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Changes in Posterior Corneal Curvature, Asphericity and Longitudinal Spherical Aberrations Following Myopic Laser in Situ Keratomileusis (LASIK)

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Abstract
Purpose: *To assess the changes in the posterior corneal curvature, asphericity and longitudinal spherical aberrations after myopic laser in situ keratomileusis (LASIK)*
Method: *Prospective nonrandomized comparative study. 68 eyes of 16 women and 18 men were included, with mean age at the time of surgery of 24.79 ±3.47 (range 20-35) years ,with a spherical equivalent(SEQ) of -1.5 to -11.75 (mean ,-5.00 ±2.168). All procedures were accomplished with the Star S4 IR excimer laser and the Moria microkeratome. (Flap size 90/130 microns). The residual stromal bed thickness of > 250 um or >50% of original thickness of the cornea was maintained. Subjective refractometry, corneal topographical analysis and pachymetry with Sirius (placido disc topography with Scheimpflug tomography) were performed before and 3 months after LASIK for myopia (n=12, range -1.5 D to -5.12 D, mean -3.20±2.10 D) and myopic astigmatism (n=56, sphere -1.5 to-10.75 D, mean -4.78 ± 2.13 D, cylinder -0.25 D to-3.5D, mean -1.07 ± 0.78D).*
Results: *Paired't' test was used for analysis. A P value ≤ 0.05 was considered to be statistically significant. Overall, change of posterior corneal curvature (-6.259±0.18D/-6.27±0.21 D, P=0.10) was not statistically significant. Change of asphericity (0.89±0.25/1.03±0.12, P <0.001) was highly significant. Change in longitudinal spherical aberrations (0.45±0.33/0.61±0.83, P=0.16) was not found to be significant.*
Conclusion: *No significant change is seen in the Posterior corneal power/ Longitudinal spherical aberrations following LASIK, but change in asphericity of the cornea (from prolate to oblate) is significant.*

Introduction

LASIK (Laser assisted in situ keratomileusis) is a keratorefractive surgery, which is used in the correction of myopia, hyperopia and astigmatism[1]. It combines the precision of excimer laser photo ablation with the advantages of an intrastromal procedure, thereby maintaining the integrity of the Bowman's layer and the corneal epithelium which is overlying.

LASIK surgery affects the anterior corneal surface and weakens the cornea, therefore a modification in the posterior corneal surface may be expected.[2] Post LASIK ectasia of the cornea is a progressive steepening and thinning of the cornea which results in an irregular astigmatism. It is a rare but dreaded complication. Detection of a mild keratectasia in the early stage requires knowledge of the posterior curvature of the cornea as mild degrees of iatrogenic ally induced keratectasia may be better detected at the level of the posterior surface.

The purpose of our study was to assess changes which occurred in posterior corneal curvature, asphericity and longitudinal spherical aberrations between preoperatively and 3 months postoperatively, to look for significant differences.

In our study we used the SIRIUS (Costruzione Strumenti Oftalmici, Florence, Italy) corneal topography machine for imaging. It combines 22 ring Placido disc topography with Scheimpflug tomography of the anterior segment. It provides information on pachymetry, elevation, curvature and dioptric power of both anterior and posterior corneal surfaces over a diameter of 12mm. It captures Scheimpflug images of the anterior segment through a rotating camera, which provides a picture in 3 dimensions.

It is a non-contact procedure. A series of 25 Scheimpflug images and a Placido based image are analysed to provide data regarding anterior and posterior corneal surfaces. It is capable of measuring up to 35,632 points from the anterior and up to 30,000 points from the posterior corneal surface.

Method

This was a prospective non-randomized comparative study. The study was carried out in 68 eyes of 16 women and 18 men. (34 bilateral patients).All patients had been operated upon by a single surgeon at Government Medical College and Hospital, Nagpur, which is a tertiary care centre.

Inclusion Criteria

All patients were above 18 years of age.

Had a stable refraction for a year. (A change in the refractive power of not more than 0.5 D in 6 months/a change of not more than 1 D in a year)

Exclusion Criteria

Keratoconus
Pellucid marginal degeneration
One eyed patient
Uncontrolled diabetes mellitus
Pregnant and lactating females
Contact lens warpage
Glaucoma
Severe dry eye & other ocular surface disorders
Immunocompromised status
Connective tissue disorders
Patient with high expectations.

Evaluation of the cornea with Sirius topography was done preoperatively and at 3 months post operatively.

For simple myopia, refractive error ranged from (n=12, range -1.5 D to -5.12 D, mean - 3.20±2.10 D), and for myopic astigmatism it ranged from(n=56, sphere -1.5 to-10.75 D, mean -4.78 ± 2.13 D, cylinder -0.25 D to-3.5D, mean -1.07 ± 0.78D).

Spherical Equivalent (SEQ) was calculated as- Sum of sphere power with half of cylinder power. Spherical Equivalent (SEQ) ranged from -1.5 to -11.75, mean -5.00± 2.168. In all patients a residual stromal bed thickness of > 250 um or >50% of original thickness of the cornea was maintained. All the patients underwent standardized ablation procedure. All procedures were performed with the Star S4 IR Excimer Laser after creation of a hinged flap with the Moria microkeratome (90/130 u head). The ablation depth was calculated by the Munnerlyn formula, i.e., ablation depth (um)=1/3 x [intended correction in dioptres x (optical zone in mm)^2].

Table 1: Central ablation depth in simple myopia and mopic astigmatism

	Intended central ablation depth	
	Range	Mean
Simple Myopia	25.4-70 um	46.36± 28.04 um
Myopic Astigmatism	36-134 um	82.24± 26.57 um.
Overall (Myopes+ Myopic Astigmatism)	25.4 to 134 um	75.91 ± 28.22 um

Overall the intended central ablation depth ranged from 25.4 to 134 (mean, 75.91± 28.22) um. For simple myopia, it ranged from 25.4 to 70 (mean, 46.36± 28.04) um. For myopic astigmatism, it ranged from 36 to 134 (mean, 82.24± 26.57) um.

Ablation diameter on an average was 6.5mm.Ring size was selected on the basis of average keratometric values and white to white value in mm. After stromal ablation the under surface of the flap and the stromal bed was irrigated with Balanced Salt Solution to remove any debris and flap was repositioned. Postoperatively the patient was put on antibiotic eye drops (moxifloxacin 0.5 %), steroid eye drops (predacetate 1%), & lubricating eye drops (carboxymethylcellulose 0.5 % eye drops).Post operatively the patient was followed up at 24 hours, 10 days, 1 month and at 3 months.

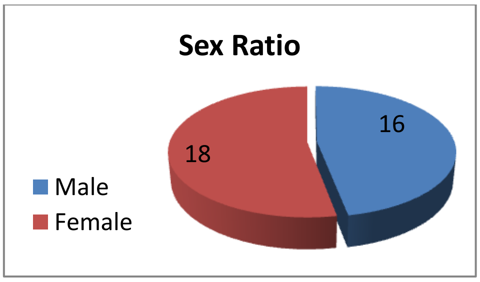
At each follow up visual acuity testing , slit lamp evaluation was done to check for any ocular surface issues, infectious keratitis, LASIK flap/ interface related complications. No complications occurred in any patient and no retreatment was necessary in the follow up period.

The changes which occurred in the posterior corneal curvature (mean at 3mm), asphericity at 6mm and longitudinal spherical aberrations at 4mm were compared between preoperatively and 3 months postoperatively, to look for significant differences. The changes in these parameters were assessed in two groups' i.e. simple myopesvs myopic astigmatism.

For statistical analysis, Paired 't' test was used and software OpenEpi was used . A p value ≤0.05 was considered to be statistically significant.

Observation and Results

In a study of total 34 patients , 16 women and 18 men, average age at the time of surgery was 24.79± 3.47(range, 20-35) years.



Preoperatively Uncorrected visual acuity (UCVA) ranged from 0.6 to 1.9 with a mean of 1.2± 0.39 while the post-operative UCVA ranged from -0.1 to 0.3, mean 0.07 ±0.21. (Visual acuity is expressed in terms of Log Mar).

Spherical Equivalent preoperatively ranged from -1.5 to -11.75, mean -5.00± 2.168. SEQ for simple myopia ranged from -1.5 to -5.12, mean -3.20 ± 2.15. SEQ for myopic astigmatism ranged from -1.5 to -11.75, mean -5.31 ±2.16.

Table 2: For overall group (simple myopia & myopic astigmatism), changes in the Posterior corneal curvature, Asphericity and Longitudinal spherical aberrations before and 3 months after Myopic LASIK (n=68)

	Before	At 3 months	P value
PCC	- 6.259±0.18D	-6.27±0.21 D	0.10
Q	0.89±0.25	1.03±0.12	<0.001
LSA	0.45±0.33	0.61±0.83	0.16

PCC-Posterior Corneal Curvature, Q- Asphericity, LSA-Longitudinal Spherical Aberrations

Overall, change of posterior corneal curvature (-6.259±0.18D/-6.27±0.21 D, P=0.10) was not statistically significant. Change of asphericity (0.89±0.25/1.03±0.12, P < 0.001 was highly significant. Change in longitudinal spherical aberrations (0.45±0.33/0.61±0.83, P=0.16) was not found to be significant.

Table 3: For simple myopia, the changes in Posterior Corneal curvature, Asphericity and Longitudinal spherical aberrations before and 3 months after Myopic LASIK (n=12)

	Before	At 3 months	P value
PCC	-6.15±0.16	-6.11±0.16	0.100
Q	0.92±0.14	1.04±0.12	P<0.001
LSA	0.30±0.35	0.54±0.83	0.11

Table 4: For myopic astigmatism, the changes in Posterior corneal curvature, Asphericity and Longitudinal spherical aberrations before and 3 months after Myopic LASIK (n=56)

	Before	At 3 months	P value
PCC	-6.28± 0.18	-6.31± 0.21	0.107
Q	0.86±0.25	1.03± 0.12	P<0.001
LSA	0.48±0.34	0.62±0.84	0.165

From above tables 3 and 4 we can appreciate that the changes in posterior corneal curvature and longitudinal spherical aberrations were not significant in the post-operative myopic as well as myopic astigmatism group, whereas change in asphericity was highly significant with a p value of <0.001 in both the groups.

Table 5: A comparison of total pachymetry between pure myopia and myopic astigmatism group pre operatively and post operatively at 3 months.

	Pure myopia	Myopic Astigmatism	Overall group
TP1	533±24.42	527.87±24.09	528.77±23.51
TP2	488.16±44.50	441.91±44.10	450.07±44.77

TP-Total Pachymetry

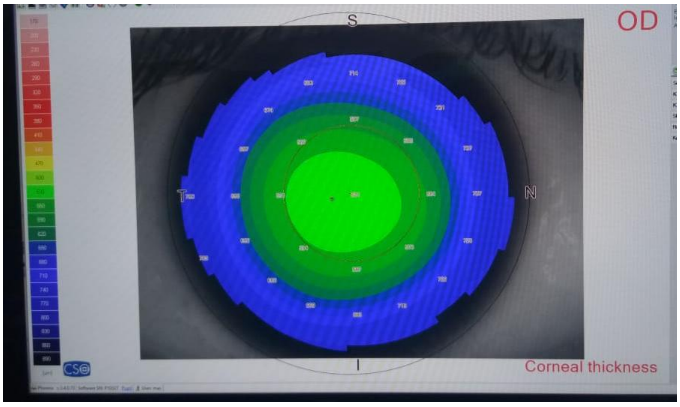


Figure 1 Pachymetry map of patient prior to undergoing LASIK with apical pachymetry of 518 um as indicated by central cool colour.

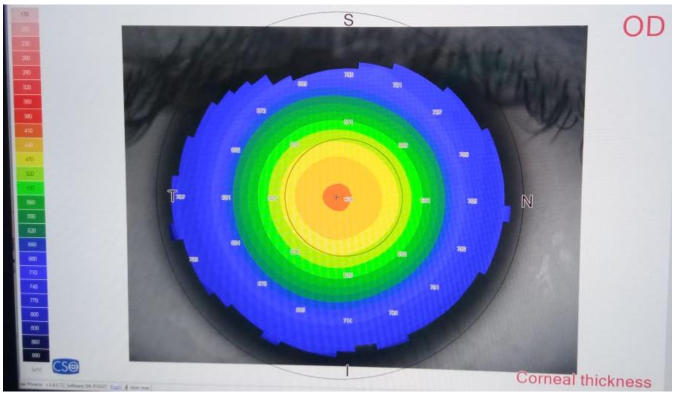


Figure 2: Pachymetry map of same patient post LASIK surgery showing reduced apical pachymetry of 429 um as indicated by central warm colour.

Discussion

In the normal cornea, physiologic stress is borne uniformly throughout the corneal stroma. However the tensile strength of the cornea is not uniform through the superior- inferior or anterior-posterior directions. The anterior 40 % of the stroma has significantly greater tensile strength than the posterior 60 %. This fact has significant implications for excimer laser corneal refractive surgical procedures.

Due to the relative increased weakness of the posterior stroma, LASIK performed with a thicker corneal flap results in deeper ablations into functionally weaker tissues. A thinner corneal flap would mitigate this difference, however overall LASIK appears to have a greater effect on postoperative corneal biomechanics as opposed to surface ablation.

Post LASIK corneal ectasia is a rare but serious complication. This complication may progress to myopic regression, decreased visual acuity and corneal thinning, which may eventually require corneal transplantation for visual rehabilitation.

According to various studies, the residual corneal bed thickness is a key factor to avoid the development of post LASIK iatrogenic corneal ectasia. Many refractive surgeons advocate that the RSBT should not be less than 250 um to avoid iatrogenic keratectasia.[3,4,5]

Wang[6] (1999) found that posterior corneal bulge correlates with residual corneal bed thickness, and the risk of ectasia may be increased if the residual corneal bed thickness is less than 250um. In our study the flap size taken was 90/130 um , while maintaining the residual corneal bed thickness > 250 um in all cases.

In previous studies, Seitz[7] (2001) reports increased negative keratometricdiopters of the posterior corneal curvature following LASIK, and suggest that mild keratectasia of the cornea might be common in the early period after LASIK. A 2002 study by Dimitri[8]et al, reports no significant change in mean keratometric power of the posterior corneal surface at 3 months post LASIK. A 2013 study by Khairat[9], utilising Pentacam to assess changes in the

anterior and posterior corneal surfaces post LASIK reports similar findings as Dimitri et al.
In our study, we did not find statistically significant changes in the posterior corneal curvature post LASIK at 3 months, in simple myopic group as well as myopic astigmatism group.
The index of asphericity (Q) is an indicator of the change in curvature upon movement from the centre to the periphery of the cornea. A normal cornea is prolate (i.e. flattening towards the periphery). A prolate surface has a negative Q value and an oblate surface has positive Q value. In our study, a significant change was seen in the Q (asphericity) value, for the posterior corneal surface at 3 months postoperatively, with a positive shift in the Q value, in simple myopes& myopic astigmatism patients. So the shape of the posterior corneal surface changes from a prolate surface to an oblate surface, which shows steepening towards the periphery.
Highly significant changes in Q value post LASIK were also reported by Bottos[10] with a tendency of the Q value to become more positive following myopic ablation. The findings of change in asphericityin our study are consistent with reports by Hou[11] et al who found that the Q value showed a statistically significant positive shift.
The normal cornea does not have a perfect aspherical design.
This design of the cornea may lead to generation of positive longitudinal spherical aberrations, in people who have a pupil size more than 3mm.[12]
Spherical aberrations are higher order aberrations which can occur in combination with any degree of lower order aberrations and can potentially induce glare and halo and diminish contrast sensitivity.
Spherical aberrations occur when peripheral light rays reach the retina out of sync with the central light rays, either reaching the retina before(positive spherical aberration) or after (negative spherical aberration) central rays. Spherical aberrations are a common cause of halos around point light sources and can cause night vision complaints.
Photoablative or incisional refractive surgery on the eye brings about a significant improvement in the lower order refractive errors (defocus and regular astigmatism) but also leads to the development of higher order corneal aberrations, which are not observed prior to surgery.[13]
In a normal cornea, the Q value ranges from -0.18 to -0.30, it leads to the generation of positive spherical aberration.[14,15]
If the diameter of the pupil remains constant, then the higher order spherical aberrations will become a function of the value of asphericity, refractive index, and radius of curvature. If the asphericity, refractive index, pupil diameter, remain constant then there will be a decrement in the the spherical aberration with a flattening of the corneal surface and increment in the spherical aberrations with an increase in the curvature of the cornea.
If the curvature remains equal, then the longitudinal spherical aberration would become negative if the corneal surface is more prolate; they would become positive if it is less prolate, spherical, or oblate . The more oblate the cornea the greater are the positive spherical aberrations.
Kohnen T et al state that myopic LASIK induces positive spherical aberrations.[16]Similar findings regarding statistically significant elevation of spherical aberrations post LASIK surgery were stated by Miller et al.[17]
However in our study, we found no statistically significant change in the longitudinal spherical aberrations in the post-operative group following LASIK surgery.

Conclusion

From the results of our study we can conclude that the procedure of myopic LASIK does not cause significant changes in the posterior corneal surface.

References

1. Pallikaris IG, Papatzanaki ME, Stathi EZ, Frenschock O, Georgiadis A. Laser in situ keratomileusis. *Lasers Surg Med*. 1990;10:463–468.
2. Dupps WJ Jr. Biomechanical modeling of corneal ectasia.*J Refract Surg*. 2005;21:186–190.

3. Seiler T, Koufala K, Richter G. Iatrogenic keratectasia after laser in situ keratomilieusis. J Refract Surg 1998; 14:3 12-7.
4. Seiler T, Quurke A W. Iatrogenic keratectasia after LASIK in a case of forme frustekeratoconus. J Cataract Refract Surg 1998; 24:1007-9.
5. Probst LE, Machat JJ. Mathematics of laser in situ keratomilieusis for high myopia. J Cataract Refract Surg 1998;24:190-5.
6. Wang Z, Chen J, Yang B. Posterior corneal surface topographic changes after laser in situ keratomilieusis are related to residual corneal bed thickness. Ophthalmology. 1999;106:406-409.
7. Seitz B, Torres F, Langenbucher A, Behrens A, Suarez E. Posterior Corneal Curvature Changes after Myopic Laser In Situ Keratomilieusis. J Ophthalmol 2001 ;108:666-673.
8. Azar DT, Koch DD. Laser fundamentals, surgical techniques and complications. Taylor, chapter 2002, 11:163-170.
9. Khairat Y, Mohamed Y et al. Evaluation of corneal changes after Myopic LASIK using the Pentacam. Clinical Ophthalmology. 2013:7; 1771-1776.
10. Bottos KM, Leite MT, Aventura-Isidro M, et al. Corneal asphericity and spherical aberration after refractive surgery. *J Cataract Refract Surg*. 2011;37:1109–1115 .
11. Hou J, Wang Y, Li J, Yang XY, Zhang L. Change of asphericity of posterior corneal surface after refractive surgery. *Zhonghua Yan Ke Za Zhi*. 2011;47:223–227.
12. Applegate RA. Limits to vision: can we do better than nature? J Refract Surg. 2000; 16(5): S547-51.
13. Applegate RA, Howland HC. Refractive surgery, optical aberrations, and visual performance. J Refract Surg. 1997;13:295-299
14. Guillon M, Lydon DP, Wilson C. Corneal topography: A clinical model. Ophthal Physiol Opt. 1986; 6(1):47-56.
15. Lam A, Douthwaite W. Measurement of posterior corneal asphericityon Hong Kong Chinese: A pilot study. Ophthal Physiol Opt. 1997;17(4): 348-56.
16. Kohnen T, Mahmoud K, Buhren J. Comparison of corneal higher-order aberrations induced by myopic and hyperopic LASIK. Ophthalmology .2005 Oct;112(10):1692.
17. Miller JM, Anwaruddin R, et al. Higher order aberrations in normal, dilated, intraocular lens, and laser in situ keratomilieusis corneas. J Refract Surg.2002;18(5):S579-83.