MARKER-BASED VERSUS MARKERLESS TORIC IOL ALIGNMENT: DEMONSTRATED BENEFIT OF AN AUTOMATED MARKERLESS SYSTEM

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Abstract
Objective: To study the difference between intended and achieved postoperative intraocular lens (IOL) axis using an automated recognition system (ZEISS Cataract Suite markerless) and traditional manual marking as well as the difference in the 0-180° axis obtained with these two procedures.

Methods: In this randomized and prospective study, 19 eyes with senile cataract were included and divided into two groups: the manual marking group with 12 eyes and the automated recognition group including 7 eyes. In all cases, a D4 a photograph of the implant was obtained and the measurement of the axis of the implant was performed by means of the software GIMP 2.8.3©. The difference in the 0-180° axis between these two techniques was also measured for each patient.

Results: The differences between intended and achieved postoperative IOL axis were 4.7±2.8° and 3.6±1.5° in the manual and automated groups, respectively (p=0.90), although a lower variability was present in the automated group. The mean offset in the 0-180° axis between manual marking and automated recognition was found to be 2.1±1.7°.

Conclusion: In our study, IOL alignment with the ZEISS Cataract Suite markerless was at least as precise as manual marking of the toric axis, but in our setting, the ZEISS Cataract Suite is an easier, faster and more comfortable procedure.

Introduction
The implantation of toric intraocular lenses (IOLs) has been demonstrated to be an efficient and safe procedure to provide a complete visual restoration after cataract surgery in eyes with pre-existing astigmatism due to corneal toricity. Excellent visual, refractive and even visual quality outcomes have been reported with this type of IOLs. However, the predictability of the refractive correction achievable with toric IOLs can be compromised by an improper alignment of the cylinder axis of the IOL during surgery. This misalignment may be a consequence of instability of the IOL within the capsular bag which can be minimized by means of an appropriate haptic design as well as of an inadequate marking of the axis. It should be considered that a mismatch of 11.5° between corneal and IOL axes can lead to residual astigmatism that is 40% of the initial astigmatic power. Even an only 3° misalignment might result in a residual astigmatism of 10% of the initial power. Therefore, an extremely accurate marking of the toric IOL axis is crucial to obtain a good visual outcome.

Traditionally, the marking of the corneal axis has been performed manually, with an inherent lag error that cannot be completely avoided. In a cohort study using the manual marking, a mean error in reference axis marking of 2.4±0.8° before toric IOL implantation was reported. This error was combined with a mean error in alignment axis marking of 3.3±2.0° and in toric IOL alignment of 2.6±2.6°, leading to a mean total error in IOL alignment of 4.9±2.1°. It should be noted that the manual marking has several inconveniences such as the requirement of a considerable period of time for
marking prior to surgery, the movement of the patient to a sitting position, the difficulty of the patient in concentrating on fixation (especially under anaesthesia), and the high dependency on operator ability and experience.

A new concept of toric IOL implantation: markerless IOL alignment

A new concept of toric IOL alignment has been recently developed, the markerless alignment using the “ZEISS Cataract Suite markerless” (Figure 1), an integrated system of biometry, computer-assisted surgery and surgical field visualization with injection of all relevant IOL alignment data into the eyepiece of the surgical microscope. In our study we used the following system versions: ZEISS Cataract Suite markerless: 1.0, CALLISTO eye 3.1, IOL Master 500 V7.7 and OPMI Lumera 700 (2.5).

Initially, a photograph of the eye is taken by the IOLMaster 500 biometer and the data is transferred via USB key to the CALLISTO eye system. The IOL Master 500 with the new Option Reference Image automatically acquires the reference image in case of astigmatism during routine biometry. An image of the eye is taken along with the keratometry measurement, all with one device. Both reference image and keratometry data are transferred to the CALLISTO eye computer assisted cataract surgery system. The image is later used for intra-operative matching with the live eye image. The next system version will include the FORUM data management system, which receives the biometry data and reference image in DICOM format for later import into the computer assisted cataract surgery system CALLISTO eye. This eliminates the need for manual transfer of data via portable storage media. CALLISTO eye matches the reference image for alignment to the patient’s eye and tracks the image in real time (Figure 2). The target axis is displayed as an overlay on the live image for markerless and precise toric IOL alignment. Pre- and intra-operative marking of the cornea is not any longer required. The data injection function of the OPMI Lumera family displays the toric IOL alignment axis in high resolution and colour in the eyepiece. This new technology has been designed to achieve automated and highly precise matching and tracking of the axis. Furthermore, in our view patient comfort is increased because the unpleasant manual marking procedure is not any longer needed.

Benefit of ZEISS Cataract Suite markerless IOL alignment over traditional procedure

We performed a randomized and prospective study comparing the difference between intended and achieved postoperative IOL alignment axis using the ZEISS Cataract Suite markerless (automatic recognition) and traditional marking (manual, with pendular marker and Mendez ring) as well as the difference in the 0-180° axis obtained with these two procedures. A total of 19 eyes with senile cataract inducing a significant visual deterioration were enrolled and divided into two groups: the manual group including 12 eyes in which manual marking was performed, and the automated group including 7 eyes in which an automated recognition was used. In all cases, a D4 photograph of the implant was obtained and the measurement of the post-operative axis of the implant was performed by means of the software GIMP 2.8.3®.

In this series, the differences between intended and achieved postoperative IOL axis were 4.7±2.8° and 3.6±1.5° in the manual and automated groups, respectively. This difference did not reach statistical significance (p=0.90), although a lower variability was present in the automated group. The offset in the 0-180º axis between manual marking and automated recognition was also analysed in 9 eyes, by using the CALLISTO eye system intraoperatively (Figure 3). The mean offset was found to be 2.1±1.7° which is consistent with the mean error value in reference axis marking before toric IOL implantation found in a previous study of Visser et al.4 Therefore, it seems that the ZEISS Cataract Suite markerless system supposes a benefit in terms of IOL alignment over manual marking allowing a less variable IOL axis positioning which is required for an optimal astigmatic correction.

Femtolaser-assisted cataract surgery has found increasing application in the last years and therefore care has to be taken that other new technologies, like the ZEISS Cataract Suite
markerless, are compatible with femto-cataract surgery. One typical side effect of femto-cataract surgery is the induction of a mild circumferential subconjunctival hemorrhage.\(^5\) The recognition of scleral vessels with the ZEISS Cataract Suite markerless system can be perfectly performed even if conjunctival hemorrhages occur during femto-cataract surgery. This shows that the IOL alignment with the ZEISS Cataract Suite markerless system is compatible with femtosecond laser cataract surgery and can therefore be adapted to the latest premium technology.

**Conclusions**
In our study, IOL alignment with the ZEISS Cataract Suite markerless was at least as precise as that achieved with manual marking of the toric axis, but in our setting the ZEISS Cataract Suite markerless was an easier, faster and more comfortable procedure, which seems to be less dependent on the surgical skills or the user. The implantation of toric IOL becomes easier for beginning surgeons and do not require same experience than in manual marking. Due to the display of the toric IOL alignment axis in the eyepiece of the OPMI Lumera 700 surgical microscope, there is no distraction from the surgical field.

The precision achieved in IOL alignment with this technology allows a highly predictable astigmatic correction and therefore an efficient visual rehabilitation. Likewise, this automated IOL marking is compatible with femto-cataract surgery, even in cases of conjunctival haemorrhage. To sum up, the ZEISS Cataract Suite markerless is a step forward to the premium cataract surgery of the future: a simplified, automated, reproducible and fast surgical procedure.

**References**


Figure 1. ZEISS Cataract Suite system

Figure 2. Automated recognition of the axis 0-180° with identification of limbal vessels

Figure 3. Analysis of the offset in the 0-180° axis between manual marking and automated recognition using the Callisto system intraoperatively