INTRODUCTION

Cataract surgery is constantly evolving. As a result of increased safety and of the availability of «premium» intraocular lenses, the spectrum of patients that undergo this procedure is also changing, with younger patients undergoing lens removal in order to correct refractive errors and presbyopia. Femtosecond assisted cataract surgery promises increased precision and safety for this procedure1-6. As a new technique, it has a higher cost that must be borne in part by the patient and thus it is often offered, due to its predictability, to patients that will receive «premium» lenses, in whom the management of astigmatism is specially important in order to achieve an optimum visual outcome. Surgical induced astigmatism depends on the size of the incision, as well as on its location, its shape and on surgical manipulation. It is reasonable to expect that the femtosecond platform will improve the management of astigmatism, since it is able to create incisions of any desired size, shape and location.

Our center recently started performing femtosecond assisted cataract surgery. The aim of this article is to report the initial results of this procedure, with special emphasis on surgical induced astigmatism.

METHODS

This retrospective study included patients undergoing cataract surgery by the same surgeon (LAR). After an in-depth discussion of the possible risks and benefits of the use of the femtosecond laser, patients willing to
undergo the procedure signed the informed consent form. Patients who declined femtosecond assisted surgery who underwent micro-coaxial phacoemulsification during the same period were included as a control group. All patients agreed to allow their clinical data to be included in this study, which adhered to the tenets of the Declaration of Helsinki. Exclusion criteria were: presence of corneal leucomas, irregular astigmatism, previous ocular surgery, glaucoma, lens or zonular instability, blood, or any other material in the anterior chamber and a preoperative pupillary dilation smaller than 6 mm.

Preoperatively, patients underwent a detailed clinical assessment, which included slit-lamp biomicroscopy, tonometry, measurement of uncorrected and corrected distance visual acuity, manifest refraction, and corrected near visual acuity. Measurement of axial length and biometry were performed with the IOL-Master Interferometer (Carl Zeiss Meditech, Inc., Dublin, CA). Pachymetry and corneal topography (Allegro Oculyzer; Wavelight Fort Worth, TX), specular microscopy (TOPCON SP-3000P), and macular examination with optical coherence tomography (Cirrus OCT; Carl Zeiss Meditech, Inc.) were also performed.

All surgeries were performed under topical anesthesia. Topical drops of 1% tropicamide, 10% phenylephrine, and 1% cyclopentolate were applied for pupillary dilation. The LenSx laser system (Alcon, Inc., Fort Worth, TX) was used to perform the femtosecond assisted cataract procedures. The LenSx software allows the storage of the preferred patterns for capsulorhexis, lens fragmentation, primary and secondary incision patterns. The femtolaser was programmed to fit the usual surgical procedure of the surgeon (LAR), who performs the primary incision at 135°, with the secondary incision (of 1 mm) at 75°, separated 60°. The pattern of the primary incision was trapezoidal, set to 2.2 mm at the outer edge and 2.4 at the inner edge and was performed in three planes.

The LenSx laser system uses a sterile disposable patient interface (PI). The PI, composed of an applanation lens, suction ring, and tubing, is mounted onto the distal end of the laser-focusing objective and serves as a sterile barrier between the patient and the laser. The delivery system is lowered until the PI makes contact with the patient’s eye. Sensors in the delivery system detect the objective’s position and applanation force, which is indicated on the delivery system touch screen. The surgeon can monitor the applanation of the cornea using the video microscope and apply suction when the applanation force indicator is in the yellow or green zone. The surgical display presents live microscopic and optical coherence tomography images of the anterior segment. The surgeon can optimize centration, the corneal incision boundaries and pupil centration. Using the optical coherence tomography image, capsulotomy peak and trough, lens offsets, corneal thickness, and wound tunnel length can be checked and modified as necessary. A foot switch controls the actual application of the laser treatment, which is monitored on the video screen. The LenSx treatment starts with the capsulorhexis, followed by lens fragmentation and the primary and secondary incisions. Suction is released as soon as treatment is complete, and the patient is then led to the operating room.

The laser-created corneal incisions were dissected bluntly. Viscoelastic was injected in the anterior chamber. The laser-created anterior capsulotomy flap was removed with forceps. The lens segmentation was completed using a direct chop technique, followed by phacoemulsification with the Constellation Vision System Unit (Alcon, Inc., Fort Worth, TX) and implantation of a foldable intraocular lens in the capsular bag. Surgery finished with stromal hydration of the primary incision and, if necessary, of the secondary incision.

In the control micro-coaxial phacoemulsification group, surgery started with the secondary incision, performed with a 25G needle at 75°. Viscoelastic was injected in the anterior chamber. A 2 mm diamond-tipped knife was used to make the primary incision at 135°. The capsulorhexis was performed with forceps. After hидродисsection, surgery was completed with the same technique used in the laser group.

Patients were treated postoperatively with tobramycin 3 mg/ml and dexamethasone 1 mg/ml (Tobra-dex®, Alcon , Inc., Fort Worth, TX) 1 drop 4 times daily for one week and pranoprophen 1 mg/ml (Oftalar®, Alcon , Inc., Fort Worth, TX) 1 drop 4 times daily for one week and 3 times daily for one week. Patients were seen on the day after surgery and then one week and 6 weeks later. Corneal astigmatism was measured at each visit with a keratometer (TOPCON KR8800). The amount of surgical induced astigmatism was calculated using vector analysis using the preoperative and the postoperative corneal astigmatism measured at week 6. Best-corrected visual acuity, intraocular pressure measurement and slit-lamp biomicroscopy were performed at each postoperative visit. At week 6, fundus examination was also performed.

Statistical analysis was performed using SPSS for Windows software (version 13.0, SPSS, Inc.). Best-corrected visual acuity was measured on a decimal scale. It was converted to LogMar for statistical analysis and reconverted to decimal scale for easier comprehension. Non-parametric tests were used to compare parameters between groups due to small size of the groups. A P value less than 0.05 was considered statistically significant.

RESULTS

Twenty-five eyes of 14 patients were operated with the femtosecond laser and compared with 25 eyes of 13
patients operated with micro-coaxial phacoemulsification. The demographic characteristics of both groups are recorded in Table 1. Best-corrected presurgical visual acuity was 0.8 or better in 16 eyes included in the femtosecond assisted group. The lens implanted was multifocal or toric multifocal in all but 2 eyes. In the micro-coaxial group, best-corrected presurgical visual acuity was 0.8 or better in 8 eyes and monofocal lenses were implanted in 10 eyes. Preoperative visual acuity was significantly higher in the femtolaser group (P=0.012); however, there were no significant differences in postoperative visual acuity (P=0.408). The difference in age between both groups was not statistically significant.

No intrasurgical complications were detected in either group. Intraocular pressure spikes, defined as an intraocular pressure of 25 mmHg or higher, were detected in 9 eyes of the femtosecond assisted group and 8 eyes of the micro-coaxial phacoemulsification group. Moderate to severe corneal edema was detected in 3 eyes of the femtosecond assisted group and 5 eyes of the micro-coaxial phacoemulsification group. The difference was not statistically significant.

The surgical induced astigmatism was slightly higher in the femtosecond assisted group compared to the micro-coaxial phacoemulsification group (0.49 diopters [D] versus 0.41 D, respectively). However, this difference was not statistically significant, Table 2. No difference was detected in the axis of surgical induced astigmatism between both groups.

**DISCUSSION**

The current advances in ocular surgery have made phacoemulsification a minimally invasive, safe procedure. Emphasis is now being placed on the predictability of the visual and refractive outcomes. Femtosecond lasers offer the advantage of making two of the most crucial steps towards obtaining these outcomes easier and more reproducible: capsulorhexis and corneal incisions. It has been shown that the size and position of the capsulorhexis is determinant in the effective lens position, which is essential for the correct calculation of the intraocular lens7. An irregular capsulorhexis may contract asymmetrically and lead to lens decentration and tilt. As regards the corneal incisions, manual incisions are very difficult to reproduce. Different incisions lead to different induced astigmatism and the prediction of surgical induced astigmatism is essential to achieve target refraction.

The Alcon LenSx laser was the first femtosecond laser to receive Food and Drug Administration clearance for its use in cataract surgery. The results from the current published studies have been promising1-6. It has been shown that there is a learning curve in the use of the femtolaser8. Complications such as the presence of small anterior capsular tags, anterior radial tears, posterior capsular ruptures and dropped nucleus are more frequent during the first cases. Most of these complications arise from inadequate removal of the laser-created capsulotomy flap. In many cases, there remain adherence that must be gently broken with a forceps when

| Number of patients | 14 | 13 |
| Number of eyes     | 25 | 25 |
| Age (mean)         | 65.21 (range 50 to 80) | 70.46 (range 60 to 80) |
| Gender             | 10 women, 4 men | 6 women, 7 men |
| Preoperative visual acuity (mean) | 0.81 (range 0.3 to 1) | 0.63 (range 0.05 to 1) |
| Type of lens       | Monofocal 2 eyes, Toric 0 eyes, Multifocal 15 eyes, Toric multifocal 8 eyes | Monofocal 10 eyes, Toric 2 eyes, Multifocal 13 eyes, Toric multifocal 0 eyes |
| Postoperative visual acuity | 0.97 (range 0.7 to 1.2) | 0.96 (range 0.6 to 1.5) |
| Complications      | IOP spikes 9 eyes, Corneal edema 3 eyes | IOP spikes 8 eyes, Corneal edema 5 eyes |

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<th>Surgical induced astigmatism</th>
<th>Femtosecond group</th>
<th>Phacoemulsification group</th>
<th>P Mann-Whitney</th>
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<td>Surgical induced astigmatism</td>
<td>0.50 D (0.22 D)</td>
<td>0.41 D (0.28 D)</td>
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<td>Axis</td>
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<td>79.72° (47.57°)</td>
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removing the capsulotomy flap. In our study, no serious complications were detected in either group. This may be due to adjustments performed in the training performed by the manufacturer, which has benefitted from early experience and to the surgeon’s experience.

Incision size seems to be the main clinical factor in the amount of surgical induced astigmatism after phacoemulsification. The smaller the incision, the less the surgical induced astigmatism. Reported surgical induced astigmatisms of between 0.24 D and 0.56 D have been described for 2.2 mm incisions. Up until now, the authors have performed 2 mm incisions for micro-coaxial phacoemulsification because we believed it was an ideal size, with the best balance between the pros and cons of small incisions. Luo et al have recently reported the outcomes of cataract surgery performed with 3 incision size-dependent phacoemulsification groups (1.8, 2.2, and 3.0 mm). The mean surgical induced astigmatism in the 1.8 and 2.2 mm groups was significantly less than that in the 3.0 mm group after 1 month, without significant differences between the 1.8 and 2.2 mm groups. No significant difference in ultrasound time and cumulative dissipated energy was found between the 3 incision size groups; neither were there differences in central corneal endothelial cell loss between the 3 groups after 3 months. However, the 1.8 mm incision group had a total wound enlargement of 11.4% during surgery, significantly higher than for the 2.2 mm (1.59%) and 3 mm (0.42%). Wound gape and maximal corneal incision thickness were also higher in the 1.8 mm group.

As we started to perform femtosecond assisted cataract surgery, we chose to perform slightly larger (2.2 mm) incisions, with a trapezoidal shape. This decision was based on the previous experience in femtolasercataract surgery, which suggests that the inner lip of the primary incision be enlarged to allow for an easy insertion of the phaco tip and to avoid a strip in Descemet’s membrane and on the manufacturer’s recommendations. The incision was made in three planes, to ensure it was self-sealing (fig. 1).

In our practise, cataract surgery is often performed as a refractive procedure, with the implantation of toric, multifocal or toric multifocal intraocular lenses. This is reflected by the high preoperative visual acuity in both groups, but specially in the femtosecond assisted group. In fact, all but two of the eyes included in the femtolaser assisted group received these lenses. This spectrum of patients requires a precise management of astigmatism. Therefore, we decided to study if there were any changes in the surgical induced astigmatism with the new procedure, as compared with micro-coaxial phacoemulsification, since this would influence the power of the lens and the target position in toric lens.

We found that the surgical induced astigmatism in the femtosecond group was slightly higher that for the micro-coaxial phacoemulsification group, although the difference was not statistically significant. In both cases, induced astigmatism was low and similar to previous reports for 2 to 2.2 mm incisions. It is possible that a real difference in surgical induced astigmatism may not have been detected due to the small sample size. In fact, a difference in surgical induced astigmatism may have been expected due to the difference in incision size. Furthermore, we found that cortical removal in femtosecond surgery took longer and required greater manipulation, so that there may have been more damage to the incision. This has also been reported by other authors. It has been hypothesized that the energy produced by the femtosecond laser may have some effect on the cortical fibers and the posterior capsule leading to increased adherence of the cortex to the capsular edge. This may also explain the higher incidence of capsular blow-out with hydrodissection.

Our study has several disadvantages. It is a short, retrospective case series and patients were not randomised. Furthermore, the size of the incisions was not the same in the femtolaser assisted and the micro-coaxial phacoemulsification group. However, we believe that in the spectrum of patients that will be offered femtolaser assisted surgery the management of astigmatism is specially important. Surgeons starting to perform femtolaser surgery should study their surgical induced astigmatism, so that they may perform the necessary adjustments either in their preferred surgical technique or in the intraocular lens power and position calculation.

ACKNOWLEDGEMENT SECTION

The authors wish to thank Dr. Marceliano Crespo, for the development of the program used for the calculation of surgical induced astigmatism.

The authors confirm that the study and data accumulation were carried out in conformity with all na-
tional laws, an informed consent was obtained from all patients and the study was in adherence to the tenets of the Declaration of Helsinki.

REFERENCE