

An Innovative Model for Microsurgical Training at a Spine Surgery Center in Mexico City

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ABSTRACT

Objective: Microsurgery is an advanced surgical procedure which requires advanced skills and techniques. These skills and techniques can generally be learned, practiced, replicated, improved, and evaluated. The majority of models and training pads in microsurgery have been reported to be used in fields other than spine surgery. This study was designed to develop and evaluate a portable, reusable and economical microsurgery training model that can be used by spinal surgery trainees in order to learn basic skills and gain self-confidence within microsurgery.

Methods: We developed a simulation training program that was implemented at a spine surgery center in Mexico City. The study involved six residents from the center who volunteered to participate in a 5-day assessment before and after the implementation of our model. The students were instructed in a simulation of laminectomy and repair of the dura mater during their training. A 5-point Likert scale was used to determine the level of confidence of surgical trainees in performing laminectomy and dural repair using microsurgical technique (where 1 represents no confidence and 5 represents excellent confidence). Five experienced spinal surgeons evaluated trainees blindly using the Stanford Microsurgery and Resident Training (SMaRT) scale. There are nine categories in the SMaRT scale, each of which is graded on a 5-point Likert scale. Results from quantitative and categorical data were analyzed using Student's t-tests and two-sample tests of proportions.

Results: The residents evaluated were aged 31 ± 1.4 years. None of them had previously undergone microsurgery. Training took an average of 4.75 hours. All participants were unable to complete the exercise before the training model, but all completed it afterward, with a mean time of 22.3 minutes. The median self-confidence score of surgical trainees increased from 1.5 to 3.5 after the exercise ($P = 0.026$). After the dural repair exercise, the participants completed an average of 5 ± 0 stitches, which was significantly higher than their initial average of 0.5 ± 0.8 stitches ($P < 0.001$). The SMaRT score increased from 13.7 to 28.3 after training ($P = 0.0001$).

Conclusion: Training with simulated models can standardize skills and increase confidence. With the training model proposed in the study, participants are able to develop the skills necessary to perform spine microsurgery. A further study is needed to establish the validity of our training model for spine microsurgery.

INTRODUCTION

Microsurgery has become a significant component of several surgical specialties [1]. As a complex surgical procedure, microsurgery requires highly advanced skills that can be taught, reproduced, improved, and assessed [2,3]. A traditional approach to microsurgery training is based on the Halsted model, which emphasizes the need for residents to repeatedly undergo surgery under the supervision of experienced surgeons to become proficient in performing operations [1,4]. However, the ethical concern for patient safety along with the reduction in surgical procedures resulting from the COVID-19 pandemic results in an insufficient number of trainees being exposed to surgical procedures. The training and attainment of skills in both basic and advanced surgical techniques are therefore highly limited [5-8].

The need for microsurgical skill development, teaching, and maintenance has compelled surgical training centers to implement innovative training strategies that provide a secure, controlled, and effective learning environment. A wide variety of training models have been developed, but most of them have examined areas other than spine surgery, for exam-

ple, gauze exercises to improve revascularization techniques, mannequin heads with small balloons to improve deep microsurgical skills in neurosurgery, silastic tubes and chicken wings arteries for performing anastomosis, and the chicken egg and skull model to support endoscopy using the endonasal transsphenoidal approach [9-11].

Therefore, the authors developed a simulation training model in which spinal surgical trainees can acquire and enhance basic microsurgery skills during the training process, as well as enhance their self-confidence as they take part in the training process. This study aims to evaluate the effectiveness of this model for training in spinal microsurgery.

METHODS

During the study, we evaluated residents from a spine surgery center in Mexico City. In the exercise, the participant was required to complete a laminectomy with a high-speed burr and repair the dura with five 10-0 nylon stitches within a time limit of 30 minutes. A performance evaluation of the participant was conducted prior to and five days after the exercise.

We used a 5-point Likert scale to assess the level of confidence among

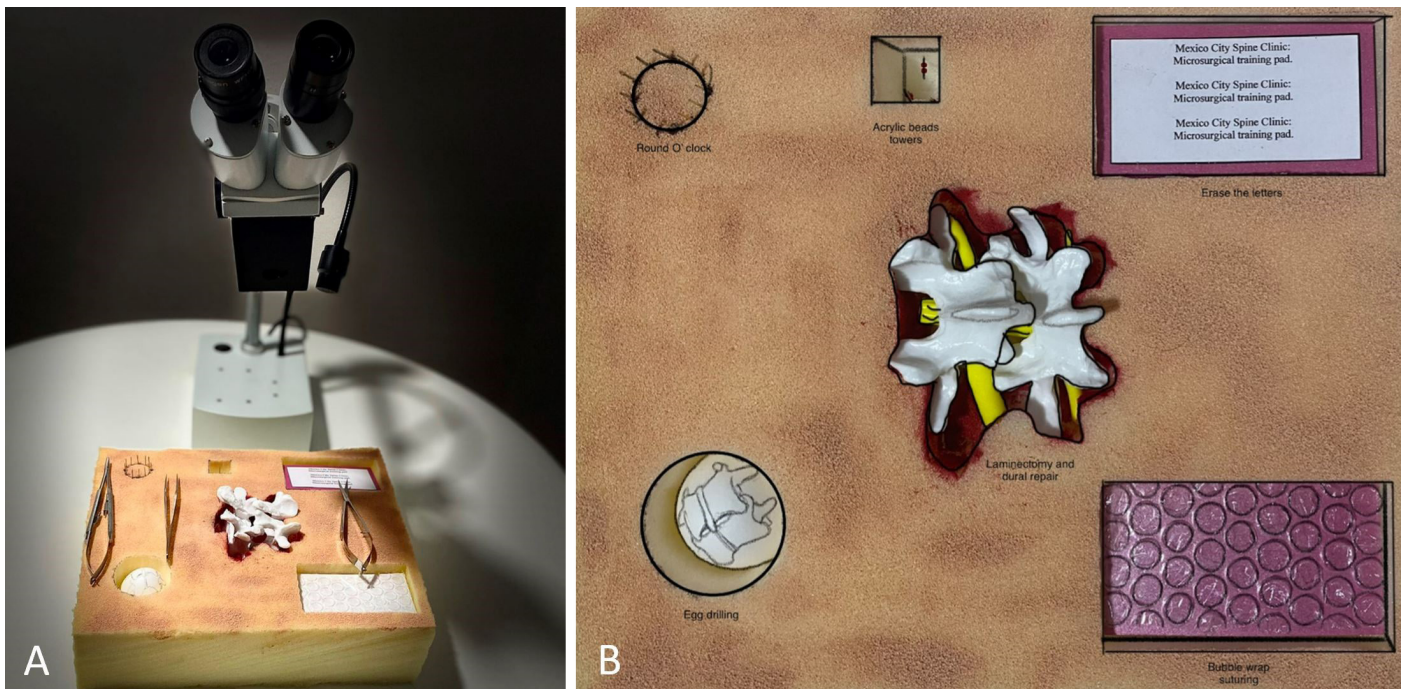


Figure 1. Arrangement of the microscope, instruments, and basic exercises. (A) Microscope and microsurgical training pad equipped with basic microsurgical instruments, including micro scissors, dissection forceps, and a microsurgical needle holder. (B) A single training pad can accommodate six different exercises, allowing trainees to practice with both hands to simulate the patient's back, and to practice fine movements only using the wrist and fingers to reduce physiological tremor.

surgical trainees regarding performing laminectomy and dural repair using microsurgical technique (with 1 being no confidence and 5 being an excellent level of confidence). The study defined previous surgical experience as performing at least five microsurgical procedures as the primary surgeon (i.e., performing more than 80% of all procedures) [12].

The video recordings of the exercises were taken and examined by five experienced spine surgeons who are professors at the Spine Surgery Course and members of the Mexican Association of Spine Surgeons. The Stanford Microsurgery and Resident Training (SMaRT) rating scale was used to evaluate the performance of the participants in this study [13]. Based on the SMaRT scale, nine categories were evaluated on a Likert scale of 1 to 5. These categories include instrument handling, respect for tissue, efficiency, suture handling, suturing technique, quality of knot, final product, operation flow and overall performance. We blinded the evaluators by concealing information about both the participants and the timing of the study (before or after the training).

Step-by-step Instructions for Each Exercise

There were five basic exercises and a final exercise performed on a 30 x 30 x 7 cm foam pad with a stereomicroscope (Zeigen™, Mexico City). There was a 10x magnification on the objective, and the working distance between the objective and the objective lens was 30 cm (12 inches). Figure 1 shows the microscope, the instruments, and basic exercises placed in the proper arrangement, as they should be used. The final activity served as an evaluation exercise because it allowed the skills developed in the previous exercises to be incorporated into the final one.

Round the clock

We arranged sewing needles of normal size in a circular pattern to form a circle with a diameter of 3.4 cm. The 10-0 suture was tied at 12:00 o'clock as the starting point and passed through the sewing needle holes clockwise and counterclockwise (Figure 2A) [13].

Three towers

There was a cubic space measuring 2 x 2 x 4 cm, containing two parallel needles arranged vertically and a third needle arranged horizontally. Ten acrylic beads were placed on one of the needles. During the training, the trainees were required to move the 10 beads from one needle to another (Figure 2B).

Erasing letters

In a cardboard card printed in Arial 12 font and measuring 9 x 5 cm, the caption reads "Mexico City Spine Clinic: Microsurgical training pad". The trainee had to use a needle to erase the letters without damaging the cardboard that surrounds the letters (Figure 2C) [14].

Bubble wrap cutting and suturing

The trainee was presented with a cardboard card measuring 9 x 5 cm, enclosed with bubble wrap measuring 1 cm in diameter. The trainee was instructed to cut the bubble wrap with micro scissors and suture it with simple (interrupted), continuous, or anchored stitches (Figures 2D-E) [15].

Eggshell drilling

An eggshell was positioned in a 4 x 4 x 6 cm space. The image of a vertebra was then drawn on the eggshell. The eggshell should be drilled using a high-speed microsurgical drill (32,000 revolutions per minute) along the edges of the vertebra on the eggshell without rupturing the membrane (Figure 2F).

Final activity

This step involved the simulation of laminectomy and duraplasty in order to evaluate the performance of incorporated skills which were developed in the earlier exercises. An anatomical model of vertebrae was made of polyvinyl chloride with a silicone pad in the middle. The laminectomy was simulated using a microsurgical drill, followed by simulated dura repairs completed with 10-0 nylon interrupted stitches (Figure 3).

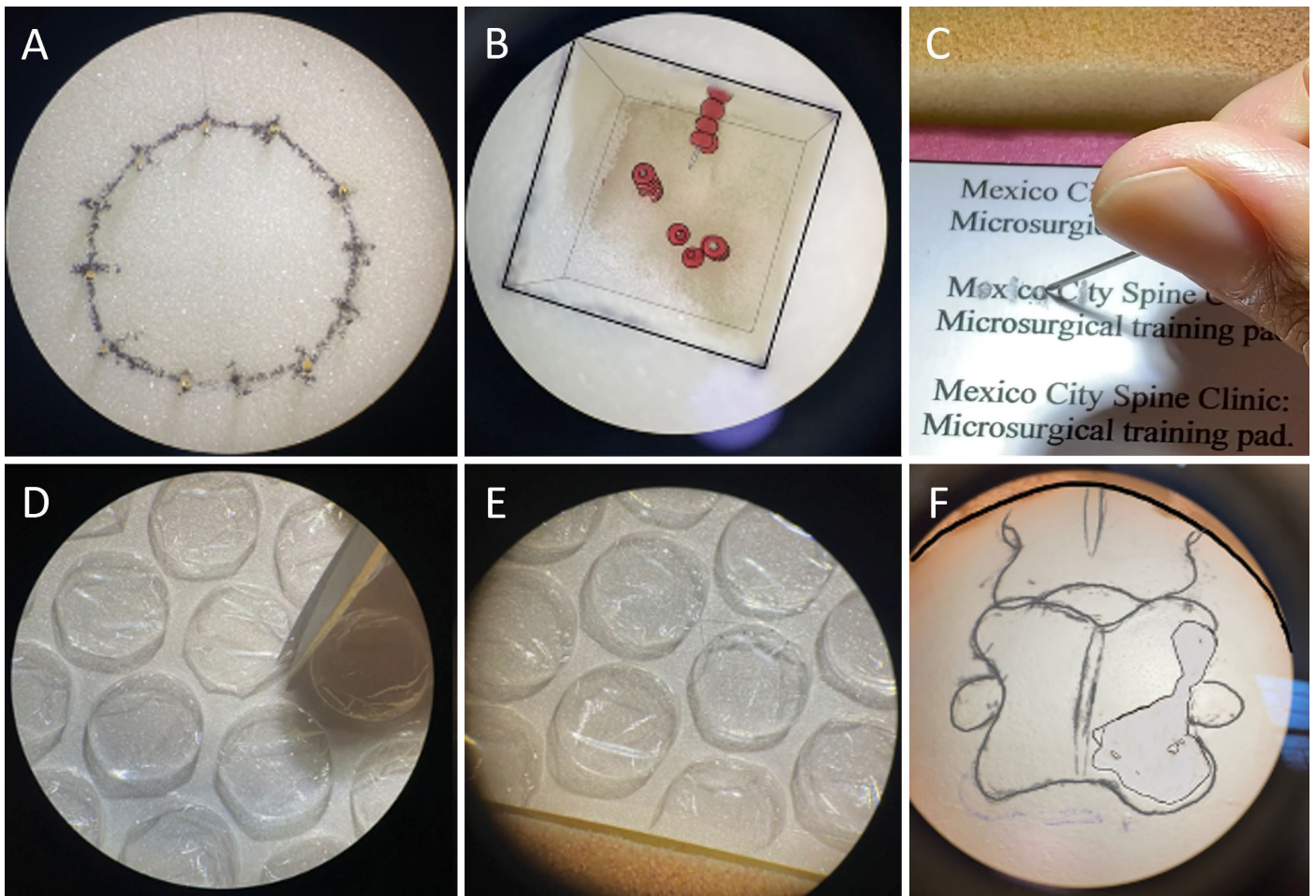


Figure 2. A step-by-step description of each exercise. (A) Round the clock. The needles are arranged in a circular pattern to create a circle with 3.4 cm (1.33 inches) diameter. In this procedure, the first suture is tied at 12:00 o'clock as the starting point, followed by the sutures passing through the sewing needle holes clockwise and counterclockwise. (B) Three towers. In a cubic space measuring 2 x 2 x 4 cm, two parallel needles are arranged vertically, and a third needle is arranged horizontally. A total of ten acrylic beads are placed on one needle. Participants in the training session are required to move ten beads from one needle to another. (C) Erasing the letters. The card measures 9 x 5 cm and has a caption in Arial 12 that reads "Mexico City Spine Clinic: Microsurgical training pad". In this exercise, the trainee is required to erase the letters using a needle without damaging the cardboard that surrounds them. (D) Bubble wrap cutting. Each trainee receives a cardboard card measuring 9 x 5 cm, enclosed in bubble wrap measuring 1 cm in diameter. The trainee is required to cut the bubble wrap using micro scissors. (E) Bubble wrap suturing. The trainee is then instructed to suture the bubble wrap either with simple (interrupted), continuous, or anchored stitches after cutting it. (F) Eggshell drilling. During the process, a shelled egg is placed in a space that measures 4 x 4 x 6 cm. An image of a vertebra is then drawn on the eggshell. Using a high-speed microsurgical drill (32,000 revolutions per minute), the edge of the vertebra on the eggshell is drilled through without causing any damage to the membrane.

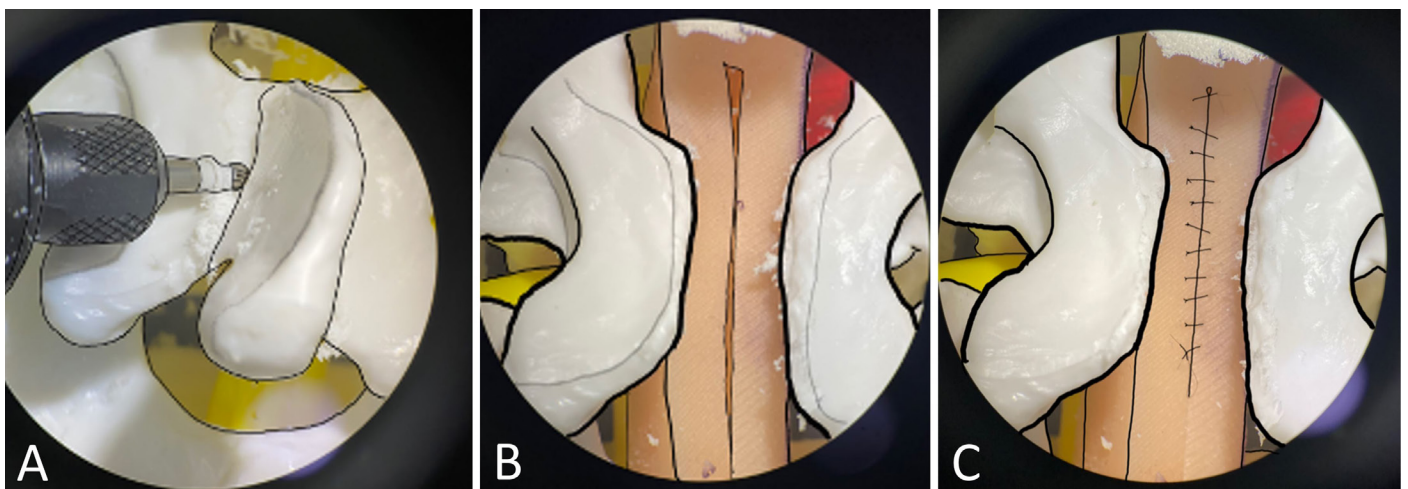


Figure 3. A final activity is used to assess all the earlier skills. (A) With the assistance of a microsurgical drill, a simulated laminectomy is performed. (B) Simulation of laminectomy with silicone pad exposure. (C) Simulated dura repair with interrupted stitches.

Table 1. A Comparison of SMaRT Scores Before and After Training

Category	Before training	After training	P value
Instruments handling, mean (SD)	1.9 (0.6)	3.3 (0.2)	0.0030
Respect for tissue, mean (SD)	1.6 (0.3)	3.1 (0.3)	0.0008
Efficiency, mean (SD)	1.5 (0.3)	3.1 (0.5)	0.0007
Suture handling, mean (SD)	1.4 (0.2)	3.1 (0.5)	0.0000
Suturing technique, mean (SD)	1.5 (0.5)	3.2 (0.5)	0.0007
Quality of knot, mean (SD)	1.5 (0.5)	3.1 (0.3)	0.0012
Final product, mean (SD)	1.5 (0.5)	3.2 (0.3)	0.0018
Operation flow, mean (SD)	1.4 (0.4)	3.0 (0.4)	0.0001
Overall performance, mean (SD)	1.3 (0.3)	3.1 (0.4)	0.0001
Total score, mean (SD)	13.7 (3)	28.3 (1.2)	0.0001

SD, standard deviation; SMaRT, Stanford Microsurgery and Resident Training Scale.

Statistical Analysis

We reported parametric quantitative variables with the means and standard deviations, and categorical variables with the frequency and percentage. Non-parametric, quantitative variables were expressed as medians and interquartile ranges. The participants were categorized based on their age, previous training experience, exercise duration, and training hours. Students' t-tests were used to analyze quantitative data, and an immediate form of the two-samples test of proportions was used to analyze categorical data. A Wilcoxon Signed Rank test was used to compare the magnitude of the quantitative variables before and after the intervention. The interobserver agreement was measured with Cohen's kappa. Statistical analyses were conducted with Stata 14 (Stata Corporation, TX 77845, USA).

RESULTS

The average age of the six residents evaluated was 31 ± 1.4 years. None of these residents had any previous experience performing microsurgery. An average of 4.75 ± 0.9 hours was devoted to the training program by each participant.

After the training model was implemented, 100% of the participants completed the exercise within their maximum time limit of 30 minutes, compared to 0% of participants before the training model, with a mean time of 22.3 minutes.

According to the self-confidence scale used for surgical trainees, a median rating of 1.5 was reported before the exercise; however, after the exercise the median rating was 3.5 ($P = 0.026$).

As a result of the dural repair exercise, the participants completed an average of 5 ± 0 stitches, which is significantly higher than the average of 0.5 ± 0.8 stitches they completed before the exercise ($P < 0.001$). According to Table 1, the SMaRT scores improved from 13.7 to 28.3 before and after the training process ($P = 0.0001$).

DISCUSSION

Microsurgery is an extremely specialized field that requires a high level of skill and knowledge. These skills include microdissection, handling instruments and tissues, adaptation to microscopic vision, and the coordinated use of the hand and eye. A wide variety of training methods may be used in microsurgery training programs, including animals, virtual models, and

artificial models [1,9]. These types of programs provide trainees with the opportunity to become familiar with basic surgical techniques in a laboratory environment before applying that knowledge to actual patients in the operating room [2].

In this study, we seek to design a training program through a simulation training model, which would enable spinal surgery trainees to acquire early experience with microsurgery as well as improve their confidence. Following completion of the training, the participants demonstrated significant improvements in the time required to complete the exercise, the number of knots successfully tied, and the items assessed on SMaRT scales, as well as the participants' perceptions of their confidence as a result of the training. In the present study, a 5-day microsurgery training program was implemented based on previous studies [2-4,9,12-15]. Nevertheless, there has not yet been a consensus regarding the ideal duration of a microsurgery course.

Due to the ethical issues associated with animal models, and the fact that virtual models are currently expensive and not widely accessible, artificial models are highly appealing since they do not have these disadvantages [1,2,10]. In one study, the use of animal models was reduced on the first day of training when an artificial model was used, while on the third day of training, the number of patent anastomoses increased [2]. In the present study, an innovative training pad was developed which has the potential of being widely available as well as affordable. In addition, a key benefit of this model is that it features a sponge surface that allows us to include six different exercises (Figure 1). It is therefore possible for trainees to place both hands on the pad to simulate a patient's back and to reproduce fine movements using only their wrists and fingers, thereby decreasing physiological tremor [16].

Handling sutures is one of the first challenges trainees encounter in microsurgery. Considering this issue, it has been recommended that the first exercises be focused on handling instruments and sutures (under control, in single passes, never grasp the needle tip, pull the needle out on a curve). Our simulation model began with a validated exercise called "round the clock", which enables trainees to become familiar with the use of microsutures [17]. The "three towers" exercise was specifically designed to improve movement in a restricted space with varying depths and directions [16]. In the next exercise, trainees erased letters, which was intended to teach them how to handle tissue in a careful, appropriate, and safe manner while causing the least amount of damage to it [14]. A bubble wrap suturing procedure involved cutting, dissecting, and suturing. It was initially intended to simulate arachnoids and blood vessels [10,15]. The model used egg shield

drilling as a prelude to the last activity, which was simulation of laminectomy and duraplasty. Egg shield drilling was initially described as a way to simulate the delicate membrane in the transsphenoidal approach [11,16].

Study Limitations

It has been argued that trainee performance should be monitored immediately after training as well as after a certain period of time, in order to measure retention over time [12]. The main reason for this is that practice alternating with periods of rest (distributed practice) creates a constructive environment in which skills are acquired as well as retained more effectively than practice delivered continuously (massed practice). This study, however, did not examine the effects of training immediately following training, which constituted one of its limitations. A further limitation was that only a pre- and post-evaluation was conducted following the five consecutive days of practice (mass practice), thus the gradual efficacy of the training could not be measured.

Models may be validated in a variety of ways, including content validity (the ability to measure a specific skill), construct validity (the test is designed to assess the skill level for which it was designed), concurrent validity (the model produces the same results as the gold standard) and predictive validity (the model can produce the same results in the operating room) [1,9,13]. In this study, a blind evaluation was presented with both content and construct validity. However, the study was unable to assess concurrent validity because there has not been a gold standard for microsurgical practice in the field of spine surgery. There is also a need for further studies to assess the retention of acquired skills and the predictive validity of the results [1,4,9].

CONCLUSION

The proposed training model provides a unique opportunity for trainees to acquire and develop advanced skills related to spine microsurgery, which are required in the clinical practice of the specialty. A training program with artificial models allows for the standardization of skills and the improvement of confidence through a consistent training approach. Further research is necessary to develop new and validated training models for spine microsurgery.

ARTICLE INFORMATION

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