Clinical evaluation of surgery-induced astigmatism in cataract surgery using 2.2 mm or 1.8 mm clear corneal micro-incisions

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Abstract
● **AIM:** To evaluate corneal astigmatism after phacoemulsification using 2.2 mm or 1.8 mm clear corneal micro-incisions and its effects on visual function.

● **METHODS:** Sixty cases (60 eyes) with cataract were randomly divided into groups A (*n*=30) and B (*n*=30) respectively underwent 2.2 mm and 1.8 mm clear corneal tunnel incision phacoemulsification combined with folding intraocular lens implantation from the time direction of 11:00. On day 1 and at 1, 4, and 6wk after operation, patients' vision was measured and both the corneal curvature and corneal thickness (CT) were recorded using Pentacam.

● **RESULTS:** The measured surgery-induced astigmatism (SIA) in both groups A and B peaked on day 1 after operation, and then gradually decreased and eventually stabilized in week 4. No statistically significant difference was found in corneal astigmatism between two groups (*P*>0.05). The measured corneal astigmatism at 4wk and 6wk postoperatively were 0.28±0.09 D and 0.27±0.10 D for groups A and 0.27±0.09 D and 0.25±0.10 D for groups B without statistically significant difference (*P*>0.05). In addition, no significant differences in visual acuity and CT were found between groups A and B before or after operation.

● **CONCLUSION:** Both 2.2 mm and 1.8 mm micro-incision cataract surgeries result in relatively small SIA with no difference in visual function and corneal astigmatism between two surgery approaches. Thus, the two types of surgical systems are safe and efficient for cataract treatment, by which satisfactory uncorrected visual acuity can be regained early postoperatively.

INTRODUCTION

With the development of new surgical tools and techniques, the reform of cataract surgery from eyesightregaining surgery into refractive surgery has been widely accepted because refractive surgery offers more accurate sur-gical design and quicker functional vision recovery. Surgical induced astigmatism (SIA) was one of the factors that influences the desirable refractive outcome[1]. SIA was related to the length, type, location, structure of the incision, *etc*[1]. However, the most significant factor is incision width[2]. As a result, cataract surgeries through small corneal incisions are increasing in popularity[3-4], although the proper size for a truly an asti-gmatogenic cataract incision has not been established. Masket *et al*[5] have demonstrated that SIA with 2.2 mm micro-coaxial incisions induce less astigmatism postoperatively compared to traditional 3.0 mm clear corneal incisions. The reduction of the incision size induces less postoperative astigmatism after cataract surgery[6-7]. Few studies have compared SIA with smaller than 2.2 mm incision. The purpose of this study was to compare the effect of two types of micro-incisions in phacoemulsification, 2.2 mm *vs* 1.8 mm, on corneal astigmatism and visual function.

SUBJECTS AND METHODS

A total of 60 subjects (60 eyes) who were diagnosed with senile cataract were enrolled from August 2014 to August 2015 at Tianjin Medical University Eye Hospital. Written informed consent was obtained from the patients. The study was approved by the Institutional Review Board of the Tianjin Medical University Eye Hospital and performed in accordance with the tenets of the Declaration of Helsinki. Those patients with a history of corneal trauma, or corneal disease (dystrophies, degenerations, infections, *etc*.), that might influence corneal topography were excluded from the

study. Patients those with axial length of >25 mm and corneal endothelial cells of <1500/mm^2) and with systemic diseases such as diabetes, high blood pressure were also excluded. The study involved 21 males and 39 females, at the age of 50-88 years (median of 68.82±8.50). The cataract lens nuclei were evaluated by the LOCS standard; 26 cases were identified at level II, 21 cases at level III, and 13 cases at level IV[8]. All of the patients underwent general eye examinations, in which cornea and intraocular lens (IOL) power were examined. The following measurements were collected before operation, on day 1 after operation, and at weeks 1, 4 and 6 after operation: visual acuity tested with logMAR (EDTRS), slit-lamp microscope, and corneal curvature and corneal thickness (CT) examined with Pentacam (Oculus Gmbh, Wetzlar, HE, Germany). All the examinations were completed by a single ophthalmologist (Yang J).

Operation Procedures and Grouping All operations were performed under topical anesthesia by a single skilled ophthalmologist (Zhang H). Sixty cases (60 eyes) with cataract were randomly divided into two groups: A and B. No significant difference in the age, gender, or lens nucleus hardness was found between groups A and B (Table 1). After ocular anesthesia (three drops of 0.4% oxybuprocaine hydrochloride were applied), groups A and B respectively underwent 2.2 mm and 1.8 mm clear corneal tunnel incision surgery using 2.2 mm double-edged keratome (Alcon) and 1.8 mm single-edged keratome (Bausch and Lomb) at the 11 o'clock position of the limbus. Auxiliary incision was performed using 1 mm stab knives (Alcon) and 1.5 mm. stab knives (Bausch and Lomb) at the 2 o'clock position of the limbus with Duo-viscoat infused into the anterior chamber for maintaining the anterior chamber and protecting the corneal endothelial cells. Continuous curvilinear capsulorhexis was then performed using capsulorhexis forceps (Duckworth and Kent LTD.), which were always centered with a diameter of 5.5 mm. Subsequently, groups A and B respectively underwent phacoemulsification using Intrepid Infiniti and Stellaris systems, which residual lens cortex was removed using an automatic perfusion system and viscoat infused into the anterior chamber and capsular bag. Group A had SN60WF IOL implanted using Monarch III IOL injector and D-collet, whereas group B had MI60 IOL implanted using Hydroport PS27 IOL injector. After the removal of viscoat, the primary incision was thoroughly irrigated with balanced salt solution, creating a watertight seal of anterior chamber. Postoperative treatment consisted of Tobradex (0.3% tobramycin and 0.1% dexamethasone eye drops) 4 times a day for 1wk which was then tapered over next 3wk.

Statistical Analysis All data were analyzed using Statistical Package for Social Sciences (IBM SPSS version 19.0; SPSS Inc., Chicago, IL, USA). Vector analysis was conducted

Table 1 Preoperative data of the two groups before cataract surgery

Parameters	Group A	Group B	P
Age (a)	68.63±9.90	68.50±8.39	0.96
Gender (M/F)	11/19	10/20	0.94
Lens nucleus hardness (Ⅱ / Ⅲ / Ⅳ)	12/11/7	14/10/6	0.87

for SIA on the basis of corneal curvature measured before operation and at 4wk and 6wk postoperatively. Sampling distribution of the test statistics of groups A and B was compared using one-way ANOVA and Chi-square test corneal astigmatism comparison was conducted by repeated variance analysis on 1d, 1, 4 and 6wk postoperatively. Independent *t*-test was performed to compare visual acuity, corneal astigmatism, SIA and CT between group A and group B. Paired *t*-test was used to compare corneal astigmatism and SIA in group A and group B. *P* value of <0.05 was considered statistically significant.

RESULTS

Complications During and After Operation and Incision Healing Operation of all of the patients went smoothly, without rear capsular rupture, vitreous prolapse, iris injuries, or other complications during and after operation. No water leakage from the incisions was observed after operation, and the edema around the corneal incision gradually vanished within one week after operation. Weekly follow-up revealed no IOL shift, bag shrinkage, intraocular infection or any other complication.

Vision Before and After Operation Visual acuity of groups A and B before and after operation is given in Table 2. Groups A and B showed no statistically significant difference in visual acuity before operation (*t*=0.77, *P*=0.45). Both groups showed substantial improvement in visual acuity after operation. In addition, groups A and B showed no significant difference in visual acuity on day 1 and at weeks 1, 4 and 6 after operation (*P*>0.05).

Corneal Astigmatism and Surgical Induced Astigmatism Corneal astigmatism in groups A and B before and after operation are listed in Table 3. Groups A and B showed no statistical difference in corneal astigmatism before operation (*P*>0.05). No statistically significant difference was found in the corneal astigmatism between groups A and B on 1d, 1, 4 and 6wk postoperatively (*F*=1.45, *P*=0.24). However, the within-group comparison of groups A and B showed significant difference in corneal astigmatism on 1d, 1, 4 and 6wk postoperatively (*F*=20.59, *P*<0.05). The levels of corneal astigmatism of group A at 4wk and 6wk postoperatively were 1.02±0.57 D and 0.99±0.56 D respectively, without significant difference (*P*=0.84), whereas those of group B in 4 and 6wk after operation were 0.86±0.57 D and 0.84±0.57 D, without significant difference as well (*P*=0.91). Groups A and B had higher corneal astigmatism on day 1 postoperatively than that

Table 2 LogMAR visual acuity before and after operation $\bar{x} \pm s$

Parameters	Group A (n=30)	Group B (n=30)	P
Preoperation	0.86±0.35	0.94±0.44	0.45
1d postoperation	0.14±0.19	0.10±0.10	0.27
1wk postoperation	0.07±0.07	0.04±0.06	0.12
4wk postoperation	0.05±0.05	0.04±0.05	0.37
6wk postoperation	0.04±0.05	0.03±0.05	0.49

Table 3 Corneal astigmatism before and after operation $\bar{x} \pm s$

Parameters	Group A (n=30)	Group B (n=30)	P
Corneal astigmatism (D)			
Preoperation	0.93±0.59	0.89±0.63	0.773
1d postoperation	1.48±0.74	1.20±0.68	0.239
1wk postoperation	1.18±0.71	1.11±0.77	0.239
4wk postoperation	1.02±0.57	0.86±0.57	0.239
6wk postoperation	0.99±0.56	0.84±0.57	0.239
SIA (D)			
4wk postoperation	0.28±0.09	0.27±0.09	0.468
6wk postoperation	0.27±0.10	0.25±0.10	0.484

Table 4 CT before and after operation μm, $\bar{x} \pm s$

Parameters	Group A (n=30)	Group B (n=30)	P
Preoperation	541.80±33.78	540.10±32.12	0.842
1d postoperation	590.30±51.38	588.57±44.92	0.139
1wk postoperation	559.80±39.08	562.00±31.77	0.812
4wk postoperation	558.33±38.22	546.40±31.27	0.191
6wk postoperation	556.50±39.83	546.17±31.69	0.208

before operation, mainly because of edema around the corneal incisions after operation. The incisions healed gradually with time, and the corneal astigmatism of the groups decreased and stabilized week 4 after operation. Corneal astigmatism of groups A and B before operation and at weeks 4 and 6 after operation was analyzed by the vector-time method. The SIA values in groups A and B at week 4 after operation were 0.28±0.09 D and 0.27±0.09 D respectively. No statistically significant difference in SIA at weeks 4 and 6 after operation was identified between two groups.

Corneal Thickness CT in groups A and B before and after operation are listed in Table 4. Groups A and B showed no significant difference in CT before operation, on day 1 and at weeks 1, 4 and 6 after operation (P>0.05).

DISCUSSION
With the development of phacoemulsification and foldable IOL, current cataract surgery has become a micro-incision surgery characterized by short operation time, fewer damages to eyes, and quicker vision recovery. The initial micro-incision phacoemulsification combined with folding IOL implantation adopted double hand operation with 1.4-1.6 mm incisions, having clear practice curves compared with coaxial incision phacoemulsification, in addition, the two incisions caused relatively poor anterior chamber stabilization, low operation efficiency, and more mechanical injuries because of the repeated in-and-out operations of surgical instruments[9]. Currently, the initial method has been replaced with micro-incision coaxial phacoemulsification using 2.2 mm incision (Intrepid Infiniti system, Alcon) or 1.8 mm incision (Stellaris system, Bausch and Lomb). Several studies have found no significant difference in SIA between the 2.6 mm and 2.2 mm

incision phacoemulsification combined with folding IOL implantation using Intrepid Infiniti phacoemulsification system (Alcon)[10]. However, the optimal size of coaxial micro-incision remains uncertain.

Either the clear corneal incision or its healing after operation may cause changes in corneal shape[11]; therefore, changes in corneal astigmatism after operation are a main factor influencing vision[12]. The current micro-incision cataract surgery reduces the impact of incision length and shape on corneal astigmatism, and its sutureless incision avoids the effect of any suture on astigmatism[6]; thus, the location and direction of incision is a factor influencing corneal astigmatism. Tejedor and Murube [13] reported that changes in corneal astigmatism of a temporal incision (3.5 mm) after operation are not significantly different from that of in any other direction. Altan-Yaycioglu et al[14] revealed that compared with temporal, upper, upper temporal, and upper nasal incisions (3.5 mm), nasal incision had the greatest impact on corneal astigmatism, whereas the temporal and upper temporal incisions had the smallest SIA, probably because the temporal and upper temporal incisions were further from the optical center of the cornea. Furthermore, the upper incision is under continuous oppression from the eyelid for certain anatomic reasons, thereby affecting the incision healing after operation. The operative routes of the nasal and upper incisions are steeper by the nose-bridge, eyebrow, and/or orbital depth, with higher incision tension, as well as heat-loss and repeated incision disturbance caused by surgical instruments, aggravating the deformation of corneal incision.

The present study found that both groups A and B showed remarkably improved vision after operation. Uncorrected visual acuity was affected by the edema around the corneal incision on day 1 after operation. The edema around the corneal incision was resolved in week 1 after operation, and vision became stable at the time. Moreover, groups A and B showed no significant difference in vision on day 1 and at weeks 1, 4 and 6 after operation (P>0.05). Thus, uncorrected visual acuity recovered rapidly following 2.2 mm/1.8 mm micro-incision cataract surgery with early stabilization of refraction. Groups A and B also showed no significant difference in corneal astigmatism on day 1 and at weeks 1, 4 and 6 after operation (P>0.05). In particular, groups A and B showed increased corneal astigmatism on day 1 after

operation, which was primarily due to the edema around the corneal incision. The incisions healed gradually with time, and corneal astigmatism decreased and stabilized at week 4 after operation. Wang *et al*[10] reported previously the similar recovery process as we found in this study. In this study, groups A and B had a clear corneal micro-incision placed at 11 o'clock. This was done to avoid placing the incision at any radial direction with high corneal curvature. By these means, 1) obtaining similar SIA between groups is possible, and 2) by using the 2.2 mm micro-incision there would be little effect on alleviating the large amount of radial curvature[5,10]. Several methods can be used to calculate corneal astigmatism. These methods include: sine-cosine law (Jaffe Clayman Method), polar values, vector analysis, and the Holladay-Cravy-Koch Method[15]. The latter adopted vector analysis for calculating SIA. This method includes both the magnitude and direction of the SIA to reflect any surgery induced changes in the corneal astigmatism[16]. By using this analytic formula, group B was shown to have smaller SIA values than group A at weeks 4 and 6. Although there was a slight difference, these values were not statistically significant. CT had no differences between the two groups pre- or postoperation. In summary, we found that both 2.2 mm and 1.8 mm micro-incision cataract surgery had relatively small SIA and quick refraction stabilization after operation, thus we conclude that both types of surgical systems are safe and efficient in micro-incision cataract treatment given the satisfactory effects on regaining uncorrected visual acuity at the early postoperative stage.

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