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ORIGINAL PAPER

Corneal power measurement with a new aberrometer/corneal topographer in eyes after small incision lenticule extraction for myopia

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Abstract

Purpose To assess corneal power measurements obtained by the OPD SCAN III Topographer in eyes with prior myopic small incision lenticule extraction (SMILE) surgery.

Methods Sixty untreated myopic eyes of sixty subjects and forty previous myopic SMILE surgery eyes of forty subjects were consecutively enrolled in the present study. Manifest refraction, OPD SCAN III and Pentacam HR were performed. Keratometric measurements assessed by OPD SCAN III—simulated keratometry, average pupil power and effective central corneal power (ECCP) were compared with mean keratometry (Km) obtained by Pentacam HR in the untreated group and the clinical history method (CHM) in the treated group.

Results In the untreated group, no statistically significant differences were revealed between all corneal power measurements obtained with OPD SCAN III and Km. In the treated group, all the corneal power measurements were statistically different from the CHM except for the Haigis method and the Shammas method, while ECCP had a statistically but not clinically significant overestimation of 0.42 D with 95% limit of agreement (LOA) of − 0.81 D to 1.64 D. The three modified ECCP had better prediction performance with narrower 95% of LOA lying in (− 1.20, 1.20 D) (− 1.22, 1.23 D) and (− 0.90, 1.00 D), respectively.

Conclusions The ECCP provided with OPD SCAN III could be used as an alternative option for the CHM after specific modifications in eyes with previous myopic SMILE surgery when the preoperative data are unavailable considering the narrowest agreement between the modified ECCP and the CHM. Otherwise, caution must be raised considering the wide LOA.

Keywords Refractive surgery · Keratometry · Myopia · SMILE · OPD SCAN III

Introduction

Inaccurate corneal power measurement is the main factor that leads to refractive surprise after phacoemulsification and intraocular lens (IOL) implantation in cataractous eyes with prior myopic photorefractive keratectomy (PRK) or laser assisted

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in situ keratomileusis (LASIK) [1]. The errors induced by that myopic laser refractive surgeries disrupt the physiological ratio of anterior-to-posterior corneal curvature and make the keratometric index (normally 1.3375) used by conventional keratometry (manual, automated, Placido-based topography) invalid. To overcome this problem, various approaches have been introduced to improve the precision of corneal refractive power analysis after excimer laser surgery, including the clinical history method (CHM) [2], the contact lens method [3], Haigis equivalent formulas method [3], Wang-Koch-Maloney method [4], the Shammas method [5] and other methods [6].

Small incision lenticule extraction (SMILE) has shown promising results for correcting myopia and gained world widely acceptance in recent years [7, 8]. The no-flap procedure largely preserves the anterior corneal surface and produces distinct changes in the anterior corneal shape compared to flap-based LASIK [9]. However, the same dilemma has to be faced for the ophthalmologists that how to minimize the postoperative corneal power misevaluation and determine IOL accurately to achieve target refraction in subsequent cataract surgery. To the best of our knowledge, a few published studies have investigated corneal power assessment in eyes after SMILE surgery.

The relatively new multifunctional device, OPD Scan III (version 1.1604, Nidek Technologies, Gamagori, Japan), provides multiple corneal power values, such as simulated keratometry (SimK), average pupil power (APP) and effective central corneal power (ECCP). In the present study, corneal power measurements offered by OPD Scan III in post-SMILE eyes are compared with the keratometric values obtained by CHM—and 3 additional methods: Haigis equivalent formulas method, the Wang-Koch-Maloney method and the Shammas method.

Materials and methods

Subjects population

Forty eyes of forty consecutive patients who underwent myopic SMILE surgery at Hankou Aier Eye Hospital and sixty eyes of sixty volunteers who had routine examination before refractive surgery from August 2017 to September 2017 were enrolled in the prospective study as the treated group and the untreated group, separately. The inclusion criteria were age older than 18 years, absence of ocular diseases other than myopia or myopic astigmatism, no contact lens wearing in the 4 weeks before examination and no previous ocular surgery except for corneal refractive surgery in the treated group. The exclusion criteria were complications of corneal refractive surgery, uncorrected distance visual acuity worsen than 20/25, follow-up less than 3 months and incomplete preoperative data in the treated group. Before enrollment, all subjects had signed informed consent. The study adhered to the tenets of Declaration of Helsinki and was approved by ethics committee of Hankou Aier Eye Hospital.

Examination

In the untreated group, non-cycloplegic manifest refraction, Pentacam HR rotating Scheimpflug camera (version 1.20r112, Oculus Inc, Germany) and OPD SCAN III were performed.

In the treated group, all eyes had routine preoperative examinations, including subjective and non-cycloplegic manifest refraction, non-contact tonometry, slit-lamp biomicroscopy, indirect ophthalmoscopy and Pentacam HR. SMILE procedures were performed by one experienced surgeon (XL) using a VisuMax femtosecond laser system (Carl Zeiss Meditec AG, Germany) as described in previous study [10]. The lenticule diameter (optical zone) was 6.0–6.5 mm, and the cap diameter was 7.3 mm. The intended cap thickness was between 110 and 120 μm in all cases. All patients completed regular follow-up postoperatively, 3 months or later manifest refraction; Pentacam HR and the Nidek OPD Scan III were performed.

Only one eye was randomly selected for the study. Given the high repeatability for Pentacam HR and OPD SCAN III in measuring corneal power parameters reported by former researches [11, 12], only the first measurement with no artifacts induced by blinking or tear film break (with a quality specification of "OK" in Pentacam HR) was used for analysis.

Assessment of corneal power measurements

The Nidek OPD Scan III, which projects 33 vertical and 39 horizontal rings to cover almost the entire cornea from 0.5 to 11.0 mm, measures 11,800 points

of the anterior corneal surface for corneal profiles reconstruction, which provides the following keratometric parameters.

1. *Simulated Keratometry (SimK)* This value is the arithmetic mean of the flattest and 90-degree-apart meridian power at approximately 3.3 mm diameter converted from the average axial curvature (in meters) using the standard keratometric index (n = 1.3375). It derives from the thin-lens formula for paraxial imagery which considers the cornea as a fictitious single refractive surface (meant to represent both the anterior and posterior corneal surfaces) and reads as

$$\text{Corneal power} = (n-1)/\text{corneal radius}$$

where n is the traditional keratometric index of refraction (1.3375) and 1 is the refractive index of air.
2. *Average pupil power (APP)* According to the manufacturer, this value is the arithmetic mean of the flattest and 90-degree-apart meridian power using the traditional keratometric index (1.3375) at the pupil-centered zone, which may more approximate the actual corneal power from the view of optical transmission. The device gives options of the pupil diameter ranging from 3.0 to 9.0 mm for APP. A diameter of 3.0 mm was arbitrarily chosen in the untreated group, while diameters of ranging from 3.0 to 6.0 mm were selected in the treated group for analysis and abbreviated as APP_{3mm}, APP_{4mm}, APP_{5mm} and APP_{6mm}, respectively.
3. Effective central corneal power (ECCP). According to the manufacturer, this value aims to improve the accuracy of corneal power estimation in eyes with previous corneal refractive surgery. It is established by the postoperative central corneal power and the amount of surgical induced refractive correction, which was obtained by subtracting the postoperative central corneal power from the estimated preoperative central corneal power determined through comparison of the peripheral corneal power from the topography, considering that there are a relatively constant relation between the central corneal curvature and the peripheral corneal curvature in unoperated eyes. A default of 4.5 mm ECCP is displayed in the incorporated software.

Pentacam HR topographer provides a series of keratometric parameters. In our study, we only included mean keratometry (Km) for analysis. This value is the arithmetic mean of the pair of meridians 90 degrees apart with the greatest difference in axial power within the central 3.0 mm. It is equivalent to the simulated K of traditional corneal topographers, which is calculated by entering the average axial curvature (in meters) into the aforementioned thin-lens formula.

Formulas to predict postoperative corneal power

The postoperative corneal power in the treated group was assessed by means of the clinical history method (CHM). Surgical-induced SE was calculated by subtracting postoperative spherical equivalents at the corneal plane (SEco) using a vertex distance of 12 mm from preoperative SEco, and the obtained value has been subtracted from the preoperative keratometric measurement((obtained with Pentacam HR in the current study)) to derive the theoretical postoperative corneal power.

The keratometry calculated from the following published equations was also included: (1) Haigis equivalent power formula, in which Kc = 1.119 *Post SimK(SimKpost) − 5.78 [3]; (2) Wang-Koch-Maloney equation, in which Kc = 1.114 SimKpost-6.1 [4]; (3) the Shammas formula, in which Kc = 1.14 SimKpost-6.8 [5].

In the present study, The CHM value is adopted as the benchmark for comparisons between various keratometric parameters obtained with OPD SCAN III and the formulas estimated postoperative corneal power.

Statistical analysis

All the data were analyzed using MedCalc Version 11.4.2 for Windows (MedCalc Software, Belgium). Kolmogorov–Smirnov test was performed before parameters expressed as the mean ± standard deviation (SD). Comparisons among all the corneal power measurements were performed using one-way analysis of variance (ANOVA) for repeated measures with Bonferroni multiple comparisons. The relationship between ECCP and the CHM value was evaluated with the Pearson correlation test and linear regression. Bland–Altman plots were used to assess the agreement between corneal power measurements provided by

OPD SCAN III and Km in the untreated group, various corneal power measurements and the CHM in the treated group [13]. A P value of less than 0.05 was considered statistically significant.

Results

The mean age was 22.98 ± 3.82 years (range: 18 to 36 years) in the untreated group and 22.63 ± 4.53 years (range: 18 to 37 years) in the treated group. The mean SE was − 3.56 ± 2.60 diopters (D) (range: − 1.00 to − 8.00 D) in the untreated group. In the treated group, the mean preoperative and postoperative SE was − 4.90 ± 2.11 D (range: − 1.50 to − 9.50 D) and 0.18 ± 0.40 D (range: − 0.63 to 1.33 D), respectively. The mean follow- up was 129.05 ± 22.83 days (range: 93 to 178 days).

In the untreated group, Km, SimK, APP_{3mm} and ECCP were 42.96 ± 1.68 D, 42.98 ± 1.67 D, 42.96 ± 1.68 D and 43.04 ± 1.70 D, respectively. ANOVA disclosed no significant difference among corneal power measurements obtained by OPD Scan III and Km. The 95% limits of agreement (LOA) between SimK and Km, APP_{3mm} and Km, ECCP and Km was − 0.38 to 0.32 D,− 0.37 to 0.36 D,− 0.31 to 0.49 D, respectively.

In the treated group, the preoperative Km was 42.61 ± 1.22 D, the postoperative theoretical K measured by CHM was 37.84 ± 2.05 D. Table 1 shows comparison of postoperative corneal power values obtained by OPD SCAN III and other formulas with the CHM value. There were significant difference between all corneal power measurements and the CHM except for the Haigis method and the Shammas method, which underestimated corneal power by 0.18 D and 0.39 D, separately. Corneal power values measured by OPD SCAN III significantly overestimated postoperative corneal power, with ECCP overestimated least by 0.42 D, which is not clinically relevant [14].

Figure 1a–i displays the Bland–Altman plots comparing the corneal power measurements obtained by OPD SCAN III and various formulas with the CHM value. The 95% LOA of the Haigis method and CHM, the Shammas method and CHM was − 1.72 to 1.36 D and − 1.93 to 1.16 D, respectively. The narrowest 95% LOA of numerous corneal power parameters obtained with OPD SCAN III was achieved by ECCP (− 0.81 D, 1.64 D), which was even slightly better than that of the Haigis method and CHM.

Pearson correlation revealed a high correlation between ECCP and the CHM value ($r = 0.9541$, $P < 0.001$), as displayed in Fig. 2. Thus, we got a formula using linear regression ($R^2 = 0.9087$) as following: the adjusted ECCP 1 ($ECCP_{adjst1}$) = 1.0630* ECCP − 2.8256 (formula 1), which could estimate the theoretical corneal power based on the ECCP displayed by OPD SCAN III. To simplify the formula 1, we converted into the $ECCP_{adj1}$ = (1 + 0.0630)*ECCP − 2.8256 = ECCP − (2.8256–0.0630*ECCP); in the present study, the mean value of 38.26 D for ECCP was entered into the latter part of the formula 1; then, we got the formula 2: the adjusted ECCP 2 ($ECCP_{adj2}$)- = ECCP − 0.41, which could be easily used for primary estimation of the theoretical corneal power in daily clinical practice. Meanwhile, to further increase the predictive accuracy of the formula 1, we also explored the potential influential factor that may impact the predictive error and found that Pre SEco was significantly correlated with predictive error($r = -0.5618$, $P < 0.001$); thus, we proposed the formula 3 based on multivariate linear regression, the adjusted ECCP 3 ($ECCP_{adj3}$) = 0.858*ECCP + 0.286*Pre SEco + 7.067 ($R^2 = 0.941$), which could most accurately estimate the theoretical corneal power considering that it has taken into account more impacting factors. The difference between the $ECCP_{adj1}$, $ECCP_{adj2}$, $ECCP_{adj3}$ and CHM was decreased to (0.001 ± 0.61) D, (− 0.004 ± 0.62) D, (− 0.05 ± 0.49) D, respectively ($P > 0.05$). Figure 3a–c shows high level of agreement between all the three forms of adjusted ECCP and the CHM value, in which the narrowest 95% of LOA was achieved by the $ECCP_{adj3}$. Table 2 displays the percentage of estimative error compared to the CHM value within ± 0.50 D and ± 1.00 D obtained with the Haigis method, the Shammas method, ECCP and its three adjusted forms, in which the $ECCP_{adj1}$ had the most accurate estimation, with ± 0.50 D being achieved in 30 (75%) of eyes. For measurements within ± 1.00 D, the $ECCP_{adj3}$ had the most accurate estimation (95%).

Discussion

Previous researchers have proposed numerous approaches attempting to solve the puzzle and improved the accuracy of corneal power estimation

Table 1 Postoperative corneal power calculated by various methods (n = 40 eyes)

Corneal power measurement	Mean ± SD(D)	Mean difference versus CHM(D)	P value*	95% LOA versus CHM(D)
CHM	37.84 ± 2.05	–	–	–
SimK	38.82 ± 1.64	0.98 ± 0.83	$P < 0.01$	− 0.64 to 2.60
3 mm APP	38.54 ± 1.80	0.70 ± 0.65	$P < 0.01$	− 0.58 to 1.97
4 mm APP	38.62 ± 1.76	0.77 ± 0.67	$P < 0.01$	− 0.55 to 2.09
5 mm APP	38.69 ± 1.72	0.85 ± 0.73	$P < 0.01$	− 0.57 to 2.27
6 mm APP	38.79 ± 1.67	0.95 ± 0.81	$P < 0.01$	− 0.63 to 2.53
ECCP	38.26 ± 1.84	0.42 ± 0.62	$P < 0.01$	− 0.81 to 1.64
Haigis	37.66 ± 1.83	− 0.18 ± 0.79	$P = 1.00$	− 1.72 to 1.36
Wang-Koch-Maloney	37.15 ± 1.83	− 0.69 ± 0.79	$P < 0.01$	− 2.24 to 0.85
Shammas	37.46 ± 1.87	− 0.39 ± 0.79	$P = 0.16$	− 1.93 to 1.16

CHM keratometry measured by clinical history method, *LOA* limits of agreement, *SimK* simulated keratometry, *APP* average pupil power, *ECCP* effective central corneal power

*Bonferroni multiple comparisons with the clinical history method

in eyes after corneal refractive surgery (PRK or LASIK) [1–5, 15]. Recently, SMILE procedure has been widely implement as an alternative to LASIK for treatment of myopia and myopia astigmatism [7, 8]. However, few studies have focused on corneal power estimation in eyes after myopic SMILE surgery.

In our study, the corneal power measurements provided by OPD SCAN III were compared with Km measured by Pentacam HR in the untreated eyes. Excellent agreements were exhibited between corneal keratometry parameters measured by OPD SCAN III and Km, with 95% of LOA all lying in (− 0.50 D, 0.50 D). Thus, we could speculate that these corneal power parameters could be interchangeable in clinical use in the virginal eyes.

In the post-SMILE eyes, all keratometric parameters measured with OPD SCAN III overestimated the theoretical corneal power significantly. It was not surprising that the SimK overestimated the CHM by 0.98 D. Similar findings have been reported in previous studies [1, 16–18]. The corneal refractive surgery corrects the myopia or myopic astigmatism through ablating a certain amount of corneal tissue and flattening the anterior corneal surface, resulting in the physiologic anterior-to-posterior corneal curvature ratio variable and the standard keratometric index (n = 1.3375) invalid. As a consequence, the traditional simulated keratometry constantly overestimates corneal power in postmyopic corneal refractive surgery. To overcome this problem, a variable keratometric index could be applied instead of the fixed keratometric index [19].

The average pupil power, which calculates the corneal power centered on the pupil axis instead of the cornea apex compared to SimK, may represent the accurate corneal power from the perspective of optical transmission. However, the present study disclosed that the average pupil power constantly overestimated theoretical corneal power in eyes after SMILE procedure, with the least overestimation of 0.70 D by 3 mm APP. Meanwhile, the overestimation by APP increased correspondingly as the entrance pupil diameter increased. The conventional keratometric index (n = 1.3375) used in the calculation mainly contributed to the estimation error.

The effective central corneal power, according to the manufacturer, aiming to increase the accuracy of corneal power for postoperative corneas, got no particularly satisfied results in our study. A value of 0.42 D was overestimated by ECCP compared to the CHM value, which was statistically significant but not clinically relevant. The Bland–Altman analysis disclosed a wide agreement of 95% LOA (− 0.81, 1.64 D) with barely 40% of predictive error lying in ± 0.50 D and 85% of predictive error lying in ± 1.0 D. To further improve the predictive ability of ECCP, we proposed three formulas to adjust the measured ECCP. Encouragingly, all the three adjusted ECCP had no significant difference compared to the CHM, with 95% of LOA lying in (− 1.20, 1.20 D), (− 1.22, 1.23

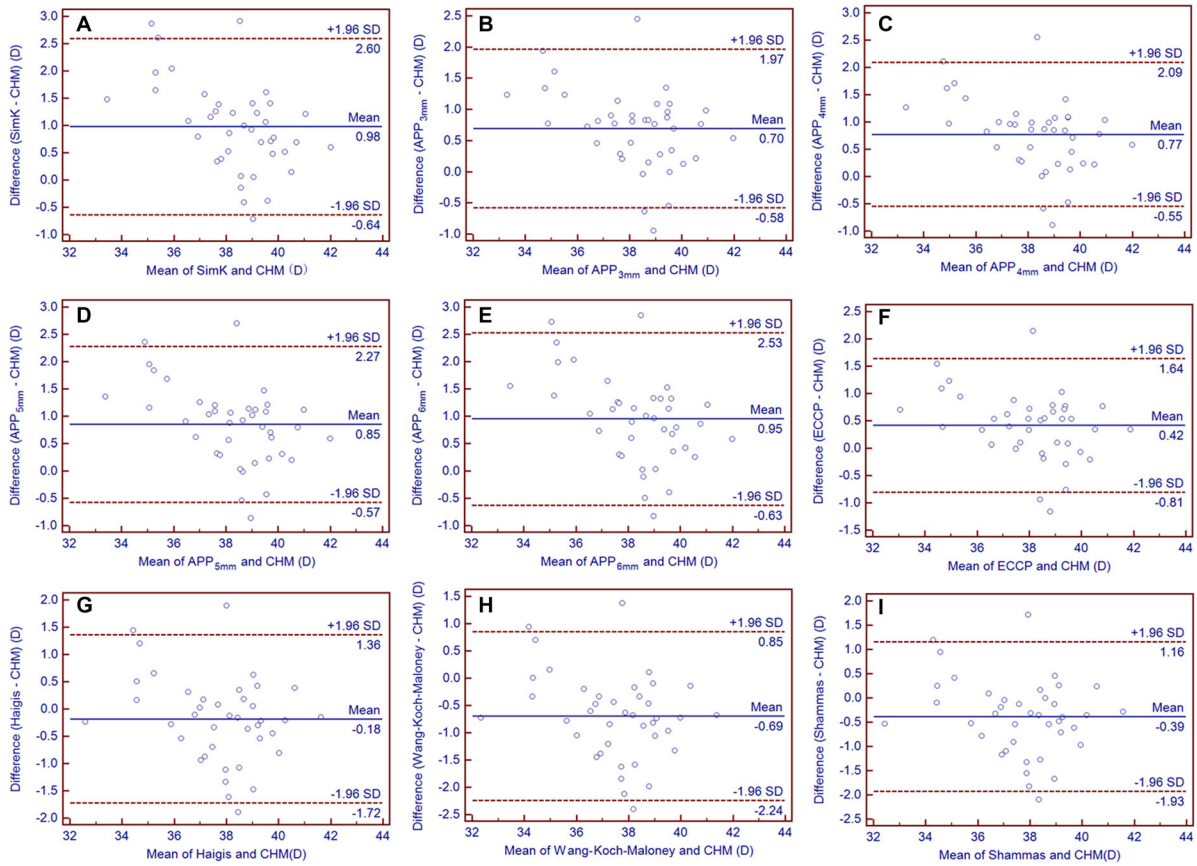


Fig. 1 Bland–Altman plots of agreement between corneal power measurements obtained with OPD SCAN III along with three author-proposed methods against CHM (**a–i** represent SimK, APP_{3mm}, APP_{4mm}, APP_{5mm}, APP_{6mm}, ECCP, the Haigis method, the Wang-Koch-Maloney method and the Shammas method, respectively). The solid line represents the mean difference (bias). The upper and lower lines represent the 95% LOA (The 95% LOA is shown with the dashed lines.) (*CHM* keratometry measured by clinical history method, *LOA* limits of agreement, *SimK* simulated keratometry, *APP* average pupil power, APP_{3mm}, APP_{4mm}, APP_{5mm} and APP_{6mm} represent 3 mm APP,4 mm APP, 5 mm APP and 6 mm APP, respectively; *ECCP* effective central corneal power.)

D) and (− 0.90, 1.00 D), respectively. The $ECCP_{adj1}$ displayed the highest predictability, with ± 0.50 D being achieved in 30 (75%) of eyes. For measurements within ± 1.00 D, the $ECCP_{adj3}$ demonstrated the highest predictability (95%). However, the $ECCP_{adj3}$ required the preoperative SE, which may be just inaccurate or missing induced from a long time lapse. Thus, the $ECCP_{adj1}$ and $ECCP_{adj2}$ could be considered in this situation, while the former had the slightly higher predictive accuracy, the later was easier to use in clinical practice with a sacrifice of accuracy. According to the manual, the ECCP is established after the preoperative central corneal curvature has been determined by comparing the peripheral with the central corneal power from the topography. Therefore, we may speculate that the ECCP is calculated from a regression formula which is based on the amount of keratometric diopter changes of anterior corneal surface due to the refractive procedure, though the manufacturer has not given the formula in the detail. Our analysis indicated that ECCP did have the potential to increase the accuracy of evaluating corneal power after SMILE procedure with the precondition of slight modification. Previously, Qian et al. [10] had assessed corneal power distribution using the ray tracing method with Pentacam in eyes undergoing SMILE surgery and found that the peripheral decrease in corneal power occurred beyond the size of the cap, which is distinct from the common recognition that the peripheral corneal shape outside

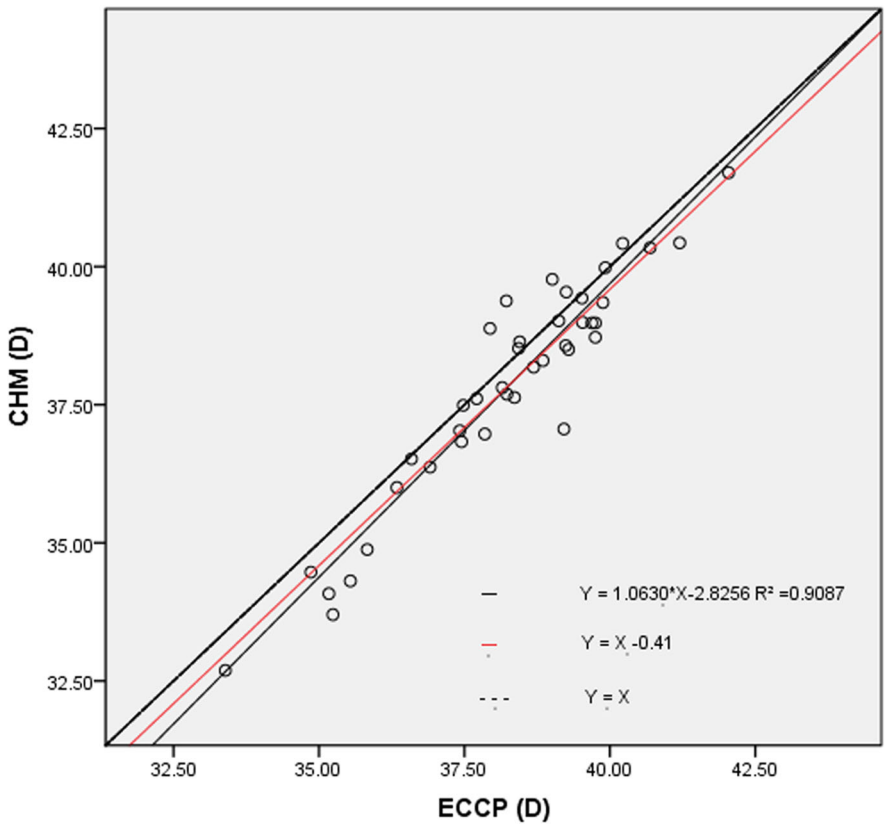
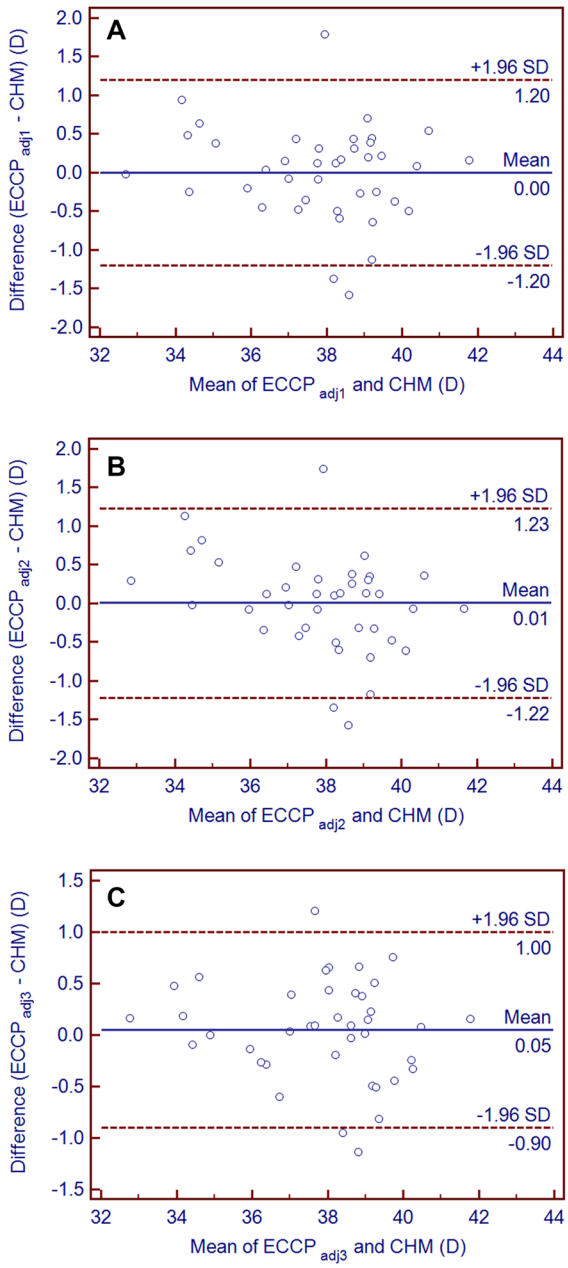


Fig. 2 Scatterplots presenting the CHM against the OPD SCAN III ECCP results (*CHM* clinical history method, *ECCP* effective central corneal power)

the size of the cap remains constant before and after refractive surgery. Giving that peripheral corneal power has been involved in the calculation of ECCP, further investigation would be warranted to explore the potential mechanism, which may further improve the accuracy of corneal power evaluated by the ECCP.

This is the first study to evaluate corneal power in eyes after SMILE using OPD SCAN III. Previously, researchers had assessed the predictive ability of Pentacam in measuring post-SMILE corneal power. Wei et al. [18] reported that the 4.0, 4.5 and 5.0 mm Equivalent Keratometry readings (EKR), which was proposed by Holladay et al. [20] for the evaluation of total corneal power after corneal refractive surgery, accurately estimated theoretical corneal power calculated by CHM in eyes after SMILE and the 95% of LOA was (− 0.94, 0.90 D), (− 0.83, 0.88 D), (− 0.84, 0.88 D), respectively, which were better than previous results reported in post-PRK eyes (− 1.65 D to 1.17 D for 4.5 mm EKR) [21]. Another keratometric parameter—total corneal refractive power (TCRP), which was calculated by means of ray tracing, has the advantage to overcome the keratometric index error in postoperative corneal power evaluation. Qian et al. [22] revealed that pupil-centered 3.0 mm ring and 4.0 mm ring TCRP (6.63 ± 1.20 D and 6.64 ± 1.16 D) matched the surgical induced SE change precisely (6.61 ± 1.37 D). In eyes after PRK, Oh et al. [23] disclosed that pupil-centered 4 mm zone TCRP had the least difference with surgical induced manifest refraction change (0.28 ± 0.55 D). Considering that the pupil-centered 3.0 mm ring TCRP (42.93 ± 1.52 D) significantly underestimated simulated keratometry (43.42 ± 1.49 D) in normal eyes by 0.49 D reported in a previous large sample study [24], direct comparison with the theoretical postoperative power using CHM values may reveal different results.

As a secondary outcome, the current study assessed the agreement of corneal power evaluation between several approaches proposed by previous investigators and the CHM. Among the three published equations, the only method that shown statistically significant difference with the CHM was the Wang-Koch-Maloney method. It was not surprising that the



◀**Fig. 3** Bland–Altman plots of agreement between three forms of ECCP after adjusted against CHM (**a**–**c** represent $ECCP_{adj1}$, $ECCP_{adj2}$ and $ECCP_{adj3}$, respectively). The solid line represents the mean difference (bias). The upper and lower lines represent the 95% LOA (The 95% LOA is shown with the dashed lines.) (*CHM* keratometry measured by clinical history method, *LOA* limits of agreement, *ECCP* effective central corneal power, $ECCP_{adj1}$ adjusted effective central corneal power according to formula 1($ECCP_{adj1}$ = 1.0630*effective central corneal power − 2.8256), $ECCP_{adj2}$ adjusted effective central corneal power according to formula 2 ($ECCP_{adj2}$ = effective central corneal power − 0.41), $ECCP_{adj3}$ adjusted effective central corneal power according to formula 3 ($ECCP_{adj3}$ = 0.846*effective central corneal power − 0.331*Delta_SEco + 7.067))

Wang-Koch-Maloney method underestimated the CHM, since this method converts the corneal power measured by topography back to the anterior corneal power first and then subtracts the posterior corneal power(4.9 D), which is further modified to 6.1 D by Wang [4]. The Wang-Koch-Maloney method could be considered as a simplification of Gaussian optics formula, which consistently underestimated corneal power in eyes after myopic refractive surgery [16, 17].

While the Haigis method and the Shammas method underestimated the corneal power with respect to CHM value by 0.18 D and 0.39 D, which was comparable to 0.17 D and 0.36 D in Wei et al.'s study [18]. The Shammas method is a clinically derived method based on a regression formula between the CHM and postoperative keratometric values [5], which was supposed to present the best ability in assessing the actual corneal power in eyes with previous corneal surgery compared to the CHM. In the current study, the wide LOA (− 1.93 to 1.16 D) indicated that the Shammas method seemed to be not a compelling alternative to the CHM method. The discrepancy may partly due to the selection of the sample, the diversity of the topographer devices and the disparity of surgical techniques. The Haigis equivalent power formula is a theoretical equation derived from performing model calculations on a myopic Gullstrand eye using customized computer programs [3]. Wide agreement was achieved between the Haigis method and the CHM with a 95% LOA of − 1.72 to 1.36 D, with 55% of predictive error lying in ± 0.50 D and 77.5% of predictive error lying in ± 1.0 D, indicating that caution should be raised when the Haigis method was used as an alternative to the CHM.

The present study has limitations. First, we only evaluated a small size of subjects with myopic SMILE surgery, not including other popular surgical techniques such as PRK and LASIK, Further studies with a larger sample of subjects comprised of different surgical therapies would be necessary to confirm the current results. Second, we have not evaluated the enrolled treated group preoperatively using OPD SCAN III, which makes evaluation of surgical induced

Table 2 Distribution (%) of differences between series of postoperative corneal power values and the CHM within ± 0.50 D and ± 1.00 D

Method	Mean difference[a] (D)	No. (%) within ± 0.50 D	No. (%) within ± 1.00 D
The Haigis method	− 0.18	22 (55)	31 (77.5)
The Shammas method	− 0.39	20 (50)	30 (75)
ECCP	0.42	16 (40)	34 (85)
$ECCP_{adj1}$	0.00	30 (75)	36 (90)
$ECCP_{adj2}$	0.10	29 (72.5)	35 (87.5)
$ECCP_{adj3}$	0.23	28 (70)	38 (95)

CHM clinical history method, *ECCP* effective central corneal power, $ECCP_{adj1}$ adjusted effective central corneal power according to formula 1($ECCP_{adj1}$ = 1.0630*effective central corneal power − 2.8256), $ECCP_{adj2}$ adjusted effective central corneal power according to formula 2 ($ECCP_{adj2}$ = effective central corneal power − 0.41), $ECCP_{adj3}$ adjusted effective central corneal power according to formula 3 ($ECCP_{adj3}$ = 0.846*effective central corneal power − 0.331*Delta_SEco + 7.067), [a]versus clinical history method. Delta_SEco = preoperative and postoperative spherical equivalent change at the corneal plane

refractive change by corneal power measurements unavailable. Third, we have chosen the CHM as the benchmark in our study. Recently, increasingly researchers suspected the accuracy of CHM because the preoperative data could be imprecise or unstable either due to inaccurate measurements or interval changes in the corneal curvature or lens power and clarity. However, the CHM could be used with caution in selected subjects [17, 18]. In the current study, we investigated previous SMILE surgery eyes in short-term follow-up and intended to find an alternative method to the CHM. The limitation of CHM itself has been controlled to the mildest level and might have little impact on the accuracy of our results. Certainly, a further study using the gold standard method—the back-calculated method instead of the CHM would be needed to verify the present results.

In summary, the current study evaluated the agreement of corneal power estimation with respect to CHM in eyes with prior myopic SMILE surgery using OPD SCAN III. The ECCP could be used as an alternative option for the CHM after specific modifications when the preoperative data were unavailable. Otherwise, caution must be raised considering the wide LOA. Nonetheless, a corneal power measurement shown large discrepancy does not mean they will present inferior refractive outcomes in IOL power calculation in postoperative eyes.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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