·Clinical Research·

Repeatability and agreement of CCT measurement in myopia using entacam and ultrasound pachymetry

Yong-Heng Luo [1], Qian Zhong [2], Ping-Bo Ouyang [1], Xiao-Jian Guo [1], Xuan-Chu Duan [1]

[1]Department of Ophthalmology, the Second Xiangya Hospital, Central South University, Changsha 410011, Hunan Province, China

[2]Department of Ophthalmology, Rikang Hospital, Guangxi Traditional Chinese Medical College, Nanning 530011, Guangxi Zhuang Autonomous Region, China

Correspondence to: Xuan-Chu Duan. Department of Ophthalmology, the Second Xiangya Hospital, Central South University, Changsha 410011, Hunan Province, China. duanxchu@yahoo.com.cn

Received: 2012-01-31 Accepted: 2012-05-07

Abstract

• AIM: To evaluate the repeatability of central corneal thickness (CCT) measurement by entacam, and agreement of CCT measured by Pentacam and ultrasound pachymetry (USP) in Chinese myopia. Thereby investigate the possibility of Pentacam as a substitute for USP in CCT measurement before refractive surgery. The effects of corneal curvature measured by Pentacam on CCT were also evaluated.

• METHODS: One hundred and forty-eight right eyes of 148 individual with myopia were included in this study. Three successive Pentacam CCT measurements followed by 10 successive ultrasound pachymetry were carried out in the 148 eyes. Mean of CCT taken by each device was calculated for comparison. According to the CCT measured by USP, all the 148 eyes were divided into 3 groups: <520μm, 520-560μm, >560μm. For all eyes and each group the CCT obtained by Pentacam and USP were compared. Anterior corneal curvature of the 148 eyes was also adopted for correlation analysis with CCT obtained by ultrasound pachymetry. In addition, CCT measurement using 60 random selected Scheimpflug images was performed by 3 skilled investigators at different time, and this was repeated for 3 times by a forth investigator to assess repeatability of Pentacam CCT measurement using Scheimpflug images.

• RESULTS: Intraclass correlation coefficient (ICC) analysis revealed high intraobserver repeatability (ICC=0.994, F= 158.60, P<0.001) for CCT measurement by Pentacam. The interobserver (ICC=0.998, F =494.73, P <0.001) and intraobserver (ICC=0.997, F=383.98, P<0.001) repeatability for Pentacam CCT measurements using Scheimpflug images were also excellent. There was high positive correlation between the CCT values measured by Pentacam and ultrasound pachymetry (r=0.963, P<0.001). Bland-altman plots showed that the Pentacam underestimate the CCT by 8.02μm compared with ultrasouond pachymetry.The differences between Pentacam and USP increased as the CCT readings by USP increased (Pentacam *vs* USP: slope=-0.04, P< 0.05). The 95% upper and lower limits of agreement between CCT values obtained from the two devices were +9. 33 μm and -25.37 μm. No significant association could be found between CCT and anterior corneal curvature.

• CONCLUSION: Inter- and intraobserver variability for CCT measurements by Pentacam was considerably below clinically significant levels. CCT of myopia obtained by Scheimpflug camera, Pentacam, were highly correlated to that by ultrasound pachymetry. However, the values obtained are not directly interchangeable between Pentacam and ultrasound pachymetry as the 95% limits of agreement are relatively wide. Pentacam can be a useful instrument for measuring CCT in candidates to refractive surgery in clinic.

• KEYWORDS: pentacam; central corneal thickness; ultrasound pachymetry; repeatability; agreement
DOI:10.3980/j.issn.2222-3959.2012.03.15

Luo YH, Zhong Q, Ouyang PB, Guo XJ, Duan XC. Repeatability and agreement of CCT measurement in myopia using entacam and ultrasound pachymetry. *Int J Ophthalmol* 2012;5(3):329-333

INTRODUCTION

Recently more and more myopia search for keratorefractive surgery, especially laser *in situ* keratomileusis (LASIK). Central corneal thickness (CCT) is important in the pre-refractive sugery assessment of patients, for which depth of incisions and ablations in cornea are required. For severe myopia that consider for enhancement surgery, the CCT is especially important because of more ablation in the cornea [1]. Moreover, the myopia is a risk factor for primary open-angle glaucoma. Exclusion of glaucoma in candidates to keratorefractive surgery also requires reliable and convenient corneal pachymetry. Ultrasound pachymetry (USP), which is considered to be "gold standard" of CCT measurement in clinic [2-4], is the most popular device to measure corneal thickness. The use of topical anesthetics and corneal contact during measurement may lead to risk of corneal abrasions and infections, though it is fast and very convenient to repeat several measurements to minimize measurement error. Furthermore, its accuracy is significantly affected by the skills of technicians [5]. Recently, some non-contact applications for CCT measurement are available as alternatives to ultrasound pachymetry [6], including Pentacam (Oculus, Inc., Wetzlar, Germany). The Pentacam is a rotating Scheimpflug camera that acquires three-dimensional images of the anterior segment. Using this device, topographic cornea thickness and other corneal parameters such as corneal curvature can be obtained very easily at the same time. The latter is also important in corneal power calculations. Comparisons between CCT obtained by the Pentacam and the USP have been performed in normal [3, 7-10] and keratoconic eyes [11,12]. Post-LASIK CCT measurements with each pachymetry have been performed made by Ciolino *et al* [12] and Ho *et al* [13]. However, the corneal curvature and different grades of thickness has not been taken into consideration in previous comparisons.

In this study, we evaluated repeatability of CCT measurement by Pentacam, and compared CCT obtained by Pentacam and ultrasound pachymetry (SP-3000; Tomey Technology, Nagoya,Japan) in Chinese myopia. Thereby to evaluate the possibility that Pentacam as a substitute for ultrasound pachymetry in CCT measurement before refractive surgery. The effects of corneal curvature measured by Pentacam on CCT were also evaluated.

MATERIALS AND METHODS

Subjects In this prospective cross-sectional study, 148 right eyes of 148 candidates to LASIK for myopia consulting the Refractive Surgery Unit at the Second Xiangya Hospital of the Central South University from April to October 2009 were recruited. The mean age of subjects enrolled was (24.72±5.35) years (range 15-36 years), with 88 males and 60 females. The mean spherical equivalent (SEQ) was (-6.72±3.15)D (range: -1.00 to -15.00D). All participants with best corrected visual acuity of 1.0 or better, and had no history of corneal pathology, previous ocular trauma or intraocular surgery. Contact lens, if any, had been taken off for over 4 weeks. The protocol of this research was approved by the Medicine Human Ethics Committee of the Second Xiangya Hospital of the Central South University. Oral informed consent before inclusion in the study was obtained from all the subjects.

Methods In the first part of the study, CCT measured by Pentacam and USP was obtained from all the 148 eyes. Measurements of each device were taken between 9:00 a.m. and 5:00 p.m., after all subjects had been awake for at least one hour, and measurements were performed before any contact procedures.

Non-contact measurement by Pentacam was first carried out. Three measurement of each eye was performed by the same operator. The subject was asked to fixate on a blinking blue light. To reduce operator-dependent variables, the Rotating Scheimpflug imaging was automatically performed when the image was in focus and the corneal vertex correctly aligned. The camera rotated 180°, obtaining 25 slit images of the anterior segment, and generated a three-dimensional model of the anterior eye [7], Topographic corneal thickness, corneal curvature, anterior chamber angle, volume and height were calculated by the software. Subject eye movement was constantly monitored by the system, and quality factor was automatically evaluated. Only scans with quality factor more than 95% were included. For every measurement, the Pentacam was aligned singly to eliminate interdependence of the readings. Pupil center thickness (recorded as CCT and corresponded to CCT of USP) were adopted to evaluate the intraobserver variability. Mean of the CCT as well as anterior corneal curvature (k1, k2) of the 3 successive scans in each eye were also calculated for analysis.

Ultrasound pachymetry was performed by another skilled investigator after 5-minute break. To maintain masking, the investigator was unaware of the CCT readings taken by the Pentacam. After topical anaesthesia with 0.4% oxybuprocaine ydrochloride, ten contact measurements were made with the probe perpendicular to the cornea as similar to a previous study [15]. The mean of 10 CCT measurements of each eye was adopted.

In the second part of the study, we evaluated the interobserver and intraobserver repeatability of Pentacam CCT measurement using Scheimpflug images. Sixty Scheimpflug images of different subjects were randomly selected. Pentacam CCT measurement with the 60 images was performed by 3 skilled investigators at different time. In addition, 3 discontiguous CCT measurement with intervals no less than 10 days was taken by a forth investigator. Each investigator was unaware of the CCT readings taken by others.

Statistical Analysis Statistical analysis was performed using SPSS for Windows, version 16.0 (SPSS Inc, Chicago, Illinois, USA). All values are described as mean±standard deviation (SD). Intraclass correlation coefficient (ICC) analysis and one-way analysis of variance (*ANOVA*) was performed to assess the repeatability of Pentacam. Differences of CCT measurement between Pentacam and USP were compared using the paired samples *T* test. Pearson product correlation analysis was also used to examine the association between the two devices and that between anterior corneal curvature and CCT. The agreement between Pentacam and USP was analyzed using the Bland-Altman method. A P-value of <0.05 was considered statistically significant.

RESULTS

The CCT values of the 148 eyes obtained by Pentacam were 530.32±31.72, 528.26±31.43 and 529.18±31.84, repectively (Figure 1). No significant difference exist among the 3 successive scans (F=0.157, P=0.854).Intraclass correlation coefficient analysis also revealed excellent intraobserver repeatability (ICC=0.994, F=158.60, P<0.001) for CCT measurements by Pentacam.

Regarding repeatability of the Pentacam CCT measurement using Scheimpflug images, the 60 images came from 34 males and 26 females (age: 23.82±5.21 years, range: 15 to 36 years). The spherical equivalent refraction was -6.59 ± 3.12D (range: -1.00 to -13.25D). The CCT obtained from the 60 Scheimpflug images were, respectively, 530.43 ± 33.20μm, 532.87±33.53 and 529.35±33.23μm for the three investigators and 530.03 ±29.04μm, 531.72 ±29.31μm and 528.67±28.45μm for the 3 discontinuous measurements by the fourth investigator, Figure 2. There was no significant difference among the three investigators (F=0.167, P= 0.847), nor do there difference among 3 discontinuous measurements taken by the forth investigator(F=0.004, P= 0.846). Intraclass correlation coefficient analysis also revealed excellent intersession (ICC=0.998, F=494.73, P< 0.001) and intraobserver (ICC=0.997, F=383.98, P<0.001) repeatability for Pentacam CCT measurements using Scheimpflug images.

The mean CCT of the 148 eyes obtained by Pentacam was 529.25±31.47μm (range from 457 to 604μm), and those obtained by USP was 537.27±32.83μm (range from 469 to 609μm). There was high positive correlation between the CCT values measured by Pentacam and USP (r=0.963, P< 0.001). However, significant difference exist between the two devices (t=-11.03, P<0.001). When the difference were compared against their means (Bland-altman plots), the Pentacam appeared to underestimate the CCT by 8.02μm compared with USP. The 95% upper and lower limits of agreement (LOA) between the Pentacam and USP were +9.33μm and -25.37μm, Figure 3.

According to the CCT measured by USP, all the 148 eyes were divided into 3 groups: <520μm, 520-560μm, >560μm. For each group the Bland Altman plots for CCT obtained by Pentacam and USP are shown in Figure 4. These differences between Pentacam and USP increased as the CCT readings by USP increased (Pentacam vs USP: slope=-0.04, P<0.05). The mean keratometry readings measured in dioptres (D) of the 3 groups was described as Table 1. There was no significant difference among these 3 groups in k1(F=0.718, P=0.490) or k2 (F=0.063, P=0.939). In addition, no significant association could be found between CCT and K1 (r=-0.043, P=0.604), nor do there association between CCT and K2 (r=0.019, P=0.818) in the 148 eyes.

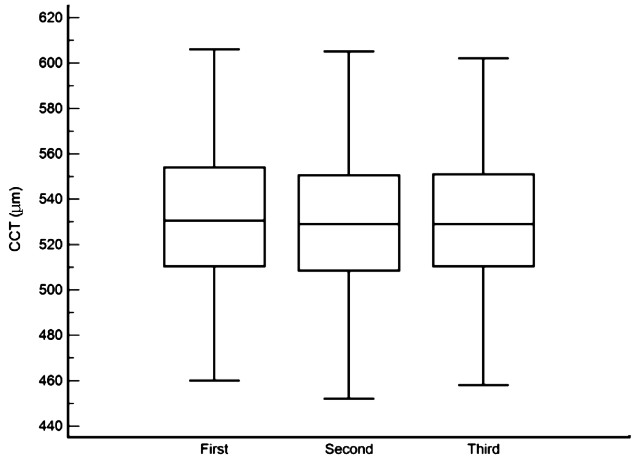

Figure 1 The box and whisker plot of 3 CCT readings of the 148 eyes by Pentacam.

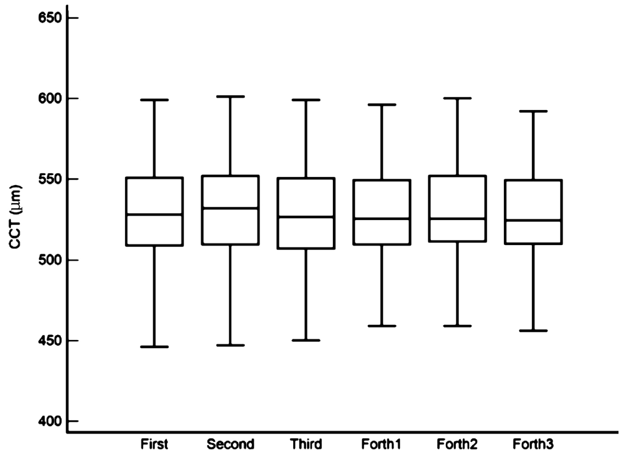

Figure 2 The box and whisker plot of 6 CCT readings of the 60 Scheimpflug images by 4 investigators using Pentacam.

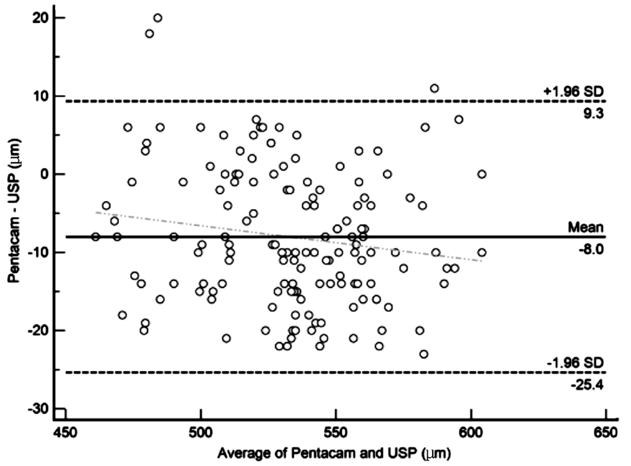

Figure 3 Bland-Altman plot of CCT measured by Pentacam and ultrasound pachymetry in the 148 eyes.

Table 1 Anterior corneal curvature of the 148 eyes

CCT (μm)	n	K1 (D)	K2 (D)
<520	45	43.19±1.36	43.25±1.28
520-560	66	43.00±1.51	43.18±1.72
>560	37	42.78±1.80	43.14±1.35

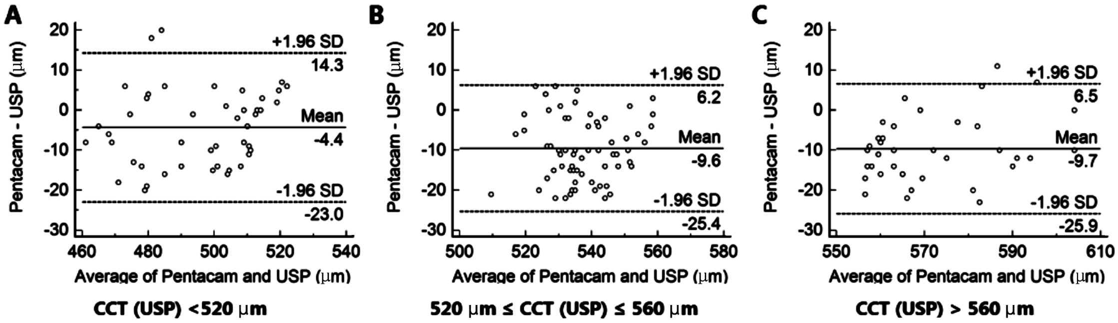

Figure 4 Bland–Altman plot of CCT measured by Pentacam and ultrasound pachymetry in 3 groups.

DISCUSSION

Accurate measurements of central corneal thickness (CCT) are essential in assessment of refractive surgery [16] and non refractive corneal surgery and glaucoma [17,18]. It is also helpful for the monitor of certain corneal diseases such as Fuchs endothelial dystrophy [19] and keratoconus [11]. Ultrasound pachymetry, widely used in CCT measurement, is theoretically performed over the pupil center. Its accuracy and repeatability depend on the perpendicularity of the probe's application to the cornea center. However, inaccuracies would arise in the operation process taken by the most experienced operators. Indeed the poor repeatability of USP undermines its position as the CCT measurement of choice [20]. Therefore, it is important for us to find a method less affected by corneal factors and skill of operators. Pentacam that determines CCT by acquiring images on the front and back corneal surface [2,6] offers a non-invasive CCT measurement. At the same time, it is developed to calculate corneal curvature, anterior chamber depth and chamber angle during the measurement.

Some studies [7,8,21,22] have reported that the repeatability of CCT measurements taken by Pentacam was high. Excellent repeatability with an ICC of 0.980 and 0.985 has been reported by Barkana *et al* [22]. Our study showed similar intraobserver repeatability (ICC=0.994) for CCT measurements by Pentacam, and satisfactory intra- and interobserver repeatability (ICC, 0.998 and 0.997) in CCT measurement using Scheimpflug images.

Instruments for clinical use should be not only repeatable but also accurate. Although pervious research indicated that CCT measured by Pentacam was highly agreeable with USP for normal eyes [8, 9]. Trendency that Pentacam measured CCT consistently thinner (-6μm) than USP was conclude in some studies [7,24]. Moreover,Fujioka *et al* [3] and *Al-Mezaine et al* [9] found that Pentacam overestimated CCT by 6 and 10μm compared with USP. It also overestimated CCT in post-LASIK or photorefractive keratectomy corneas [13, 14]. In this study, the Pentacam showed high correlation with USP (r=0.963)but underestimated CCT by about 8μm compared with USP in myopia. However, the good correlation observed between the two devices suggests that the results could be consistent by use of a correction coefficient. The LOA between the Pentacam and USP found in our study (95% LOA, -25.37 to 9.33μm) were comparable but slightly smaller than those from another study, which have made similar comparisons in myopia, in which the 95% LOA ranged from -31 to +19μm[25].

The differences between Pentacam and USP were not constant but increased with higher CCT readings (slope = -0.04, P<0.05). In myopia with CCT less than 520μm, the difference was smaller than that in other two groups (both P<0.05). While difference was not significant (P=0.94) between normal and thicker cornea. It means that for the subjects with thin central cornea the Pentacam would be more agreeable with USP. Although the differences were shown to be statistically significant in all the 3 groups, it could be argued that they are not clinically significant. However, the biomechanical stability of the post-LASIK cornea is related to residual corneal thickness. Therefore, Pentacam that underestimate the CCT prompt less ablation in cornea for safe refractive sugery. More importantly, Pentacam may be more applicable for the decision of whether a patient is suitable for LASIK enhancement. the Panda *et al*[26] and Chen *et al*[27] indicated that the CCT was not associated with corneal curvature. Data in our study show that there is no difference between cornea of different thickness and anterior corneal curvature, and the correlation between CCT and K value was negative in myopia (all P> 0.05). However, Pentacam can be a clinically useful instrument for measuring CCT and corneal curvature in a single unit.

The results of our present work suggest that inter- and intraobserver variability for CCT measurements by Pentacam was considerably below clinically significant levels. CCT values obtained by Scheimpflug camera, Pentacam, were highly correlated to ultrasound pachymetry in myopia. However, the values obtained are not directly interchangeable between Pentacam and USP as the LOA are relatively wide. Pentacam can be a useful instrument for measuring CCT in candidates to refractive surgery in clinic.

Acknowledgements: The authors thank Yue-Hua Li and Fang Fan for providing helpful suggestions to the manuscript.

REFERENCES

1 Muallem MS, Yoo SH, Romano AC, Marangon FB, Schiffman JC, Culbertson WW. Flap and stromal bed thickness in laser in situ keratomileusis enhancement. *J Cataract Refract Surg* 2004;30 (11): 2295-2302

2 Swartz T, Marten L, Wang M. Measuring the cornea: the latest developments in corneal topography. *Curr Opin Ophthalmol* 2007;18(4): 325-333

3 Fujioka M, Nakamura M, Tatsumi Y, Kusuhara A, Maeda H, Negi A. Comparison of Pentacam Scheimpflug camera with ultrasound pachymetry and noncontact specular microscopy in measuring central corneal thickness. *Curr Eye Res* 2007;32(2):89-94

4 Prospero Ponce CM, Rocha KM, Smith SD, Krueger RR. Central and peripheral corneal thickness measured with optical coherence tomography, Scheimpflug imaging, and ultrasound pachymetry in normal, keratoconus-suspect, and post-laser *in situ* keratomileusis eyes. *J Cataract Refract Surg* 2009;35(6):1055-1062

5 Hitzenberger CK, Baumgartner A, Drexler W, Fercher AF. Interferometric measurement of corneal thickness with micrometer precision. *Am J Ophthalmol* 1994;118(4):468-476

6 Konstantopoulos A, Hossain P, Anderson DF. Recent advances in ophthalmic anterior segment imaging: a new era for ophthalmic diagnosis? *Br J Ophthalmol* 2007;91(4):551-557

7 O'Donnell C, Maldonado-Codina C. Agreement and repeatability of central thickness measurement in normal corneas using ultrasound pachymetry and the OCULUS Pentacam. *Cornea* 2005;24(8):920-924

8 Lackner B, Schmidinger G, Pieh S, Funovics MA, Skorpik C. Repeatability and reproducibility of central corneal thickness measurement with Pentacam, Orbscan, and ultrasound. *Optom Vis Sci* 2005;82(10):892-899

9 Al-Mezaine HS, Al-Amro SA, Kangave D, Sadaawy A, Wehaib TA, Al-Obeidan S. Comparison between central corneal thickness measurements by oculus Pentacam and ultrasonic pachymetry. *Int Ophthalmol* 2008;28(5):333-338

10 Ucakhan OO, Ozkan M, Kanpolat A. Corneal thickness measurements in normal and keratoconic eyes: Pentacam comprehensive eye scanner versus noncontact specular microscopy and ultrasound pachymetry. *J Cataract Refract Surg* 2006;32(6):970-977

11 de Sanctis U, Missolungi A, Mutani B, Richiardi L, Grignolo FM. Reproducibility and repeatability of central corneal thickness measurement in keratoconus using the rotating Scheimpflug camera and ultrasound pachymetry. *Am J Ophthalmol* 2007;144(5):712-718

12 Ciolino JB, Khachikian SS, Belin MW. Comparison of corneal thickness measurements by ultrasound and scheimpflug photography in eyes that have undergone laser in situ keratomileusis. *Am J Ophthalmol* 2008;14(1): 75-80

13 Ho T, Cheng AC, Rao SK, Lau S, Leung CK, Lam DS. Central corneal thickness measurements using Orbscan II, Visante, ultrasound, and Pentacam pachymetry after laser *in situ* keratomileusis for myopia. *J Cataract Refract Surg* 2007;33(7):1177-1182

14 Wheeler NC, Morantes CM, Kristensen RM, Pettit TH, Lee DA. Reliability coefficients of three corneal pachymeters. *Am J Ophthalmol* 1992; 113(6):645-651

15 Javaloy J, Vidal MT, Villada JR, Artola A, Alió JL. Comparison of four corneal pachymetry techniques in corneal refractive surgery. *J Refract Surg* 2004; 20(1): 29-34

16 Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. *Surv Ophthalmol* 2000;44(5):367-408

17 Heijl A, Leske MC, Bengtsson B, Hyman L, Hussein M. Reduction of intraocular pressure and glaucoma progression: results from the Early Manifest Glaucoma Trial. *Arch Ophthalmol* 2002;120(6):1268-1279

18 Borboli S, Colby K. Mechanisms of disease: Fuchs' endothelial dystrophy. *Ophthalmol Clin North Am* 2002;15(1):17-25

19 Wu LL, Suzuki Y, Ideta R, Araie M. Central corneal thickness of normal tension glaucoma patients in Japan. *Jpn J Ophthalmol* 2000;44(6): 643-647

20 Jain R, Dilraj G, Grewal SP. Repeatability of corneal parameters with Pentacam after laser *in situ* keratomileusis. *Indian J Ophthalmol* 2007 55 (5): 341-347

21 Miranda MA, Radhakrishnan H, O'Donnell C. Repeatability of corneal thickness measured using an Oculus Pentacam. *Optom Vis Sci* 2009;86(3): 266-272

22 Barkana Y, Gerber Y, Elbaz U, Schwartz S, Ken-Dror G, Avni I, Zadok D. Central corneal thickness measurement with the Pentacam Scheimpflug system, optical low-coherence reflectometry pachymeter, and ultrasound pachymetry. *J Cataract Refract Surg* 2005;31(9):1729-1735

23 Shankar H, Taranath D, Santhirathelagan CT, Pesudovs K. Anterior segment biometry with the Pentacam: comprehensive assessment of repeatability of automated measurements. *J Cataract Refract Surg* 2008;34 (1):103-113

24 Amano S, Honda N, Amano Y, Yamagami S, Miyai T, Samejima T, Ogata M, Miyata K. Comparison of central corneal thickness measurements by rotating Scheimpflug camera, ultrasonic pachymetry, and scanning-slit corneal topography. *Ophthalmology* 2006;113(6):937-941

25 Hashemi H,Mehravaran S. Central corneal thickness measurement with Pentacam, Orbscan II, and ultrasound devices before and after laser refractive surgery for myopia. J Cataract Refract Surg 2007;33 (10): 1701-1707

26 Panda A, Venkateswarlu K, Angra SK, Kalra VK, Mohan M. Correlation between central corneal thickness and curvature (a clinical study). *Indian J Ophthalmol* 1985;33(2):91-94

27 Chen MJ, Liu YT, Tsai CC, Chen YC, Chou CK, Lee SM. Relationship between central corneal thickness, refractive error, corneal curvature, anterior chamber depth and axial length. *J Chin Med Assoc* 2009;72(3): 133-137