Cassini: Providing True Axis and Magnitude of Astigmatism

Multicolored spot reflection topography produces repeatable measurements.

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Responsible for approximately two-thirds of the total ocular refractive power, the anterior corneal surface is the most significant contributor to ocular refraction. Because this region of the cornea offers undisturbed imaging accessibility, it has been extensively studied.

A long-standing technology for anterior surface evaluation is Placido-disc projection topography. These non-contact topography devices enable single-shot capture of the cornea, thus reducing motion artifacts. Placido-disc topography has several limitations, however, which include skew ray error, lower data reliability at the corneal center, and susceptibility to error in areas of abrupt corneal elevation changes.

Some newer systems have incorporated color-coded specular reflection and forward ray tracing, allowing imaging of radial in addition to contour topographic changes in the cornea. Instead of the traditional concentric mires pattern used in Placido-ring topographers, the prototype VU Topographer (Vrije Universiteit Medical Center) used a color-coded, chess-like pattern to reconstruct the anterior corneal surface. The aim of this primitive multicolor-coded corneal topographer was to eliminate source-image mismatch and enable one-to-one correspondence. In principle, it has been shown to be superior in reconstructing features of the anterior corneal surface that are not rotationally symmetric.

LED POINT SOURCES

Like the VU Topographer, the commercially available Cassini system (i-Optics) also uses a multicolor (red, yellow, and green) spot pattern. However, instead of projecting a limited number of color-coded squares onto the cornea in a chessboard-like pattern, this topographer applies up to 700 light emitting diode (LED) point sources onto the cornea and evaluates their reflection image pattern as raw data (Figure 1). The Cassini’s software locates feature points in reflected images and accounts for smearing and deformation in irregular corneas.

Cassini provides axial (Figure 2A) and tangential curvature, refractive power (Figure 2B), and elevation maps calculated on an 8.5-mm corneal diameter. The device also calculates steep and flat keratometry (K), axis orientation, and related astigmatism, as well as four topographic indices relating to surface asphericity, two keratoconus indices, and four image quality indices.

CLINICAL EVALUATION

Due to its novelty, clinical validation of the Cassini has yet to be achieved; however, we recently reported its use...
in central corneal dystrophy imaging\textsuperscript{12} and forme fruste keratoconus diagnosis.\textsuperscript{13} We have also examined the clinical feasibility of multicolored spot reflection corneal topography in a large number of healthy and precataract eyes by investigating the distribution and repeatability of steep meridian and magnitude of astigmatism measurements.

In our study, three successive acquisitions with Cassini with at least 75% coverage as reported by the quality factor (QF) were obtained in each eye. The magnitude of astigmatism was defined as the difference between the steep meridian K minus the flat meridian K, and the axis of astigmatism was reported by the steep meridian orientation. Measurement repeatability was evaluated by the standard deviation of the three values of each parameter investigated. Patients were categorized into a control group (group A; 175 eyes), consisting of healthy, noncataract patients, and a cataract group (group B; 175 eyes), consisting of pre-surgery cataract patients with at least a classification of 1 on the Lens Opacity Classification System III.\textsuperscript{14,15} These two groups were further stratified according to each eye’s magnitude of astigmatism in order to investigate the relationship between repeatability of axis and magnitude measurement in each eye versus the mean magnitude of astigmatism in the specific eye. The subgroups were as follows:

- **Subgroup 1**: astigmatism between 0.00 and 0.99 D;
- **Subgroup 2**: astigmatism between 1.00 and 1.99 D;
- **Subgroup 3**: astigmatism between 2.00 and 2.99 D; and
- **Subgroup 4**: astigmatism greater than 3.00 D.

In group A, the mean age was 35.7 ±12.3 years (range, 10–65 years) and the mean preoperative astigmatism was 1.60 ±1.45 D (range, 0.04–9.94 D). We characterized the astigmatism in this group as with-the-rule (WTR) because the steep meridian was between 80° and 110° in 73% of eyes. The average steep axis orientation was 94.78 ±28.01° (range, 4°–179.78°; Figure 3A).

The mean age in group B was 73.6 ±6.4 years (range, 61–91 years), and the mean preoperative astigmatism was 1.60 ±1.45 D (range, 0.04–9.94 D). We characterized the astigmatism in this group as against-the-rule (ATR), as the steep axis in 69% of the eyes was between either 0° and 20° or 150° and 180°. The average steep axis orientation was 137.4 ±55.8° (range, 2.00°–178.8°; Figure 3B).

**RESULTS**

Results of our study are outlined in Tables 1 and 2 and
in Figures 4 and 5. Astigmatism magnitude repeatability was not statistically significantly different among the paired subgroups. In group A, astigmatism repeatability ranged from 0.25 in subgroup 1 to 0.33, 0.64, and 0.59 D in subgroups 2, 3, and 4, respectively. In group B, astigmatism repeatability ranged from 0.35 in subgroup 1 to 0.59, 0.65, and 0.61 D in subgroups 2, 3, and 4, respectively.

Our work confirms previous studies investigating corneal astigmatism distribution\textsuperscript{16} and the increasing prevalence of ATR astigmatism with age.\textsuperscript{17} Specifically, in our study, the younger population had predominantly WTR astigmatism and the older population predominantly ATR.

Additionally, our study results were in line with previous studies regarding the distribution of astigmatism. In a recent evaluation of 1,230 eyes in which mean patient age was 75.54 ±10.71 years, 79.5% of eyes had 1.50 D or less of corneal astigmatism, 9.69% had more than 2.08 D, 4.61% had more than 2.50 D, 1.93% had 3.00 D or more, and 0.96% had more than 3.50 D.\textsuperscript{18} Others have reported that more than 40% of eyes had more than 1.00 D of astigmatism\textsuperscript{19} and 25% had more than 1.50 D.\textsuperscript{20}

When we used Cassini to calculate the distribution of astigmatism in our study population, about 60% of group A and 50% of group B had 1.00 D or more of astigmatism. Additionally, the repeatability of astigmatism measurement in both groups was less than 0.65 D, a parameter that slightly increased as the magnitude of astigmatism increased. By contrast, the repeatability of axis measurement improved as the magnitude of astigmatism increased (Tables 1 and 2 and Figure 4). Specifically, for example, in group B, repeatability was 1.25° in subgroup 2 and 0.62° in subgroup 4 in the
same subgroups in group A, repeatability was 1.44° and 1.14°, respectively. These results may be explained by the fact that, in the older age group B, astigmatism was largely ATR, with the steep axis oriented largely horizontally. This may bear clinical value, as the Cassini device may be used to determine the correct axis for toric IOL placement.

SURGICAL PLANNING

Accurate representation of the anterior corneal surface on topography has become an important component of cataract surgery planning and continual developments in this area have led to innovative proposals for more accurate imaging.² ²² In addition to accounting for spherical error, achieving emmetropia often requires astigmatism correction with toric IOLs and/or astigmatic keratotomy. Therefore, proper identification of preoperative corneal astigmatism, both in magnitude and axis, is crucial.

Astigmatism shifts from WTR to ATR occur with age. In our study, repeatability of astigmatism axis was less than 3° and repeatability of astigmatism magnitude measurements was less than 0.60 D when taken with the multicolor spot reflection topography of the Cassini. These may be seen as impressive sensitivity benchmarks. Even better repeatability on axis measurement was noted in eyes with higher astigmatism.

AN INTEGRAL TOOL

Over the past few years, we have become accustomed to the use of extensive corneal imaging for preoperative planning in cataract and refractive surgeries, for postoperative assessments in these surgeries, and also when dealing with corneal irregularities such as scars and keratoconus. The traditional modalities of Placido-disc topography and Scheimpflug tomography have been illustrative; however, the Cassini system with its brilliant precision and repeatability has further helped in cases in which the first two technologies were in disagreement or central irregularities had to be studied.

For the past year, the Cassini system has been an integral component of our routine diagnostics protocol for IOL calculation, corneal screening for refractive surgery, post-LASIK assessments, and understanding irregular corneas and their topography-guided normalization.

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