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Evaluation of an interlaced triple procedure: penetrating keratoplasty, extracapsular cataract extraction, and nonopen-sky intraocular lens implantation

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Abstract

To evaluate an interlaced triple procedure that involved penetrating keratoplasty (PKP), extracapsular cataract extraction (ECCE) using diathermy capsulotomy, and nonopen-sky intraocular lens (IOL) implantation.

This retrospective study involved data from 34 patients who were diagnosed with severe corneal opacities and cataracts. These patients were divided into an interlaced procedure group (21 patients) and a traditional procedure group (13 patients). In the interlaced group, the method of continuous curvilinear capsulorhexis (CCC) was completed via diathermy capsulotomy. The donor corneal button was sutured at 8 positions (at equal intervals) using 10-0 nylon sutures, and the IOL was inserted into the capsular bag using a closed anterior chamber approach at the 10:30 to 12 o'clock positions between the sutures. In the traditional group, CCC was completed using side-port capsular forceps, and the IOL was implanted using an open anterior chamber approach.

In the interlaced group, the CCC, open-sky, and total operation times were significantly shorter than in the traditional group ($P < .05$). Neither the best-corrected visual acuity (BCVA) nor corneal endothelial cell density was significantly different between the groups at 1 and 6 months after the operation.

This interlaced triple procedure for the treatment of corneal diseases with cataracts appears to be feasible and practical.

Abbreviations: BCVA = best-corrected visual acuity, CCC = continuous curvilinear capsulorhexis, CECD = corneal endothelial cell density, ECCE = extracapsular cataract extraction, IOL = intraocular lens, PKP = penetrating keratoplasty.

Keywords: diathermy capsulotomy, extracapsular cataract extraction, nonopen-sky, penetrating keratoplasty, triple procedure

1. Introduction

Triple surgery involving penetrating keratoplasty (PKP), extracapsular cataract extraction (ECCE), and intraocular lens (IOL) implantation is an effective treatment for patients with corneal pathologies complicated by cataracts.[1–12] Compared with staged surgery, the most important advantages of triple surgery are that it leads to quick improvements in visual acuity, avoids the adverse effects of a second surgery on the donor corneal button, and reduces costs.[1,3,5,8,13] However, traditional triple surgery can involve more risk compared to staged surgery because performing IOL implantation in the open-sky state entails a longer open state duration, which increases the intraoperative risks and difficulty of accurately and safely inserting the IOL into the capsular bag.[14–20] Moreover, the surgical training period associated with traditional triple surgery is prolonged compared to that associated with staged surgery.

Multiple clinical studies have investigated potential improvements to the triple surgery procedure. Menapace et al[21] investigated replacing the trephined cornea with a temporary artificial cornea. Malbran et al[22] explored the use of a pressurized system to ensure the stability of the operating environment after PKP. Using lamellar keratoplasty to create a more favorable visual environment prior to cataract surgery has also been considered.[23,24] Last, Yokokura et al[25] investigated the use of chandelier lighting to allow the procedure to be carried out in a closed state. However, these modifications all increased the difficulty of the triple surgery.

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Table 1

Demographic and clinical characteristics of the patients.

	Interlaced group	Traditional group
Age, y		
Mean ± SD	58.4 ± 11.6	51.2 ± 20.0
Gender		
Female	8	7
Male	13	6
Main diagnosis		
Herpetic keratitis and keratoleukoma	5	4
Corneal dystrophy	2	1
Endothelial dysfunction	9	3
Corneal ulcer	1	–
Corneal degeneration	3	5
Bullous keratopathy	1	–
Comorbidities		
Iritis/uveitis	–	1
Glaucoma	3	2
Diabetes	1	1
Hypertension	2	–
Arthritis deformans	1	–
Number of previous surgeries		
0	8	5
1–3	11	5
≥4	2	3

To eliminate any excess steps and the risk factors associated with the open-sky state, and to ensure overall safety and effectiveness of the triple surgery, we investigated changing the order of the traditional triple surgery by devising an interlaced procedure. After excision of the patient's cornea, continuous curvilinear capsulorhexis (CCC) was completed using an electric capsulorhexis instrument, and the IOL was then inserted into the capsular bag between the donor corneal button and recipient bed as the donor corneal button was sutured with 8 interrupted sutures. This not only reduces the open-sky time, but also compared with the previous modified procedures, it removes the need for an additional incision. The purpose of this study was to compare this interlaced triple surgery procedure with the traditional procedure.

2. Materials and methods

2.1. Study design and patients

This retrospective study involved data from 34 patients who had been diagnosed with severe corneal opacities and cataracts (with no retinal diseases or optic nerve dysfunction), and who had undergone PKP, ECCE, and IOL implantation at Qingdao Eye Hospital in China between January 2008 and December 2015. These patients were divided into 2 groups: an interlaced procedure group (21 patients) and a traditional procedure group (13 patients). There were 13 men and 8 women in the interlaced group, with a mean age of 58.4 ± 11.6 years. There were 6 men and 7 women in the traditional group, with a mean age of 51.2 ± 20.0 years. The patients' demographic and clinical characteristics are shown in Table 1.

The study followed the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Qingdao Eye Hospital. Due to the retrospective nature of the study, the informed consent was waived. The patients all underwent a best-corrected visual acuity (BCVA) assessment (scored with reference to the logarithm of the minimum angle of resolution [LogMAR]), B-scan ocular ultrasound, and visual evoked potential assessment prior to the operation. The triple surgeries were all performed by the same surgeon (LX).

The surgeries were videotaped, and the CCC time, open-sky time (from the trephination of the recipient's cornea to completion of the 8 interrupted sutures around the donor corneal button), total operation time, rates of successful CCC, and accurate IOL insertion into the capsular bag were determined after the operation. After the operation, the donor corneal button transparency, anterior chamber, IOL position, and intraoperative complications were evaluated. Ultrasound biomicroscopic results were also recorded, where necessary. The patients also underwent a BCVA assessment at 6 months postsurgery and a corneal endothelial cell density (CECD) assessment at 1 and 6 months.

2.2. Surgical technique

2.2.1. Preoperative preparation. For each patient, the refractive state of the eye to be operated on was evaluated, and an IOL was selected accordingly. The IOL power was calculated using the Sanders–Retzlaff–Kraff formula. The donor corneas were obtained from the Qingdao Eye Hospital Eye Bank (only donors without infectious diseases, tumors, or other diseases that affect the donors were selected).

The patients were examined and then given an anesthetic. Peribulbar or general anesthesia was selected according to each patient's condition. The patients who underwent peribulbar anesthesia were given 50 mg oral methazolamide and a venous transfusion of mannitol 1 hour prior to the operation. The intraocular and orbital pressures were evaluated subjectively, using a technique that involves pressing one's fingers against the eyeball. When the eyeballs were fully anesthetized, the intraocular and orbital pressure decreased, which improved the conditions for carrying out the operation. Disinfection and sterilization was then performed after the anesthetic was administered.

2.2.2. Surgical procedure. In the interlaced group, 1.0% tropicamide was used preoperatively to dilate the pupils. A Flieringa ring was fixed to the globe using a surgical microscope and 7-0 silk sutures (Fig. 1A). PKP was performed using a Hessburg Barron Vacuum Trephine (Katena Products Inc., Denville, NJ) to prepare the donor corneal button and recipient bed (Fig. 1D). The mean diameter of the donor corneal button was 7.90 ± 0.24 mm, and the mean diameter of the recipient bed was 7.64 ± 0.27 mm. The iris was separated from the cornea when a partial anterior synechia was observed, and for patients with severe defects of the iris, an iridoplasty was performed after the IOL implantation. CCC was conducted using diathermy capsulotomy (Fig. 1G). ECCE was initiated at the previous incision, and the remaining cortex was subsequently manually removed (Fig. 1H). VISCOAT (Alcon, Fort Worth, TX) was applied to the pupil area and donor corneal endothelium to provide protection. The donor corneal button was then sutured at eight positions (at equal intervals) using 10-0 nylon sutures (Fig. 1I, J). Subsequently, VISCOAT was injected to dilate the capsular bag, and the IOL (Akreos Adapt IOL; Bausch & Lomb Inc., Rochester NY) was inserted and adjusted at the 10:30 to 12 o'clock positions between the sutures (Fig. 1J, K). After rinsing off the VISCOAT, the donor corneal button was sutured using 7 stitches, and then the main incision was closed with a final stitch (Fig. 1L).

In the traditional group, the CCC was completed using side-port capsular forceps, and the IOL was implanted using an open

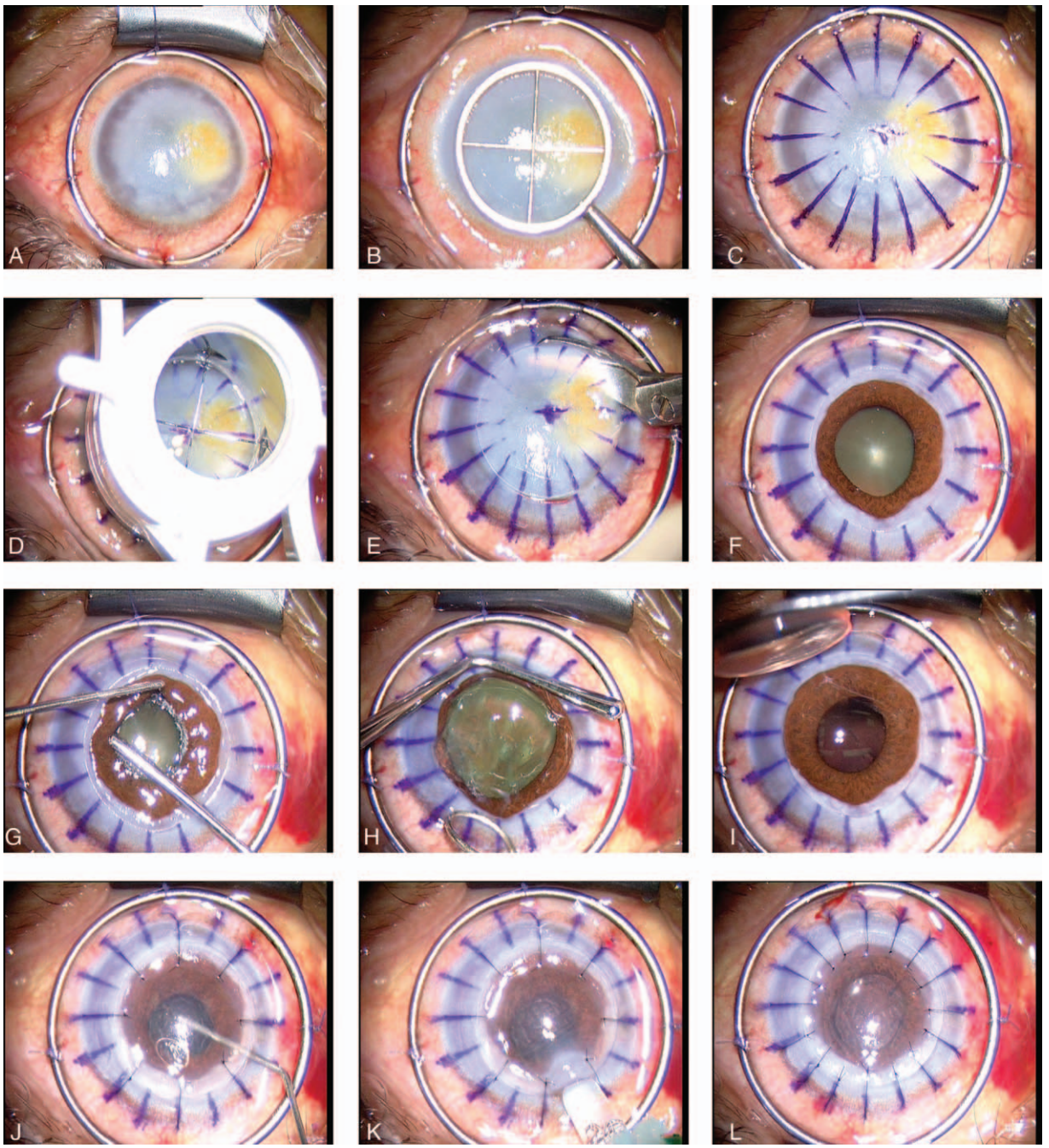

Figure 1. Surgical procedure. (A) Suturing of Flieringa ring. (B, C) Positions of dye. (D) Use of the Hessburg–Barron vacuum trephine. (E, F) Removal of the recipient's cornea. (G) CCC using diathermy capsulotomy. (H) ECCE. (I, J) Suturing of the donor corneal button at eight positions. (K) Insertion of IOL at the 10:30 and 12 o'clock positions. (L) Suturing of the remnant corneal button. CCC = continuous curvilinear capsulorhexis, ECCE = extracapsular cataract extraction, IOL = intraocular lens.

anterior chamber approach. The other details were the same as in the interlaced group.

2.2.3. Postoperative medication. The patients were administered 1.5 g cefuroxime sodium intravenously twice a day for 3 days and 150 mg hydrocortisone intravenously once a day for 3 days. This was followed on the 4th day after the operation by beginning an oral prednisone course of 50 mg, which was reduced by 10 mg every 3 days. In addition, 1% tobramycin and dexamethasone eye drops (Alcon, Fort Worth, TX) and 1% tobramycin and dexamethasone ointment (Alcon) were locally administered 4 times a day and once at night, respectively. After 1 week, 1% cyclosporine A eye drops (Northern China Pharmaceutical Group Corp., Shijiazhuang, China) were administered 4 times a day.

2.2.4. Statistical analysis. Mann–Whitney *U* tests were used to compare the CCC time, open-sky time, total operation time, BCVA, and CECD between the 2 groups. The difference in the change in BCVA (from before to after the operation) was analyzed using a paired-samples *t* test, and the differences in the BCVA (preoperatively and at 6 months after the operation) and CECD (at 1 and 6 months after the operation) were analyzed

Table 2

Between-group differences in intraoperative variables.

	Interlaced group	Traditional group	*P*
Total operation time, min	45.0 ± 6.0	51.5 ± 3.0	.000*
Open-sky time, s	777 ± 49	1023 ± 115	.000*
CCC time, s	21 ± 8	52 ± 5	.000*
Successful CCC completion, % (n)	95 (20)	77 (10)	.274
Accurate IOL insertion, % (n)	95 (20)	77 (10)	.274

The statistics represent means ± standard deviations unless otherwise stated. *$P < .05$. CCC = continuous curvilinear capsulorhexis, IOL = intraocular lens.

using independent-samples *t* tests. The rates of successful CCC completion and accurate IOL insertion were analyzed using Fisher exact test. Statistical significance was defined as $P < .05$. The times, BCVA, and CECD are presented as mean ± standard deviation, and the rates of successful CCC completion and accurate IOL insertion are expressed as percentages (with frequencies).

3. Results

In the interlaced group, the CCC time was 21 ± 8 seconds, the open-sky time was 777 ± 49 seconds, and the total operation time was 45.0 ± 6.0 minutes. These durations were significantly shorter than those in the traditional group (52 ± 5 seconds, 1023 ± 115 seconds, and 51.5 ± 3.0 minutes, respectively; Table 2). In the interlaced group, the success rate of CCC was 95% (20/21), and the rate of accurate IOL implantation was 95% (20/21). There were no significant differences in either of these rates compared to those in the traditional group (77% [10/13] and 77% [10/13], respectively; Table 2).

There was a significant between-group difference in the change in BCVA (from before to after surgery; $P < .05$). However, the between-group differences in the BCVA (preoperatively and at 6 months after the operation) and CECD (at 1 and 6 months after the operation) were not significant ($P > .05$; Table 3). In the interlaced group, the BCVA was 1.8 ± 0.39 LogMAR preoperatively and 0.83 ± 0.26 LogMAR at 6 months. The mean CECD was 2272 ± 592 and 1639 ± 480 cells/mm^2 at 1 and 6 months, respectively. In the traditional group, the BCVA was 1.94 ± 0.20 LogMAR preoperatively and 0.79 ± 0.26 LogMAR at 6 months. The mean CECD was 2375 ± 587 and 1777 ± 754 cells/mm^2 at 1 and 6 months, respectively.

None of the patients experienced graft rejection, retinal detachment, vitreous hemorrhage, or IOL dislocation (Figs. 2 and 3).

Table 3

Between-group differences in BCVA and CECD.

	Interlaced group	Traditional group	*P*
BCVA, LogMAR			
Preoperative	1.8 ± 0.39	1.94 ± 0.20	.153
Postoperative: 6 mo	0.83 ± 0.26	0.79 ± 0.26	.632
CECD, cells/mm^2			
Postoperative: 1 mo	2272 ± 592	2375 ± 587	.652
Postoperative: 6 mo	1639 ± 480	1777 ± 754	.583

The statistics represent means ± standards deviation. BCVA = best-corrected visual acuity, CECD = corneal endothelial cell density, LogMAR = logarithm of the minimum angle of resolution.

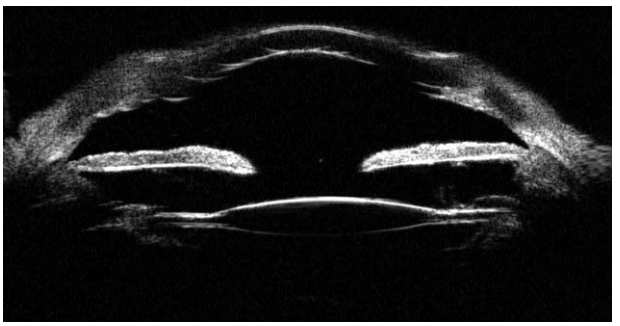

Figure 2. Postoperative results of a representative patient visualized using ultrasound biomicroscopy. The anterior chamber angle was open, and the IOL was accurately inserted into the capsular bag. IOL = intraocular lens.

4. Discussion

Cataract extraction and IOL implantation are usually performed using an open-sky approach when they are combined with PKP. The longer the duration in the open state, the higher the risks to the patient involving changes in intraocular pressure, posterior capsule rupture, prolapse of the vitreous body, and choroidal hemorrhage.[1,3,5,8,13] Most importantly, the rate of accurate IOL implantation into the capsular bag in the open-sky state is relatively low. This may be related to the effects of the pressure inside and outside the capsular bag, the patient's condition, and the surgeon's skill.[16–20,26]

In triple surgery, accurate IOL implantation into the capsular bag can reduce the probability of subsequent adverse events during the later stages of the surgery, including endothelial damage.[27] Surgeons carrying out triple surgery must be experienced and skilled. Although several researchers have developed modifications to the traditional triple surgery procedure that increase the safety of the procedure,[21–25] these modifications increase the duration and cost of the operation. Moreover, for intractable cases with severe corneal opacity or irregular corneal morphology, the applicability of the modifications is limited.

In the present study, we changed the order of the traditional triple surgery. The IOL was quickly and accurately inserted into the capsular bag at the 10:30 and 12 o'clock positions along the groove in the closed chamber as the donor corneal button was sutured to the recipient bed. This represents a significant refinement of the traditional triple surgery procedure, and the total operation time was reduced compared with those reported for other modified triple surgery approaches (Table S1, http://links.lww.com/MD/B849). The successful CCC and accurate IOL insertion rates were also improved compared to those reported for other approaches (Table S1, http://links.lww.com/MD/B849). However, there was a significant decrease in the open-sky time compared with the method involving chandelier lighting investigated by Yokokura et al.[25]

These results indicate that our surgical approach could reduce the surgical time and risks much more than other modified triple surgery approaches. The interlaced approach optimized the procedure, and the introduction of this approach may reduce the training period associated with triple surgery. The IOLs were accurately implanted into the capsular bag between the donor corneal button and recipient bed, which is similar to routine IOL implantation during cataract surgery.

There is a potential risk of corneal endothelial damage when the IOL is placed into the capsular bag between the donor corneal

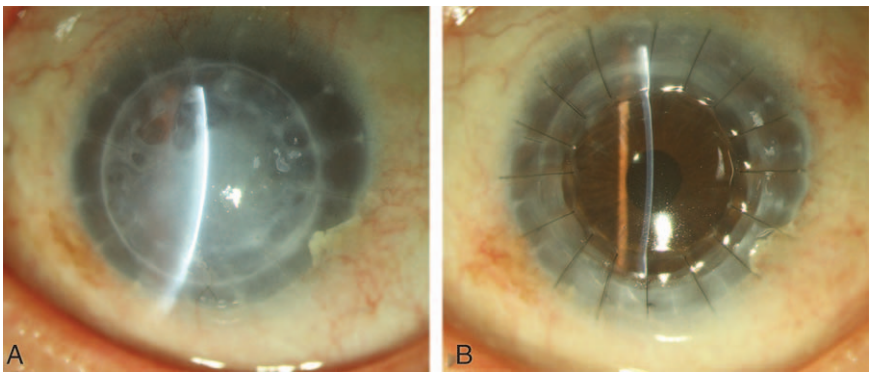

Figure 3. Photographs of anterior segment in a representative patient. (A) Preoperative, (B) postoperative (at 6 months), showing that the donor corneal button remained transparent.

button and recipient bed. However, research has suggested that IOL implantation does not increase the risk of donor failure,[27] but the method of cataract extraction (ECCE or phacoemulsification) may influence the risk to the endothelium.[28,29] In our study, satisfactory graft clarity, endothelial cell density, and visual acuity were observed during the follow-up period. The endothelial cell density was in a controllable range compared with other triple surgeries.[30]

However, the present study has a few limitations. Due to the single-center nature of the study and the limited number of patients, there were relatively few cases involving the triple surgery procedure. In addition, we compared the interlaced triple surgery with modified triple surgery approaches investigated in other studies (Table S1, http://links.lww.com/MD/B849). However, the comparisons lacked standardized definitions and protocols, and the surgeries were performed by different surgeons, which affect the validity of the comparisons. Another limitation is that the present study was retrospective and only focused on the effects of the interlaced procedure on effectiveness, efficiency, and complications. We did not compare results between patients with different primary diseases (with different etiologies), though there may be primary disease-specific differences in the effectiveness of the procedure. Addressing these limitations necessitates carrying out a prospective study with a large number of participants.

5. Conclusions

In conclusion, the interlaced triple surgery involving PKP, ECCE, and nonopen-sky IOL implantation for the management of combined corneal pathologies and cataracts appears to be safe, effective, simple, and economical. However, long-term follow-up studies of patients who undergo this modified triple surgery are required.

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