PLASTIC RECONSTRUCTIVE & REGENERATIVE SURGERY

2024;2:57-63
DOI: 10.57604/PRRS-795

THE ROLE OF STRUCTURED TRAINING IN LEARNING MICROSURGERY: A NARRATIVE REVIEW

Marcello Molle[1], Simone La Padula[2]

[1] Multidisciplinary Department of Medical-Surgical and Dental Specialties, Plastic Surgery Unit, Università degli Studi della Campania "Luigi Vanvitelli", Naples, Italy; [2] Department of Plastic, Reconstructive, Aesthetic Surgery, Section of Plastic, Reconstructive, Aesthetic Surgery, Department of Public Health, Federico II University, Naples, Italy

Summary

Background and introduction. Microsurgery has transformed reconstructive surgery, offering superior aesthetic and functional outcomes, particularly in complex cases. Mastery of microsurgery is challenging due to the intricate nature of procedures and the precision required, leading to a steep learning curve. Various training methods, including traditional animal models and emerging synthetic alternatives, have been developed to enhance skill acquisition. Structured training programs, supported by national and international societies, are crucial for improving competency, with emphasis on both objective and subjective measures of performance.

Material and methods. This review utilized the PubMed database to analyze literature on microsurgery training, employing search terms like "Microsurgery" AND "training resident". After systematic filtering, 15 relevant articles were included, encompassing studies evaluating improvements in anastomosis time and patency rates, along with resident confidence.

Results. Key findings included a 2022 study revealing a 41% patency rate among 1.792 anastomoses performed by residents after a 7-month training course with Wistar rats. Training duration significantly influenced performance. A virtual training program in low-resource settings demonstrated improved confidence in microsurgical skills, although statistical significance was limited by sample size. An Italian study indicated that structured long-term training led to significant improvements in Global Rating Scale (GRS) scores and reduced procedure times.

Discussion and conclusions. The findings emphasize the effectiveness of structured, hands-on training in enhancing microsurgical skills. While remote training offers valuable introductory knowledge, in-person practice remains essential for developing the precision required in microsurgery. An integrated training approach combining both methods could improve global access to microsurgical education, equipping practitioners with necessary skills for success in the field. Overall, structured training enhances residents' confidence and technical competence.

Key words: microsurgery, training resident, learning curve

Received: September 20, 2024
Accepted: November 10, 2024

Correspondence

Marcello Molle
E-mail: marcello.molle@libero.it

How to cite this article: Molle M, La Padula S. The role of structured training in learning microsurgery: a narrative review. PRRS 2024;2:57-63. https://doi.org/10.57604/PRRS-795

INTRODUCTION

Microsurgery has revolutionized reconstructive surgery, delivering exceptional aesthetic and functional outcomes, especially in complex cases requiring meticulous tissue reconstruction. Since the advent of the first successful free flap procedure, microsurgery has established itself as the gold standard in reconstructive techniques. However, mastering this intricate field presents significant challenges due to the precision required and the delicate nature of the procedures involved. The small size of the anatomical structures being manipulated means that even minor errors can result in complications, creating a steep learning curve for aspiring microsurgeons [1].

To navigate these challenges, a variety of training approaches have emerged, each focusing on different models and techniques to facilitate skill acquisition. Historically, animal models have been the cornerstone of microsurgical training, offering students the opportunity to practice on living tissue that closely resembles human anatomy. However, ethical concerns and the demand for more accessible alternatives have prompted the development of synthetic models, which are both cost-effective and replicable. These synthetic models range from simple homemade solutions to sophisticated, realistic models created by specialized companies.

Microsurgical training requires a significant investment of time and commitment throughout a surgeon's residency. Various metrics have been proposed to assess microsurgical competency. Different residency programs have adopted methods such as the Intercollegiate Surgical Curriculum [2], which outlines the necessary depth of knowledge for surgical trainees, or the SMaRT (Stanford Microsurgery and Resident Training) Scale [3]. These approach aligns with established developmental frameworks, like the Dreyfus and Dreyfus model, which evaluates trainees' competencies before they progress to the next level of residency [4]. The "10,000-hour rule" [5] and the adage "practice makes perfect" are commonly cited in surgical training contexts, reinforcing the notion that deliberate and repetitive practice is essential to achieving a high level of proficiency in microsurgery.

Recognizing the importance of structured and standardized training, national and international microsurgery societies have established courses aimed at enhancing surgical education [1]. These courses, often organized into progressive levels of difficulty, have become critical components of a surgeon's training and professional credentials. In certain countries, such as Italy, the completion of these courses is a prerequisite for obtaining a specialist diploma in microsurgery [6]. Training typically begins with basic courses that utilize simple synthetic models (e.g., gauze or silicone tubes) [7-9], progresses to more complex cadaveric models (e.g., chicken legs), and culminates in advanced courses involving live models (e.g., rats or pigs) for practicing vascular anastomosis [10,11].

The primary objective of these training programs extends beyond refining the technical skills required for microsurgical procedures; they also aim to enhance the speed and confidence of learners in performing these tasks. Evaluating the impact of these courses involves both objective and subjective measures. Objective metrics may include the time taken to complete procedures, the patency rates of anastomoses, and the overall quality of tissue handling. In contrast, subjective measures assess learners' confidence and comfort levels with the techniques they are acquiring [12].

This review seeks to explore the existing literature on the effects of microsurgery training courses, focusing on both objective performance outcomes and subjective self-assessments by participants.

MATERIAL AND METHODS

In our search for literature related to the training of residents in microsurgery, we utilized the PubMed database, employing the following search terms: "microsurgery" AND "training resident" and "microsurgery" AND "learning curve". This comprehensive search resulted in a total of 904 articles.

Following this initial search, we systematically removed duplicates to ensure that our dataset consisted only of unique studies. Next, we conducted a careful review of the titles and abstracts of the remaining articles to identify those that aligned with our specific research criteria. This process allowed us to narrow down our selection to 15 articles that met our criteria for inclusion: these were prospective or retrospective studies that evaluated either improvements in the time and patency of microsurgical anastomoses or assessed the confidence of residents in performing these intricate procedures.

As part of our review process, we attempted to obtain the full texts of all identified articles. Unfortunately, we were unable to access the full text of two papers, which led to their exclusion from further consideration. Additionally, upon thorough examination of the remaining articles, we found that four did not meet our quality standards or relevance to our focus area and subsequently removed them from our review.

Given the small number of articles [13-21] that ultimately aligned with our research objectives, we concluded that a narrative review was the most appropriate approach to synthesize the available evidence.

RESULTS

A 2022 study [13] evaluated the improvement in performance during the execution of end-to-end and end-to-side anastomoses by 44 residents attending a 7-month course on Wistar strain rats, with the support of 2 tutors. Over the course, a total of 1792 anastomoses were performed, 1557 of which were end-to-end and 215 end-to-side, with an average patency rate (i.e., the vessels remained open) of 41%. This rate was independent of the residents' surgical specialty and experience level. The factor that most influenced the patency of the anastomoses was the duration of the training period. As training time increased, the time required to perform dissection and anastomosis decreased, resulting in improved performance. Additionally, technical mistakes were independently associated with thrombosis in the anastomoses.

A study published in February 2024 [14] by the Plastic Surgery Foundation's Surgery in Humanitarian Alliance for Reconstruction, Research, and Education (SHARE) examined confidence in performing specific microsurgical techniques after a remote training program. The program was designed primarily for practitioners from low-resource settings. The study involved 10 participants with varying levels of training, who were self-selected from the 2021-2022 SHARE Global Fellowship cohort. These participants, coming from low-resource environments, took part in a 1-day virtual course.

The training utilized low-cost microsurgical instruments, and a 1:1 instructor-to-participant ratio was maintained. Instructors were board-certified plastic surgeons with specialized training in microsurgery and at least 5 years of teaching experience.

Participants' confidence was assessed using the Likert scale, which ranges from 1 (not at all confident) to 5 (extremely confident), covering both theoretical and technical aspects. The theoretical aspects included the indication for using microsurgical flaps, selecting the appropriate flap, and patient care and monitoring. The technical aspects focused on performing anastomosis and managing microsurgery complications.

Post-course satisfaction with the learning objectives was notably high, with 60% of participants rating it as "very good" and 40% as "excellent". Participants also reported significant improvements in various microsurgical skills. Suture handling showed the highest improvement, with a Likert score of 4.60 ± 0.55. End-to-end anastomosis followed closely with 4.40 ± 0.55, while instrument selection, vessel preparation, and economy of motion each received a score of 4.20 ± 0.45. These results highlight the participants' strong satisfaction and perceived progress in key microsurgical techniques after completing the virtual course.

The most notable improvement was observed in performing anastomosis, with the Likert score increasing from 2.10 before the course to 3.20 after. However, this result was not statistically significant due to the small sample size of the study.

An Italian study tried [15] to standardize a long-term microsurgical training program for Orthopedics and Hand Surgery residents and to document the benefits gained through weekly practice on in vivo models. In 2016, a teaching protocol was approved, focusing on microsurgery with live Wistar rats. During the first three years of the program, students practiced to develop manual dexterity and confidence with microsurgical instruments on non-living models. They then progressed to ex vivo exercises on chicken leg models using microscopes or loupes. Finally, in vivo rat exercises were introduced for residents in the last two years, especially those pursuing a supplementary diploma in Hand Surgery.

The training outcomes were assessed using the Global Rating Scale (GRS) and the time required to complete each procedure. A two-tailed Student's t-test was used to compare the initial and final results, with a significance threshold of $p < 0.05$. Out of the thirty microsurgical sessions offered weekly, 8 residents completed the full microvascular training. The results showed a significant improvement in GRS scores, rising from an initial 15 ± 2 points to 21 ± 6 points at the end of the course ($p < 0.005$). The time required to complete an anastomosis also significantly improved, decreasing from an average of 31:18 ± 9:21 minutes at the start to 21:15 ± 6:10 minutes by the end ($p < 0.005$).

Ko et al. [16] implemented microvascular training curriculum for each third-year resident during their rotation on the hand and upper-extremity service. The training began with foundational skills in microvascular surgery using non-living models and then advanced to performing end-to-end arterial anastomoses on live rat femoral arteries in the second session. The outcomes were evaluated based on three key metrics: the GRS score, the successful achievement of vessel patency, and the time required to complete the procedures.

Of the twelve residents who completed the microvascular training curriculum, none had performed an arterial anastomosis prior to the course. Six of the residents did not feel knowledgeable or comfortable with microsurgery, while the others were only slightly comfortable and somewhat knowledgeable about the procedure. Interestingly, six of the twelve residents felt that their residency training in microsurgery had been adequate. Eight residents believed that microvascular training held the appropriate level of importance in their field, while four felt there should be more training.

Outcome evaluations revealed significant improvement in skills, as the mean GRS score increased from 15 ± 4 points initially to 20 ± 3 points at the end of the course ($p < 0.005$). Initially, eleven of the twelve residents achieved scores that rated the quality of their anastomosis as poor (n = 6) or moderate (n = 5). By the final assessment, nine residents achieved excellent quality, two performed with moderate quality, and only one was still rated as poor. Significant improvements, ranging from 18 to 28%, were noted across all five components of the GRS evaluation ($p < 0.02$).

The time to complete an end-to-end arterial anastomosis also improved dramatically, with the average time decreasing by 12:31 minutes – from 37:17 ± 8:41 minutes at the start to 24:46 ± 5:32 minutes at the final attempt ($p < 0.005$). Furthermore, the percentage of residents who successfully achieved a patent anastomosis increased substantially. While only half of the residents achieved a patent anastomosis during their initial attempt, by the end of the training, eleven out of twelve were able to perform a patent anastomosis successfully.

In a recent study examining [17] the impact of experience on surgical techniques, researchers divided fifteen surgeons into three groups based on their microsurgical expertise: novice, intermediate, and expert. Each surgeon performed a total of 20 anastomoses on synthetic polyvinyl alcohol vessels with a 2 mm diameter – 10 by hand and 10 with robotic assistance – in a controlled laboratory environment.

Outcome evaluations included the time taken to complete each procedure and the assessment of technical errors, such as backwall suturing and leakage. Demographic information was also collected to provide context for the findings. The results revealed statistically significant differences in manual anastomosis times, with the novice and intermediate groups performing slower than the expert group ($p < 0.01$). Interestingly, there was no significant difference in completion times between groups for robot-assisted anastomoses.

The study highlighted that novice surgeons exhibited the steepest learning curve when performing hand-sewn anastomoses. Conversely, experts demonstrated remarkable efficiency, completing the 10th robotic session in just 14 minutes, compared to 33 minutes at their second session. Notably, all groups managed to reduce their mean completion times by half over the course of the 10 robotic sessions.

In a retrospective, observational, analytic, and transversal study [18], Santamaria et al. aimed to evaluate the impact of a two-day course on attendees' perspectives toward reconstructive microsurgery. An 11-item survey was distributed to 1,513 participants who had completed at least 60% of the course attendance. The survey gathered data on various aspects of the attendees' experiences, and both descriptive and analytic statistical methods were employed to analyze the responses. The impact of the course was assessed through answers to specific questions related to its usefulness, the increase in interest in microsurgery, the desire to pursue a microsurgical career, attendance at in-person conferences, and the overall score of the event.

Out of the eligible participants, 1,111 (73.4%) completed the survey, with 55.8% identifying as plastic surgery residents. Remarkably, after attending the course, 98.9% expressed a desire to pursue a career in reconstructive microsurgery, indicating a significant positive impact on their career aspirations. However, it was noted that 45% of attendees planned to discontinue their attendance at in-person conferences. The overall satisfaction score for the event was high, averaging 9.06 ± 0.9 on a scale from 0 to 10, regardless of the respondents' current training status.

Velayos et al. [19] implemented a learning program consisted of basic, transitional, and experimental models designed to enhance surgical skills. The experimental model focused on several complex procedures, including tail vein cannulation, intestinal resection and anastomosis, as well as the dissection, division, and anastomosis of major blood vessels such as the inferior vena cava and aorta. Wistar rats were utilized for the training, with a demographic composition of 66.7% male and an average weight of 406.9 ± 38.9 grams. Importantly, the program adhered to the principles of the 3Rs (Replacement, Reduction, and Refinement) and received approval from the animal welfare committee, ensuring ethical compliance.

The results demonstrated varying times for the different surgical procedures. The mean time for tail vein cannulation was recorded at 2.4 ± 1.2 minutes. For intestinal resection followed by jejunocolic anastomosis, the mean times were 14.8 ± 2.7 minutes and 10.4 ± 3 minutes, respectively, with all anastomoses proving functionally valid. In terms of vascular procedures, the mean time for vessel dissection was 22.9 ± 7.7 minutes. Aortic artery anastomosis took an average of 17.2 ± 7.1 minutes, while vena cava anastomosis averaged 25.9 ± 7.3 minutes. Functionally, 66.7% of the vena cava anastomoses were deemed valid, compared to 88.9% for the aortic anastomoses.

An important observation was that the time required for all procedures generally decreased after the third attempt, indicating a learning effect. However, the time for vena cava anastomoses remained consistent across all nine procedures. These findings highlight the effectiveness of the learning program in improving surgical skills and procedural efficiency, particularly for more complex vascular anastomoses.

Cutaneat et al. [20] delivered a comprehensive training curriculum over a span of five days between 2017 and 2020, focusing on critical skills for microsurgery, including microscopic field manipulation, knot tying, nondominant hand usage, 3-D modeling and anastomosis, and hands-on tissue experience. To evaluate the effectiveness of the curriculum, the Kirkpatrick model was utilized, assessing four levels: (1) participants' feedback, (2) skills development using a validated objective assessment tool (the Global Assessment Score form) and CUSUM charts to track proficiency gains, (3) and (4) skill retention and long-term impact.

A total of 155 participants completed the curriculum, contributing to 5,425 hours of training. Feedback indicated high satisfaction, with over 75% of students rating the course as excellent and the remainder as good. Every participant affirmed that the curriculum met their expectations and expressed willingness to recommend it to others. Statistically significant improvements were observed in anastomosis attainment scores, with median scores rising from 4 on days 1 and 3 to 5 on days 4 and 5 ($W = 494.5$, $p = 0.00170$). Additionally, the frequency of errors decreased with successive attempts, as indicated by a chi-square value of 9.81 ($p = 0.00174$). Notably, the steepest learning curve was identified in the anastomosis and patency domains, requiring an average of 11 attempts to achieve proficiency.

The impact of the training was further highlighted by survey responses, with 88.5% of participants indicating they could effectively apply the skills learned, and 76.9% reporting that they had implemented these skills within six months following the course. The evaluation process identified key areas for improvement, prompting the implementation of targeted actions in subsequent programs to enhance the training experience further.

Chauhan et al. [21] focused on evaluating the effectiveness of a structured training curriculum for trainees in microsurgery, specifically the Fundamentals of Microsurgery Skills (FMS) curriculum. This curriculum included a series of progressively challenging tasks designed to enhance the technical skills necessary for successful microsurgical procedures. The tasks encompassed the following progression: (1) rubber band transfer, (2) coupler tine grasping, (3) glove laceration repair, (4) synthetic vessel anastomosis, and (5) vessel anastomosis in a deep cavity.

To assess the technical performance of resident anastomoses, evaluations were conducted in the operating room using the SMaRT tool. This evaluation tool provided a standardized measure to quantify the quality of the surgical skills demonstrated by the residents during actual patient care. Additionally, to gauge learner anxiety and workload during the training and surgical performance, two validated assessment tools were employed: the National Aeronautics and Space Administration Task Load Index (NASA-TLX) and the Short-Form Spielberger State-Trait Anxiety Inventory (STAI-6).

The results of the study revealed that a total of 62 anastomoses were performed by residents in the operating room. Notably, a higher completion rate of FMS tasks was associated with an increased mean SMaRT score ($p = 0.05$), indicating improved technical performance. Conversely, this higher task completion was also linked to a lower mean STAI-6 score, suggesting a decrease in performance anxiety ($p = 0.03$). Furthermore, regression analysis illustrated that residents achieving higher SMaRT scores exhibited lower NASA-TLX scores ($p < 0.01$), indicating a reduced mental workload, as well as lower STAI-6 scores ($p < 0.01$), underscoring reduced anxiety levels during performance.

DISCUSSION AND CONCLUSIONS

The results from these studies underscore the diverse approaches to microsurgical training, which carry significant implications for developing technical skills and broader applications in low-resource settings. Davis et al. [14] study demonstrated the effectiveness of a remote training program tailored for surgeons in under-resourced environments. Despite the inherent limitations of virtual instruction, participants reported notable improvements in their confidence, particularly regarding suturing and performing end-to-end anastomoses. The observed increases in Likert scale scores for specific technical skills highlight the potential of remote, low-cost educational methods to equip practitioners with fundamental microsurgical techniques. However, the lack of statistical significance – likely due to the small sample size – indicates a need for larger-scale studies to validate these findings more robustly.

Conversely, Lefevre et al. [13] provided valuable insights into the outcomes of in-person, long-term training, emphasizing the importance of prolonged hands-on experience. The Wistar rat-based training achieved a patency rate of 41% across 1,792 anastomoses, with results independent of the trainees' prior experience. Notably, the study identified training duration as the most influential factor in enhancing performance. As residents accumulated more exposure, their dissection and anastomosis times decreased, reflecting the value of repeated practice in achieving technical mastery. Additionally, technical errors were significantly associated with thrombosis, reinforcing the need for precision in microsurgical training.

D'Orio et al. [15] and Ko et al. [16] research further corroborate that structured, long-term programs enhance both GRS scores and procedural efficiency. The gradual

progression from non-living models to live rats in the Italian study led to significant increases in GRS scores and notable reductions in procedure times. Similarly, Ko et al.'s curriculum for third-year residents resulted in improved skill assessments and higher rates of vessel patency. The findings illustrate that initial discomfort with microsurgical techniques can be overcome through sustained training, as evidenced by the significant improvement in residents' GRS scores ($p < 0.005$) and the shift in anastomosis quality from poor to excellent for most participants.
Both studies emphasize the crucial role of hands-on, supervised practice with live models in developing competency in microsurgery. The consistent and cumulative training approach is evident across the reviewed studies, irrespective of whether the methodologies were remote or in-person. A key takeaway is that while virtual courses can effectively introduce surgeons to essential techniques, in-person practice remains indispensable for developing the precision and expertise required in microsurgery.
In conclusion, the reviewed studies highlight the effectiveness of structured, hands-on training alongside innovative remote training methodologies in enhancing microsurgical skills. Remote training provides valuable introductory knowledge and confidence, particularly for practitioners in low-resource settings, while in-person training with live models is essential for honing technical precision. An integrated approach that balances both training methods can significantly enhance global access to microsurgical education, ensuring that practitioners worldwide acquire the skills necessary to excel in the field.

Conflict of interest statement

The authors report no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

MM: A,D,S,W.
SL: A, O (revision and supervising)

Abbreviations

A: conceived and designed the analysis
D: collected the data
DT: contributed data or analysis tool
S: performed the analysis
W: wrote the paper
O: other contribution (specify contribution in more detail)

Ethical consideration

Not applicable.

References

1 Tang CQY, Seeli SB, Rugiero C, et al. International residents' perspectives on education and challenges in microsurgery training. J Hand Microsurg 2022;15:295-298. https://doi.org/10.1055/s-0042-1744211
2 Available at: https://www.iscp.ac.uk
3 Satterwhite T, Son J, Carey J, et al. The Stanford Microsurgery and Resident Training (SMaRT) Scale: validation of an on-line global rating scale for technical assessment. Ann Plast Surg 2014;72(Suppl 1):S84-S88. https://doi.org/10.1097/SAP.0000000000000139
4 Dreyfus SE, Dreyfus H. A five-stage model of the mental activities involved in directed skill acquisition. Distribution 1980;22.
5 Anders Ericsson K. Training history, deliberate practise and elite sports performance: an analysis in response to Tucker and Collins review – what makes champions? Br J Sports Med 2013;47:533-535. https://doi.org/10.1136/bjsports-2012-091767
6 Available at: https://www.microchirurgia.org/corsi-avanzati-di-microchirurgia
7 Sapino G, Gonvers S, Cherubino M, et al. Synthetic simulators for microsurgery training: a systematic review. Plast Reconstr Surg Glob Open 2024;12:E6004. https://doi.org/10.1097/GOX.0000000000006004
8 Avelar TM, Lovato RM, Barbosa TG, et al. Evaluation of konjac noodle as a microsurgery training model: learning curve analysis. Rev Col Bras Cir 2023;50:E20233528. https://doi.org/10.1590/0100-6991e-20233528-en
9 Bykanov A, Kiryushin M, Trube M, et al. A novel low-cost device for tool targeting training and microsurgical hand tremor assessment. Surg Neurol Int 2024;15:227. https://doi.org/10.25259/SNI_271_2024
10 Belykh E, Lei T, Safavi-Abbasi S, et al. Low-flow and high-flow neurosurgical bypass and anastomosis training models using human and bovine placental vessels: a histological analysis and validation study. J Neurosurg 2016;125:915-928. https://doi.org/10.3171/2015.8.JNS151346
11 Ceccato GHW, Foltran RS, Franke K, et al. Two-stage pulsatile human placenta model for microvascular anastomosis training in neurosurgery. World Neurosurg 2023;179:185-196.e1. https://doi.org/10.1016/j.wneu.2023.08.118
12 Carolan D, Milling R, Quinlan C, et al. Are plastic surgery trainees accurate assessors of their own microsurgical skill? JPRAS Open 2023;37:24-33. https://doi.org/10.1016/j.jpra.2023.04.004
13 Lefevre E, Ganau M, Zaed I, et al. Learning curve and influencing factors of performing microsurgical anastomosis: a laboratory prospective study. Neurosurg Rev 2022;45:3271-3280. https://doi.org/10.1007/s10143-022-01856-7
14 Davis GL, Abebe MW, Vyas RM, et al. Results of a pilot virtual microsurgery course for plastic surgeons in LMICs. Plast Reconstr Surg Glob Open 2024;12:E5582. https://doi.org/10.1097/GOX.0000000000005582
15 D'Orio M, Passiatore M, Caruso L, et al. Outcomes of a long-terms microvascular training for residents in orthopedic. Georgian Med News 2022:38-41.

16 Ko JW, Lorzano A, Mirarchi AJ. Effectiveness of a microvascular surgery training curriculum for orthopaedic surgery residents. J Bone Joint Surg Am 2015;97:950-955. https://doi.org/10.2106/JBJS.N.00854

17 Frieberg H, Winter JM, Engström O, et al. Robot-Assisted Microsurgery-what does the learning curve look like? JPRAS Open 2024;42:33-41. https://doi.org/10.1016/j.jpra.2024.07.009

18 Santamaría E, Nahás-Combina L, Altamirano-Arcos C, et al. Master series microsurgery for residents: results from a comprehensive survey of a multitudinous online course during COVID-19 pandemic. J Reconstr Microsurg 2021;37:602-607. https://doi.org/10.1055/s-0041-1723822

19 Velayos M, Estefanía-Fernández K, Fernández Bautista AJ, et al. Towards a standardized initial training program in experimental microsurgery for pediatric surgeons. Hacia un programa inicial de formación estandarizadoen microcirugía experimental para cirujanos pediátricos. Cir Pediatr 2023;36:83-89. https://doi.org/10.54847/cp.2023.02.16

20 Cuteanu A, Hellich A, Cardinal AL, et al. Evaluation of a microsurgery training curriculum. J Reconstr Microsurg 2023;39:589-600. https://doi.org/10.1055/a-2003-7689

21 Chauhan R, Ingersol C, Wooden WA, et al. Fundamentals of microsurgery: a novel simulation curriculum based on validated laparoscopic education approaches. J Reconstr Microsurg 2023;39:517-525. https://doi.org/10.1055/a-2003-7425