Int J Clin Exp Med 2018;11(9):9931-9940
www.ijcem.com /ISSN:1940-5901/IJCEM0079945

Original Article

Fusion Phaco complex phacoemulsification through a coaxial 2.2 mm micro-incision: a clinical study

Jing Wu[1], Guanlu Liang[2], Qianyin Zheng[3], Fengying He[4], Jian Liu[2], Wen Xu[1]

[1]Department of Ophthalmology, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China; [2]Department of Ophthalmology, Zhejiang Hospital, Hangzhou, Zhejiang, China; [3]Department of Ophthalmology, Taizhou Hospital, China; [4]Department of Ophthalmology, Huzhou Central Hospital, Huzhou, Zhejiang, China

Received May 20, 2018; Accepted August 1, 2018; Epub September 15, 2018; Published September 30, 2018

Abstract: Objective: The aim of this study was to observe the clinical outcomes of coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsification, comparing it with standard 3.0 mm small incision phacoemulsification. Methods: A randomized prospective study was conducted. A total of 99 eyes from 81 patients were enrolled and randomly divided into the micro-incision cataract surgery (MICS group), with 51 eyes undergoing coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsification, and the small incision cataract surgery (SICS group), with 48 eyes undergoing traditional 3.0 mm incision phacoemulsification. Average phaco power (AVE) and effective phaco times (EPT) were recorded during the operation. Patients were followed up one day, one week, one month, and three months after the operation. Postoperative uncorrected visual acuity, corneal endothelial cells (CECs) count, surgically induced astigmatism (SIA), retinal thickness, central cornea thickness, and intraocular pressure (IOP) were recorded. Results: No significant differences were found in the following clinical characteristics, visual acuity, hardness of the lens nucleus (4-5 class of nucleus), EPT(s), CECs, central cornea thickness, retinal thickness at the macular area, and intraocular pressure (IOP). AVE was lower in the MICS group than the SICS group ($P<0.05$). Additionally, SIA in the MICS group was less than that in the SICS group, at every time point ($P<0.05$). Conclusion: Coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsifiation can reduce SIA and save AVE, contributing to the recovery of visual function. Coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsifiation is a safe and reliable procedure for treatment of cataracts.

Keywords: micro-incision, small incision, Fusion Phaco complex, average phaco power, human

Introduction

Cataract surgery has experienced remarkable growth in recent decades with the development of phacoemulsification machines in the late 1960s and foldable intraocular lenses (IOLs) in the late 1980s. These developments have led to micro-incision cataract surgery (MICS), a technique with 1.8-2.2 mm incision sizes that causes less damage to ocular structures [1, 2]. Bimanual MICS can effectively reduce SIA, compared with conventional small-incision cataract surgery (SICS), and improves visual performance in pseudophakic patients by preserving their corneal aberrometric patterns [3]. Micro-incision cataract surgery has many disadvantages, including a steep learning curve, anterior chamber instability due to leakage through 2 incision sites, and limitations due to small instruments [4]. There remains a debate regarding the best absolute incision size for micro-coaxial cataract surgery. Cataract micro-incision phacoemulsification surgery can generally fall into two categories, including coaxial micro-incision phacoemulsification surgery and bimanual non-coaxial micro-incision phacoemulsification. In clinic, bimanual non-coaxial micro-incision phacoemulsification has been widely used before with the 1.4 mm incision size [5, 6]. Previous studies have shown that bimanual non-coaxial micro-incision phacoemulsification can effectively reduce surgically induced astigmatism, assisting with rapid recovery of vision in early stages [7]. However,

lots of disadvantages have also appeared. For example, there are no 1.4 mm artificial lens that can be matched with this surgery [8]. Hence, this surgery needs to enlarge the incision size, which can generate secondary damage to the eyes. Moreover, there are many disadvantages compared with coaxial micro-incision phacoemulsification surgery. It has a longer operating time, longer learning curve, easier to burn the cornea, and intraoperative poor stability of the anterior chamber [9, 10]. Therefore, use of bimanual non-coaxial microincision phacoemulsification has been gradually reduced.

Traditional standard coaxial phacoemulsification surgery generally refers to cataract phacoemulsification surgery with a 2.5-3.2 mm incision size. The operating process of coaxial micro-incision phacoemulsification surgery is similar to standard coaxial phacoemulsification surgery. However, coaxial micro-incision phacoemulsification surgery, due to better stability of the anterior chamber, can effectively reduce the incision size and shorten the learning curve [11, 12]. Ophthalmologists are concerned about the lower efficiency of phacoemulsification because of the attenuation of needles in the operation. Therefore, they have introduced more phacoemulsification energy, which may cause more harm, impacting the safety and effectiveness of the surgery.

In the present study, WHITESTAR Signature® Phacoemulsification System was used to perform both surgery methods. SICS employs traditional pattern needles to perform phacoemulsification. Suction pumps adopt the dual pump mode, the same as with MICS. WHITESTAR Signature® System has not been applied broadly in clinic. This study provides a clinical evaluation of coaxial 2.2 mm microincision Fusion Phaco complex phacoemulsifiation by WHITESTAR Signature® System. This study also compared standard 3.0 mm small incision phacoemulsification with this system from multiple perspectives, including average phaco power (AVE), effective phaco times (EPT), corneal endothelial cells (CECs) counts, surgically induced astigmatism (SIA), retinal thickness, central cornea thickness, and ocular pressure. Therefore, this study aimed to determine the optimum conditions for performing cataract surgery with this new system.

Materials and methods

Subjects

This prospective randomized study comprised of patients undergoing coaxial 2.2 mm microincision Fusion Phaco complex phacoemulsifiation and standard 3.0 mm small incision phacoemulsification, between August 2014 and December 2014, at the Second Affiliated Hospital of Medical School, Zhejiang University. Patients meeting the following criteria were included in this study: 1) Age-related cataracts and/or complicated cataracts; 2) Equal to or older than 40 years old; 3) Healthy corneal endothelial cells and CECs were more than 1000 cells/mm^2; 4) No systemic diseases, lens dislocation, corneal degeneration, uveitis, glaucoma, retinopathy, eye traumas, age-related macular degeneration, and other fundus progressive lesions; and 5) No previous history of ophthalmologic surgery, including corneal refractive surgery, retinal laser surgery, and other intraocular operations. Eyes were randomized and divided for treatment with the WHITESTAR Signature® Phacoemulsification System (micro-incision group: 41 patients with 51 eyes and small-incision group: 40 patients with 48 eyes). The study protocol followed guidelines of the Declaration of Helsinki and was approved by the University's Ethics Committee. Written informed consent was obtained after both surgical systems were described to the patients.

Patient examinations

Complete examinations, before surgery, were performed. Inspection items could be divided into three types, including clinical characteristics, general examinations of the eyes, and special examinations of the eyes. For clinical characteristics examination, names, gender, age, and contacts were collected. For general examinations, slit lamp microscope examinations, funduscopic examinations, and uncorrected visual acuity (UCVA) examinations were performed. For special examinations, intraocular pressure (IOP) (NT-2000, Nidek, Japan), ultrasound and corneal curvature with a phacoemulsification instrument (WHITESTAR Signature, Abbott, USA), visual acuity, IOL master (Carl Zeiss Meditec AG, Jena, Germany), corneal topography (Orbscan II, Bausch & Lomb, USA), corneal endothelial cells counts (I Konan,

Non Con Robo, Konan Medical, Inc., Hyogo, Japan), and optical coherence tomography (Cirrus HD-OCT, 4000, Zeiss, Germany) were used to examine in-group patients. Patients had nuclear or cortico nuclear cataracts of grades I to IV, according to the Emery-Little classification system. Postoperative follow up of each patient was arranged at one day, one week, one month, and three months after the operation. Surgically induced astigmatism was calculated using one day, one week, one month, and three months of postoperative keratometric power. Corneal endothelial function was evaluated by measuring the mean cell density and central corneal thickness (CCT). Endothelial cell counts in the central cornea were performed using a noncontact specular microscope (NonconRobo, Konan Medical). More than 2,000 endothelial cells were required for analyses. This number was selected to reduce sampling errors. Central corneal thickness was assessed with an AL-100 ultrasonic pachymeter (Tomey Corp.). UCVA, IOP, and slit lamp microscope examinations were performed at one day after surgery. UCVA, IOP, slit lamp microscope examinations, CECs, corneal topography, and optical coherence tomography were used for reexaminations at one week, one month, and three months.

Surgical technique

The same surgeon, familiar with both coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsifiation and standard 3.0 mm small incision phacoemulsification, performed all surgeries. Preoperatively, the pupil was dilated with a combination of topical tropicamide 1.0% (Ocutropic) and phenylephrine 2.5% (Mydfrin). Local anesthesia was achieved with topical lidocaine 2% and proparacaine hydrochloride 0.5% (Alcaine). Surgery was performed through a self-sealing temporal clear corneal incision. Sodium hyaluronate 1.0% (HyalPlus) was used to reform and stabilize the anterior chamber and to protect the corneal endothelium. Hydrodissection and hydrodelineation were achieved using balanced salt solution (BSS). Akahoshipre chopper (Duckworth &Kent Ltd.) was used to fracture the nucleus. Phacoemulsification was performed in the capsular bag and cortical lens material was aspirated with a coaxial irrigation/aspiration (I/A) tip. Phacoemulsification probes were inserted into the incision of the surgical eye. The lenticular nucleus was smashed into shape of chyle with ultrasonic energy, which was subsequently aspirated by the (irrigation/aspiration) system. Regarding the WHITESTAR Signature® Phacoemulsification System (peristaltic pump was used during phacoemulsification with Ellips FX technology; Venturi pump was performed during irrigation/aspiration), parameters were set as follows: 70% of the upper limit of ultrasound energy and negative pressure of 480 mmHg; flow rate: 46 mL/min and 80 cm height of infusion bottle. The position of the incision was in 1:30 (45°) of the transparent corneal side and viscoelastic substance was injected into the anterior chamber. The position of 2.2 mm clear corneal tunnel incision was in 10:30 (135°) of the marginal corneal. Moreover, the lens nucleus received phacoemulsification and was removed, then the residual lens cortex was removed by irrigation/aspiration needles. Viscoelastic substance was injected into the capsular bag and anterior chamber. Additionally, IOL with the corrected position was implanted into the capsular bag. Viscoelastic substance was removed and the incision was sealed. The position of 3.0 mm clear corneal tunnel incision was in 10:30 of the cornea. The diameter of phacoemulsification needles, irrigation/aspiration needles, and perfusion cannula was 3.0 mm. Furthermore, the traditional model of needles was used during standard 3.0 mm small incision phacoemulsification. In both groups, IOL implantation was performed under the protection of an ophthalmic viscosurgical device (OVD), which was subsequently removed through aspiration. After phacoemulsification and after IOL implantation, AVE and EPT were recorded for both groups. Postoperative therapy consisted of levofloxacin (Cravit) and prednisolone (Pred Forte) eye drops, four times a day for four weeks.

Statistical analysis

Data are expressed as mean ± standard deviation. Mann-Whitney test was used for statistical comparison between the two groups. Student's t-test was used to evaluate various relationships between the two groups, including clinical characteristics, hardness of the lens nucleus, average phaco power (%), effective phaco time (s), corneal endothelial cells, surgically induced astigmatism, retinal thickness, central cornea

Table 1. Clinical characteristics of all patients in this study

MICS group				SICS group			
Eyes number	Gender	Age	Uncorrected visual acuity	Eyes number	Gender	Age	Uncorrected visual acuity
1	female	65	0.2	1	female	80	0.25
2	male	45	0.3	2	female	54	0.15
3	male	45	0.5	3	female	82	0.08
4	male	83	0.25	4	female	50	0.3
5	female	78	0.3	5	female	71	0.3
6	female	79	0.4	6	female	71	0.2
7	female	81	0.02	7	male	57	0.2
8	female	71	0.06	8	female	63	0.6
9	male	70	0.6	9	female	81	0.15
10	male	86	0.04	10	female	76	0.3
11	male	86	0.3	11	female	81	0.15
12	female	80	0.3	12	male	72	0.5
13	female	80	0.8	13	female	66	0.04
14	female	67	0.02	14	female	80	0.4
15	female	65	0.6	15	male	53	0.1
16	female	63	0.08	16	male	77	0.6
17	female	70	0.12	17	female	73	0.6
18	female	72	0.3	18	male	65	0.15
19	male	73	0.01	19	female	65	0.01
20	male	67	0.6	20	female	73	0.8
21	female	58	0.01	21	female	59	0.25
22	male	76	0.08	22	female	77	0.3
23	female	79	0.06	23	female	72	0.12
24	female	59	0.08	24	female	78	0.4
25	female	69	0.15	25	female	70	0.06
26	male	82	0.1	26	female	86	0.2
27	female	60	0.3	27	male	82	0.06
28	female	58	0.6	28	female	79	0.2
29	female	51	0.1	29	male	50	0.2
30	female	59	0.01	30	female	63	0.04
31	male	67	0.6	31	female	60	0.6
32	female	42	0.04	32	female	80	0.2
33	female	70	0.5	33	female	71	0.01
34	female	70	0.4	34	female	62	0.08
35	female	68	0.15	35	female	78	0.08
36	female	72	0.3	36	male	87	0.4
37	female	60	0.4	37	female	88	0.06
38	female	61	0.25	38	female	66	0.25
39	male	72	0.01	39	female	58	0.3
40	male	72	0.5	40	male	76	0.3
41	female	80	0.25	41	female	72	0.25
42	female	78	0.08	42	male	68	0.04
43	female	79	0.02	43	male	79	0.01
44	male	73	0.06	44	female	62	0.6
45	female	78	0.25	45	female	76	0.02
46	female	78	0.25	46	female	77	0.4

47	female	66	0.02	47	female	66	0.06
48	female	66	0.01	48	female	74	0.1
49	female	71	0.4	/	/	/	/
50	male	74	0.1	/	/	/	/
51	female	70	0.02	/	/	/	/

Table 2. The hardness of the lens nucleus in MICS group and SICS group

Group	Classification	4-5 class of nucleus		0-3 class of nucleus	
		Eyes	Classification	Eyes	Classification
Micro incision	3.23±0.75	13	4.12±0.30	38	2.92±0.60
Small incision	3.20±0.69	12	4.08±0.29	36	2.90±0.50
t value	0.190		0.272		0.141
P value	0.850		0.788		0.888

Table 3. Comparison of average phaco power (AVE) (%) and effective phaco times (EPT) (s) in MICS group and SICS group

Group	Eyes	Average ultrasonic energy	Phaco time
Micro incision	51	10.04%±3.34%	5.25±5.55
Small incision	48	13.06%±4.71%	5.37±4.88
t value		-3.701	-0.114
P value		<0.001	0.910

thickness, and intraocular pressure. Analyses were performed using SPSS for windows software (SPSS 21.0 (Armonk, NY: IBM Corp.)). *P*-values less than 0.05 are considered statistically significant.

Results

Patients

This randomized prospective study was conducted in the Eye Center of the Second Affiliated Hospital of Zhejiang University, between August 2014 to December 2014. A total of 99 eyes from 81 patients were enrolled and randomly divided into two groups: micro-incision cataract surgery (MICS group) (male: 15 and female: 36), with 51 eyes undergoing coaxial 2.2 mm micro-incision Fusion Phaco complex phacoemulsification, and small incision cataract surgery (SICS group) (male: 11 and female: 37), with 48 eyes undergoing traditional 3.0 mm incision phacoemulsification. **Table 1** shows that the mean patient age was 69±10.19 years in the MICS group and 70.96±97 years in the SICS group. There were no statistically significant differences between the two groups regarding age and sex. No patients dropped out of the study. **Table 2** shows the hardness of the nucleus, classed by Emery-Little classification system in the MICS group and SICS group. There were no significant difference between the two groups. There were also has no significant differences regarding hardness of the lens nucleus, graded with 4-5 grades. Moreover, preoperation uncorrected visual acuity (UCVA) (LogMAR) was 0.90±0.58 (MICS group) and 0.81±0.48 (SICS group), respectively. There were no significant differences between the two groups (t=0.804, P=0.423). Postoperative uncorrected visual acuity of LogMAR values in the MICS group were 0.44±0.31 (one day), 0.39±0.34 (one week), 0.39±0.35 (one month), and 0.35±0.33 (three month), respectively. Postoperative uncorrected visual acuity of LogMAR values in the SICS group were 0.37±0.35 (one day), 0.41±0.39 (one week), 0.40±0.38 (one month), and 0.31±0.29 (three month), respectively. There were no significant differences between the two groups in different follow-up times (t=1.087, P=0.280; t=-0.274, P=0.785; t=-0.118, P=0.906; t= 0.618, P=0.538).

AVE (%) and EPT(s)

There were 51 eyes in the MICS group and 48 eyes in the SICS group. AVE values were (5.25±5.55) s in the MICS group and (5.37±4.88) s in the SICS group. There were significant differences in AVEs of the two groups (**Table 3**) (t value=-3.701, *P* value<0.001). However, EPT values were 10.04%±3.34% in the MICS group and 13.06%±4.71% in the SICS group. There were no significant differences in

Table 4. Corneal endothelial cells (CECs) in MICS group and SICS group (cell/mm^2)

Group	Eyes	Pre-operation	Post-operation (one week)	Post-operation (one month)	Post-operation (three months)
Micro incision	51	2648.80±231.93	2265.67±401.96	2248.37±442.90	2330.98±405.76
Small incision	48	2618.42±313.84	2172.44±551.27	2174.50±555.07	2258.33±493.11
t value		0.550	0.957	0.734	0.802
P value		0.584	0.341	0.465	0.424

Table 5. Central cornea thicknesses in MICS group and SICS group (μm)

Group	Eyes	Pre-operative	Post-operation (one week)	Post-operation (one month)	Post-operation (three months)
Micro incision	51	550.02±35.01	569.12±39.69	564.47±37.89	564.90±36.76
Small incision	48	548.75±35.61	559.60±37.73	559.75±43.26	560.52±34.84
t value		0.179	1.221	0.578	0.608
P value		0.858	0.225	0.564	0.545

Table 6. Retinal thicknesses in the macular area in MICS group and SICS group (μm)

Group	Pre-operative		Post-operation (one week)		Post-operation (one month)		Post-operation (three months)	
	Eyes	Retinal thickness	Eyes	Retinal thickness	Eyes	Retinal thickness	Eyes	Retinal thickness
Micro incision	42	188.62±96.60	31	227.45±55.24	38	238.29±48.21	34	210.38±68.81
Small incision	32	189.25±93.13	31	238.35±50.28	30	226.13±63.29	30	218.33±74.50
t value		-0.028		-0.824		0.899		-0.444
P value		0.978		0.413		0.372		0.659

EPTs of the two groups (**Table 3**) (t value=-0.114, *P* value=0.910), suggesting that the micro-incision method consumes less energy than the small incision method.

CECs and thickness of central cornea

There were no significant differences in CECs between the two groups at different follow-up times (t=0.957, 0.734, 0.802; P=0.341, 0.465, 0.424). Moreover, CECs before the operation in the two groups were compared with CECs at different follow-up times after the operation. There were no significant differences in CECs at preoperative and different time points of post-operation (**Table 4**). For example, t-values and *P*-values of preoperative CECs were 0.550 and 0.584, respectively. T-values and *P*-values of postoperative CECs (one month) were 0.734 and 0.465, respectively. Moreover, an Orbscan II system was employed to perform corneal topography examinations to evaluate the corneal edema. Results indicated no significant differences in thickness of central corneas between the two groups at different follow-up times (one week, one month, and three months) after the operation (t=0.179, 1.221, 0.578, 0.608; P=0.858, 0.225, 0.564, 0.545) (**Table 5**). In addition, this study compared the thickness of central corneas before the operation in the two groups with the thickness of central corneas at different follow-up times after the operation. Results indicated that thickness differences in the MICS group were (19.10±31.92) μm, (14.45±30.40) μm, and (14.88±25.76) μm, respectively. Thickness differences in the SICS group were (10.85±31.40) μm, (11.00±33.83) μm, and (11.77±29.11) μm, respectively. There were no significant differences in thickness of central corneas in preoperative and different time points of post-operation (t=1.295, 0.534, 0.564; P=0.198, 0.594, 0.574) (**Table 5**).

Retinal thickness at the macular area and SIA

There were 42 preoperative eyes in the MICS group and 32 in the SICS group. Optical coherence tomography was used to measure retinal thickness at the macular area. There were no significant differences at different time points

Table 7. Surgically induced astigmatism (SIA) in MICS group and SICS group

Group	Eyes	Post-operation (one week)	Post-operation (one month)	Post-operation (three months)
Micro incision	51	0.46±0.32	0.40±0.40	0.35±0.30
Small incision	48	0.95±0.65	0.71±0.46	0.54±0.46
t value		-4.696	-3.579	-2.382
P value		<0.001	0.001	0.020

Table 8. Ocular pressure (intraocular pressure) in MICS group and SICS group

Group	Eyes	Pre-operative	Post-operation (one day)	Post-operation (one week)	Post-operation (one month)	Post-operation (three months)
Micro incision	51	14.86±2.61	15.85±5.99	15.22±3.73	14.55±3.86	14.34±2.77
Small incision	48	14.12±2.58	14.43±3.57	13.84±2.60	13.36±2.37	13.86±2.32
t value		1.428	1.423	2.144	1.834	0.937
P value		0.157	0.158	0.035	0.070	0.351

of post-operation between the two groups (t=-0.824, 0.899, -0.444; P=0.413, 0.372, 0.659) (**Table 6**). In addition, this study compared retinal thickness at the macular area before the operation in the two groups with that of different follow-up times after the operation. Results indicated that difference values in the MICS group were (27.48±87.00) μm, (51.82±95.32) μm, and (23.26±92.90) μm, respectively. Difference values in the SICS group were (51.71±103.40) μm, (36.80±74.02) μm, and (17.55±77.30) μm, respectively. There were no significant differences in retinal thickness at the macular area in the two groups (t=-1.016, 0.710, 0.268; P=0.313, 0.480, 0.789) (**Table 6**). Moreover, corneal topography examinations were performed before and after the operation. Vector analytical method was used to calculate SIA values in the two groups. SIA values at different follow-up times (one week, one month, and three months) in the MICS group were (0.46±0.32) D, (0.40±0.40) D, and (0.35±0.30) D, respectively. These values were all lower than that in the SICS group (0.95±0.65) D, (0.71±0.46) D, and (0.54±0.46) D. There were statistically significant differences between the two groups (t=-4.696, -3.579, -2.382; P<0.001, 0.001, 0.020). Additionally, different values of SIA at different follow-up times between the two groups were progressively smaller, indicating that SIA can be reduced by recovery after surgery (**Table 7**).

IOP

There were 51 eyes in the MICS group and 48 eyes in the SICS group. IOP values of the MICS group were 15.85±5.99 mmHg, 15.22±3.73 mmHg, 14.55±3.86 mmHg, and 14.34±2.77 mmHg at one day, one week, one month, and three months after the operation, respectively. IOP values were 14.12±2.58 mmHg, 14.43±3.57 mmHg, 13.84±2.60 mmHg, 13.36±2.37 mmHg, and 13.86±2.32 mmHg in the SICS group at one day, one week, one month, and three months after the operation, respectively. There were no significant differences in IOPs between the two groups at different follow-up times (t=1.423, 2.144, 1.834, and 0.937; P=0.158, 0.035, 0.070, and 0.351). Moreover, this study compared IOPs before the operation in the two groups with IOPs at different follow-up times after the operation. There were no significant differences in IOPs in preoperative and different time points of post-operation (**Table 8**). For example, preoperative t-values and *P*-values of the CECs were 1.428 and 0.157, respectively.

Complications

According to the three-month postoperative examinations, no cases had posterior capsular ruptures, collapse of the anterior chamber, iris prolapsed, choridal detachment, expulsive hemorrhages, and other complications. No cases of glaucoma, uveitis, retinal detachment, entophthalmia, and other complications had arisen. Moreover, no intraoperative complications were noted.

Discussion

Technological advances in recent decades, particularly in phaco techniques and IOL

designs and materials, have led to smaller incisions than ever before. This, in turn, has led to better safety and efficacy for cataract surgery. Bimanual and coaxial MICS induces less astigmatism than conventional small-incision phacoemulsification [13-15]. However, when considering the efficacy and safety of cataract surgery, questions about tissue trauma should be evaluated along with endothelial cell damage and tunnel integrity. Several studies have shown that endothelial damage correlates not only with incision size but also with intraoperative surgical parameters, such as phaco time, ultrasound energy, and use of sleeveless phaco [16]. Bimanual phacoemulsification is thought to create mechanical tunnel damage due to insertion of instruments into a small incision. Tissue damage has also been associated with increased temperatures at the incision site due to the sleeveless phaco tip. More edema at incision sites of bimanual MICS procedures, compared with coaxial MICS and coaxial SICS techniques, confirms the findings of *in vivo* studies, which have shown greater alteration of the tunnel anatomy with sleeveless versus sleeved phacoemulsification [17].

The goal of ophthalmic surgery is to obtain the desired effects with minimum trauma to the eye. In this regard, small-incision clear corneal phacoemulsification continues to garner significant interest because it reduces the need for suturing. It also decreases SIA and surgical time, compared with standard cataract surgery [18]. However, if corneal incisions are too small or tight, instruments used during capsulorhexis and phacoemulsification are difficult to maneuver and the use of phaco tips and irrigation tips can induce mechanical trauma. Hence, the incision can be deformed at the end of the surgery, leading to wound trauma, with an additional incision required for IOL implantation [19]. Although developments in surgical instruments and phacoemulsification machines will help to resolve these problems, an optimum incision size for micro-coaxial cataract surgery should be established.

In the present study, no significant differences were found regarding clinical characteristics, hardness of the lens nucleus, effective phaco time (EPT) (s), corneal endothelial cells (CECs), central cornea thickness, retinal thickness at the macular area, and ocular pressure ($P>0.05$). Average phaco power (AVE) (%) was lower in the MICS group than in the SICS group ($P<0.05$). Surgically induced astigmatism (SIA) in the MICS group was less than that in the SICS group at every time point ($P<0.05$). Several preoperative and intraoperative parameters, such as nucleus grade, patient age, long phacoemulsification times, and high ultrasound energy, can affect endothelial cell loss after phacoemulsification [20]. Corneal distortion, irrigation solution turbulence, and mechanical trauma by instruments, nuclear fragments, IOL contact, and free oxygen radicals can also cause corneal damage during cataract surgery [21]. Lee et al. reported the close relationship between corneal endothelial cell loss rates and hardness of the lens nucleus [22]. A hard nucleus needs longer operative times and higher AVE, which could lead to more damage to the corneal endothelium. Therefore, it is important to preserve the integrity of corneal endothelial cells. In this study, CECs in the MICS group were slightly more than in the SICS group. Nevertheless, there were no statistically significant differences in CECs between the two groups ($P>0.05$). It was speculated that both methods exhibited excellent safety. However, the MICS method reduces the usage of AVE and displays higher cleaning efficiency than the SICS method, which could protect the integrity of corneal endothelial cells. Hayashi et al. thought that enlargement of 0.5 mm diameter of the incision could increase the corneal astigmatism of 0.25D [23]. The smaller incision means quicker cure of the wound and lower incidence of postoperative infections [24, 25]. Macular edema is a common cause that affects visual recovery after cataract surgery. One study has reported that incidence of macular edema was 0.1%~2.35% [26].

In the present study, there were no differences in incidence of macular edema between the two approaches. These factors combine to damage the corneal endothelium. With the 3.0 mm phaco system, surgical astigmatism might affect the corneal endothelial cells. With the 3.0 mm phaco system, the incision stretched more between the initial measurement and post-phacoemulsification measurements in the micro-incision group. There were no significant changes in incision size after phacoemulsification and IOL implantation. Although changes in incision size do not directly reflect wound integ-

rity, it was expected that during phacoemulsification, there would be more mechanical stress at the wound site with the 3.0 mm system. Other factors that could have influenced this result are phacoemulsification times. Longer times were required with the 3.0 mm system in the small-incision group, indicating that higher thermal energy might conduct to the wound and damage its integrity. These findings are contradictory to those in a study by Berdahl et al. [27], indicating that bimanual phacoemulsification with a smaller incision causes more stress to the wound than micro-coaxial surgery or conventional cataract surgery.

The first limitation of the present study was that it did not compare various settings for the 1.8 mm system. One of the most powerful advantages of the 1.8 mm system is that it is based on a fluidics system, in which fluidics can be switched back and forth between vacuum module and flow module during surgery. Thus, the surgeon can adjust various settings. According to Yang and Lu [28], the burst technique might have advantages in cases of hard nuclear-type cataracts with the Stellaris system. Therefore, further studies comparing the burst technique and the continuous mode technique in micro-coaxial phacoemulsification using the same machines are needed. The second limitation of this study was the limitation of keratometric power measurement. The diopter error tolerance of autokeratometry could influence calculations of SIAs.

As technical obstacles created by such small incisions are gradually overcome, the trend toward smaller incisions will continue. Although smaller incisions are generally better in cataract surgery, maintenance of wound and corneal endothelial integrity must also be considered. The present study compared the two systems in terms of AVE (%), EPT (s), counts of corneal endothelial cells, surgery induced astigmatism, retinal thickness, central cornea thickness, and intraocular pressure. Both systems were safe and effective in micro-coaxial phacoemulsification. The 2.2 mm system was more effective in cataract surgery. Further clinical studies are necessary to compare phacoemulsification settings in each system, determining optimum conditions for performing micro-coaxial cataract surgery.

Acknowledgements

The authors would like to thank the Zhejiang Science and Technology Project (2017C03046) for financial support.

Disclosure of conflict of interest

None.

Address correspondence to: Wen Xu, Department of Ophthalmology, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China. E-mail: xuwen2003@zju.edu.cn

References

[1] Wang Y, Xia Y, Liu X, Zheng D, Luo L, Liu Y. Comparison of bimanual and micro-coaxial phacoemulsification with torsional ultrasound. Acta Ophthalmol 2012; 90: 184-187.

[2] Shentu X, Zhang X, Tang X, Yu X. Coaxial microincision cataract surgery versus standard coaxial small-Incision cataract surgery: a meta-analysis of randomized controlled trials. PLoS One 2016; 11: e0146676.

[3] Chen C, Zhu M, Sun Y, Qu X, Xu X. Bimanual microincision versus standard coaxial small-incision cataract surgery: meta-analysis of randomized controlled trials. Eur J Ophthalmol 2015; 25: 119-127.

[4] Weikert MP. Update on bimanual microincisional cataract surgery. Curr Opin Ophthalmol 2006; 17: 62-67.

[5] Kurz S, Krummenauer F, Gabriel P, Pfeiffer N, Dick HB. Biaxial microincision versus coaxial small-incision clear cornea cataract surgery. Ophthalmology 2006; 113: 1818-1826.

[6] Can I, Bostancı Ceran B, Soyugelen G, Takmaz T. Comparison of clinical outcomes with 2 small-incision diffractive multifocal intraocular lenses. J Cataract Refract Surg 2012; 38: 60-67.

[7] Wilczynski M, Supady E, Loba P, Synder A, Palenga-Pydyn D, Omulecki W. Evaluation of surgically induced astigmatism after coaxial phacoemulsification through 1.8 mm microincision and standard phacoemulsification through 2.75 mm incision. Klin Oczna 2012; 113: 314-320.

[8] Kim YK, Kim YW, Woo SJ, Park KH. Comparison of surgically-induced astigmatism after combined phacoemulsification and 23-gauge vitrectomy: 2.2-mm vs. 2.75-mm cataract surgery. Korean J Ophthalmol 2014; 28: 130-137.

[9] von Sonnleithner C, Bergholz R, Gonnermann J, Klamann MK, Torun N, Bertelmann E. Clinical results and higher-order aberrations after 1.4-

mm biaxial cataract surgery and implantation of a new aspheric intraocular lens. Ophthalmic Res 2015; 53: 8-14.
[10] Dewey S, Beiko G, Braga-Mele R, Nixon DR, Raviv T, Rosenthal K; ASCRS Cataract Clinical Committee, Instrumentation and IOLs Subcommittee. ASCRS cataract clinical committee, instrumentation and IOLs subcommittee. microincisions in cataract surgery. J Cataract Refract Surg 2014; 40: 1549-1557.
[11] Yu JG, Zhao YE, Shi JL, Ye T, Jin N, Wang QM, Feng YF. Biaxial microincision cataract surgery versus conventional coaxial cataract surgery: meta-analysis of randomized controlled trials. J Cataract Refract Surg 2012; 38: 894-901.
[12] Vasavada V, Vasavada AR, Vasavada VA, Srivastava S, Gajjar DU, Mehta S. Incision integrity and postoperative outcomes after microcoaxial phacoemulsification performed using 2 incision-dependent systems. J Cataract Refract Surg 2013; 39: 563-571.
[13] Vasavada AR, Nath V, Raj S, Vasavada V, Vasavada S. Technology and intraocular lenses to enhance cataract surgery outcomes-Annual review (January 2013 to January 2014). Asia Pac J Ophthalmol (Phila) 2014; 3: 308-321.
[14] Jalil A, Steeples L, Subramani S, Bindra MS, Dhawahir-Scala F, Patton N. Microincision cataract surgery combined with vitrectomy: a case series. Eye (Lond) 2014; 28: 386-389.
[15] Denoyer A, Ricaud X, Van Went C, Labbé A, Baudouin C. Influence of corneal biomechanical properties on surgically induced astigmatism in cataract surgery. J Cataract Refract Surg 2013; 39: 1204-1210.
[16] Alió JL, Abdou AA, Soria F, Javaloy J, Fernández-Buenaga R, Nagy ZZ, Filkorn T. Femtosecond laser cataract incision morphology and corneal higher-order aberration analysis. J Refract Surg 2013; 29: 590-595.
[17] Denoyer A, Ricaud X, Van Went C, Labbé A, Baudouin C. Influence of corneal biomechanical properties on surgically induced astigmatism in cataract surgery. J Cataract Refract Surg 2013; 39: 1204-1210.
[18] Al Mahmood AM, Al-Swailem SA, Behrens A. Clear corneal incision in cataract surgery. Middle East Afr J Ophthalmol 2014; 21: 25-31.
[19] Gutierrez L, Rodríguez P, García DA. Intraoperative Opacification of a hydrophilic acrylic with hydrophobic surface IOL with spontaneous resolution in 24 hours. J Refract Surg 2013; 29: 360-362.
[20] Hwang HB, Lyu B, Yim HB, Lee NY. Endothelial Cell Loss after Phacoemulsification according to Different Anterior Chamber Depths. J Ophthalmol 2015; 2015: 210716
[21] Reuschel A, Bogatsch H, Oertel N, Wiedemann R. Influence of anterior chamber depth, anterior chamber volume, axial length, and lens density on postoperative endothelial cell loss. Graefes Arch Clin Exp Ophthalmol 2015; 253: 745-752.
[22] Lee KM, Kwon HG, Joo CK. Microcoaxial cataract surgery outcomes: comparison of 1.8 mm system and 2.2 mm system. J Cataract Refract Surg 2009; 35: 874-880.
[23] Hayashi K, Hayashi H, Nakao F, Hayashi F. The correlation between incision size and corneal shape changes in sutureless cataract surgery. Ophthalmology 1995; 102: 550-556.
[24] Chee SP, Bacsal K. Endophthalmitis after microincision cataract surgery. J Cataract Refract Surg 2005; 31: 1834-1835.
[25] Behrens A, Stark WJ, Pratzer KA, McDonnell PJ. Dynamics of small-incision clear cornea wounds after phacoemulsification surgery using optical coherence tomography in the early postoperative period. J Refract Surg 2008; 24: 46-49
[26] Loewenstein A, Zur D. Postsurgical cystoid macular edema. Dev ophthalmol 2008; 47: 148-159.
[27] Berdahl JP, DeStefeno JJ, Kim T. Corneal wound architecture and integrity after phacoemulsification; evaluation of coaxial, microincision coaxial, and microincision bimanual techniques. J Cataract Refract Surg 2007; 33: 510–515.
[28] Yang J, Lu Y. A clinical report on the use of burst mode phacoemulsification. Zhonghua Yan Ke Za Zhi 2005; 41: 27-33.