TITLE: **BIOMETRIC CHARACTERIZATION OF THE ANTERIOR SEGMENT IN A SAHRAWI PEDIATRIC POPULATION**

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DECLARATION OF INTEREST: None of the authors have any proprietary interests or conflicts of interest related to this submission. This submission has not been published anywhere previously and it is not simultaneously being considered for any other publication

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ABSTRACT

Purpose: To examine the biometric characteristics of the anterior segment in a group of Sahrawi children.

Methods: A total of 66 children (33 male and 33 female, aged between 8 and 13 years) participated in this prospective, observational study. The non-invasive Pentacam Scheimpflug imaging device was used to measure corneal thickness (CT) (at the thinnest corneal point), mean anterior (Km Ant) and posterior (Km Post) corneal radii, corneal volume (CVol), anterior chamber depth (ACD) and anterior chamber volume (ACVol). The contribution of age and gender to the various parameters was investigated.

Results: Corneal thickness values of the present group of Sahrawi children were 521.70 ± 3.92 µm. Boys had thicker corneas than girls, although this difference was not significant. Strong correlations were revealed between corneal thickness and corneal volume ($r = 0.835$; $p < 0.001$), as well as between anterior and posterior corneal radii ($r = 0.916$; $p < 0.001$) and between anterior chamber depth and anterior chamber volume ($r = 0.845$; $p < 0.001$). Weaker, but significant correlations were encountered between several other pairs of ocular parameters. Age and gender were found to influence anterior chamber depth and anterior chamber volume values.

Conclusions: Different measurement procedures and ethnic background preclude any direct comparison of the present results with published data, although corneal thickness in Sahrawi children was found to be lower than previously reported in children of similar age but different ethnicity.

Key Words: Corneal thickness; Corneal topography; Glaucoma prevention; Paediatric ocular biometry; Scheimpflug imaging

INTRODUCTION

For many years, ultrasound techniques have been considered the gold standard for ocular biometry. However, some limitations of ultrasound pachymetry have been described, mainly arising from inaccuracies in the calibration of sound transmittance of the ocular media and from diverse possible measurement errors associated with corneal indentation and probe placement, as well as with the need to instill corneal anesthetic[1-3]. Imaging techniques based on Scheimpflug photography allow for the point by point non-invasive exploration of corneal thickness, anterior chamber depth and corneal and anterior chamber volume, in addition to the topographical assessment of anterior and posterior corneal surfaces[4], thus providing an excellent opportunity for precise characterization of the anterior ocular segment.

Corneal thickness evaluation is important, particularly for the diagnosis and management of glaucoma, as it has been shown to modulate applanation tonometry measurements[5,6]. Besides, there is a growing interest in laser refractive surgery in the pediatric population, both for amblyopia management in children with spectacle and contact lens intolerance[7] and for the treatment of hyperopia, with or without hyperopic anisometropic amblyopia[8].

Several studies have investigated the variations in central corneal thickness (CCT) among children from various ethnic groups and the influence of age and gender within the same group. Indeed, African American children were found to have thinner CCT values than Caucasians[9,10] or Hispanics[11]. Similarly, the average central corneas of Japanese children were encountered to be thinner than in Caucasians but thicker than in African American children[12], whereas Chinese children were found to have thicker corneas than Malayan or Indian Children[13]. Other authors failed to discover any significant difference among racial subgroups[14]. The effect of age on CCT is still uncertain. Thus, while some studies fail to demonstrate any effect of age on CCT [11,15,16], others describe an increase in CCT values until the age of 5[9] or 9[14], with either a decrease between the ages of 10 and 14[14] or an approximation to adult values after the age of 5[12]. Finally, most authors agree that CCT is not influenced by gender[11,16,17], although some studies have reported a small, albeit statistically significant interaction of gender and CCT, with boys having thicker corneas than girls[13,15].

To the best of our knowledge, there are no published studies offering a complete biometric description of the anterior ocular segment in children. With this aim in mind, a prospective, observational study was designed to investigate corneal thickness (CT), mean anterior (Km Ant) and posterior (Km Post) corneal curvature, corneal volume (CVol), anterior chamber depth (ACD) and anterior chamber volume (ACVol) in a Sahrawi pediatric population.

MATERIALS AND METHODS

Patients

The present study was carried out on a group of Sahrawi children hosted for summer holidays in Alicante, Spain, and as part of the ongoing FUNCAVIS project (*Fundación para la Calidad Visual*). A total of 66 children (50% males, 50% females) between the ages of 8 and 13 years (mean age 10.63 years; SD = 1.66 years) were enrolled in the study. Participants with a previous history of ocular surgery, ocular trauma and ocular pathology, as well as those under topical medication, were excluded from the investigation. None of the participants was born prematurely nor had any present or past history of contact lens wear. All participants showed good cooperation during the study.

Full explanation of the research was provided, including Pentacam measurement procedures, and written informed consent was obtained from a parent or legal guardian of each of the participants. The Declaration of Helsinki tenets of 1975 (as revised in Tokyo in 2004) were followed throughout the study and the study was given clearance by the Ethics Committee of the Hospital International Medimar Alicante.

The Pentacam system

The Pentacam (Oculus, Inc.) imaging device, which has been employed in ophthalmic practice since 2004, employs the Scheimpflug photographic technique to acquire multiple images of the anterior ocular segment. Its characteristics and operational principles have been extensively described in the literature[4]. In essence, it utilizes a rotating monochromatic slit-light source (blue LED at 475 nm) to capture 50 sectional images yielding 138.000 true elevation points, thus constructing a 3-dimensional view of the anterior segment of the eye, as well as allowing for the complete anterior and posterior topographic analysis of the cornea.

Corneal thickness, mean anterior and posterior corneal curvature, corneal volume, anterior chamber depth and anterior chamber volume were assessed. Corneal pachymetry was recorded at the thinnest point of the cornea. Mean corneal curvature (Km) is calculated by averaging the radii of the flat and steep meridians in a central 3.0 mm zone. Corneal volume is defined by the anterior and posterior corneal surface boundaries and a 10.0 mm diameter around the corneal vertex. Anterior chamber depth is determined by the distance between the corneal endothelium, in line with the corneal vertex, and the anterior surface of the lens. Finally, anterior chamber volume is calculated similarly to corneal volume, with the posterior surface of the cornea and the anterior surface of the iris and lens acting as anatomical boundaries.

Procedure

All participants underwent a complete ophthalmological and optometric examination, including visual acuity evaluation, slit-lamp exploration, non-cycloplegic autorefraction and ocular fundus inspection. No previously undiagnosed abnormalities were detected upon slit-lamp observation of the anterior segment.

Testing took place with natural pupils and under the same conditions in ambient illumination. Participants were instructed to keep both eyes open and to look at the fixation target for the duration of the scan, which was adjusted at 2 seconds. Eyes were randomly examined. In order to avoid the documented daily changes in corneal thickness and other parameters, all measurements were conducted between 11:00 AM and 14:00 PM, after all participants had been awake for at least 4 hours[18].

Three consecutive Pentacam measurements were taken by an experimented investigator and the mean of the three readings was used for analysis. In order to avoid inter-examiner variability, all measurements were conducted by the same investigator (R.P.C). The imaging device was calibrated prior to the start of each new set of measurements.

Data analysis

Statistical analysis of the data was performed with the SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) for Windows. All data were analyzed for normality using the Kolmogorov-Smirnov test. No statistical difference could be found between right and left eyes. Therefore, data from right eyes was arbitrarily chosen for statistical purposes. A between-subjects analysis of variance (ANOVA) was used to investigate the interaction of gender on the various ocular parameters under examination. Pearson correlation test was employed to evaluate the relationship between ocular parameters. A *p-value* of 0.05 or less was considered to denote statistical significance throughout the study.

RESULTS

A total of 66 eyes from 66 children (33 males and 33 females) were included in the study. All data were found to follow a normal distribution. All eyes were found to have a refractive error ranging from emmetropia to +1.00 D, with the exception of two eyes presenting moderate myopia and three eyes with moderate hyperopic astigmatism. Mean and Standard Deviation (SD) values for corneal thickness, mean anterior and posterior corneal curvature, corneal volume, anterior chamber depth and anterior chamber volume are displayed in **Table 1**. A between-subjects ANOVA revealed a statistically significant effect of gender on ACD ($p = 0.010$) and ACVol ($p = 0.030$). No other statistically significant contributions of gender were discovered, although for both Km Ant (7.80 ± 0.36 mm in males; 7.66 ± 0.28 mm in females) and Km Post (6.47 ± 0.34 mm in males; 6.32 ± 0.28 mm in females), differences approached statistical significance ($p = 0.076$ and $p = 0.065$ respectively). Males (526.70 ± 31.18 µm) were found to have slightly thicker corneas than females (516.30 ± 31.72 µm), albeit this difference failed to reach statistical significance ($p = 0.205$).

Analysis with the Pearson's correlation coefficient revealed significant and relatively strong correlations between Km Ant and Km Post ($r = 0.916$; $p < 0.001$), Km Ant and CVol ($r = -0.406$; $p = 0.001$) and ACVol ($r = 0.369$; $p = 0.002$), Km Post and CVol ($r = -0.552$; $p < 0.001$) and ACVol ($r = 0.318$; $p = 0.009$), ACD and ACVol ($r = 0.845$; $p < 0.001$) and between CT and CVol ($r = 0.835$; $p < 0.001$). Age was found to be weakly correlated with ACD ($r = 0.245$; $p = 0.047$) and ACVol ($r = 0.239$; $p = 0.053$). No correlation between age and CT was disclosed.

DISCUSSION

As far as a literature review has exposed, this study is one of the first to aim at a global non-invasive characterization of the anterior ocular segment in a group of children of Sahrawi ethnicity. Several previous researchers have explored various isolated ocular parameters, mainly central corneal thickness by means of ultrasound pachymetry. The present study evaluated corneal thickness, anterior and posterior corneal curvature, corneal volume, anterior chamber depth and anterior chamber volume, and also examined the relationship between these parameters and the possible contribution of age and gender to the results.

The mean CT of the group under study was of 521.70 ± 31.92 µm, with males having slight, but not statistically significant thicker corneas than females. These values are lower than previously reported[11-17] and can only be considered comparable to those of a sample of African-American children of similar age[11] (see **Table 2**). The negligible effect of age and the probably very weak contribution of gender are in agreement with earlier studies.

Three different factors may account for the discrepancies in corneal thickness values. Firstly, ethnicity has been shown to be a determinant factor when measuring corneal thickness. The Sahrawi population originates from a mixed heritage, mainly Arab and Berber, thus presenting a different ethnic background to the groups previously studied. The relative geographical proximity to the African ethnicity may help to explain the mentioned similarities between the present group and the African-American group.

Secondly, it is prudent to admit the difficulties encountered in comparing outcomes different instruments. Indeed, previous studies have compared the Pentacam system with other methods for measuring corneal thickness. Fujioka and coworkers examined the Pentacam, ultrasound pachymetry and noncontact specular microscopy, finding a good agreement between the three methods of measurement, although pair-wise comparisons revealed statistically significant differences between them[19]. Similarly, Barkana et al. compared the Pentacam, ultrasound and optical low-coherence reflectometry pachymeters, failing to discover any statistically significant difference between these devices and reporting excellent intraoperator repeatability and interoperator reproducibility for the Pentacam system[20]. The same authors, however, advocated for further studies before these instruments could be used interchangeably.

Finally, the present method for the evaluation of corneal thickness was based on the identification of the thinnest point of the cornea. Previous research by Rüfer and coworkers disclosed that the thinnest point of the cornea is rarely located at its exact geometrical center, with an actual position mostly inferior and temporal from that point[21,22]. The difference between the central thickness and the thickness at the thinnest point of the cornea was found by these authors to be statistically significant, and of the order of 10 to 12 µm. The Pentacam system, like other imaging devices, determines both the location of the thinnest point of the cornea and its value. This information could be very relevant for the calculation of the residual corneal thickness when planning for refractive surgery procedures and for the precise measurement of intraocular pressure in glaucoma screening and management.

Previous authors have addressed possible differences in corneal thickness between children of different refractive status[15]. Thus, myopic children were found to have thinner corneas than both emmetropic and hyperopic children, albeit statistically significant differences were only revealed between the emmetropic and hyperopic and between the hyperopic and myopic groups[15]. The present limited sample of children had a refractive status ranging from emmetropia to +1.00 D, with only two eyes with moderate myopia and three eyes with moderate hyperopic astigmatism. Therefore, the characteristics of this study sample precluded any statistical analysis of the possible associations between refractive status and ocular parameters.

Corneal radius values were similar to those reported by previous authors[23]. It may be relevant to note that the measurement of mean K values offers a better repeatability than individual measures of flat and steep radii, an effect that has been suggested to result from the noise-reducing benefit of averaging two values[24].

Corneal thickness was not found to correlate with Km Ant. This finding is in disagreement with published research by Tong and coworkers, where a weak ($r = 0.19$) but statistically significant correlation was encountered between these paramenters[13], although other researchers failed to replicate this correlation[23]. A positive, strong correlation was discovered between CT and CVol. The relationship between CT and CVol, as well as the other strong and statistically significant reported correlations between pairs of ocular parameters, are easily explainable from a simple geometrical standpoint. Thus, for example, it is to be expected that, in healthy subjects, a flatter Km Ant would be generally associated with a flatter Km Post or that an increase in ACD would result in a subsequent increase in ACVol values. In fact, a purist mathematical approach may consider a certain degree of dependence between some of these variables, thus precluding the statistical analysis of correlation.

Gender was found to be a contributing factor to both ACD and ACVol and a weak correlation was discovered between age and ACD. However, sample size should be considered an important limitation of the study when interpreting these findings. Further research on a larger sample, within the same ethnic group, including an equal number of males and females and presenting a greater range of ages would permit a more robust statistical approach and lead to more conclusive evidence.

In summary, the characteristics of the Pentacam system imaging methodology allow for a fast (less than 2 seconds), non-invasive procedure, which ensures patient collaboration. This is particularly important when patients are of a young age or displaying a restive or anxious behavior. The precise biometric characterization of the anterior segment of the eye is of crucial importance to establishing baseline criteria whereupon anomalies can be judged, diagnosed and managed.

REFERENCES

1. Reader AL, Salz JJ. Differences among ultrasound pachymeters in measuring corneal thickness. *J Refract Surg*. 1987;3:7-11.
2. Urbak SF. Ultrasound biomicroscopy. III. Accuracy and agreement of measurements. *Acta Ophthalmol Scand*. 1999;77:293-297.
3. Tam ES, Rootman DS. Comparison of central corneal thickness measurements by specular microscopy, ultrasound pachymetry and ultrasound biomicroscopy. *J Cataract Refract Surg*. 2003;29:1179-1184.
4. Buehl W, Stojanac D, Sacu S, Drexler W, Findl O. Comparison of three methods of measuring corneal thickness and anterior chamber depth. *Am J Ophthalmol*. 2006;141:7-12.e1.
5. Kniestedt C, Lin S, Choe J, Bostrom A, Nee M, Stamper RL. Clinical comparison of contour and applanation tonometry and their relationship to pachymetry. *Arch Ophthalmol*. 2005;123:1532-1537.
6. Brandt JD, Beiser JA, Kass MA, Gordon MO. Central thickness in the Ocular Hypertension Treatment Study (OHTS). *Ophthalmology*. 2001;108:1779-1788.
7. Ghanem AA, Nematallah EH, El-Adawy IT, Anwar GM. Facilitation of amblyopia management by laser in situ keratomileusis in children with myopic anisometropia. *Curr Eye Res*. 2010;35:281-286.
8. Astle WF, Huang PT, Ereifej I, Paszuk A. Laser-assisted subepithelial keratectomy for bilateral hyperopia and hyperopic anisometropic amblyopia in children: one-year outcomes. *J Cataract Refract Surg*. 2010;36:260-267.
9. Muir KW, Duncan L, Enyedi LB, Freedman SF. Central corneal thickness in children: Racial differences (black vs. white) and correlation with measured intraocular pressure. *J Glaucoma*. 2006;15:520-523.
10. Semes L, Shaikh A, McGwin G, Bartlett JD. The relationship among race, iris color, central corneal thickness, and intraocular pressure. *Optom Vis Sci*. 2006;83:512-515.
11. Dai F, Gunderson CA. Pediatric central corneal thickness variation among major ethnic populations. *J AAPOS*. 2006;10:22-25.
12. Hikoya A, Sato M, Tsuzuki K, Koide YM, Asaoka R, Hotta Y. Central corneal thickness in Japanese children. *Jpn J Ophthalmol*. 2009;53:7-11.
13. Tong L, Saw SM, Siak JK, Gazzard G, Tan D. Corneal thickness determination and correlates in Singaporean schoolchildren. *Invest Ophthalmol Vis Sci*. 2004;45:4004-4009.
14. Hussein MA, Paysse EA, Bell NP, et al . Corneal thickness in children. *Am J Ophthalmol*. 2004;138:744-748.
15. Coste R, Cornand E, Denis D. Pachymétrie cornéenne centrale dans la population pédiatrique par microscopie spéculaire non-contact : à propos de 405 cas. *J Fr Ophtalmol*. 2008;31:273-278.
16. Osmera J, Filous A, Hlozánek M. Central corneal thickness, intraocular pressure and their correlation in healthy Czech children aged 7-17. *Cesk Slov Oftalmol*. 2009;65:19-23.
17. Haider KM, Mickler C, Oliver D, Moya FJ, Cruz AO, Davitt BV. Age and racial variation in central corneal thickness of preschool and school-aged children. *J Pediatr Ophthalmol Strabismus*. 2008;45:227-233.

18. Harper CL, Boulton ME, Bennett D, et al. Diurnal variations in human corneal thickness. *Br J Ophthalmol*. 1996; 80: 1068-1072.
19. 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; 32:89-94.
20. Barkana Y, Gerber Y, Elbaz U, et al. Central corneal thickness measurement with the Pentacam Scheimpflug system, optical low-coherence reflectometry pachymeters, and ultrasound pachymetry. *J Cataract Refract Surg*. 2005;21:1729-1735.
21. Rüfer F, Sander S, Klettner A, Frimpong-Boateng A, Erb C. Characterization of the thinnest point of the cornea compared with the central corneal thickness in normal subjects. *Cornea*. 2009;28:177-180.
22. Khoramnia R, Rabsilber TM, Auffarth GU. Central and peripheral pachymetry measurements according to age using the Pentacam rotating Scheimpflug camera. *J Cataract Refract Surg*. 2007;33:830-836.
23. Basmak H, Sahin A, Yildirim N. The reliability of central corneal thickness measurements by ultrasound and Orbscan System in schoolchildren. *Curr Eye Res*. 2006;31:569-575.
24. Shankar H, Taranath D, Santhirathelagan CT, Pseudovs K. Anterior segment biometry with the Pentacam: Comprehensive assessment of repeatability of automated measures. *J Cataract Refract Surg*. 2008;34:103-113.

TABLES

Table 1: Mean ± SD values for corneal thickness (CT), mean anterior (Km Ant) and posterior (Km Post) corneal curvature, corneal volume (CVol), anterior chamber depth (ACD) and anterior chamber volume (ACVol)

CT (μm)	Km Ant (mm)	Km Post (mm)	CVol (mm^3)	ACD (mm)	ACVol (mm^3)
521.70 ± 3.92	7.73 ± 0.32	6.39 ± 0.31	59.18 ± 3.94	2.99 ± 0.33	168.35 ± 34.27

Table 2: Mean ± SD values for corneal thickness (CT) as compared with previous studies, with indication of the ethnic characteristics of the study sample and pachymetry technique

	Technique	Ethnicity	CT (µm)
Dai and Gunderson[11]	Ultrasound pachymetry	African-American	523 ± 40
		Caucasian	563 ± 36
		Hispanic	568 ± 44
Hikoya *et al*[12]	Ultrasound pachymetry	Japanese	544.3 ± 36.9
Tong *et al*[13]	Slit-lamp optical pachymetry	Chinese	543.6 ± 32
		Other	536.6 ± 31.5
Hussein *et al*[14]	Ultrasound pachymetry	Caucasian	551 ± 48
		Hispanic	550 ± 48
Coste *et al*[15]	Specular microscopy	Not specified	529 ± 32
Osmera *et al*[16]	Ultrasound pachymetry	Caucasian	554 ± 33
Haider *et al*[17]	Ultrasound pachymetry	African-American	535 ± 35
		Caucasian	558 ± 38
The present study	Scheimpflug imaging	Sahrawi	521.70 ± 3.92