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Microsurgical Simulation. An Educational Strategy to Improve the Learning Curve Based on a Simulation Model

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Abstract

Background: Microsurgery requires significant precision and skills. Simulation is a useful tool for the development of skills and abilities and is part of resident's education and training programs. Several evaluation measures have been developed to assess the learning curve and skills learned in the simulation. The OSATS scale is a tool that can be implemented in microsurgery to measure skills and the learning curve. This ability cannot be achieved through observation, because it takes a lot of skill and experience. **Material and Methods:** Prospective study, experimental, single-blind, including 28 residents who were evaluated for 4 weeks on a voluntary basis. Fourteen students were randomly divided into an experimental group and 14 students into a control group. The study evaluated the average time to perform a microsurgical anastomosis, using the OSATS scale at the beginning of the study and at the end to get the results. **Results:** The average initial time to perform microsurgical anastomosis in the experimental group was 19 minutes and an average score of 6.8 points on the OSATS scale was obtained. The control group performed an average time of 21 minutes and a score of 6.3 points on the OSATS scale ($p > 0.05$). After performing the training in the simulation microsurgery model, the experimental group and the control group were compared, finding a reduction in the final average time of 12 minutes to perform a microsurgical anastomosis and a score of 17 points on the OSATS scale; comparing the control group, the average time was 19 minutes and a score of 7 points on the OSATS scale ($p > 0.05$). **Discusion:** A statistically significant difference was found in the experimental group in the evaluated parameters: average time for microsurgical anastomosis, tissue manipulation, dexterity movements, use of equipment, and microsurgical planning; however, no statistically significant difference was found for the knowledge of the steps to follow during the microsurgical procedure. When comparing the studies where simulation is implemented for the residents, an improvement in the learning curve and positive results for medical training were observed. **Conclusion:** The implementation of simulation models for residents in training is a feasible and efficient tool to generate confidence in microsurgical skills. Residents develop skills and aptitudes in microsurgical training by decreasing the time and improving the learning curve in microsurgical techniques. It is important to highlight the importance of reducing economic costs in training materials, which is possible with the proposal presented in comparison with other models found in international literature.

Keywords

Simulation, Microsurgery, Learning Curve, Resident Education, Microsurgical Training

1. Introduction

Microsurgery is an integral component of different surgical specialties and requires specific technical skills that are acquired through structured training. Learning these skills involves overcoming a learning curve. Training methods in microsurgery vary among countries; however, it remains essential for a broad range of reconstructive procedures [1].

Simulation has long been a tool in surgical education to assist in developing surgical skills in risk-free environments, allowing for standardized teaching [2]. Evidence shows that skills learned in simulation translate into improved performance in the operating room, offering a solution for mastering the technical demands of microsurgery [3].

Several simulation models for high- and low-fidelity microsurgical practice have demonstrated successful skill acquisition among residents. While the use of such models varies across training programs, microsurgical simulation has become an essential component of reconstructive surgery training [4].

Microsurgery training requires time and dedication throughout residency [5]. Numerous validated assessment scales exist to determine the learning curve and the skills obtained through simulation. With increasing interest in microsurgical simulation, it is essential to have tools that allow trainees to reach specific performance levels required for clinical procedures [6]. Assessment tools must be practical, reproducible, objective, valid, and reliable to be considered standard [7]. As simulators become widely accepted, national and international standardization of skill-assessment techniques will be necessary [6].

The Objective Structured Assessment of Technical Skill (OSATS) meets these characteristics and is a useful tool for assessing skill acquisition in microsurgical simulation [8].

This study analyzed the improvement in the learning curve of residents from plastic surgery, otorhinolaryngology, ophthalmology, and neurosurgery, as well as the time required to perform a vascular anastomosis and verify vessel patency. Our objective was to determine whether simulation models serve as a useful educational application in microsurgical training.

2. Materials and Methods

2.1. Study Design and Investigation Methods

This prospective, single-blind experimental study was approved by the Ethics and Research Committee at the Hospital Central Sur de Alta Especialidad (HCSAE) (resolution number 39 - 23). Single-blind refers to the fact that the evaluators (two microsurgeons with more than 10 years of experience) were blinded to group allocation, while participants were aware of their assigned group. All participants provided informed consent.

A total of 32 residents from surgical specialties volunteered to participate; 28 completed the full 4-week training program and were included in the final analysis (Figure 1). Residents were randomized into an experimental group (n = 14) and a control group (n = 14). Two-person teams in each group performed exercises twice a week for 3 hours over four modules (4 weeks).

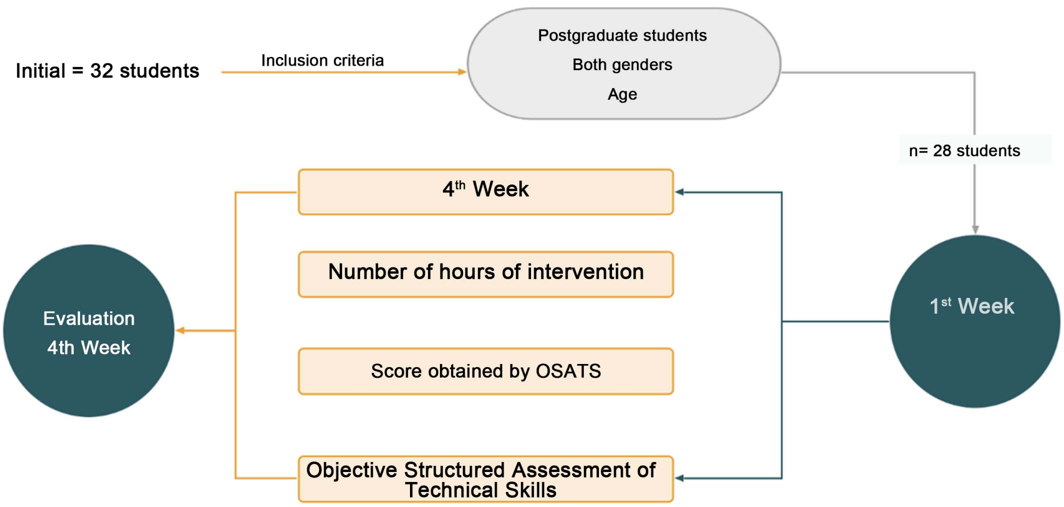

Figure 1. Study design.

Fourteen students were randomly divided into an experimental group and fourteen students into a control group. Two person teams per group were formed and performed exercises 2 times a week for 3 hours. The primary focus was on basic skills and progressed through a maximum of 4 modules (4 weeks), divided into sessions to achieve microsurgical anastomosis. Prior to each assignment, residents were asked to watch a video from the Department of Plastic and Reconstructive Surgery on the basics of microsurgical suturing. Photographs were taken before and after each session and the resident's performance was recorded (Figure 2).

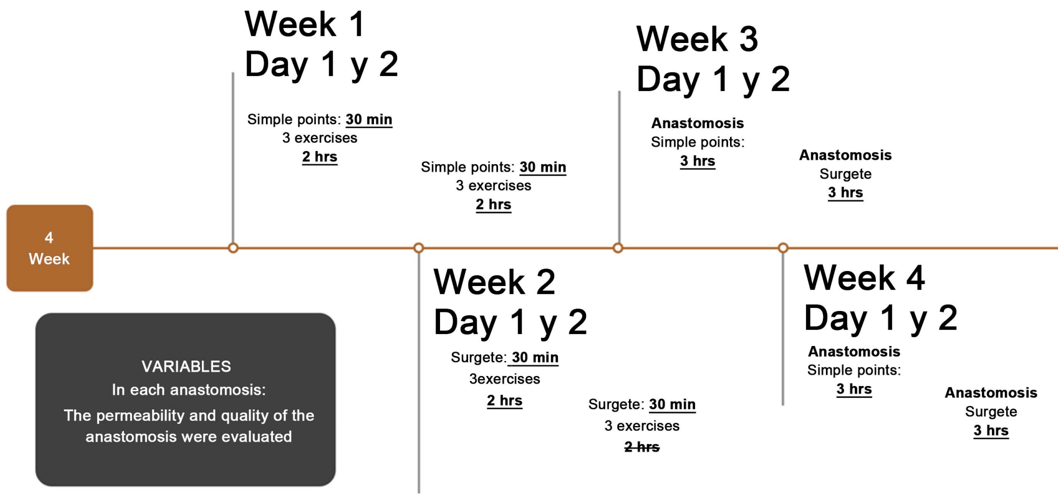

Figure 2. Program distribution.

Experimental and control groups

The experimental group received direct supervision and immediate feedback from two experienced microsurgeons during each session.

The control group performed the same exercises, with access to the same videos, materials, microscopes, and simulation models as the experimental group.

The only difference was the absence of direct, real-time supervision.

2.2. Microscope Setup

A Zeiss Universal OPMI microscope was used for the study (Figure 3). The microscope allows viewing the resident in a 5X field, at a distance of 25 cm. This setup was replicated for each test and session.

Figure 3. Zeiss universal OPMI microscope.

2.3. Latex Model

In the first two modules a 3 mm high fidelity latex strip recommended by the IMSS (International Microsurgery Simulation Society) was used [9]. To perform simple stitches and continuous surging during the first module. For the second module, anastomosis was performed starting with the posterior wall with simple stitches and completing a total of 8 stitches.

2.4. Anatomosis Model

For the third and fourth modules, a higher fidelity biological model was used. The chicken thigh has proven to be an effective training model for learning microsurgical motor skills, making it an attractive model for simulation when dissecting vascular structures [10]. In the third module, simple stitches and continuous suture techniques were performed, and in the fourth module, terminoterminal anastomosis was performed, both techniques were performed with 10-0 nonabsorbable suture (**Figure 4**).

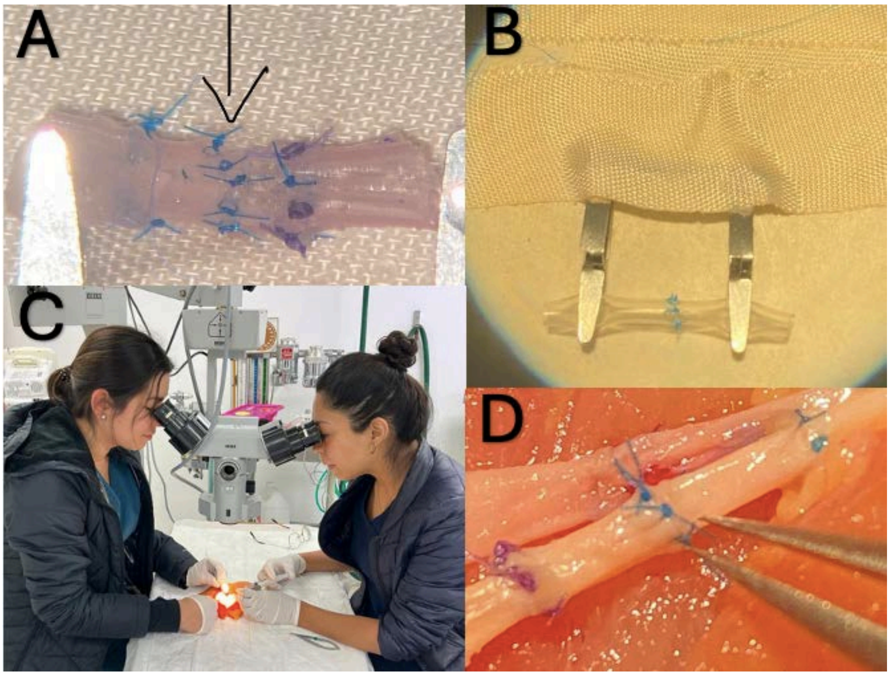

Figure 4. (A) Plastic surgery residents performing simulation. (B) Testing on silastic material. (C) Anterior and posterior wall anastomosis on simulation model. (D) Evaluation on chicken thigh.

2.5. Resident Evaluation

Two plastic surgeons with more than 10 years of experience in microsurgery evaluated and rated the photographs and video recordings of all volunteer residents. The study evaluated the average time to perform a microsurgical anastomosis, as well as tissue manipulation, dexterity movements, proper use of instruments, microsurgical planning, knowledge of the steps to be followed during the procedure, and the OSATS scale was used at the beginning and end of the study to get the results. The sessions were recorded and monitored by the author. After each session the experimental group received a commentary by the expert surgeons, in addition to reviewing a summary of their performance and results on the simulator.

2.6. Statistical Analysis

Data were summarized as measures of central tendency and dispersion, average (standard deviation), medians (interquartile range) or number of patients (percentages). For qualitative variables, the Chi-square test or Fisher's exact test was used; for continuous variables, depending on the distribution, the Student's t test or the Mann-Whitney U test for two samples was used. A bilateral p value < 0.05 was taken as statistically significant. All statistical analyses were performed with SPSS software version 26.0 for Windows (SPSS Inc. Chicago, IL, USA).

3. Results

3.1. Statistical Evaluation

A total of 28 residents were evaluated for 4 weeks on the microsurgical simulator. Thirty-two residents started the simulation, but 4 were eliminated for not completing the modules. The remaining 28 residents who completed the 4 weeks all attended both sessions. Some students were unable to complete the training for both sessions due to scheduling conflicts with other curriculum requirements.

3.2. Analysis of Individual Log Values

The results of the simulation were evaluated by 2 surgeons specialized in microsurgery, assigning a grade for each exercise of the participants. The residents in the experimental group and the control group were evaluated individually. The time to perform a total of 8 simple microsurgical stitches and complete a continuous suture in the different modules was obtained, as well as a score on the OSATS scale for each resident evaluated. The residents in the experimental group had access to the videos for feedback on their simulation practices.

3.3. Group Evaluations

The average initial time to perform microsurgical anastomosis in the experimental group was 19 minutes and an average score of 6.8 points on the OSATS scale was obtained. The control group got an average time of 21 minutes and a score of 6.3 points on the OSATS scale ($p > 0.05$). After performing the training with the simulation in the microsurgery model, the experimental group and the control group were compared, finding a reduction in the final average time of 12 minutes to perform a microsurgical anastomosis and a score of 17 points on the OSATS scale, while the control group got an average time of 19 minutes and a score of 7 points on the OSATS scale ($p > 0.05$).

4. Discussion

Microsurgery has become a necessary technique in different surgical specialties such as otorhinolaryngology, plastic surgery, hand surgery, neurosurgery, ophthamology, maxillofacial surgery, urology, transplant surgery and gynecology [11]. It is a complex technique that requires hand-microscope-eye coordination, delicate handling of the tissues with the microvascular instruments, as well as a fluid, steady and fast technique [12].

Microsurgical skills can be improved with learning and training. The learning curve in this technique becomes difficult when limited to observation and infrequent cases [13]. Simulation has been implemented as a standardized teaching tool for the acquisition of complex skills, as well as to decrease the learning curve in medical training, in addition to not risking patient safety [14].

Resident physicians in training with microsurgical competence must undertake hours in training to develop microsurgical skills. Unfortunately, the microscope presents a barrier to training, as well as the cost, portability, and availability of instrumentation [15]. In our study we had the laboratory and the appropriate conditions to be able to perform the simulation. However, simulations can be performed with multiple accessible and available equipment in order to perform microsurgical skills that have shown statistically significant improvements [13]. In addition, the use of educational resources on the Internet can improve knowledge as well as microsurgical skills [15].

There are several described and validated scales to assess microsurgical competences and skills; it is worth mentioning that the OSATS scale described by Reznick *et al.* [16] In an attempt to find the most appropriate method to assess skills, we used the OSATS scale at the beginning and at the end of our study to evaluate the residents in our program. OSATS has been shown to be useful not only in summative assessment, but also in formative learning.

In our study, statistically significant improvements were observed in various scores of microsurgical skills among the residents evaluated in all four sessions. A significant improvement was found in the OSATS score by the intervention group: 6.7 vs. 12 points ($p < 0.05$). As in the Sayadi *et al.* study, the use of simulation in microsurgery demonstrated an improvement in scores over three sessions ($p < 0.01$). The time to perform anastomosis was also evaluated and was shown to be statistically significant ($p < 0.01$). It is worth mentioning that only two residents were evaluated in this study, but it shows that simulation improves microsurgical skills [13].

The time to perform microsurgical anastomosis was shortened from 21 min to 12 min among the intervention group vs. 21 min to 17 min by the control group ($p < 0.05$). Boro *et al.* [17] demonstrated in their study "chicken quarter" that the time can be decreased by more than 50% through the use of simulation devices; likewise, the perception, integration and automation process permits the tasks to be repeated in a similarly with gradual and systemic modifications.

At the end of the sessions, a satisfaction survey was conducted in both groups, in which 90% of the participants recommended continuing with the microsurgery training. They were satisfied and willing to continue improving their microsurgical skills. In the Rojas *et al.* study, 34 residents were evaluated regarding their satisfaction with the microsurgical suturing and dissection technique using the OSATS scale, of which 94.2% showed satisfaction when performing this technique in simulation. Thus, the OSATS proves to be a valuable and reliable evaluation instrument for teachers to assess skills and abilities in microsurgical simulation (Figure 5) [18].

Evaluated Parameter	Experimental Group (Initial)	Experimental Group (Final)	Experimental Group (Initial)	Experimental Group (Final)	p-value
Time (min)	19 ± 3.2	12 ± 2.5	21 ± 3.0	19 ± 2.8	<0.05
Score (OSASTS)	6.8 ± 0.8	17 ± 1.5	6.3 ± 1.0	7 ± 1.2	<0.05

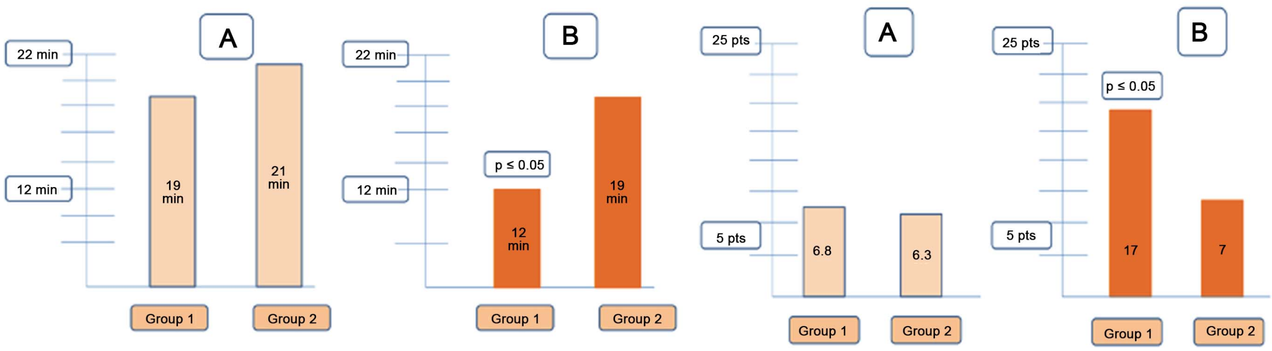

Figure 5. Results.

Microvascular surgery training courses and training centers are generally very few known and offered during residency training. These centers require certain licenses, authorizations and expensive equipment to perform the simulations, as well as the use of live models that make it difficult to perform the practices, limiting the number of residents who take courses for their education [19]. At our hospital, we have an area designated for microsurgical practice. Inexpensive simulation models can enhance the development of microsurgical skills and abilities. We decided to use synthetic tubes of 2 mm in size to perform terminoterminal anastomosis recommended by the IMSS, as well as chicken arterial vessels, because of their high fidelity in the simulation proven in several international studies as an essential low-cost instrument for microsurgical education [17].

The use of simulation is expected to generate a standardized teaching in microsurgery, broaden the knowledge and experience of professors, develop a standardized evaluation for microsurgical skills, and incorporate them into the residency programs in order to enhance the integral care of the patients.

Study limitations

This study has several limitations:

The small sample size may limit generalizability.

It was conducted at a single institution, which may reduce external validity.

The training period lasted only 4 weeks, which may not fully capture long-term skill retention.

Future studies should consider multicenter designs, longer training periods, and follow-up evaluations.

Cost considerations

Low-cost simulation models, such as latex strips and chicken thigh vessels, have been widely described as cost-effective compared with live animal models and high-fidelity simulators [17] [19]. Their use reduces the economic burden on training programs while providing high educational value. This supports our conclusion that the models used in this study help reduce training costs.

5. Conclusions

Microsurgery is a useful skill that requires high precision and surgical hands-on skills for the management of multiple reconstructive procedures. It is achieved through deliberate and continuous practice. The use of simulation has proven to be an effective procedure for learning skills and improving the microsurgical learning curve. Therefore, it is considered a fundamental element to develop confidence in microsurgical skills and to enhance subsequent skills at the end of residency training. In addition, it identifies those with particular interest, talent and aptitude for microsurgery.

Microsurgical simulation not only significantly improves residents' technical skills, but also reduces training costs and increases patient safety.

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Note

All the principles outlined in the Helsinki Declaration of 1975, as revised in 2000, have been followed in all the experiments involving human subjects during the current study. The ethics and research committees approved this study under the number: 39-23.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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