

# Application of the Modular and Step-Up Training Model in Manual Small Incision Cataract Surgery Training

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## Abstract

**Objective** To establish a modular and step-up training model for manual small incision cataract surgery (MSICS) and preliminarily apply it to cataract surgery training for resident physicians in ophthalmology. **Methods** A modular and step-up training model was developed based on the technical hierarchy of corneoscleral tunnel construction. This model was implemented among resident physicians at the Eye Hospital of Wenzhou Medical University. The training involved sequential modules of theoretical instruction, Dry-lab, Wet-lab, MSICS simulator practice, and live surgery, categorized by the complexity of corneoscleral tunnel construction. Surgical performance scores, operation duration, complication rates, and independent surgery completion rates were evaluated during live human eye surgeries. **Results** After training, all trainees successfully performed live human eye surgeries. Compared to the first live surgery, the second surgery showed improved performance scores, shorter operation times, and reduced complication rates. For initial live surgeries, the average score was  $12.47 \pm 1.65$ , with an independent surgery completion rate of 73.7% and a complication rate of 21.1%. **Conclusion** The modular and step-up training model for MSICS effectively equips ophthalmology residents with practical surgical skills for live human eye surgeries, demonstrating safety and efficacy as a training method.

## Keywords

Ophthalmology; Microsurgery; Cataract Extraction; Modular and step-up; Medical Education.

## 1. Introduction

Ophthalmology is a highly specialized and practice-oriented clinical discipline. Microsurgery is a key technique that ophthalmology residents must master during their training [1]. Cataract is the leading reversible cause of blindness in China. According to a 2015 report, there were 11 million cataract patients in China, and with the aging population, this number is increasing at a rate of 800,000 per year [2]. In contrast, China has a low cataract surgery rate [3,4] and a surgical coverage rate of only 35.7% [2]. High-quality, efficient training of cataract surgeons is of great significance for blindness prevention and treatment. Manual small incision cataract surgery (MSICS) does not require special equipment or consumables and has a low surgical cost. In areas with underdeveloped economies and poor medical conditions, MSICS is an effective alternative to phacoemulsification. Therefore, ophthalmologists should master MSICS techniques.

For ophthalmology microsurgery teaching, most hospitals still adopt the traditional "apprenticeship" model [5], which provides limited hands-on opportunities. Furthermore, increasingly tense doctor-patient relationships and growing patient awareness of rights make this traditional model unsuitable for the current environment. To improve the efficiency and

safety of cataract surgery training, simulation training methods have emerged, including virtual reality (VR) simulators [3,6-9], Wet-lab (animal tissue practice) [10-12], and Dry-lab (non-animal tissue practice) [13]. The effectiveness and safety of various simulation training methods have been continuously confirmed. However, no formal, standardized training course currently exists. Based on a national-level continuing education platform, the Eye Hospital of Wenzhou Medical University has established a modular and step-up microsurgery training model and applied it to MSICS training for ophthalmology resident physicians. The specific implementation process and application effects are described below.

## **2. Materials and Methods**

### **2.1. Subjects**

Resident physicians specializing in ophthalmology (professional master's degree students) who underwent standardized residency training at the Eye Hospital of Wenzhou Medical University from June 2018 to June 2019 were selected as study subjects. A total of 19 residents were included (4 males, 15 females). All subjects had completed the Phase I and Phase II Basic Microsurgery Skills courses for residents at the Eye Hospital of Wenzhou Medical University.

### **2.2. Methods**

#### **2.2.1. Training Process**

The modular and step-up MSICS training course was based on the corneoscleral tunnel construction steps and consisted of the following modules: theoretical teaching, Dry-lab (non-animal tissue practice), Wet-lab (animal eye practice), MSICS simulator training, and live surgery. The corneoscleral tunnel construction steps were further divided according to difficulty level for sequential teaching (paracentesis creation and viscoelastic replacement, central tunnel dissection, extension of both sides of the tunnel, creation of the tunnel internal opening, and scleral groove creation). The theoretical teaching module covered the anatomical characteristics of the corneoscleral tunnel, surgical instruments used in tunnel construction, and key points and precautions for each step. The Dry-lab module involved using tomatoes to practice scleral groove creation and scleral tunnel dissection, and using tennis balls to practice anterior chamber paracentesis. The MSICS simulator training module involved using a high-fidelity small incision cataract simulator to practice each step of corneoscleral tunnel construction. The Wet-lab module involved using pig eyes to practice corneoscleral tunnel construction. Finally, residents participated in clinical surgical practice under the direct guidance of an instructor. After each module, a corresponding assessment was conducted. Residents could only proceed to the next module after passing the assessment by the simulator's built-in evaluation system or a senior faculty member. Those who failed the assessment repeated the module until they passed.

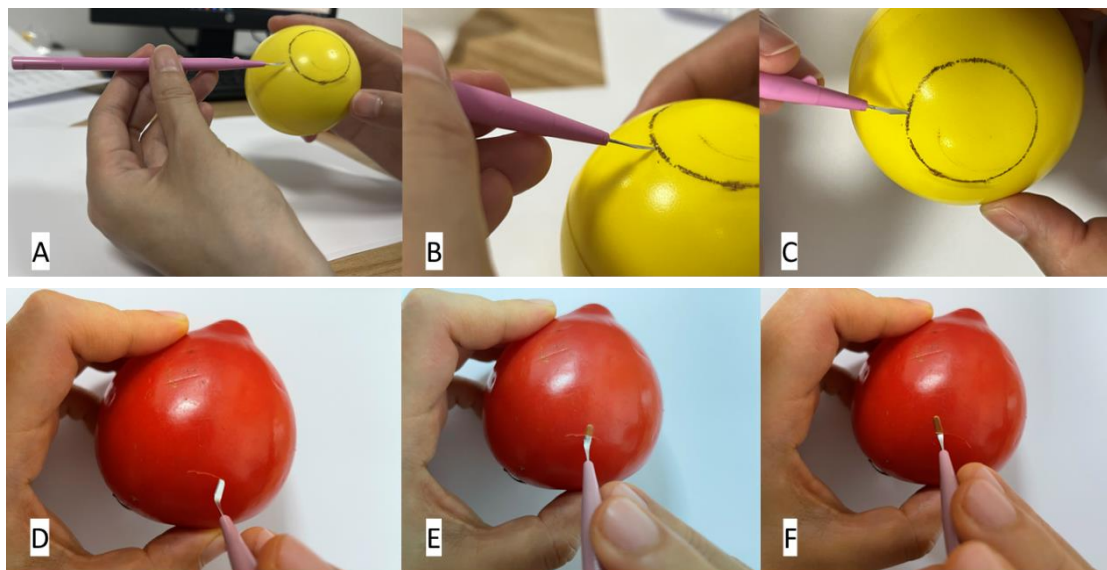


Figure 1. Figures A-C show using a tennis ball to practice instrument grip and paracentesis angle for anterior chamber entry. Figures D-E show using a tomato to practice scleral groove creation and scleral tunnel dissection.

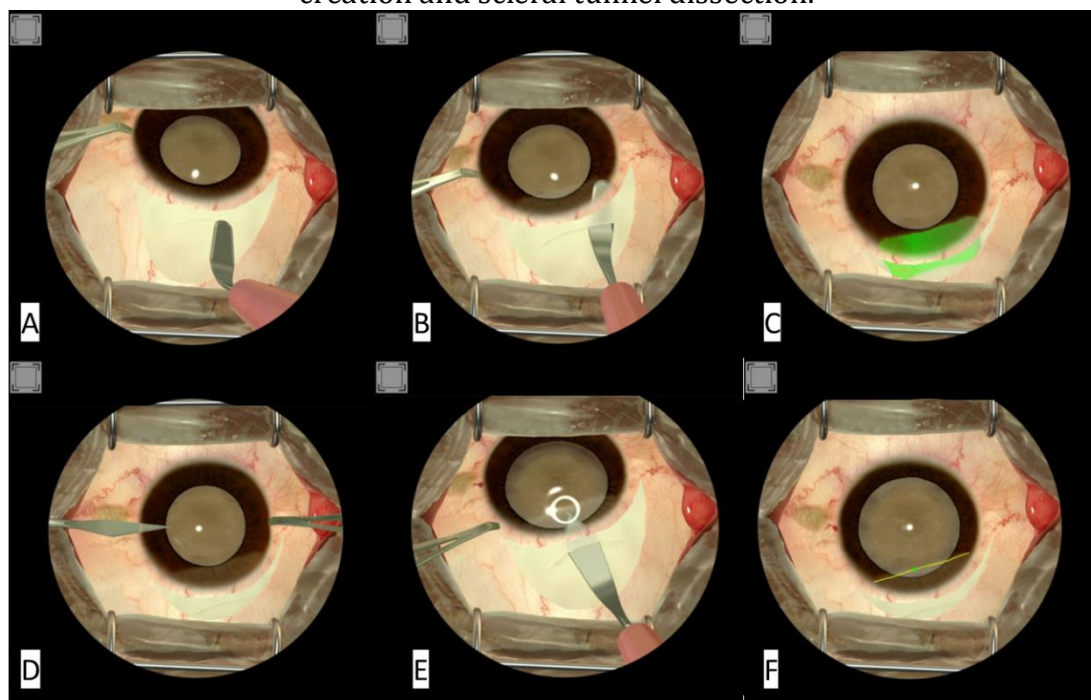


Figure 2. MSICS simulator interface. (A) Scleral groove creation; (B) Scleral tunnel dissection; (C) Overlay assessment interface for tunnel dissection, with green indicating the dissected area and color shade indicating thickness; (D) Anterior chamber paracentesis; (E) Creation of the tunnel internal opening; (F) Overlay assessment interface for internal opening creation, with yellow line indicating the opening range and straight line indicating uniform thickness of the internal opening of tunnel).

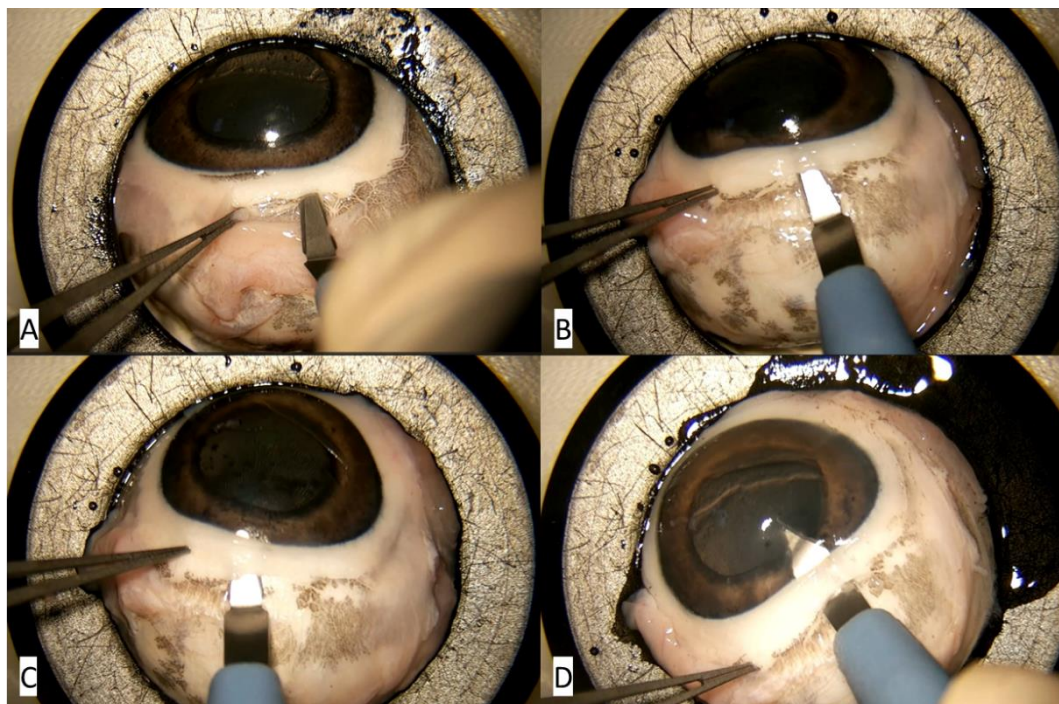


Figure 3. Animal eye practice. (A) Scleral groove creation; (B) Central tunnel dissection; (C) Extension of both sides of the tunnel; (D) Creation of the tunnel internal opening).

**2.2.2. Evaluation of Training Effectiveness**

Videos of two live human eye surgeries performed by each trainee were collected and coded. Two clinical instructors blindly rated the videos using the OSCAR scale, scoring both specific surgical steps and overall performance. The main outcome measures for training effectiveness were: surgical performance score, operation duration, independent surgery completion rate, and complication rate.

**2.3. Statistical Analysis.**

Data were analyzed using SPSS 26.0 software. Normally distributed continuous data were expressed as (mean ± standard deviation) and compared using paired samples t-test. Non-normally distributed continuous data were expressed as (median, interquartile range) and compared using the Wilcoxon signed-rank test. Categorical data were expressed as (n, %) and compared using the chi-square test ( $\chi^2$  test). All tests were two-tailed, and a P-value < 0.05 was considered statistically significant.

**3. Results**

**3.1. OSCAR Scores for Surgical Steps.**

Live human eye surgeries were scored according to seven steps: scleral fixation, scleral groove creation, paracentesis creation, viscoelastic replacement, scleral tunnel dissection, corneoscleral tunnel dissection, and tunnel internal opening creation. The scores for each step were higher in the second live surgery compared to the first. The difference in the viscoelastic replacement step was statistically significant (t=3.01, P=0.007). Detailed scores for each step are shown in Table 1.

Table 1. OSCAR scores for two live human eye surgeries ( $\bar{x}\pm s$ )

Surgical Step	First Live Surgery	Second Live Surgery	t	P
Scleral fixation	1.21±0.63	1.42±0.61	0.89	0.385
Scleral groove creation	1.63±0.50	1.68±0.48	0.33	0.749

Paracentesis creation	1.26±0.87	1.74±0.45	1.92	0.070
Viscoelastic replacement	0.89±0.81	1.47±0.51	3.01	0.007b
Scleral tunnel dissection	1.26±0.81	1.47±0.77	0.78	0.448
Corneoscleral tunnel dissection	1.42±0.84	1.63±0.76	0.89	0.385
Creation of Internal Tunnel Opening	1.32±0.86	1.47±0.84	0.59	0.563
Total	9.00±3.96	10.89±2.05	1.78	0.093

<sup>a</sup> $P < 0.05$ , <sup>b</sup> $P < 0.01$

### 3.2. Global Performance Scores.

Global performance scores for live human eye surgeries were evaluated from five aspects: wound deformation, microscope centration, corneal and scleral handling, intraocular manipulation, and effectiveness of manipulation. The scores for each aspect were higher in the second live surgery compared to the first. The differences in "corneal and scleral handling" and the total global score were statistically significant ( $t=2.14, 2.40$ ;  $P=0.046, 0.027$ ). The global performance scores are shown in Table 2.

Table 2. Global performance scores for two live human eye surgeries ( $\bar{x} \pm s$ )

Evaluation Criteria	First Live Surgery	Second Live Surgery	t	P
Wound deformation	2.16±0.50	2.42±0.61	1.56	0.135
Microscope centration	2.37±0.76	2.63±0.50	1.16	0.262
Corneal and scleral handling	2.05±0.71	2.53±0.51	2.14	0.046a
Intraocular manipulation	2.53±0.70	2.74±0.45	1.07	0.297
Effectiveness of manipulation	1.89±0.66	2.16±0.69	1.32	0.205
Total	11.0±1.92	12.47±1.65	2.40	0.027a

<sup>a</sup> $P < 0.05$ , <sup>b</sup> $P < 0.01$

### 3.3. Operation Duration.

The construction of the corneoscleral tunnel was divided into five steps for timing: scleral groove creation, paracentesis creation, viscoelastic replacement, tunnel dissection, and tunnel internal opening creation. The duration for each step was shorter in the second live surgery compared to the first. The differences in scleral groove creation, paracentesis creation, and viscoelastic replacement were statistically significant ( $P=0.001, 0.023, 0.031$ ). The specific operation durations for each step are shown in Table 3.

Table 3. Operation duration for two live human eye surgeries ( $\bar{x} \pm s$ , M (P25, P75))

Surgical Step	N (surgeries)	First Live Surgery Duration (s)	Second Live Surgery Duration (s)	t/Z	P
Scleral groove creation	18	171.00(108.25, 233.25)	87.00(52.75, 111.00)	-3.46	0.001b
Paracentesis	15	40.73±24.88	24.27±11.57	2.56	0.023a

creation					
Viscoelastic replacement	15	56.00(28.00, 111.00)	28.00(23.00, 42.00)	-2.16	0.031a
Tunnel dissection	10	219.50±85.93	296.20±165.96	1.33	0.215
Creation of Internal Tunnel Opening	13	121.85±87.97	80.92±45.27	1.70	0.115

<sup>a</sup> $P < 0.05$ , <sup>b</sup> $P < 0.01$

### 3.4. Complication Rate.

The complication rate for the first surgery was 42.1% (8/19), including premature entry into the anterior chamber in 15.8% (3/19), touching intraocular tissues in 21.1% (4/19), and iris prolapse in 5.3% (1/19). The complication rate for the second surgery was 21.1% (4/19), including premature entry in 15.8% (3/19) and tear of the external tunnel wall in 5.3% (1/19). Although the complication rate decreased in the second surgery compared to the first, the difference was not statistically significant ( $\chi^2=1.946$ ,  $P=0.148$ ).

### 3.5. Independent Surgery Completion Rate.

The independent surgery completion rate was 57.9% for the first surgery and 73.7% for the second surgery. Although the rate increased in the second surgery, the difference was not statistically significant ( $\chi^2=1.052$ ,  $P=0.495$ ).

## 4. Discussion

Cataract is the leading cause of blindness in China. The primary goal of current blindness prevention and treatment efforts in China is to address blindness and severe visual impairment caused by cataracts [14]. Training cataract surgeons and increasing the cataract surgery rate are particularly important for blindness prevention and treatment. Currently, cataract surgery teaching in China mostly employs theoretical teaching, surgical observation, and Wet-lab practice [15]. Wet-lab provides an experience close to live human eye surgery, but preparing and storing the materials is difficult, and it cannot provide personalized practice. High-fidelity surgical simulators, based on virtual reality interaction technology, offer a realistic surgical experience without material limitations. They allow unlimited repetitive practice, and trainees can selectively practice specific modules according to their needs. The effectiveness of Wet-lab teaching and simulator teaching for microsurgery training has been confirmed, but there is a lack of standardized curricula. The modular and step-up training model is the standard for international minimally invasive surgery training, and structured curricula help improve training pass rates [16]. This model builds upon the traditional apprenticeship model by adding structured theoretical training and phased skill operation modules, along with an introduced scoring system. This study applied the modular and step-up model to MSICS training. Corneoscleral tunnel construction was divided into steps by difficulty, and different modules (theoretical teaching, Dry-lab, Wet-lab, MSICS simulator, and live surgery) were conducted step-by-step. Trainees could only proceed to the next module after passing the assessment of the previous one. The surgical steps progressed gradually by difficulty, and the training modules progressed step-by-step from theory to preclinical training to clinical practice. This stepwise learning path better follows the learning curve and helps enhance trainees' motivation. The modular and step-up model achieved preliminary success in MSICS training. After training, the initial live surgery performance total score for the trainees reached  $12.47 \pm 1.65$ , with an independent surgery completion rate of 73.7%.

Dry-lab is suitable for practicing instrument handling and angle control. High-fidelity surgical simulators enhance fine motor skills and provide unlimited practice. Wet-lab simulates the tactile feel of real tissue and enhances understanding of anatomical structures. Diverse simulation training helps strengthen microsurgical skills from multiple dimensions. Furthermore, the operational differences brought by various simulation scenarios can enhance trainees' ability to handle different surgical situations, facilitating the transfer of preclinical surgical skills to real-life clinical surgeries. This study included 19 ophthalmology resident physicians who completed 38 live human eye surgeries. After simulation training and transition to clinical surgery, compared to the first live surgery, the second surgery showed higher surgical performance scores, shorter operation duration, lower complication rate, and higher independent surgery completion rate. This indicates that the modular and step-up MSICS training model has a good skill transfer rate. Through preclinical laboratory training, most resident physicians could transfer their surgical skills to the clinical real surgery setting.

The learning curve for MSICS is steep. Resident physicians need extensive surgical practice to master the skills, especially the corneoscleral tunnel construction step [17]. Surgical performance, postoperative outcomes, and complication rates are related to surgeon experience [18]. A study on the learning curve of MSICS for residents at Aravind Eye Hospital found that 50.5% of surgeries performed by second-year residents required assistance from a senior physician, compared to 24.4% for third-year residents [17]. In this study, the initial independent surgery completion rate for resident physicians on live human eyes was 73.7%, which is higher than reported in the literature. This suggests that the modular and step-up training model helps resident physicians gain both surgical skills and psychological preparation preclinically, allowing them to perform real surgeries more competently. The reported complication rate for first-year residents performing MSICS is 17% [18], which is lower than the 21.1% found in this study. This difference may be because this study only counted the complication rate during the residents' second live surgery. With more practice and accumulated surgical experience, the complication rate is expected to decrease further.

## 5. Conclusion

The modular and step-up training model, through its system of "phased practice - multidimensional simulation - rigorous assessment," provides a safe and effective method for MSICS skill training and offers a replicable framework for microsurgical skill training. Future work should increase the number of live surgeries performed to explore the learning curve for live surgery within this modular and step-up MSICS training model. Although many challenges exist in ophthalmology microsurgery training, an effective, efficient, and safe training method can be developed by establishing structured curricula, utilizing various teaching methods, and increasing educational investment.

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