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Comparison of outcomes of laser refractive surgery (LRS) alone and LRS with laser asymmetric keratectomy in patients with myopia

A retrospective study

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Abstract

To compare and analyze the postoperative 1-year outcomes of laser refractive surgery (LRS) alone vs LRS with laser asymmetric keratectomy (LAK), in patients with myopia, for preventing and resolving LRS complications.

This retrospective study compared the preoperative and 1-year postoperative outcomes between the control and comparison groups using a sum of deviations in corneal thickness in 4 directions >80 μm. The control group included 41 patients with myopia (41 eyes) who underwent LRS. The comparison group included 33 patients (33 eyes) who received LAK-linked LRS. Age, spherical equivalent (SE), sphere, cylinder, uncorrected distance visual acuity (UDVA), pupil size, kappa angle, central corneal thickness, corneal irregularity in the 3.0 mm zone on Orbscan maps (SUM), distance between the maximum posterior elevation (best-fit-sphere) and the visual axis (DISTANCE), postoperative blurring scores, frequency of postoperative myopic regression, and efficiency index were compared.

Preoperative age ($P=.198$), SE ($P=.686$), sphere ($P=.562$), cylinder ($P=.883$), UDVA ($P=.139$), pupil size ($P=.162$), kappa angle ($P=.807$), central corneal thickness ($P=.738$), corneal irregularity ($P=.826$), SUM ($P=.774$), and DISTANCE ($P=.716$) were similar between the 2 groups. The 1-year postoperative SE ($P=.024$), sphere ($P=.022$), corneal irregularity ($P=.033$), SUM ($P=.000$), DISTANCE ($P=.04$), blurring scores ($P=.000$), and frequency of postoperative myopic regression ($P=.004$) were significantly decreased in the comparison group compared to the control group. UDVA ($P=.014$) and the efficiency index ($P=.035$) were higher in the comparison group.

LAK with LRS improved corneal symmetry by reducing the SUM and DISTANCE. UDVA and efficiency index were also improved and blurring and myopic regression were reduced postoperatively.

Abbreviations: BFS = best-fit-sphere, BSCVA = best spectacle corrected visual acuity, CCT = central corneal thickness, IOP = intraocular pressure, LAK = laser asymmetric keratectomy, LRS = laser refractive surgery, SE = spherical equivalent, UCVA = uncorrected visual acuity preoperative, UDVA = uncorrected distance visual acuity.

Keywords: laser asymmetric keratectomy, laser refractive surgery, myopia

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1. Introduction

Complications such as myopic regression, blurring, and in severe cases, halos at night are reported in a fraction of patients who have undergone laser refractive surgery (LRS).[1–7] Postoperative myopic regression is caused by increased central corneal thickness (CCT) and steepening after surgery.[1] Changes in corneal morphology after surgery are caused by 3 factors, namely: the ablation profile, the healing process, and the biomechanical response of the cornea to a change in its shape.[8] In particular, corneal biomechanical changes induced by the interaction between corneal thickness, corneal stiffness, and intraocular pressure are the main causes of changes in corneal morphology.[8–12] Corneal thickness is a major factor for corneal asymmetricity in LRS, especially its deviations. After LRS, if a large deviation in corneal thickness is observed, the thin regions of the cornea are more likely to be steepened as a result of the intraocular pressure, leading to increased changes in myopic regression.[13–15]

Laser asymmetric keratectomy (LAK) is a biomechanical customized asymmetric corneal ablation method of recent description. This procedure helps balance the symmetry of the cornea with a central point. The improved corneal morphology has been shown to be maintained without corneal deformity for 1 year.[13–15] In addition, laser correction surgery combined with LAK reduced the total corneal thickness deviation in central symmetry, and at 1-year postoperatively, it reduced blurring scores in myopic middle-aged patients with a sum of deviations in corneal thickness in 4 directions ≥80 μm.[15]

In order to further compare the outcomes of both aforementioned procedures, young patients with myopia and high levels of asymmetricity caused by a sum of deviations in corneal thickness in 4 directions ≥80 μm, were selected for this study. We analyzed and compared the 1-year postoperative outcomes of conventional LRS alone, which improves only the refractive errors; and LAK-linked LRS, which is a biomechanical customization method, that improves both refractive errors and corneal symmetricity simultaneously in young patients with myopia.

2. Patients and methods

This retrospective study considered patients who were treated at the Woori Eye Clinic from 2013 to 2018. Forty-one patients (41 eyes) who underwent LASIK or LASEK alone, and who showed a sum of deviations ≥80 μm in corneal thickness in 4 directions, were included in the control group. Thirty-three patients (33 eyes) who received LAK-linked LASIK or LASEK, and who showed a sum of deviations ≥80 μm in corneal thickness in 4 directions, were included in the comparison group. We surveyed the right eyes exclusively. The preoperative and 1-year postoperative results between the 2 groups were retrospectively analyzed. This study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 1983, and was approved by the Korean National Institute for Bioethics Policy (approval number: P01-202001-21-005). Due to the retrospective nature of the study, the requirement for informed consent was waived.

Patients with refractive error underwent LASIK or LASEK alone or combined with LAK using a 193-nm ISO-D200 laser (Kera Harvest Inc., Taiwan). Laser correction was performed by the same surgeon using the same method. Local anesthesia was induced by instillation of 0.50% proparacaine hydrochloride (Alcaine, Alcon NV, Vilvoorde, Belgium). For LASIK, a 9.0 to 9.5-mm diameter flap was made using an M2 Moria Keratome (Moria Inc., Antony, France); for LASEK, a 9.0 to 9.5-mm diameter patch of corneal epithelium was removed with a brush. For refractive correction, laser ablation was performed in the 6.5 mm optic zone to correct myopia and astigmatism. To perform LAK,[13,15] we used Vision-Up software (WellC, South Korea) to analyze the CCT deviations based on Orbscan II (Bausch & Lomb, Bridgewater, NJ) corneal maps. These served also to predict corneal myopic change as a result of the removal of the thicker corneal regions as determined by LAK. Therefore, we were able to ablate the cornea to create central symmetry without changing the refractive power.[13,15] A rating[2] for blurring was recorded using a subjective scale: 0 = none, 1 = mild, 2 = moderate, and 3 = severe or disturbing. The following variables were analyzed: the pre- and postoperative uncorrected far visual acuity (UDVA), spherical equivalent (SE), sphere, cylinder, intraocular pressure (IOP), kappa angle on Orbscan map, CCT, corneal irregularity in the 3.0 mm zone on Orbscan maps, pupil size, blurring severity, sum of deviations in corneal thickness in 4 directions based on Orbscan maps (asymmetric pachymetric distribution), distance (mm) between the maximum posterior elevation (best-fit-sphere [BFS]) and the visual axis, efficiency index (postoperative uncorrected visual acuity/preoperative best spectacle corrected visual acuity [BSCVA]), safety index (postoperative BSCVA/preoperative BSCVA), and percentage of myopic regression. Refraction was measured using an auto refractometer/keratometer and calculated as the SE.

UDVA was measured from a distance of 3 m using the Han Chun Suk visual distance acuity chart. UDVA was converted to the logarithm of the minimum angle of resolution (LogMAR) for statistical analysis. Myopic regression during the follow-up period was defined as changes in myopia, indicated by SE ≥1.0 diopter after the surgery.

Pre- and postoperative deviations in corneal thickness (asymmetric pachymetric distribution) were analyzed using the following method: first, the thickness was measured using Orbscan maps in 8 locations, 2.5 mm from the center of the cornea (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°); the differences in thickness between symmetrically opposed locations were then calculated for 4 directions (0°–180°, 45°–225°, 90°–270°, and 135°–315°), along with the sum of the differences (Fig. 1).[13,15] The distance between the maximum posterior elevation (BFS) and the visual axis was analyzed by conversion to the distance between the *X* and *Y* coordinates of the thinnest point and the center of the cornea on an Orbscan map (Fig. 1).[13,15] For statistical analyses, independent samples *t*-tests were performed using SPSS, version 18.0 (IBM Corp., Armonk, NY). *P*-values < .05 were considered statistically significant. Data are presented as the mean ± standard deviation unless otherwise noted.

3. Results

The preoperative results (Table 1) show that the ages of the control and comparison groups were 23.08 ± 4.99 and 21.45 ± 3.22 years, respectively (*P* = .198). The men to women ratios in the control and comparison groups were 16:25 and 18:15, respectively. There were no significant differences between the 2 groups in SE, sphere, cylinder, IOP UDVA (LogMAR), best corrected far vision, pupil size, kappa angle on Orbscan map, CCT, corneal irregularity, sum of deviations in corneal thickness (μm) in 4 directions, and distance between the maximum posterior elevation (BFS) and the visual axis.

The postoperative results (Table 2) illustrate that LASIK was performed in 8 subjects (8 eyes; 4 patients in the control group and the other 4 in the comparison group). The rest of the subjects in both groups underwent LASEK. The SE and sphere (diopters) were −0.38 ± 0.46 and −0.36 ± 0.36 in the control group and −0.14 ± 0.38 and −0.13 ± 0.28 in the comparison group (*P* = .024 and *P* = .022, respectively). Cylinders and IOP were similar between the 2 groups (*P* = .238). UDVA (LogMAR) was 0.09 ± 0.16 and 0.02 ± 0.06 (*P* = .014) in the control and comparison groups, respectively. The comparison group experienced significant improvements in SE, sphere, and UDVA. Pupil size, kappa angle on Orbscan map, and CCT were similar between the 2 groups (*P* = .271, *P* = .490, and *P* = .629, respectively). The corneal irregularities (diopters) in the 3.0 mm zone on the Orbscan maps were 2.27 ± 3.01 and 1.21 ± 0.34 (*P* = .033) in the control and comparison groups, respectively. The sums of deviations in corneal thickness in 4 directions (μm) were 106.32 ± 5 0.44 and 50.37 ± 17.75 (*P* = .000) in the control and comparison groups, respectively. The distances (mm) between the maximum posterior elevation (BFS) and visual axis were 0.81 ± 0.28 and 0.46 ± 0.28 (*P* = .04) in the control and comparison groups, respectively. Further, the control and

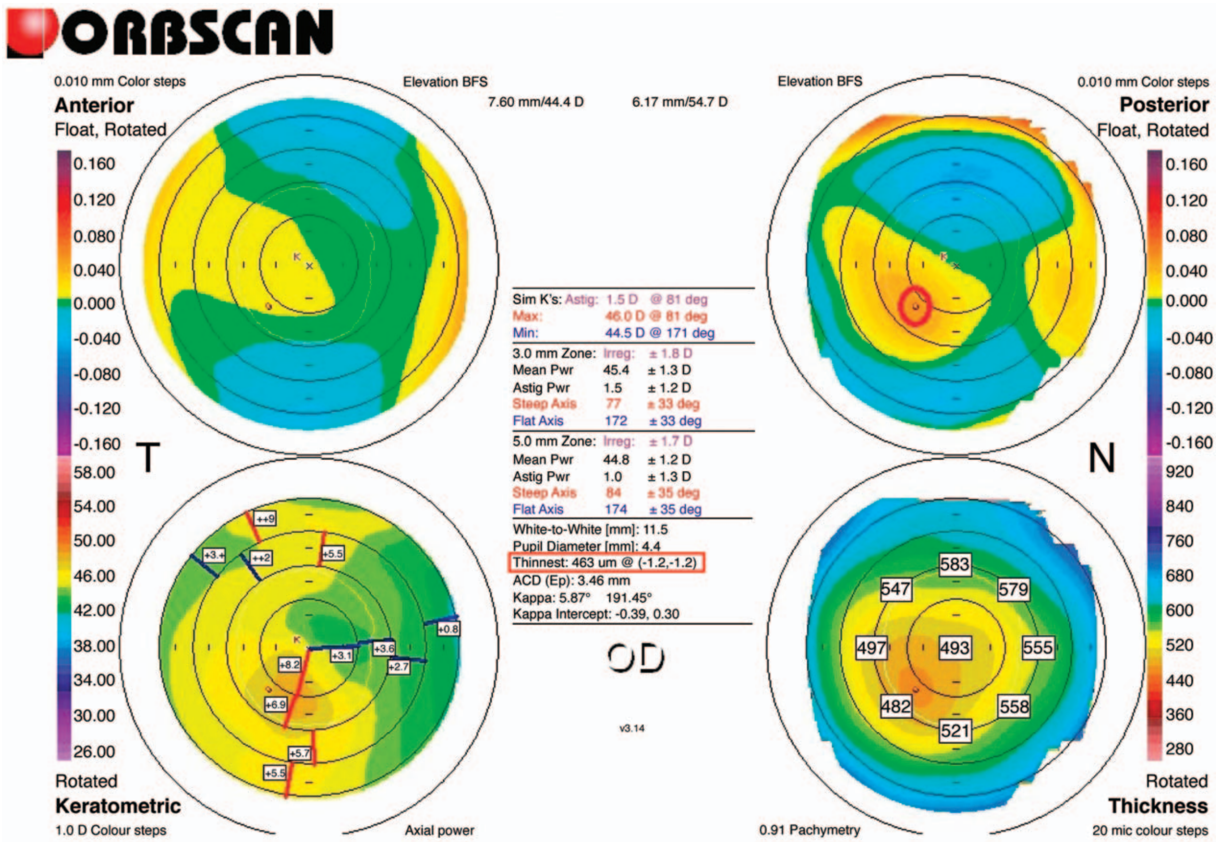

Figure 1. Orbscan map. Right lower pachymetric map: An example of the measurement of the differences in thickness between symmetrically opposed points (0°–180°, 45°–225°, 90°–270°, and 135°–315°). The pachymetric map (right lower): 0° to 180°: 58 μm; 45° to 225°: 97 μm; 90° to 270°: 62 μm; 135° to 315°: 11 μm; total: 228 μm. Right upper map: measurement of the distance between the maximum posterior elevation (best-fit-sphere: BFS) and the visual axis. Corneal apex: inferior-temporally deviated (right upper red circle). The thinnest point (X, Y) is indicated by the lower red square.

comparison groups had blurring scores of 1.24 ± 0.94 and 0.18 ± 0.39 (P = .000), respectively. The sum of deviations in corneal thickness in 4 directions, the distance between the maximum posterior elevation (BFS) and visual axis, and the blurring scores were significantly lower in the comparison group compared to the control group. The myopic regression rates were 12.2% and 0% in the control and comparison groups, respectively (P = .004), and the efficiency index (postoperative uncorrected visual acuity/preoperative BSCVA) was 0.86 ± 0.22 in the control group and 0.95 ± 0.10 in the comparison group (P = .035). In the compari-

Table 1

Preoperative outcomes.

Outcomes	Control Group (LRS Only)	Comparison Group (LAK with LRS)	*P*-value
No. of patients (eyes)	41 (41)	33 (33)	–
Age (yr)	23.08 ± 4.99	21.45 ± 3.22	.198
Male to female ratio	16:25	18:15	.119
SE (diopters)	−4.12 ± 1.96	−4.37 ± 2.98	.686
Sphere	−4.04 ± 1.43	−4.17 ± 2 .25	.562
Cylinder	−0.50 ± 0.27	−0.40 ± 0.24	.883
Intraocular pressure (mm Hg)	13.64 ± 0.86	13.74 ± 0.76	.347
UDVA (LogMAR)	0.99 ± 0.07	0.93 ± 0.21	.139
Pupil size (mm)	4.63 ± 0.66	4.42 ± 0.63	.162
Kappa angle (°)	4.56 ± 1.19	4.48 ± 1.56	.807
CCT (mm)	542.69 ± 50.21	548.62 ± 49.20	.738
Corneal irregularity in 3.0 mm zone (diopters)	1.44 ± 0.37	1.46 ± 0.38	.826
Sum of deviations in corneal thickness in 4 directions (μm)	129.61 ± 43.24	126.85 ± 38.69	.774
Distance (mm) between the maximum posterior elevation (BFS) and the visual axis	0.87 ± 0.37	0.90 ± 0.40	.716

Corneal irregularity: corneal irregularity (diopters) in the 3.0 mm zone on Orbscan maps.

BFS = best-fit-sphere, CCT = central corneal thickness, LAK = laser asymmetric keratectomy, LogMAR = logarithm of the minimum angle of resolution, LRS = laser refractive surgery, SE = spherical equivalent, UDVA = uncorrected distance visual acuity.

Table 2

One-year postoperative outcomes.

Outcomes	Control group (LRS only)	Comparison group (LAK with LRS)	*P*-value
LASIK:LASEK (eyes)	4:37	4:29	–
SE (diopters)	−0.38 ± 0.46	−0.14 ± 0.38	.024
Sphere	−0.36 ± 0.36	−0.13 ± 0.28	.022
Cylinder	−0.40 ± 0.21	−0.27 ± 0.16	.238
UDVA (LogMAR)	0.09 ± 0.16	0.02 ± 0.06	.010
Intraocular pressure (mm Hg)	13.84 ± 0.76	13.94 ± 0.86	.348
Pupil size (mm)	5.53 ± 0.35	4.30 ± 0.79	.271
Kappa angle (°)	4.39 ± 1.15	4.42 ± 1.75	.490
CCT (mm)	498.27 ± 35.37	493.15 ± 51.47	.629
Corneal irregularity in 3.0 mm zone (diopters)	2.27 ± 3.01	1.21 ± 0.34	.033
Sum of deviations in corneal thickness in 4 directions (μm)	106.32 ± 50.44	50.37 ± 17.75	.000
Distance (mm) between the maximum posterior elevation (BFS) and the visual axis	0.81 ± 0.28	0.46 ± 0.28	.04
Blurring scores	1.24 ± 0.94	0.18 ± 0.39	.000
Myopic regression, eyes (%)	5 (12.2)	0 (0)	.004
Efficiency index	0.86 ± 0.22	0.95 ± 0.10	.035
Safety index	1.00	1.00	–

Corneal irregularity: corneal irregularity in the 3.0 mm zone on Orbscan maps.

BFS = best-fit-sphere, CCT = central corneal thickness, LAK = laser asymmetric keratectomy, LASEK = laser epithelial keratomileusis, LASIK = laser in situ keratomileusis, LogMAR = logarithm of the minimum angle of resolution, LRS = laser refractive surgery, SE = spherical equivalent, UDVA = uncorrected distance visual acuity.

son group, the myopic regression rate was significantly lower, and the efficiency index was significantly higher. The safety index (postoperative BSCVA/preoperative BSCVA) was not statistically different between the 2 groups. Intraocular pressures were within normal limits pre- and postoperatively.

4. Discussion

In this study, the 2 patient groups were similar preoperatively with regard to age, SE, sphere, cylinder, pupil size, kappa angle, CCT, corneal irregularity in the 3.0-mm zone on Orbscan maps, UDVA, sum of deviations in corneal thickness in 4 directions, and distance between the maximum posterior elevation (BFS) and the visual axis. However, the postoperative myopic regression rate was 12.2% in the control group, which is much higher than those reported in other studies.[1–4] When the sum of deviations in corneal thickness in 4 directions on an Orbscan map is >80 μm, intraocular pressure causes the protrusion of thin regions of the cornea, which steepens the cornea further, leading to myopic regression. In the comparison group, which underwent LAK-linked LRS, the sum of deviations in corneal thickness in 4 directions was significantly decreased. Moreover, the reduction in the distance between the maximum posterior elevation (BFS) and the visual axis led to an improvement in corneal symmetricity. There was significant subjective reduction in blurring, and there was significant quantitative reduction in corneal irregularities in the 3.0 mm zone on the Orbscan maps in the comparison group. Also, myopic regression was not observed. These outcomes may be attributable to the excellent corneal point symmetry effect of LAK.[13,14] However, for reshaping of the cornea after LAK, the greater the CCT, the higher the postoperative time required.

The 1-year postoperative outcomes were also compared in this study. In the comparison group, the 1-year postoperative sum of deviations in corneal thickness in 4 directions was 50.37 μm on average, which was superior to that of the control group, with an average of 106.32 μm. In the control group, myopic regression was observed in 5 eyes (12.2%) 1 year after the operation. The rate of myopic regression increased over time, with 12 patients (12 eyes, 29.3%) experiencing myopic regression 5 years after the operation. However, in the comparison group, the corneal symmetry may be well maintained over a prolonged period of time. Because LAK is a recently developed technology, we were only able to follow up the patients for 1 year; thus, future studies with longer follow-up time, that is, more than 1 year, are warranted to investigate myopic regression over time.

Using LAK, the side effects caused by corneal deformity are expected to be significantly lower, and an additional comparison study is required to assess this aspect. The use of LAK has only been reported recently[13–15]; moreover, unlike the previously reported wavefront- and topography-guided LASIK or LASEK, LAK reduces corneal thickness deviations by asymmetric corneal ablation. Further, it increases the corneal symmetricity by decreasing the distance between the maximum posterior elevation (BFS) and the visual axis, and thereby, it is expected to prevent corneal biomechanical changes.[16–27] LAK can asymmetrically ablate thick areas of the cornea compared to LASIK or LASEK, which symmetrically ablate the cornea. Therefore, LAK can improve corneal symmetricity and result in better postoperative outcomes in corneas with a large sum of deviations in corneal thickness (≥80 μm). Moreover, it has been reported that LAK, in which only the thick parts of the cornea are cut to create central symmetry, can be a good method to:

(1) reduce the effects of intraocular pressure pushing outwards on the thin parts of the cornea in keratoconus;
(2) lessen the asymmetric morphology of the cornea; and
(3) reduce the incidence of optical aberrations.[8–15]

LAK may be useful as a corrective measure for patients who complain of side effects such as blurring caused by corneal distortion after cataract and glaucoma surgeries that lower intraocular pressure and corneal stiffness.[26–32] In addition, further research on LAK and treatment indications needs to be conducted. We suggest that LAK may be useful for new, advanced biomechanical customized refractive surgery, as a treatment of distorted corneas after intraocular surgery (including cataract and glaucoma operations, among others), as a potential treatment of early keratoconus by reducing the effect of intraocular pressure that pushes the thin parts of the cornea outwards, and as a treatment for posterior corneal ectasia. However, further studies are needed to establish the effectiveness of this method.

In conclusion, LAK-linked LRS resulted in an improved sum of deviations in corneal thickness and significantly reduced blurring and myopic regression with good visual outcomes 1-year postsurgery.

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