Corneal Evaluation in Healthy Brazilian Children Using a Scheimpflug Topography System

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Abstract

Purpose: To identify the distribution and variation in corneal topography, thickness, and elevation in healthy Brazilian children as measured by the Pentacam Scheimpflug system (Oculus Optikgeräte GmbH, Wetzlar, Germany).

Methods: Healthy children between 7 and 11 years of age were scanned using the Pentacam Scheimpflug corneal topography system (Oculus Optikgeräte GmbH, Wetzlar, Germany). The exclusion criteria were inability to undergo the ocular exam, history of any ocular diseases (including strabismus, amblyopia, cataracts, retinal disorders, and allergic conjunctivitis), and topographic diagnosis of corneal ectasia based on the modified Rabinowitz/McDonnell criteria for keratoconus. The right eye of each subject was selected for analysis. The parameters evaluated were central corneal thickness (CCT), thinnest pachymetry (TP), average pachymetric progression index (PPIave), anterior and posterior elevation (AE and PE), anterior and posterior best fit sphere (ABFS and PBFS), pachymetric difference between the apex and the thinnest point (PDAT), Ambrosio's relational thickness (ARTMax), overall Belin/Ambrósio Enhanced Ectasia display score (BAD-D), simulated keratometry (SimK), astigmatism in SimK (SimK astig), maximum keratometry (K max), asphericity (Q value), and anterior chamber depth (ACD).

Results: A total of 160 children (69 male, 91 female) were included in this study. The mean age of the children was 8.82 ± 1.23 years (ranging from 7 to 11 years). The mean CCT was 553.81 ± 32 µm, and mean TP was 547.95 ± 32.06 µm. The TP was most commonly located in the inferotemporal quadrant in 93.125% (149) eyes. The mean PPIave was 1.00 ± 0.14, similar to that of normal adults. The mean ABFS and PBFS values were 7.49 ± 3.26 and 10.54 ± 6.25, respectively. ART Max and D averaged 446.57 ± 81.20 and 0.78 ± 0.65, respectively. Mean ± SD values for SimK, SimK astig, and K max were 43.35 ± 1.31 D, 0.92 ± 0.66 D, and 44.40 ± 1.45 D respectively. The K max and SimK astig values were close to those reported by other topographic systems for children. Q value and ACD averaged 0.39 ± 0.12 and 3.065 ± 0.2745 mm.

Conclusion: This study provides normative values for corneal topography, thickness, and elevation in healthy Brazilian children. These results may provide helpful information for diagnosis of corneal diseases in children. Further studies are needed to evaluate the role of tomography in identifying early forms of ectasia in this age group.

Keywords: Cornea; Children; Topography; Healthy; Pentacam; Scheimpflug

Introduction

In clinical practice and research involving the use of keratometric readings of the anterior surface of the eye, the study of the posterior aspects of the cornea and its pachymetric distribution are very important for understanding how the cornea behaves structurally. These parameters are needed to identify abnormal corneas and to predict how they will behave in the future and after surgical procedures. Until techniques such as slit-scanning and Scheimpflug imaging were developed, the field of corneal imaging was restricted to the analysis of the shape and optical quality of the cornea’s anterior surface with Placido disc-based topography systems [1]. These are still the most commonly used technologies for corneal imaging, though they lack the ability to diagnose subclinical keratoconus, contact lens corneal warpage, and corneas that are not suitable for refractive surgeries. These new anterior segment imaging technologies are capable of reconstructing the three-dimensional structure of the cornea from two-dimensional optical cross-sections, greatly enhancing our ability to investigate the properties of the cornea. There are currently five devices on the market that are based on these technologies: Orbscan IIz (Bausch & Lomb Surgical, Inc), Pentacam (Oculus, Inc), the Galilei (Ziemer Ophthalmic Systems AG), the Precisio (Ligi Tecnologie Mediali), and the Sirius (CSO Ophthalmic). The Orbscan IIz is the only slit-scanning-based technology; the others involve Scheimpflug-based technology [2].

The Pentacam corneal tomographer (Oculus Optikgeräte GmbH, Wetzlar, Germany) is a Scheimpflug-based topographer that can provide readings and analyses of the anterior and posterior surfaces of the cornea, as well as measurements of corneal thickness. Since its launch in 2004, it has become a popular device for evaluating the anterior segment of the eye. Previous studies have demonstrated excellent reproducibility of the automated measurements of the
anterior segment structures [3-6]. The Pentacam system may be used to
diagnose keratoconus, to screen corneas for refractive surgery, to
monitor post-surgical corneas, to calculate the keratometric index and
intraocular lens power, and to assess intraocular lens implants. Studies
have provided normative data on the anterior segments of adults [7], as
well as on changes in posterior corneal elevation following the use of
an excimer laser [8]. In order to avoid undetectable keratoconus, new-
generation devices now offer features and algorithms that help to
differentiate keratoconus from normal corneas [9,10]. It is important
to recognize the influences of aging on the shape of the anterior and
posterior surfaces of the cornea [11], especially in patients who have
cataracts and who have undergone corneal refractive surgery—other
words, patients who are in most need for accurate keratometric
parameters in the selection of the correct intraocular lens [12].

Despite the vast amount of data on these corneal parameters in
adults, similar information on children is still scarce [13], which can
limit the use of the Pentacam for identifying abnormal corneas. Some
studies have shown that the onset of keratoconus typically occurs
during puberty [14]. However, when this condition develops sooner (as
in cases of pediatric keratoconus), it seems to progress faster and to be
more advanced at the time of diagnosis than keratoconus in adults
[15]. Due to its advanced stage at diagnosis, pediatric keratoconus
bears a higher risk of corneal scarring than adult cases, an issue which
limits the use of the Pentacam for identifying abnormal corneas. Some
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[15]. Due to its advanced stage at diagnosis, pediatric keratoconus
bears a greater need for penetrating keratoplasty [16]. All of this
information justifies the importance of obtaining keratometric,
pachymetric, and elevation data from pediatric patients in order to
diagnose corneal abnormalities earlier and, ideally, to avoid
progression to such advanced stages and subsequent losses in quality of
life.

The purpose of this study was to establish a database of normative
corneal topography measurements from healthy children between 7
and 11 years of age using the Pentacam corneal topography system.

Patients and Methods

The present study was reviewed and approved by the Research
Ethics Committee of the University of Campinas (UNICAMP) in
Campinas, São Paulo, Brazil under CAAE Registry number
54921916.9.0000.5404, and the tenets of the Declaration of Helsinki
were followed. The study was based on a retrospective review of the
ophthalmological medical records of healthy children enrolled in
second to fifth grade of the State of São Paulo public school system in
2011. As it was a retrospective review of the ophthalmological medical
records of patients that were examined in the past, the informed
counsel was dispensed with no harm to the patients. The Honorato
Faustino State School was chosen randomly for these exams as part of
a partnership with the state government, and children from 7 to 11
years of age who agreed to participate of the study and whose parents
and guardians agreed to their participation were included. The
exclusion criteria were inability to undergo the ocular exam, history of
any ocular diseases (including strabismus, amblyopia, cataracts, retinal
diseases, and allergic conjunctivitis), and topographic diagnosis of
corneal ectasia based on the modified Rabinowitz/McDonnell criteria
for keratoconus [17]. The ocular tomographic exam was performed
using the OCULUS-Pentacam Scheimpflug Topography System.

During the examinations, the patients were comfortably positioned at
the instrument with proper placement on the chin rest and forehead
strap. The patients were asked to blink a few times and to open both
eyes and stare at the fixation target. The system, which was in
automatic release mode, started the scan after proper alignment was
obtained. Twenty-five single Scheimpflug images within captured for
each eye within 2 seconds. Two experienced ophthalmologists and
corneal specialists in a dimly lit room performed all of the
tomographic exams, and the tomography was repeated until acceptable
image quality was obtained (image quality defined as “OK” according
to the built-in Examination Quality Specifications). Details are shown
in Figure 1. The analysis of the captured images considered the
topographic, pachymetric, and elevation parameters, and maps,
graphs, and indices have been created.

Central corneal thickness (CCT) was recorded at the apex of the
cornea when the patient fixated on the target of the topographer. The
thinnest point (TP) and its distance to the CCT in micrometers (µm)
were recorded. All of these calculations are exemplified in Figure 2.

Anterior and posterior maps were used in the calculations of the
anterior and posterior elevations at the thinnest point (AETP and
PETP), as well as anterior and posterior elevation in the best fit sphere
(ABFS and PBFS) using a fixed optical zone of 8.0 mm, as seen in
Figure 3.

The mean value of the pachymetric progression index (PPIave)
was recorded, as were the anterior elevation (AE) and posterior elevation
(PE). The relational thickness parameter was calculated as the ratio of
the PPI value to Ambrosio’s relational thickness (ART), which refers to
the relational thickness of the TP with PPIMax (ARTMax). Using the
Belin/Ambrosio Enhanced Ectasia display, a calculation was made
based on the anterior and posterior elevations and on the distribution
of thickness and the overall value, which was referred to as BAD-D.
The BAD-D was recorded and used in the description of how the
thickness of the cornea changed between the thinnest area and the
periphery. Another parameter recorded was the asphericity of the
cornea, which is measured by a Q value in which an oblate cornea has
a positive value and a prolate cornea has a negative value. To avoid
redundancy of the data, we included only the right eye. The data was
manually transferred to Microsoft Excel (Microsoft, Redmond,
Washington).

Statistical analyses were performed using the R Project software,
version 3.0 (R Foundation for Statistical Computing Platform, Vienna,
Austria). The mean, standard deviation, range, and confidence interval
(95% CI) were calculated for each parameter in question. The
probability of distribution was calculated using the skewness and
kurtosis descriptors.

Results

A total of 160 healthy children from 7 to 10 years of age were
included in this study. Of these subjects, 69 were male and 91 were
female (43.1% and 56.9%, respectively). The average patient age was
8.82 ± 1.23 years. Table 1 summarizes the results.
Simulated flat keratometry (flat SimK), simulated steep keratometry (steep SimK), and maximum keratometry (K max) in diopters (D) were 42.95 ± 1.32 (range: 39.10 to 46.70), 43.86 ± 1.40 (range: 40.20 to 48.00), and 44.40 ± 1.45 (range: 40.50 to 48.50), respectively. SimK and SimK astigmatism (SimK astig) values were 43.35 ± 1.31 (range: 39.65 to 47.00) and 0.92 ± 0.66 (range: 4.80 to 0), respectively, and they were also measured in diopters (D).

In the analysis of corneal thickness, the mean CCT was found to be 553.81 ± 32 µm (range: 481 to 640), and mean TP was 547.95 ± 32.06 µm (range: 469 to 629). The TP was most commonly located in the inferotemporal quadrant in 93.125% (149) eyes. The distribution of thickness was represented in PPIave and ARTMax, which were 1.00 ± 0.14 (range: 0.64 to 1.45) and 446.57 ± 81.20 (range: 223 to 745), respectively.
The introduction of corneal tomographers such as the Orbscan llz (Bausch & Lomb Surgical, Inc), the Pentacam (Oculus, Inc), and the Galilei (Ziemer Ophthalmic Systems AG), both the anterior and posterior corneal surfaces came to be measured along with the pachymetry at each point, and elevation maps are now produced. These advancements provide information that was previously lacking with the Placido disk-based keratoscopy, and this information helps in the diagnosis of diseases by identifying different patterns of anterior and posterior topographies. This new data also aids in disease monitoring by providing additional parameters and more detailed information. These Pentacam measurements are currently being used in the formulation of new algorithms for the diagnosis of keratoconus and in the creation of built-in software that is capable of categorizing corneas as normal or as having cases of subclinical keratoconus [20]. An example of this is the new software adaptation to the Pentacam Scheimplug Tomography (Oculus, Wetzlar, Germany) called the Belin/Ambrosio Enhanced Ectasia Display (BAD). The BAD software combines anterior and posterior elevation data with pachymetric data to provide a three-dimensional tomographic representation of the cornea’s shape. A previous study showed that the thickness profile provided by the Pentacam and the BAD software can detect early keratoconus with a sensitivity and specificity of 98% [9]. The details provided by the Pentacam are reliable because the equipment has a high level of reliability and repeatability for keratometric and pachymetric readings [21,22]. The measurement of corneal thickness is essential in the diagnosis and evaluation of multiple ocular and corneal diseases, for establishing surgical indication, and for monitoring certain pathologies. Corneal thickness is considered an important indicator of corneal health, and it can be evaluated through the use of several methods, including ultrasonic pachymetry, optical slit-lamp pachymetry, confocal microscopy, specular microscopy, and partial coherence interferometry. Several reports have found corneal thickness measurements performed by the Pentacam and its pachymetric map to be reliable and reproducible [5,23-26].

With reports that the onset of keratoconus typically occurs during puberty [14] and that vision-related quality of life is worse among these patients [27], the detection of abnormal corneas in children has gained significant importance. It may be difficult to distinguish subclinical keratoconus from regular myopic astigmatism during a routine eye exam. Proper and prompt diagnosis of keratoconus is crucial for a better understanding of disease progression, for early treatment, and to avoid decreases in young patients’ BCVA and the subsequent impact on productivity and quality of life [28]. While advanced keratoconus is easily diagnosed by slit-lamp biomicroscopy and corneal curvature readings, diagnosing subclinical keratoconus remains a challenge. Another benefit of topography evaluation is greater sensitivity to the subtle changes in topographic parameters in children with subclinical expressions of keratoconus and suspicious topographic corneal patterns. In patients who have already been diagnosed with keratoconus, topography exams are important for analyzing progression and establishing surgical indication.

Previous studies have provided substantial information and many normative values for corneal power, astigmatism, corneal thickness and pachymetric progression indices in adults. However, these parameters have not been studied in children using current tomographers such as the OCULUS-Pentacam Scheimplug topography system. Our study provides normative data resulting from the use of Pentacam Scheimplug corneal topography in children from

| Age (y) | Mean ± SD | Range | Skew | Kurtosis |
|--------|-----------|-------|------|----------|
| 8.819 ± 1.233 | 7 to 11 | -0.06 | -1.13 |
| 553.81 ± 32 | 481 to 640 | 0.06 | -0.67 |
| 547.95 ± 32.06 | 469 to 629 | 0.05 | -0.84 |

**Table 1:** Measurements from 160 children's eyes evaluated using the OCULUS-Pentacam Scheimplug topography system.

Using the anterior and posterior maps, the data on AE, PE, ABFS, and PBFS in µm was +3.20 ± 1.91 (range: -1 to +13), 5.09 ± 3.43 (range: -3 to +20), +7.49 ± 3.26 (range: -4 to +26), and +10.54 ± 6.25 (range: -3 to +30), respectively.

The overall Belin/Ambrosio's Enhanced Ectasia display score (BAD-D) was calculated using elevation, thickness, and the distribution of the aforementioned thickness data, and the result was 0.78 ± 0.65 (range: 1.14 to 2.42). The shape of the cornea was analyzed based on its asphericity, which was a Q value of -0.39 ± 0.12 (range: -0.77 to -0.05).

**Discussion**

Before the advent of Scheimplug technology, Placido disk-based computer assisted videokeratoscopy was the best way to clinically evaluate corneal topography. It detected the curvature and corneal power of the anterior surface of the cornea, and its application is well known, including among pediatric patients. Before Scheimplug technology, most classification criteria for keratoconus were based on anterior corneal curvature data derived from corneal topography [18,19]. With the introduction of corneal tomographers such as the Orbscan llz (Bausch & Lomb Surgical, Inc), the Pentacam (Oculus, Inc), and the Galilei (Ziemer Ophthalmic Systems AG), both the anterior and posterior corneal surfaces came to be measured along with the pachymetry at each point, and elevation maps are now produced. These advancements provide information that was previously lacking with the Placido disk-based keratoscopy, and this information helps in the diagnosis of diseases by identifying different patterns of anterior and posterior topographies. This new data also aids in disease monitoring by providing additional parameters and more detailed information. These Pentacam measurements are currently being used in the formulation of new algorithms for the diagnosis of keratoconus and in the creation of built-in software that is capable of categorizing corneas as normal or as having cases of subclinical keratoconus [20]. An example of this is the new software adaptation to the Pentacam Scheimplug Tomography (Oculus, Wetzlar, Germany) called the Belin/Ambrosio Enhanced Ectasia Display (BAD). The BAD software combines anterior and posterior elevation data with pachymetric data to provide a three-dimensional tomographic representation of the cornea's shape. A previous study showed that the thickness profile provided by the Pentacam and the BAD software can detect early keratoconus with a sensitivity and specificity of 98% [9]. The details provided by the Pentacam are reliable because the equipment has a high level of reliability and repeatability for keratometric and pachymetric readings [21,22]. The measurement of corneal thickness is essential in the diagnosis and evaluation of multiple ocular and corneal diseases, for establishing surgical indication, and for monitoring certain pathologies. Corneal thickness is considered an important indicator of corneal health, and it can be evaluated through the use of several methods, including ultrasonic pachymetry, optical slit-lamp pachymetry, confocal microscopy, specular microscopy, and partial coherence interferometry. Several reports have found corneal thickness measurements performed by the Pentacam and its pachymetric map to be reliable and reproducible [5,23-26].

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This study on healthy children between 7 and 11 years of age found a relative similarity between children's mean CCT, TP, PPlave and BAD-D values and those of normal adults. The results also reflected a relative difference between children's values and the values in subclinical and keratoconus patients found by Ambrósio et al. [9], that studied 113 normal and 44 eyes with keratoconus from brazilian patients aged between 11.7 to 78 years (mean 38.7 ± 17.9 years), and Vazquez et al. [30], that studied 189 normal and 44 eyes with keratoconus and their fellow eyes from argentine patients aged between 14 and 71 years (mean 32.3 ± 8.1 years), as seen in Table 2. It seems that children's corneas become thinner from the periphery to the center the same way and as fast as adult corneas do, a finding that suggests that this parameter could be used to identify pediatric corneas that differ from healthy parameters. More studies are needed to significantly distinguish between normal and abnormal corneas based on these parameters.

| Current Study | Vázquez et al. - 2014 | Ambrósio et al. - 2011 |
|---------------|----------------------|----------------------|
| Mean ± SD     | Normal SC KC KC Cutoff | Normal KC Cutoff |
| CCT (µm)      | Mean ± SD Mean ± SD Mean ± SD Mean ± SD Mean ± SD |
| 553.81 ± 32   | 532 ± 33 502 ± 37 491 ± 39 | 550.53 ± 0.35 483.34 ± 41.88 529 |
| TP (µm)       | 547.95 ± 32.06 | 528 ± 32 489 ± 37 474 ± 43 | 545.20 ± 34.27 448.70 ± 52.96 504 |
| PPlave        | 1.00 ± 0.14 | 0.97 ± 0.14 1.42 ± 0.48 1.79 ± 0.77 1.09 | 0.87 ± 0.21 2.42 ± 1.74 1.06 |
| ART MAX       | 446.57 ± 81.20 | 445 ± 87 269 ± 101 223 ± 109 | 507.36 ± 128.56 180.78 ± 78.21 339 |
| BAD-D         | 0.78 ± 0.65 | 1.03 ± 0.7 4.26 ± 3.03 6.08 ± 3.98 | 1.61 |

SD: Standard Deviation; 95% CI: Confidence Interval; SC: Sub Clinical; CCT: Central Corneal Thickness; KC: Kerato Conus; TP: Thinnest Pachymetry; PPlave: Average Pachymetric Progression Index; ARTMax: Maximum Ambrosio Relational Thickness; BAD-D: Overall Beltri/Ambrosio Enhanced Ectasia Display score; The Pentacam Scheimpflug corneal topography system (Oculus Optikgerate GmbH, Wetzlar, Germany).

**Table 2:** Measurements of 160 children's eyes and cutoff values in the current study and as reported in other studies.

K max (42.95 ± 1.32) and SimK astig (0.92 ± 0.66) values were found to be similar to those found through the use of other topographic systems with older technologies (computerized videokeratoscopy) and newer technologies (slit-scanning and Scheimpflug) among healthy children and adults [29,31]. These values represent a low overall level of corneal astigmatism in the pediatric population of this study. These indices were also found to be similar to those of other studies (Table 3).

| Method          | No. of eyes | SimK max (D) | SimK min (D) | SimK Astig (D) |
|-----------------|-------------|--------------|--------------|----------------|
| Current Study   | Pentacam    | 160          | 43.86        | 42.95          | 0.92           |
| Ortiz-Toquero et al. | Gailiel G4 | 56           | 44.22        | 43.22          | 0.97           |
| Ortiz-Toquero et al. | Allegro Topoyer | 56           | 44.07        | 43.12          | 0.95           |
| Reddy et.       | Orbscan II z | 100          | 44.26        | 43.56          | 0.69           |
| Liu et.         | Orbscan     | 94           | 44.24        | 43.31          | 0.9            |
| Bogan et.       | CMS         | 216          | 43.39        | 0.8            |
| Rabinowitz et al. | TMS-1      | 390          | 43.7         |                |

**Table 3:** Simulated keratometry (SimK) findings in different studies.

As Table 4 shows, we also compared the parameters between males and females and found the values to be similar. The mean Q value was -0.39 ± 0.12, a finding which suggests that children's corneas are more prolate than those of African-American adults (-0.26 ± 0.19) and of Caucasian adults (-0.20 ± 0.12) in studies that used the Pentacam [32]. Younger corneas seem to be more prolate than those of older patients (7 years -0.3919 ± 0.02438; 11 years -0.3309 ± 0.03195; p=0.1428), but...
further studies on more subjects are needed to prove this information with statistical significance.

|                  | Males (n: 69) | Females (n: 91) | P-value |
|------------------|---------------|-----------------|---------|
| **CCT**          | Mean          | SD              | Mean    | SD    | <0.05   |
|                  | 549.1         | 33.78           | 557.4   | 30.3  |         |
| **TP**           | 543.7         | 34.21           | 551.2   | 30.12 | <0.0001 |
| **PPLave**       | 0.986         | 0.1369          | 1.002   | 0.1351| <0.0001 |
| **PE**           | 4.406         | 3.683           | 5.604   | 3.169 | <0.0001 |
| **ABFS**         | 7.406         | 2.83            | 7.549   | 3.572 | <0.0001 |
| **PBFS**         | 8.739         | 6.416           | 11.9    | 7.596 | <0.0001 |
| **PDAT (μm)**    | 5.478         | 4.661           | 6.154   | 5.084 | <0.0001 |
| **ART MAX**      | 445.4         | 86.61           | 447.5   | 77.32 | <0.0001 |
| **BAD-D**        | 0.709         | 0.6337          | 0.8358  | 0.6637| <0.0001 |
| **SimK**         | 43.13         | 1.557           | 43.61   | 1.303 | <0.0001 |
| **Flat SimK**    | 42.68         | 1.432           | 43.15   | 1.197 | <0.0001 |
| **Sleep Sim K**  | 43.58         | 1.556           | 44.08   | 1.244 | <0.0001 |
| **SimK Astig**   | -0.901        | 0.6993          | -0.9282 | 0.624 | <0.0001 |
| **K max**        | 44.06         | 1.595           | 44.66   | 1.271 | <0.0001 |
| **Q Value**      | -0.381        | 0.1673          | -0.3756 | 0.1338| <0.0001 |
| **ACD**          | 3.12          | 0.2664          | 3.023   | 0.2745| <0.0001 |

SD: Standard Deviation; CCT: Central Corneal Thickness; TP: Thinnest Pachymetry; PPLave: Average Pachymetric Progression Index; AE: Anterior Elevation; PE: Posterior Elevation; K: Keratometry; SimK: Simulated Keratometry; ABFS: Anterior Best Fit Sphere; PBFS: Posterior Best Fit Sphere; PDAT: Pachymetric Difference Between the Apex and the Thinnest Point; Kmax: Maximum Keratometry; BAD-D: Overall Belin/Ambrósio Enhanced Ectasia Display score; The Pentacam Scheimpflug corneal topography (Oculus Optikgerate GmbH, Wetzlar, Germany)

Table 4: Comparison of Pentacam parameters between male and female pediatric patients.

This study is the first to report on the corneal parameters of healthy Brazilian children. Some limitations must be noted, however: though the parameters are similar to those found in the general population, the age range of our study was between 7 and 11 years, and it is not known how the corneas of younger and older children behaves and whether these same parameters can be applied to other pediatric age groups. Because the current study is descriptive in nature, its statistical significance cannot be compared to that of other populations (such as adults and patients with keratoconus corneas). Therefore, it is difficult to determine similarities and differences between these findings and others. It is also important to note that, while the tomographic exam requires only two seconds capturing all of the images, the patient to remain immobile and fixate on the target, which could be difficult to achieve among younger patients.

This is the first study in the literature to provide normalized values for keratometry, pachymetry, and relational data from Brazilian children’s corneas using the Pentacam Scheimpflug topography system. It can provide a good foundation for the comparison of abnormal pediatric corneal topography to normal cases. This data may prove useful in the field to help distinguish between normal and abnormal corneas, as well as in future comparative studies that consider different corneal diseases in children. Further studies are needed to evaluate the role of tomography in identifying early forms of ectasia in children.

References

1. Klyce SD (2000) Corneal topography and the new wave. Cornea 19: 723-729.
2. Oliveira CM, Ribeiro C, Franco S (2011) Corneal imaging with slit-scanning and Scheimpflug imaging techniques. Clin Exp Optom 94: 33-42.
3. Pinero DP, Saenz Gonzalez C, Alio JL (2009) Intraobserver and interobserver repeatability of curvature and aberrometric measurements of the posterior corneal surface in normal eyes using Scheimpflug photography. J Cataract Refrac Surg 35: 113-120.
4. Chen D, Lam AK (2007) Intrasession and intersession repeatability of the Pentacam system on posterior corneal assessment in the normal human eye. J Cataract Refrac Surg 33: 1817-21.
5. Shankar H, Taranath D, Santhirathelagan CT, Pesudovs K (2008) Anterior segment biometry with the Pentacam: comprehensive assessment of repeatability of automated measurements. J Cataract Refrac Surg 34: 103-113.
6. Chen D, Lam AK (2009) Reliability and repeatability of the Pentacam on corneal curvatures. Clin Exp Optom 92: 110-118.
7. Feng MT, Belin MW, Ambrosio R, Grewal SP, Yan W, et al. (2011) International values of corneal elevation in normal subjects by rotating Scheimpflug camera. J Cataract Refrac Surg 37: 448-454.
8. Ciolino JB, Belin MW (2006) Changes in the posterior cornea after laser in situ keratomileusis and photorefractive keratectomy. J Cataract Refrac Surg 32: 1426-1431.
9. Ambrosio R, Alonso RS, Luz A, Coca Velarde LG (2006) Corneal-thickness spatial profile and corneal-volume distribution: tomographic indices to detect keratoconus. J Cataract Refrac Surg 32: 1851-1859.
10. Hashemi H, Mehrvaran S (2010) Day to Day Clinically Relevant Corneal Elevation, Thickness, and Curvature Parameters Using the Orbscan II Scanning Slit Topographer and the Pentacam Scheimpflug Imaging Device. Middle East Afr J Ophthalmol 17: 44-55.
11. Dubbelman M, Sicam VA, Van der Heijde GL (2006) The shape of the anterior and posterior surface of the aging human cornea. Vision Res 46: 993-1001.
12. Borasio E, Stevens J, Smith GT (2006) Estimation of true corneal power after keratorefractive surgery in eyes requiring cataract surgery: BESSt formula. J Cataract Refrac Surg 32: 2004-2014.
13. Zheng Y, Huang G, Huang W, He M (2008) Distribution of central and peripheral corneal thickness in Chinese children and adults: the Guangzhou twin eye study. Cornea 27: 776-781.
14. Sahin A, Yildirim N, Basmak H (2008) Two-year interval changes in Orbscan II topography in eyes with keratoconus. J Cataract Refrac Surg 34: 1295-1299.
15. Léoni-Mesplé S, Mortemousque B, Touboul D, Malet F, Praud D, et al. (2012) Scalability and severity of keratoconus in children. Am J Ophthalmol 154: 56-62.
16. El-Khouri S, Abdelmassih Y, Hamade A, Slim E, Cherfan CG, et al. (2016) Pediatric Keratoconus in a Tertiary Referral Center: Incidence, Presentation, Risk Factors, and Treatment. J Refrac Surg 32: 534-541.
17. Cavas-Martinez F, De la Cruz Sanchez E, Nieto Martinez J, Fernandez Canavate FJ, Fernandez-Pacheco DG (2016) Corneal topography in keratoconus: state of the art. Eye Vis 3: 5.
18. Quisling S, Sjoberg S, Zimmerman B, Goinis K, Sutphin J (2006) Comparison of Pentacam and Orbscan II on posterior curvature topography measurements in keratoconus eyes. Ophthalmology 113: 1629-1632.
19. de Sanctis U, Loiacono C, Richiardi L, Turco D, Mutani B, et al. (2008) Sensitivity and specificity of posterior corneal elevation measured by Pentacam in discriminating keratoconus/subclinical keratoconus. Ophthalmology 115: 1534-1539.

20. Arbelaez MC, Sekito MB (2013) Screening for subclinical keratoconus. Oman J Ophthalmol 6: 1-2.

21. Hamer CA, Buckhurst H, Purslow C, Shum GL, Habib NE, et al. (2016) Comparison of reliability and repeatability of corneal curvature assessment with six keratometers. Clin Exp Optom 99: 583-589.

22. Modis L, Szalai E, Nemeth G, Berta A (2011) Reliability of the corneal thickness measurements with the Pentacam HR imaging system and ultrasound pachymetry. Cornea 30: 561-566.

23. Mueller A, Thomas BC, Auffarth GU, Holzer MP (2016) Comparison of a new image-guided system versus partial coherence interferometry, Scheimpflug imaging, and optical low-coherence reflectometry devices: Keratometry and repeatability. J Cataract Refract Surg 42: 672-678.

24. Chen S, Huang J, Wen D, Chen W, Huang D, et al. (2012) Measurement of central corneal thickness by high-resolution Scheimpflug imaging, Fourier-domain optical coherence tomography and ultrasound pachymetry. Acta Ophthalmol 90: 449-455.

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

26. Jahadi Hosseini HR, Katab B, Khalili MR, Abtahi MB (2010) Comparison of corneal thickness measurements using Galilei, HR Pentacam, and ultrasound. Cornea 29: 1091-1095.

27. Aydin Kurna S, Altun A, Gencaga T, Akkaya S, Sengor T (2014) Vision related quality of life in patients with keratoconus. J Ophthalmol 2014: 694542.

28. Kymes SM, Walline JJ, Zadnik K, Gordon MO, Collaborative Longitudinal Evaluation of Keratoconus study group (2004) Quality of life in keratoconus. Am J Ophthalmol 138: 527-535.

29. Reddy SP, Bansal R, Vaddavalli PK (2013) Corneal topography and corneal thickness in children. J Pediatr Ophthalmol Strabismus 50: 304-310.

30. Ruisenor Vazquez PR, Galletti JD, Minguez N, Delrivo M, Fuentes Bonthoux F, et al. (2014) Pentacam Scheimpflug tomography findings in topographically normal patients and subclinical keratoconus cases. Am J Ophthalmol 158: 32-40 e2.

31. Ortiz-Toquero S, Zuniga V, Rodriguez G, de Juan V, Martin R (2016) Agreement of corneal measurements between dual rotating Scheimpflug-Placido system and Placido-based topography device in normal and keratoconus eyes. J Cataract Refract Surg 42: 1198-1206.

32. Fuller DG, Alperin D (2013) Variations in corneal asphericity (Q value) between African-Americans and whites. Optom Vis Sci 90: 667-673.