SHORT COMMUNICATION

# Development and evaluation of a low-cost dual-view microsurgical training system using repurposed equipment

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**Abstract**

*Background:* Effective microsurgical training requires continuous supervision and shared visualization between trainee and instructor. Dual-head operating microscopes facilitate this interaction but are expensive and often unavailable in many teaching hospitals, particularly in resource-limited settings, thereby restricting structured skill development. *Aim and Objective:* To develop and evaluate a low-cost dual-view microsurgical training system for resident education. *Material and Methods:* A nonfunctional single-head operating microscope was restored and modified with a beam splitter and digital camera to allow simultaneous external monitor visualization. The practice model was mounted on a repurposed adjustable base for improved stability and focusing. The system was integrated into a five-stage structured training program. Outcomes were assessed descriptively based on system performance, supervision continuity, workflow efficiency, and trainee feedback. *Results:* The modified system provided stable magnification and adequate image clarity. Continuous monitor-based visualization enabled uninterrupted supervision and timely feedback without disrupting workflow. Trainees adapted easily and showed progressive improvement in microsurgical handling and confidence. Faculty reported teaching efficiency comparable with conventional dual-head training. *Conclusion:* A cost-effective dual-view microsurgical teaching platform can be developed using simple modifications and existing resources. Integrated with a structured curriculum, it supports effective supervision and skill acquisition in resource-constrained settings.

**Keywords**: Microsurgical training, Surgical education, Low-cost innovation, Dual-view microscope, Simulation-based training, Resource-limited settings, Frugal innovation

## Introduction

Microsurgery is a key part of present-day reconstructive and plastic surgery and is routinely used for limb and digit replantation, free tissue transfer, vascular repair, lymphatic procedures, and nerve reconstruction. Performing these operations safely depends largely on the surgeon's ability to work accurately under magnification, maintain good hand–eye coordination, handle delicate tissues gently, and place fine sutures reliably, often using 9-0 or 10-0 nylon. Such skills develop only with repeated practice and close supervision and cannot be learned through reading or observation alone [1,2]. Training therefore needs to occur in a controlled setting where mistakes can be corrected early and technique can gradually improve.

The use of the operating microscope in surgery began in the early twentieth century, when Nylen and Holmgren first described its application in otological procedures [3,4]. Since then, the microscope has become central to microsurgical training, mainly because it offers stable magnification, adequate illumination, and reliable depth perception. In most training centers today, dual-head microscopes are preferred for teaching. They allow both the trainee and the instructor to view the same field at the same time, which makes it easier to demonstrate technique, point out errors as they occur, and give immediate feedback during practice [5].

Many teaching hospitals, especially in low- and middle-income countries, simply do not have access to this type of equipment. When such facilities are lacking, structured microsurgical training becomes difficult and the learning experience varies widely between centers and even between individual trainees. In units that rely on single-head microscopes, the supervisor often has to stop the trainee and take over the eyepieces to see the operative field. This breaks the flow of practice and limits the opportunity for continuous guidance.

To deal with limited infrastructure, many training programs use simulation models so that residents can practice outside the operating room. Simple inanimate models such as latex sheets, glove conduits, and synthetic tubes are commonly used in the early phase of training. They are safe and easy to access, but they do not provide realistic tissue handling or tactile feedback [6]. Biological models, including chicken thigh vessels and chicken mesentery, offer better tissue behavior at very low cost and can be used repeatedly without major ethical concerns [7,8]. For advanced training, live animal models are still considered the closest approximation to clinical conditions because blood flow can be assessed and vessel patency can be tested directly. However, these models require specialized facilities, ethical approval, and higher expenditure [9]. Although these options support stepwise skill development, they do not solve the problem of limited teaching visibility when a dual-view microscope is not available.

In recent years, there has been growing interest in frugal innovation in healthcare, where practical and affordable solutions are developed using locally available resources. In the context of surgical training, this approach helps reduce dependence on expensive imported equipment and makes skill development more accessible across different institutions. From this perspective, there is a clear need for a teaching system that allows both the trainee and the instructor to view the operative field at the same time, without placing a heavy financial burden on the institution. In this study, we describe the development of a self-engineered dual-view microsurgical training setup created by modifying a fixed-focus single-head operating microscope using simple optical and mechanical adaptations. The system was integrated into a stepwise training program aimed at gradual skill development. The objective was to examine whether this platform could function reliably in routine training and whether it was acceptable and useful from the trainee's perspective.

## Material and Methods

### Study design and setting

This study was carried out as a prospective descriptive educational study in the microsurgery training area of a tertiary care teaching hospital. The intention was to design and use a low-cost dual-view microsurgical training setup created from repurposed equipment and to observe how well it functioned in routine resident training. Rather than focusing on formal performance scoring or statistical comparison, the emphasis was placed on practical usability, system reliability, and feedback from trainees during regular training sessions. Approval was obtained from the institutional ethics committee before starting the project. Participation was voluntary, and written informed consent was taken from all residents. All activities involving animals followed institutional animal ethics guidelines and applicable national regulations for laboratory animal care.

**Participants**

Plastic surgery postgraduate residents at different stages of training were invited to participate. Residents who had not previously undergone formal microsurgical fellowship training were eligible. Trainees who were unable to complete the full training sequence were excluded to ensure consistency of exposure. Baseline information regarding year of training, prior microsurgical exposure, and self-reported confidence was recorded before initiation of the curriculum.

**Development of the dual-view microsurgical system**

**Restoration of base microscope**

A fixed-focus, single-head operating microscope that had been lying unused due to mechanical problems was selected for modification. As shown in Figure 1, the base microscope was retrieved from storage prior to restoration and optical modification. Although the mechanical arm was nonfunctional, the optical components and illumination system remained intact, making the instrument suitable for repurposing as the foundation of the training system.

**Integration of beam splitter and digital output**

To allow both the trainee and the instructor to see the same field at the same time, a small, inexpensive optical beam splitter was fitted into the optical path above the objective lens. A compact digital camera with HDMI output was attached to the splitter and connected to an external monitor. The monitor was placed where the supervisor could view it comfortably during the session. This arrangement made it possible to observe the operative field continuously without disturbing the trainee's use of the eyepieces (Figure 2).


**Figure 1: Fixed-focus single-head operating microscope prior to modification**

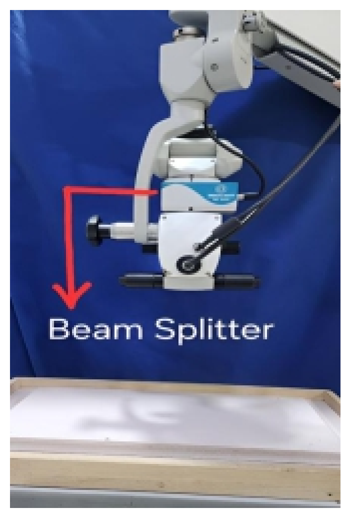


**Figure 2: Beam splitter integrated into the optical pathway for dual-view visualization.**

**Fabrication of adjustable support platform**

The original microscope did not have any provision for vertical height adjustment, which made fine focusing difficult. To solve this, the practice model (chicken mesentery) was mounted on the base of an ophthalmic refracto-meter that was no longer in clinical use. This base allowed small, controlled height movements for fine focus and provided good stability during practice. In day-to-day use, the adjustment was smooth enough to achieve reliable focus across different specimen thicknesses and felt comparable to the movement of standard microscope stands (Figure 3). Standard microsurgical instruments, lighting, suction, and cautery were obtained from existing institutional resources, ensuring minimal additional cost.

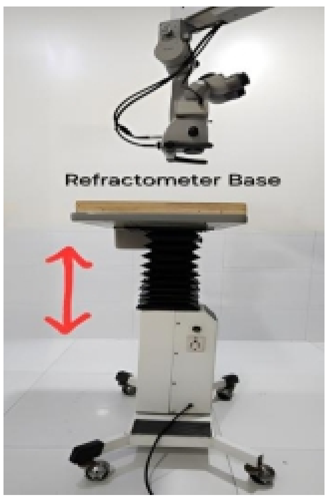


**Figure 3: Repurposed ophthalmic refracto-meter base used as adjustable support platform.**

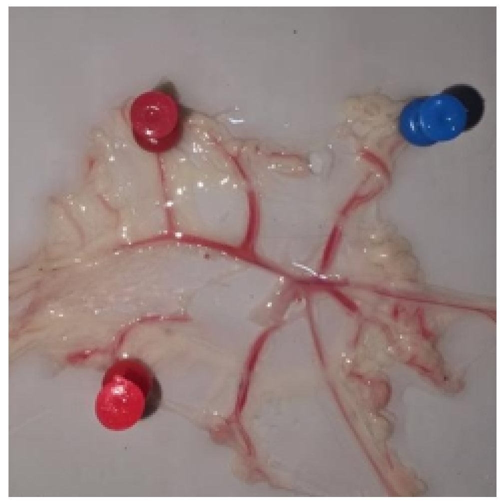

**Figure 4: Chicken mesentery model prepared for microsurgical training.**

**Figure 5: Simultaneous instructor-trainee visualization using digital output.**

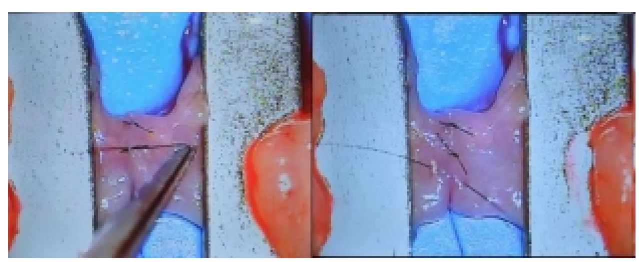

**Figure 6: Zoomed monitor image showing fine suture placement and tissue handling during microsurgical practice.**

**Training curriculum**

A structured five-stage curriculum was designed to allow progressive development of microsurgical skills, incorporating principles of graded complexity and repetitive practice [10,11].

**Stage 1: Microscope familiarization**

At the beginning of training, residents were introduced to basic microscope handling. Time was spent adjusting the eyepieces, getting comfortable with posture and hand positioning, and learning how to judge depth under magnification. Simple targeting and pick-up exercises were used so that trainees could develop steadier hand movements and better spatial orientation before moving on to suturing tasks.

**Stage 2: Inanimate suturing models**

Once the trainees were comfortable with the microscope, they practiced suturing on latex sheets and rolled glove segments. This helped them work on needle control, knot tying, spacing of sutures, and depth perception in a controlled setting. Because the models were inexpensive and easy to replace, residents were able to repeat the exercises many times and correct mistakes early without pressure [12].

**Stage 3: Chicken mesentery model**

Fresh chicken mesentery was used once the residents were comfortable with basic suturing. Fine mesenteric vessels, usually around 0.8–1.0 mm in diameter, were carefully dissected and prepared for end-to-end anastomosis. The thin and translucent tissue allowed good visualization under the microscope and behaved similarly to delicate biological vessels. This helped trainees learn gentle tissue handling and improve precision while suturing. Figure 4 shows pinned chicken mesentery with clearly visible fine vascular branches suitable for microdissection and suturing practice. The translucent tissue offers good visual clarity while maintaining biological realism. This stage allowed extensive repetition without ethical constraints and served as an effective intermediate step before live animal training [13].

**Stage 4: Live animal model**

After obtaining approval from the institutional animal ethics committee, rat femoral vessels were introduced for live practice. Residents performed both arterial and venous anastomoses under supervision. Patency was checked using the milking test and by observing distal filling. Working with pulsatile vessels exposed trainees to real-time bleeding control and tissue response, which helped bridge the gap between laboratory practice and clinical microsurgery [14,15].

**Stage 5: Supervised integrated practice using dual-view system**

In the final stage, residents carried out complete microsurgical tasks while the supervisor followed the procedure on the monitor. This allowed the instructor to comment and guide the trainee as the work was being done, without having to interrupt the session or take over the microscope. The continuous view made it easier to point out small technical errors and correct them early (Figure 5).

Figure 6 shows high-magnification view of the operative field displayed on the external monitor.. The image demonstrates precise needle placement, suture passage, and controlled tissue handling during microsurgical practice. Enhanced magnification allows clear visualization of tissue edges, suture alignment, and instrument tip control, supporting real-time instructor supervision and immediate feedback without interrupting the trainee's microscope access.

**Outcome assessment**

The outcomes were reviewed in a descriptive manner rather than through formal scoring. Attention was paid to how easy the system was to use during routine sessions, how stable the setup felt during fine movements, and whether the image quality was adequate for teaching. We also noted whether continuous supervision could be maintained without interrupting the trainee. Feedback from residents was obtained through informal structured discussions at the end of training sessions. These discussions focused on how comfortable they felt using the microscope, whether their confidence in performing microsurgical tasks had improved, and how they perceived their progress over time. Observations from the supervising faculty regarding ease of teaching and continuity of workflow were also recorded.

**Ethical considerations**

All participating residents provided written informed consent. Animal handling and surgical procedures were carried out in accordance with institutional animal ethics guidelines and relevant regulatory requirements. No clinical patient data were collected or used in this study.

**Results**

The modified dual-view microscope system functioned reliably throughout the training period and remained stable during repeated use. The optical clarity was adequate for fine microsurgical work, and the monitor display allowed the supervising faculty to observe the operative field continuously without interfering with the trainee's binocular view. Alignment of the optical components remained consistent after installation, and no major technical adjustments were required during routine sessions. Residents adapted quickly to the modified setup during the initial familiarization phase. Most trainees reported that basic microscope handling, posture adjustment, and depth perception became comfortable within the first few sessions. The ability to visualize the same field simultaneously allowed the instructor to correct hand positioning, instrument angulation, and working distance early, which reduced repeated errors during subsequent practice.

During inanimate model training, residents demonstrated improved confidence in needle handling and knot tying. Repetition on latex sheets and glove conduits allowed them to refine suture spacing and depth judgment without time pressure. Trainees were able to correct minor technical mistakes independently after receiving verbal guidance, and overall fluency in hand movements improved steadily over successive sessions.

Progression to the chicken mesentery model provided a noticeable increase in technical challenge. The fine caliber of the vessels and fragile tissue required careful handling and more precise needle placement. Residents initially took longer to complete anastomoses but gradually developed smoother movements and improved control. The translucent tissue allowed clear visualization of needle passage and suture placement, which facilitated self-correction. Many trainees felt that this stage closely resembled handling of delicate human tissues and served as an effective bridge between synthetic models and live tissue practice.

In the live animal stage, trainees were exposed to pulsatile vessels and active bleeding control. Early attempts required closer supervision, particularly for vessel alignment and tension control during suturing. With repeated practice, residents demonstrated better coordination and improved confidence in managing tissue response and maintaining luminal patency. The milking test provided immediate feedback on technical adequacy and reinforced the importance of precise suturing. The dual-view system played a central role during supervised integrated practice. Continuous visualization on the monitor allowed instructors to provide timely guidance without interrupting the workflow or exchanging eyepieces. Small technical errors, such as uneven bite depth, excessive tissue traction, or sub-optimal needle angles, were identified and corrected in real time. This uninterrupted supervision reduced procedural pauses and improved continuity of training sessions.

Feedback from residents indicated improved comfort with microscope ergonomics, better hand–eye coordination, and increased confidence in attempting microsurgical tasks. Trainees appreciated the stepwise structure of the curriculum and felt that the gradual increase in difficulty prevented early frustration. The chicken mesentery model was frequently highlighted as particularly useful for developing fine tissue handling skills. Supervising faculty reported improved efficiency of teaching compared with conventional single-head microscope training. The ability to observe the operative field continuously simplified instruction, reduced the need to physically intervene, and allowed more consistent feedback throughout each session. Overall, the modified system was considered practical, easy to maintain, and suitable for repeated training use within existing institutional resources.

**Discussion**

Microsurgical training continues to be challenging in many teaching institutions, largely because the infrastructure required for effective supervision is expensive and often shared among multiple departments. In routine training environments, the main limitation is not magnification itself, but the inability of the trainer and trainee to observe the operative field simultaneously when only a single-head microscope is available. In the present study, a nonfunctional single-head operating microscope was modified to create a dual-view teaching setup using a beam splitter and monitor output. During regular use, the system remained stable and practical, and it allowed continuous supervision without interrupting the trainee's workflow. This addressed a common educational gap using equipment that was already available within the institution.

The importance of shared visualization during microsurgical teaching has been discussed previously in the optics and surgical education literature. Cordero (2014) explained the role of beam splitters in operating microscopes and highlighted how a portion of the optical signal can be diverted to an assistant scope or camera without compromising the primary binocular view [16]. While this principle has traditionally been used in high-end microscopes, its application in low-cost educational setups has been limited. The present study demonstrates that the same optical concept can be adapted in a practical and affordable manner using repurposed equipment, thereby making dual-view supervision accessible in resource-constrained settings.

Digital visualization has also been explored as a teaching aid in microscopic surgery. Ilgner and Westhofen (2007) evaluated a high-definition stereoscopic video system attached to an operating microscope for training purposes and reported that digital visualization improved supervision and learner engagement when direct shared viewing was not feasible [17]. Although their system relied on advanced imaging hardware, the underlying goal was similar to ours improving real-time supervision and feedback. More recently, Chai *et al*. (2020) described the use of a low-cost digital microscope for maintaining microvascular skills outside formal laboratories, especially during periods when access to training facilities was limited [18]. Their work demonstrated that acceptable skill practice can occur even with simplified imaging systems.

Several groups have explored the use of smartphones and portable cameras to expand access to microsurgical practice outside formal laboratories. Johnson and Johnson (2024) demonstrated that a smartphone camera could be used as the microscopic field for basic microsurgical skills training, allowing trainees to practice fine suturing and receive visual feedback without reliance on a conventional operating microscope [19]. Their work highlighted the potential role of widely available consumer devices in supporting early skill acquisition when access to institutional facilities is limited. These findings support the broader concept that digital visualization can enhance accessibility and continuity of training. The present system differs in that it preserves true microscope ergonomics and optical characteristics while adding shared visualization for supervised teaching.

The staged training structure used in our program also aligns with established educational principles. Couceiro *et al*. (2015) described a microsurgical training pathway using two nonliving models to allow gradual skill acquisition before advancing to higher-fidelity tasks [20]. Their findings emphasized that early exposure to simple models helps reduce cognitive overload and improves confidence before progressing to more complex tissue handling. Mattar *et al*. (2021) evaluated a structured microsurgical training program and demonstrated that consistent supervision and progressive task difficulty were essential for sustained skill development [21]. In our experience, beginning with microscope familiarization and inanimate models, followed by chicken mesentery and then live animal work, allowed residents to build technical confidence in a logical sequence.

Live animal training remains an important component of advanced microsurgical education. Shurey *et al*. (2014) reviewed the role of rat models in microsurgery training and described their value in teaching vessel handling, bleeding control, and patency assessment [22]. At the same time, they highlighted ethical considerations and the need to use animal models judiciously. In the present study, restricting animal use to later stages of training helped optimize learning while limiting unnecessary animal exposure.

A major strength of the present work lies in combining a frugal technical innovation with a structured training pathway. Rather than replacing conventional microscopes or simulation laboratories, the system enhances existing resources and improves the quality of supervision during everyday training. This approach is particularly relevant for teaching hospitals where funding constraints often limit access to advanced equipment but where training demands remain high.

There are several limitations that should be acknowledged. The study relied primarily on descriptive observations and trainee feedback rather than formal objective scoring systems. The number of trainees and duration of exposure may differ between institutions, which may influence reproducibility of outcomes. Long-term transfer of skills to independent clinical microsurgery was not assessed. Future work should aim to incorporate validated assessment tools and multi-center evaluation to strengthen evidence for wider implementation.

## Conclusion

This study demonstrates that a functional dual-view microsurgical teaching system can be developed by repurposing an existing single-head operating microscope using simple optical and mechanical modifications. When integrated into a structured, stepwise training program, the system enabled continuous supervision, improved teaching efficiency, and supported progressive skill development without significant additional cost or infrastructure requirements. Rather than replacing conventional training platforms, this approach enhances existing resources and expands access to effective microsurgical education, particularly in institutions where dual-head microscopes are not readily available. By restoring shared visualization between trainee and instructor, the system addresses a practical barrier commonly encountered in routine training. The model is feasible, adaptable, and suitable for repeated use within standard institutional settings, and it offers a sustainable pathway for strengthening microsurgical training capacity in resource-limited environments.

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