Corneal incision on steepest meridian in phacoemulsification, could it correct the corneal astigmatism?

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Abstract

Introduction: Cataract surgery is regarded as refractive surgery when we are aiming at eliminating corneal astigmatism. So when planning a surgery both spherical and astigmatic components should be taken into account to achieve emmetropia postoperatively

Purpose: Measuring the changes of keratometric reading (K1, K2) after phacoemulsification surgery with planned incision on the steepest meridian in 50 eyes presenting as well with corneal astigmatism checking if this planned incision on steepest meridian could be an effective method or not to decrease the corneal astigmatism.

Patients and Methods: A prospective study included 50 eyes of 35 patients that had immature senile cataract with corneal astigmatism more than 1 Diopter. Patients had been recruited and followed up in private eye center in Cairo. Phacoemulsification was done in all cases with placing the main clear corneal incision (0.5 mm from anatomical limbus, 2 mm tunnel length, 3 mm widths) on the steepest meridian. Follow up of patients included UCVA and BCVA at recorded 3 visits; 1 week, 1 month and 3months postoperatively, K-reading changes after 3 months postoperatively detected with pentacam, also, slit-lamp to assess both anterior and posterior segments.

Results: this study showed a statistically significant change of front corneal astigmatism of 0.70 D and of 0.07 D of back corneal astigmatism.

Conclusion: This method is effective in mild degree corneal astigmatism (up to 1D), while higher degree of astigmatism may need different method of intervention to be more effective in correction of astigmatism. We recommended measuring the IOL power depending on expected postoperative keratometric reading.

Introduction:

Cataract is the leading cause of preventable blindness and visual impairment throughout the world according to world health organization (WHO). Cataract affects 20.5 million Americans aged 40 years and older or about 1 in every 6 people in this age range. Cataract surgery includes Intracapsular cataract extraction, Extracapsular cataract extraction, phacoemulsification, Manual small-incision cataract surgery and femtosecond laser-assisted cataract surgery. (1)

Astigmatism may result from curvature abnormalities of the cornea (Fig. 1). (2)

Calculation of intraocular lens implant power requires calculation of corneal curvature power and axial length of eye. (4)

There are different types of formula available for IOL power calculation, Royal college of ophthalmologists recommendations AL < 22.0 mm-Hoffer/SRK-T, AL 22.0-24.5 mm –SRK-T/Holliday/Haggies, AL > 24.6 mm –SRK-T. (5)

Previous studies highlighted that measuring of IOL power is based upon preoperative Keratometric reading consequently they did not account on the change of K-reading produced by cataract surgery.

Cornea is a transparent avascular tissue that acts as a barrier against infection and form with the tear film, the refractive surface of the eye. It is prolate in shape, its anatomy is shown in Fig. 2. The corneal horizontal diameter is 11.5 to 12.0 mm (6) and it is 1.0 mm larger than the vertical diameter. Corneal shape and curvature are governed by the intrinsic biomechanical structure and extrinsic environment. Anterior stromal rigidity is important in maintaining the corneal curvature. (7)

Differences in collagen bundle organization of anterior stroma contribute to a tighter cohesive strength that explain why the anterior curvature resist change to stromal hydration more than posterior stroma, which tend to more easily develop folds. (8)

Astigmatism is responsible for 13% of refractive error of human eye. High degree of astigmatism is associated with amblyopia and some association between astigmatism and development of myopia. In astigmatism, the refractive power of the eye varies in different meridian so the image is formed as a conoid of sturm which formed of a primary focal line (called sturm's line), a circle of least confusion and a secondary focal line (sturm's line) perpendicular to the first one (Fig. 3). (10)

Corneal astigmatism, lenticular astigmatism and retinal astigmatism summation form the total astigmatism of the eye. Most astigmatism is corneal in origin. (12)

Javal rule is used to predict total astigmatism based on corneal astigmatism

At = K + P (Ac) K & P are constant by 0.5 and 1.25 respectively. The average non corneal astigmatism was found to be -0.46: -0.50 D (Dunne, 1991) while posterior corneal astigmatism is 0.18: -0.31 D (13)

Astigmatism can be classified according to axis direction (Fig. 4) into with the rule astigmatism, in which the steepest meridian is near the vertical than the horizontal (90+-30), against the rule astigmatism, in which the steepest meridian is near the horizontal than the vertical (180+-30), and Oblique astigmatism, in which both meridian are more than 30 degrees from the horizontal and vertical meridians (45+_15) (11, 13).

About 70% of cataract population has at least 1.00D of astigmatism & 33% of patients undergoing cataract surgery are eligible for treatment of pre-existing astigmatism. (14). Prevalence of corneal astigmatism before cataract surgery is 67.7% corneal astigmatism between 0.25 & 1.25 D, 27.5% was 1.25D or higher and 4.8% has less than 0.25 D of corneal astigmatism. (15)

Cataract surgery is regarded as refractive surgery when we are aiming at eliminating corneal astigmatism. So when planning a surgery both spherical and astigmatic components should be taken into account to achieve emmetropia postoperatively. (16)

Developments in phacoemulsification devices, changes in operation techniques and use small incision in cataract surgery led to reduction of operation–induced astigmatism. There are several techniques for dealing with the preexisting astigmatism intraoperatively. The most important step in treating the astigmatism is to find out the exact source, magnitude and axis of astigmatism then take the decision about the exact technique that's appropriate for the case. (17)

Cylindrical component is evaluated by automated and manifest refraction, placido ring reflections, keratometry, corneal topography and wave front aberrometry. Other factors need to be taken into account such as age and the corneal characteristic of both eyes. (17). Javal rules predicted the total astigmatism of eye based on the corneal astigmatism. (18) Total astigmatism = K + P (corneal astigmatism) K, P represent constant 0.5 and 1.25 respectively. Keller and colleagues supported Javal's rule by studying total corneal astigmatism by a computer assisted videokeratoscope. (19)

Corneal astigmatism measured by topography or keratometry and refractive cylinder measured by wavefront or manifest refraction, the difference is known as ocular residual astigmatism. (20, 21)

Corneal topography gives qualitative and quantitative image map based on evaluation of corneal curvature. It evaluates 8000:10000 points. In contrast, manual keratometry has only 4 data points within 3mm to 4 mm of central anterior surface of cornea, while low magnitude of astigmatism so may be useful in screening astigmatism. Corneal topography and keratometry are objective measures of corneal refractive power. (22)

The corneal or limbal incisional procedures to correct preoperative astigmatism have to involve keratometry, topography, refraction or a combination because treatment of refractive astigmatism without regard to corneal astigmatism may result in remaining or even increase in corneal astigmatism.

Faber perform perforating anterior transverse incision to reduce idiopathic astigmatism. (23)

Lans first appreciated that the flattening in a corneal meridian after placing a transverse incision was associated with steepening in the opposite meridian. (24) also demonstrate that the deeper and longer incision had more effect. **Nordan** proposed a simple method of straight transverse keratotomy with target corrections 1–4 D. (25)

So the surgical procedures to correct corneal astigmatism include: 1) Creating a clear corneal incision (CCI) on steep meridian of astigmatism during phacoemulsification, (26) biaxial microincision phaco with enlargement of one incision to 2.8 is not astigmatic neutral. (27)

It was found that 2.75mm CCI induced small astigmatic change regardless site of incision, (28) while superior 2.8mm CCI show larger astigmatic change than temporal which considered astigmatic neutral. (29)

The clear corneal temporal incision (CCTI) showed less SIA than clear corneal on axis incision (CCOI). Incision between 1.6:2.3 mm had better SIA than small incision cataract surgery. SIA is the change occurs in postoperative astigmatic value than preoperative. It can simply be detected by subtraction method or Fourier, Jaffe, Cleymans nector analysis. (30)

2) Opposite side clear corneal incision (OCCI): When corneal incision on opposite sites 180 degree on steepest meridian is made, that leads to more flattening of cornea. **Lever & Dahan** were the first to apply an OCCI on steep axis (31) that showed Keratometric astigmatic changes of 0.75 to 2.80 D postoperatively. (32) So it can be used to correct mild to moderate astigmatism. (33)

3) Limbal relaxing incision (LRI): In LRI two small curvilinear limbal incisions are done on steep axis to make it flat. Its preferred technique to reduce preexisting mild to moderate astigmatism or even high, as its easy, quick, low cost, less irregularity and refraction variability, earlier stability in vision and less glare (34) but its surgeon dependent as its far from center so it has less flattening effect so it need to be large to get the needed effect while denervation of cornea can occur lead to dry eye and healing problems.

5) Toric Intraocular lens implantation (TIOL): It can be used for correction of moderate to high astigmatism. Its advantage is that it's precise, predictable and reliable. First foldable silicon toric plate haptic IOL was implanted in 1992 by grabow and shepherd. (35)

Perfect astigmatism correction can be done by TIOL. A lot of factors may affect the efficacy of correction of astigmatism by TIOL as incision location and rotation of TIOL. It was proven that corneal incision on steepest axis could reduce the cylinder power of TIOL and lower the chance of postoperative irregular astigmatism that lead to improve of the postoperative quality of vision. (36)

Patients And Methods:

This is study was a prospective study which included 50 eyes of 35 patients that had immature senile cataract with corneal astigmatism more than 1Diopter. Patients had been recruited and followed up in Al-Azhar University hospitals, Cairo, Egypt. All patients have been counselled and informed about their participation in this study, as well as signing a consent of participation and publication. This study was approved by the ethical committee of Al-Azhar University. All data and consents are rolled in the patients' files in the hospital archives.

Exclusion criteria include patients presented with non-senile cataract, or cataract associated with local eye disease such as pellucid marginal degeneration or previous ocular operation in same eye such as glaucoma, refractive or retinal surgery. Also, patients on systemic or local medication such as steroids or glaucoma treatment, also those having systemic disease that will affect corneal healing. Patient with complicated cataract surgery.

History and Examination: History of any systemic disease and drug intake, history of previous ocular surgery or medication. Visual acuity (uncorrected and best corrected) was done using Snellen chart. Slit-lamp examination was done to detect any signs of old surgery, conjunctival or scleral thinning and inflammation, corneal opacity and haziness, pupil shape and reactivity, grade and size of the nucleus, site of opacity and zonular integrity and strength. Fundus examination when are possible to detect any retinal or optic nerve disease such as diabetic retinopathy or optic nerve atrophy.

All patients underwent these investigations: 1) Pentacam to assess corneal topography and tomography. 2) Partial coherence interferometry device (IOL Master) had been used to detect the IOL power.

Operative procedure was as in usual phacoemulsification techniques but with placing the main clear corneal incision (0.5 mm from anatomical limbus, 2.5mm tunnel length, 3 mm widths) on the steepest meridian.

All patients were undergone uneventful phacoemulsification cataract surgery through a 3.00 mm clear corneal incision planned on steepest axis meridian wherever it was. It was placed at 0.5 mm from posterior limbus and fashioned with a length of 2.00 mm.

Follow up of patients included: 1) Visual acuity by Snellen chart to detect UCVA and BCVA at recorded 3 visits; 1 week, 1 month and 3months postoperatively. 2) Slit lamp examination to assess the cornea, lens and bag as well as fundus examination to exclude any recent changes or postoperative retinal complications. 3) K-reading changes after 3 months postoperatively detected with pentacam.

Results:

We performed a prospective, clinically controlled study on 50 cataractous eyes of 35 patients, 25 females and 10 males.

(Figure.5) Our patients was recruited and followed in ophthalmology department of Al-Azhar university hospital and private eye center.
No intraoperative complication occurred in our patients.

Statistical analysis: All collected questionnaires were revised for completeness and consistency. Precoded data was entered on the computer and statistically analyzed using SPSS version 17.0. Data was summarized using mean and standard deviation and percentiles for quantitative variables and frequency and percentage for qualitative variables. P-values equal to or less than 0.05 were considered statistically significant, less than 0.01 is highly clinically significant and more than 0.05 is not clinically significant. Graphs were used to illustrate some information.

The cataract operation was done for 31 right eyes and 16 left eyes in each patient the location of incision was on the steep corneal meridian. (Table.1) (Figure.6)

The keratometric readings

Reduction of the corneal astigmatism manifested by decrease in the keratometric readings was one of our goals in this study. Improvement of the mean minimum and maximum keratometric reading was achieved. Regarding the flattest meridian keratometric reading; the mean preoperative was 43.71 ± 1.52.

After 3 month of operation the mean K-reading became 44.30 ± 1.17. The mean difference in K-reading was – 0.04 diopter between the preoperative and 3months postoperatively. The P-value was 0.665 that mean it's not clinically significant. 60% of patients show decrease of flattest meridian K-reading after 3 months of operation while 40% of patients show increase of K-reading. (Table 1;2) (Fig. 7,8)

Table 1
flattest meridian K-reading mean and mean difference between preoperative and postoperative.

flattest meridian	Pre op	Post 3 months	Mean Difference	% Change	Paired t-test	
K-reading	**No.=50**	**No.=50**			**t**	**P-value**
Mean ± SD	43.71 ± 1.52	44.3 ± 1.17	-0.04	-0.07	0.438	0.665
Range	41.5–47.3	42.3–46.6				

Table 2
percentages of patients show changes in the flattest meridian K-reading.

Flattest meridian K-reading difference	*No.*	*%*
Decreased	*34*	*60.0%*
Increased	*16*	*40.0%*
Stable	*0*	*0.0%*
Total	*50*	*100.0%*

Regarding the steepest meridian keratometric reading; the mean preoperative was 46.77 ± 2.26. After 3 month of operation the mean K-reading became 46.16 ± 1.66. The mean difference in K-reading was – 0.61 diopter between the preoperative and 3months postoperatively. The P-value was 0.001 that mean it's highly clinically significant. 83.3% of patients show decrease of steepest meridian K-reading after 3 months of operation while only 6.7% of patients show increase of K-reading and only 10% are stable. (Table 3,4,5) (Figure.9,10)

Table 3
steepest meridian K-reading mean and mean difference between preoperative and postoperative.

Steepest meridian	Pre op.	Post 3 months	Mean Difference	% Change	Paired t-test	
K-reading	**No.=50**	**No.=50**			**t**	**P-value**
Mean ± SD	46.77 ± 2.26	46.16 ± 1.66	-0.70	-1.23	3.627	0.001
Range	43.5–52	43–49				

Table 4
percentage of patients shows changes in steepest meridian K-reading.

Steepest meridian K-reading difference	**No.**	**%**
Decreased	41	83.3%
Increased	5	6.7%
Stable	4	10.0%
Total	50	100.0%

Table 5
Corneal front astigmatism changes.

Corneal front Astigmatism	Pre op.	Post 3 months	Mean Difference	% Change	Wilcoxon Ranks test	
	No.=50	**No.=50**			**Z**	**P-value**
Median(IQR)	1.90 (1.2–3.3)	1.40 (1–2.4)	-0.70	-20.40	-3.670	< 0.001
Range	0.7–5.1	0.5–4.1				

Corneal back astigmatism

The corneal back astigmatism median was 0.40 (0.2–0.5) preoperatively and became 0.20 (0.1–0.3) after 3 months of operation. The mean difference was − 0.07diopter and the P-value was 0.026. That means the change is clinically significant. (Table 6) (Figure.11)

Table 6
corneal back astigmatism changes.

Corneal back astigmatism	Pre op.	Post 3 months	Mean Difference	% Change	Wilcoxon Ranks test	
	No.=50	**No.=50**			**Z**	**P-value**
Median(IQR)	0.40 (0.2–0.5)	0.20 (0.1–0.3)	-0.07	-17.44	-2.232	0.026
Range	0.1–0.8	0–1.1				

Regarding the mean keratometric (Km); the mean preoperative was 45.64 ± 1.80. After 3 month of operation the mean Km became 45.31 ± 1.36. The mean difference in Km reading was − 0.33 diopter between the preoperative and 3months postoperatively. The P-value was 0.010 that mean it's highly clinically significant. 66.7% of patients show decrease of Km after 3 months of operation while 26.7% of patients show increase of Km reading and stable Km in 6.7% of patients. (Table 7,8) (Fig. 12;13)

Table 7

Km mean and mean difference between preoperative and postoperative.

Km	Pre op	Post 3 months	Mean Difference	% Change	Paired t-test	
	No.=50	**No.=50**			**t**	**P-value**
Mean ± SD	45.64 ± 1.80	45.31 ± 1.36	-0.33	-0.67	2.751	0.010
Range	42.5–49.65	42.65–47.8				

Table 8

percentage of patients show changes in Km.

Change of Km	**No.**	**%**
Decreased	37	66.7%
Increased	8	26.7%
Stable	5	6.7%
Total	50	100.0%

Table 9

corneal front Q-value changes. By Wilcoxon test.

Value Front	Pre	Post	%Change	Test value	P-value	Sig.
Median (IQR)	-0.54 (-0.77 – -0.31)	-0.53 (-0.75 – -0.36)	0.19 (0.05–0.24)	-0.062	0.951	NS
Range	-1.04 – -0.13	-0.99 – -0.2	0.02–0.53			

Table 10

corneal front Q-value changes. By Wilcoxon test

Value back	Pre	Post	%Change	Test value	P-value	Sig.
Median (IQR)	-0.59 (-0.64 – -0.36)	-0.37 (-0.55 – -0.13)	0.225 (0.1–0.32)	-2.687	0.007	HS
Range	-0.7 – -0.15	-1.25 – -0.02	0.01–0.61			

Table 11
keratoconus indices changes.

Keratoconus Indices	Pre		Post		Test value	P-value*	Sig.
	No.	**%**	**No.**	**%**			
No	50	100.0%	19	40.0%	25.714	> 0.001	HS
Yes	0	0.0%	28	60.0%			

Q-value

The corneal front Q-value median was – 0.54(-0.77 – -3.3) preoperatively and became – 0.53 (-0.75 – -0.36) after 3 months of operation. The P-value was 0.951. That means the change is non-significant. (Table.9) (Figure.14,15)

The corneal back Q-value median was – 0.59(-0.64 – -0.36) preoperatively and became – 0.37(-0.55 – -0.13) after 3 months of operation. The P-value was 0.007. That means the change is highly significant. (table.10) (Figure.16)

Keratoconus indices

The preoperative pentacam analysis shows that all the patients were negative for keratoconus, while 60.0% (18 patients) of our patients show keratoconus postoperatively. (table.11)

Discussion:

Nowadays cataract surgery has been changed from simple cataract extraction to a refractive procedure aiming at elimination of corneal astigmatism. A lot of surgeons are targeting to correct both spherical and cylinder component during phacoemulsification to get best quality of vision and visual acuity postoperatively. (37)

It has been estimated that the prevalence of corneal astigmatism in cataract patient who is going to do a cataract surgery is 64.4% corneal astigmatism between 0.25:1.25 D, 22.2% was 1.50 D or higher and only 13.2% has no corneal astigmatism. (38) Reduction of preexisting astigmatism can be done during phacoemulsification surgery by modifying shape, length, location and type of incision. (39)

Previous studies have found that different small incisions of phacoemulsification lead to different degrees of surgically induced astigmatism. **Shaw et al** reported that surgically reduced corneal astigmatism was 0.23 D when using 3.2mm clear corneal incision at superior temporal in all right eyes and superior nasal in all left eyes. (40) In this study, 3.00 mm incision was used. It was located on the steepest axis which leads to a reduction of the corneal astigmatism by 0.7 D. They used auto-refracto-keratometer to detect astigmatism changes, but in our study we used pentacam which is more accurate. They also reported that the steepest component of astigmatism was statistically significantly reduced postoperative and no significant change at the flat component. The conclusion was similar to results of this work. (40)

Wang et al reported that the incision size had a main impact on postoperative corneal astigmatism and reducing the incision size can minimize postoperative corneal astigmatism. All incisions in their study were made at the same location (at 10 o'clock position) instead of adjusting according to preoperative astigmatism. Orbscan topography was employed in this study to measure the curvature of the anterior surface of cornea, amplitude and the axis of corneal astigmatism after 3 months of operation. They reported that preoperative corneal astigmatism was the same in each group (0.8 ± 0.3 D) while postoperative astigmatism was 0.8 ± 0.3 D in the 2.2 mm group, 0.7 ± 0.4 D in the 2.6 mm group and 1.1 ± 0.5 D in the 3.0 mm group. So they concluded that the corneal astigmatism changes were reduced by moving from 3.0 mm incision to 2.6 mm incision, but moving from 2.6 mm incision to a smaller incision (2.2 mm) offered no further benefit in reducing the corneal front astigmatism changes. (41) In this study we used 3.00 mm small coaxial incision on steep meridian which form a reduction of corneal astigmatism by only 0.7 D. while they locate the incision at 10 o'clock position. Also they used orbscan to detect astigmatic changes while in this study pentacam was used which is more accurate.

Chang et al reported that surgical changes of corneal astigmatism when using 3.0 mm prelimbal incision on steep meridian was 0.28 D if incision site is temporal, 0.40 D if the incision is superior temporal and 0.46 D if the incision is superior. So they concluded that changing the site and location of same incision can lead to a difference in reduction of preexisting astigmatism. (42)

In this study, we studied the effect of 3.00 mm clear corneal incision on axis of steepest meridian of corneal astigmatism and confirmed that planned corneal incision on steepest meridian is still one of simple methods for correction of small degree of corneal astigmatism. We used 3.00 mm clear corneal incision on steepest axis, 0.5 from anatomical limbus and with tunnel length 2.00 mm to make a flattening effect and reduction of astigmatism which has been detected by pentacam postoperatively.

This study showed that the Flat Keratometric reading changed but was not clinically significant while steepest Keratometric reading is always decreased with mean of 0.61D. Mean keratometric reading (Km) decreased with mean of 0.33D. The Corneal front astigmatism decreased by mean difference 0.70 D, while corneal back astigmatism decreased by means difference 0.07D both were statistically significant. By using IOL calculation T-plus program we found that: for any patient intended to have surgery to reduce the corneal front astigmatism (K1-K2) by 1 D postoperatively we need to increase the IOL power by 0.50 D to target the same refraction.

This study analyzed postoperative astigmatism after phacoemulsification surgery through a specific 3.00 mm clear corneal incision. The incision was located on the steepest corneal meridian in all patients. Astigmatism was measured by pentacam preoperative and 3 months postoperatively. The mean reduction of corneal astigmatism was 0.70 D. The steepest keratometric reading was statistically significantly lower postoperatively than preoperatively ($p = 0.001$). There was no significant difference in the minimum keratometric reading ($p = 0.665$). Corneal front astigmatism and corneal back astigmatism was significantly decreased. Pachymetry after 3 months of surgery increased by mean difference 5.30 micron but it is insignificant. So this study concluded that CCI with 3.2mm incision on steepest meridian can be used as a simple method to correct preoperative corneal astigmatism via flattening of steepest keratometric reading. This method is effective in mild degree corneal astigmatism (up to 1D), while higher degree of astigmatism may need different method of intervention to be more effective in correction of astigmatism. We recommended measuring the IOL power depending on expected postoperative keratometric reading. The change of corneal front surface Q-value was statistically insignificant and the change of back surface Q-value was statistically significant from − 0.59 preoperatively to -0.37 postoperatively. To our knowledge no previous studies have comment on Q-value. Keratoconus indices showed that 60% of patients postoperatively tending to have a degree of keratoconus. To our knowledge no previous studies have comment on keratoconus indices.

As was detected in this work, the change of the front corneal astigmatism by doing 3.00 mm clear corneal incision SIA is 0.7 D and the IOL power calculation is depending on axial length and keratometric reading which show changes after operation. So we recommend measuring the IOL power depending on postoperative keratometric reading.

Declarations

No conflict of interest

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Figures

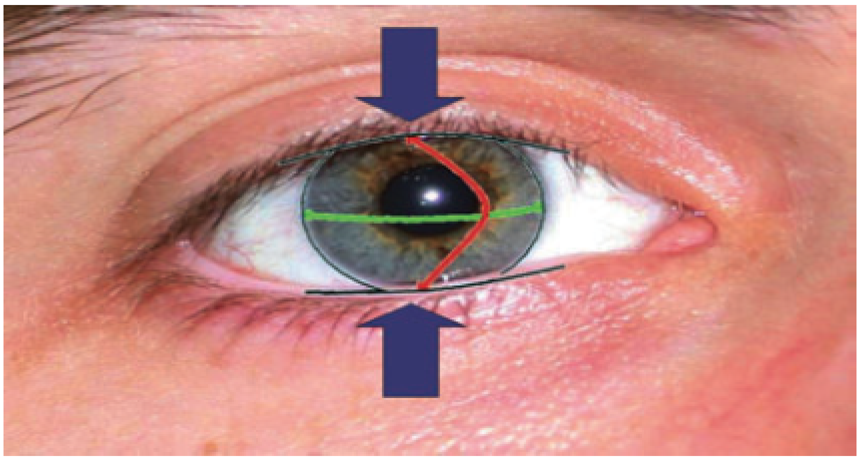

Figure 1

Illustration of the eyelid pressure theory of corneal astigmatism development. (3)

Figure 2

Light micrograph of normal endothelium (original magnification100). Note the single-cell endothelial layer with a Descemet membrane of uniform thickness (epithelial surface at top of figure). (9)

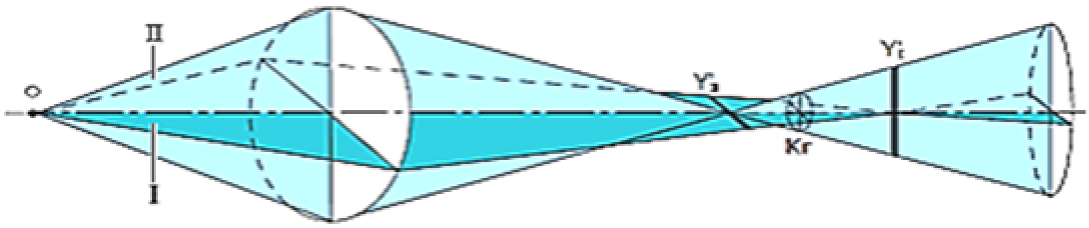

Figure 3

The two main meridians are perpendicular to each other. The object (O) is represented as a line segment at the focal points of the two meridians. Circle of least confusion present midway between these two focal points. (11)

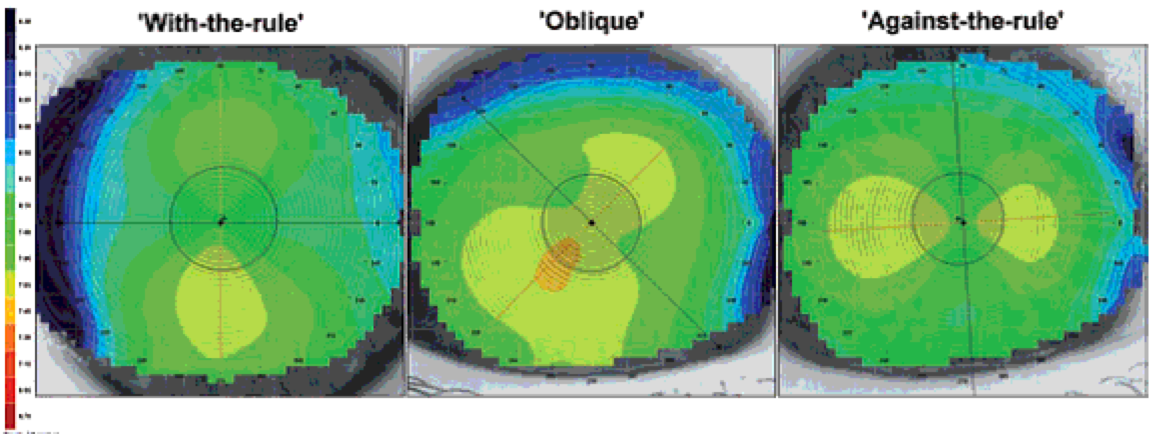

Figure 4

Example of the classification of corneal astigmatism according to the axis. Astigmatism with-the-rule (WTR) (where the steepest corneal meridian is oriented approximately vertically) (left), against-the-rule (ATR) (where the steepest corneal meridian is oriented close to horizontal) (right) or as oblique (where the steepest corneal meridian is oriented at an oblique angle) (centre). Axial curvature corneal topography maps are shown here for three different subjects. (3,13)

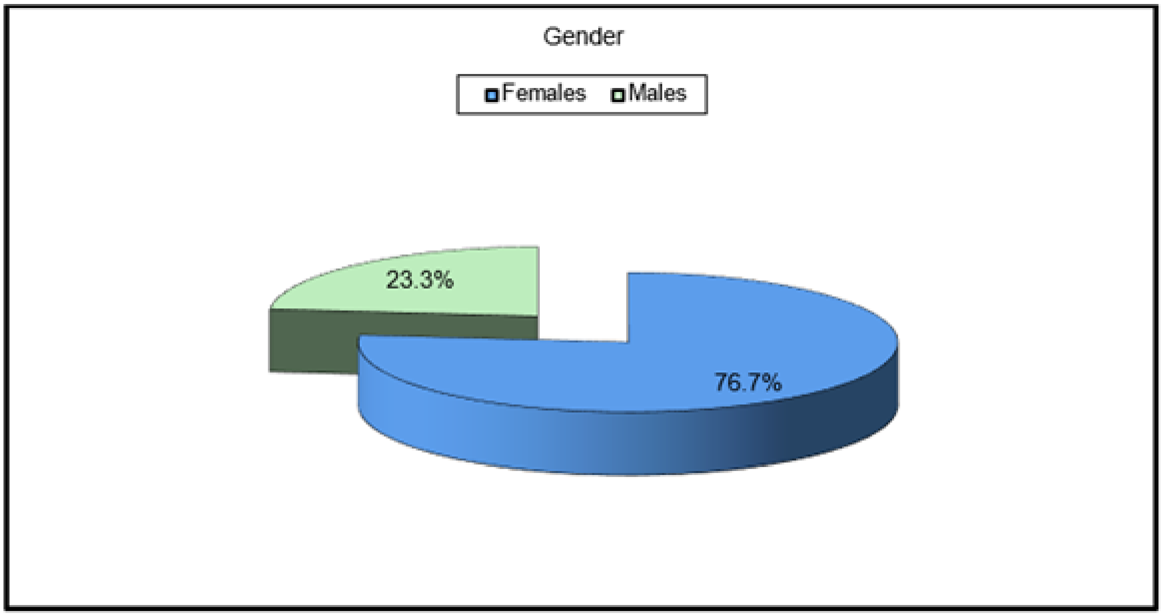

Figure 5

Gender percentage on the study.

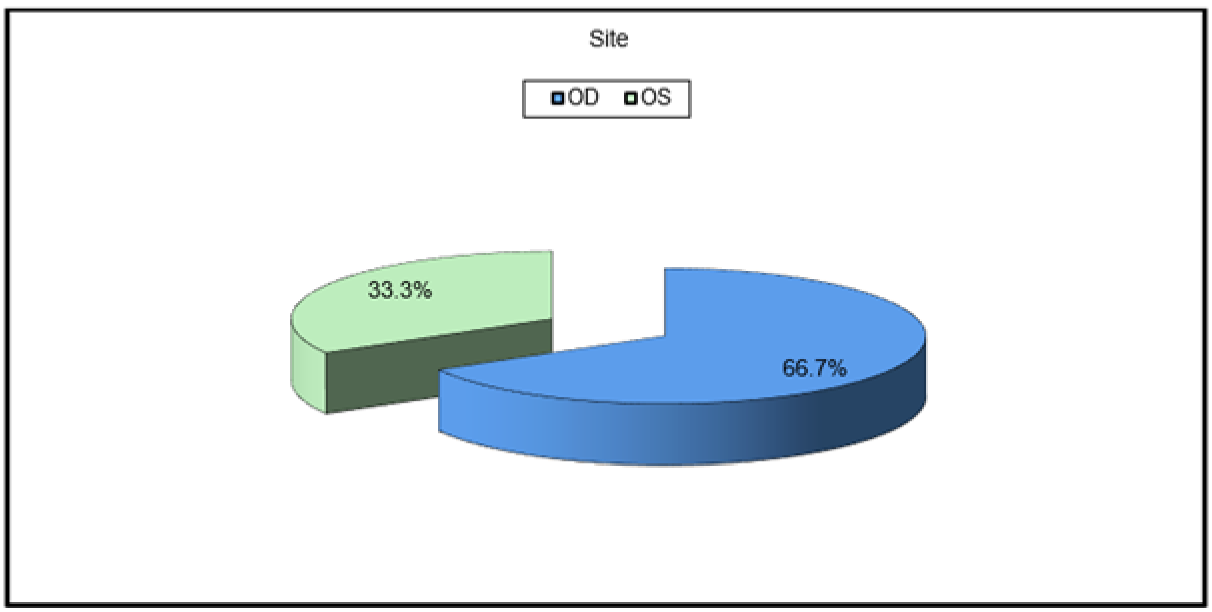

Figure 6

Percentage of right and left eyes included in the study.

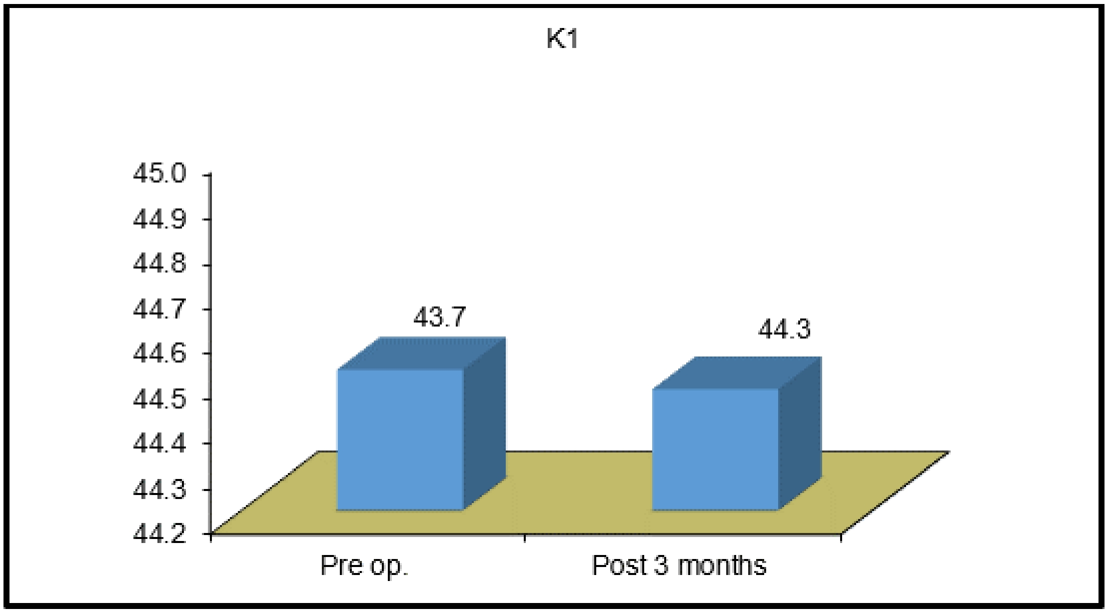

Figure 7

Flattest meridian K-reading preoperative and postoperative changes.

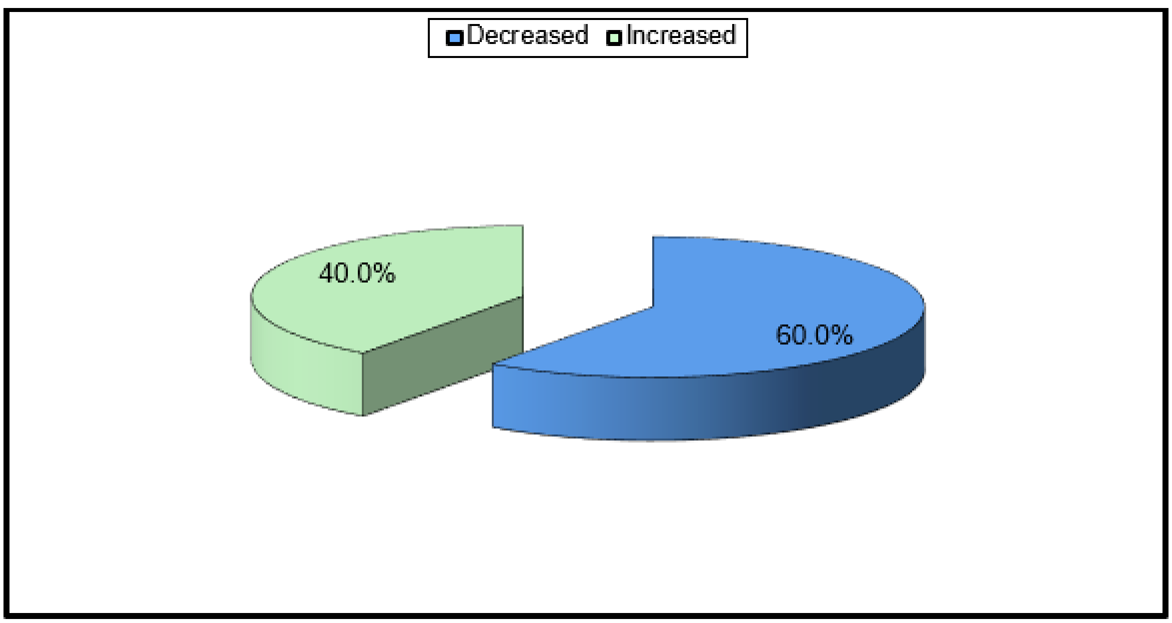

Figure 8

Percentage of flattest meridian K-reading change.

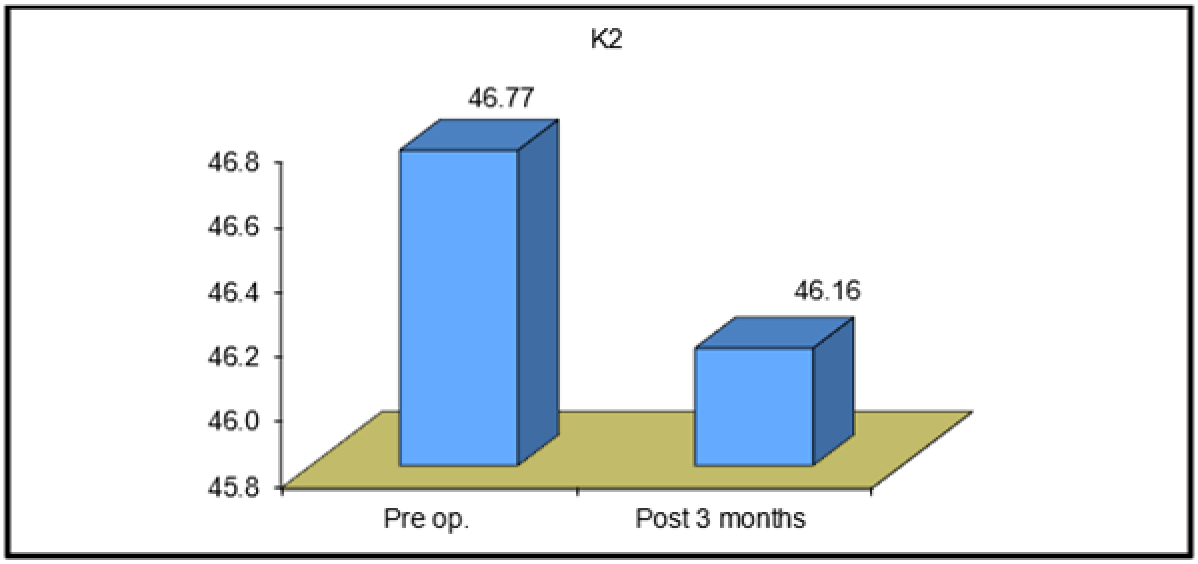

Figure 9

Steepest meridian K-reading preoperative and postoperative changes.

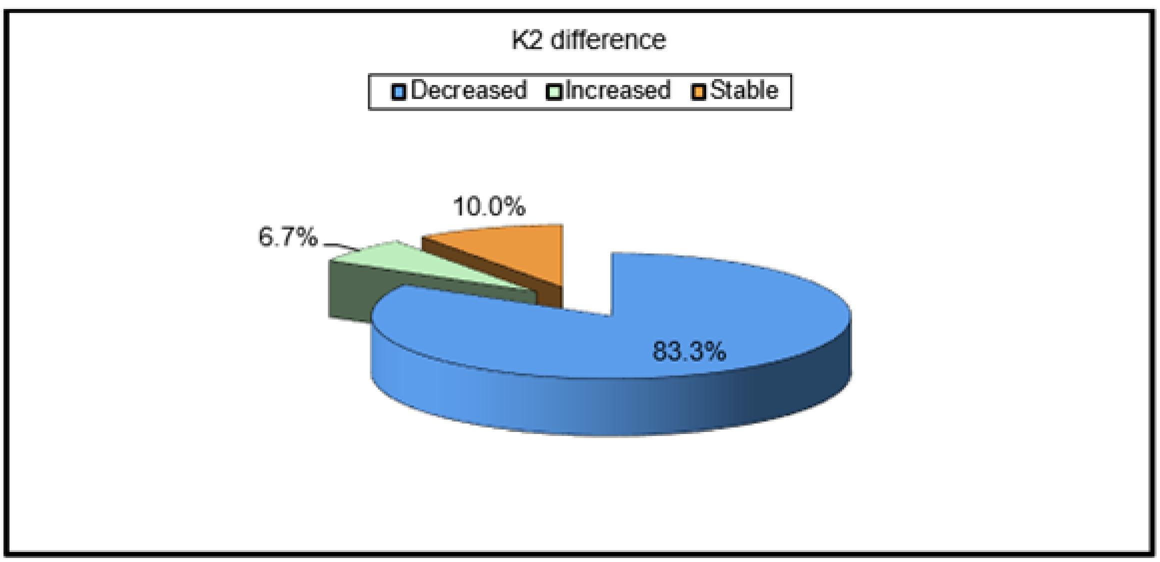

Figure 10

Percentage of steepest meridian K-reading changes

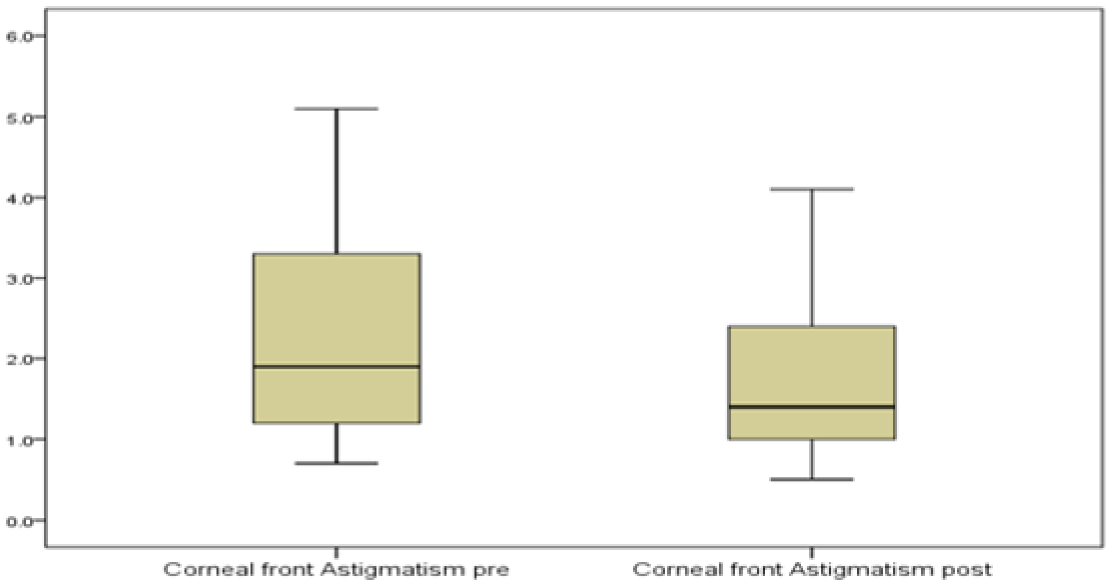

Figure 11

Changes in corneal front astigmatism.

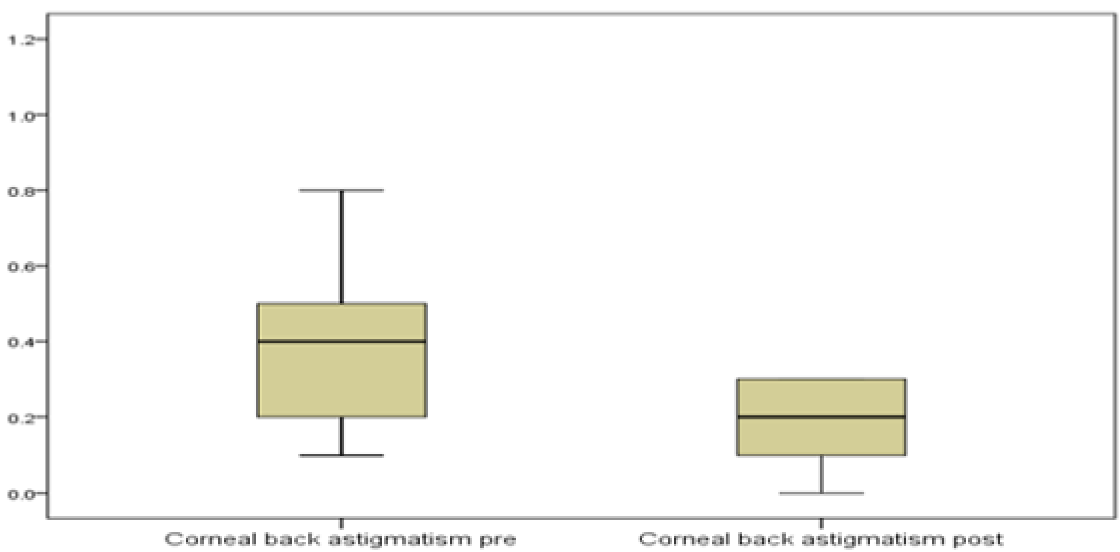

Figure 12

Changes in corneal back astigmatism.

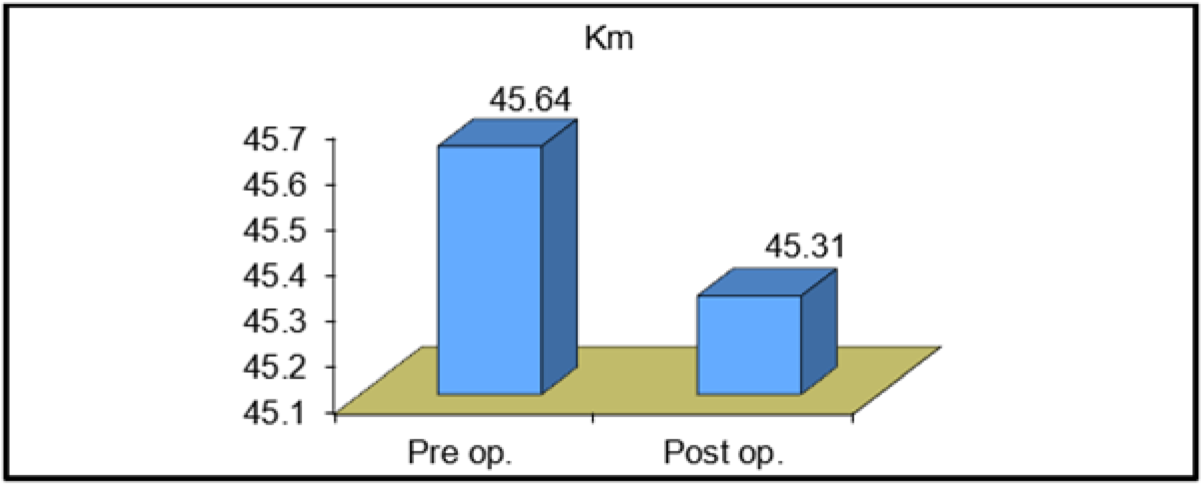

Figure 13

Km preoperative and postoperative changes

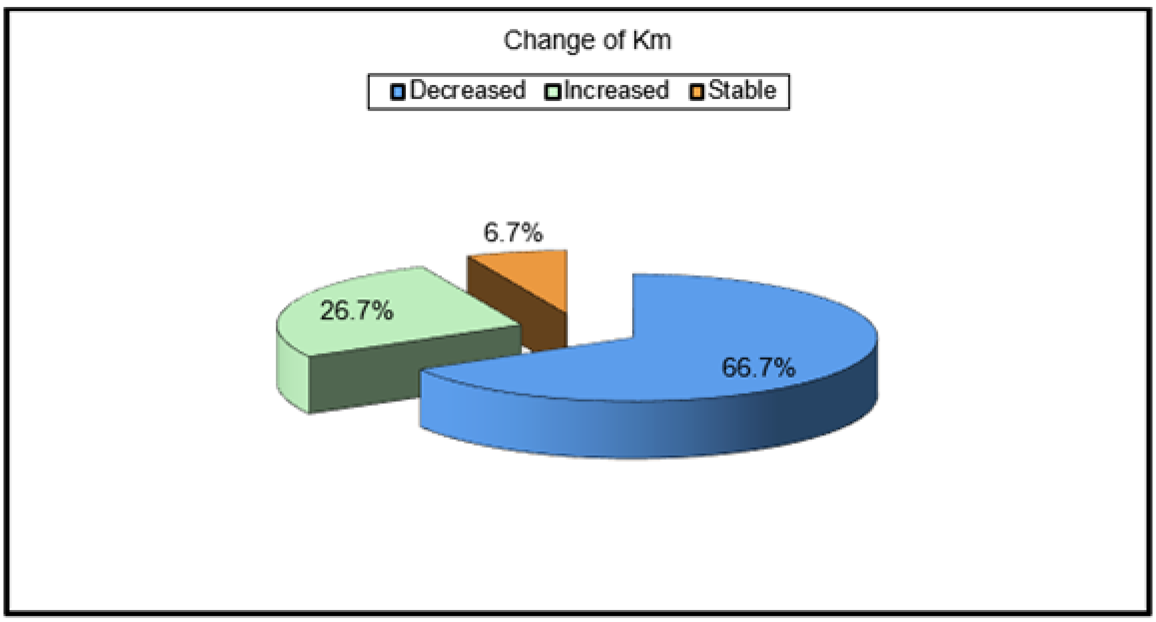

Figure 14

Percentage of Km reading changes.

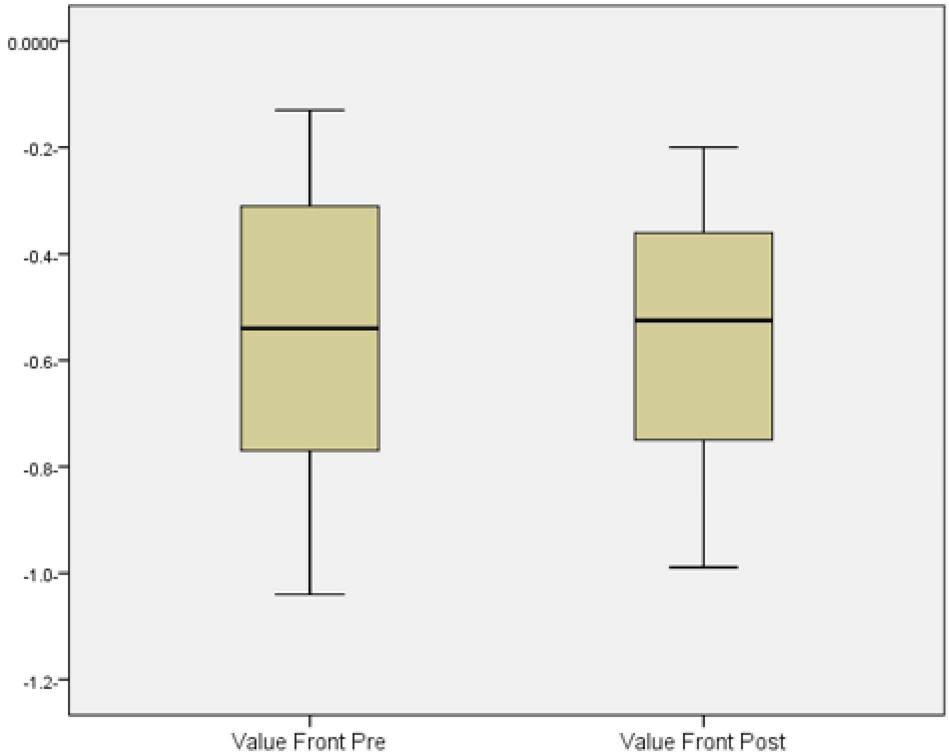

Figure 15

Changes in corneal front Q-value.

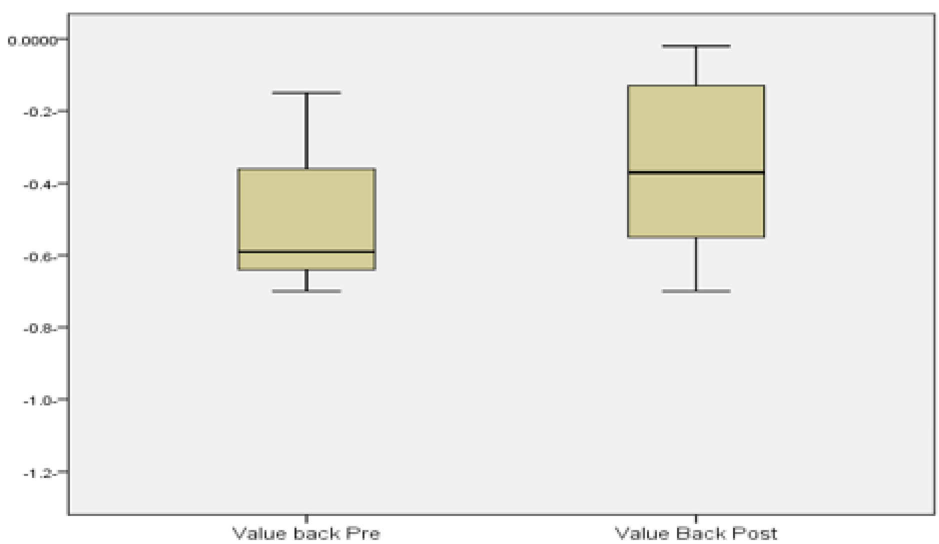

Figure 16

Changes in corneal back Q-value.