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Analysis of the Factors Affecting Decentration in Photorefractive Keratectomy and Laser In Situ Keratomileusis for Myopia

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Abstract

To evaluate the relationship between ablation zone decentration measured by corneal topography and various factors such as sex, age, order of operation, preoperative sedative prescription, ablation diameter and depth, type of procedure (photorefractive keratectomy=PRK, laser in situ keratomileusis=LASIK), and the use of a passive eye tracker, we examined the data of 80 eyes in 50 patients. The patients received PRK (43 eyes in 30 patients) or LASIK (37 eyes in 20 patients), and were followed for 3 months postoperatively. Statistical analysis of the data was performed using t-test, ANOVA and multiple regression analysis. The overall average ablation decentration from the pupil center was 0.43±0.27 mm, 0.35±0.22 mm in PRK and 0.47±0.30 mm in LASIK. Overall 91.3% of patients were decentered less than 0.75 mm and 95.0% were decentered less than 1.00 mm, while 93.9% of patients were decentered less than 0.75 mm in PRK and 88.7% were decentered less than 0.75 mm in LASIK. The most meridional displacement was toward the superonasal quadrant; 46% in PRK and 51% in LASIK. There was less decentration in males, in the 2^{nd}-operated eye, in older age, PRK, in larger ablation diameter, and in shallower ablation depth, but these differences were not statistically significant.

Key Words: Decentration, photorefractive keratectomy, laser in situ keratomileusis

INTRODUCTION

Ablation zone decentration is critical to the success of refractive procedures such as photorefractive keratectomy (PRK) and laser in situ keratomileusis (LASIK) for myopia since decentration may lead to decreased visual acuity, halo, glare,[1] monocular diplopia, irregular astigmatism, and decreased contrast sensitivity.[2]

During corneal centering, the corneal light reflex has often been used, but its actual location was not accurately known. It is thought to be a virtual image of the light source, formed by the reflection of light from the anterior surface of the cornea and 3.90 mm behind the front surface of the cornea.[3] However, it was later found to be optically wrong since Uozato et al. introduced the line of sight.[3] As a result, center of entrance pupil of the eye, which is a virtual image of the real pupil center formed by the refraction of light at the cornea, is now used as the true corneal center. Although previous studies measured ablation zone decentration by corneal topographic analysis, identifying the ablation zone center and measuring its distance from the pupil center has been difficult. However, pupil-finding software was developed with the progress of topographic instruments, so we are now able to analyze ablation zone decentration from the pupil center reliably and reproducibly.

There have been very few reports comparing the decentration between PRK and LASIK. Therefore, we evaluated the amount of ablation decentration after PRK or LASIK using this pupil-finding software and compared them, analyzing the factors which affect the decentering amount using t-test, ANOVA and multiple regression analysis.

MATERIALS AND METHODS

Eighty eyes in 50 patients having PRK or LASIK

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for myopic refractive errors were studied. All procedures were performed by one surgeon at YongDong Severance Hospital between October 1997 and March 1998. We used a Schwind Keratome II excimer laser (Coherent-Schwind, Neuostheim, Germany), and automated microkeratome (Automated Corneal Shaper, Chiron Vision, Claremont, California, USA) in cases of LASIK. Corneal topographic analysis using the Orbscan (Orbtek, Salt lake city, Utah, USA) was done preoperatively and 3 months postoperatively. There were 9 males and 41 females, and their average age was 29±6.8 years (21−55 years). Their myopic refractive error was −6.56±3.24 D on average. The patients were divided into two groups. The first group comprised 43 eyes in 30 patients who had an average of −4.91±1.07 D myopia corrected by PRK. The second group comprised 37 eyes in 20 patients who had an average of −8.44±3.83 D myopia corrected by LASIK.

Our techniques for ablation centration in PRK and LASIK were as follows. In the case of PRK, the operative procedure was preceded by applying 2 drops of topical anesthetic to the operative eye. Patients observed a fixation light which was coaxial to the laser beam, with the aiming beam focused on the cornea and the fellow eye patched. After identifying the area for epithelial removal with a 7.00 mm optic zone

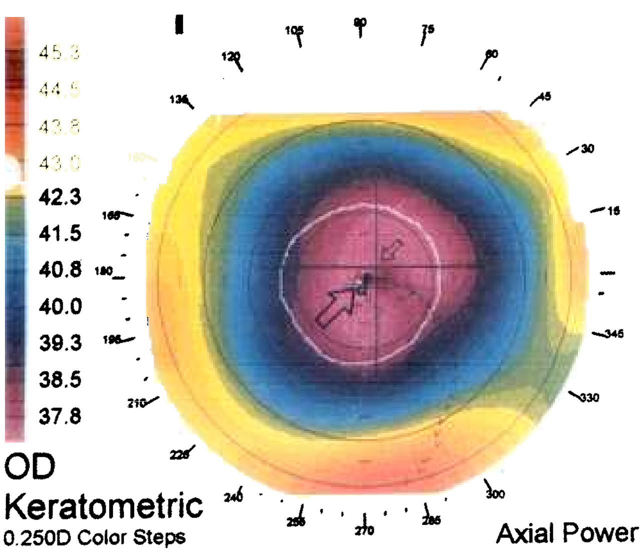

Fig. 1. The farthest 4 edges of the ablation in the X- and Y-axis were marked with a fine-tipped pen, and the intersecting point of these 4 points (small arrow) was determined to be the ablation center. The distance between the ablation center and pupillary center (large arrow) was determined to be the decentration amount.

marker, mechanical removal of the corneal epithelium was done with a blunt spatula. The center of the reticle marking on the viewing tube was set to be identical to center of entrance pupil. The laser was then applied. In the case of LASIK, the same procedure was applied except that the cornea was marked prior to automated keratotomy with a radial marker. After a flap was created with the pass of automated microkeratome, the flap was nasally flipped and the stromal bed was ablated with the same method of PRK.

Measurements of decentration were as follows. The pupillary center as determined by corneal topography was used as the reference point using pupil-finding software. The center of ablation was determined by placing a piece of transparent paper on the 3-months-postoperative corneal topograph and marking the farthest four edges of the ablation in the X- and Y-axis with a fine-tipped pen. The center of ablation was estimated to be the intersecting point of these four points (Fig. 1). The distance between the pupillary center and the ablation center was measured, and then the direction of ablation center from the reference point was calculated in degree scales.

The correlation between the decentering amount and various factors such as order of operation, sex, age (3^{rd}, 4^{th}, and 5^{th} decade), sedation (valium 5 mg administered 30 minutes before operation), type of operation (PRK vs LASIK), ablation diameter and depth, and the use of a passive eye tracker was analyzed using t-test, ANOVA and multiple regression analysis.

RESULTS

The overall mean distance between the pupillary

Table 1. Cumulative Percentage and Average Amount of Decentration

Amount of decentration (mm)	Total (80)	PRK (43)	LASIK (37)
0.50	68.3%	71.2%	64.5%
0.51−0.75	91.3%	93.9%	88.7%
0.76−1.00	95.0%	97.3%	93.0%
1.01−	100.0%	100.0%	100.0%
Average amount of decentration (mm)	0.43±0.27	0.35±0.22	0.47±0.30

PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 2. Direction of Decentration According to Operation Method and Eye

Factors	Superonasal	Superotemporal	Inferonasal	Inferotemporal
PRK (43)	20 (46%)	6 (14%)	12 (28%)	5 (12%)
LASIK (37)	19 (51%)	7 (19%)	5 (14%)	6 (16%)
Right (39)	14 (36%)	8 (21%)	9 (22%)	8 (21%)
Left (41)	23 (56%)	6 (15%)	7 (17%)	5 (12%)

PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 3. Decentration According to Sex and the Order of Operation

Sex	PRK (mm)	LASIK (mm)	Total
Male (9 persons)	0.28±0.17	0.42±0.16	0.35±0.16*
Female (41 persons)	0.42±0.34	0.52±0.23	0.47±0.28*
Order of operation			
1st eye (41 eyes)	0.36±0.28	0.50±0.37	0.43±0.32 †
2nd eye (39 eyes)	0.34±0.09	0.42±0.17	0.38±0.13 †

* p=0.09 (t-test).
† p=0.20 (t-test).
PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

center and the ablation center was 0.43±0.27 mm, 0.35±0.22 mm in the PRK group and 0.47±0.30 mm in the LASIK group. Overall, 91.3% of patients were decentered less than 0.75 mm and 95.0% were decentered less than 1.00 mm, while 93.9% were decentered less than 0.75 mm in PRK and 88.7% in LASIK (Table 1). Meridional displacement toward the superonasal quadrant was most common; 20 of 43 eyes (46%) in PRK, and 19 of 37 eyes (51%) in LASIK. The most common displacement in both eyes was also toward the superonasal quadrant; 14 of 39 eyes (36%) in the right eye, and 23 of 41 eyes (56%) in the left eye (Table 2). The decentering amount was smaller in males than females and when operating on the fellow eye, but there were no statistically significant differences (p=0.09, and p=0.20 respectively) (Table 3). Decentration was less in older people than in younger people, especially when comparing over the fifth decade with the third decade, but it was not statistically significant (p=0.24) (Table 4). Preoperative valium prescription did not affect the overall decentering amount (p=0.38) or in the third decade. (p=0.42) (Table 5). The larger the ablation diameter was, the smaller the decentration was, but it was not statistically significant (p=0.62) (Table 6). And the shallower the ablation depth was, the smaller the decentration was. In cases of similar ablation depth, the

Table 4. Decentration According to Age

Age	Total (mm)	PRK (mm)	LASIK (mm)
20−29 (48)	0.49±0.25*	0.43±0.24	0.55±0.25
30−39 (26)	0.38±0.34	0.33±0.46	0.42±0.14
40− (6)	0.32±0.07*	0.22±0.04	0.38±0.08

* p=0.24 (ANOVA).
PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 5. Decentration According to Sedation

Age	Total (mm)	PRK (mm)	LASIK (mm)	3rd decade (mm: eye)
Sedation (54)	0.45±0.16*	0.37±0.13	0.49±0.20	0.42±0.18 (20) †
No sedation (26)	0.39±0.31*	0.33±0.23	0.45±0.27	0.49±0.28 (28) †

* p=0.38 (t-test).
† p=0.42 (t-test).
PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 6. Decentration According to Ablation Diameter and Depth

Diameter (mm)	Total (mm)	PRK (mm)	LASIK (mm)
−5.99	0.46±0.32*	0.40±0.30	0.52±0.25
6.00−6.49	0.40±0.24*	0.38±0.19	0.43±0.27
6.50−	0.32±0.18*	0.30±0.19	0.33±0.17

* p=0.62 (ANOVA).
PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 7. Decentration According to Ablation Depth

Depth (mm)	PRK (mm)	LASIK (mm)
−49	0.33±0.36	
50−99	0.39±0.29*	0.44±0.26*
100−		0.50±0.16

* p=0.21 (ANOVA).
PRK, photorefractive keratectomy; LASIK, laser in situ keratomileusis.

Table 8. Decentration According to the Use of a Passive Eye Tracker

	Total (mm)
No tracking (34 eyes)	0.45±0.32*
Tracking (46 eyes)	0.39±0.25*

* p=0.26 (t-test).

amount of decentration in LASIK was greater than PRK (p=0.21) (Table 7). There was no difference in whether or not a passive eye tracker was used (p=0.26) (Table 8).

Statistically, there were no correlations (multiple regression analysis) between the magnitude of decentration and sex (p=0.25), age (p=0.15), operation method (PRK vs LASIK; p=0.10), order of operation (p=0.56), use of sedation (p=0.45), ablation diameter (p=0.65), or ablation depth (p=0.12).

DISCUSSION

Accurate and reliable centration of the PRK or LASIK procedure has been considered to be important in optimizing the patient's ultimate visual performance and minimizing optical side effects such as halo, glare, and monocular diplopia. The presence of ablation decentration does not always cause optical problems. As well, there seems to be no clear determination about what range of decentration patients can tolerate without subjective symptoms. Maloney proposed that decentration below 0.50 mm would not cause subjective symptoms such as glare and halo.[4] Machat suggested that decentration above 1.0 mm would create significant monocular diplopia, asymmetric night glare, reduced image quality, and blurred visual acuity.[5] Our centration results were superior to those of other reported series, which recorded decentration of 0.78 mm,[6] 0.52 mm,[7,8] and 0.47 mm,[9] because a passive eye tracker was used in about half our cases, even though its use was not statistically significant. As well, before starting the actual ablation, we explained the importance and reminded patients to maintain focused on the fixation target even though it would be somewhat blurred and would make them feel comfortable. In our study, the ablation decentration from the center of entrance pupil in the LASIK group was greater than in the PRK group. We attributed the greater decentration in the LASIK group to three factors. First, because higher corrections are attempted with LASIK and the procedure takes longer to complete, there is a greater chance for patient drift to occur. Second, patients with high myopia have poor uncorrected visual acuity causing visualization of the fixation light to be improper. Third, after the corneal flap is flipped, the fixation light becomes less visible due to irregular corneal stroma, and thus the existing fixation difficulties deteriorate. Involuntary eye-ball movement, iris contraction, and Bell's phenomena also cause ablation decentration. As well, there was greater decentration in the LASIK group than in the PRK group in similar ablation depth (Table 6). We attributed this to patients looking through an irregular surface by microkeratome and laser ablation, which also scatters the light of the aiming beam during LASIK.

We analyzed the meridional displacement seen in our study. When decentration was examined, a tendency towards superior decentration was seen in both PRK and LASIK (60% and 70% respectively). Decentration towards the nasal area was seen in 74% (PRK) and 65% (LASIK). When the cornea was divided into four quadrants, superonasal displacement was most common in both PRK and LASIK (46% and 51% respectively). Superonasal displacement was also common in both right and left eyes (36% and 56% respectively). The reason for the tendency towards superonasal displacement seen in our study was not well understood. However, two factors may contribute; the microscopic light response of the pupil during fixation was shown to have an effect toward the superonasal quadrant, and the flexed chin of patients due to excessive tension may have caused the superior decentration.

The published methods of measuring ablation decentration are variable. Cavanaugh et al. only visually estimated the ablation center on the computer screen.[7,8] Lin et al marked the apparent X and Y limits of the ablation zone and then took the intersecting point of these four points as the ablation center.[10] Sun et al. used a pair of compasses to confirm that the distance from the ablation center to the zone edge was equal in opposite directions.[11] In our study, the distance between the pupil center, which is determined automatically by pupil-finding software of corneal topography, and the ablation center, which is the intersecting point of the X and Y axes, was the decentering amount. However, this method required the observer to identify four specific points subjectively on a corneal topographic map.

Our study also showed that a tendency toward less decentration from the pupil center was found in males, in older people, when operating in the fellow eye, in ablating larger areas or with less depth. However, these differences were not significant statistically (Table 3, 4 and 5). Whether or not the patient was prescribed valium preoperatively did not affect the decentration, but in easily excited, young people, it was helpful to decrease the decentering amount (Table 4). In this study, we realized that ablation decentration was usually toward the superonasal quadrant, and considerable precaution should be taken for the ablation not to be decentered from the pupil center when ablating the cornea in patients undergoing their first operation and in young females with high dioptric powers, especially by LASIK, because unlike PRK, poorly-centered LASIK retreatment is complicated.[5] We would also suggest that administration of a preoperative sedative is helpful in young patients.

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