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Validating a Low-Fidelity Model for Microsurgical Anastomosis Training

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Background: With cost, size, and availability in mind, we developed a low-fidelity microsurgery anastomosis model for mastery of the tool skills needed to execute microsurgical procedures. The model combined the use of a cannulated Konnyaku Shirataki (KS) noodle with a low-cost, industrial inspection, trinocular stereo (IITS) microscope. The purpose of this study was to establish face and construct validity of this novel "combined" microsurgery training tool.

Methods: Fifteen participants, divided into 3 groups based on microsurgery experience, attempted microsurgical anastomoses of a cannulated KS noodle using the IITS microscope. Participants were asked to (1) manipulate the noodle ends adjacent to each other, (2) place a single 7-0 nylon suture through the opposed ends, and (3) complete the anastomosis. To determine construct validity, the performance of the microsurgical repair (maximum score 53 points) and time-to-anastomosis was assessed. To determine face validity, microsurgeons were given a 25-item, 5-point scale survey rating their experience with the model.

Results: Participants included 5 microsurgeons, 5 experienced trainees, and 5 novices. The microsurgeons judged the IITS microscope to be a close analog to an operating microscope (4.6/5 points), the combined model to have high educational value (4.7/5 points), and somewhat technical similarity with microsurgery in the operating room (OR) (3.7/5 points). The median technical score was 50 among microsurgeons, 40 among experienced trainees, and 27 among novices. Increased training level was associated with greater technical score among all 3 groups ($p=0.002$). The median time-to-anastomosis was 5.88 minutes for microsurgeons, 8.37 minutes for experienced trainees, and 17.10 minutes for novices. Increased training level was associated with shorter time-to-anastomosis ($p=0.003$).

Conclusion: The use of the KS noodle with a benchtop stereo microscope is a novel approach to microsurgical training. It is inexpensive, available, conducive to high-repetition training, and suited to many learning environments. Microsurgeons found that this combined model was representative of microsurgery in the OR, and we concluded face validity. Furthermore, an association was demonstrated between training level and performance on the model, suggesting construct validity.

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Instructing learners on the microsurgical repair of nerves and anastomosis of small vessels is a specialized segment of surgical training for which simulation has traditionally been difficult to arrange. Microsurgical simulations require 2 elements to master the tools required for repair: a binocular stereo microscope to help learners master the visuospatial aspects of microsurgery and a repair model that emulates the architecture and texture of living structures[1]. Training those basic tool skills to achieve accuracy at speed (fluency) on low-fidelity simulations can serve as a prelude for acquisition of more advanced skills on more complex models and has the potential to decrease complications and operating room (OR) time during surgery[2-4].

Microsurgical training models can broadly be classified into 3 groups: synthetic, nonliving, and virtual reality[1]. Synthetic and nonliving low-fidelity models allow the introduction of fundamental manual microsurgical tool skills to the learner through high repetition at low cost[5,6]. To simulate microsurgical nerve repair, models have used twine wrapped in cellophane cling and rubber thread covered in a Steri-Strip[7,8]. Synthetic models have included latex gloves sutured into tubes, ready-made synthetic tubing of various materials, and a synthetic model made to represent rat femoral artery[9-12].

Although high-fidelity models including vessel repair in the rabbit ear, anastomosis of the femoral artery in the live rat, and live animal or cadaveric models used for nerve repair training are the gold standards for microsurgical skill acquisition[13-15], they require facilities for maintaining and operating on live animals as well as housing a microscope that has sufficient magnification, working distance, and the stereoscopic capability to perform the required surgeries[16]. If manual and visuospatial tool skills can be acquired on low-fidelity simulations before introduction to an in vivo model, it is likely that the learner will derive more benefits from the in vivo model and will more rapidly acquire the "goal" skills resulting in lower costs, decreased time commitment, and fewer animals euthanized[16].

Prunieres et al. developed a training model for small vessel anastomosis based on the repair of a cut and cannulated Konnyaku Shirataki (KS) noodle[17]. KS noodles are traditional Japanese noodles made of konjac yam and are sufficiently representative of handling a small vessel or nerve; the noodle is both delicate enough to show where it has been mishandled but malleable enough to allow for necessary manipulation. Although this model provided the learner with a realistic learning platform and the repair was accomplished with standard microoperating instruments, it required a standard operating stereo microscope and, importantly, was not validated.

With cost, space, and access in mind, we have developed a low-fidelity microsurgery "combined" training model (MSCTM) that pairs a low-cost, industrial inspection, trinocular stereo (IITS) microscope with the KS noodle simulation. Success with the model requires mastery of the manual microsurgical tool skills and the ability to use those tools under magnification. The goal of our project was to determine whether this MSCTM was both face and construct valid.

Establishing the validity of microsurgery training models is crucial in determining the value of a particular model[18] because there are invariably questions of effectiveness of the model and the ability for the model to faithfully represent microsurgical repair. Face validity assesses whether a model is representative of the environment it seeks to replicate. To test for face validity, we hypothesized that microsurgeons would find that the MSCTM represented microsurgery reality for anastomosis of a blood vessel and repair of a nerve. Construct validity is the degree to which a test measures what it claims to measure. To test construct validity, we hypothesized that there was a direct, positive relationship between an operator's experience and the operator's performance when considering both time and precision of the repair.

Materials and Methods

This study received IRB approval, exempt category 1, took place from September 2018 to September 2019 at an urban academic medical center, and was performed in the orthopaedic surgical skills training laboratory.

Participants

Study participants were members of our institution. Participation was voluntary. Participants were separated into 3 groups by their level of microsurgery expertise as follows: fellowship-trained microsurgeons, experienced trainees (2-6 months of microsurgical experience), and novices without any previous microsurgery experience.

The Model

The MSCTM pairs an industrial inspection trinocular stereo (IITS) microscope with the Konnyaku Shirataki (KS) noodle anastomosis simulation model modified from Prunieres et al[17]. Figure 1 shows an image of the MSCTM and its components.

Dried KS noodles (Japan Gold USA) were cooked for 5 minutes in boiling water, strained to remove excess starch, and 1 tablespoon of olive oil was added to prevent sticking. Noodles were then stored in an air-tight container and refrigerated until use. Fresh noodles were prepared every 14 days to prevent discrepancies because of degradation. Noodles were selected for the uniformity of diameter; the average width of a selected noodle was 1.5 mm. Noodles were divided in half, and each half was precannulated with a 0.7-mm IV catheter to create a lumen in both halves of the noodle (Video 1). The catheters at each end, having passed through the entire noodle half, were then retracted to allow sufficient space for suturing.

Microsurgery tools included Bishop forceps, straight tying forceps, Castroviejo suture forceps, a microneedle holder, and microstraight scissors (Symmetry Surgical; Fig. 2). Noodle anastomosis was performed with 4 simple sutures using 7-0 nylon (Ethicon) passed with a P-1, 11 mm, 3/8 circle, reverse cutting needle. The IITS microscope (AmScope SM-4NTP, United Scope LLC) was used for visualization (Fig. 1-A). The microscope is capable of 7× to 45×

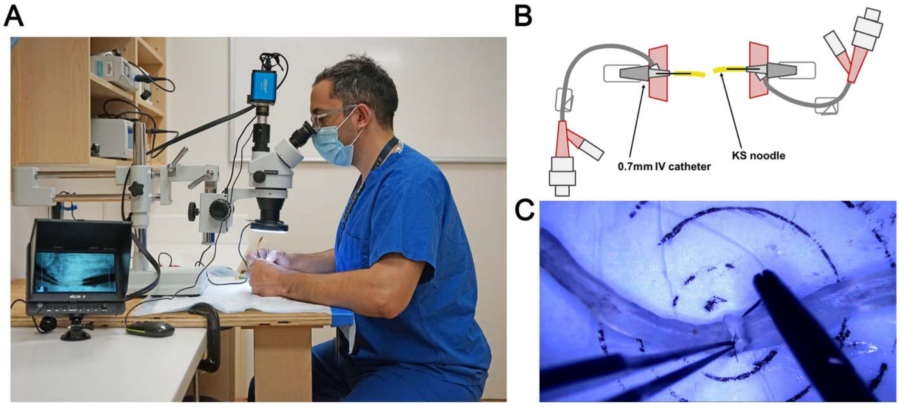

Fig. 1

Microsurgery "combined" training model (MSCTM) for microsurgical anastomosis. **Fig. 1-A**, MSCTM model, which pairs a benchtop, industrial inspection trinocular stereo (IITS) microscope with the Konnyaku Shirataki (KS) noodle anastomosis simulation. A 1080p video camera is attached to the microscope's trinocular port, capable of recording to an SD card and simultaneously connecting to a 7-inch HDMI LED monitor for real-time observation and video recording of each procedure, facilitating in-depth performance review. **Fig. 1-B**, Illustration of the KS noodle model. Selected noodles are divided in half, and each half is precannulated to create a lumen. **Fig. 1-C**, KS noodle anastomosis; of note, the microscope stage is covered with a blue plastic sheet with a uniform target, which acts as the center for study activity, and ensures that all activity is visible on the video camera.

magnification, comparable with a standard operating stereo microscope.

Before study participation, a brief demonstration on the use of the instruments was given to all participants. Participants were given the microsurgery tools and asked to complete an anastomosis of a KS noodle while visualizing through the IITS microscope. A leakless anastomosis of a KS noodle is shown in Video 2.

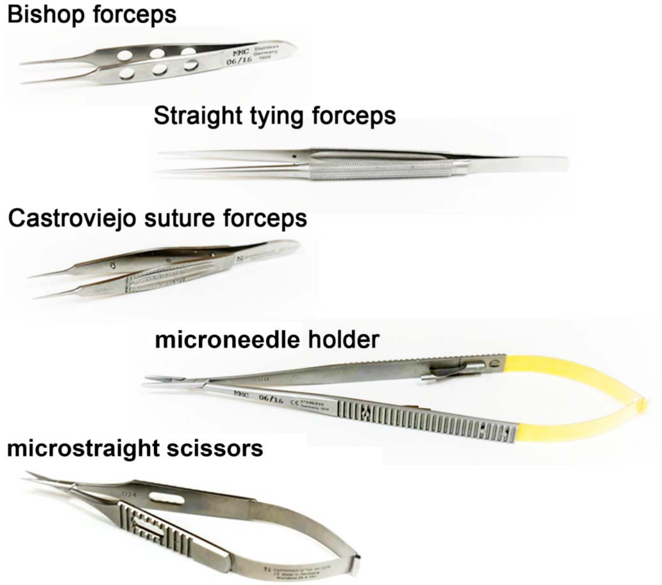

Fig. 2

Microsurgery instruments. Depicted are the microsurgery instruments used for anastomosis of the Konnyaku Shirataki (KS) noodle. Instruments included Bishop forceps, straight tying forceps, castroviejo suture forceps, a microneedle holder, and microstraight scissors.

Face Validity

For face validation of the MSCTM, the 5 microsurgeons were given a 3-part, 25-item survey regarding their experience with the MSCTM after the performance of the study tasks. Only microsurgeons were asked to answer/evaluate the questions/statements because these required previous knowledge of real-life microsurgery. The survey included questions and statements, rated using a 5-point Likert scale, regarding model function and technical similarity, and educational value to microsurgery (Table I).

Construct Validity

We created a performance score sheet to grade participants on microsurgical technique, anastomosis patency, and noodle integrity after anastomosis (Fig. 3). Performance was evaluated by a single trained investigator. Scores for each technical task and total technical score (maximum total score 53) were obtained for each participant. Task 3 involving noodle anastomosis was timed.

Other technical skills analyzed were noodle damage (sum of tasks 1c + 1d + 2c + 3a + 3b; maximum score 25), accuracy of holding the noodle over the target area (sum of tasks 1e + 2d + 3e; maximum score 9), handling of microsurgical instruments (sum of tasks 1a + 1b + 2b; maximum score 7), suture skills (sum of tasks 2c + 3b + 3c; maximum score 16), and visuospatial skills (sum of tasks 1e + 2c + 2d + 3b + 3c + 3e; maximum score 25).

Statistical Analysis

For face validity, the mean score and percentages were calculated for each question/statement. A value of 4 (80%) or greater was considered sufficient.

Differences in technical scores and time to completion among attending, trainee, and novice were compared using

TABLE I Face Validity

Educational Value	Mean (Range), Percentage
1. The "model" (microscope and Konnyaku Shirataki noodle) allows training of microsurgery manual skills	4.6 (4, 5), 92%
2. The model is useful for acquiring real-life manual and visuospatial skills in microsurgery	4.8 (4, 5), 96%
3. The model (microscope and noodle) reinforce a learner's visuospatial skills	4.8 (4, 5), 96%
4. The model can reinforce microsurgical instrument skills	4.6 (4, 5), 92%
5. The model can reinforce the tasks needed to perform an anastomosis	4.6 (4, 5), 92%
6. The model is a good way to prepare for a real-life microsurgery	4.4 (3, 5), 88%
7. The model is a useful training tool for microsurgery novices	4.6 (4, 5), 92%
8. The model is a useful training tool for residents and fellows	4.6 (4, 5), 92%
9. The model has value as a microsurgery training tool	4.8 (4, 5), 96%
10. The model has value as a microsurgery testing tool	4.8 (4, 5), 96%
11. The instructions to start an exercise on the model were clear	5 (5), 100%
12. The results/mistakes of my performance on the model were clear	4.8 (4, 5), 98%
13. It would be clear to a student, which skills (manual or visuospatial) need improvement	4.6 (3, 5), 92%
Overall educational value	4.7
Model function and technical similarity	
Technical similarity	
1. The model gave a sense of what microsurgery would be like	4.2 (3, 5), 84%
2. The steps performed with the model accurately reflect the steps taken during the actual microsurgical procedure	3.6 (2, 5), 72%
3. The movements performed creating the anastomosis accurately reflect the movements used during the actual microsurgical procedure	4 (3, 5), 80%
4. How similar is anastomosing a Shirataki noodle to anastomosing a small vessel in the OR?	3.3 (2, 4), 66%
5. How closely does the microsurgery "combined" training model replicate your experience with microsurgery in the OR?	3.4 (3, 4), 68%
Overall technical similarity	3.7
Instruments	
1. How similar were the operating instruments to the instruments you use in the OR?	4.2 (2, 5), 84%
Microscope Function	
1. How closely does the AmScope microscope replicate the OR microscope?	4.1 (3, 5), 82%
2. How similar is the microscope magnification capability to the OR microscope?	4.8 (4, 5), 96%
3. How similar was the visualization to that you experience with the OR microscope?	4.4 (4, 5), 88%
4. How similar is the microscope lighting to the microscope you use in the OR?	5 (5), 100%
Overall microscope function	4.6
Vessel replicate function	
1. How closely does the Shirataki noodle replicate a small vessel?	3.3 (3, 4), 66%
2. How realistic is the size of the noodle compared with a small vessel?	4.2 (3, 5), 84%
Overall vessel replicate function	3.8

Questions/statements were rated on a 5-point Likert scale by each of the 5 microsurgeons. None of the questions/statements featured a "not applicable (N/A)" answer option.

For each question/statement, the average score of the microsurgeon ratings and the range of ratings are indicated. Overall ratings represent the average score for questions/statements in each domain.

Questions and statements regarding educational value to microsurgery were rated as follows:

Strongly disagree		*Somewhat agree*		*Strongly agree*
1	2	3	4	5

Questions and statements regarding model function and technical similarity were rated as follows:

Not at all		*Somewhat*		*Very closely*
1	2	3	4	5

Subject ____________ Training level ________________________ Noodle # _________ Suture #__________

53 possible points

Task 1: Handle the noodles with microsurgery instruments
Goal – appose noodle ends without macerating edges (15 points total)

a) Selects appropriate instruments – 1 point (yes/no) ________
b) Grips instruments appropriately – 1 point (yes/no) ________
c) Handles noodle appropriately – max. 5 points ________
   a. 5 points – grips noodles at middle belly
   b. 3 points- grips noodles at or near ends
   c. 1 point – damages noodle
d) Apposes noodle ends together – max.5 points ________
   a. 5 points – brings noodles end-to-end without damaging
   b. 3 points – brings noodles end-to-end with some damage to ends
   c. 1 point – ends not apposed
e) Keeps noodle centered over target – 3 points ________

Task 2: Place first simple suture through both noodle ends
Goal – create one suture that links two noodle ends together without damaging noodle integrity, leaving gap between noodles or linking noodles asymmetrically (14 points total)

a) Picks up needle appropriately – 1 point (yes/no) ________
b) Maintains stability of needle – max. 5 points ________
   a. 5 points – maintains full stability anchoring hand/extremity to surface
   b. 3 points- maintains some stability with unsteady hand
   c. 1 point – drops needle repeatedly
c) Passes suture – max. 5 points ________
   a. 5 points – passes suture at appropriate equal distance from both noodle ends, with needle 90 degrees to noodle on entry
   b. 3 points – passes suture through both ends, with difference in distance from ends
   c. 1 point – damages noodle, suture pulls out
d) Keeps noodle centered over target – 3 points _________

Task 3: Complete anastomosis (4 circumferential interrupted sutures)
Goal – link noodles together, keeping lumen patent, minimizing gapping and without damaging noodle integrity (24 points total)

a) Handles noodles appropriately – max. 5 points __________
   a. 5 points – grips noodles far from ends,
   b. 3 points- grips noodles at or near ends,
   c. 1 point – damages noodle
b) Passes suture – max. 5 points ________
   a. 5 points – passes suture at appropriate equal distance from both noodle ends
   b. 3 points – passes suture through both ends, with difference in distance from ends
   c. 1 point – damages noodle, suture pulls out
c) Ties suture – max. 6 points __________
   a. 6 points – completes knot with 3 throws
   b. 5 points – completes knot with 2 throws
   c. 1 point – able to only complete 1 throw
d) Creates anastomosis – max. 5 points _________
   a. 5 points -- patent anastomosis with minimal leaks
   b. 3 points – anastomosis without patency
   c. 1 point – anastomosis with significant gaps or leaks
e) Keeps noodle centered over target – 3 points _________

Fig. 3
Microsurgery technical scoring sheet. Participants' performance was graded using this technical scoring sheet. The 3 tasks evaluated were the following: (1) opposition of the 2 noodle ends over the center of the target, (2) placement of a single simple suture linking both noodle ends together, and (3) anastomosis of 2 noodle ends connected to IV catheters using 4 simple interrupted sutures. Scores for each technical task and a total technical score (maximum total score 53) were obtained for each participant.

Kruskal-Wallis tests. Wilcoxon rank-sum tests were used for post hoc pairwise comparisons between groups with Bonferroni correction for multiple testing.

Source of Funding

This study was funded by a grant from Ethicon/DePuy Orthopedics, Grant ID #316397.

Results

Fifteen subjects participated in this study to establish face and construct validity of the MSCTM: 5 microsurgeons, 5 experienced trainees, and 5 novices. All participants were asked to perform a microsurgical anastomosis of a KS noodle by completing the following 3 tasks: (1) opposition of the 2 noodle ends over the center of the target, (2) placement of a single simple suture linking both noodle ends together, and (3) anastomosis of 2 noodle ends using 4 simple interrupted sutures.

Face Validation

Face validation of the MSCTM was assessed by 5 microsurgeons using a 25-item questionnaire (Table I). Face validity scores of statements regarding the models' educational value for microsurgery training and reinforcing microsurgical instrument skills, visuospatial adaptation to the microsurgical environment, and manual microsurgical skills were ≥ 4 (80%). Thus, the MSCTM value as a microsurgery training tool was judged sufficient by the microsurgeons. Furthermore, microsurgeons deemed the MSCTM to allow clear assessment of mistakes and clear identification of skills that need improvement (mean scores 4.8 and 4.2, respectively; Table I). The overall technical similarity of the MSCTM with microsurgery in the OR was determined somewhat closely to close (overall score 3.7).

The mean face validity score of the microsurgery instruments was 4.2 and microsurgeons judged that the microscope was a close analog to an operative microscope (overall score 4.6), giving high scores to the magnification, visualization, and lighting (mean score 4.8, 4.4, and 5, respectively; Table I). Microsurgeons viewed that the noodle itself only somewhat resembled a small vessel (mean score 3.3) but that the noodle size was similar to a small vessel (mean score 4.2).

Construct Validation—Microsurgical Technique

The median total score of microsurgical technique was 50 (range, 50-50) among microsurgeons, 40 (range, 39-47) among experienced trainees, and 27 (range, 24-36) among novices. There was a significant association between training level and total score among all 3 groups (p=0.002, Fig. 4-A). Furthermore, association reached significance for all pairwise comparisons, including microsurgeon with experienced trainee (p = 0.007), microsurgeon with novice (p = 0.007), and experienced trainee with novice (p = 0.012) (Fig. 4-A).

Construct Validation—Time of Microsurgical Repair

The median time to complete a repair of the KS noodle as described for task 3 was 5.88 minutes (range, 4.50-8.03) for experienced microsurgeons, 8.37 minutes (range, 7.53-8.80) for experienced trainees, and 17.10 minutes (range, 12.71-20.00) for novices (Fig. 4-B). A significant association existed between training level and time to anastomosis among the 3 groups (p=0.003). This association remained significant when comparing microsurgeons with novices (p=0.012) and experienced trainees with novices (p=0.012) (Fig. 4-B).

Construct Validation—Performance Analysis of Individual Tasks and Specific Technical Skills

We next determined whether the MSCTM could discriminate between experience levels and the level of performance of the individual tasks as well as specific manual and visuospatial skills (Table II). Among the 3 groups, there was a significant association between training level and task 1 performance (p=0.013), between training level and task 2 performance (p=0.005), and between training level and task 3 performance (p=0.003) (Table II). A significant association also existed between training level and lack of noodle damage (p=0.005), accuracy in holding the noodle over the target area (p=0.008), suture skills (p=0.009), and visuospatial skills (p=0.004) among all 3 groups. Pairwise comparisons between groups showed significant differences in these specific technical skills between microsurgeons and novices (p=0.007). We were unable to determine whether training level was associated with instrument handling (p=0.061).

Discussion

Increased importance is being placed on acquiring and mastering surgical skills on validated training models. Microsurgery poses unique challenges for training model design because not only are the models created for teaching microsurgical instrument tool skills, they must also teach the visuospatial skills required to use those under magnification.

Synthetic models for microsurgery have been used for decades and can be invaluable for beginners to adjust to microscope magnification and develop manual tool skills. Although nerve repair and small vessel anastomosis require slightly different skills, both require an end-to-end connection, performed generally with suture.

In 2016, Prunieres et al. described the use of the KS noodle for use in microsurgery training[17]. The noodles are inexpensive and can be prepared in bulk, and learners can therefore practice low-fidelity end-to-end repair. Differences between our setup and the setup of Prunieres et al. pertained to cannulation and sutures; although in both setups, noodles were cannulated with a 0.7-mm catheter, we used a full butterfly needle setup to achieve more stability, whereas Prunieres et al. only showed the needle and catheter without attached butterfly and tubing. Regarding sutures, although Prunieres et al. used a 10-0 suture, we used a 7-0 suture, which we felt produced similar results regarding repair, and was easier for novices to use and much less costly.

To further ensure low cost and reproducibility of our model, we sought to replicate operative microscopy in a manner that was inexpensive and easily stored. Several studies have investigated the use of alternative methods of magnification during microsurgery training. Magnifying glasses on a stand have been suggested for foundational-level training[19], and recently,

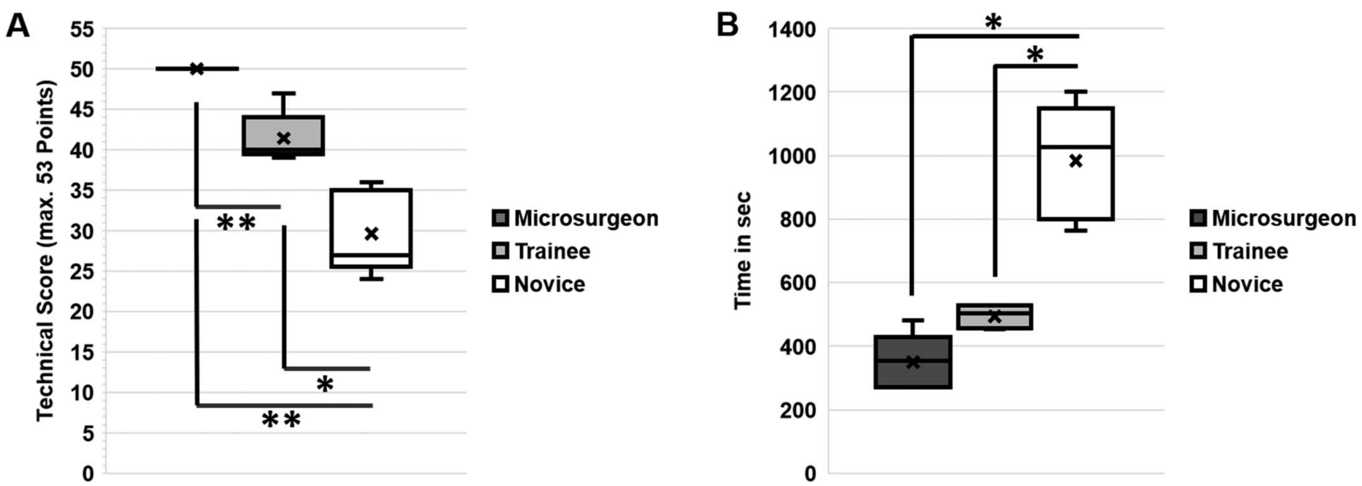

Fig. 4

Technical score and time to completion. Median and interquartile range of total technical scores (**Fig. 4-A**) and time to anastomosis completion (**Fig. 4-B**) for microsurgeons, trainees, and novices are indicated. Post hoc comparison between individual groups is indicated in the graphs; *p ≤ 0.05, **p ≤ 0.01.

Malik et al. demonstrated that home training with either jeweler's microscopes or tablet computers improved operators' performances on in-laboratory exercises using professional training microscopes[20]. We sought a device that was capable of comparable magnification and the feel of an OR microscope while remaining relatively inexpensive and easy to store. The IITS microscope fits these criteria. Where operative microscopes can cost many tens of thousands of dollars, the cost of an IITS microscope costs

TABLE II Performance Analysis of Individual Tasks and Specific Technical Skills

	Microsurgeon	Trainee	Novice	p-Value for Comparing Among 3 Groups	p-Value for Comparing Microsurgeon to Trainee	p-Value for Comparing Microsurgeon to Novice	p-Value for Comparing Trainee to Novice
Task 1 Max. 15 pts	15 (15, 15)	13 (11, 13)	13 (8, 15)	**0.013**	**0.006**	0.025	0.814
Task 2 Max. 14 pts	14 (14, 14)	12 (8, 14)	5 (2, 12)	**0.005**	0.071	**0.007**	0.033
Task 3 Max. 24 pts	21 (21, 21)	16 (13, 20)	10 (9, 16)	**0.003**	**0.007**	**0.007**	0.056
Noodle damage Max. 25 pts	25 (25, 25)	17 (13, 25)	13 (11, 15)	**0.005**	0.025	**0.007**	0.056
Accuracy Max. 9 pts	9 (9, 9)	9 (3, 9)	3 (0, 6)	**0.008**	0.180	**0.007**	0.049
Instrument handling Max. 7 pts	7 (7, 7)	7 (3, 7)	5 (3, 7)	0.061	0.180	0.025	0.381
Suture skills Max. 16 pts	16 (16, 16)	12 (10, 16)	10 (8, 13)	**0.009**	0.071	**0.007**	0.088
Visuospatial skills Max. 25 pts	25 (25, 25)	19 (18, 25)	13 (8, 19)	**0.004**	0.025	**0.007**	0.034

Data are presented as median (range). p-Values for post hoc pairwise comparisons between groups <0.017 (0.05/3) are considered statistically significant (highlighted in bold). Performance was evaluated by a single unblinded investigator.

approximately $1,000 and is capable of the most important actions of an operating microscope, stereo binocular visualization, variable magnification, and focusing through a substantial working distance.

Our microsurgeons found that the combination of the KS noodle together with the IITS microscope was sufficiently representative of the OR microsurgery environment and had a high educational value as a microsurgery training tool for both training and reinforcing microsurgical instrument skills and visuospatial adaptation to the microsurgical environment. Microsurgeons overwhelmingly felt that the IITS microscope was sufficiently representative of an OR microscope in both magnification and lighting. Most participants felt the noodle's size was similar to a small vessel, the noodle somewhat resembled a small vessel, and that anastomosing the noodle was somewhat representative of anastomosing a small vessel. We concluded that the MSCTM possesses face validity.

It is imperative that microsurgical training models possess construct validity, meaning that they are able to distinguish between experienced users/surgeons and novices when objectively assessing skill[18]. Direct observation with assessment criteria has been described as a highly reliable and valid process to objectively assess microsurgical technical skill[21]. We therefore created a novel performance assessment tool for the MSCTM, which allowed for direct grading of technical skills. Our assessment focused on surgical skill, damage to the noodle, accuracy of repair, and ability to perform tasks within a defined area. We found a significant difference in microsurgical technique and time to perform an anastomosis between microsurgeons, experienced trainees, and novices, suggesting that the model has construct validity. Furthermore, the model was able to differentiate between the marginally trained and the untrained and allowed analysis of specific manual and visuospatial skills. Although the authors were able to recreate a luminal anastomosis in 2 precannulated noodle ends during pretrial testing, none of the participants were able to recreate functional anastomoses over the course of the study. We hypothesized that for those advanced trainees and microsurgeons used to anastomosing real vessels, the noodle model may have its own learning curve which necessitates more than a single trial to overcome.

We are presenting here the face and construct validation of our low-fidelity model for microsurgical skill acquisition. It is not the final answer and not intended to be, but it is where learners can learn to use, with fluency, a binocular microscope and microsurgical tools. Once these skills are mastered, the simulations can expand to include more complex environments like the gold standard models. We will undoubtedly reduce the numbers of rats and rabbits killed and make better use of the ones we do use.

Conclusion

The MSCTM faithfully approximates the experience of handling small vessels and nerves in the OR while remaining obtainable, affordable, and available for repetitive learning that ensures skill acquisition. Because of its low cost and availability, it can be easily recreated by any surgical training program, and any microsurgery trainee can use the model for high-repetition practice to achieve the necessary visuospatial adaptation and specialized tool skills with the prospect of achieving tool-skill mastery prior to their use on live animals or in the OR. Used either alone for foundational training or in combination with higher fidelity models in a standardized course, the MSTCM represents a valuable addition to the microsurgery training armamentarium. ■

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