Ocular higher-order aberrations in patients with various refractive errors

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Abstract

Introduction:. Higher-order aberrations (HOAs) are small optical irregularities or imperfections of the eye which cannot be corrected by simple sphere and cylinder corrections. Many authors believe that HOAs are the reason many patients complain of halo, glare and decreased contrast sensitivity after successful corneal refractive surgery.(Baily et al., 2003)
Many studies in the past showed significant variability of HOAs among the individuals of same population. Popularization of laser corneal refractive surgery and its potential to induce or remove optical aberrations (both low order and higher order aberrations) is the main reason behind better understanding of the nature of aberrations as well as their influence on visual quality. (Bisneto et al., 2007)
Aim of the work: To measure and evaluate the distribution of HOAs among various refractive errors in individuals screened for refractive surgery and compare them .correlation with errors.
Patients and Methods: prospective cross sectional analytical study was conducted at ophathalmology center for refactive surgery ,sohag started in February 2016. two hundred eyes of patients with age ranging from 18-40 years were included in the study**.**
Results: Patients in hypermetropia group had statistically significant higher amount of HOA than other three groups followed by mixed group.No significant correlation of HOAs with amount of refractive error in all the groups except in mixed error group.
Conclusion: In overall comparison we noticed the mean RMS of total HOAs were significantly higher in hypermetropia group and there was a statistically significant correlation between SE of Mixed group and RMS of Total HOAs.

Introduction

Higher-order aberrations (HOAs) are small optical irregularities or imperfections of the eye which cannot be corrected by simple sphere and cylinder corrections. Many authors believe that HOAs are the reason many patients complain of halo, glare and decreased contrast sensitivity after successful corneal refractive surgery**.(Baily et al., 2003)**

Many studies in the past showed significant variability of HOAs among the individuals of same population. Popularization of laser corneal refractive surgery and its potential to induce or remove optical aberrations (both low order and higher order aberrations) is the main reason behind better understanding of the nature of aberrations as well as their influence on visual quality. **(Bisneto et al., 2007)**

New diagnostic technologies enable the detection and correction of ocular aberrations beyond defocus and astigmatis. **(Liang et al., 1997)**. by applying the root mean square (RMS) of Zernike coefficient polynomials**.(Llorente et al., 2004)**

Zernike polynomials are divided into several orders, low-order aberrations (first and second order), and high order aberrartions (third order onwards). Important higher order aberrations include coma, trefoil and spherical aberrations and they are measured by root mean square (RMS) value which represents the ocular aberrations in micrometers. Values of measured ocular aberrations in the Zernike polynomials are dependent on pupil diameter at the time of examination**.(Lim et al., 2009)**

Pupil diameter is an important factor to consider especially for those patients who are candidates for refractive surgery. The pupil size can affect the results of refractive surgeries due to its role in post operative visual symptoms such as glare and halo. The larger pupil size may also produce greater HOAs**.(de Castro et al.,2007).** HOAs and their relation to amount and type of refractive errors has been studied in a number of studies but the result are controversial. Some studies have shown no statistically significant correlation between HOAs and amount or type of refractive error**.(Porter et al.,2001)**. while others concluded a strong correlation of HOAs with myopia **.(Paquin et al., 2002)** Spherical aberrations were found significantly correlated with myopia by some authors **(Collins et al.,1995)**. while others confined their relation to high myopia only**.(Carkeet et al., 2002)** and Still others could not found any statistically significant correlation**.(Paquin rt al., 2002)** The rationale of conducting this thesis is to collect a local database HOAs among of various refractive errors in patients investigated for refractive surgery. The comparison of HAOs (in micrometers) with the amount and type of refractive error (in diopters) will help in management of these patients .

Aim of the work:

1. To measure and evaluate the distribution of HOAs among various refractive errors in individuals screened for refractive surgery and compare them .
2. To determine any correlation between the degree of refractive error (myopia,hypermetropia and astigmatism) and HOAs.

Patients and Methods:

Design:. prospective cross sectional analytical study

Patients:

This prospective cross sectional analytical study was conducted at ophathalmology center for refactive surgery ,sohag started in February 2016. two hundred eyes of patients with age ranging from 18-40 years were included in the study**.**

Methods:

- Subjects were selected from patients referred for refractive surgery to eye center from February 2016 to November 2016 who participated in a cross sectional study.
- Two hundred eyes of patients with age ranging from 18-40 years were included in the study.
- Sample size was calculated on the basis of WHO calculator and appeared to be 200 eyes. So a total of 200 eyes of 126 subjects were included in the study by non-probability (consecutive) sampling technique and two eyes of the same patient were considered independently.
- Most of the patients were evaluated to undergo refractive surgery.
- Slitlamp examination for all patients will be done to rule out conditions like dry eye , corneal diseases, cataract, corneal scar or other media opacities and surgery or trauma which could alter wavefront measurements.
- Assesment of refraction and calculation of Spherical equivalent (SE) of refractive error.
- All patints were examined for uncorrected visual acuity (UCVA) and best corrected distant visual acuity.
- In order to generate more accurate and reliable results, patients were instructed to stop using contact lenses for at least two weeks prior to aberrometry.

-HOAs will be measured using iDesign wavescan system developed by Abbott .All wavefront

measurements will be repeated 3 times for each eye. The best image will be included in the study based on the image quality. Analysis will be based on mesopic pipil size of 5 mm.

- If the wavefront refraction of the patient was consistent with the subjective refraction (differences between spherical diopter : 0.75D, cylindrical diopter : 0.5D and astigmatic axis: 15°)

-(RMS) of total HOAs,coma,spherical aberrations and trephoil will be calculated from Zernike coefficients .

- Patients are divided into 5 group on the basis of refractive error

1- low to moderate myopia (60 eyes)
2- high myopia (30 eyes)
3- Myopic Astigmatism (60 eyes)
4- Mixed (30 eyes)
5- Hypermetropia (20 eyes)

Inclusion criteria:

. Age : 18 : 40 years old
. Refraction : ± 0.5 D or more

Exclusion criteria:

1- Patients who had history of surgery and / or eye disease .
2 - Amblyopic patients

Results

A total of 200 eyes of 126 patients were studied. One hundred forty six (73%) were males and and fifty four (27%) were females.

Age of the subjects ranged from 19 to 57 years with mean age of29.1±10.6 years. Mean age of hypermetropes was 34.45±13.29 .while other four groups were 29.03±9.39, 29.2±7.08 , 30.18±9.42, 34.83±9.47 . for low to moderate myopia, high myopia , myopic astigmatism and mixed respectively.(Table1).Refractive error was described in terms of spherical equivalent in order to correlate. (Table1)

RMS of HAOs, RMS of total HAOs, spherical aberrations ,coma and trefoil were calculated in each group and compared among various groups.(Table2)

Refractive error was described in terms of spherical equivalent and used to correlate between refraction and RMS of HOAs,RMS THOA ,coma ,trefoil and spherical.(Table3)

Table(1) Groups of patients

group	(N)	Age	Spherical equivilent
Lowtomoderate myopia	**60**	**29.03±9.39**	**-3.65 (1.69)** **-3.25 (-6.75:-0.87)**
High myopia	**30**	**29.2±7.08**	**-8.69 (1.99)** **-8.00 (-13.75:-5.85)**
Myopic astigmatism	**60**	**30.18±9.42**	**-3.65 (8.88)** **-1.37 (-62 : 1.75)**
mixed	**30**	**34.83±9.47**	**-0.09 (1.85)** **0.5 (-6.75:2.5)**
hypermeteropia	**20**	**34.45±13.29**	**3.43 (1.89)** **3.25 (1-6.87)**
P value		**0.03**	**0.0001**

Table(2) show RMS of HAOs ,RMS of Total HOA, spherical aberrations ,coma and trefoil distribution of studied population

	RMS HAOs	RMSTHOAs	spherical aberrations	coma	trefoil
Group	**Mean±SD Median(range)**	**Mean±SD Median(range**	**Mean±SD Median(range**	**Mean±SD Median(range**	**Mean±SD Median(range**
Lowtomoderate myopia	**0.42±0.17 0.41 (0.11-0.98)**	**2.31±0.86 2.2 (0.78-3.81)**	**0.08±0.07 0.07 (0.006-0.34)**	**0.08±0.08 0.07 (0.002-0.61)**	**0.009±0.04 0.009 (-0.1:0.13)**
High myopia	**0.42±0.21 0.37 (0.04-1.05)**	**3.97±1.80 4.05 (0.42-6.72)**	**0.09±0.04 0.08 (0.02-0.23)**	**0.09±0.04 0.09 (0.02-0.16)**	**0.007±0.04 0.0005 (-0.08:0.07)**
Myopic astigmatism	**0.37±0.16 0.35 (0.11-1)**	**1.80±0.90 1.61 (0.67-5.24)**	**0.08±0.05 0.07 (0.01-0.28)**	**0.09±0.06 0.08 (0.01-0.24)**	**-0.008±0.04 -0.008 (-0.10:0.08)**
mixed	**0.44±0.15 0.41 (0.19-0.9)**	**1.59±0.65 1.62 (0.66-3.03)**	**0.10±0.08 0.08 (0.02-0.29)**	**0.12±0.10 0.098 (0.04-0.58)**	**0.02±0.03 0.03 (-0.06:0.06)**
hypermeteropia	**0.44±0.17 0.41 (0.25-0.68)**	**2.79±1.57 2.71 (0.75-5.46)**	**0.09±0.05 0.08 (0.04-0.21)**	**0.07±0.04 0.08 (0.01-0.11)**	**0.004±0.05 -0.004 (-0.08:0.07)**

Table (3) *Correlation between spherical equivalent and HOAs*

Group	RMS HOA	Coma	Trefoil z33	Spherical	RMS THOA
	Correlation coefficient P-value	Correlation coefficient P-value	Correlation coefficient P-value	Correlation coefficient P-value	Correlation coefficient P-value
Low-Moderate Myopia	-0.06 0.63	-0.07 0.60	-0.06 0.67	-0.03 0.83	-0.83 <0.0001
High Myopia	-0.19 0.32	-0.01 0.94	0.19 0.32	-0.06 0.74	-0.46 0.009
Myopic astigmatism	0.24 0.07	-0.07 0.58	0.14 0.28	0.32 0.01	-0.70 <0.0001
Mixed	-0.47 0.009	-0.08 0.67	0.30 0.11	0.31 0.10	0.35 0.054
Hypermetropia	0.52 0.02	-0.16 0.49	-0.07 0.77	-0.04 0.85	0.37 0.11
All group	0.06 0.43	-0.02 0.78	0.01 0.87	0.08 0.24	-0.45 <0.0001

Discussion

Our study involved 200 eyes of 126 patients where The two eyes of the same patient will be considered independently.

The mean age of our study groups was 29.1years, with a standard deviation of 10.6 years. However, the range of age was very high, from 19 to 57years.With highest Age mean belongs to the miexed group about 34.83±9.47 years followed by hypermetrops group with Age mean about 34.45±13.29 years which has great significance as studies have shown that HOAs increase with age.7-9 .

One hundred forty six (73%) were males and one hundred and fifty four (27%) were females. With majority male in all groups exept in hypermetropes group weher (90%) were females .

Refractive error was described in terms of spherical equivalent in order to correlate.In this study, four parameters were evaluated coma ,trefoil and spherical aberrations ,the wavefront

high order aberrations were studied as root mean square(RMS) value in micrometers.

RMS of total HOA varies a lot between our study groups, Patients in hypermeteropia with higher amount of THOA than other four groups with mean RMS value **0.44±0.17.**

In our study, we found that Patients in hypermetropia group had statistically significant higher amount of HOA than other three groups followed by mixed error group.similar to *(Khan* M et al.,2014)(*Khan MS* et al.,2015) who found that Patients in hypermetropia group had statistically significant higher amount of HOA than other refrative groups.

In contrary (Kirwan C et al.,2006) who reported greater higher order aberrations in myopes compared to hyperopes. However this can be due to significantly higher mean age in hypermetropic and mixed group than myopes and studies have shown that HOAs increase with age In age-matched analysis as in (Porter J et al.,2001) and (Guirao A et al.,2000) .

In our study we found out that there was no significant correlation of HOAs with amount of refractive error in all the groups except in mixed and hypermeteropic groups (P value = 0.02,0.009) respectively.

Similar to **(He J *et al.,2002)*** *who found significant correlation between hypermetropia only and HOA* ,also found out no significant relation of myopic error with HOAs .In contrary **to (Marcos *et al.,2002)*** who reported that RMS of wavefront aberrations in high myopia (>6.0 D) has statistically significant positive correlation with refractive error.

Some authors have concluded HOAs to be more in ametropia than emmetropic eyes like **(He JC, et al.,2002)** while others proposed no relationship or even an opposite relationship between refractive error and HOAs (**Collins MJ et al., 1995),(Carkeet A et al ., 2002)** and **(Wei RH et al ., 2006)**.

Spherical aberrations varies a lot between our study groups, Patients in mixed with higher amount of spherical aberrations than other four groups with mean RMS value **0.02±0.03.**

In our study Patients in mixed error group had statistically significant higher amount of spherical aberrations than other four groups while patient in hypermeteropia group has the lowest value between groups.

with statistically significant correlation between refravtive error and spherical aberrations in myopic astigmatism group only (P value= **0.01**).

in contrary **to (Lorente *et al.,2004*)**and **(Bisneto *et al.,2007)*** *who found that* Patients in hypermetropia group had statistically significant higher amount of spherical aberrations than other refractive groups.Also ***(Khan* M et al.,2014)** found out a statistically significant negative correlation `r` of Hypermetropia with RMS of Total HOAs and Spherical aberration.

coma aberrations varies between our study groups, Patients in mixed error group with higher amount of coma aberrations than other four groups with mean RMS value **0.10±0.08** .

In our study Patients in mixed error group had statistically significant higher amount of coma aberrations than other four groups followed by patient in hypermeteropia group. with no statistically significant correlation between refractive error and RMS of Coma aberration in all groups.

(Karimian F et al.,2010) reported Astigmatism is significantly correlated with total HOAs, and coma aberrations. **(Paquin et al.,2002)** found that high amounts of coma were more frequent in high myopia.

Trefoil aberrations varies between our study groups, Patients in mixed error group with higher amount of Trefoil

aberrations than other four groups with mean RMS value **0.12±0.10** .

In our study Patients in mixed error group had statistically significant higher amount of Trefoil aberrations than other four groups followed by patient in high myopia group .

with no statistically significant correlation between refractive error and RMS of Trefoil aberration in all groups.

(Wei et al.,2006) found a slightly significant correlation between myopia and primary horizontal trefoil.

In concordance with previous reports,**(Wang L et al.,2003) (Wang Y et al.,2003)** noted that the contribution of average RMS of higher order aberrations decreased as the order increased: third order aberrations predominated, followed by fourth aberrations.

(Wang L et al.,2003) investigated HOAs from third to sixth orders using WaveScan System across a 6.0 mm pupil in 532 eyes with mean WaveScan spherical equivalent of -3.39±2.84 (range, -11.56 to +7.60) D and found that spherical aberration was the predominant aberration followed by primary vertical coma.

In contrast, we observed that trefoil had the highest mean followed by coma aberration. This difference may be due to the range of refractive errors evaluated in each study.

The existing knowledge concerning the clinical significance

of HOAs and their relationship to the refractive error and the potential effectiveness of correcting HOAs in

refractive surgery encouraged us to study HOAs and MPS in our population. We believe that our results are important but studies on larger sample size are required to further evaluate, analyze and compare not only the changes in HOAs with refractive error but also their effect on patients` qualityofvision.

Conclusion

In overall comparison we noticed that 1-mean RMS of total HOAs were significantly higher in hypermetropia group.

2-there was a statistically significant correlation between SE of Mixed group and RMS of Total HOAs.

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