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Comparison of anterior segment parameter values obtained with Scheimpflug-Placido topographer, optical low coherence reflectometry and noncontact specular microscopy in morbid obesity

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Abstract. – OBJECTIVE: To investigate the measurement of anterior segment parameters using Sirius Scheimpflug-Placido topographer, Lenstar optical low coherence reflectometry (OLCR), and noncontact specular microscopy (SM) in morbidly obese and nonobese subjects.

PATIENTS AND METHODS: Twenty-eight morbidly obese subjects (BMI ≥ 40; Group 1) and 28 age- sex-matched healthy nonobese subjects (BMI 18.50-24.99; Group 2) were included in this study. Anterior segment parameters were measured by Scheimpflug-Placido topographer and OLCR. Corneal endothelial cell parameters were measured by non-contact SM. The group data were analyzed using the Mann-Whitney U test and Student's *t*-test. Bland-Altman plots were used to assess agreement among the instruments, and 95% limits of agreement (LoA) for each comparison were calculated.

RESULTS: In group 1, the mean CCT by Scheimpflug-Placido topographer, OLCR, and noncontact SM were 549.44±30.10 μm, 544.15±31.48 μm, and 541.59±29.87 μm respectively. In group 2, the mean CCT by Scheimpflug-Placido topographer, OLCR, and noncontact SM were 531.0±22.09 μm, 523.15±21.39 μm, and 521.12±21.70 μm respectively. Mean CCT values obtained by the three methods were significantly higher in the morbidly obese than the nonobese subjects. In both groups, mean CCT was significantly higher when measured by Scheimpflug-Placido topographer than by OLCR and noncontact SM, and mean AD and ACD were significantly higher when measured by Scheimpflug-Placido topographer than OLCR. No significant differences were found between mean corneal curvature and corneal astigmatism when measured by Scheimpflug-Placido topographer and OLCR.

CONCLUSIONS: The mean CCT of the morbidly obese subjects were significantly higher than the nonobese subjects when measured by all three methods. The CCT values obtained by Scheimpflug-Placido topographer were significantly higher than those by OLCR and SM.

Key Words
Anterior segment parameter, Optical low coherence reflectometry, Scheimpflug-Placido topographer, Specular microscopy.

Introduction

Assessment of anterior segment parameters is crucial in many clinical and research applications[1]. The determination of central corneal thickness (CCT) is important for the planning of refractive surgery, diagnosis of glaucoma, monitoring of corneal edema, assessment of endothelial cell functioning, diagnosis of keratoconus, and planning for corneal surgeries such as corneal cross-linking and intrastromal ring placement[2-4].

Measurement of anterior chamber depth (ACD), white-to-white (WTW) distance, corneal curvature, pupil diameter (PD), and iridocorneal angle (ICA) are important steps prior to any refractive surgery. ACD measurement is important in determining the appropriate phakic or standard intraocular lens (IOL) power and in evaluating eligibility for iris-fixated phakic intraocular lens (pIOL) implantation. Measurement of WTW distance is useful in determining the optimum IOL size. Evaluation of ICA is essential to establish the risk of angle disclosure[5,6].

Recent technological advances have enabled quantification of anterior segment parameters using non-invasive techniques. Sirius Scheimpflug-Placido topographer (Costruzione Stru-

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menti Oftalmici, Florence, Italy) is a recently introduced topographic device that combines a monochromatic rotating Scheimpflug camera and a Placido disk. It provides anterior segment measurements, anterior and posterior corneal topography and full corneal pachymetry. Optical low coherence reflectometry (OLCR, Haag-Streit AG, Köniz, Switzerland) is a new non-contact biometry device that can measure the corneal curvature, CCT, ACD, lens thickness (LT), axial length (AL). Noncontact specular microscopy (SM, Tomey, Nagoya, Japan) is used for measurement of endothelial parameters, including endothelial cell density (ECD), coefficient of variation, and percentage of hexagonal cells[7].

The prevalence of obesity, a common public health problem, is rapidly increasing. While its impact on overall health is well documented, less is known about its impact on ocular parameters. Among different eye diseases, obesity has been associated with cataract, glaucoma, diabetic retinopathy, and age-related maculopathy[8]. Despite the importance of investigating this impact, few studies have examined the associations between anterior and posterior segment parameters and obesity[9,10].

To compare the measurement of anterior segment parameters with the instruments available and the relationship between these parameters and obesity, we analyzed the values of anterior segment parameters obtained using Scheimpflug-Placido topographer, OLCR, and non-contact SM in morbidly obese and healthy nonobese subjects. To our knowledge, this was the first study to compare the use of these three methods in morbidly obese and nonobese subjects.

Patients and Methods

Patients

The study protocol was approved by the local Ethics Committee of Antalya Training and Research Hospital, Antalya, Turkey and conducted in accordance with the Declaration of Helsinki. Before initiation, all subjects signed a detail written consent form to confirm their understanding of the study procedures. The study sample was composed of two groups. Group 1 was composed of 28 morbidly obese subjects with body mass index (BMI) ≥40. Group 2 was composed of 28 age- and sex-matched healthy nonobese subjects with BMI values between 18.50 and 24.99. The inclusion criteria for all subjects were best-corrected visual acuity of 20/20 or more, refractive errors between +1.50 D and -1.50 D spherical and/or cylindrical value, and age ≥18. The exclusion criteria for all subjects were endocrine disorders (e.g., diabetes mellitus or systemic arterial hypertension); cardiovascular disease or other serious chronic systemic diseases; history of smoking or alcohol consumption; history of ocular surgery, laser therapy, ocular trauma, or anterior or posterior segment disease; use of any medication within the previous three months; strabismus; history of contact lens use; amblyopia; intraocular pressure (IOP) >21 mmHg; or glaucomatous findings (e.g., glaucomatous optic disc changes or visual field defects).

Measurement

BMI was calculated using the World Health Organization (WHO) formula (kg/m^2). All patients underwent a detailed ophthalmic examination that included visual acuity testing, refraction assessment, anterior segment slit lamp biomicroscopy, fundus examination, and IOP measurement using Goldmann applanation tonometry.

Anterior segment measurements on each subject were performed by a single well-trained operator (B.D.) who was experienced in using all three instruments. All eye measurements were performed without dilation in a dim room between 10:00 a.m. and 2:00 p.m. to minimize diurnal changes in corneal shape and thickness, at least three hours after awakening.

CCT, corneal volume (CV), corneal curvature (K1-flat and K2-steep), anterior chamber depth (ACD; the distance between the anterior corneal surface and the anterior lens surface), aqueous depth (AD; the distance between the posterior corneal surface and the anterior lens surface), anterior chamber volume (ACV), and ICA were measured by Scheimpflug-Placido topographer. CCT, ECD, coefficient of variation, and percentage of hexagonal cells were measured by non-contact SM. ACD, AL, CCT, corneal curvature, LT, PD, and WTW distance were measured by OLCR. Only the values for the right eye were used for statistical analysis.

Statistical Analysis

As the sample size was smaller than 50, the Shapiro-Wilks test was performed to examine normal distribution. The group data were analyzed and compared using the Mann-Whitney U test and Student's *t*-test. The anterior segment parameter values obtained using the three methods were compared using repeated-measures analysis of variance (ANOVA), and pairwise comparisons were performed using Bonferroni adjustment for multiple comparisons. Bland-Altman plots were used to assess agreement among the instruments, and 95% limits of agreement (LoA) for each comparison were calculated. The inter-device correlation was evaluated by calculation of the intraclass correlation coefficient (ICC). The association between the measurements using the three instruments was calculated and expressed as a Pearson correlation coefficient.

The level of significance was defined as $p<0.05$. All analyses were conducted using the SPSS 22.0 software package (SPSS Inc., Chicago, IL USA).

Results

Twenty-eight morbidly obese subjects (24 females and 4 males; Group 1) and 28 age-and-sex-matched healthy nonobese subjects (24 females and 4 males; Group 2) were examined. The mean age ± standard deviation (SD) was 36.07±7.51 years (range 18-50 years) in Group 1 and 34.73±6.58 years (range18-50 years) in Group 2 ($p=0.492$). The IOP was 16.15±2.68 mmHg in Group 1 and 15.60±1.80 mmHg in Group 2 ($p=0.384$).Whereas a significant difference in BMI was found between Group 1 (45.97±3.42 kg/m^2) and Group 2 (22.81±1.78 kg/m^2; $p<0.001$), no significant differences were found regarding age, sex, or IOP.

Comparison of Anterior Segment Parameter Values in Groups 1 and 2

The mean values of the anterior segment parameters obtained by OLCR and Scheimpflug-Placido topographer are shown in Tables I and II, respectively. The mean values of the corneal endothelial parameters obtained by noncontact SM are shown in Table III.

In Group1, the mean CCT by Scheimpflug-Placido topographer, OLCR, and noncontact SM were 549.44±30.10 µm, 544.15±31.48 µm, and 541.59±29.87 µm, respectively. In Group 2, the mean CCT by Scheimpflug-Placido topographer, OLCR, and noncontact SM were 531±22.09 µm, 523.15±21.39 µm, and 521.12±21.70 µm, respectively. Although the mean CCT obtained by the three methods was found to be significantly higher in Group 1 ($p<0.05$), the mean AL, CV, ACV, AD, ICA, LT, PD, ECD, and percentage of hexagonal cells (HC) were not found to significantly differ between the two groups.

Table I. Mean anterior segment parameter values obtained by OLCR in Groups 1 and 2.

Parameter	Group 1	Group 2	*p*
CCT (µm)	544.15±31.48	523.15±21.39	0.034[2]
AL (mm)	23.43±0.81	23.39±0.69	0.860[1]
AD (mm)	2.90±0.36	2.94±0.26	0.639[1]
ACD (mm)	3.44±0.36	3.46±0.26	0.829[1]
LT (mm)	3.94±0.32	3.85±0.27	0.250[1]
K1 (D)	43.05±1.27	43.13±1.34	0.820[1]
K2 (D)	44.10±1.29	43.96±1.34	0.702[1]
AST (D)	0.75 ±0.28	0.72±0.39	0.767[1]
WTW (mm)	12.06±0.44	12.09±0.33	0.842[1]
PD (mm)	5.03±0.78	5.23±0.99	0.412[1]

Data are mean ± standard deviation. [1]Student's t-test; [2]Mann-Whitney U test.
ACD: anterior chamber depth; AD: aqueous depth; AL: axial length; AST: astigmatism; CCT: central corneal thickness; K1: flat keratometry reading; K2: steep keratometry reading; LT: lens thickness; OLCR: optical low coherence reflectometry; PD: pupil diameter; WTW: white-to-white.

Agreements Between the Methods in Group 1

Table IV shows the results of the inter-device comparison of the anterior segment parameter values obtained using the three methods in the morbidly obese subjects. Mean CCT was found to be significantly higher when measured by Scheimpflug-Placido topographer than by OLCR ($p<0.001$) and noncontact SM ($p=0.007$), while no significant difference was found between mean CCT when measured by OLCR and noncontact SM ($p=0.218$). Mean AD and ACD were

Table II. Mean anterior segment parameter values obtained by Sirius in Groups 1 and 2.

Parameter	Group 1	Group 2	*p*
CCT (µm)	549.44±30.10	531.0±22.09	0.015[1]
AD (mm)	2.98±0.36	3.07±0.29	0.380[1]
ACD (mm)	3.53±0.36	3.59±0.30	0.506[1]
ICA	40.81±5.33	42.73±4.92	0.180[1]
ACV (mm^3)	145.44±29.13	151.92±19.63	0.349[1]
CV (mm^3)	58.41±3.02	56.98±2.26	0.057[1]
K1(D)	42.92±1.32	43.10±1.50	0.651[1]
K2 (D)	43.99±1.36	43.87±1.53	0.751[1]
Km (D)	43.45±1.25	43.48±1.50	0.933[1]
AST (D)	0.72±0.38	0.66±0.29	0.569[1]

Data are mean ± standard deviation. [1]Student's *t*-test.
ACD: anterior chamber depth; ACV: anterior chamber volume; AD: aqueous depth; AST: astigmatism; CCT: central corneal thickness; CV: corneal volume; ICA: iridocorneal angle; K1: flat keratometry reading; K2: steep keratometry reading; Km: mean keratometry reading.

Table III. Mean corneal endothelial parameter values obtained by noncontact specular microscopy in Groups 1 and 2.

Parameter	Group 1	Group 2	*p*
CCT (μm)	541.59±29.87	521.12±21.70	0.019[2]
ECD (cells/mm^2)	2648.15±171.19	2744.12±182.81	0.054[1]
SD	145.78±28.98	145.08±23.05	0.735[2]
AES (μm^2)	379.15±25.93	369.23±26.62	0.369[2]
CV (%)	38.33±5.64	39.12±4.71	0.454[2]
MES (μm^2)	915.22±273.25	941.42±188.91	0.188[2]
MinES (μm^2)	94.89±20.05	88.15±14.53	0.167[2]
HC (%)	44.21±6.14	43.77± 5.89	0.606[2]

Data are mean ± standard deviation. [1]Student's *t*-test; [2]Mann-Whitney U test.

AES: average endothelial size; CCT: central corneal thickness; CV: coefficient of variation; ECD:endothelial cell density; HC: percentage of hexagonal cells; MES: maximum endothelial size; MinES: minimum endothelial size; SD: standard deviation.

found to be significantly higher when measured by Scheimpflug-Placido topographer than by OLCR (*p*<0.001), while no significant differences were found between mean K1 (*p*=0.073), K2 (*p*=0.180), and corneal astigmatism (*p*=0.621) when measured by Scheimpflug-Placido topographer and OLCR.

Agreements Between the Methods in Group 2

Table V shows the results of the inter-device comparison of the anterior segment parameter values obtained using the three methods in the healthy nonobese subjects. Mean CCT was found to be significantly higher when measured by Scheimpflug-Placido topographer than by OLCR (*p*=0.024) and noncontact SM (*p*<0.001), whereas no significant difference was found between mean CCT measured by OLCR and noncontact SM (*p*=0.229). Mean AD and ACD were found to be significantly higher when measured by Scheimpflug-Placido topographer than by OLCR (*p*<0.001), whereas no significant differences were found between mean K1 (*p*=0.775), K2 (*p*=0.383), and corneal astigmatism (*p*=0.248) measured by Scheimpflug-Placido topographer and OLCR.

In both groups, mean CCT values obtained by the three modalities were found to be strongly correlated, with Pearson correlation coefficients ranging from 0.918 to 0.974 in Group 1 and 0.922 to 0.967 in Group 2. Bland-Altman plots of the paired CCT differences against the mean values and the 95% LoA are shown in Figure 1 and 2. In both groups, the mean K1, K2, AD, ACD, and corneal astigmatism measured by OLCR and Scheimpflug-Placido topographer were found to be strongly correlated. Mean K1, K2, and corneal astigmatism power measurements obtained by OLCR and Scheimpflug-Placido topographer showed narrow 95% limits of agreement (LoA), which implies good agreement (*p*>0.05, Bland-Altman plot analysis). In contrast, the range and 95%

Table IV. Interdevice comparison of anterior segment parameter values in Group 1.

Pairwise comparison	Mean difference ±SD value	Lower/upper	*p*[1]	PCC	ICC (95% CI)
CCT (μm)					
OLCR-SIRIUS	-5.30±9.60	-24.11/13.52	<0.001	0.952	0.975 (0.945-0.989)
OLCR-SM	2.55±7.19	-11.55/16.66	0.218	0.974	0.986 (0.969-0.994)
SIRIUS-SM	7.96±11.91	-15.90/31.60	0.007	0.918	0.957 (0.908-0.980)
AD (mm)					
OLCR-SIRIUS	-0.08±0.005	-0.19/0.01	<0.001	0.989	0.989 (0.976-0.995)
ACD (mm)					
OLCR-SIRIUS	-0.09±0.05	-0.20/0.01	<0.001	0.988	0.988 (0.974-0.995)
K1 (D)					
OLCR-SIRIUS	0.12±0.34	-0.54/0.79	0.073	0.966	0.965 (0.926-0.984)
K2 (D)					
OLCR-SIRIUS	0.10±0.39	-0.66/0.87	0.180	0.957	0.956 (0.906-0.980)
AST (D)					
OLCR-SIRIUS	0.02±0.20	-0.46/0.51	0.621	0.745	0.717 (0.432-0.872)

[1] Repeated-measures ANOVA using Bonferroni adjustment for multiple comparisons.

ACD: anterior chamber depth; AD: aqueous depth; AST: astigmatism; CCT: central corneal thickness; ICC: intraclass correlation coefficient; K1: flat keratometry reading; K2: steep keratometry reading; OLCR: optical low coherence reflectometry; PCC: Pearson correlation coefficient; SD: standard deviation; SM: specular microscopy

Table V. Interdevice comparison of anterior segment parameter values in Group 2.

Pairwise comparison	Mean difference ±SD value	Lower/upper	*p*[1]	PCC	ICC (95% CI)
CCT (μm)					
OLCR-SIRIUS	-7.80±7.91	-23.9/8.20	0.024	0.936	0.936 (0.866–0.970)
OLCR-SM	2.04±5.54	-8.83/12.91	0.229	0.967	0.954 (0.901-0.979)
SIRIUS-SM	9.88±8.66	-7.10/26.87	<0.001	0.922	0.922 (0.833-0.964)
AD (mm)					
OLCR-SIRIUS	-0.13±0.008	-0.29/0.03	<0.001	0.965	0.957 (0.907-0.980)
ACD (mm)					
OLCR-SIRIUS	-0.14±0.08	-0.30/0.02	<0.001	0.964	0.957 (0.909-0.980)
K1 (D)					
OLCR-SIRIUS	0.03±0.48	-0.93/0.98	0.775	0.943	0.948 (0.891-0.976)
K2 (D)					
OLCR-SIRIUS	0.11±0.51	-0.90/1.12	0.383	0.941	0.945 (0.884-0.974)
AST (D)					
OLCR-SIRIUS	0.07±0.22	-0.36/0.52	0.248	0.833	0.768 (0.541-0.891)

[1] Repeated-measures ANOVA using Bonferroni adjustment for multiple comparisons.
ACD: anterior chamber depth; AD: aqueous depth; AST: astigmatism; CCT: central corneal thickness; ICC: intraclass correlation coefficient; K1: flat keratometry reading; K2: steep keratometry reading; OLCR: optical low coherence reflectometry; PCC: Pearson correlation coefficient; SD: standard deviation; SM: specular microscopy

LoA for mean CCT, ACD, and AD were found to significantly differ ($p<0.05$, Bland-Altman plot analysis) for all pairwise comparisons in both groups.

Discussion

WHO defines obesity as BMI of 30 kg/m^2 or greater and morbid obesity as BMI of 40 kg/m^2 or greater[11]. Because of the potential public health impact of obesity, there is a great need to identify its effects, particularly on ocular parameters, and assess the instruments used to measure these effects[8]. In this study, we compared the values of anterior segment parameters obtained using Scheimpflug-Placido topographer, OLCR, and non-contact SM in morbidly obese and healthy nonobese individuals.

Both height and weight are dependent on complex genetic and environmental influences throughout infancy, childhood, and adulthood. In a recent study of ethnically Chinese adults in Singapore, Wong et al[12] found a positive relationship between height and AL, ACD, lens thickness, and corneal flatness. In contrast, they found no significant relationships between these parameters and weight or BMI. In a study of Singapore Chinese children, Saw et al[13] likewise found no relationship between BMI and ocular parameters, and more obese children had eyes with refractions that were more hyperopic.

Roy et al[14] found that height was positively correlated with axial length, anterior chamber depth, and vitreous chamber depth, as well as that subjects with higher BMI, tended to have refractions that were more hypermetropic.

In a study of Australian children, Ojaimi et al[15] found no strong associations among height, weight, BMI, body fat percentage, waist circumference, or refraction or axial length-corneal radius (AL/CR) ratio. While they found that weight and BMI were positively associated with ACD, this relationship was lost when boys and girls were examined separately.

In a comparison of obese and nonobese subjects, Gunes et al[9] found a significantly positive relationship between IOP and obesity and a significantly negative relationship between ACD and obesity. In contrast, they found no significant differences between mean AL, ACV, ICA, and CCT in obese and nonobese subjects.

Both Su et al[16] and Pan et al[17] found a significantly positive relationship between CCT and BMI. Su et al[16] also found a significantly positive relationship between CCT and IOP, AL, corneal curvature, BMI, and metabolic syndrome. Consistent with these findings, Pan et al[17] indicated that the major determinants of CCT are systemic factors, such as blood pressure and BMI, and/or ocular biometric parameters, such as ACD, LT, and cornea curvature. Some studies in the literature highlighted that CCT was greater in individuals with diabetes and metabolic syndrome[16,18]. The reason for this asso-

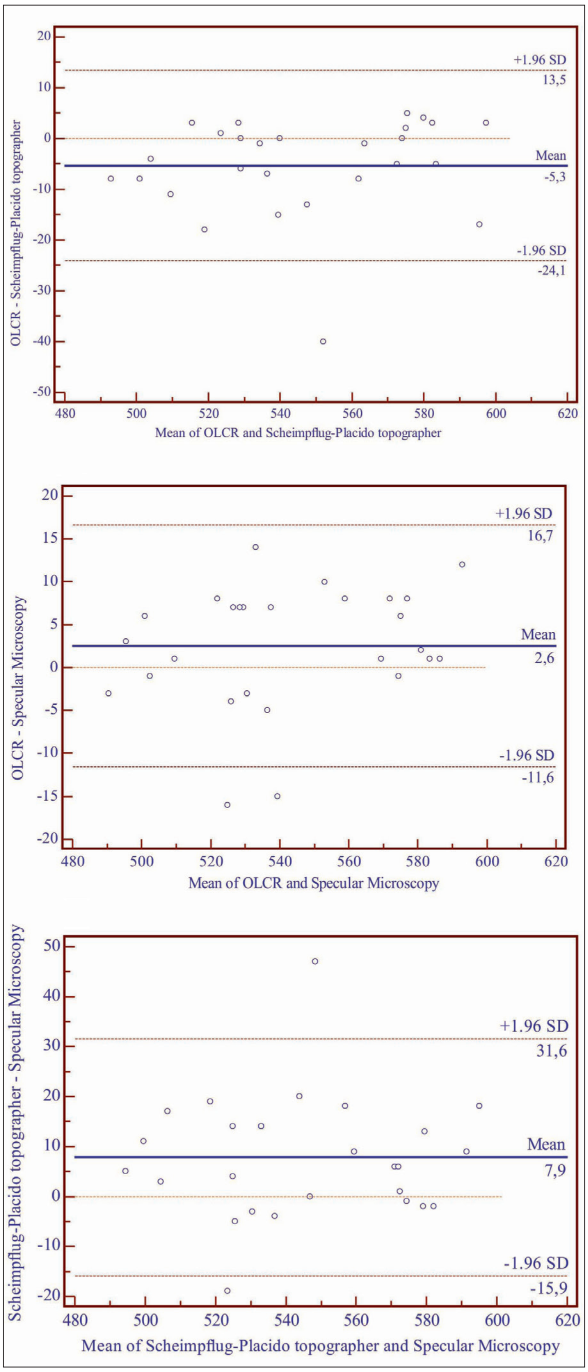

Figure 1. Blant Altman plots comparing central corneal thickness between optical low coherence reflectometry (OLCR) and Scheimpflug-Placido topographer (**A**), OLCR and Specular Microscopy (**B**), Scheimpflug-Placido topographer-Specular Microscopy (**C**) in group 1.

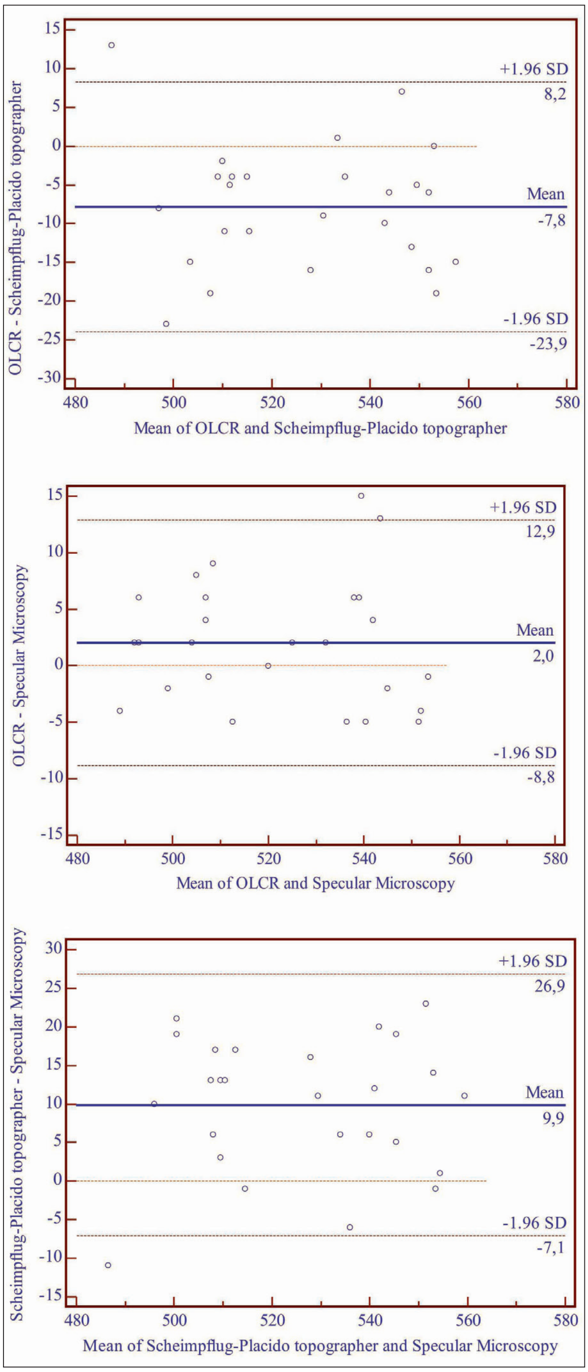

Figure 2. Blant Altman plots comparing central corneal thickness between optical low coherence reflectometry (OLCR) and Scheimpflug-Placido topographer (**A**), OLCR and Specular Microscopy (**B**), Scheimpflug-Placido topographer-Specular Microscopy (**C**) in group 2.

ciation is unclear, but it is hypothesized that these conditions alter corneal endothelial physiology, leading to an increase in CCT[19].

In our work, we observed that the mean CCT obtained by the three methods was found to be significantly higher in morbidly obese subjects than that in nonobese subjects, the mean AL, CV, ACV, AD, ICA, LT, PD, ECD, and HC were not found to significantly differ between the two groups.

It is important in evaluating the relationship between obesity and anterior segment parameters to observe the repeatability and the accuracy of the instruments used for measurement. Recognizing this consideration, several researchers have assessed these factors in the currently available technologies. Among them, Shammas et al[20] reported that the precision of the anterior segment values obtained by OLCR was extremely high. Cruysberg et al[21] found the repeatability of keratometry, CCT, and ACD values obtained by OCLR to be excellent.

In a comparison of measurement using the Sirius Scheimpflug-Placido topographer and an OLCR biometer, Chen et al[22] reported that the CCT, ACD, AD, and K measurements taken with Scheimpflug-Placido topographer to be significantly higher than those taken with OLCR. They reported good agreement between the CCT, ACD, AD, and K values obtained by Scheimpflug-Placido topography and OLCR, with a narrow 95% LoA. Their findings indicated that the two methods can be used interchangeably.

Bayhan et al[23] showed that spectral domain optical coherence tomography (SD-OCT), OLCR, and Scheimpflug-Placido topographer significantly underestimated corneal thickness compared with ultrasound pachymeter (USP). They also reported that OLCR significantly overestimated CCT compared with Scheimpflug-Placido topographer. They indicated that pairwise comparisons of all devices showed significantly good correlations.

Ucakhan et al[24] observed that Pentacam had deeper ACD values compared to the Lenstar. The authors reported that the K1, K2, and Km readings obtained by Lenstar were significantly steeper than those obtained by Pentacam. They reported that the ACD values obtained using the Lenstar and the Pentacam appear interchangeable, whereas the keratometry values obtained using the Lenstar, Pentacam, and manual keratometer significantly differ and are not interchangeable.

Huerva et al[25] showed that OLCR and the rotating dual Scheimpflug analyzer system can be used interchangeably for measurement of WTW distance, corneal astigmatism, and corneal curvature measurement but not for CCT, ACD, and PD measurement.

In both the morbidly obese and nonobese subjects in our study, we found that mean CCT was significantly higher when measured by Scheimpflug-Placido topographer than by OLCR and noncontact SM, as well as that mean AD and ACD were significantly higher when measured by Scheimpflug-Placido topographer than by OLCR. We found no significant differences between mean K1, K2, and corneal astigmatism when measured by Scheimpflug-Placido topographer and OLCR. Overall, we found anterior segment parameter values measured by OLCR, Scheimpflug-Placido topographer, and noncontact SM were significantly correlated in both the morbidly obese and nonobese subjects, a finding confirmed by Bland Altman analysis, which showed good agreement among the devices.

Conclusions

Our study yielded several findings important for clinical practice as well as further research into the the measurement of anterior segment parameters and the impact of obesity on these parameters. First, we observed that the mean CCT values obtained for morbidly obese subjects using the three methods were significantly higher than those obtained for the nonobese subjects. Second, we found that the CCT values obtained by Scheimpflug-Placido topographer were significantly higher than those obtained with OLCR and SM. Third, we found that the corneal curvature and corneal astigmatism values obtained by Scheimpflug-Placido topographer and OLCR did not significantly differ. Although highly correlated, the measurement values with these devices are not directly interchangeable in clinical practice.

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Conflict of Interest

The Authors declare that they have no conflict of interests.

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