Toric IOLs are increasingly used in cataract and refractive surgery because they provide the opportunity to correct preexisting corneal astigmatism, offering patients the chance to achieve optimal distance vision without the use of spectacles or contact lenses. However, the effectiveness of a toric IOL is determined by the position of the lens with regard to its intended axis of alignment, and every degree of misalignment leads to residual astigmatism. The excellent rotational stability of hydrophobic acrylic IOLs (mean postoperative rotation of less than 1º) indicates that accurate placement of toric IOLs is an important factor for further reducing misalignment.

Various methods are used to align the toric IOL at the desired axis, and most clinical studies describe a manual three-step ink-marking procedure. The first step consists of preoperative marking of the horizontal axis with the patient sitting in an upright position to avoid cyclotorsion. This may be done with the patient seated at the slit lamp, with a coaxial thin slit turned to the 0º–180º axis, or by using a bubble-marker or gravity marker with a calibrated horizontal position. The second step is performed intraoperatively, using the preoperative horizontal marks to position an angular graduation instrument and mark the alignment axis. The final step is to implant and rotate the toric IOL until the IOL markings agree with the alignment marks. This manual procedure for toric IOL implantation is prone to errors due to fading or washout of the ink marks. In this article, we present a novel eye-tracking device that may be used to implant toric IOLs without the need for ink-marker steps.

**SURGERY GUIDANCE 3000**

The Surgery Guidance 3000 (SG3000; SensoMotoric Instruments, Teltow, Germany) provides a better opportunity to accurately align the toric IOL during implantation. It may also be used for other aspects of lens implantation surgery, which are explained in detail below. The SG3000 consists of two units, the reference unit used to measure the patient preoperatively and the surgery pilot used in the operating room (Figure 1; for a video of the SG3000, visit http://eyetube.net/?v=swire).

The reference unit is a noncontact device that acquires a high-resolution digital image of the eye (1280 X 1024 pixels), showing the limbal vessels, scleral vessels, and iris characteristics in detail (Figure 2A). This unit also performs simultaneous keratometry, and these results—including the location of the steep and flat meridians of corneal astigmatism—are paired with the position and diameter of the limbus and pupil and shown in an overlay in a digital image (Figure 2B). Measurement can be performed in the outpatient clinic during the preoperative visit.

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**Workflow With the SG3000 System**

By Nienke Visser, MD, and Rudy M.M.A Nuijts, MD, PhD

direct link to video: http://eyetube.net/?v=swire

This tool provides increased accuracy for toric IOL orientation.
On the day of surgery, with the patient positioned in the operating room, the preoperative image is loaded into the surgery pilot and used to plan various surgical steps, including the incision location and size, the capsulorrhexis location and size, and the implantation axis for the toric IOL. The live image from the operating microscope is then matched with the preoperative image obtained with the reference unit, which is based on blood vessel and iris characteristics.

Intraoperatively, the eye-tracking technology of the SG3000 again relies on the limbal and scleral blood vessels and iris characteristics, this time to correct for rotation and translation of the eye during surgery. The eye tracker is tolerant to zoom, light changes, and other surgery interactions. The chosen configurations for the incision, capsulorrhexis, and implantation axis are shown in an overlay, which is visible through the oculars of the operating microscope and is updated in real time continually throughout the procedure.

The SG3000 allows the surgeon to align the toric IOL exactly on the desired implantation axis without the use of manual ink-marker steps (Figure 3). Furthermore, since the SG3000 also performs keratometry preoperatively, this system minimizes errors due to repeated keratometry measurements.

In addition to toric IOL alignment, the SG3000 can be used in a variety of ways. First, it helps the surgeon ensure that the correct eye of the correct patient is being operated on. Second, it may be used to plan the location and size of the main incision and paracenteses (Figure 4), using the visible preoperative keratometry results to directly position the main incision on the steep axis of the cornea. Third, the SG3000 may be used to center the capsulorrhexis according to the undilated pupil and to achieve exactly the capsulorrhexis diameter desired (Figure 5). Fourth, when a multifocal IOL is implanted, the system helps to position the IOL according to the location of the undilated pupil (Figure 6). Fifth, it may be used for teaching ophthalmology residents.

ALIGNMENT ERROR STUDY

We recently conducted a study to determine the accuracy of a manual three-step ink-marking procedure for toric IOL implantation, using the SG3000 to image these steps: (1) preoperative marking of the horizontal axis using a
Nuijts/Lane Toric Reference Marker with bubble-level (AE-2791TBL; ASICO, Westmont, Illinois); (2) intraoperative marking of the implantation axis using a Mendez degree gauge (AE-2765N; ASICO) and a Nuijts Toric Axis Marker (AE-2740; ASICO); and (3) IOL alignment along the marked implantation axis.

The mean errors in horizontal axis marking, alignment axis marking, and toric IOL alignment were $2.4^\circ \pm 0.8^\circ$ (maximum, $8.7^\circ$), $3.3^\circ \pm 2.0^\circ$ (maximum, $7.7^\circ$), and $2.6^\circ \pm 2.6^\circ$ (maximum, $10.5^\circ$), respectively. Together, these errors led to a mean total error in toric IOL alignment of $4.9^\circ \pm 2.1^\circ$; however, the range of error may be as high as $10^\circ$ for the individual steps in the marking process.

A $10^\circ$ error is clinically relevant when implanting a toric IOL because it reduces the effectiveness of the cylinder correction by approximately 30%. Furthermore, the total error in toric IOL alignment may be higher in individual cases due to ink-mark problems, such as fading, horizontal or vertical translocation, or complete washout. Orienting the toric IOL with greater accuracy is necessary in all patients to achieve the optimal cylinder correction. The SG3000 system provides the opportunity to increase the accuracy of toric IOL implantation during surgery.

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TAKE-HOME MESSAGE
- A commonly used three-step ink-marking procedure may lead to a range of errors as high as $10^\circ$ in the placement of toric IOLs.
- The SG3000 provides the opportunity to align toric IOLs with greater accuracy, which is necessary to achieve the optimal cylinder correction in all patients.