# Two Different Corneal Incision Designs for Correcting Corneal Astigmatism During Cataract Surgery With Multifocal Intraocular Lens Implantation

**Dan Liu**
Xiangya Hospital Central South University
**Cong Fan**
Xiangya Hospital Central South University
**Chunyan Li**
Xiangya Hospital Central South University
**Jian Jiang** ( jiangjianxy@126.com )
Xiangya Hospital Central South University

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# Abstract

**Background:** Multifocal intraocular lenses (IOLs) is very intolerant to residual corneal astigmatism and patients with more than 1.0 D of residual corneal astigmatism are not suitable candidates for implantation of multifocal IOLs. The purpose of this study was to evaluate the efficacy of a single clear corneal incision (CCI) or an opposite clear corneal incision (OCCI) made on a steep meridian for correction of low to moderate corneal astigmatism during implantation of multifocal IOLs.

**Methods:** This is a retrospective cohort study. A total of 50 patients with pre-operative total corneal astigmatism, ranging between 0.5 and 2.0 diopters (D), who underwent cataract surgery and received multifocal IOLs were included. Correction of corneal astigmatism was done via single CCIs on steep meridians in patients with 0.5–1.2 D total corneal astigmatisms, and OCCIs in patients with 1.3–2.0 D total corneal astigmatisms. Visual acuity, corneal astigmatism, ocular aberrations, corneal aberrations, and subjective vision quality were evaluated after surgery.

**Results:** At 12-weeks post-surgery, the mean uncorrected distance vision (UCDV) was 0.06±0.09 logarithm of the minimum angle of resolution (logMAR) and 0.03±0.09 logMAR, and the mean uncorrected near vision (UCNV) was 0.08±0.11 logMAR and 0.09±0.09 logMAR in the CCI and OCCI groups, respectively. The change in corneal astigmatism was 0.52 ± 0.22D and 1.06 ± 0.23D in the CCI and OCCI groups, respectively ($P<0.001$). Total corneal higher-order aberrations (HOAs) and trefoil increased in both groups ($P<0.05$); however, there was no difference in the change in total corneal HOAs between the two groups ($P>0.05$).

**Conclusions:** CCI and OCCI made on a steep axis could be an option for correction of mild-to-moderate astigmatism during cataract surgery with multifocal IOL implantation.


# Introduction

Residual astigmatism after cataract surgery can significantly compromise vision in patients, causing symptomatic blur and a reduction in uncorrected vision, thus affecting quality of life. Unaided visual acuity in patients with 1.0 D or more of residual refractive astigmatism after monofocal intraocular lens (IOL) may not be acceptable. [1] Multifocal IOLs are even less forgiving for corneal astigmatism, and patients receiving multifocal IOLs can be affected by as little as 0.5 D of residual refractive astigmatism. [1-2] It is estimated that 50% of cataract patients in America and 43% in China exhibit more than 1.0 D of astigmatism. [3-4] Therefore, managing preexisting corneal astigmatism at the time of cataract surgery is critical for achieving excellent visual outcomes, especially when implanting multifocal IOLs.

Several methods have been employed to correct corneal astigmatism, including corneal or limbal relaxing incisions, clear corneal incision (CCI) and opposite clear corneal incision (OCCI) applied on a steep axis, as well as implantation of toric IOLs. [5-11] Among these methods, CCI and OCCI made on a steep meridian are widely used in patients with low to moderate corneal astigmatism since this technique is simple and

requires no additional skill or instrumentation. [8-11] Previous studies have reported the use of CCI and OCCI to correct corneal astigmatism in eyes with monocular IOLs.[8-11] To our knowledge, there is no report examining the use of OCCI or CCI applied on a steep meridian to correct astigmatism when multifocal IOLs are implanted. Since a growing number of multifocal IOLs, which are less tolerant to residual corneal astigmatism than monocular IOLs,[1,2] are being used in cataract patients, it is important to evaluate whether CCI and/or OCCI are effective for correcting astigmatism in patients undergoing multifocal IOL implantation. In this study, CCI or OCCI on a steep meridian were used to correct total corneal astigmatism ranging between 0.5 and 2.0 D, during implantation of multifocal IOLs. Visual quality of life was then evaluated in patients that underwent CCI or OCCI with implantation of multifocal IOL at 12 weeks post-surgery.

# Patients And Methods

### Study design

This study is a retrospective cohort study that was performed at the Eye Center of Xiangya Hospital, Central South University, Changsha, China. Patients who underwent cataract surgery in our department were consecutively included from October 2018 to October 2019. Inclusion criteria were as follows: 1) total corneal astigmatism ranging between 0.5 D and 2.0 D preoperatively; 2) implantation of ZMB00 multifocal IOLs (Abbott Medical Optics, Inc., California□USA); and 3) a single CCI or OCCI was made on the steepest meridian. Exclusion criteria were as follows: 1) corneal astigmatism greater than 2.0 D or irregular astigmatism; 2) presence of eye disease other than cataract; 3) a history of eye trauma and/or previous ocular surgery; and 4) intra-operative complications.

Fifty eyes of 50 patients, ranging in age from 37 to 91 years, were included. One eye per one patient was used in this study. If both eyes that underwent cataract surgery were eligible for this study, the first surgical eye was selected.

Corneal astigmatism was measured with Scheimpflug topography (Pentacam; Oculus, Inc, Wetzlar, Germany), and patients were divided into a CCI group and an OCCI group by pre-operative total corneal astigmatism. Patients with 0.5–1.2D pre-operative corneal astigmatism were included in the CCI group and received a single CCI on the steep meridian, and patients with 1.3–2.0 D were included in the OCCI group and received OCCI on the steep meridian. A total of 26 patients were included in the CCI group and 24 patients were included in the OCCI group. The pre-operative clinical data of patients in the CCI and OCCI groups is described in Table 1.

The study was approved by the Xiangya Hospital ethics committee and was performed in accordance with the tenets of the Declaration of Helsinki. All patients signed informed consent forms before cataract surgery, and data were collected anonymously.

### Intraocular lens

The TECNIS ZMB00 is a UV-blocking, hydrophobic, acrylic, single-piece IOL. It has a C-loop haptic with near power added (+4.0 D) at the IOL optic plane. The IOL is designed as biconvex and consists of a wavefront-designed, anterior aspheric surface (negative spherical aberration −0.27 μm) and posterior diffractive surface with 22 diffractive rings. The IOL power was calculated by the same technician using an IOL Master 500 optical biometer (Carl Zeiss Meditec AG, Jena, Germany) using the Haigis formula. Parameters included axial length, corneal power and anterior chamber depth.

## Surgical Technique

All surgeries and corneal meridian markings were performed by the same surgeon (J.J). The steep corneal meridian was marked prior to surgery using a slit lamp. Briefly, the patient's head was positioned on the slit lamp and the patient was asked to keep the contralateral eye open and to look forward. The slit beam was narrowed to a thin slit, centered on the pupil and aligned with the 0°–180° marks of the calibrator. Then, using a sterile 30-gauge needle, two small superficial incisions were made at the periphery of the cornea where the slit beam cut the limbus at the 0°–180° position. Care was taken to keep the slit beam on the center of the pupil for alignment. Incisions were fixated with a sterile marker pen for easier intraoperative recognition. Finally, the correct position markings were verified at the slit lamp (Figure 1).

Surgery was performed using topical anesthesia in both groups. After the Mendez-style corneal marking ring was aligned to the two preoperative markings, dots were made using a blue pen on the planned meridian (Figure 1). A self-sealing 3.0 mm CCI was made 1 mm anterior to the limbus on a steep meridian using a 3.0 mm keratome (Alcon Laboratories, Inc. Fort Worth, USA). There is a 2 mm marking line on the surface of the keratome so that we can ensure that the tunnel length is 2 mm. The standard phacoemulsification procedure was performed via 2 incisions. Routine phacoemulsification was performed using a standard ultrasound technique (Centurion, Alcon Laboratories, Inc. Fort Worth, USA), followed by insertion of a foldable multifocal IOL (ZMB00). The OCCI was made on the opposite steep meridian 1 mm anterior to the limbus using the same keratome prior to removal of viscoelastic material; the length of corneal tunnel was also 2 mm. Only the phacoemulsification incision was hydrated at the end of surgery. All patients received routine postoperative topical steroids for 4 weeks and antibiotic eye drops for 2 weeks.

## Main Outcome Measures

Uncorrected distance vision (UCDV) and uncorrected near vision (UCNV) were evaluated by an optometrist; the patients and optometrists were masked during vision testing. The decimal visual acuity was then converted to a logMAR scale for statistical analysis. Corneal astigmatism was assessed using Scheimpflug topography (Pentacam ; Oculus, Inc, Wetzlar, Germany), and the root mean square (RMS) of ocular and corneal HOAs, including total HOAs, coma ($Z_3^{-1}$ and $Z_3^{1}$), spherical aberration ($Z_4^{0}$), secondary astigmatism ($Z_4^{-2}$ and $Z_4^{2}$), and trefoil ($Z_3^{-3}$ and $Z_3^{3}$), were assessed with the Zernike coefficient (iTrace, Tracey Technologies Inc., Houston, USA) in a 3.0 mm diameter central area. Astigmatic

change was calculated as the difference between mean preoperative and postoperative topographic readings. Patients with residual corneal astigmatism more than 0.5 D or 1.0 D were also counted. Surgically induced astigmatism (SIA) was evaluated using the vector analysis on Dr. Warren Hill's website (https:// sia-calculator.com/).

The Visual Function scale-14 (VF-14) was used to evaluate postoperative visual quality. The scale included 4 items: subjective vision, visual adaptation, peripheral vision and stereoscopic vision[12]. Each item was graded from 1 to 5 points, and a higher score indicated higher visual satisfaction. The final score was the average value times 20; higher scores indicated better postoperative life and visual quality.

UCDV, UCNV, total corneal astigmatism and HOAs were recorded before surgery. UCDV and UCNV were observed at 1, 4, and 12 weeks post-surgery. The HOAs were determined 12-weeks post-surgery. The VF-14 questionnaire, glare, halos, and the need for spectacles were recorded at 12 weeks post-surgery.

### Statistical Analysis

Statistical analysis was performed using SPSS software (version 21.0; SPSS, Inc.). Categorical variables were compared with use of the Fisher's exact test. A Wilcoxon Signed Ranks test was used to analyze preoperative and postoperative data. A Mann–Whitney test was used to analyze the data between the two groups. A p value less than 0.05 was considered statistically significant.

## Results

### Visual Acuity

UCDV and UCNV were significantly improved at 1, 4 and 12 weeks post-surgery in both groups compared to pre-operative values (P□0.001). There was no difference in UCDV and UCNV between the two groups post-surgery (Table 2).

### Residual Corneal Astigmatism

Residual corneal astigmatism at 12 weeks post-surgery is shown in Figure 2. Residual total corneal astigmatism was 0.2–0.8 D in the CCI group and 0.2–1.1 D in the OCCI group. In the CCI group, 9 of 26 patients (34.6%) had more than 0.5 D residual astigmatism and no patients had more than 1.0 D residual astigmatism. In the OCCI group, 13 of 24 patients (54.2%) had more than 0.5 D residual astigmatism, and 2 of 24 patients (8.3%) had more than 1.0 D residual astigmatism. The mean change in corneal astigmatism was 0.52 ± 0.22 D and 1.06 ± 0.23 D in the CCI and OCCI groups, respectively (P<0.001).

### Surgically Induced Astigmatism

The mean SIA was 0.62 ±0.16 D and 1.23±0.24 D in the CCI and OCCI groups, respectively, indicating that OCCIs caused significantly greater SIA than single CCIs (P□0.001□.

### Corneal and ocular HOAs

After cataract surgery, ocular HOAs were significantly decreased in both the OCCI and CCI groups (P<0.05) 12 weeks post-surgery. Corneal HOAs, total HOAs and trefoil increased in both groups (P<0.05). Spherical aberration and secondary astigmatism increased in the CCI group (P<0.05), but not in the OCCI group (P>0.05) (Table 3, Figure 3). Compared to the CCI group, the change in trefoil was larger and the change in secondary astigmatism was smaller in the OCCI group, which demonstrated a similar change in total HOAs in the two groups（Figrue 3）.

### Visual quality

The VF-14 scores were significantly higher in both groups at 12-weeks post-surgery (both P<0.001, Table 4). All patients reported that they were not wearing spectacles most of the time; although 10 patients (20%) needed spectacles when reading for long periods of time. A total of 9 patients (18%) reported glare and 7 (14%) reported halos, but only 2 (4%) patients reported being bothered by these phenomena when driving at night.

## Discussion

In this study, two different corneal incisions (CCI and OCCI) made at the steepest meridian were used to reduce corneal astigmatism during cataract surgery. Because the corrective effect of a single CCI made at the steepest meridian is limited, and astigmatism has not been fully corrected after CCI in eyes with more than 1.2 D of astigmatism prior to surgery, [13] CCI at the steepest meridian was only used in patients with astigmatisms between 0.5 and 1.2 D, and OCCI was used in patients with astigmatisms between 1.3 and 2.0 D. It has been reported that the mean astigmatism correction with CCI is about 0.5 D,[9,11,14,15] and the mean astigmatism correction with OCCI varies from 0.50 to 2.06 D, depending on the preoperative corneal astigmatism, as well as the location and length of the incisions. [10,11,15] In the current study, a 3.0 mm OCCI on the steep corneal meridian reduced astigmatism by 1.06 D, and single CCI reduced astigmatism by 0.52 D. The results obtained herein are within the range reported previously.[9-11,14,15]

Since vision can be affected by as little as a 0.5 D residual astigmatism with multifocal IOL implantation, patients with more than 1.0 D residual astigmatism are not recommended for multifocal IOL implantations [1,2]. In this study, patients with more than 0.5 D or 1.0 D residual corneal astigmatism were counted post-surgery. Half of the patients had less than 0.5 D residual astigmatism and almost all patients had less than 1.0 D residual astigmatism postoperatively, resulting in most patients reporting satisfaction with UCDV and UCNV after multifocal IOL implantation. At 12 weeks post-surgery, UCDV was 0.06 and 0.03 logMAR, and UCNV was 0.08 and 0.09 logMAR in the CCI and OCCI groups, respectively. This finding is consistent with the visual improvement reported by others using multifocal IOLs in patients with less than 1.0 D preoperative corneal astigmatism. [16-18]

Wavefront analysis is an objective measurement of visual quality and may predict visual complaints. Although approximately 93% of the aberration in a normal eye is known to be attributable to lower-order aberrations, HOAs are important for achieving the best optical quality in pseudophakic eyes. [19-21] In this study, the ocular HOAs decreased significantly after surgery, which indicated an increase of visual quality with mulitifocal IOL implantation. It has been shown that corneal incisions can increase the values of the root mean square (RMS) of corneal HOAs [22-25]; thus, we assessed the changes in corneal aberrations after surgery. The wavefront parameters of total HOAs, trefoil, coma, spherical aberrations, and secondary astigmatism were compared, since these aberrations constitute the major components of HOAs. In this study, both CCI and OCCI caused an increase in postoperative corneal HOAs, which is consistent with results of previous research The change in the trefoil aberration increases significantly the larger the corneal incision. [24,26] The current study found that the change of trefoil aberration was larger in the OCCI group than in the CCI group, which may be related to the additional surgical incision. However, the change in secondary astigmatism was smaller in the OCCI group than in the CCI group; thus, the change in total HOA was similar between the two groups. These findings show that compared with CCI, OCCI can increase astigmatism correction, but it does not increase the total corneal HOA.

Subjective vision quality is also an essential component for assessing visual performance. In this study, subjective vision quality was assessed using the VF-14 questionnaire. The questionnaire was used to evaluate near and far vision after cataract surgery. The findings showed that quality of life was significantly improved in both groups. Patients in our study who selected multifocal IOLs do not want to wear reading glasses after surgery. Since all patients in the current study had good UCNV and were spectacle-free most of the time after surgery, our procedure met the expectations of these patients. Glare and halo are common optical side effects after cataract surgery, especially when multifocal IOLs are inserted, and can significantly affect the visual performance and satisfaction of patients. Overall, 9 patients (18%) reported glare and 7 (14%) reported halos, while only 2 (4%) patients reported being bothered by these phenomena when driving at night.

This study had some limitations. First, this was a retrospective study and did not compare different methods for correcting corneal astigmatism. Moreover, the 12 week follow-up time was relatively short; therefore, research into long-term outcomes is necessary. Furthermore, the limited number of patients enrolled reduced the statistical power of the analysis.

In conclusion, patients in this study had satisfactory vision quality after surgery. As for the correction of corneal astigmatism, CCI/OCCI requires no additional skill or instrumentation when 3.0 mm phacoemulsification incisions are used. Therefore, for patients with mild-to-moderate corneal astigmatism who want to implantation of multifocal IOLs during cataract surgery, CCI/OCCI is a recommended method for correcting corneal astigmatism.

# Declarations

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**Compliance with Ethical Standards:**

**Conflict of interest :** All authors declares that they have no conflict of interest.

**Ethical approval:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the Xiangya Ethics Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent:** Informed consent was obtained from all individual participants included in the study.The data used to support the findings of this study are included within the article. The article has not been presented in a meeting.

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# Tables

**Table 1.** Pre-operative baseline clinical data of patients .

| | CCI group | OCCI group | P |
|---|---|---|---|
| No. | 26 | 24 | / |
| Age (year) | 64.9±9.1 | 58.9±12.4 | 0.09 |
| Female/Male | 14/12 | 11/13 | 0.78 |
| Right eye/Left eye | 11/15 | 13/11 | 0.57 |
| Nuclear opalescence grade | 2-4 | 2-4 | / |
| Mean corneal astigmatism(D) | 0.98 ±0.22 | 1.63 ±0.27 | 0.001 |
| Mean corneal power(D) | 43.87±1.76 | 43.84±1.70 | 0.97 |
| Corneal Total HOAs | 0.092±0.014 | 0.140±0.018 | 0.001 |
| Ocular Total HOAs | 0.232±0.042 | 0.286±0.023 | 0.62 |
| UCDV(logMAR) | 0.98±0.04 | 1.06±0.08 | 0.53 |
| VF-14score | 65.12±1.78 | 67.23±3.14 | 0.98 |

**Table 2.** Mean preoperative and postoperative UCDV and UCNV in two groups.

| | | OCCI group | CCI group | P |
|---|---|---|---|---|
| UCDV (logMar) | Pre-op | 1.06±0.08 | 0.98±0.04 | 0.53 |
| | Post-1 week | 0.12±0.02* | 0.10±0.02* | 0.26 |
| | Post-4 weeks | 0.09±0.02* | 0.05±0.02* | 0.87 |
| | Post-12 weeks | 0.06±0.02* | 0.03±0.01* | 0.24 |
| | Pre-op | 0.92±0.05 | 0.97±0.06 | 0.89 |
| UCNV (logMar) | Post-1 week | 0.10±0.04* | 0.09±0.02* | 0.92 |
| | Post-4 weeks | 0.09±0.01* | 0.09±0.02* | 0.20 |
| | Post-12 weeks | 0.08±0.01* | 0.09±0.01* | 0.81 |

∗Values are statistically significant compared with preoperative values ($P < 0.001$).

**Table 3.** Mean preoperative and 3-month postoperative corneal and ocular HOA in the CCI and OCCI groups.

| | Cornea | | Ocular | |
|---|---|---|---|---|
| | OCCI | CCI | OCCI | CCI |
| Total HOA | | | | |
| preoperative | 0.140 ± 0.018 | 0.092 ± 0.014 | 0.286 ± 0.023 | 0.232 ± 0.042 |
| postoperative | 0.176±0.018* | 0.127 ± 0.016* | 0.167 ± 0.018* | 0.128 ± 0.020* |
| P | 0.001 | 0.001 | 0.001 | 0.001 |
| Coma | | | | |
| preoperative | 0.065 ± 0.011 | 0.052 ± 0.011 | 0.124 ± 0.021 | 0.140 ± 0.032 |
| postoperative | 0.063±0.012* | 0.050 ± 0.010 | 0.065 ± 0.010* | 0.071 ± 0.012* |
| P | 0.001 | 0.182 | 0.001 | 0.001 |
| Spherical Aberration | | | | |
| preoperative | 0.023 ± 0.008 | 0.027 ± 0.006 | 0.049 ± 0.012 | 0.062 ± 0.014 |
| postoperative | 0.024 ± 0.007 | 0.031 ± 0.006* | 0.028 ± 0.006* | 0.038 ± 0.006* |
| P | 0.226 | 0.001 | 0.001 | 0.001 |
| Secondary Astigmatism | | | | |
| preoperative | 0.023 ± 0.007 | 0.022 ± 0.005 | 0.029 ± 0.008 | 0.032 ± 0.006 |
| postoperative | 0.023 ± 0.006 | 0.025 ± 0.005* | 0.023 ± 0.005* | 0.028 ± 0.011* |
| P | 0.797 | 0.001 | 0.001 | 0.001 |
| Trefoil | | | | |
| preoperative | 0.038 ± 0.008 | 0.041 ± 0.009 | 0.070 ± 0.011 | 0.618 ± 0.009 |
| postoperative | 0.065±0.010* | 0.059 ± 0.010* | 0.058 ± 0.010* | 0.056 ± 0.010* |
| P | 0.001 | 0.001 | 0.001 | 0.001 |

HOA: total higher-order aberrations; CCI: clear corneal incision; OCCI: opposite clear corneal incision

∗Values are statistically significant compared with preoperative examinations (P < 0.05).

**Table 4 .** Mean preoperative and 3-month postoperative VF-14 score in two groups.

| | Preoperative | Postoperative | P |
|---|---|---|---|
| CCI group | 65.12 ± 1.78 | 88.87 ± 2.13 | <0.001* |
| OCCI group | 67.23 ± 3.14 | 86.47 ± 4.25 | <0.001* |

CCI: clear corneal incision; OCCI: opposite clear corneal incision

# Figures

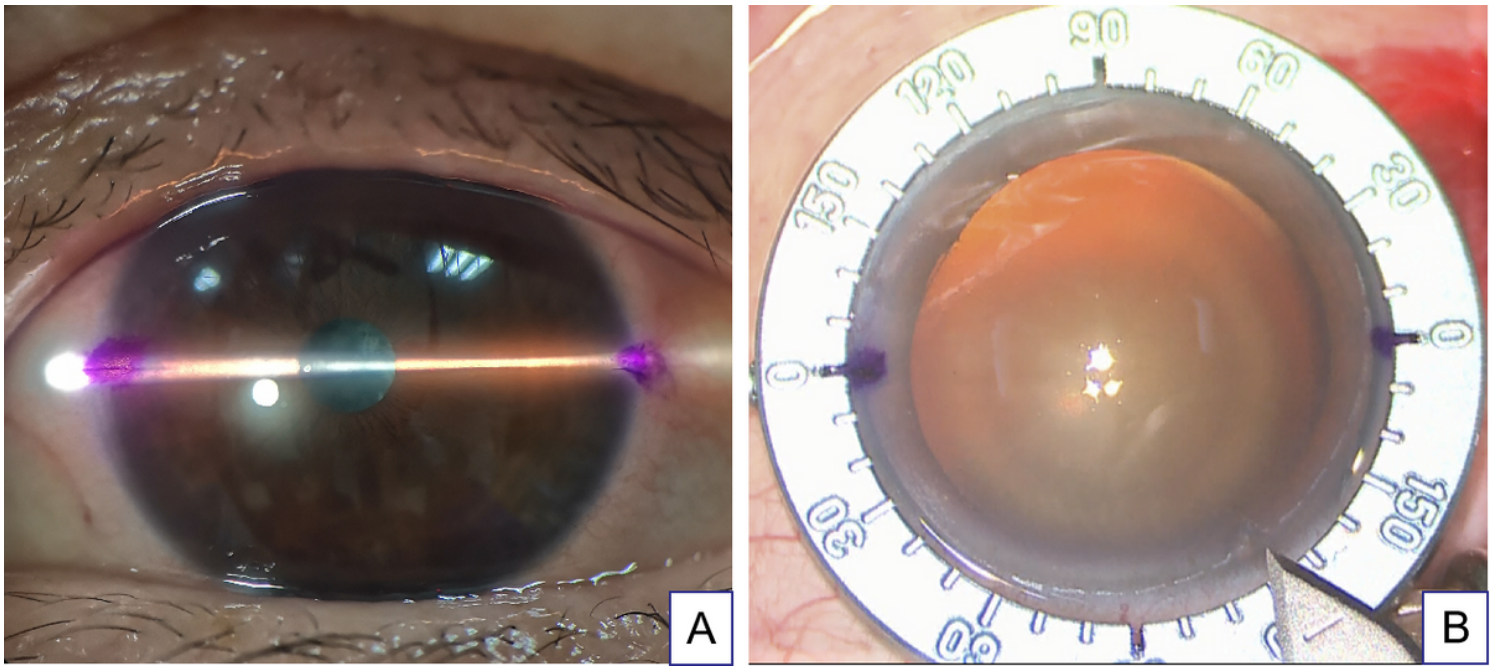


**Figure 1**

CCI was made at a planned meridian.

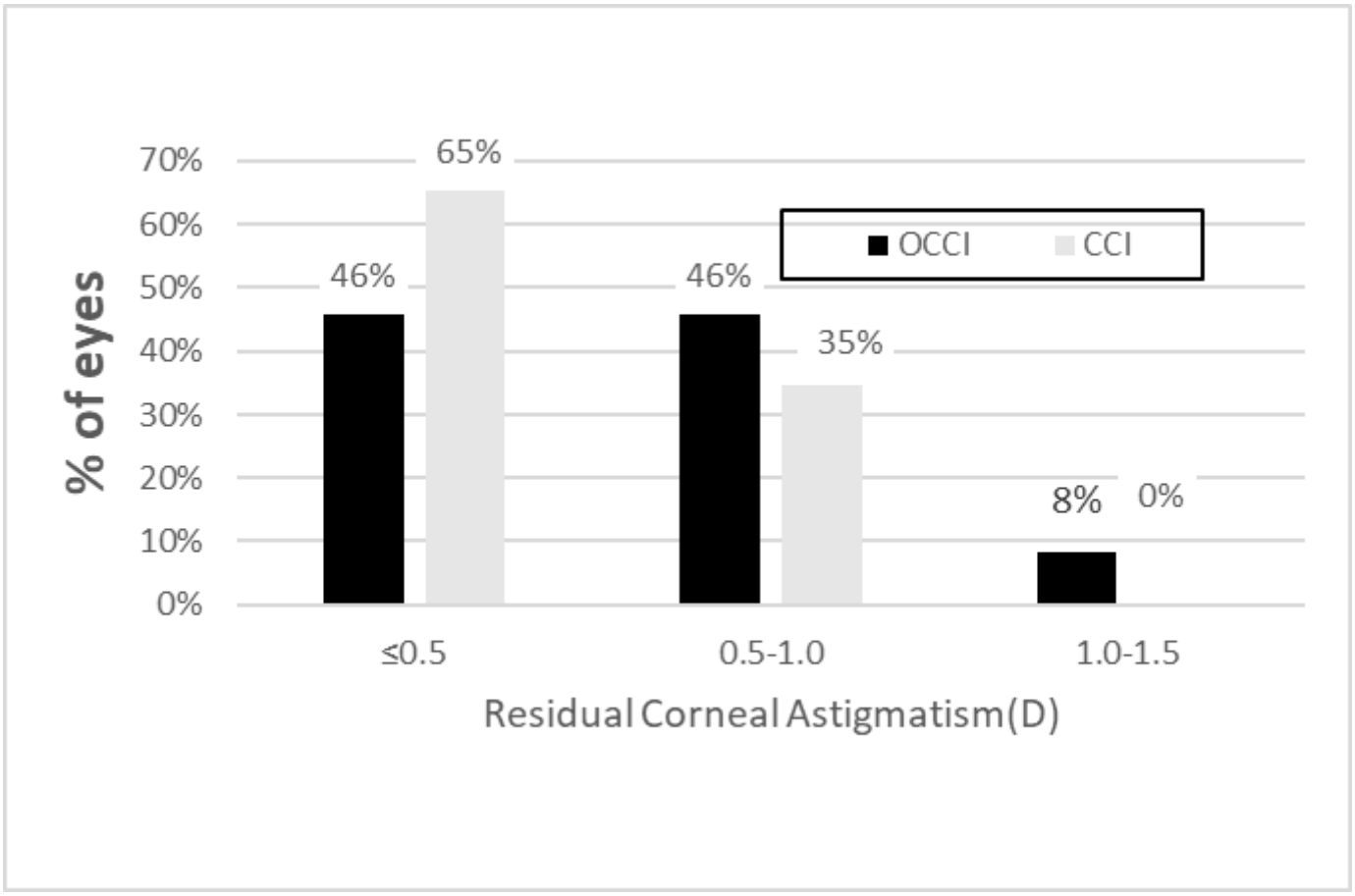


**Figure 2**

Residual Corneal Astigmatism 12 weeks post-surgery.

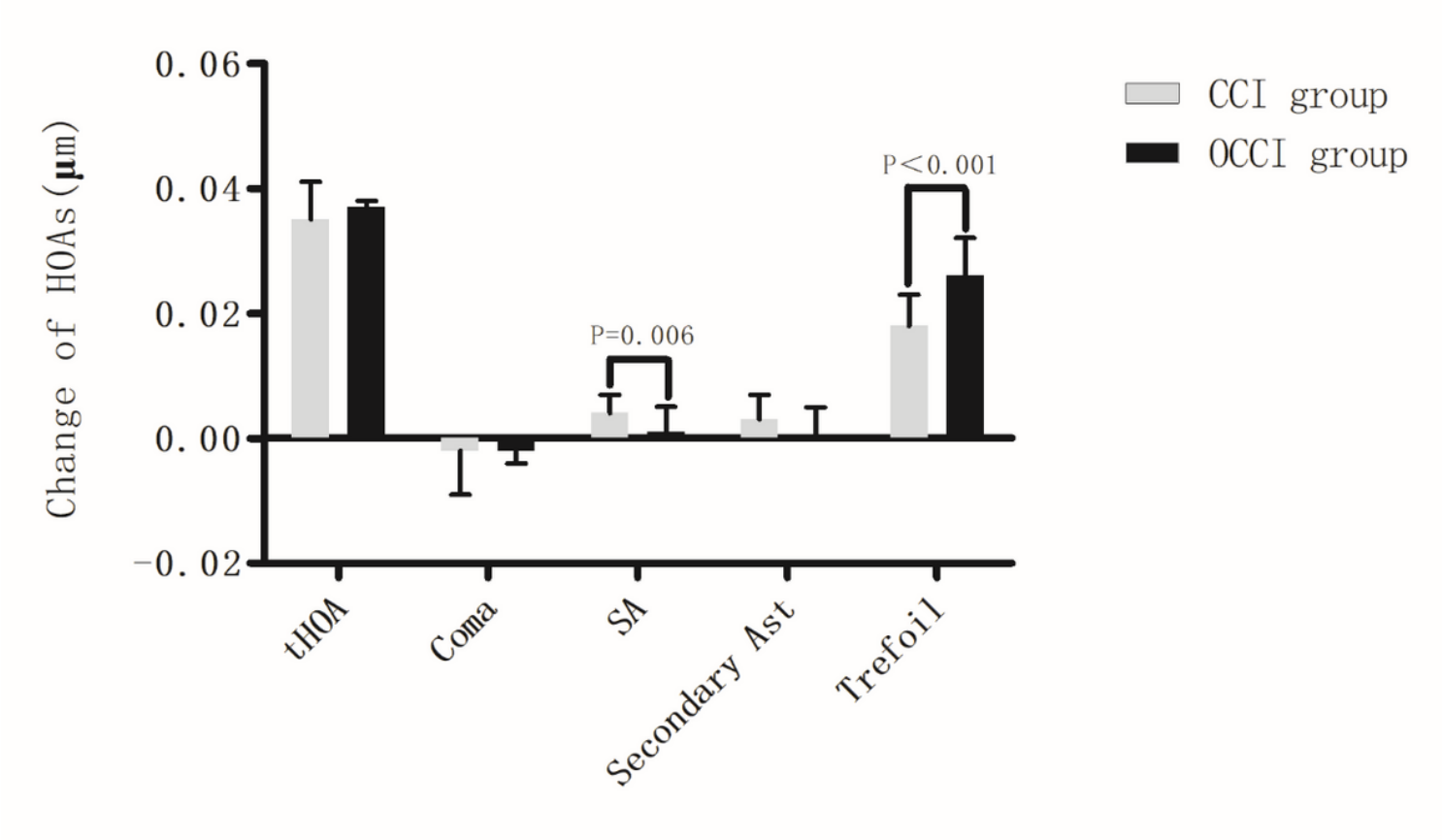


**Figure 3**

Mean change in corneal aberration in the CCI and OCCI groups.