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Original Article

Effect of corneal diameter on preoperative screening results for corneal refractive surgery

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Abstract: Aims: To investigate the impact of different corneal diameters on corneal morphology and biomechanical outcome during preoperative screening for corneal refractive surgery. Methods: A retrospective analysis was conducted on 300 patients who underwent corneal refractive surgery at Eye and ENT Hospital, Fudan University between October 2023 and December 2023. All patients had no history of keratoconus or previous corneal surgery. Patients were categorized into two groups based on corneal topography measurements: (1) normal corneal diameter group (n=159), those with corneal diameter ranging from 11.5 mm to 12.0 mm; (2) abnormal corneal diameter group (n=141), those with corneal diameter smaller than 10.0 mm or larger than 12.5 mm. Corneal thickness, morphologic data, and biomechanical data were measured using Pentacam corneal topography. Correlation analysis was conducted to explore the relationship between corneal diameter and various corneal topography and biomechanical data. Results: Significant differences were observed in corneal topography data including BFSf (F=43.21), BFSb (F=30.24), Df (F=15.32), Dp (F=32.36), Da (F=9.66), D (F=58.36), PPIavg (F=32.64), and ARTmax (F=12.06) between the groups (P<0.05). Additionally, BFSf, BFSb, Db, Dp, D, and PPIavg exhibited statistically significant differences between any two groups (P<0.05). Significant differences were also found in Df, Da, and ARTmax between small and large corneas, as well as between normal-sized and large corneas (P<0.05). Correlation analysis indicated negative correlations between corneal diameter and A1V (r=-0.12), HCdArcLength (r=-0.17), CBI (r=-0.27), bIOP (r=-0.13), Df (r=-0.025), PPIavg (r=-0.028), and TBI (r=-0.27). Conversely, BFSf (r=0.009), BFSb (r=0.001), PD (r=0.15), and ARTH (r=0.37) displayed positive correlations with corneal diameter. Conclusions: Corneal diameter significantly affects preoperative screening for corneal refractive surgery. Smaller corneal diameters exhibit a greater influence on the corneal topography BAD analysis system.

Keywords: Corneal diameter, preoperative screening results, corneal refractive surgery

Introduction

Refractive error is the most prevalent condition affecting patients' quality of life, imposing numerous daily inconveniences. In recent years, its incidence has exhibited a continuous increase [1]. Keratoconus is a slowly progressive non-inflammatory eye disease characterized by thinning and protrusion of the cornea. It is usually diagnosed in adolescence, and can lead to severe vision impairment and serves as an absolute contraindication for corneal refractive surgery, garnering attention from both patients and doctors [2]. Detecting keratoconus is pivotal for ensuring surgical safety and efficacy. Currently, clinical screening and diagnosis of keratoconus primarily rely on corneal topography and patient history [3]. The German Pentacam three-dimensional anterior segment analyzer is among the leading preoperative screening tools for corneal refractive surgery [4]. However, we have found that different corneal diameters can influence various parameters in the Pentacam report, particularly in patients with smaller corneal diameters, where abnormal corneal topography probabilities are heightened. This discrepancy may stem from the predominantly European and American demographics in the Pentacam database, posing a significant challenge for refractive surgeons in China [5]. Therefore, improving the accuracy of preoperative screening for corneal refractive surgery is crucial for the success of the procedure.

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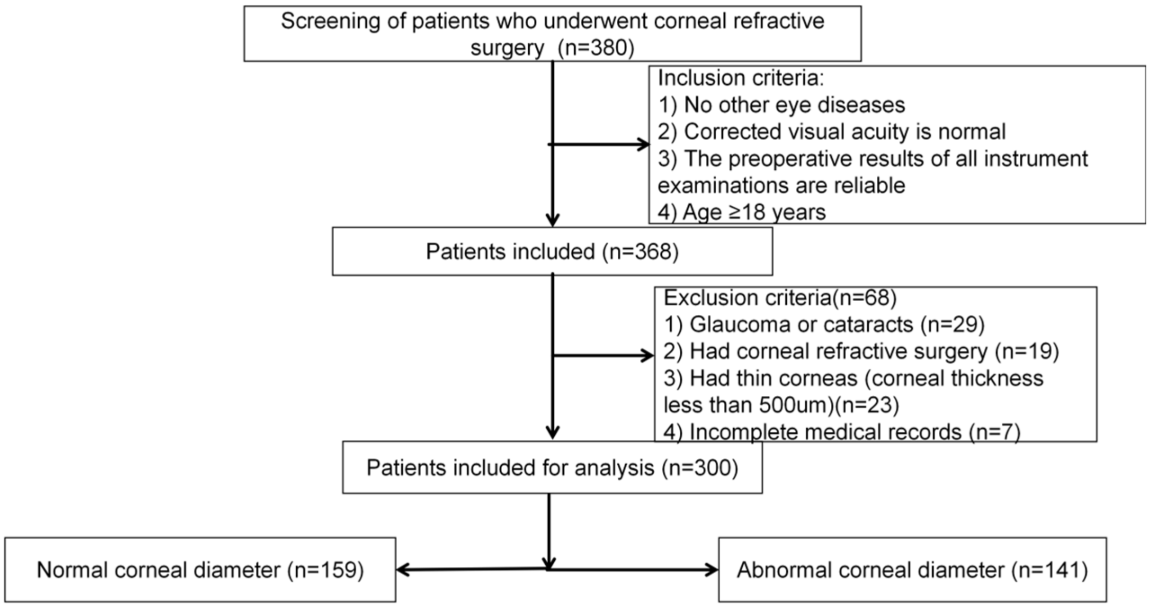

Figure 1. Flow chart.

Corneal diameter is an important measurement in diagnosing abnormal corneal diseases [6]. The standard corneal diameter range falls between 11.5 mm to 12.0 mm, with diameters below 10.0 mm termed as microcornea and those exceeding 12.5 mm labeled as macrocornea [7]. Instruments commonly employed for corneal diameter measurement encompass the IOL Master, Orbscan IIz, Pentacam, LenStar, and OCT [8]. Studies have demonstrated slight variations in corneal diameter measurements across different devices [9]. Another study indicated that corneal diameter is closely related to corneal thickness and curvature radius, with larger diameters often observed in younger individuals. Furthermore, male individuals tend to have slightly larger average corneal diameters compared to females, with diameter decreasing slightly with age [10]. However, there is currently no research indicating the impact of different corneal diameters on corneal morphology and biomechanical results during preoperative screening for corneal refractive surgery. Therefore, this study included 300 patients undergoing corneal refractive surgery to fill in this research gap.

Methods and materials

Study population

A total of 300 patients scheduled for corneal refractive surgery at The Lishui Eye and ENT Hospital, Fudan University between October 2023 and December 2023 were retrospectively included in the analysis of their preoperative examination data. Participants were categorized into two groups based on corneal diameter measured by Pentacam corneal topography: (1) normal corneal diameter group (n=159), defined as corneal diameter ranging from 11.5 mm to 12.0 mm; (2) abnormal corneal diameter group (n=141), defined as corneal diameter smaller than 10.0 mm or larger than 12.5 mm. The flow diagram detailing participant screening is depicted in **Figure 1**. This study has been reviewed and approved by the medical ethics committee of Lishui People's Hospital.

Inclusion and exclusion criteria

Inclusion criteria: 1) patients with no previous history of other eye diseases and systemic diseases that affect the eyes, but there was a need for corneal refractive surgery; 2) patients with a stable refractive status for two years (with a change in refractive power of ≤0.5 D); 3) patients with normal corrected visual acuity; 4) patients with normal preoperative results from all instrument examinations, and no eye drops were needed before the examination of the cornea; 5) patients ≥18 years of age; 6) patients with complete and standard medical records, including current and past medical history, preoperative laboratory and imaging examination results, as well as intraoperative data.

Table 1. Comparison of patients with different corneal diameters

	Normal corneal diameter (n=159)	Abnormal corneal diameter (n=141)	t	P
Age	26.34±5.98	23.36±5.21	35.12	0.001
Equivalent spherical mirror	-5.62±2.23	-5.36±2.16	3.36	0.03
Corneal thickness	546.84±27.84	549.61±30.14	1.43	0.26
Intraocular pressure	17.04±1.62	16.35±1.61	5.67	0.07
BMI	20.7±1.14	20.1±0.77	3.69	0.45
Smoking	44 (27.7%)	47 (33.3%)	2.87	0.594
Drinking	20 (12.6%)	24 (17.0%)	3.55	0.351

Exclusion criteria: 1) patients with a medical history of systemic diseases that can affect the cornea; 2) patients with a history of other eye diseases, such as glaucoma or cataracts, in addition to refractive impairment; 3) patients with a confirmed diagnosis of keratoconus or showing a tendency towards corneal ectasia; 4) patients who had undergone corneal refractive surgery in the past; 5) patients with thin corneas (corneal thickness less than 500 μm); 6) patients with incomplete clinical data.

Inspection methods

Pentacam Anterior Segment Data Analysis System: After inputting patient information into the computer, common issues were explained to the patients for better compliance. Patients were positioned with their chin and forehead securely on rest and strap, respectively, in a darkened room. After adjusting the height of the chin rest, they were instructed to open their eyes wide to fully expose the cornea, and a fixation point was provided for them to maintain steady fixation. The technician located the cornea using a joystick, and the instrument automatically focuses and gradually measures with precision. The examination results were then observed for quality, marked "OK" if acceptable; otherwise, a re-examination was necessary, beginning with the right eye followed by the left.

Corvis ST: The preparations and re-examination criteria remained the same as above. After securing their chin and forehead, they were instructed to open their eyes wide to fully expose the cornea. They were told to focus on the machine's positioning point without blinking or rotating the eyes. The instrument automatically focused and generated results.

Observation indicators

Primary outcomes included corneal topography and biomechanical assessments. Secondary outcomes included participants' ocular and systemic medical histories, family medical histories, and records of ophthalmic examinations, comprising uncorrected and corrected visual acuity tests, computerized and comprehensive refraction tests, intraocular pressure measurements, slit lamp biomicroscopy, and fundus examinations.

Manual review of printed electronic records was conducted, ensuring data integrity.

Statistical analysis

Statistical analysis and data visualization were performed using SPSS 23.0. Normally distributed data with homogeneity of variance were analyzed using one-way analysis of variance (ANOVA). Otherwise, Kruskal-Wallis H test was employed. Turkey post hoc test was conducted for pairwise comparison after one-way ANOVA. A *p*-value of less than 0.05 was considered significant. Additionally, Pearson's correlation analysis was used to explore the relationship between corneal diameter and measurements of corneal topography and corneal biomechanics.

Results

Clinical characteristics

As shown in the **Table 1**, there were significant differences in terms of age and equivalent spherical mirror between the two groups (P<0.05). However, no significant differences were observed in terms of corneal thickness, intraocular pressure, BMI, smoking, or drinking habits between the two groups (P>0.05).

Table 2. Comparison of corneal topography measurements in patients with different corneal diameters

	Small corneal diameter (n=50)	Normal corneal diameter (n=159)	Large corneal diameter (n=91)	t	P
ISA	15.21±4.62	15.23±4.21	17.65±4.12	0.86	0.42
IHA	5.84±4.41	6.85±5.13	5.96±4.12	2.31	0.08
IVA	0.12±0.02	0.13±0.01	0.11±0.03	1.26	0.27
IHD	0.13±0.04	0.11±0.01	0.13±0.02	1.74	0.15
KI	1.03±0.03	1.04±0.05	1.02±0.02	2.41	0.09
BFSf	7.62±0.23	7.84±0.23	8.03±0.23	43.21	<0.001
BFSb	6.23±0.27	6.32±0.23	6.48±0.27	30.24	0.008
Df	0.67±0.85	0.37±0.92	-0.37±0.68	15.32	<0.001
Db	0.72±0.97	0.03±0.84	-0.56±0.61	78.64	<0.001
Dp	1.45±0.87	1.02±0.71	0.57±0.74	32.36	<0.001
Dt	-0.25±0.87	-0.17±0.74	-0.32±0.78	1.67	<0.001
Da	0.71±0.68	0.68±0.52	0.42±0.62	9.66	<0.001
D	1.42±0.56	1.06±0.52	0.56±0.52	58.36	<0.001
PPIavg	1.12±1.13	1.08±0.13	0.84±0.05	32.64	<0.001
ARTmax	412.03±74.30	423.64±69.37	439.26±74.16	12.06	<0.002

Comparison of corneal topography measurements in patients with different corneal diameters

Patients with abnormal corneal diameters were further into a small cornea group (n=50), and a large cornea group (n=91). The results showed that there were significant differences among the groups in BFSf (F=43.21), BFSb (F=30.24), Df (F=15.32), Dp (F=32.36), Da (F=9.66), D (F=58.36), PPIavg (F=32.64), and ARTmax (F=12.06) (P<0.05) (**Table 2**).

Pairwise comparison of corneal topography measurements in patients with different corneal diameters

Comparative analysis was conducted on the topographic data with statistically significant differences among groups. The results showed that BFSf, BFSb, Db, Dp, D, and PPIavg all exhibited significant differences between any two groups (P<0.05). There were no differences in Df, Da, and ARTmax between small cornea and normal cornea groups (P>0.05). However, significant differences in Df, Da, and ARTmax were identified between small cornea and large cornea groups, as well as between normal cornea and large cornea groups (P<0.05) (**Table 3**).

Comparison of biomechanical data in patients with different corneal diameters

There were statistical differences between the groups in terms of HCdArcLength (F=10.12), ARTH (F=45.67), SP-A1 (F=9.04), CBI (F=36.54), and TBI (F=32.56) (P<0.05). However, no statistical differences were found in A1L, A2L, A1V, A2V, ICR, DAratio, and INR (P>0.05) (**Table 4**).

Correlation analysis between corneal diameter and corneal biomechanical data

Using corneal diameter as a continuous variable to proceed correlation analysis, we found that A1L, A2L, A2V, HCR, DA, ICR, SSI, DAratio, INR, and SP-A1 were not correlated with corneal diameter. A1V (r=-0.12), HCdArcLength (r=-0.17), CBI (r=-0.27), bIOP (r=-0.13), and TBI (r=-0.27) were negatively correlated with corneal diameter, while PD (r=0.15) and ARTH (r=0.37) were positively correlated with corneal diameter (**Table 5**).

Correlation analysis of corneal diameter and corneal topography measurements

Correlation analysis showed that ISV, IHA, IVA, IHD, KI, and Dt were not correlated with corneal diameter, while the remaining measurementsexhibited correlations. Among them, BFSf (r=

Table 3. Pairwise comparison of corneal topography measurements in patients with different corneal diameters

	Small corneal diameter vs. Normal corneal diameter	Small corneal diameter vs. Large corneal diameter	Normal corneal diameter vs. Large corneal diameter
BFSf	<0.001	<0.001	<0.001
BFSb	0.004	<0.001	<0.001
Df	0.07	<0.001	<0.001
Db	<0.001	<0.001	<0.001
Dp	1.1	<0.001	<0.001
Dt	<0.001	<0.001	<0.001
Da	<0.001	0.01	<0.001
D	<0.001	<0.001	<0.001
PPIavg	<0.001	<0.001	<0.001
ARTmax	1.1	0.004	<0.001

Table 4. Comparison of biomechanical measurements in patients with different corneal diameters

	Small corneal (n=50)	Normal corneal (n=159)	Large corneal (n=91)	Statistic	P
A1L	2.78±0.64	2.26±0.35	2.23±0.38	1.55	0.41
A2L	1.79±0.29	1.74±0.36	1.89±0.63	2.23	0.32
A1V	0.16±0.23	0.15±0.17	0.13±0.17	3.32	0.21
A2V	0.27±0.23	0.27±0.23	0.27±0.23	1.54	0.46
PD	4.97±0.23	5.04±0.23	5.07±0.23	4.18	0.02
HCR	7.05±0.73	7.06±0.71	7.04±0.72	0.36	0.74
DA	1.03±0.04	1.04±0.07	1.07±0.08	0.17	0.86
ICR	0.12±0.03	0.16±0.02	0.14±0.03	2.84	0.26
HCdArcLength	0.13±0.01	0.13±0.03	0.85±0.13	10.12	0.02
SSI	0.84±0.13	0.82±0.12	0.83±0.13	0.78	0.49
DAratio	4.39±0.42	4.38±0.37	4.38±0.35	0.07	0.96
INR	8.26±1.04	8.27±0.64	8.27±0.67	0.12	0.87
ARTH	436.46±82.13	468.32±81.34	506.04±86.45	45.67	<0.002
SP-A1	117.65±18.23	116.48±15.21	119.65±17.23	9.04	0.02
CBI	0.02±0.05	0.04±0.06	0.04±0.03	36.54	<0.002
bIOP	16.87±1.89	17.84±1.89	17.07±1.65	3.54	0.06
TBI	0.24±0.12	0.17±0.12	0.07±0.12	32.56	<0.002

0.009) and BFSb (r=0.001) were positively correlated with corneal diameter, while Df (r=-0.025) and PPIavg (r=-0.028) were negatively correlated with corneal diameter (**Figure 2**).

Discussion

This study found that measurements such as ISV, IHA, IVA, IHD, KI, and Dt exhibited no statistically significant differences between different corneal diameter groups. This may be attributed to these measurements predominantly reflecting the anterior corneal surface morphology, potentially lacking the sensitivity to detect changes. This finding aligns with the notion that keratoconus progression initiates from the posterior corneal surface [11]. Conversely, Dt, representing corneal thickness, showed no group disparities as all corneal diameter groups had thicknesses exceeding 500 micrometers. Notably, other corneal morphologic measurementsdisplayed significant differences between groups. After statistical correction, BFSf and BFSb were found to be different between any two groups, increasing with larger corneal diameters. Correlation analysis also revealed a positive correlation between corneal diameter and best-fit sphere values,

Table 5. Correlation analysis between corneal diameter and corneal biomechanical measurements

	Statistic	P
A1L	-0.02	0.85
A2L	0.07	0.12
A1V	-0.12	0.03
A2V	0.03	0.64
PD	0.15	0.003
HCR	0.03	0.64
DA	-0.05	0.38
ICR	-0.09	0.07
HCdArcLength	-0.17	0.002
SSI	-0.001	0.84
DAratio	-0.07	0.48
INR	-0.04	0.64
ARTH	0.37	<0.001
SP-A1	0.07	0.07
CBI	-0.27	<0.001
bIOP	-0.13	0.04
TBI	-0.27	<0.001

indicating that as corneal diameter increases, so does the best-fit sphere value. In addition, Db, Dp, D, and PPIavg showed significant differences between any two groups, with a negative correlation observed between these measurements and corneal diameter. This finding suggests a higher probabilities of corneal abnormalities with smaller corneal diameters, which explains why the probability of abnormalities was higher in the small corneal diameter group. The establishment and comparison of various measurements in the Pentacam corneal topography's BAD expansion analysis are typically based on the best-fit sphere. Studies have shown that different reference surfaces yield varied results [12-14]. Typically, BFS of 8 mm is used as a reference surface for comparison, and the BFS was observed to be smaller in the small corneal diameter group compared to the normal cornea group. Additionally, to highlight the morphology of keratoconus, corneal data within the central 3.5 mm range of the corneal vertex is usually excluded to establish an enhanced best-fit sphere [15, 16]. Although this improves the sensitivity of keratoconus screening, excluding central data may affects the BAD expansion analysis for small corneas. However, this cannot objectively reflect whether the cornea has conical changes. Based on the above analysis, we can conclude that corneal diameter has an impact on the diagnosis of keratoconus, especially when it is small. Consequently, relying solely on Db, Dp, D, and PPIavg values in BAD expansion analysis may not be sufficient for keratoconus diagnosis, which is consistent with prior research results [17-20].

While keratoconus diagnosis primarily relies on corneal topography, recent years have witnessed the integration of biomechanics into clinical practice, offering a novel diagnostic avenue [21, 22]. Numerous studies have demonstrated the high accuracy and sensitivity of corneal biomechanical measurements such as TBI and CBI in diagnosing keratoconus [23-26]. To refine preoperative screening for corneal refractive surgery and mitigate corneal diameter's impact on corneal morphology, this study investigated whether corneal biomechanics are affected by corneal diameter grouping. Previous studies have shown that corneal biomechanics are primarily influenced by intraocular pressure and corneal thickness [27, 28]. Higher intraocular pressure and thicker corneas have stronger resistance to deformation, resulting in more stable corneal biomechanics [29, 30]. However, this study found no significant differences in intraocular pressure or corneal thickness between groups. On the other hand, our results showed that there were intergroup differences in several biomechanical parameters, including PD, HCdArcLength, ARTH, SP-A1, CBI, and TBI, but not in the remaining ones. Correlation analysis showed negative correlations between corneal diameter and A1V, CBI, and TBI. Conversely, measurements reflecting corneal hardness, such as SP-A1, DA, and SSI, showed no correlation with corneal diameter. Based on these results, it can be inferred that in this experiment, larger corneas exhibited more stable corneal biomechanics in certain data. This, suggests that corneal diameter may not influence corneal biomechanics when diameter is less than 11.8 mm. However, larger corneal diameters may indicate more stable corneal biomechanics. This warrants further investigation to discern potential factors contributing to false-negative results in patients with larger corneal diameters.

However, this study possesses certain limitations. Firstly, its retrospective, small-sample nature may introduce selection bias. Secondly, the axial length of the eye, which also affects

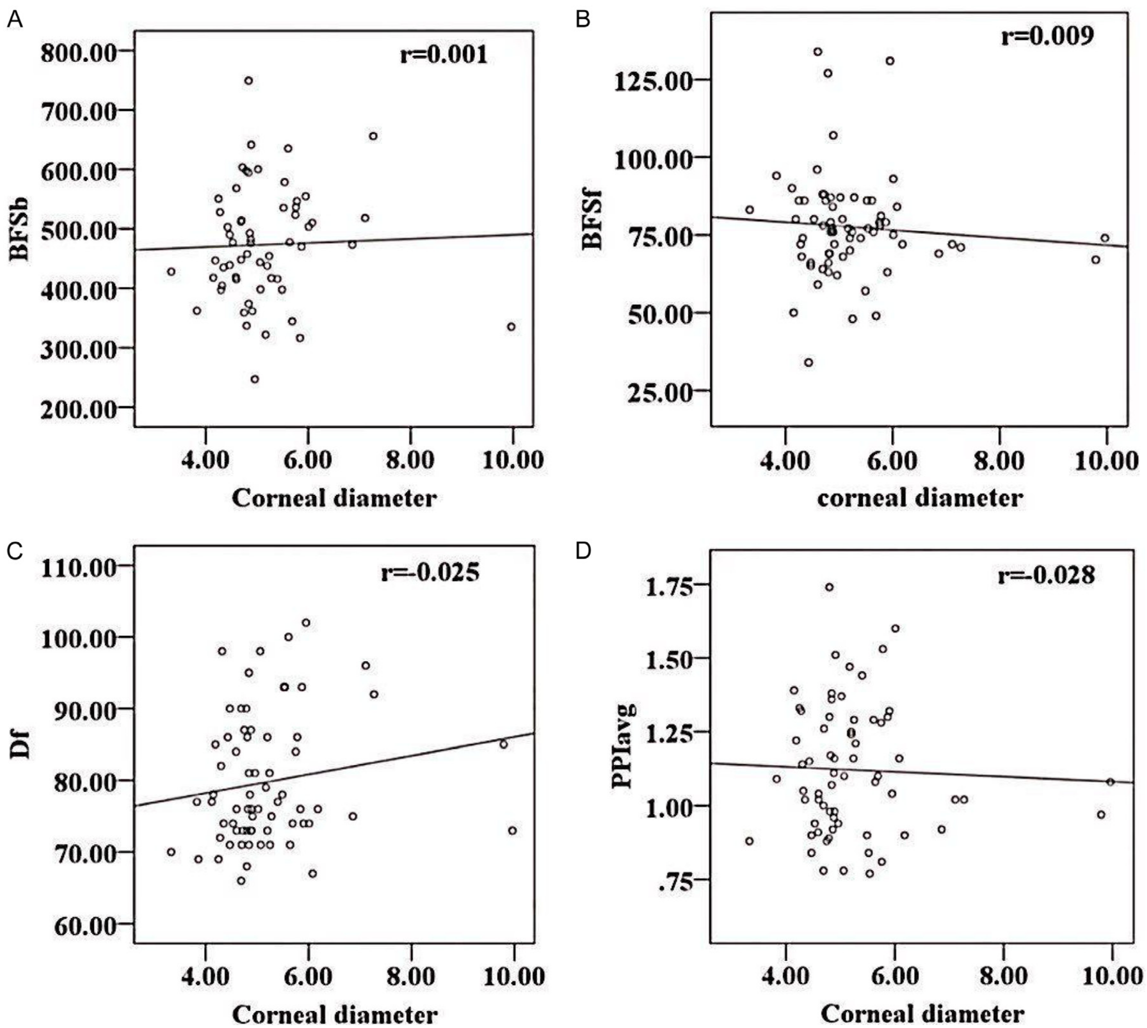

Figure 2. Correlation analysis between corneal diameter and corneal topography measurements. (A) BFSb, (B) BFSf, (C) Df, (D) PPIavg.

corneal biomechanics, was not considered. Future research should explore corneal diameter's impact on corneal biomechanics while controlling for additional influencing factors. In summary, corneal diameter exerts an impact on preoperative screening for corneal refractive surgery, with smaller diameters significantly affecting the corneal topography BAD analysis system. Therefore, combining corneal topography and biomechanical examinations in preoperative assessment may yield more accurate results.

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Disclosure of conflict of interest

None.

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