

# Posterior Corneal Curvature Assessment after Epi-LASIK for Myopia: Comparison of Orbscan II and Pentacam Imaging

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**Purpose:** To compare the changes in posterior corneal curvature using scanning slit topography (Orbscan II) and Scheimpflug imaging (Pentacam) before and after Epi-laser *in situ* keratomileusis (LASIK) for myopia.

**Methods:** In a prospective observational case-series study, 20 myopic patients having undergone Epi-LASIK were examined serially with two different devices, Orbscan II and Pentacam, preoperatively and one month postoperatively. Posterior central elevation (PCE) and posterior maximal elevation (PME) were compared between the two devices, and the changes in parameters after Epi-LASIK were analyzed using a difference map.

**Results:** All parameters (preoperative and postoperative PCE and preoperative and postoperative PME) that were measured using the Orbscan II were significantly greater compared to those of the Pentacam (for all  $p < 0.001$ ). PCE and PME were significantly increased one month postoperatively in the Orbscan II measurements ( $p < 0.05$ ) but were not significantly increased in the Pentacam measurements. Also,  $\Delta$ PCE and  $\Delta$ PME, in the difference map obtained by each serial scanning, were significantly greater in the Orbscan II measurements than with the Pentacam ( $p = 0.012$ ,  $p = 0.016$ ).

**Conclusions:** The Pentacam measurements displayed significantly reduced values in all parameters related to posterior corneal elevation compared to those of the Orbscan II. The Pentacam showed no significant change in posterior corneal curvature after Epi-LASIK, based on the difference map.

**Key Words:** Epi-laser *in situ* keratomileusis, Orbscan II, Pentacam, Posterior central elevation, Posterior maximal elevation

Corneal ectasia is a serious complication after laser refractive surgery, which include photorefractive keratectomy (PRK), Epi-laser *in situ* keratomileusis (LASIK), and LASIK [1-14]. This complication may progress to myopic regression, decreased visual acuity and corneal thinning, which may eventually require corneal transplantation for visual rehabilitation. Many researchers have been concerned about early detection of ectatic change, and several

papers have reported that posterior corneal elevation was observed in the eyes after laser refractive surgery [1-14].

However, most of these studies that mention posterior corneal changes are based on Orbscan II measurements of posterior corneal elevation [1-10,13]. Recently, reports using the Pentacam demonstrated that the posterior corneal elevation after PRK or LASIK is less common than previously reported with the Orbscan II [15,16]. Because the Orbscan II is based on slit scan beam imaging and uses mathematical calculations to recreate the posterior cornea, this strategy can cause false positive readings of posterior corneal elevation [17]. In contrast, the Pentacam uses a rotating Scheimpflug camera to directly image the posterior cornea and analyzes the posterior corneal elevation without mathematical calculations [18].

The present study measured the posterior central elevation (PCE) and posterior maximum elevation (PME) above

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the best fit sphere in eyes before and after Epi-LASIK for the first time based on difference maps integrated by serial measurements in individuals and compared these measurements between the Orbscan II and the Pentacam.

## Materials and Methods

Forty eyes of 20 patients undergoing Epi-LASIK for myopia were enrolled in this prospective observational case series. All surgeries were performed using the Amadeus II microkeratome (Ziemer, Port, Switzerland) and VISX S4 (AMO, Irvine, CA, USA) at the Ophthalmologic Department of Kangnam St. Mary's Hospital. The epithelial sheet was reflected nasally in all cases. The nature and purpose of the study were explained in detail to all patients, and informed consent was obtained before commencement. The study was approved by the Kangnam St. Mary's Hospital Institutional Review Board. Both Orbscan II (Bausch & Lomb, Rochester, NY, USA) and Pentacam (Oculus, Wetzlar, Germany) images were obtained on the same day, and preoperative and postoperative (1 month after surgery) images were serially measured in both eyes of all enrolled patients.

Measured variables included PCE, and PME above the best fit sphere as a preoperative and postoperative values,

**Table 1.** Demographics and refractive status of 40 eyes that underwent Epi-LASIK

	Mean $\pm$ SD
Preoperative mean SE correction (D)	-5.71 $\pm$ 2.41
Preoperative CCT ( $\mu$ m)	523.6 $\pm$ 48.7
Mean ablation depth ( $\mu$ m)	85.5 $\pm$ 35.8
RBT ( $\mu$ m)	438.1 $\pm$ 28.3

LASIK = laser *in situ* keratomileusis; SE = spherical equivalent; D = diopter; CCT = central corneal thickness; RBT = residual bed thickness.

**Table 2.** Inter-device comparison of parameters between Orbscan II and Pentacam

Parameter	Mean $\pm$ SD ( $\mu$ m)		<i>p</i> -value
	Orbscan II	Pentacam	
Preoperative			
PCE	28.40 $\pm$ 3.36	5.61 $\pm$ 1.14	<0.001
PME	30.67 $\pm$ 3.07	14.17 $\pm$ 3.54	<0.001
Postoperative			
PCE	46.53 $\pm$ 3.94	5.92 $\pm$ 1.42	<0.001
PME	53.17 $\pm$ 3.60	16.33 $\pm$ 3.73	<0.001

Paired *t*-test.

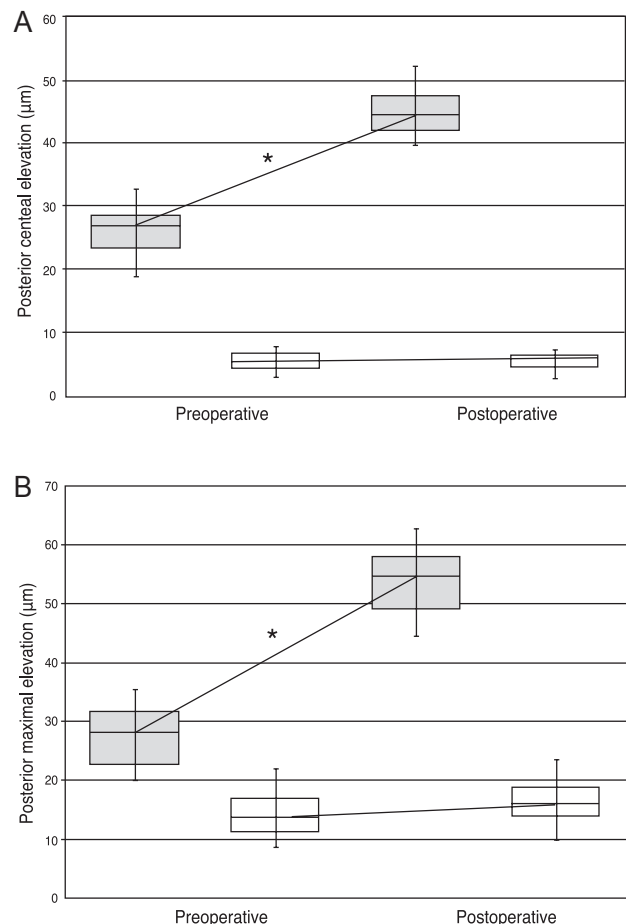
PCE = posterior central elevation; PME = posterior maximal elevation.

and difference maps were obtained by serial imaging. The pre-operative posterior best-fit float sphere was adjusted to the post-operative posterior best-fit float sphere in posterior elevation maps in both machines. PCE and PME values were respectively compared between the two devices using a difference map.

Statistical analysis was performed using SPSS ver. 13.0 (SPSS Inc., Chicago, IL, USA). The paired *t*-test was employed when comparing pre- and post-operative values and inter-device differences. Results were considered statistically significant if a *p*-value < 0.05 was obtained.

## Results

The mean age of the 14 women and 6 men in this study was 24  $\pm$  2.37 years (range, 20 to 32 years). Table 1 shows demographic data for the 40 eyes that underwent Epi-LASIK. All parameters measured using the Orbscan II were significantly greater, compared to those of the Pentacam (*p* < 0.001 for all parameters) (Table 2). Preoperative PCE and PME were greater when measured using the



**Fig. 1.** Intra-device comparison of pre-operative and post-operative values (\**p* < 0.05). PCE = posterior central elevation; PME = posterior maximal elevation.

**Table 3.** Inter-device comparison of the change in posterior corneal curvature after Epi-LASIK

	Difference map ( $\mu\text{m}$ )		<i>p</i> -value
	Orbscan II	Pentacam	
$\Delta\text{PCE}$	$18.3 \pm 2.63$	$1.94 \pm 1.32$	0.012
$\Delta\text{PME}$	$22.5 \pm 5.32$	$2.08 \pm 2.29$	0.016

Paired *t*-test.

LASIK = laser *in situ* keratomileusis; PCE = posterior central elevation; PME = posterior maximal elevation.

Orbscan II compared to the Pentacam ( $p < 0.001$ ). Postoperative PCE and PME were also greater when measured using the Orbscan II compared to the Pentacam ( $p < 0.001$ ). There was a significant inter-device difference between the Orbscan II and the Pentacam for all parameters.

When measured using the Orbscan II, the postoperative PCE and PME values after Epi-LASIK were significantly increased compared to the preoperative values ( $p = 0.010$ ,  $p = 0.048$ , respectively). When measured using the Pentacam, PCE and PME values after Epi-LASIK were slightly increased compared to the preoperative values. However, the increases were not significant ( $p = 0.284$ ,  $p = 0.43$ , respectively) (Fig. 1).

The average PCE change ( $\Delta\text{PCE}$ ) and PME change ( $\Delta\text{PME}$ ) were  $18.3 \pm 2.63 \mu\text{m}$  and  $22.5 \pm 5.32 \mu\text{m}$ , respectively, when analyzed using the Orbscan II difference map. The average  $\Delta\text{PCE}$  and  $\Delta\text{PME}$  were  $1.94 \pm 1.32 \mu\text{m}$  and  $2.08 \pm 2.29 \mu\text{m}$ , respectively, when analyzed using the Pentacam difference map. These  $\Delta\text{PCE}$  and  $\Delta\text{PME}$  values in the difference map obtained by two serial scans were significantly greater for the Orbscan II than for the Pentacam ( $p = 0.012$ ,  $p = 0.016$ , respectively) (Table 3).

## Discussion

Our study demonstrated that significant posterior corneal elevation was not observed in patients after Epi-LASIK when measured using the Pentacam. Recent studies using the Pentacam showed no significant posterior corneal displacement after laser refractive surgery [15,16]. Ciolino and Belin [15] demonstrated that no significant posterior corneal surface displacement was observed using the Pentacam in 103 postoperative LASIK eyes and 18 postoperative PRK eyes. In addition, posterior corneal displacement was not significantly different between the LASIK and PRK patients. However, measurements using the Orbscan II exhibited a significant change in posterior corneal elevation after Epi-LASIK, and the change in posterior corneal elevation was greater using the Orbscan II compared to the Pentacam. Hashemi and Mehravaran [16] reported that the Pentacam yielded no significant postoperative changes

in 30 LASIK eyes and 16 PRK eyes compared to the Orbscan II. Ha et al. [19] also demonstrated that the change in posterior corneal elevation after PRK was greater for the Orbscan II compared to the Pentacam.

Our study used a difference map to compare the posterior corneal change between two devices after Epi-LASIK. A difference map is an image that represents the change between serial elevation maps in an individual. While previous studies compared the change after laser refractive surgery by analyzing the subtracted values between preoperative and postoperative measurements [2,4,5,10,15,19], our study has merit in that we compare the change in the posterior corneal elevation ( $\Delta\text{PCE}$ ,  $\Delta\text{PME}$ ) on a difference map. There were no significant changes in PCE and PME on the difference map obtained by serial measurements in the Pentacam, although significant changes in PCE and PME were observed in measurements from the Orbscan II.

The inter-device difference for posterior corneal elevation may be explained by the difference in the manner of scanning between the two devices. The Orbscan's possible sources of error have been discussed in several studies because many studies using the Orbscan II have determined a much larger value of posterior elevation. Also, some authors reason that keratectasia detected by this device is an artifact [1,4,9,10,13,19-21] and suggested that the Orbscan II might overestimate the posterior corneal elevation due to the "noise" of the measurements and the inaccuracy of system realignment for the second measurement. Additionally, the Orbscan may have an inaccuracy due to the scanning manner itself. The Orbscan II uses only a horizontally moving slit scan beam to produce multiple slit images of the cornea. Alternatively, the Pentacam is a rotating Scheimpflug camera that provides 25 to 50 images during one scan in less than 2 seconds, yielding 500 true elevation points per image. To capture the images of the anterior segment, the rotating wheel produces slit images in two dimensions, and the integration of multiple two-dimensional images allows for the generation of a three-dimensional model. The slit images are photographed at an angle from  $0^\circ$  to  $180^\circ$  to avoid shadows from the nose. Every picture is a complete image through the cornea at the specific angle, so a true  $360^\circ$  image of the anterior segment of the eye is acquired. Therefore, the Pentacam can obtain more uninterrupted posterior corneal images and may be less influenced by factors such as postoperative subclinical corneal haze. Additionally, the posterior change measured by the Pentacam was more reliable due to the better intra-session and intersession repeatability on posterior best fit sphere, and its intraclass correlation values were 0.99 or above [22,23].

Our study has a limitation in that the sample size was relatively small and the correlations with other parameters, such as ablation size or depth, were not analyzed. Also, one month was too short a time to fully assess the corneal

change after Epi-LASIK. According to Miyata's report of the time course of changes in corneal forward shift after excimer laser photorefractive keratectomy, forward corneal shift progressed up to 6 months postoperatively [24]. Further studies including late postoperative data and additional parameters are necessary.

The present study found that the Pentacam exhibited significantly reduced values in all parameters related to posterior corneal elevation compared to those of the Orbscan II. Pentacam measurements demonstrated no significant change in posterior elevation between preoperative and postoperative eyes after Epi-LASIK, based on a difference map. In contrast, the Orbscan II measurements displayed a greater posterior corneal elevation after Epi-LASIK. These findings indicate that the prevalence and extent of posterior corneal changes after corneal refractive surgery, including Epi-LASIK, may be overestimated in the Orbscan II. In conclusion, the Pentacam may be a better tool for investigating posterior corneal elevation in eyes after corneal refractive surgery.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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## References

- Wang Z, Chen J, Yang B. Posterior corneal surface topographic changes after laser in situ keratomileusis are related to residual corneal bed thickness. *Ophthalmology* 1999;106:406-9.
- Kamiya K, Oshika T, Amano S, et al. Influence of excimer laser photorefractive keratectomy on the posterior corneal surface. *J Cataract Refract Surg* 2000;26:867-71.
- Baek T, Lee K, Kagaya F, et al. Factors affecting the forward shift of posterior corneal surface after laser in situ keratomileusis. *Ophthalmology* 2001;108:317-20.
- Seitz B, Torres F, Langenbucher A, et al. Posterior corneal curvature changes after myopic laser in situ keratomileusis. *Ophthalmology* 2001;108:666-72.
- Hernandez-Quintela E, Samapunphong S, Khan BF, et al. Posterior corneal surface changes after refractive surgery. *Ophthalmology* 2001;108:1415-22.
- Sharma N, Rani A, Balasubramanya R, et al. Posterior corneal topographic changes after partial flap during laser in situ keratomileusis. *Br J Ophthalmol* 2003;87:160-2.
- Lee DH, Seo S, Jeong KW, et al. Early spatial changes in the posterior corneal surface after laser in situ keratomileusis. *J Cataract Refract Surg* 2003;29:778-84.
- Yoshida T, Miyata K, Tokunaga T, et al. Difference map or single elevation map in the evaluation of corneal forward shift after LASIK. *Ophthalmology* 2003;110:1926-30.
- Miyata K, Tokunaga T, Nakahara M, et al. Residual bed thickness and corneal forward shift after laser in situ keratomileusis. *J Cataract Refract Surg* 2004;30:1067-72.
- Twa MD, Roberts C, Mahmoud AM, Chang JS Jr. Response of the posterior corneal surface to laser in situ keratomileusis for myopia. *J Cataract Refract Surg* 2005;31:61-71.
- Grzybowski DM, Roberts CJ, Mahmoud AM, Chang JS Jr. Model for nonectatic increase in posterior corneal elevation after ablative procedures. *J Cataract Refract Surg* 2005;31:72-81.
- Kim HJ, Song IK, Joo CK. Keratectasia after laser in situ keratomileusis: clinicopathologic case report. *J Korean Ophthalmol Soc* 2005;46:910-4.
- Cairns G, Ormonde SE, Gray T, et al. Assessing the accuracy of Orbscan II post-LASIK: apparent keratectasia is paradoxically associated with anterior chamber depth reduction in successful procedures. *Clin Experiment Ophthalmol* 2005;33:147-52.
- Ueda T, Nawa Y, Masuda K, et al. Posterior corneal surface changes after hyperopic laser in situ keratomileusis. *J Cataract Refract Surg* 2005;31:2084-7.
- Ciolino JB, Belin MW. Changes in the posterior cornea after laser in situ keratomileusis and photorefractive keratectomy. *J Cataract Refract Surg* 2006;32:1426-31.
- Hashemi H, Mehravaran S. Corneal changes after laser refractive surgery for myopia: comparison of Orbscan II and Pentacam findings. *J Cataract Refract Surg* 2007;33:841-7.
- Cairns G, McGhee CN. Orbscan computerized topography: attributes, applications, and limitations. *J Cataract Refract Surg* 2005;31:205-20.
- Kopacz D, Maciejewicz P, Kecik D. Pentacam: the new way for anterior eye segment imaging and mapping. *Klin Oczna* 2005;107:728-31.
- Ha BJ, Kim SW, Kim SW, et al. Pentacam and Orbscan II measurements of posterior corneal elevation before and after photorefractive keratectomy. *J Refract Surg* 2009;25:290-5.
- Ormonde S, Waterman C, McGhee C. Changes in the posterior corneal surface after LASIK. *J Cataract Refract Surg* 2004;30:533-4.
- Nawa Y, Masuda K, Ueda T, et al. Evaluation of apparent ectasia of the posterior surface of the cornea after keratorefractive surgery. *J Cataract Refract Surg* 2005;31:571-3.
- Maldonado MJ, Nieto JC, Diez-Cuenca M, Pinero DP. Repeatability and reproducibility of posterior corneal curvature measurements by combined scanning-slit and placido-disc topography after LASIK. *Ophthalmology* 2006;113:1918-26.
- Chen D, Lam AK. Intrasession and intersession repeatability of the Pentacam system on posterior corneal assessment in the normal human eye. *J Cataract Refract Surg* 2007;33:448-54.
- Miyata K, Kamiya K, Takahashi T, et al. Time course of changes in corneal forward shift after excimer laser photorefractive keratectomy. *Arch Ophthalmol* 2002;120:896-900.