after ICL implantation

Parameters	Preoperative	1 Month postoperative	3 Months postoperative	6 Months postoperative	12 Months postoperative
ACV (mm^3)	191.24 ± 11.18	141.53 ± 16.77*	142.11 ± 15.89*	142.05 ± 14.76*	142.07 ± 16.62*
ACA (°)	36.93 ± 4.75	25.17 ± 5.64*	25.23 ± 6.05*	25.30 ± 5.14*	25.32 ± 7.24*
CACD (mm)	3.59 ± 0.17	2.83 ± 0.24*	2.96 ± 0.25*±	2.94 ± 0.36*±	2.95 ± 0.31*±
PACD (mm)	2.78 ± 0.21	2.13 ± 0.19*	2.19 ± 0.13*	2.12 ± 0.17*	2.15 ± 0.20*
PD (mm)	5.11 ± 0.56	4.77 ± 0.88	4.79 ± 0.90	4.75 ± 1.04	4.82 ± 1.17
CCT (μm)	500.39 ± 19.71	504.16 ± 20.12	501.16 ± 19.52	503.06 ± 22.14	502.06 ± 20.86
K1 (D)	43.28 ± 1.11	42.89 ± 1.07	42.96 ± 1.15	42.88 ± 1.31	42.74 ± 1.39
K2 (D)	44.65 ± 1.34	44.42 ± 1.31	44.35 ± 1.28	44.58 ± 1.40	44.47 ± 1.44
IOP (mmHg)	11.33 ± 2.41	12.19 ± 3.11	12.12 ± 2.92	12.69 ± 2.64	12.43 ± 3.57
Vault (mm)	–	0.556 ± 0.033	0.431 ± 0.056 ±	0.429 ± 0.049 ±	0.426 ± 0.064 ±

Data are mean ± SD of 34 eyes preoperatively, 1, 3, 6 and 12 months after ICL implantation

ACV anterior chamber volume, *ACA* anterior chamber angle, *CACD* central anterior chamber depth, *PACD* peripheral anterior chamber depth, *PD* pupil diameter, *CCT* central corneal thickness, *IOP* intraocular pressure

* Statistically significant difference from preoperative value, ± statistically significant difference from 1 month postoperative value

Spearman's rho test was used to measure the correlation between the central ICL vault and CACD at 1 month postoperatively; we found a statistically significant negative correlation (Spearman's correlation coefficient $r = -0.8224$, $p < 0.001$). We also found a statistically significant positive correlation between the central ICL vault and PD at 1 month postoperatively (Spearman's correlation coefficient $r = 0.9429$, $p < 0.001$).

At the 3-month visit, the ACV, ACA, CACD and PACD had decreased significantly from the preoperative values ($p < 0.001$), while PD, CCT, keratometric values (K1 and K2) and IOP showed insignificant changes with p values of 0.083, 0.872, 0.274, 0.349 and 0.228, respectively (Table 2).

There were no statistically significant changes in AC parameters between 1 and 3 months after ICL implantation except for the ICL vault,

which decreased from 0.556 ± 0.033 mm 1 month post-surgery to 0.431 ± 0.056 mm 3 months postoperatively ($p < 0.0001$), and CACD, which increased from 2.83 ± 0.24 mm 1 to 2.96 ± 0.25 3 months postoperatively with $p = 0.0323$ (Table 2). We found no statistically significant changes in AC parameters among the 3-, 6- and 12-month results after ICL implantation as all p values were >0.05 (Table 2).

DISCUSSION

The implantation of ICL has been shown to be an effective surgical treatment for the correction of refractive errors, offering good optical quality. With expanding use of ICLs worldwide, several studies addressing their efficacy and safety have been done and are still of current interest [1, 2, 6, 10–13]. Our study aimed to

evaluate AC changes after ICL implantation using the Pentacam. Our results pointed to significant changes in ACA, ACV, CACD and PACD 1, 3, 6 and 12 months after surgery as compared to the preoperative parameters. On the other hand, we found insignificant changes in CCT, K readings, PD and IOP.

We found that ACA decreased by 31.8%, 31.6%, 31.5% and 31.4% at 1, 3, 6 and 12 months postoperatively, respectively. ACA changed from $36.93° \pm 4.75°$ preoperatively to $25.17° \pm 5.61°$ 1 month postoperatively to $25.23° \pm 6.05°$ 3 months postoperatively and to $25.3° \pm 5.14°$ 6 months postoperatively. These results were the same as those of Chung and associates [10] who detected a 31.7% reduction in the trabecular-iris angle (from $38.1° \pm 8.7°$ to $26.0° \pm 6.5°$) using UBM (ultrasound bio-microscopy) 1 month after surgery. Fernández-Vigo and associates [11] found an angle reduction of 34.5% 3 months after surgery using Fourier-domain optical coherence tomography, and they suggested that this reduction was caused by the convex shape of the ICL and not due to disturbed aqueous flow. In our study, there were no statistically significant differences between ACAs at 1 and 3 months postoperatively ($p = 0.966$). Thus, the initial narrowing of the ACA remained stable for 3 months post-surgery. Consistently, this was the case in Fernández-Vigo and associates' study [11] with no significant change in 3 months and in Chung and associates study [10] as there were no significant changes in ACA from 1 month postoperatively until the end of follow-up, which was a mean of 33 months.

Our results showed a significant reduction in CACD by about 21.17%, 18.11%, 18.10% and 17.83% at 1, 3, 6 and 12 months postoperatively, respectively. This reduction was mainly due to vaulting of the ICL, as the CACD is measured postoperatively from the back surface of the cornea to the anterior surface of the ICL. We found statistically significant negative correlation between the vault and CACD. The central ICL vault in our study was 0.556 ± 0.033 mm 1 month postoperatively and decreased significantly to 0.431 ± 0.056 mm 3 months after implantation ($p < 0.0001$); it then decreased insignificantly to 0.429 ± 0.049 and 0.426 ± 0.064 mm 6 and 12 months postoperatively, respectively. These results are in line with results of Ju et al. [12]. They found that mean ACD measured with AS-OCT was 3.28 ± 0.14 mm preoperatively and 2.45 ± 0.22 mm 3 months after surgery. ACD showed a statistically significant reduction of 25.4% ($p < 0.01$) in their study.

We found that PD insignificantly decreased by 6.7%, 6.2%, 7% and 5.7% at 1, 3, 6 and 12 months postoperatively, respectively. Although the change was statistically insignificant, it is worth mentioning that the p value was 0.062, which means it was close to the significance. This was different from results of previous studies [13, 14], where a significant reduction in PD was observed both 1 and 3 months after ICL implantation. Li and associates [13] attributed this reduction to the contact between the iris and ICL, which limits postoperative pupil movements, as they found a significant correlation between lower degrees of myopia and decreased size of the pupil. Our results were different perhaps because our patients had higher degrees of myopia as mean SE was -16.91 ± 2.37 D in our study, while it was -12.50 ± 4.28 in their study. We also found a statistically significant positive correlation between the vault and PD. This was also found by Chen et al. [9] who stated that pupil size is a vital factor in vault change, with an increasing vault observed postoperatively from 1 day to 1 week associated with the lessening effects of pharmacological miosis and increasing pupil size.

IOP was elevated >21 mmHg in 14.7% (5 eyes) of our cases, with three eyes showed the increased IOP during the first week, which can be related to retained viscoelastic material, while two eyes had high IOP after 1 month; this may have been due to a steroid-induced response. This was nearly the case in Almalki and colleagues' study [15]; they found elevated IOP in 10.8% of cases. CCT showed a non-significant change in our cases; this was because of proper IOP control and minimal or no surgical trauma to the endothelium. Also, K readings suffered from insignificant changes because the incision was small in size (3 mm) and temporal in site.

Our study was limited by the relatively small number of subjects. The follow-up period was 12 months, but some changes may continue to evolve later. We had no chance to use another imaging technique besides the Pentacam to compare their results.

CONCLUSIONS

Our results support the view that ICL implantation is a safe and effective option for treatment of high myopia and that the Pentacam can be used to evaluate anterior segment parameters. ICL implantation reduces the ACA and CACD significantly. These changes should be considered during evaluation of case eligibility for ICL implantation. ICL implantation has an insignificant effect on pupil size and corneal curvature, which may guarantee good quality of vision after surgery.

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