

## Accuracy of Different Topographic Instruments in Calculating Corneal Power after Myopic Photorefractive Keratectomy

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### Abstract

**Purpose:** To compare the corneal power measurements obtained using different topographic instruments after myopic photorefractive keratectomy (PRK).

**Methods:** Patients with myopia who were candidates for corneal refractive surgery were sequentially included. Pre-PRK and six months post-PRK corneal powers were measured using Javal manual keratometer, Orbscan II, Galilei, Tomey TMS4, and EyeSys 2000 topographers. Measured values were compared with those obtained using the clinical history method (CHM).

**Results:** This study included 66 eyes of 33 patients. The lowest keratometric measurements were obtained using the Galilei topographer ( $42.98 \pm 1.69$  diopters, D) and the highest measurements were obtained using the Javal manual keratometer ( $43.96 \pm 1.54$  D) preoperatively. The same order was observed postoperatively. Effective refractive power (EffRP) measured using EyeSys was most similar to the values obtained using CHM (ICC, intraclass correlation coefficient = 0.951), followed by the total corneal power measured using the Galilei system (ICC = 0.943). The values obtained using the adjusted EffRP formula ( $\text{EffRP} - 0.015 \times \Delta \text{Refraction} - 0.05$ ) were more consistent with the values obtained using CHM (ICC = 0.954) compared to those obtained with the adjusted average central corneal power formula measured using the Tomey system (ICC = 0.919).

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### INTRODUCTION

Photorefractive keratectomy (PRK) is an approved method for application of excimer laser in corneal refractive surgery. It has been shown to be effective and safe in the correction of refractive errors.<sup>[1,2]</sup> However, there are still significant challenges including inaccurate measurement of corneal power and intraocular pressure after corneal laser refractive surgery.<sup>[3-7]</sup> Intraocular lens (IOL) power calculation

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**Conclusion:** Post-PRK corneal powers measured using the adjusted EffRP formula were the most similar to values obtained using CHM.

**Keywords:** Corneal Topography; EyeSys Corneal Analysis System; Galilei Dual Scheimpflug Analyzer; Photorefractive Keratectomy

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is based mainly on the measurement of corneal power, axial length, and estimated lens position after surgery,<sup>[8-11]</sup> and is known to be less predictable after refractive surgery.<sup>[12-14]</sup> A significant source of error is the fact that most keratometers measure the central corneal radius of curvature and assume a spherocylindrical cornea, which is incorrect after myopic refractive surgery,<sup>[14]</sup> leading to overestimation of the corneal refractive power and consequently, hyperopic outcomes.<sup>[12,15]</sup> Furthermore, keratometric measurement errors occur due to an altered corneal refractive index.<sup>[14]</sup> Since the cornea becomes flattened after myopic laser surgery, the anterior chamber is incorrectly assumed to be shallow in the widely used third generation IOL formulas, such as the Holladay, Hoffer Q, and SRK/T, while it actually has remained negligibly altered.<sup>[16]</sup>

Various methods have been developed to improve the accuracy of corneal power estimation. For many years, the clinical history method (CHM) has been considered to be the gold standard; however, preoperative measurements are not always available and postoperative refraction may not be accurate and stable because a myopic shift may occur during the progression of cataract. Although newer and more promising approaches including topographic techniques have been introduced, there are still significant conflicts among the outcomes.<sup>[17]</sup> The aim of this study was to compare the accuracy of CHM with different techniques (manual keratometry, Orbscan II, Tomey, EyeSys, and Galilei) for corneal power calculation after myopic photorefractive keratectomy.

## METHODS

Patients who were included in the study were candidates for photorefractive surgery aged between 18 to 40 years; had stable myopic refraction for at least 12 months; had no history of systemic disease, autoimmune disease, or immunosuppressive therapy; were not pregnant or lactating; were not using topical ophthalmic medications; and had no contraindication for PRK. Patients who had unstable refraction after surgery or were lost to follow up were excluded. Soft contact lens usage was ceased at least two weeks prior to surgery. The study protocol was approved by our University Ethics Committee, and written informed consent was obtained from all participants.

Complete eye exam, manifest refraction, cyclorefraction, intraocular pressure (IOP) measurement,

dilated fundus examination, measurement of corneal curvature by Javal manual keratometer (Haag-Streit, Switzerland), Orbscan II (Bausch & Lomb, Rochester, NY), Galilei Dual Scheimpflug Analyzer (Ziemer Ophthalmic Systems, Switzerland), Tomey TMS-4 (Tomey, Japan), EyeSys 2000 Corneal Analysis System (EyeSys Vision, Houston, TX), and pachymetry (Nidek, Japan) were performed for all patients preoperatively and six months post-PRK after stability of refraction.

## Scientific Definitions

- Clinical history method (CHM): This is the method of determining the real corneal power following PRK or laser in-situ keratomileusis (LASIK) using preoperative keratometric data as well as preoperative and postoperative refraction:

$$K_{eff} = K_{pre} - \Delta Ref^{[18]}$$

Where  $K_{eff}$  is the corneal power to be included in calculation formulas,  $K_{pre}$  is the preoperative mean corneal power, and  $\Delta Ref$  is the change in refraction. These are measured as spherical equivalent.

- Average central corneal power (ACCP): This is the average of the mean powers of the central Placido rings over the central 3.0 mm of the cornea, as displayed by the Tomey Topography Modeling System.
- Adjusted ACCP (adj ACCP): This is one of the formulas for determining the real corneal power following PRK/LASIK using the ACCP from the Tomey device:
 
$$Adj\ ACCP = ACCP - 0.16 * \Delta Ref^{[19]}$$
- Effective refractive power (EffRP): This is the effective refractive power of the cornea within 3 mm that is measured by the EyeSys device:
- Adjusted EffRP (adj EffRP): This is one of the formulas to determine the real corneal power following PRK/LASIK using the EffRP from the EyeSys device<sup>[20]</sup>

$$Adj\ EffRP = EffRP - 0.015 * \Delta Ref - 0.05^{[20]}$$
- Total corneal power (TCP): This is the total corneal power within 4 mm measured using the Galilei device.
- Refraction Correction (RC): This is the corrected refraction at the corneal surface (if vertex distance = 0.012 m).
 
$$RC = Spectacle\ refraction / (1 - 0.012 * spectacle\ refraction).$$

## Surgical Technique

After prep, drape, and instillation of three drops of topical tetracaine 0.5%, the corneal epithelium was gently debrided after exposure to ethanol 15% for 20 seconds. Laser ablation was performed using the Nidek EC-5000 excimer laser machine (Nidek Co. Ltd., Japan). The optical zone was 6.0 mm up to 6.5 mm with a transition zone up to 1.5 mm. Treatments were conventional. Immediately after ablation, the ocular surface was rinsed with chilled saline for 10 seconds. This was followed by one drop of topical chloramphenicol 0.5%, a topical nonsteroidal anti-inflammatory drug, and an extended wear soft bandage contact lens. Patients who needed ablation for more than 75 micrometers had a pledget soaked in mitomycin C 0.02% that was applied for 10–30 seconds then rinsed with 50 mL balanced salt solution. After PRK, patients were treated with topical chloramphenicol 0.5% and betamethasone 0.1% four times a day for two weeks. Then, betamethasone was replaced by topical fluorometholone four times a day, which was tapered in two months. Follow-up examinations were scheduled at one day, three days, seven days, one month, three months, and six months postoperatively. No additional surgery was performed during follow-up.

## Statistical Analysis

Data was analyzed using the SPSS version 21 statistical software (SPSS Inc., Chicago, IL). Normality was checked using the Kolmogorov-Smirnov test. Normally distributed data were expressed as mean  $\pm$  standard deviation, median, and range, with 95% confidence interval (95% CI). To evaluate the difference between the two sets of data, we used repeated measure analysis of variance. Multiple comparisons were made using the Bonferroni method. Intraclass correlation (ICC) analysis was used to evaluate the difference in measurements between the two sets. In the last step to have a measure of agreement, we used the 95% limit of agreement (95% LOA) and Bland-Altman graph. *P* values less than 5% ( $P < 0.05$ ) were considered statistically significant.

## RESULTS

A total of 66 eyes of 33 patients (16 men and 17 women) were included in the study. Patients' mean age was  $26.9 \pm 5$  years, ranging from 20 to 40 years. Mean spherical equivalent refraction and mean central corneal thickness were  $-3.69 \pm 1.7$  D (range, -7.7 to -2.2 D) and  $539 \pm 22.1$   $\mu$ m (range, 500 to 589  $\mu$ m) respectively, at baseline.

Keratometric values at baseline and post-PRK are shown in Tables 1 and 2, respectively. In general, the lowest keratometric measurements were obtained using the Galilei topographer and the highest measurements

**Table 1. Baseline keratometric readings using different methods**

	Mean*	SD	Minimum	Median	Maximum
Manual keratometer	43.96	1.54	40	43.5	47
Orbscan II	43.82	1.55	40.05	43.5	47.25
Tomey	43.86	1.51	40.17	43.415	46.58
Galilei	42.98	1.69	38.63	42.68	46.38
EyeSys	43.73	1.58	40.32	43.33	46.77

\*Data are shown in diopters. SD, standard deviation

**Table 2. Post-PRK keratometric measurements using different methods and formulas**

	Mean*	SD	Minimum	Median	Maximum
Manual keratometer	41.21	1.99	37.00	41.12	45.60
Orbscan II	41.17	1.99	37.20	41.28	45.60
Tomey	41.14	2.00	36.92	41.07	45.33
Galilei	40.45	2.13	35.17	40.47	44.72
EyeSys	40.92	2.02	36.88	40.96	45.33
Adj ACCP	40.76	2.10	36.02	40.71	45.15
Adj EffRP	40.55	2.16	35.93	40.54	45.10
CHM	40.62	2.01	35.80	40.61	45.05

\*Data are shown in diopters. PRK, photorefractive keratectomy; SD, standard deviation; Adj ACCP, adjusted average central corneal power (measured using Tomey system); Adj EffRP, adjusted effective refractive power (measured using EyeSys system); CHM, clinical history method

were obtained using the Javal manual keratometer. Using ICC analysis, EyeSys values, followed by Galilei values, were most consistent with the CHM values compared with other systems [Table 3]. Bland-Altman plots with 95% LOA are shown in Figure 1. Total corneal power measured using Galilei had a higher correlation with CHM measurements compared to Orbscan II keratometric values. Moreover, similar results were seen between the manual keratometer and Orbscan II. Adj EffRP formula (using the EyeSys system) was the best predictor of post-PRK corneal power (95% LOA: -0.14 to 0.32) [Table 3].

## DISCUSSION

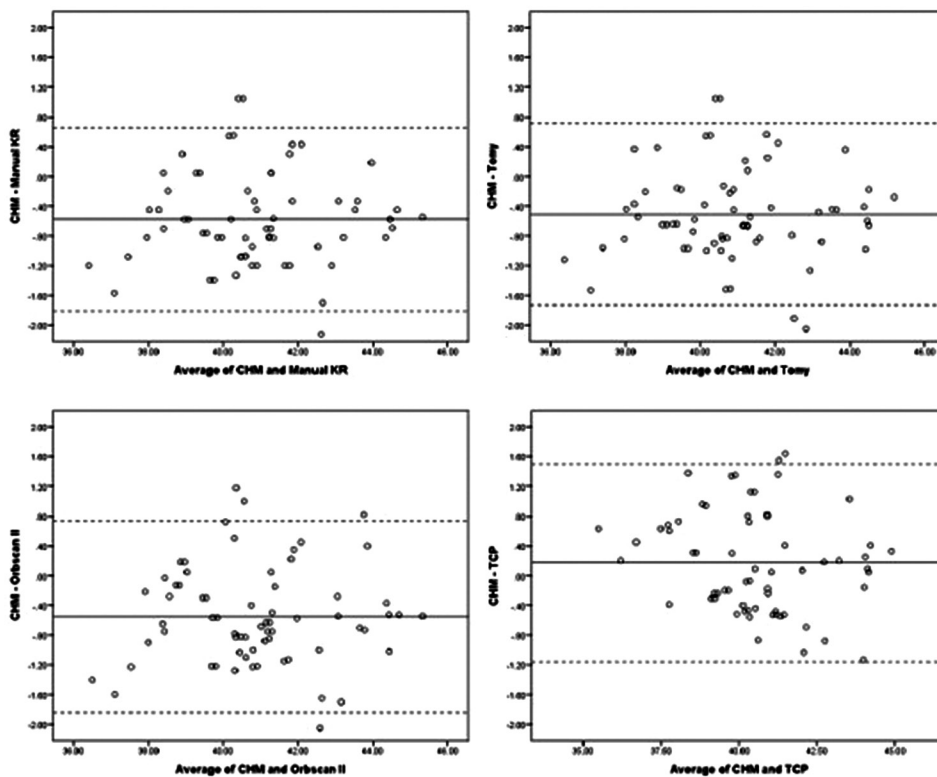
Despite improvements in topographic techniques and formulas, there are still significant differences in corneal power measurements after refractive surgery. In this study, we showed that corneal power obtained by using EyeSys, which was used in the adjusted EffRP formula, was the most consistent with CHM values. This was followed by TCP values obtained by using Galilei (ICC, 0.954 vs 0.943) in comparison with other keratometric techniques. In contrast, manual keratometry and Orbscan II were the least consistent. (ICC = 0.912).

The manual keratometers measure only four discrete paracentral points on the anterior cornea. These systems

**Table 3. Correlation of post-PRK keratometric values measured using different methods and formulas with clinical history method as gold standard**

	Manual keratometer	Orbscan II	Tomey	Galilei	EyeSys	Adj ACCP	Adj EffRP
ICC	0.912	0.912	0.922	0.943	0.951	0.919	0.954
Δ Mean (Diopter)±SD	-0.58±0.63	-0.55±0.66	-0.51±0.62	0.17±0.68	-0.32±0.55	-0.14±0.63	0.11±0.56
Δ Range	-2.12-1.05	-2.05-1.18	-2.05-1.05	-1.13-1.64	-1.70-0.81	-1.58-1.59	-1.29-1.28
95% CI	-0.85--0.33	-0.82--0.27	-0.77--0.26	-0.09-0.47	-0.56--0.11	-0.4-0.11	-0.14-0.32
P*	<0.001	<0.001	<0.001	0.777	<0.001	>0.99	>0.99
95% LoA (Lower to Upper)	-1.81-0.65	-1.84-0.74	-1.73-0.71	-1.16-1.50	-1.24-1.04	-1.37-1.09	-0.99-1.21

\*Based on repeated measure analysis of variance; multiple comparisons were made using the Bonferroni method; PRK, photorefractive keratectomy; ICC, intraclass correlation; SD, standard deviation; Δ, difference; CI, confidence interval; LoA, limits of agreement; Adj ACCP, adjusted average central corneal power (measured using Tomey system); Adj EffRP, adjusted effective refractive power (measured using EyeSys system)



**Figure 1.** Bland–Altman plots (95% limits of agreement) illustrate the differences in corneal power measurements between values obtained using Javal manual keratometer, Orbscan II, Tomey, and Galilei topographers versus values obtained by clinical history method. Manual KR, manual keratometer; CHM, clinical history method; TCP, total corneal power measured by Galilei topographer.

assume that the central cornea is spherical and that the posterior cornea has a radius of curvature 1.2 mm smaller than its anterior counterpart.<sup>[21]</sup> Earlier topographic devices, including Tomey, calculate the keratometric values within the 3-mm zone; as they are based on the reflection, they fail to consider the posterior plane of the cornea. However, Orbscan II uses a slit scanning method in addition to the Placido disc, which can calculate posterior corneal power using the triangulation method.<sup>[21]</sup>

Hussein et al<sup>[22]</sup> developed a method for measuring

corneal power by topography within the pupil area and showed that mean central keratometry, using topography in patients with small ablation zones and those with greater corrections, was different from manual keratometry. In contrast, Seitz et al<sup>[23]</sup> reported that manual keratometry following PRK in myopic patients was the best choice. In the current study, there was not significant difference between post PRK mean keratometric values using Javal, Orbscan II, and Tomey.



Seitz et al<sup>[23]</sup> and Sonego-Krone et al<sup>[24]</sup> suggested Orbscan as a criterion for determining the real corneal power following myopic LASIK. In addition, Qazi et al reported satisfactory results after using Orbscan II for determining the real corneal power after refractive surgery.<sup>[21]</sup> However, the accuracy of this method is not confirmed yet. In the present study, within the 3-mm zone, values obtained using the Orbscan II and manual keratometry were not significantly different from each other, but they were significantly different from those obtained using EffRP, TCP, and CHM ( $P < 0.01$ ).

The EyeSys system is one of the topographical methods that calculate the mean corneal power within a 3-mm zone. In our study, the mean EffRP calculated using EyeSys was  $40.92 \pm 2.02$  D after PRK, which was significantly lower than Tomey ( $41.14 \pm 2.00$  D) and manual keratometry values ( $41.21 \pm 1.99$  D) ( $P < 0.05$ ). The difference may be because the central flat spots are considered in the EyeSys system, unlike in manual keratometry and Tomey system. However, these values were greater than those obtained using CHM ( $40.62 \pm 2.01$  D) and TCP 1-4 mm ( $40.45 \pm 2.13$  D).

The Galilei Dual Scheimpflug Analyzer is an optical system for corneal topography and three-dimensional analysis of the anterior eye segment based on a revolving dual-channel Scheimpflug camera and a Placido disc. Hua et al<sup>[25]</sup> reported a high correlation among TCP calculated using Galilei, ray tracing method, IOL master keratometric values, and CHM in post-LASIK eyes. In a review article, Koch<sup>[26]</sup> reported that IOL calculation formulas based on TCP measurements using with either Scheimpflug or OCT technology may be more promising because they use the patient's actual data, not an average value obtained by regression, and do not require historical data. Schuster et al<sup>[27]</sup> also showed that using Scheimpflug technology (Pentacam HR) for corneal power measurement and IOL calculation yielded improved postoperative results for patients with previous corneal refractive surgery. In the present study, we also found that there was a considerable correlation between TCP and CHM (ICC = 0.943).

In summary, we showed that the adjusted EffRP formula (using EyeSys system) was the most consistent with CHM (ICC = 0.954, -0.14 to 0.32 95% LoA) followed by TCP (using Galilei system) post-PRK. Although improvements have been achieved using more developed topographic instruments and newer formulas for corneal power measurement after refractive surgery, there are still significant differences among various methods.

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Nil.

### Conflicts of Interest

There are no conflicts of interest.

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