Coaxial, microcoaxial, and biaxial microincision cataract surgery

Prospective comparative study

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PURPOSE: To compare the intraoperative and postoperative results of 3 phacoemulsification techniques.

SETTING: Atatürk Training and Research Hospital, 2nd Ophthalmology Department, Ankara, Turkey.

METHODS: In this prospective randomized study, patients had standard coaxial (2.8 mm incisions), microcoaxial (2.2 mm incisions), or biaxial microincision (1.2 to 1.4 mm trapezoidal incisions) phacoemulsification. Intraoperative phaco parameters and total surgical time were measured and complications recorded. Postoperative visual acuity improvement, pachymetric differences, and surgically induced astigmatism (SIA) results were compared.

RESULTS: Each group comprised 45 eyes. There were no significant differences between the 3 groups in demographic, morphologic, or preoperative surgical data. The mean effective phaco time was 2.56 seconds $\pm$ 2.46 (SD) in the standard coaxial group, 1.98 $\pm$ 1.91 seconds in the microcoaxial group, and 1.29 $\pm$ 1.85 seconds in the biaxial microincision group (P<.05). The mean total surgical time was 14.48 $\pm$ 4.21 minutes, 13.01 $\pm$ 3.66 minutes, and 18.79 $\pm$ 6.58 minutes, respectively (P<.01), and the mean measured final incision size was 2.83 $\pm$ 0.11 mm, 2.26 $\pm$ 0.07 mm, and 1.89 $\pm$ 0.21 mm, respectively. The mean SIA 90 days postoperatively was 0.46 diopter (D), 0.24 D, and 0.13 D, respectively (P<.01). There was no statistically significant difference in the complication rate, visual acuity gain, or pachymetric change between the groups (P>.05).

CONCLUSIONS: All 3 techniques were reliable, functional, and effective, yielding good visual outcomes and low phaco parameters and complication rates. Biaxial microincision surgery, with the smallest incisions, induced less astigmatism and reduced all intraoperative phaco parameters except total surgical time.

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Today, standard coaxial phacoemulsification can be performed through a 2.8 to 3.2 mm incision. Other techniques use even smaller incisions (ie, microincisions). They include microcoaxial phacoemulsification, which uses a 1.8 to 2.2 mm incision, and biaxial microincision cataract surgery (MICS), which uses a 1.2 to 1.4 mm incision. In microcoaxial phacoemulsification, irrigation, aspiration, and phacoemulsification are performed with the same instrument (phaco handpiece), used in standard coaxial phacoemulsification.[1–3] The only difference between the 2 techniques is the smaller main incision in microcoaxial phacoemulsification, which is the result of the development of the phaco tip sleeves. In biaxial MICS, however, the irrigation and phacoemulsification aspiration steps are separate; an irrigation chopper is used for irrigation and a sleeveless phaco tip for aspiration and phacoemulsification.[4–6]

Microincision phacoemulsification provides advantages over standard coaxial techniques and thus has become popular. Use of a smaller incision allows the surgeon to incorporate a refractive element into the

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cataract surgery procedure; the smaller incision causes less surgically induced astigmatism (SIA) and can correct presurgical corneal astigmatism.[7,8] Microincision techniques protect the biomechanics and prolate shape of the cornea and result in improved visual quality,[9,10] rapid wound healing and visual rehabilitation, less inflammation, lower endophthalmitis risk, and fewer intraoperative complications.[7,11]

As with all techniques, microincision surgery has advantages and disadvantages. Biaxial MICS, which uses the smallest incisions (as small as 0.7 mm[12]), was first reported by Shearing et al.[13] in 1985 and then developed and popularized by Pandey et al.[14] and Alió et al.[7,10] The main advantage of the technique is that separating irrigation and aspiration improves anterior chamber fluid dynamics and thus followability of the nucleus. In addition, the surgeon uses 2 hands, increasing phaco efficiency and facilitating maneuvers in the subincision area. The decreased turbulence leads to less invasive surgery and less trauma to surrounding tissue.[15,16] The disadvantages of biaxial MICS include anterior chamber instability, limitations of vacuum levels,[1,2] and potential trauma caused by the mechanical and thermal impact on the wound.[17–20] Microcoaxial phacoemulsification has the advantages of standard coaxial phacoemulsification and, unlike biaxial MICS, does not have a steep learning curve.[3] The main disadvantage of the technique is the decreased followability of the nucleus, which can increase turbulence and reduce efficacy.

In this prospective randomized study, we compared standard coaxial phacoemulsification, microcoaxial phacoemulsification, and biaxial MICS in groups of patients matched in demographics. We also sought to determine whether there were disadvantages to switching from standard coaxial phacoemulsification to microincision techniques.

PATIENTS AND METHODS

This prospective randomized study comprised patients having phacoemulsification between November 2006 and September 2008. All patients agreed to participate, met the inclusion criteria, and signed an informed consent agreement before having any procedure. The study was approved by the hospital's ethics committee and performed in accordance with the ethical principles of the Declaration of Helsinki.

Patients were assigned to have standard coaxial phacoemulsification through a 2.8 mm incision (standard coaxial group), microcoaxial phacoemulsification through a 2.2 mm incision (microcoaxial group), and or biaxial MICS through a 1.2 to 1.4 mm trapezoidal incision (biaxial MICS group). Patients who had previous ocular surgery or eye disease that might affect the final visual acuity (eg, amblyopia, corneal scar, glaucoma, retinal or macular disorders) were excluded.

All patients had detailed clinical and biomicroscopic ophthalmic examinations before surgery. Lens hardness was graded using the Emery and Little classification.[21] Other evaluations included refraction, corrected distance visual acuity (CDVA), and corneal toricity by corneal topography (Keratron Scout, Optikon 2000). Central corneal thickness (CCT) was measured with an ultrasound pachymeter (B.V. International/Quantel) with the patient fixating on a target positioned straight ahead.

For preoperative preparation, the following standard dilation regimen was used in all 3 groups: cyclopentolate hydrochloride 1.0%, phenylephrine hydrochloride 2.5%, and ketorolac tromethamine 0.5%. In all groups, conjunctival sac antisepsis was by povidone–iodine 5.0%.

The same surgeon (İ.C.) performed all operations using topical anesthesia of lidocaine hydrochloride plus adrenaline and bupivacaine hydrochloride 0.5%. Phacoemulsification was performed using a half-moon supracapsular nucleofractis technique[22] and an Infiniti Vision Systems phaco unit (Alcon, Inc.). Hydrodelineation and hydrodissection were performed using a 27-gauge hydrodissection cannula. Nucleofractis and quadrant removal were performed following the half-moon supracapsular nucleofractis technique. Table 1 shows the phaco parameters by group.

The time between the creation and closure of the corneal incision by stromal hydration was recorded as the total surgical time. The following intraoperative phacoemulsification parameters were recorded: phaco time, mean phaco power (ie, average ultrasound power), and effective phaco time (EPT) (time required had 100% power been used throughout). The EPT was calculated using the following formula: phaco time $\times$ mean phaco power/100.[23] Intraoperative complications were recorded. The mean lens hardness, mean pupil diameter, and mean capsulorhexis diameter, factors that can affect phaco time and facility, were also evaluated.

Complete postoperative ophthalmic examinations were performed at 1, 7, 30, and 90 days. Postoperative complications were recorded. The amount of SIA was calculated using vector analysis.

Statistical analysis was performed using SPSS for Windows software (version 13.0, SPSS, Inc.). Pearson chi-square and 1-way analysis of variance tests were used to compare parameters between groups. Two-way analysis of variance was used for all tests. A P value less than 0.05 was considered statistically significant.

RESULTS

The study comprised 135 eyes (96 patients), with 45 eyes per group. Table 2 shows the patients' demographics and preoperative characteristics. There was

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Table 1. Phaco parameters by group.

	Phaco Technique		
Parameter	Standard Coaxial	Microcoaxial	Biaxial MICS
Main incision size (mm)	2.8	2.2	2 × 1.2/1.4*
Planned capsulorhexis (mm)	4.5–5.0	4.5–5.0	4.5–5.0
Phaco needle	0.9 mm flared Kelman ABS (Alcon)	0.9 mm flared Kelman ABS	0.9 mm straight
Sleeve	0.9 mm blue microsleeve (Alcon)	0.9 mm pink ultrasleeve (Alcon)	Sleeveless
Chopper	Chang microfinger (Katena Instruments)	Chang microfinger	Fine-Nagahara irrigating chopper (MST)
Machine settings			
Power (%)	50	50	40
Burst on (ms)	30	30	30
Burst off (ms)	5	5	5
Vacuum (mm Hg)	400	400	300
Aspiration rate (cc/min)	42	42	25
Bottle height (cm)	110	110	110
Cortex and OVD removal	Bimanual I/A	Bimanual I/A	Bimanual I/A
I/A set	Buratto bimanual I/A tips (Alcon, Grieshaber)	Buratto bimanual I/A tips	Du-02301 and Du-02302 cannulas (Duet)
Machine settings			
Vacuum (mm Hg)	600	600	600
Aspiration rate (cc/min)	60	60	60
Bottle height (cm)	110	110	110
Injector and cartridges	Royale injector, C and D cartridges (Alcon)	Royale injector, C and D cartridges	LP 604350 (Medicel); Acri.Shooter A2-2000 (Acri.Tec)
Incision closure	Stromal hydration with BSS	Stromal hydration with BSS	Stromal hydration with BSS
Endophthalmitis prophylaxis	1.0 mg/0.1 mL cefuroxime in AC	1.0 mg/0.1 mL cefuroxime in AC	1.0 mg/0.1 mL cefuroxime in AC

AC = anterior chamber; BSS = balanced salt solution; I/A = irrigation/aspiration; MICS = microincision cataract surgery; OVD = ophthalmic viscosurgical device
*Trapezoidal

no statistically significant difference between groups in any preoperative parameter.

Table 3 shows the intraoperative parameters and complications. There was no statistically significant difference between groups in mean pupil or capsulorhexis diameter, percentage of eyes having hydrodelineation, or phaco (ultrasound) time ($P>.05$). The mean phaco power was statistically significantly lower in the biaxial MICS group than in the standard coaxial group and the microcoaxial group ($P = .001$ and $P = .009$, respectively). The mean EPT was statistically significantly higher in the standard coaxial group than in the biaxial MICS groups ($P = .014$); there was no significant difference between the standard coaxial group and the microcoaxial group ($P = .570$) or between the microcoaxial group and the biaxial MICS group ($P = .374$). The total surgical time was statistically significantly longer in the biaxial MICS group than in the other 2 groups (both $P = .001$).

In terms of safety, there was no statistically significant difference between the groups in the mean pachymetry or in the change in pachymetry at any postoperative visit (Table 4 and Figure 1).

Intraoperative complications were posterior capsule rupture in 1 eye (2.2%) each in the standard coaxial group and the biaxial MICS group and iris prolapse through the incision site in 1 eye (2.2%) in the microcoaxial group and 2 eyes (4.4%) in the biaxial MICS group; the difference between groups was not statistically significant ($P = .602$ and $P = .360$, respectively; Pearson chi-square test). No eye had vitreous loss, and all eyes had successful intraocular lens (IOL) implantation in the capsular bag.

Postoperative complications were anterior chamber inflammation that resolved with treatment in 2 eyes (4.4%) and posterior capsule opacification in 1 eye (2.2%) in the biaxial MICS group; the difference between groups was not statistically significant ($P = .131$ and $P = .602$, respectively; Pearson chi-square test). There were no other postoperative complications, including significant intraocular pressure increase.

There was no statistically significant difference between groups in the mean CDVA at 90 days or in the mean increase in CDVA ($P>.05$) (Table 4). The mean visual rehabilitation rate (recovery time to reach best CDVA) was statistically significantly shorter in the

Table 2. Patient demographics and preoperative characteristics.

Parameter	Phaco Technique: Standard Coaxial (2.8 mm)	Microcoaxial (2.2 mm)	Biaxial MICS (1.2-1.4/1.8 mm)	*P* Value
Eyes/patients (n)	45/33	45/31	45/32	—
Males/females (n)	19/14	17 /14	14/18	.501†
Mean age (y) ± SD	66.2 ± 12.6	65.8 ± 13.2	61.5 ± 8.1	.109*
Mean follow-up (d) ± SD	446.2 ± 98.4	430.5 ± 69.2	428.3 ± 142.1	.692*
Mean CDVA (logMAR) ± SD	0.59 ± 0.46	0.46 ± 0.27	0.44 ± 0.29	.089*
Mean cataract hardness ± SD	2.37 ± 0.73	2.22 ± 0.88	2.06 ± 0.91	.238*
Mean CCT (μm) ± SD	543.82 ± 36.80	543.87 ± 31.48	547.18 ± 34.92	.879*

CCT = central corneal thickness; CDVA = corrected distance visual acuity; MICS = microincision cataract surgery
*One-way analysis of variance
†Pearson chi-square test

biaxial MICS group than in the microcoaxial group (P = .040) (Table 4 and Figure 2).

The percentage enlargement ratio from the planned incision width was statistically significantly smaller in the biaxial MICS group than in the standard coaxial group (Table 3) (P = .001). The difference between the microcoaxial group and the biaxial MICS group was at the limit of statistical significance (P = .056).

There was a statistically significant difference between the 3 groups in the mean SIA (P = .001) as well as between the standard coaxial group and the microcoaxial and biaxial MICS groups (both P = .001) and between the microcoaxial group and the biaxial MICS group (P = .023) (Table 4).

DISCUSSION

In this study, we compared 3 phacoemulsification techniques: standard coaxial, microcoaxial, and biaxial MICS. We wanted to see whether the smaller incisions

Table 3. Intraoperative parameters.

Parameter	Phaco Technique: Standard Coaxial	Microcoaxial	Biaxial MICS	*P* Value
Mean pupil diameter (mm)	7.60 ± 0.77	7.52 ± 1.16	7.80 ± 0.80	.369†
Mean capsulorhexis diameter (mm)	5.16 ± 0.70	5.16 ± 0.62	4.93 ± 0.33	.089†
Hydrodelineation, n (%)	32 (71.1)	33 (72.1)	36 (80.0)	.600‡
Mean phaco time (min)	0.27 ± 0.19	0.20 ± 0.13	0.19 ± 0.23	.121†
Mean phaco power (%)	13.48 ± 7.63	12.39 ± 8.10	7.79 ± 6.00	.001†
Mean EPT (sec)	2.56 ± 2.46	1.98 ± 1.91	1.29 ± 1.85	.019†
Mean total surgical time (min)	14.48 ± 4,21	13.01 ± 3.66	18.79 ± 6.58	.001†
Mean final incision (mm)	2.83 ± 0.11	2.26 ± 0.07	1.89 ± 0.21	.001†
Incision enlargement (mm)				.001†
Mean ± SD	0.031 ± 0.046	0.068 ± 0.076	0.131 ± 0.195	
Change (%)	1.07	2.72	5.00	
Implanted IOL,* n (%)				—
AcrySof Natural SN60AT	17 (37.8)	18 (40.0)	—	
AcrySof IQ SN60WF	27 (60.0)	25 (55.6)	—	
AcrySof ReSTOR SA60D3	1 (2.2)	1 (2.2)	—	
Acrysof Toric SN60T5	—	1 (2.2)	—	
Akreos MI-60	—	—	20 (44.4)	
Acri.LISA 366D	—	—	25 (55.6)	

Means ± SD
EPT = effective phaco time; IOL = intraocular lens; MICS = microincision cataract surgery; n = number of eyes
*All AcrySof, Alcon; Akreos MI-60, Bausch & Lomb; Acri.LISA 366D, Carl Zeiss Meditec AG
†One-way analysis of variance
‡Pearson chi-square

Table 4. Postoperative outcomes.

Parameter	Phaco Technique: Standard Coaxial	Microcoaxial	Biaxial MICS	*P* Value*
Mean CDVA (logMAR) at 90 days	0.11 ± 0.19	0.07 ± 0.13	0.02 ± 0.06	.013
Mean CDVA increase (logMAR)	−0.28 ± 0.43	−0.39 ± 0.38	−0.41 ± 0.29	.954
Mean CDVA recovery (days)	40.9 ± 34.9	47.9 ± 34.3	25.1 ± 30.1	.005
Mean SIA (D)	0.46	0.24	0.13	.001
CCT (µm)				
1 day				
Mean	566.7 ± 40.4	577.0 ± 47.7	570.8 ± 89.6	.805
Mean increase	23.9 ± 29.5	36.6 ± 31.5	20.7 ± 90.5	.531
7 days				
Mean	557.6 ± 40.0	554.5 ± 34.5	552.8 ± 33.0	.828
Mean increase	14.8 ± 28.4	10.7 ± 16.2	8.7 ± 25.9	.506
30 days				
Mean	547.5 ± 40.1	543.9 ± 33.4	549.1 ± 33.7	.766
Mean increase	3.6 ± 23.4	0.08 ± 14.3	4.0 ± 16.0	.544
90 days				
Mean	546.0 ± 37.0	540.7 ± 32.2	546.1 ± 31.2	.704
Mean increase	−1.4 ± 23.5	−3.6 ± 14.7	0.3 ± 14.1	.608

Means ± SD
CCT = central corneal thickness; CDVA = corrected distance visual acuity; MICS = microincision cataract surgery; SIA = surgically induced astigmatism
*One-way analysis of variance

of the latter 2 techniques confer advantages over the standard technique and to determine the advantages and disadvantages of each technique. To limit bias, patients assigned to the 3 groups were similar in preoperative characteristics and the intraoperative parameters were standardized.

We assessed the efficiency of the techniques by analyzing the amount of phaco (ultrasound) energy used and the total surgical time. The least amount of ultrasound energy was in the biaxial MICS group. Although there was no significant difference in phaco time between the groups, the difference in the phaco power percentage between the biaxial MICS group and the other 2 groups was statistically significant. The only statistically significant difference in EPT was between the standard coaxial group and the biaxial MICS group. Based on our findings, the biaxial MICS technique was the most efficacious. We also found no difference in efficacy between standard coaxial phacoemulsification and microcoaxial phacoemulsification, which indicates that the smaller incision in the latter technique does not negatively affect efficacy. Our findings agree with those in previous studies[7,8,24–26] that report less ultrasound output with the biaxial MICS technique. To our knowledge, there are no published studies comparing the ultrasound energy used in microcoaxial phacoemulsification and in standard coaxial phacoemulsification.

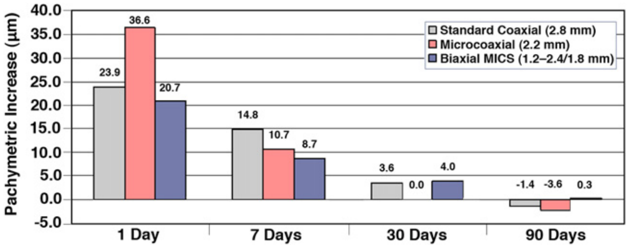

Figure 1. Change in CCT postoperatively (MICS = microincision cataract surgery).

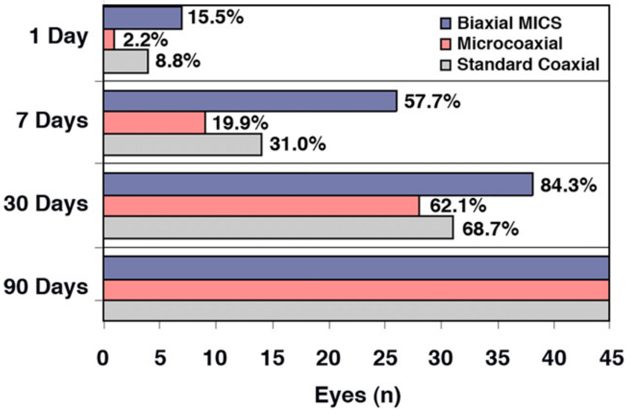

Figure 2. Visual recovery time; that is, time to best visual acuity postoperatively (MICS = microincision cataract surgery).

In our study, the mean total surgical time was statistically significant longer in the biaxial MICS group because IOL implantation through the microincision takes more time than implantation through a larger incision. There was no statistically significant difference in total surgical time between the standard coaxial group and the microcoaxial group. Thus, we believe that converting from standard coaxial to microcoaxial phacoemulsification will not lengthen the duration of surgery.

Two concerns about the biaxial MICS technique are wound leakage and safety. Although several cadaver, animal, and human studies report continuous ingress through the wound into the anterior chamber,[17–20] others report favorable results in human eyes.[7,9,27–29] There were few intraoperative complications and no cases of wound burn or Descemet membrane damage in our study. We believe this is because we used the burst mode, power modulation, and a half-moon supracapsular nucleofractis technique,[22] which reduces the EPT.

We evaluated the increase in CCT and the complication rates to determine the effect of the techniques on surrounding tissue. Although there was no significant difference between the groups in the change in CCT, the smallest increase was in the biaxial MICS group and largest increase, in the microcoaxial group. A study by Lundberg et al.[30] found that corneal thickness on the first postoperative day correlated with intraoperative trauma to the endothelium and with the endothelial cell loss 3 months postoperatively. We did not evaluate corneal endothelial loss but rather used the increase in CCT and recovery rate to determine whether the techniques caused endothelial damage. Even though there was no statistically significant difference between the 3 groups, our results indicate that the biaxial MICS technique caused the least trauma to the corneal endothelium by decreasing turbulence in the anterior chamber. There was no statistically significant difference between the 3 techniques in the intraoperative or postoperative complication rate or between the 2 microincision techniques and standard coaxial technique in reliability.

There were also no statistically significant differences between groups in visual acuity outcomes and visual recovery time. Thus, we believe there will be no loss in visual function when switching from standard coaxial phacoemulsification to microincision techniques. Visual recovery time (ie, time to reach best visual acuity postoperatively) is an indicator of functionality and reliability. In our study, the mean recovery time was 40.9 days in the standard coaxial group, 47.6 days in the microcoaxial group, and 25.1 days in the biaxial MICS group. The time was statistically significantly shorter in the biaxial MICS group than in the standard coaxial group. Kurz et al.[26] also found that the recovery time to best acuity was shorter after biaxial MICS than after standard coaxial phacoemulsification. This finding, combined with the CCT results, indicates that biaxial MICS is the least invasive of the 3 techniques.

In our study, the microcoaxial group had the longest visual recovery time and the highest CCT values on the first postoperative day. This seems to suggest that the technique is the most invasive. However, the mean EPT in the microcoaxial group was shorter than in the standard coaxial group. We believe that fluid dynamics (eg, turbulence) in the anterior chamber play a significant role in these findings; that is, it is important to maintain a balance between repulsing factors (phaco power and irrigation) and attracting factors (aspiration and outflow through the main incision). In coaxial phacoemulsification, outflow through the wound is the same as during aspiration. In microcoaxial phacoemulsification, in which the incisions are smaller, the outflow, and therefore the attracting forces, are less than in standard coaxial phacoemulsification, which puts the balance in favor of the repulsing forces. As a result, phacoemulsification becomes more difficult and turbulence increases, which is why microcoaxial phacoemulsification has a greater risks for unfavorable effects on surrounding tissue. We believe that this mechanism is the reason for the longer visual recovery time and the edema on the first postoperative day in the microcoaxial group.

Incision size is the main clinical factor in the amount of SIA after phacoemulsification. The smaller the incision, the less the SIA.[7,8,31,32] The mean incision at the end of surgery was 2.83 mm in the standard coaxial group, 2.26 mm in the microcoaxial group, and 1.89 mm in the biaxial MICS group. Vector analysis showed the incisions resulted in a mean SIA of 0.45 D, 0.24 D, and 0.13 D, respectively. These results confirm that smaller incisions minimize astigmatism.

In conclusion, our results indicate that switching from conventional standard coaxial phacoemulsification to a microincision phacoemulsification technique will not result in a significant loss of efficiency, reliability, or visual function. Also, the microcoaxial phacoemulsification technique has the advantages of a small incision and does not require an additional learning curve when converting from a standard coaxial technique. However, a more detailed comparison of the effect of microcoaxial phacoemulsification and standard coaxial phacoemulsification on surrounding tissue is required. The biaxial MICS technique, which has a longer learning curve for the phacoemulsification and IOL implantation stages, has clinical advantages in terms of a shorter EPT, reduced visual recovery time, and less SIA.

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