Original Article

Corneal astigmatism change and wavefront aberration evaluation after cataract surgery: "Single" versus "paired opposite" clear corneal incisions

Hasan Razmjoo, Nima Koosha, Mohammad Hadi Vaezi, Behrooz Rahimi, Alireza Peyman

Department of Ophthalmology, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Background: Correcting the pre-existing astigmatism is an optimal goal in cataract surgery. The aim of this study is to compare the astigmatic correcting effect of a single regular 3.2 mm clear corneal incision (CCI) with paired opposite CCI in cataract patients and effect of these incisions on optical aberrations using the wavefront quantitative analysis.

Materials and Methods: This was a randomized controlled trial study undertaken in an ophthalmology referral center on 50 patients planned for cataract surgery who were randomized to either single 3.2 mm CCI or paired opposite CCI group. Post-operative evaluation was performed at 12 weeks and included refraction, keratometery, corneal topography and wavefront analysis. Corneal astigmatism and post-operative values were compared in two groups.

Results: The mean pre-operative corneal astigmatism was 2.58 ± 1.03 D in the single incision group and 2.70 ± 0.94 D in the paired opposite incisions group. After 12 weeks of surgery, the corneal astigmatism was reached to 2.15 ± 0.82 D in single incision group and 1.63 ± 1.21 in the paired opposite incisions group. There was a statistically significant difference in two arms of treatment regarding to surgically induced astigmatism after 3 months. The mean post-operative total and higher order aberrations and values were not significantly different in two groups.

Conclusion: The results of our study showed that paired opposite incisions is an effective procedure for reducing pre-existing corneal astigmatism in cataract surgery. Paired incisions did not show any beneficial effect regarding wavefront aberrations compared with conventional single incision method.

Key Words: Astigmatism, cataract, opposite clear corneal incision, optical aberrations, single clear corneal incision

Address for correspondence:
Prof. Alireza Peyman, Feiz Hospital, Qods sq., Isfahan, Iran.
E-mail: peyman@med.mui.ac.ir

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INTRODUCTION

Cataract surgery is one of the most common and successful surgical procedures in the world.[1] The presence of pre-existing astigmatism (PEA) reduces visual acuity and affects the quality of vision after surgery.[2] Hence, correcting PEA is a main objective of modern small-incision cataract surgery.[3]

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Clear-corneal small incision is the favorite approach for many cataract surgeons in phacoemulsification, which allows for rapid visual rehabilitation after the surgery,[4-5] and can modify corneal astigmatism by altering corneal shape.[6] It has been reported that size, shape and location of clear corneal incision (CCI) can affect corneal astigmatism.[7]

Corneal incisions cause a flattening of the incised meridian and the surgeon may wish to make the incision in steepest median in order to reduce PEA.[2,8] A second CCI opposite (180°) to the first incision-paired opposite CCI - is reported to increase the flattening effect of CCI and provide an enhanced effect for correcting pre-existing corneal astigmatism in cataract surgery[7] [Figure 1].

On the other hand, corneal incisions change corneal shape and may induce optical aberrations.[9]

After cataract surgery, the optical quality of the cornea is crucial for good visual outcome[10] and distorted optical quality of the cornea after surgery would limit the visual performance of the eye.[11] Thus, reduction in astigmatism is not enough as cataract surgery modifies corneal shape and a major concern is to know the possible changes in the corneal optics induced by cataract surgery.

At present, one of the most widely used technique for evaluating corneal optical quality is corneal topography.[11] Another technique, wavefront analysis, allows quantitative characterization of localized changes in the corneal shape with Zernike polynomial.[12,13]

Because of the importance of optical aberrations on quality of vision and high accuracy of wavefront analysis in quantitative measurement of these aberrations, assessing the influence of surgical incisions on optical aberration by this quantitative technique is demanding.

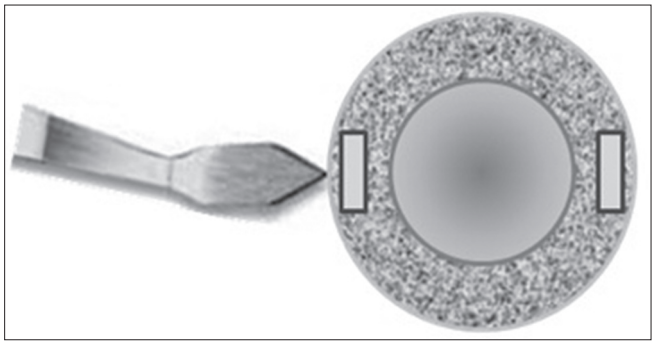

Figure 1: Opposite clear corneal incisions placed at the 3 o'clock and 9 o'clock positions for against the rule astigmatism

The aim of this study was to compare the astigmatic correcting effect of single CCI with paired opposite CCI_s in cataract patients and effect of these incisions on corneal aberrations using the wavefront quantitative analysis.

MATERIALS AND METHODS

This was a randomized controlled trial study. The target population was patients with a cataract of grade 2+ to 4+ (lens opacities classification system III,[14]) planned for cataract surgery and consented to participate in this study. Eligibility criteria included good general health, no other corneal pathology such as corneal scar, pterygium or keratoconus and corneal keratometeric astigmatism greater than 1.5 diopters. Patients with any ocular diseases, such as corneal opacities or irregularity, dry eye, amblyopia, anisometropia, glaucoma and retinal abnormalities were not included. Cataracts other than nuclear or corticonuclear, any complication during or after surgery, suturing the site of incision at the end of surgery and loss of follow-up were excluded from the study.

The target sample sizes were calculated with a 5% significance level and an 80% power in a pilot study before recruiting patients.

Participants were randomly assigned into two groups, single CCI or paired opposite CCI_s. Clinical examination data recorded in the pre-operative evaluation, performed within 5 days before surgery, included: Refraction, applanation tonometry, slit lamp examination, dilated fundoscopy, keratometry, biometery (intraocular lens [IOL] Master, Carl Zeiss Jena, Germany) and IOL calculation.

The horizontal axis marked on the limbus before surgery with the patient in an upright position.

All surgery was performed by the same surgeon on an inpatient basis. The steep meridian marked using Mendez Axis Marker. After topical anesthesia and strict aseptic precautions, a self-sealing 3.2 mm CCI was made on steep meridian 1 mm anterior to limbus. After viscoelastic injection, a similar incision was made opposite (180°) to the first incision on the steep axis in paired opposite CCI_s group (25 eyes) [Figure 1]. One incision was used for phacoemulsification and the other was left unused. After 6 mm circular curvilinear capsulorrhexis, routine phacoemulsification was performed and a same foldable aspheric acrylic IOL was inserted in the capsular bag. Irrigation and aspiration of the viscoelastic was performed. Merely the phacoemulsification incision was hydrated at the end of surgery. Routine post-operative examinations were performed at 1, 3 and 7 days.

Post-operative evaluation was performed at 12 weeks and included best corrected distance visual acuity (BCDVA) by Snellen chart, refraction, keratometry, corneal topography (Orbscan II, Bausch and Lomb) and wavefront analysis (Zywave version. 3.21 Bausch and Lomb).

Statistical analysis

All descriptive statistics are presented as means and standard deviations for quantitative variables and as relative frequencies and percentages for categorical variables. *t*-test and Mann-Witney (for non-parametric variables) were used to compare the pre-operative and post-operative mean corneal Zernike aberrations in the two groups. The level of significance was set at $P < 0.05$ and all tests were two-tailed. The analysis of data was performed by the predictive analytic software (SPSS version 20) for windows.

Ethics

The design of this study was approved in Ethics committee of Vice Chancellor for Research, Isfahan University of Medical Sciences (project no. 391296). All participants received trial information and provided written informed consent. Furthermore, the confidentiality of all information was managed carefully by researchers.

RESULTS

In all, 50 eyes (25 patients in the single CCI group and 25 patients in the paired opposite CCI_s group) completed the study and were evaluated for the outcomes. There were 27 female (54%) and 23 male (46%) patients. The mean age of all participants was 65.9 (SD = 10.17) with a range of 29-78 years. The baseline characteristics of patients were balanced across treatment arms, indicating the success of randomization.

The mean pre-operative corneal astigmatism was 2.58 ± 1.03 D in the single CCI group and 2.70 ± 0.94 D in the paired opposite CCI_s group. After 12 weeks of surgery, the corneal astigmatism was reached to 2.15 ± 0.82 D in single CCI group and 1.63 ± 1.21 in the paired opposite CCI_s group. The mean change in amount of corneal astigmatism was 0.43 ± 0.21 D and 1.07 ± 0.27 D in single CCI and paired opposite CCI_s groups, respectively ($P < 0.001$) Table 1. Using *t*-test analysis, there was no statistically significant difference between two groups regarding to pre-operative corneal astigmatism ($P > 0.05$). The final BCDVA was similar between the groups.

Analysis of vectors of astigmatic change using Alpins's method,[15] revealed a mean surgically induced astigmatism (SIA) of 1.01 ± 1.02 D in the single CCI and 1.59 ± 0.70 D in the paired opposite CCI_s group. After 12 weeks, there was a statistically significant difference in two arms of treatment regarding to SIA, astigmatism correction index and index of success ($P < 0.05$) [Table 2].

The mean post-operative total optical higher order aberrations (HOA_s) values were 1.51 ± 0.62 µm for single CCI group and 1.53 ± 0.98 µm for paired opposite CCI_s group. The difference between groups was not significant ($P = 0.927$).

Analyses of some individual Zernike terms such as horizontal and vertical coma aberrations and horizontal and vertical trefoil showed no significant difference between groups [Table 3].

Table 1: Corneal astigmatism before and 12-weeks after surgery

Follow-up period	Group	Mean astigmatism (D)	Standard deviation
Pre-operative	Single clear corneal incision	2.58	1.03
	Paired opposite clear corneal incisions	2.70	0.94
12 weeks post-operative	Single clear corneal incision	2.15	0.82
	Paired opposite clear corneal incisions	1.63	1.21

Table 2: Surgically induced astigmatism 12-weeks after surgery

Astigmatism Indices	Single CCI group mean (SD)	Paired opposite CCI_s group mean (SD)	*P* value
Surgically induced astigmatism	1.01 (1.02)	1.59 (0.70)	0.024
Astigmatic correction index	0.39 (0.30)	0.63 (0.25)	0.005
Keratometric index of success of astigmatism surgery	0.84 (0.14)	0.56 (0.36)	0.001
Keratometric magnitude of error	−1.57 (1.07)	−1.11 (0.93)	0.117
Keratometric arithmetic angle of error	−8.79 (30.61)	4.30 (22.08)	0.089
Keratometric torque effect	−0.10 (0.99)	0.02 (0.77)	0.642

CCI: Clear corneal incision

Table 3: Wavefront error values (µm) of corneal higher order aberrations

Cataract surgery	HOA	Vertical trefoil	Horizontal trefoil	Vertical coma	Horizontal coma
Single clear corneal incision	1.51±0.62	0.12±0.18	−0.06±0.52	−0.02±0.33	−0.02±0.26
Paired opposite clear corneal incisions	1.54±0.98	0.08±0.28	0.13±0.51	−0.06±0.31	0.06±0.27
P value	0.927	0.566	0.201	0.541	0.274

HOA: Higher order aberrations denotes total higher order aberrations excluding lower order aberrations such as sphere and cylinder

All surgeries were otherwise uneventful and there were no cases of endophthalmitis.

DISCUSSION

We measured corneal topography and wavefront aberrations post-operatively in 25 eyes having single CCI and 25 eyes having paired opposite CCI_s to evaluate the effects of these incisions on astigmatism and optical aberrations post-operatively.

Our study showed that paired opposite CCI_s can enhance the effects of single CCI and modulate PEA in cataract surgery. The astigmatic change was 1.07 D in patients with paired opposite CCI_s, which was significantly different from pre-operative one. The results of our study suggest that the paired opposite CCI_s technique may correct PEA to a greater extent than a single CCI. This is in line with previous research. Ben Simon and Desatnik with the same paired opposite CCI_s technique achieved a mean astigmatic correction of 1.3 D.[2] In other studies, the mean reduction in corneal astigmatism ranged from 0.50 D to 2.06 D.[7,16,17] This difference may be rooted in difficulty in placing the surgery exactly in the correct meridian. As previously shown, even a small degree of deviation may greatly reduce the astigmatism-neutralizing effect.[18] In this study, we used the vector analysis for evaluating astigmatism change.

The mean SIA was 1.59 D in our paired opposite CCI_s group, which is similar to what reported by Khokhar *et al*. (SIA = 1.61 D),[19] and Ben Simon and Desatnik.[2] However, a mean SIA of 2.25 D was reported by Lever and Dahan,[7] 1.75 D by Tadros *et al*.[17] and 2.10 D by Qammar and Mullaney.[16] This difference may be due to different amounts of pre-existing astigmatism in these studies.[19]

This study used wavefront aberrometers to measure the various optical elements of the eye. No statistically significant difference was found between single CCI and paired opposite CCI_s with respect to generating total HOA_s. Furthermore, there was no significant difference in individual HOA_s such as coma and trefoil. This indicated that these two types of surgery are not significantly different regarding to the amount of optical HOA_s, 12 weeks after surgery.

Paired opposite CCI_s was first described by Lever and Dahan in 2000.[7] Until now, several studies indicated the positive advantages of paired opposite CCI_s; Ben Simon and Desatnik compared the effects of paired opposite CCIs and a single CCI in correcting PEA. They found that paired opposite CCI_s has an enhanced effect in correcting astigmatism compared with a single CCI when using keratometric findings.[2] Paired opposite CCIs is a relatively simple technique requiring no extra surgical equipment.[16] Our study showed that this method is a safe and effective procedure in reducing pre-existing corneal astigmatism in cataract surgery with the same amount HOA_s such as coma and trefoil.

Although endophthalmitis and early wound-related complications are inherent disadvantages of CCI,[20,21] no cases of endophthalmitis were seen in our study. This is in line with the results of Miller *et al*. that reported a low prevalence of endophthalmitis after temporal clear cornea incision phacoemulsification (0.05%).[22]

Our study while having much strength included some limitations that should be considered. In our study, we did not analyze effects of the surgically induced change in optical aberrations on image quality using an image plane metric, such as the point-spread function or Modulation Transfer Function (MTF). Furthermore, the small sample size inhibits more subgroup analysis. More research to assess the long-term outcomes and a larger sample is warranted.

Despite these limitations, the current study appears to be unique in that it used a standardized measure,[11-13] to quantitatively evaluate the optical wavefront aberrations of paired opposite CCI_s in addition to its astigmatic correction, in comparison with single CCI and provides further evidence for the applications of paired opposite CCI_s in cataract surgery.

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