

Synthetic simulators for microsurgery training: A systematic review

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Background: Microsurgery is a cornerstone of reconstructive surgery but requires intensive training and a steep learning curve. Simulation models have become essential in microsurgical education, as they provide safe, ethical, and cost-effective alternatives to live animal training. Synthetic simulators, in particular, are increasingly used to build basic technical skills, maintain dexterity, and potentially serve as assessment tools for microsurgical progression. This review examines the current literature on synthetic models and their role in microsurgical training.

Material & Methods: A PRISMA-guided systematic review (1980–2021) was conducted using Web of Science, Scopus, and PubMed with the terms *microsurg AND (training OR model OR simulator)*. Original studies on synthetic microsurgery training simulators were included; in vivo models, reviews, and abstracts were excluded. Simulators were categorized by training level (basic, intermediate, advanced). Extracted data included device type, materials, training level, exercise type, duration, evaluation, and outcomes. No statistical analysis was performed due to study heterogeneity.

Results: From the 612 articles initially identified, 39 met the inclusion criteria, resulting in 40 studies describing 38 different synthetic microsurgery training devices. Among these, 11 studies focused on basic skills, 20 on intermediate techniques, and 9 on advanced training. Devices were produced using a variety of materials: 28 relied on synthetic polymers (e.g., latex, silicone, polyurethane, polyvinyl chloride), 5 on plant-based materials, 3 on metals, and 1 used a virtual reality platform.

Most of the studies (30/39, 64%) were primarily descriptive, while 16 evaluated training outcomes. Participants were mainly medical students, residents, or trainees (26 studies), with 10 studies involving surgeons and 3 including mixed populations. Overall, outcomes were considered satisfactory, with a reported improvement in dexterity and microsurgical abilities.

However, standardized assessment tools were not consistently used across studies. Different methods included global rating scales (GRS), the Objective Structured Assessment of Technical Skills (OSATS), task-specific checklists such as the Stanford Microsurgical and Resident Training system (SmaRT), and the Anastomosis Lapse Index (ALI). In two studies, simulators were used as preoperative warm-up tools, and in one study they served to establish baseline microsurgical skills. Training progression was explicitly evaluated in 10 studies.

Conclusions: The acquisition of microsurgical skills requires dedication and continuous practice, but traditional training models such as animal or cadaveric tissues are limited by ethical issues, costs, and logistical constraints. Synthetic simulators provide a safe, accessible, and cost-effective alternative that can be used to develop and maintain dexterity, evaluate learning progression, and even serve as warm-up tools before operative procedures. Although living animal models remain the gold standard due to their physiological realism, synthetic devices have evolved considerably in recent years, offering practical and ethically sound training opportunities. When incorporated into structured training programs, these simulators not only complement ex vivo and in vivo models but also have the potential to significantly reduce animal use while supporting the progressive acquisition of basic, intermediate, and advanced microsurgical skills.

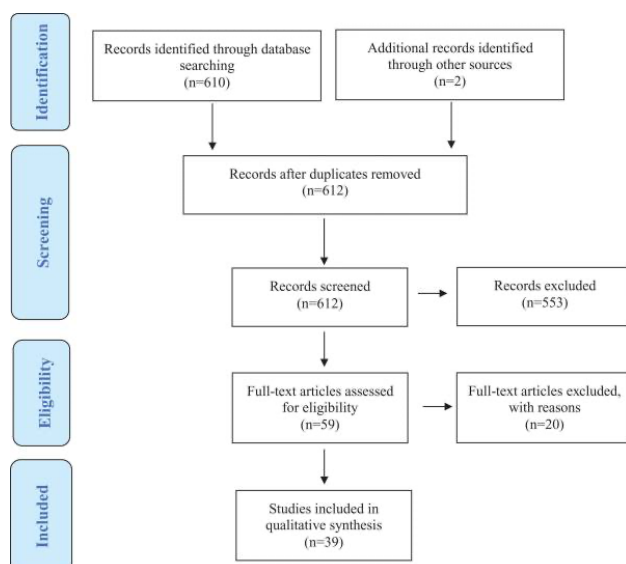


Fig. 1. Flow diagram showing the systematic search strategy conducted in adherence to the PRISMA guidelines.