

# The effect of preoperative keratometry on visual outcomes after moderate myopic LASIK

Steven M Christiansen<sup>1</sup>  
Marcus C Neuffer<sup>1</sup>  
Shameema Sikder<sup>2</sup>  
Rodmehr T Semnani<sup>1</sup>  
Majid Moshirfar<sup>1</sup>

<sup>1</sup>John A Moran Eye Center, University of Utah, Salt Lake City, UT, <sup>2</sup>Wilmer Eye Institute, Johns Hopkins University, Baltimore, MA, USA

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Correspondence: Majid Moshirfar  
65 Mario Capecchi Drive,  
Salt Lake City, UT 84132, USA  
Tel +1 801 581 2352  
Fax +1 801 581 3357  
Email [majid.moshirfar@hsc.utah.edu](mailto:majid.moshirfar@hsc.utah.edu)

**Purpose:** To evaluate visual outcomes in moderately myopic eyes with flat and steep corneas (preoperatively) that have been treated with laser-assisted in situ keratomileusis (LASIK).

**Patients and methods:** Records of ninety-six eyes with average preoperative keratometry (K) values between 39.9 and 42.0 diopters (D) (flat) were matched with 103 eyes with preoperative K values between 46.0 and 47.2 D (steep) that underwent LASIK between March 2007 and March 2010 for moderate myopia, and were retrospectively reviewed. The primary outcome measures used to determine the effect of preoperative keratometry on visual prognosis were refraction, visual acuity, change in keratometry ( $\Delta K$ ), and change in spherical equivalent ( $\Delta SE$ ), measured at 1, 3, 6, and 12 months postoperatively.

**Results:** Significant differences were found at 6 months postoperatively between the flat group and steep group in SE ( $P = 0.029$ ), sphere ( $P = 0.018$ ),  $\Delta K$  ( $P = 0.002$ ), percentage of eyes achieving SE of  $-0.25$  to  $+0.25$  D ( $P = 0.0125$ ),  $-0.26$  to  $-0.50$  D ( $P = 0.003$ ),  $-0.51$  to  $-1.00$  D ( $P = 0.044$ ), and the percentage of eyes achieving uncorrected distance visual acuity of 20/15 or better ( $P = 0.0006$ ).

**Conclusion:** Moderately myopic eyes with flatter corneas preoperatively have better visual prognosis following LASIK compared with moderately myopic eyes with steeper corneas.

**Keywords:** keratometry, cornea, LASIK, refractive surgery

## Introduction

The relationship between preoperative keratometry (K) and visual outcomes in laser-assisted in situ keratomileusis (LASIK) has been studied in high myopia and hyperopia, but not in moderate myopia. Rao et al report increased undercorrection in eyes with preoperative spherical equivalent (SE) of  $-10.0$  to  $-11.9$  diopters (D), and in eyes with flat corneas compared with steeper corneas.<sup>1</sup> Williams et al, conversely, reported undercorrection and loss of best spectacle corrected visual acuity (BSCVA) following hyperopic LASIK in eyes with steep corneas, compared with flat corneas.<sup>2</sup> To our knowledge, to date no study has analyzed visual prognosis based on preoperative keratometry in moderately myopic LASIK. In this retrospective analysis, we studied the relationship between preoperative keratometry and postoperative visual outcomes in flat and steep corneas treated with LASIK for the correction of moderate myopia ( $-2.00$  to  $-5.99$  D).

## Patients and methods

From March 2007 to March 2010, a total of 1131 eyes underwent LASIK for the correction of moderate myopia at the John A Moran Eye Center, University of Utah.

Of these, 96 eyes with average K of 39.9 D to 42.0 D (flat) were compared with 103 eyes with average K of 46.0 D to 47.2 D (steep). All eyes had been targeted for emmetropia and treated with the VISX™ Star S4 CustomVue Excimer Laser System (Abbott Medical Optics Inc, Santa Ana, CA), had received no prior eye surgeries, and had received follow-up for at least 6 months. Eyes that had been classified as “high risk” or “moderate risk” (using Randleman’s Ectasia Risk Factor Score System) were excluded, leaving only eyes classified as “low-risk” for ectasia.<sup>3</sup>

All eyes were stringently screened for keratoconus, and the presence of risk factors associated with forme fruste keratoconus, using slit-lamp examination, retinoscopy, topography, and Rabinowitz criteria.<sup>4–6</sup> Additionally, all eyes were screened for asymmetry, non-orthogonal bowties, or skewed radial axes, with topographic analysis using the Orbscan® IIz (Bausch and Lomb, Rochester, NY). Corneal K values were measured using an Atlas™ Corneal Topographer (Carl Zeiss Meditec Inc, Dublin, CA).

Eyes were placed into two groups based on preoperative average K, where  $K_{\text{average}} = (K_{\text{flat}} + K_{\text{steep}})/2$ . Eyes with average K values of 39.9 D to 42.0 D were placed in the “flat group” and eyes with average K values of 46.0 D to 47.2 D were placed in the “steep group.” Eyes were matched according to preoperative age, SE, sphere, and cylinder. Residual stromal thickness (RST) was calculated by subtracting flap thickness and ablation depth from preoperative corneal thickness. Change in K ( $\Delta K$ ) was calculated as preoperative minus postoperative average K. Change in SE ( $\Delta SE$ ) was calculated as postoperative SE minus preoperative SE. Table 1 shows the

demographic and preoperative characteristics. Differences between the two groups were statistically evaluated using an independent Student’s *t*-test of equal variance and a two-sided *z*-test for proportions.

## Description of procedure

LASIK was performed using standard protocol by two refractive eye surgeons at the Moran Eye Center, University of Utah. K readings were considered in the planning stage prior to surgery, and the same nomogram was used for all treatments. The residual stromal bed was planned to be >260  $\mu\text{m}$  to avoid excessive corneal thinning associated with post-LASIK ectasia. Superior hinged lamellar flaps were created with a Hansatome Microkeratome (Bausch and Lomb Surgical, Rochester, NY) using a 160  $\mu\text{m}$  plate and 9.0 mm ring. Laser ablation was performed using the VISX™ Star S4 CustomVue system, creating a 6.5 mm optical zone with 8.0 mm blend zone. Following ablation, the flap was replaced and the patients then received fluoroquinolone and prednisolone acetate 1% drops. Standardized graphs were used to analyze accuracy, efficacy, safety, and stability. SE was measured at the spectacle plane. Uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), and average K measurements were performed at 1, 3, 6, and 12 month postoperative visits. The primary endpoint reported in this study is 6 months postoperatively.

## Results

Table 1 shows the preoperative patient characteristics by group. No statistically significant difference existed

**Table 1** Demographic and preoperative characteristics

Demographics	Flat	Steep	
Patients (n)	64	77	
Eyes (n)	96	103	
Male:female	2:3	3:4	
Preoperative characteristics	Mean $\pm$ SD (range)	Mean $\pm$ SD (range)	P-value
Age (y)	37.9 $\pm$ 9.3 (23 to 62)	39.0 $\pm$ 8.6 (22 to 54)	0.387
Spherical equivalent (D)	-3.61 $\pm$ 0.99 (-2.00 to -5.75)	-3.76 $\pm$ 1.12 (-2.00 to -5.875)	0.255
Sphere (D)	-3.95 $\pm$ 1.01 (-2.25 to -6.50)	-4.16 $\pm$ 1.21 (-2.25 to -6.75)	0.182
Cylinder (D)	0.66 $\pm$ 0.56 (0.00 to 2.75)	0.76 $\pm$ 0.73 (0.00 to 2.75)	0.307
Keratometry (D)	41.4 $\pm$ 0.50 (39.9 to 42.0)	46.5 $\pm$ 0.33 (46.0 to 47.2)	4.46 $\times 10^{-156}$
Pachymetry ( $\mu\text{m}$ )	557 $\pm$ 29 (507 to 640)	555 $\pm$ 32 (500 to 632)	0.653
Ablation depth ( $\mu\text{m}$ )	52 $\pm$ 15 (15 to 89)	56 $\pm$ 17 (12 to 93)	0.186
RST ( $\mu\text{m}$ )	336 $\pm$ 41 (274 to 436)	336 $\pm$ 44 (278 to 448)	0.989
Low Randleman risk score (%)	100	100	
Rabinowitz criteria (%)	0	0	

**Notes:** Values are calculated using homoscedastic independent Student’s *t*-test; Low Randleman risk score: 0–2; Rabinowitz criteria: Keratometry > 47.2.

**Abbreviations:** SD, standard deviation; D, diopters; RST, residual stromal thickness.

between the flat and steep matched cohort groups in mean preoperative age ( $P = 0.387$ ), SE ( $P = 0.255$ ), sphere ( $P = 0.182$ ), cylinder ( $P = 0.307$ ), pachymetry ( $P = 0.653$ ), ablation depth ( $P = 0.186$ ), or residual stromal thickness ( $P = 0.989$ ). As expected, a significant difference was found between the flat and steep groups in mean preoperative K ( $P = 4.46 \times 10^{-156}$ ).

Table 2 shows the outcomes measured at 6 months postoperatively. Significant differences were found between the flat and steep groups in SE ( $P = 0.029$ ), sphere ( $P = 0.018$ ), K ( $P = 1.21 \times 10^{-42}$ ), and  $\Delta K$  ( $P = 0.002$ ). There was no statistically significant difference in cylinder ( $P = 0.294$ ) or  $\Delta SE$  ( $P = 0.823$ ).

Figure 1 shows a stratification of eyes into the percentage of eyes achieving SE of  $-0.25$  to  $+0.25$  D,  $-0.26$  to  $-0.50$  D, and  $-0.51$  to  $-1.00$  D, measured at 6 months postoperatively. All three categories showed a statistically significant difference between the flat and steep groups. Seventy-five percent of eyes in the flat group achieved SE of  $-0.25$  to  $0.25$  D, compared with 60% in the steep group ( $P = 0.0125$ ). Four percent of eyes in the flat group achieved SE  $-0.50$  to  $-0.26$  D, compared with 17% in the steep group ( $P = 0.003$ ). Five percent of eyes in the flat group achieved SE of  $-0.51$  to  $-1.00$  D, compared with 14% in the steep group ( $P = 0.044$ ). A significant difference was also found in the percentage of eyes achieving UDVA of 20/15 or better (Figure 2), where 42% of eyes in the flat group achieved UDVA of 20/15 or better, compared with 19% in the steep group ( $P = 0.001$ ). No significant difference was found between the two groups in change in Snellen Lines of CDVA (Figure 3). In the flat and steep groups, respectively, 72% and 66% had  $\leq 0.25$  D of refractive astigmatism (Figure 4). Five percent of eyes in the flat group and 2% of eyes in the steep group experienced a change in SE greater than 0.50 D between 6 and 12 months postoperatively, though this difference was not significant (Figures 5 and 6).

## Discussion

To the best of our knowledge, this is the first study to analyze visual outcomes in moderate myopia, comparing notably flat and steep preoperative keratometry using a matched cohort study design. The flat and steep groups were matched by age, preoperative SE, and preoperative cylinder, as well as having identical microkeratome models and excimer laser ablation platforms. The results suggest that moderately myopic eyes with flatter corneas have better visual outcomes than those with steeper corneas.

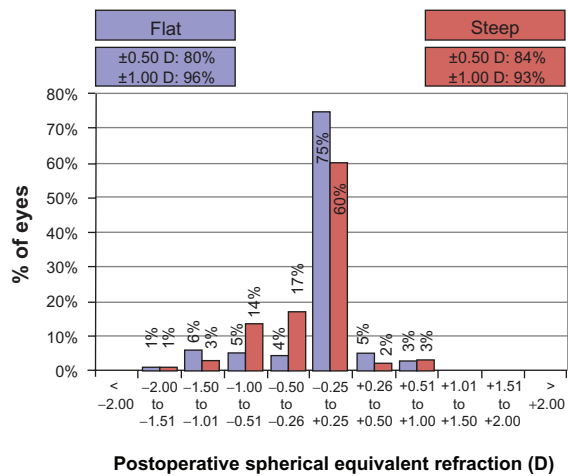
The clinical relevance of this study is best understood through comparison with the results of previous studies that examined eyes with high myopia and hyperopia. Our study, focusing on eyes with moderate myopia of  $-2.00$  to  $-5.99$  D, contradicts the results of previous studies that examined eyes with high myopia prior to LASIK.<sup>1,7-13</sup> Rao et al found that eight eyes with K  $< 43.5$  D and myopia of  $-10.0$  to  $-11.9$  D had a 3-month SE that was significantly different compared with sixteen eyes with K  $> 44.5$  and similarly high myopia. They also suggested a trend toward undercorrection, though the trend was not statistically significant and had an  $r^2$  value of just 0.03.<sup>1</sup> Perez-Santonja et al also reported a tendency toward undercorrection in eyes with flatter corneas that had received LASIK for the correction of high myopia of  $-8.00$  to  $-20.00$  D.<sup>7</sup> This study differs from the two studies mentioned above, because it examined a greater sample of eyes, including eyes with moderate myopia of  $-2.00$  to  $-5.99$  D. Several authors have found that, after myopic procedures, induced spherical aberrations tend to be positive and correlated with the magnitude of the intended correction. They have also made the observation that corneal asphericity, tissue removal, and tissue remodeling have made it difficult to establish an optimum profile. In our study, however,  $\Delta SE$  was similar in the flat and steep groups. Thus, our findings are unlikely to be explained solely by tissue remodeling,

**Table 2** Outcomes at 6 months postoperatively

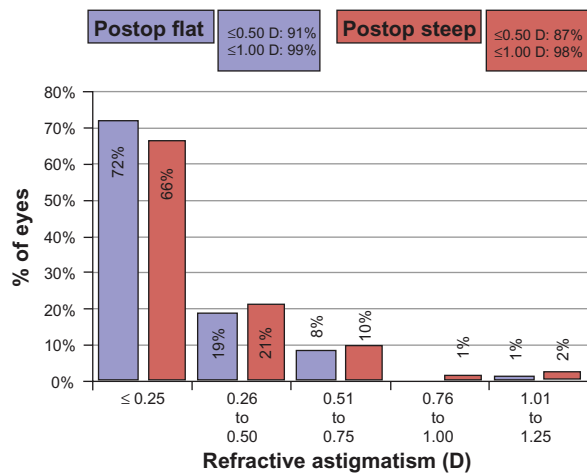
	Flat	Steep	P-value
	Mean $\pm$ SD (range)	Mean $\pm$ SD (range)	
Spherical Equivalent (D)	$-0.10 \pm 0.45$ ( $-1.63$ to $1.00$ )	$-0.23 \pm 0.43$ ( $-1.75$ to $0.75$ )	0.029
Sphere (D)	$-0.21 \pm 0.47$ ( $-1.75$ to $0.75$ )	$-0.37 \pm 0.47$ ( $-2.00$ to $0.50$ )	0.018
Cylinder (D)	$0.23 \pm 0.27$ ( $0.00$ to $1.25$ )	$0.27 \pm 0.30$ ( $0.00$ to $1.25$ )	0.294
Keratometry (D)	$38.90 \pm 1.11$ ( $36.00$ to $41.19$ )	$43.30 \pm 1.08$ ( $41.31$ to $46.19$ )	$1.21 \times 10^{-42}$
$\Delta K$ (D)	$2.55 \pm 1.11$ ( $0.45$ to $5.25$ )	$3.17 \pm 0.96$ ( $0.97$ to $4.94$ )	0.002
$\Delta SE$ (D)	$3.52 \pm 1.13$ ( $1.25$ to $6.125$ )	$3.55 \pm 1.15$ ( $0.75$ to $6.13$ )	0.823

**Note:** Values are calculated using homoscedastic independent Student's t-test.

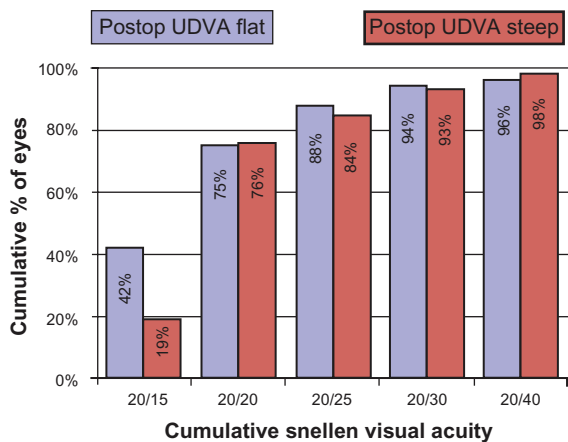
**Abbreviations:** SD, standard deviation; K, keratometry; D, diopters; SE, spherical equivalent;  $\Delta K$ ,  $K_{\text{avg}(\text{preop})} - K_{\text{avg}(\text{postop})}$ ;  $\Delta SE$ ,  $SE_{\text{postop}} - SE_{\text{preop}}$ .



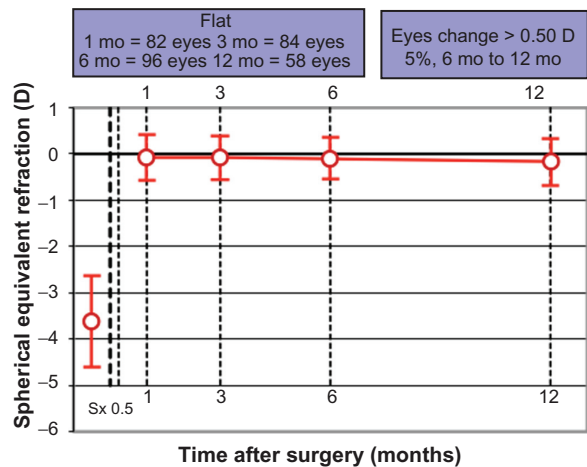
**Figure 1** Distribution of postoperative SE refraction, with a higher percentage of eyes being closer to plano in the flat group than in the steep group.  
**Abbreviation:** D, diopters.



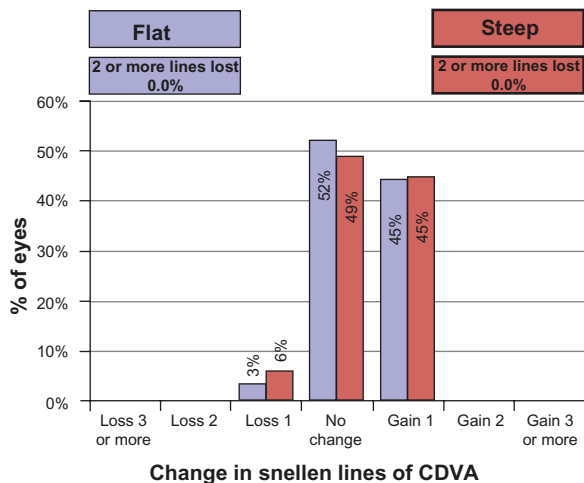
**Figure 4** Postoperative refractive astigmatism with the majority of eyes in each group achieving ≤0.25 diopters of astigmatism.



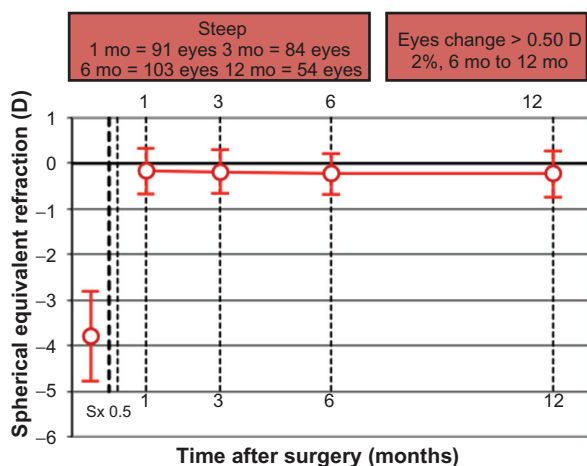
**Figure 2** Postoperative visual acuity.  
**Note:** More eyes achieved UDVA of 20/15 in the flat group than in the steep group.  
**Abbreviation:** UDVA, uncorrected distance visual acuity.



**Figure 5** Flat group demonstrating small changes in postoperative SE refraction over 12 months.  
**Abbreviation:** SE, spherical equivalent.



**Figure 3** Number of lines of CDVA lost or gained after surgery between the flat and steep groups.  
**Abbreviation:** CDVA, corrected distance visual acuity.



**Figure 6** The steep group, demonstrating small changes in postoperative SE refraction over 12 months.  
**Abbreviation:** SE, spherical equivalent.

corneal asphericity, and spherical aberration, which may occur secondarily to ablation efficiency reduction.<sup>14–19</sup>

Two other studies, although they examine hyperopic LASIK, coincide with our results. Williams et al prospectively examined 6-month follow-up data and found an increased incidence of loss of BSCVA with eyes that had preoperative K >44.0 D.<sup>2</sup> Esquenazi et al found that undercorrection occurred more frequently in eyes with preoperative K >45.0 D.<sup>20</sup> Furthermore, several studies have examined the effect of preoperative K on outcomes in surface ablation. However, these results should be cautiously applied to LASIK, because the flap created causes changes in the cornea that are not present in surface ablation techniques.<sup>3,21</sup> The flap can vary in size depending on preoperative keratometry, and by itself can induce astigmatism or hyperopia, depending on hinge position and depth of stromal involvement.<sup>22,23</sup>

A weakness of our study is that it is retrospective and that RST was calculated instead of being measured intraoperatively, which could have affected calculations for Randleman's criteria. It is also possible that eyes in the steep group were subject to subclinical keratectasia not seen in evaluation of preoperative topography, thus providing a possible explanation for suboptimal outcomes in comparison to eyes in the flat group. However, screening with the use of Rabinowitz's criteria, ideally, eliminated eyes with forme fruste keratoconus. Furthermore, our findings were consistent with those of Ortega-Usobiaga et al, who found no post-LASIK ectasia among eyes with steep corneas preoperatively.<sup>24</sup> Applying Randleman's Ectasia Risk Factor Score System demonstrated that all eyes in each group were classified as low-risk for ectasia and did not meet Rabinowitz's criteria for forme fruste keratoconus (Table 1). However, despite our efforts to screen for ectasia-risk, the possibility remains of subclinical and subtopographical keratectasia characteristics in the eyes with steep corneas, which could manifest at a follow-up time of greater than 12 months.

## Conclusion

Moderately myopic eyes with flatter corneas tend to have better visual outcomes after LASIK than those with steeper corneas. Further studies should be performed to better define the effect that keratometry has on LASIK outcomes at varying levels of preoperative refraction. The findings of this study will assist surgeons to better predict prognosis in eyes with K of 39.9 to 42.0 D, which may previously have been found ineligible for moderate myopic LASIK,

and also to consider more aggressive laser ablation in eyes with K of 46.0 to 47.2 D, so as to avoid the undercorrection described in this study. At present, many refractive surgeons use nomograms that do not include preoperative K values to calculate postoperative refraction. We suggest that preoperative K should be one of the featured factors in pre-treatment nomogram calculation.

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## Disclosure

The authors have no financial interests in any materials or products discussed in this manuscript, or any other disclosures.

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