IOLMaster keratometry for the calculation of toric intraocular lens power and orientation

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ABSTRACT

In the implantation of intraocular lenses (IOL) stringent requirements are made on achieving the refractive target. This necessitates the exact determination of the basic data needed for IOL power calculation – both the axial length and, in particular, the corneal power – and additionally the cylinder power and its axis in the case of a toric lens. This gives rise to the question, especially for the implantation of toric lenses, as to what instrument system is more suitable: a topography system, a manual keratometer or the keratometer of the IOLMaster on the basis of the reproducibility of individual measurements.
The reproducibility of the measurement of the spherical equivalent (SE) with the IOLMaster – here the mean difference between the minimum and maximum SE of 3 individual measurements per eye – was 0.09 ± 0.06 D [0 – 0.52].
The deviations within one measurement series were very low: in 79% the deviations were lower than 0.125 D, in 93% lower than 0.25 D, in 99% lower than 0.50 D and in 100% lower than 1.00 D.
The reproducibility of the measurement of the power of the astigmatism – here the mean difference between the minimum and maximum astigmatism of 3 individual measurements – was 0.21 ± 0.17 D [0 – 1.35].
The deviations of the measured values in the measuring series were low here also: 43% lay within 0.125 D, 74% within 0.25 D, 92% within 0.50 D and 99% within 1.00 D. The reproducibility of the axis measurements was dependent on the power of the astigmatism.
The deviation between the maximum and minimum axial values for astigmatisms from 0.76 D were smaller than 5 degrees on average and smaller than 2 degrees on average from 2.5 D.
In regard to the clinical requirements the IOLMaster demonstrated its suitability for measuring exact basic data for the calculation and implantation of toric intraocular lenses.

The importance of toric intraocular lenses for the correction of higher astigmatism, and of cataract patients in particular, is growing. In the past 10 years the IOLMaster has become established as the gold standard for biometry and IOL power measurement and helps to obtain optimal refractive outcomes after intraocular lens implantation.
While only the mean corneal power is of significance in the IOL power calculation of spherical lenses, the power and position of the corneal astigmatism plays an additional important role in the implantation of toric lenses. To determine the basic data for the calculation of a toric IOL, manual and automatic keratometers and topography systems are available.
A retrospective clinical study is aimed at clarifying to what extent keratometry with the IOLMaster clinically provides sufficiently exact values for calculating the power of a toric intraocular lens, as well as an adequately exact axis for the implantation. The measured values obtained are compared with the clinical requirements.

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METHODS

The measured values were obtained within the framework of clinical studies for refractive corneal surgery at the Eye Clinic of the Helios Klinikum in Erfurt, Germany. The study was approved by the Ethics Committee of the Thuringian Regional Medical Council ("Landesärztekammer Thüringen").

The patients are not a cataract population, but they are nevertheless suitable for evaluating the reproducibility of corneal power measurements.

Keratometry data was obtained with the IOLMaster within the framework of the preliminary examinations of 106 patients (210 eyes).

The mean age of the examined population was 35.4 ± 9.4 years [21.0 … 62.5], with 58% female and 42% male.

The subjective refraction was:

Sphere: -4.14 ± 1.44 D [0 to -9.00]

Cylinder: -0.71 ± 0.82 D [0 to - 6.00]

Spherical equivalent (SE):

-4.5 ± 1.4 D [-1.63 to -9.00]

Fig. 1 shows the distribution of the spherical equivalent in the examined population. The powers were calculated from the measured anterior corneal radii with a corneal refractive index of 1.3375.

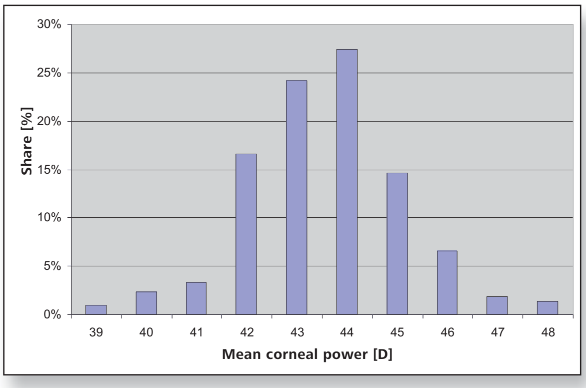

Fig. 1: Distribution of corneal power in the examined population, divided into 1 D groups.

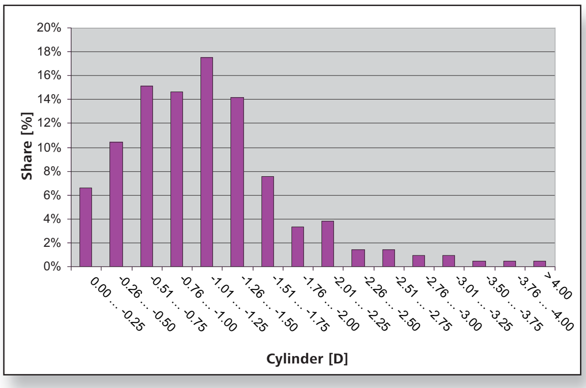

Fig. 2: Distribution of cylinder powers in the examined population, divided into 0.25 D groups.

Fig. 2 shows the power of the astigmatisms, divided into groups of 0.25 D.

A patient population typical of refractive myopia correction is evident in Figs. 1 and 2.

The mean axial length of the population was 25.02 ± 0.88 mm [22.55 … 27.12] and the mean anterior chamber depth 3.74 ± 0.31 mm [2.19 … 4.39].

No previous ophthalmic pathologies were present apart from the myopia or myopic astigmatism to be treated.

During the examinations the patients were also measured with the keratometer of the IOLMaster. Three individual measurements per eye were performed immediately after another, the refractive power in the strongest and weakest meridian was measured and the axis was determined.

The individual values were compared to obtain information on the reproducibility per eye. For this purpose, both the minimum and the maximum values of the corneal power per principal meridian, the spherical equivalent (SE), the power of the astigmatism and the axis were determined in each case. The difference between the maximum and minimum values of the respective measured value per eye was used as a measure of the "quality" of one measuring series per eye.

In the examinations of the astigmatism, the eyes were grouped according to cylinder powers because, as is widely known, the accuracy of axial measurements is heavily dependent on the cylinder power.

In the manner described, results were obtained both for the reproducibility of the spherical equivalent and for the power and position of the cylinder.

RESULTS

The reproducibility of the spherical equivalent (SE) of the corneal power – the mean difference between the minimum and maximum SE of 3 individual measurements per eye – was 0.09 ± 0.06 D [0 – 0.52] with a variation coefficient of 0.03.

The distribution of the differences between the minimum and maximum SE is shown in Fig. 3.

The deviations within one measurement series were very low: in 79%, the deviations were lower than 0.125 D, in 93% lower than 0.25 D, in 99% lower than 0.50 D and in 100% lower than 1.00 D.

This verified very high reproducibility.

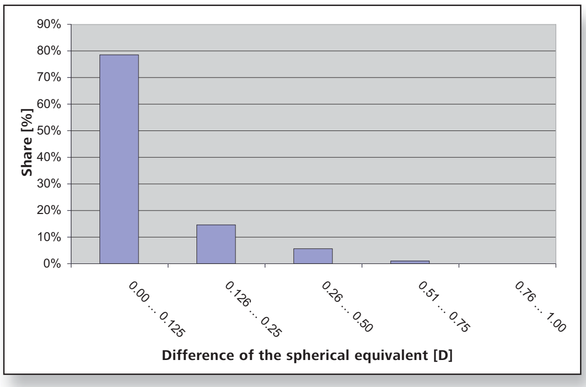

Fig. 3: Distribution of the difference of the SE, determined from the minimum and maximum SE of the 3 individual measurements.

The reproducibility of the measurement of the astigmatism power – the mean difference between the minimum and maximum astigmatism of the individual measurement – was 0.21 ± 0.17 D [0 – 1.35].

The distribution of the differences between the individual measurements is shown in Fig. 4. The deviations of the measured values in the measuring series were low here also: 43% lay within 0.125 D, 74% within 0.25 D, 92% within 0.50 D and 99% within 1.00 D.

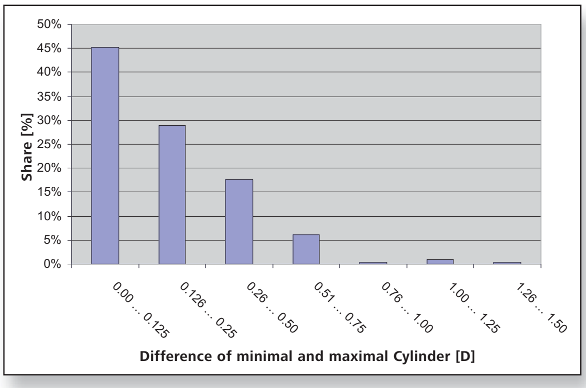

Fig. 4: Share of the differences between the maximum and minimum astigmatism of the individual measurements in the population – all eyes.

Fig. 5 shows the subpopulation with an astigmatism of 1 D and greater, as toric lenses are not generally indicated for low astigmatism. 111 of the 210 eyes are contained in this subpopulation. The mean difference between the minimum and maximum astigmatism powers was 0.23 ± 0.21 D [0 – 1.12] in this subpopulation.

In 43% of the eyes the deviation lay within 0.125 D, in 71% within 0.25 D, in 89% within 0.50 D and in 98% within 1.00 D.

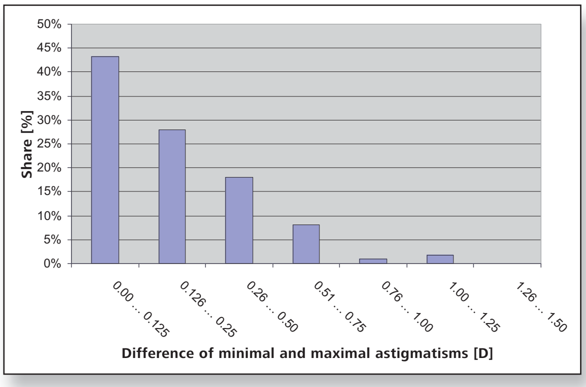

Fig. 5: Share of the differences between the maximum and minimum astigmatism of the individual measurements in the subpopulation with astigmatism ≥1.00 D.

In assessing the suitability of the system for determining the basic data for toric lens implantation, not only the power of the astigmatism and the fluctuations in its measured value, but also the precision with which the position of the astigmatism is determined plays an important role, as errors in angle measurement can lead to postoperative refractive deviations from the target in sphere and cylinder.
As the precision with which the position of astigmatisms is determined is heavily dependent on the power of the astigmatism, patient groups with astigmatism differences of 0.25 D are formed.

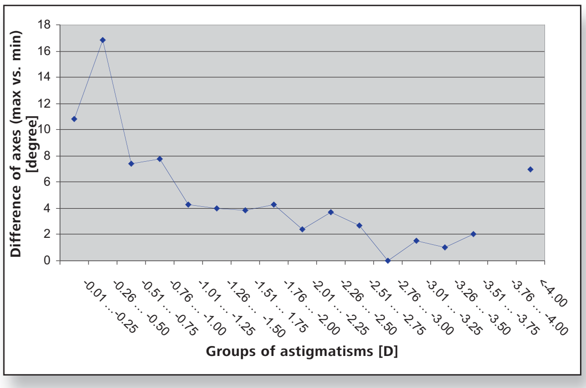

Fig. 6: Mean difference between the maximum and minimum axial values of the astigmatism within the "Astigmatism groups" with three individual measurements per eye in each case.

Fig. 6 shows the dependence of the mean variance in the axial measurement on the cylinder power. It is not possible, of course, to measure axes for astigmatisms below 0.50 D with great accuracy. With higher astigmatism, the measuring accuracy increased and on average achieved good reproducibility with values lower than 5 degrees for 0.76 D and lower than 2 degrees from 2.5 D.

In the following the double angle plot compares the difference between the first and second individual measurements of the examined patient population. The comparison of the first and third or second and third individual measurement yields comparable results.

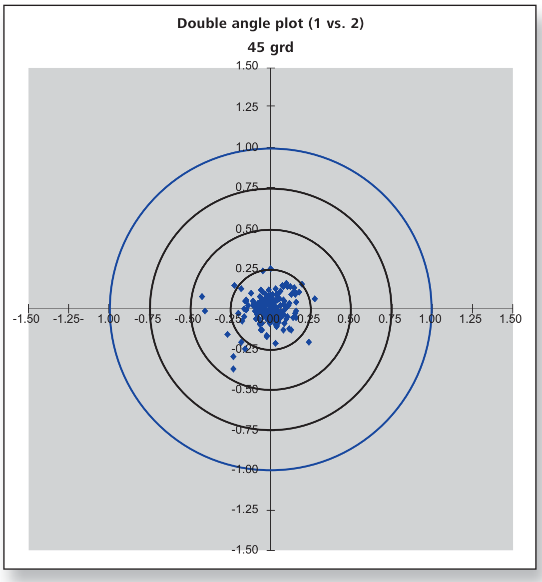

Fig. 7: Comparison of the first and second individual measurements

The differences are smaller than 0.5 D, and the axial differences are distributed statistically.

COMPARISON OF THE MEASURED VALUES WITH THE CLINICAL REQUIREMENTS

The clinical requirements on the reproducibility of the astigmatism measurement emerge, among other things, from the resultant refractive errors in sphere and cylinder which result from an incorrect axial measurement.
To determine the differences between the planned and achieved sphere or cylinder, the error vector was calculated according to Eydelmann[2].

The differences – planned versus achieved – were calculated on the assumption that, within the framework of the implantation, the spherocylindrical values of the IOL do not change and that postoperatively the IOL is only displaced by a small angle relative to the planned axis.

This is shown in Figs. 8 and 9.

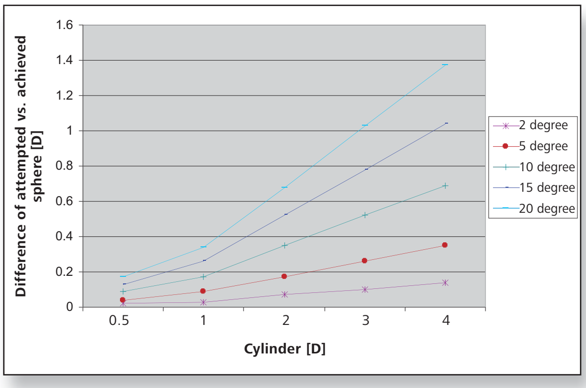

Fig.8: Calculated spherical error for a toric intraocular lens displaced by a certain angle as a function of the power of the preoperative astigmatism.

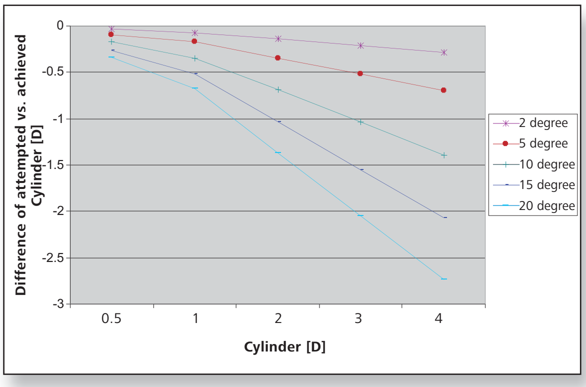

Fig. 9: Calculated cylinder error for a toric intraocular lens displaced by a certain angle as a function of the power of the preoperative astigmatism.

The diagrams show that significant deviations from the planned sphere and cylinder can already occur postoperatively with measuring errors of 5 degrees in astigmatism correction using toric IOLs with a cylinder component of more than 3 D.

DISCUSSION

Clinical experience shows that about 90% of eyes after the implantation of spherical intraocular lenses lie within ± 0.5 D of the planned postoperative refraction (SE)[12].

With its very good reproducibility, the keratometer of the IOLMaster provides good data for this purpose (Fig. 3). The deviations of the SE in the measuring series presented here were very low: in 79% the deviations were lower than 0.125 D, in 93% lower than 0.25 D, in 99% lower than 0.50 D and in 100% lower than 1.00 D.

The reproducibility of the spherical equivalent (SE) was 0.09 ± 0.06 D [0 – 0.52]. This concurs very favorably with the values of 0.069 D found by Vogel et al. regarding variability within a measuring series of one examiner and 0.088 D for variability within a group of examiners [1].

Several studies have compared the IOLMaster technology to, for example, manual keratometers [5, 6], Scheimpflug analyzers [4], topographers [10,11] and a new biometer [7,8,9] and showed comparable results to those of the IOLMaster.

To permit comparable high refractive target accuracy in the implantation of toric lenses as known in implantation of spherical lenses, a high level of reliability is required in determining the preoperative cylinder axis as other parameters can also influence the refractive target.

To ensure that deviations of sphere and cylinder at approximately 0.25 and 0.50 D, attributable alone to a possible displacement of the axis, are not exceeded, an accuracy of about 5 degrees with a cylinder of 2 D and of about 2 degrees with a cylinder of 4 D is required in determining the axis of the preoperative cylinder (Figs. 8 and 9). Fig. 6 shows that these requirements are achieved on average by the keratometer of the IOLMaster.

90% of the individual measurements lie within 5 degrees for a cylinder of 2 D and more (19 out of 21 eyes) and 86% with 2 degrees for 2.75 D and more (6 out of 7 eyes). For a cylinder greater than 4 D, however, only one measured value was obtained.

CONCLUSION

The IOLMaster shows very good reproducibility for keratometer measurements.

It not only meets the clinical requirements for measuring the basic keratometric data for spherical intraocular lenses, but is also very suitable for determining the basic data for toric lenses.

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