Corneal Higher-Order Aberrations after Phacoemusification

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Abstract: Background: Cataract surgery has gained worldwide acceptance as a vision-correction operation. Cataract surgery has changed from a sight-saving operation to a refractive procedure. However, cataract surgery is currently associated with the degradation of visual quality with the appearance of artifacts such as halos, glare, and starbursts. The reduction in visual quality is mainly attributed to the development of higher-order aberrations (HOAs) induced by cataract surgery. **Aim of the Work:** To evaluate the corneal higher order aberration one week before and 3 months after phacoemulsification surgery using 3.2mm keratome with clear corneal incisions. **Patient & Methods:** A total of 50 eyes from 50 patients (23 right eyes and 27 left Eyes) were analyzed in this prospective study. **Results:** According to Astigmatism: there is significant difference between pre and post according to astigmatism which it is decreased postoperative. According to coma: there is no significant difference between pre and post according to coma. According to trifoil: significant difference between pre and post according to Trifoil I which it is increased postoperative. According to Spherical aberration: there is significant difference between pre and post according to spherical aberration which it is decreased postoperative. **Conclusions:** Cataract operation should be preceded by Pentacam to evaluate astigmatism, coma, trefoil & spherical aberrations to consider them during surgery.

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Key words: corneal higher order aberrations, phacoemulsification, coma, trifoil, spherical aberration & astigmatism.

1. Introduction

In the past, the goal of cataract surgery was more purely medical and restorative. The surgery was performed when it was medically necessary to remove a cloudy lens in order to restore a person's ability to see (usually with the aid of eyeglasses or contact lenses after surgery).1 An increasingly important goal of modern cataract and implant surgery is to obtain the most desirable refractive outcomes for the patients and to decrease their dependence on spectacle corrections. Pre-existing corneal astigmatism is a significant component of preoperative ametropia. To achieve satisfactory postoperative refractive results, it is important to correct pre-existing spherical errors by accurate biometry and intraocular lens (IOL) power calculation, and to manage preoperative corneal cylinder errors by a suitable method based on preoperative corneal topography that enables cataract surgeons to achieve excellent unaided visual acuity in the absence of vision-limiting ocular co morbidities. Since HOAs can impact visual performance and contrast sensitivity, they are considered important indices in the field of quality of vision and deserve attention. In addition, today, attention to HOAs after laser refractive surgery has become one of the important issues in the assessment of the quality of laser refractive methods. Implantation of intraocular lenses has caused many studies to demonstrate changes in HOAs after surgery. There has been more attention to HOAs among cataract patients and myopes compared to other ocular conditions. The decision to correct HOAs or not is a challenging one for which no definite answer has been found.**2**

2. Patient and Methods

A total of 50 eyes from 50 patients (23 right eyes and 27 left eyes) were analyzed in this prospective study.

Inclusion Criteria:

Patients with moderate cataracts (nuclear opalescence 3, cortical cataract 2, posterior subscapular 1, or more severe cataracts according to the Lens Opacity Classification System III.3 Significant reduction in visual quality were included.

The exclusion criteria:

With ophthalmic problems (a preoperative corneal disorder, concurrent pterygium, ocular surface or eyelid problems, or ocular inflammatory conditions), previous surgery on the eye involved in the study, and systemic problems (connective tissue disorders). The patients who had bilateral cataract surgery, only Cases that had absent topographic or HOA data or poor quality in the acquired scan image were also excluded.

Surgical Technique:

All surgery was performed by experienced surgeons Using (Megatron S4 device). Main incision was made at the steepest meridian of each patient using 3.2 m, a 2 temporal incisions were made at 3 & 9 clock.

After peribulbar anesthesia & sterilization done, a main 3.2-mm clear corneal incision was made using a trapezoidal diamond blade followed by a paracentesis incision of 1 mm using a paracentesis knife. Once capsulorrhexis was performed, hydrodissection, chopping, nuclear rotation, and phacoemulsification were carried out. The cortex was then aspirated and the intraocular lens was injected into the capsular bag. After the viscoelastic were removed, the incisions were hydrated with a balanced salt solution.

Measurement of Corneal HOAs:

All patients had a full ophthalmologic examination preoperatively, including visual acuity, tonometry, refraction, slitlamp evaluation, topography (fundoscopy. Corneal HOAs were measured using the CSO Siruspentacam with Scheimpflug technology). The instrument determined the corneal surface aberrations calculated from the Placido disk capture, and Zernike coefficient values were obtained. With the patient's cooperation and a stable tear film, HOAs were measured several times and 1 reading was selected for use in the study.

Each Zernike term was reported as a corresponding Zernike coefficient with its sign. Approximately 3 month after surgery, corneal HOAs were measured using the Zernike coefficient values and compared with the preoperative data.

Statistical analysis:

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done:

- Paired sample t-test of significance was used when comparing between related sample.
- The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following:
- Probability (P-value).
  - P-value ≤0.05 was considered significant.
  - P-value ≤0. 01 was considered as highly significant.
  - P-value >0.05 was considered insignificant.

3. Results:

Table (1): Comparison between pre and post according to K.

K reading	Pre (N=50)	Post (N=50)	Paired Sample t-test		
			Mean Diff.	t	p-value
K1 Mean±SD Range	 42.32±2.12 38.55-46.19	 42.37±2.10 38.39-45.55	-0.05±0.68	-0.558	0.579
K2 Mean±SD Range	 44.04±2.50 40.57-49.07	 44.20±2.35 40.68-49.61	-0.17±0.81	-1.452	0.153

t- Paired Sample t-test; p-value >0.05 NS

This table shows no statistically significant difference between pre and post according to K reading.

Table (2): Comparison between pre and post according to astigmatism.

Astigmatism	Pre (N=50)	Post (N=50)	Paired Sample t-test		
			Mean Diff.	t	p-value
Astigmatism I Z 22 Mean±SD Range	 1.23±1.08 0.28-5.48	 0.86±0.49 0.18-1.69	0.37±1.21	2.154	0.036*
Astigmatism II Z42 Mean±SD Range	 0.11±0.18 0.01-0.71	 0.17±0.25 0-0.92	-0.06±0.26	-1.586	0.119
Astigmatism III Z 62 Mean±SD Range	 0.05±0.07 0.01-0.27	 0.08±0.16 0-0.6	-0.03±0.17	-1.253	0.216

t- Paired Sample t-test; p-value >0.05 NS; *p-value <0.05 S

This table shows statistically significant difference between pre and post according to astigmatism I.

Regarding the study, the average age at the time of the operation of patients undergoing phacoemulsification is [59.74±5.10] ranged from 50 to 68 years there was a higher percent of male patients (33 patients) with cataract (66%) as regards to female (17patients) percent (34 %). The mean preoperative K1 reading is [42.32±2.12] SD and 3 month postoperatively was [42.37±2.10] SD (range of 46.19–45.55). The mean preoperative K2 reading is [44.04±2.50] SD and 3 month postoperatively was [44.20±2.35] SD (range of 49.07–49.61). There was no statistically significant difference between pre and post according to K reading. (P<0.001). (Table 1)

The mean preoperative Astigmatism1 reading is [1.23±1.08] SD and 3 month postoperatively was [0.86±0.49] SD [range of (0.28-5.48)–(0.18-1.69)]. There was shows statistically significant difference between pre and post according to astigmatism. (Table 2).

The mean preoperative Coma reading is [0.24±0.17] SD and 3 month postoperatively was [0.28±0.13] SD [range of (0.03-0.67)–(0.04-1.31)]. There was shows no statistically significant difference between pre and post according to coma 1. (Table 3)

Table (3): Comparison between pre and post according to Coma.

Coma	Pre (N=50)	Post (N=50)	Paired Sample t-test		
			Mean Diff.	t	p-value
Coma I Ƶ 31 Mean±SD Range	 0.24±0.17 0.03-0.67	 0.28±0.13 0.04-1.31	-0.04±0.37	-0.863	0.392
Coma II Ƶ 51 Mean±SD Range	 0.06±0.06 0-0.16	 0.06±0.04 0.01-0.16	0.00±0.06	0.360	0.720
Coma III Ƶ 71 Mean±SD Range	 0.05±0.07 0-0.29	 0.09±0.12 0-0.4	-0.03±0.11	-2.213	0.032*

t- Paired Sample t-test; p-value >0.05 NS; *p-value <0.05 S

This table shows statistically significant difference between pre and post according to Coma III.

The mean preoperative Trifoil1 reading is [0.23±0.16] SD and 3 month postoperatively was [0.42±0.66] SD [range of (0.03-0.63)–(0.02-2.56)]. There was shows statistically significant difference between pre and post according to trifoil 1. (Table4)

Table (4): Comparison between pre and post according to trifoil.

Trifoil	Pre (N=50)	Post (N=50)	Paired Sample t-test		
			Mean Diff.	t	p-value
Trifoil I Ƶ 33 Mean±SD Range	 0.23±0.16 0.03-0.63	 0.42±0.66 0.02-2.56	-0.20±0.53	-2.648	0.011*
Trifoil II Ƶ 53 Mean±SD Range	 0.08±0.09 0-0.29	 0.10±0.10 0.01-0.35	-0.02±0.10	-1.447	0.154
Trifoil III Ƶ 73 Mean±SD Range	 0.28±0.81 0-3	 0.09±0.18 0-0.7	0.19±0.85	1.571	0.123

t- Paired Sample t-test; p-value >0.05 NS; *p-value <0.05 S

This table shows statistically significant difference between pre and post according to Trifoil I.

The mean preoperative spherical aberration 1 reading is [-0.10±0.08] SD and 3 month postoperatively was [-0.03±0.18] SD [range of (-0.18_0.14) –(-0.19_0.47)]. There was shows statistically significant difference between pre and post according to spherical aberration 1. (Table5)

Table (5): Comparison between pre and post according to spherical.

Spherical Aberration	Pre (N=50)	Post (N=50)	Paired Sample t-test		
			Mean Diff.	t	p-value
Spherical I Z 42 Mean±SD Range	 -0.10±0.08 -0.18_0.14	 -0.03±0.18 -0.19_0.47	-0.07±0.16	-3.225	0.002*
Spherical II Z 60 Mean±SD Range	 0.00±0.09 -0.1_0.24	 -0.03±0.05 -0.15_0.03	0.03±0.12	1.665	0.102

t- Paired Sample t-test; p-value >0.05 NS; *p-value <0.05 S
This table shows statistically significant difference between pre and post according to spherical I.

4. Discussion

Today, cataract surgery is regarded as a refractive surgery, aiming pseudophakic emmetropia, which makes eliminating corneal astigmatism critical. 4 After cataract surgery, some patients can achieve surprisingly good uncorrected distance vision, whereas others complain of visual disturbances, such as glare, halos, and starbursts, which are induced by residual astigmatisms and the HOAs generated by the cornea, intraocular lens, or other intraocular structure.5 Naturally occurring (idiopathic) astigmatism is frequent, with up to 95% of eyes having detectable astigmatism. 6

It is estimated that approximately 70% of the general cataract population has at least 1.00 diopter (D) of astigmatism, and approximately 33% of patients undergoing cataract surgery are eligible for treatment of preexisting astigmatism.7

The effects of residual corneal astigmatisms have been discussed extensively.8 And.**9**found that the location of the incision was the most significant factor affecting astigmatisms induced by surgery. However, little is known about the changes in corneal HOAs after cataract surgery. Because about 80% of human eye aberrations occur on the corneal surface.10 It is reasonable to focus on this structure.11 found that patients with cataract surgery presented with larger corneal aberrations than those without cataract surgery. Although small-incision cataract surgery was developed to retain corneal optical quality with less iatrogenic corneal damage, changes in HOAs after surgery should not be neglected.12 **Ferrer-Blasco** studied prevalence of corneal astigmatism before cataract surgery and found that; in 13.2% of eyes no corneal astigmatism was present; in 64.4%, corneal astigmatism was between 0.25 and 1.25 diopters (D) and in 22.2%, it was 1.50 D or higher.13

HOAs as well as LOAs are important to consider to achieve the best optical quality.14 Previous studies reported that the change in corneal aberrations following cataract surgery depend on the size. 5 And location.11Of the corneal incision and the type of the IOL.

In our current study, we investigated the change in corneal HOAs according to the incision location at the steepest meridian.

Because HOAs greater than the 6th Zernike polynomial do not make a significant clinical contribution and the 3rd-order trefoil and coma and the 4th-order spherical aberration constitute the major component of HOAs, we compared those parameters.**15**

Corneal incisions made on a steep meridian in the astigmatic cornea induce corneal flattening along that meridian. However, we hypothesized that making incisions on a steep meridian could affect differently the incision axis and its opposite corneal axis 180 degrees away. Although the incision meridian would become flat on both sides, the opposite axis 180 degrees away could become less flat than the incision axis. **Guirao et al.,** found changes in the magnitude and orientation of aberrations, with a mean induced astigmatism at the surgical meridian and **Marcos** found significant changes in vertical astigmatism (2.47 mm and 1.74 mm, respectively).16

Ken Hayashi et al., Postoperatively, ocular and corneal HOAs were greater in eyes with high preexisting corneal astigmatism than in eyes with low preexisting astigmatism, which impaired photopic LCVA and mesopic visual acuity & found that ocular total HOAs and 3rd-order coma-like aberrations were significantly greater after cataract surgery in eyes with high preexisting corneal astigmatism that had toric or nontoric IOL implantation than in eyes with low preexisting corneal astigmatism that had nontoric IOL implantation; the values were similar in eyes with high preexisting astigmatism that had toric or nontoric IOL implantation. In addition, ocular 4th-order sphericallike aberrations did not differ significantly.

In our study, there was decrease in astigmatism value by 0.036 from preoperative to postoperative.16

Bassam Elkady & Yao found that no statistically significant changes were found in any aberration postoperatively and all aberration values except HOA decreased slightly, with no statistically significant differences between the follow-up visits.11 & 17

In our study there is Coma aberration could be a good parameter to confirm this concept. Because corneal coma aberration stands for the refractive difference between both sides of the cornea. In this study, we observed changes in corneal HOAs. The peak changes in HOAs occurred on postoperative day 1 and gradually returned to baseline values 3 months after surgery. Interestingly, there is no significant changes in coma after cataract surgery but there is significant changes in trifoil & spherical abrasions. There is a decrease in corneal astigmatism after phacoemulsification with incision at the steepest meridian.

Conclusion

Cataract operation should be preceded by Pentacam to evaluate astigmatism, coma, trefoil & spherical aberrations to consider them during surgery.

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