·Clinical Research·

Kappa angles in different positions in patients with myopia during LASIK

Hui Qi[1,2], *Jing-Jing Jiang*[3], *Yan-Ming Jiang*[1], *Li-Qiang Wang*[1], *Yi-Fei Huang*[1]

[1]Department of Ophthalmology, Chinese PLA General Hospital, Beijing 100853, China
[2]Department of Ophthalmology, Bethune International Peace Hospital of PLA, Shijiazhuang 50082, Hebei Province, China
[3]Department of Ophthalmology, Beijing Children's Hospital, Capital Medical University, Beijing 100045, China
Correspondence to: Yi-Fei Huang. Department of Ophthalmology, Chinese PLA General Hospital, Fuxing Road No. 28, Haidian District, Beijing 100853, China. 301yk@sina.com
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Abstract

• **AIM: To investigate the difference in kappa angle between sitting and supine positions during laser-assisted *in situ* keratomileusis (LASIK).**

• **METHODS: A retrospective study was performed on 395 eyes from 215 patients with myopia that received LASIK. Low, moderate, and high myopia groups were assigned according to diopters. The horizontal and vertical components of kappa angle in sitting position were measured before the operation, and in supine position during the operation. The data from the two positions were compared and the relationship between kappa angle and diopters were analyzed.**

• **RESULTS: Two hundred and twenty-three eyes (56.5%) in sitting position and 343 eyes (86.8%) in supine position had positive kappa angles. There were no significant differences in horizontal and vertical components of kappa angle in the sitting position or horizontal components of kappa angle in the supine position between the three groups (P>0.05). A significant difference in the vertical components of kappa angle in the supine position was seen in the three groups (P<0.01). Differences in both horizontal and vertical components of kappa angles were significant between the sitting and supine positions. Positive correlations in both horizontal and vertical components of kappa angles (P<0.05) were found and vertical components of kappa angle in sitting and supine positions were negatively correlated with the degree of myopia (sitting position: r=-0.109; supine position: r=-0.172; P<0.05).**

• **CONCLUSION: There is a correlation in horizontal and vertical components of kappa angle in sitting and supine positions. Positive correlations in both horizontal and vertical components of kappa angle in sitting and supine positions till the end of the results. This result still needs further observation. Clinicians should take into account different postures when excimer laser surgery needs to be performed.**

• **KEYWORDS:** kappa angle; myopia; keratomileusis; laser *in situ*; supine position
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INTRODUCTION

Several advantages including painless, fast recovery, steady curative effects, extensive application scope, and less postoperative complications have made laser *in situ* keratomileusis (LASIK), a popular treatment method for both ophthalmologists and myopia patients [1]. However, with the improvement of uncorrected visual acuity, some other side-effects including loss of night vision, glare, and reduction of contrast sensitivity have also emerged [2]. Previous studies have demonstrated that eccentric ablation is a major influence on visual quality [3-4], and kappa angle has been acknowledged as the main cause of eccentric ablation[5-6]. The human eye is a complex optical system, and several significant parameters including eye axis, visual axis, pupillary axis, kappa angle, and alpha angle play important roles in vision quality. Kappa angle is the angle between optical axis and visual axis, which is about 5° for normal human eye [7]. Investigation of kappa angle could be of important clinical significance. Most ablations are centered on the pupil center in LASIK; as the optical ablation zone is relatively large (the diameter of the optical zone is generally larger than 6 mm), and the diversion between the optical center and pupil center is very small, slightly eccentric ablation will not substantially influence visual quality [6]. Previous studies have demonstrated that eccentricity <0.5 mm could not significantly affect the best corrected visual acuity. However, larger kappa angle can result in pronounced eccentric ablation and thus increase the high-order aberration and comatic aberration. The increased high-order aberration and especially comatic aberration can induce several postoperative complications including visual loss, glare, and poor night vision[8-9].

Many investigations have demonstrated the benefits of moving centration to adjust for large kappa angles [10-13]. Comparison with pupil centered LASIK suggests that higher order aberrations are less when a large kappa angle is considered [10]. However, a small randomized comparison showed no statistical differences between the two methods, this may be because of the small samples size[14]. While kappa angle is increasingly being considered in LASIK, the kappa angle should also be considered when determining surgical correction amount in strabismus, and larger kappa angle could be found in patients with exotropia than the ones with esotropia [15]. In addition, blurred vision, glare, halo, and decreased contrast sensitivity can also be found in patients treated with implantation of intraocular lenses (especially the multifocal intraocular lens)[16], which could also be partially caused by the kappa angle. So the kappa angle may be important for many types of refractive surgery.

Cyclotorsion is found for most eyeballs and the pupil center is shifted upward or toward the upper nasal region when the position of patient is changed from sitting to supine position in LASIK [17-18]. Accordingly it has been suggested that this phenomenon should be monitored to correct for errors during ablation [19]. We hypothesized that kappa angle could also change in a similar manner.

The distribution of kappa angle in myopia patients and the effects of different positions on kappa angle have not been reported to date. In the present study, kappa angles in sitting and supine positions were recorded in myopia patients before and during the operation, and then the changes in the kappa angles in supine position during the operation were analyzed to provide evidence for improving the quality of LASIK.

SUBJECTS AND METHODS

Subjects In this retrospective study, 395 eyes from 215 patients (including 113 males and 102 females) that had been treated with LASIK in the Laser Treatment Center of the Chinese PLA General Hospital between July and December, 2010 were included. The inclusion criteria were patients who 1) have had myopia for more than 2y and the deepening development each year was not greater than 0.50 D; 2) had myopia within 12.00 D, astigmatism within -4.00 D; 3) had no active eye lesions; 4) voluntarily opted for surgery; 5) were 18-50 years old; 6) had normal tear secretion. The exclusion criteria were patients with 1) keratoconus; 2) occult keratoconus; 3) ocular fundus pathology. The patients were divided into low (below -3.00 D), moderate (-3.00 D to -6.00 D), and high myopia (>-6.00 D) groups. This work has been carried out in accordance with the Declaration of Helsinki of the World Medical Association. This study was approved ethically by the Peoples' Liberation Army General Hospital. All patients provided informed written consent.

Measurement Processes Horizontal and vertical components of kappa angle in the sitting position were measured by Oculus Pentacam analytical system (Oculus Optikgeräte GmbH, Germany) before the operation. For LASIK, routine preoperative preparations were performed, and the eye to be operated was sterilized. The patient was put in supine position, and an eye-speculum was used to hold the eye open. The patient was asked to look at the indicator light above, before corneal flap making, during which process a reflective point at the corneal vertex (the center of optical axis) and red reflection (the central of optic axis) could be seen. X and Y axis tracking modulations of an Allegretto Wavelight Excimer Laser System (WaveLight Laser Technologie AG, Germany) were used to overlap these two reflective points, then obtain the kappa angles in supine position with the references of horizontal and vertical regulating quantities that were displayed by the system. The brightness during the process was carefully adjusted to ensure the size of pupil was identical to the size measured by the Oculus Pentacam Analytical System before the operation. The vector analysis method was used for the objective analysis of the angular dimension and direction of the kappa angle [20]. The components of optical axis from pupillary axis were resolved into X-axis (horizontal) and Y-axis (vertical), and the components toward the upper nasal side was considered as positive, while components toward lower temporal side was considered as negative. In the present study, kappa angle in the sitting position was measured by an intermediate ophthalmologist, and measurement in supine position was done by a senior ophthalmologist who operate the LASIK.

Statistical Analysis SPSS 17.0 (SPSS Inc., Chicago, IL, USA) software was used for the statistical analyses. Data were presented as numbers and percentages for categorical data and mean values±standard deviation (SD) for numeric data. One-way analysis of variance (ANOVA) was used to investigate the relationship between the distribution of kappa angle and diopter, paired t-test was used for the comparison of quantitative data between sitting and supine positions, and Pearson's correlation analysis was used to investigate the relationship between the horizontal and vertical components of kappa angles in sitting and supine positions. $P<0.05$ was considered statistically significant.

RESULTS

Background Characteristics The mean age of the patients was 23.2±5.1y (range 17 to 54y). Forty patients with a total of 61 treated eyes (including 28 right eyes and 33 left eyes, the mean diopter was -2.20±0.83 D) were placed into the low myopia group, 122 patients with a total of 208 treated eyes (including 105 right eyes and 103 left eyes, the mean diopter was -4.58±0.89 D) were in the moderate myopia group, and

Table 1 Distribution of kappa angles in sitting and supine positions *n* (%)

Eye	Position	Superior nasal	Inferior nasal	Superior temporal	Inferior temporal
Right eye (*n*=199)	Sitting	89 (44.7)	25 (12.6)	51 (25.6)	34 (17.1)
	Supine	151 (75.9)	33 (16.6)	10 (5.0)	5 (2.5)
Left eye (*n*=196)	Sitting	79 (40.3)	30 (15.3)	67 (34.2)	20 (10.2)
	Supine	126 (64.3)	33 (16.8)	23 (11.8)	14 (7.1)
Total (*n*=395)	Sitting	168 (42.5)	55 (13.9)	118 (29.9)	54 (13.7)
	Supine	277 (70.1)	66 (16.7)	33 (8.4)	19 (4.8)

Table 2 Offsets of kappa angle and diopter in sitting and supine positions $\bar{x} \pm s$, μm

Groups	Diopter	Position	Horizontal offset	Vertical offset
Low myopia (*n*=61)	-2.20±0.83	Sitting	13.9±142.80	63.8±150.60
		Supine	74.6±138.37	-4.9±107.48
		P	<0.001	0.0112
Moderate myopia (*n*=208)	-4.58±0.89	Sitting	-0.6±113.84	60.8±132.25
		Supine	81.0±138.02	13.8±104.91
		P	<0.001	<0.001
High myopia (*n*=126)	-7.39±1.23	Sitting	3.0±141.91	79.6±158.1
		Supine	68.9±146.10	43.6±100.62
		P	<0.001	0.0005

P: Comparisons between sitting and supine positions. The offsets of kappa angle comparison between the low, moderate, and high groups for sitting horizontal: *P*=0.7389; for sitting vertical: *P*=0.5015; for supine horizontal: *P*=0.7450; for supine vertical: *P*=0.0005, comparison between each groups, *P* value all for <0.01.

71 patients with a total of 126 treated eyes (including 66 right eyes and 60 left eyes, the mean diopter was -7.38±1.23 D) were in the high myopia group.

Kappa Angle Measurements From the total of 395 eyes including 199 right eyes and 196 left eyes in this study, both positive and negative kappa angles were found, but most of them were positive kappa angles. Data of the kappa angles in the left and right eyes were found to be symmetric. More positive kappa angles were found when the position was changed from sitting to supine position (Table 1; Figure 1).

Change in Kappa Angles with Position Horizontal components of kappa angles increased when the position of the patient changed from sitting to supine, while vertical components of kappa angles decreased. The horizontal and vertical components of the kappa angles were significantly different in sitting and supine positions and positive relationships were also found ($r_{horizontal}$=0.562, $r_{vertical}$=0.501; $t_{horizontal}$=-11.57, $t_{vertical}$=7.24, P<0.05). The relationship between kappa angle and diopter showed no significant difference among low, moderate and high groups in the horizontal component in the sitting (P=0.7389) and supine (P=0.7450) positions or the vertical components of kappa angle in the sitting position (P=0.5015); in contrast, a significant difference in the vertical component was found in the supine positions in the three groups (P=0.0005 between each group and P<0.01 for all groups). No association between the horizontal components and diopter was found in either sitting or supine position (P>0.05), while negative association between the vertical components and diopter was found in either sitting or supine position ($r_{sitting}$=-0.109, r_{supine}=-0.172; P<0.05), suggesting that the vertical component increased with diopter. Positive associations between the vertical and horizontal components were also found in both sitting and supine positions, which means that when the horizontal and vertical components of kappa angle increased in the sitting position, the horizontal and vertical components of kappa angle also increased in the supine position (Tables 2 and 3).

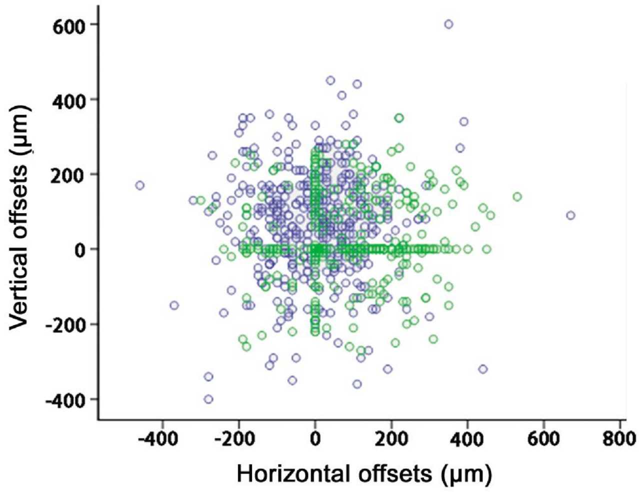

Figure 1 Distribution of kappa angles in sitting and supine positions Blue circles on the X-axis represent horizontal components and Y-axis represent vertical components of kappa angle in sitting position; Green circles on the X-axis represent horizontal components and Y-axis represent vertical components of kappa angle in supine position.

Table 3 Comparison of kappa angle between sitting and supine positions $\bar{x} \pm s$, μm

Orientation	Position	Offset (n=395)	t	r	P
Horizontal	Sitting	6.43±127.78	-11.57	0.562	<0.001
	Supine	7.07±140.45			
Vertical	Sitting	7.23±14.37	7.24	0.501	<0.001
	Supine	5.29±105.11			

r: Pearson's correlation coefficient.

DISCUSSION

Angle kappa is defined as the angle between optical axis and visual axis, with recent advancements of refractive surgery, angle kappa stands as an important consideration in improving visual outcomes. Adjusted kappa angle of LASIK is to minimize the risk of decentration and improve the visual quality.

The aim of this study was to investigate the distribution of kappa angles in myopia and whether kappa angle changes occur when the patient changes from sitting to supine position. To achieve more accurate results we measured the angle kappa in a large sample of patients with myopia that received LASIK. Low, moderate, and high myopia groups were assigned according to diopters. Let the patients relax and look at indicator light, then measured the size of pupil by the video pupil tracking and adjust the brightness carefully to ensure the size of pupil was identical to the size measured by the Oculus Pentacam analytical system before the operation.

The findings of the present study showed that the kappa angles could be positive or negative in patients with myopia, however, most of the myopia patients had a positive kappa angle. This trend is in agreement with previous studies [6]. In addition, we also found that the kappa angle in the left and right eyes were symmetric. The horizontal component of kappa angle was increased when the patient changed from sitting to supine position, while the vertical component was decreased. More positive kappa angles were found in the supine position than in the sitting position, especially more kappa angles were found in superior nasal region, which is in accordance with the cyclotorsion effects [17-19]. We observed more positive kappa angles in the right than left eyes when the position was changed from sitting to supine position. Right eye was operated first, the patient felt more nervous than left eye was operated. Cyclotorsion of the right eye occurs more than left eye.

Horizontal component of kappa angle was not associated with diopter, while increased vertical component of kappa angle was found in patients with higher diopter, which could be caused by the deeper anterior chamber, longer ocular axis, and macular dislocation in such patients. Therefore, investigating the pattern of kappa angle changes in different positions, and seriously considering the role of kappa angle in refractive surgeries could be of importance in reducing complications including glare and halo, and increase the visual quality by correcting kappa angle[5].

The study has some limitations. A main defect in the methodology which is measuring kappa angle in the setting and supine positions with two different machines: pentacam in the sitting position and the allegretto machine in the supine position. There is no method to measure kappa angle in both positions now. In addition to the factors investigated in the present study, some other factors including age, depth of anterior chamber, and length of ocular axis are also associated with the size of kappa angle [8,21], while gender has not been correlated with kappa angle [22] but we did not investigate any other factors in this study. We also did not investigate outcomes of the LASIK in order to evaluate whether these differences in kappa angle did have an effect upon the visual quality after operation, these points remain to be answered by further research.

In conclusion, we found that the majority of patients with myopia had positive kappa angles. Kappa angle was altered according to patient position with increased horizontal component and decreased vertical component when changing from sitting to supine position. This information should provide important background for refractive surgery.

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