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ARTICLE

# Effectiveness of a microsurgery training program using a chicken wing model

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**ABSTRACT**

Microsurgical skills are essential for plastic surgeons in the modern times. Chicken wing model for microsurgery training offers an easy and cost-effective alternative to the traditional live rat model. A prospective study was conducted over a period of 6 months. Fifteen resident doctors in the department of plastic surgery were enrolled. Each of them underwent one session of microsurgery training on chicken wings (ulnar artery) every week for 15 weeks. The pre-training and post-training microvascular anastomosis were recorded and analyzed by two blinded investigators using a modification of the Structured Assessment of Microsurgery Skills (SAMS) tool. The pre- and post-training scores were compared. Twelve residents completed the requisite number of training sessions and were included in the final analysis. The mean diameter of the chicken wing ulnar artery was 1.04 mm (SD:0.11). All trainees demonstrated an improvement in the total scores. There was significant improvement in the mean scores (Pre-training: 33.46 vs. post-training: 41.42, $p = 0.002$). There was also a significant decrease in the total number of errors (Pre-training: 6.75 vs. post-training: 4.79, $p = 0.012$). However, there was no significant improvement in the average time taken to perform anastomosis (Pre-training: 58.03 mins vs. post-training: 52.51 mins, $p = 0.182$). We concluded that chicken wing is a useful training model for microsurgery. It helps in improving the overall microsurgical skill as well as reducing the average number of errors. This model is cost-effective, easily available, and easy to set-up. The wide assortment of vessels with varying diameters provides opportunities for training of microsurgeons of different skill levels.

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Microsurgery training; chicken wing; microsurgery training model; resident training; animal model; simulated surgical training

## Introduction and background

The traditional method of surgical training was described by Halsted and it has been practiced throughout the world for over a century. In his own words, this method was described as 'See one, do one, teach one [1]. More than other surgical skills, microsurgery has a steep learning curve [2] as well as high risk of failure associated with even small mistakes, which can lead to complete failure of the surgery. Thus, it is not feasible for the junior trainees to learn the skill and art of microsurgery in live surgeries in the initial part of their training. To overcome this, multiple training models have been described, the most common ones are animal and synthetic models [3].

Animal models are probably the most commonly used simulation for microsurgery training. Their main advantage is that they provide the 'look and feel' of live tissue. The ideal animal model should mimic the clinical situation closely and should be easy to use. The ease of use includes ease of access, cost-effectiveness, ease of set up and ease of replication. In addition, the model should be 'humane' for the animal [4]. Animal models which are used for surgical training may be live or cadaveric.

Live models better simulate the actual surgical scenario with respect to blood flow and its consequences, which is especially useful in vascular (and microvascular) surgery. However, cadaveric animal models also offer several advantages. Compared to synthetic models, they offer a more realistic experience. This is due to the consistency of natural tissue as well as the tissue arrangement (e.g. presence of adventitia around a blood vessel). Cadaveric animal models also compare favorably with live animal models in terms of availability, cost, ease of set up, ease of disposal, and ethical considerations. More specifically, they do not require special facilities for raising or maintaining live animals and they do not require anesthesia. The most popular cadaveric animal tissue models are chicken, turkey, rat and porcine models [3, 5–10]. Their main disadvantage is the absence of a dynamic blood flow.

There is no substantial evidence to justify the use of live animal models over other training models for microsurgery. The use of low fidelity models may achieve similar levels of competence in microsurgery at much lower costs [11]. Despite the criticisms, microsurgery training on live animal models is still considered by many to be the gold standard. Short duration training microsurgery training courses on live animals (especially rats) remain very popular across the globe. These courses are usually attended by trainees in external institutes and hence are limited by their accessibility and non-longitudinal, one-time nature [12]. Short-term intensive training courses have also been shown to improve microsurgical skills; however, regular refresher courses are usually recommended to maintain and further develop microsurgical skills [13].

In this study, we evaluated the effectiveness of a regular microsurgery training program using chicken wings in improving the microsurgical skills of residents, and in the process, we attempted to validate the chicken wing model.

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Figure 1. Training setup. Operating microscope with recording camera attached on one port, recording device, and screen in the background.

## Materials and methods

Prior approval was obtained from the institutional ethics committee. A prospective analytical study was carried out over a period of 6 months. Fifteen resident doctors in plastic surgery were initially enrolled. They underwent a regular microsurgery training program on chicken wings. The training program included one training session every week. In the first session (pre-training session), the residents were demonstrated the dissection of a chicken wing for identifying the correct vessels (ulnar artery) and also the correct procedure for microsurgical vascular anastomosis. During each subsequent session, the residents practiced microvascular anastomosis in a chicken wing. A senior surgeon was available during the training sessions to supervise and guide the trainees. Each resident had to complete 15 training sessions before the final evaluation.

The pre- and post-training microvascular anastomoses by each resident were recorded by a video camera attached to the operating microscope (Figure 1). Both of these anastomoses were done on the same vessel, that is, chicken wing ulnar artery (Figure 2). The chicken ulnar artery was chosen for sake of uniformity, it has an average diameter of approximately 1 mm [14]. 10-0 nylon suture was used for all the anastomoses. The video recordings were numbered using a random number chart and given to two examiners (Examiner A and Examiner B) for analysis of the microsurgery skill using a modification of the Structured Assessment of Microsurgery Skills (SAMS) method. The examiners were blinded to the identity of the operating surgeon and his/her status of microsurgery training program (pre-training or post-training). The findings of the analysis were recorded in proformas.

SAMS is a validated tool for objective assessment of microsurgical skills in live models [15]. The modifications made to SAMS were toward addressing the absence of dynamic blood flow in a chicken wing model. The last two points under the 'Judgement' category of the GRS were modified. These were modified according to the patency test being used in the chicken wing model, that is, saline infusion across the anastomotic site. The permission to use and modify SAMS was obtained from the authors of the original paper.

IBM SPSS Statistics 20.0 software was used for all statistical analyses. $p$-value less than 0.05 was considered to be significant. For each of the two evaluators, the total Global Rating Scale (GRS) scores were calculated by adding the scores from each of the 12 items (scored from 1 to 5) to arrive at a total score (out of a maximum of 60). Inter-observer reliability for each individual item in the GRS as well as for the total score was checked with the Cronbach's alpha coefficient. Alpha values less than 0.6 were considered unacceptable, between $0.6-0.7$ were considered acceptable, values of $0.7-0.8$ were considered good, and values greater than 0.8 were considered excellent.

The mean and median of the scores given by both the evaluators was calculated for each of the 12 items as well as for the total GRS. Wilcoxon rank test was used to compare pre- and post-training results under various categories.

## Results

Initially, 15 senior residents in the Department of Plastic and Reconstructive Surgery were included in the study. However, only 12 of them finished the required 15 training/practice sessions in the stipulated time period, and only they were included in the final analysis (Figure 3). The chicken wings were procured from a

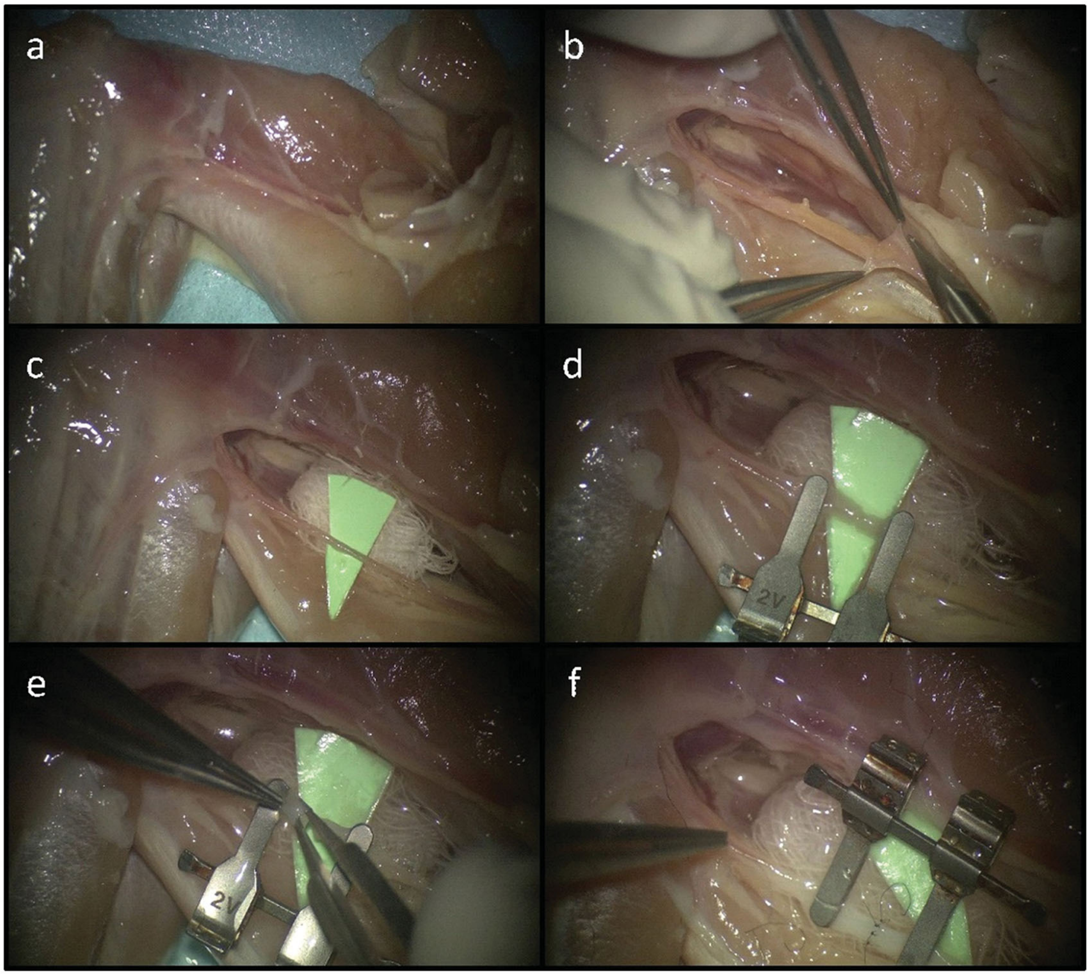


Figure 2. Dissection and microvascular anastomosis of chicken wing ulnar artery. (a) Chicken upper wing showing the superficial accompanying vein of ulnar artery, (b) Dissection of ulnar artery, (c) Ulnar artery completely dissected, (d) Double clamps applied after dividing the ulnar artery, (e) Vessel dilatation and preparation for anastomosis, (f) Completed anastomosis using 10-0 nylon.

local meat shop. On average, one chicken wing cost 18 Indian rupees (Approximately 0.25 USD).

A total of 24 videos were collected for the final analysis. These included 12 'pre-training' videos (first session) and 12 'post-training' videos (last session). The mean diameter of the vessel for all 24 recorded session was 1.04 mm (Range: 0.80 mm – 1.20 mm, SD: 0.11). The mean vessel diameter in pre-training sessions was 1.09 mm (Range: 1.00 mm – 1.20 mm, SD: 0.10) and for post-training sessions was 0.99 mm (Range: 0.80 mm – 1.10 mm, SD: 0.09).

All the trainees were senior residents (M.Ch.) in Plastic and Reconstructive surgery. Out of the 12 trainees, two trainees were in the first year of senior residency, six trainees were in the second year of residency and four trainees were in the third year of residency. The mean values of pre-training GRS scores were 29.50 (SD: 2.12), 35.92 (SD: 7.16), and 31.75 (SD: 3.20) for 1st, 2nd, and 3rd-year residents, respectively. While the post-training GRS scores were 38.25 (SD: 8.13), 43.92 (SD: 3.01), and 39.25 (SD: 2.25) respectively. The sample size in each year of residency was too low to allow for a meaningful subgroup analysis.

The mean time taken (from vessel dissection and isolation, up to removal of clamps after the anastomosis) on the pre-training session was 58.03 min (Median: 59.78, Range: 43.25 – 80.54, SD: 9.56) and on the post-training session was 52.51 min (Median: 52.34, Range: 33.21 – 73.38, SD: 12.28). Although the mean

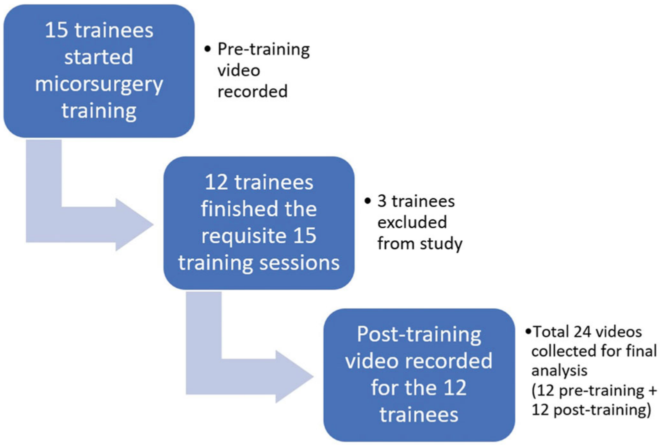


Figure 3. Study population.

post-training time was lesser than the pre-training time, the difference was not statistically significant ($p = 0.182$).

All the GRS scores (pre- and post-training) of both examiners were compared for inter-observer reliability using the Cronbach's alpha coefficient. The inter-observer reliability was found to be excellent with alpha = 0.906. The average of the two examiners'

Table 1. Comparison of Pre-training and Post-training GRS scores.

| *Trainee* | *Pre-training GRS (Examiner A)* | *Pre-training GRS (Examiner B)* | *Post-training GRS (Examiner A)* | *Post-training GRS (Examiner B)* | *Average Pre-training GRS* | *Average Post-training GRS* |
|---|---|---|---|---|---|---|
| *1* | 28.00 | 30.00 | 42.00 | 37.00 | 29.00 | 39.50 |
| *2* | 33.00 | 29.00 | 34.00 | 31.00 | 31.00 | 32.50 |
| *3* | 23.00 | 23.00 | 46.00 | 38.00 | 23.00 | 42.00 |
| *4* | 40.00 | 36.00 | 43.00 | 39.00 | 38.00 | 41.00 |
| *5* | 27.00 | 29.00 | 47.00 | 41.00 | 28.00 | 44.00 |
| *6* | 29.00 | 29.00 | 37.00 | 36.00 | 29.00 | 36.50 |
| *7* | 41.00 | 37.00 | 47.00 | 38.00 | 39.00 | 42.50 |
| *8* | 33.00 | 34.00 | 46.00 | 40.00 | 33.50 | 43.00 |
| *9* | 37.00 | 31.00 | 45.00 | 33.00 | 34.00 | 39.00 |
| *10* | 46.00 | 42.00 | 51.00 | 41.00 | 44.00 | 46.00 |
| *11* | 33.00 | 37.00 | 43.00 | 41.00 | 35.00 | 42.00 |
| *12* | 40.00 | 36.00 | 51.00 | 47.00 | 38.00 | 49.00 |
| *Mean* | 34.17 | 32.75 | 44.33 | 38.50 | 33.46 | 41.42 |

pre- and post-training GRS scores for each trainee were calculated (Table 1). The overall mean pre-training GRS score was 33.46 (Median: 33.75, SD: 5.81) and the post-training GRS score was 41.42 (Median: 42.00, SD: 4.29). The difference between the two scores was statistically significant ($p = 0.002$). The mean increase in the GRS score was 7.96 (Median: 7.25).

Further, each of the 12 items in the GRS for pre-training and post-training were also compared. The mean scores for each of the 12 items in the GRS were calculated and compared between the pre-training and post-training sessions (Table 2). There was a statistically significant improvement in each of the 12 items of the GRS ($p < 0.05$). The biggest improvement was seen in 'Visuo-spatial ability: Suture placement' (mean improvement of 0.88), while the smallest improvement was seen in 'Dexterity: Tissue handling' (mean improvement of 0.50). Among the broad categories of 'Dexterity', 'Visuo-spatial ability', 'Operative flow' and 'Judgement', there was a significant improvement in each of them (Table 2). The improvements in total scores of these categories were 1.83, 2.08, 2.00, and 2.13, respectively.

The average number of errors in pre-training sessions was 6.75 (SD: 1.95), while the average number of errors in post-training sessions was 4.79 (SD: 1.62). This difference in the number of errors was statistically significant ($p = 0.012$). Overall (including pre-training and post-training sessions), the most common error was 'Planning: Loss of central view' followed by 'Visuo-spatial ability: Unequal stitch bites'. The least common error overall was 'Visuo-spatial ability: Suture cut through' followed by 'Dexterity: Vessel tear' and 'Judgement: Excessive sutures'.

## Discussion

With increasing knowledge of adult learning and the pressures of the modern clinical environment, Halsted's training methods have come under question. With shorter working hours for residents, emphasis on efficient utilization of operating room time, greater complexity of cases, increased awareness of patient safety, and higher expectations by patients, there is a lesser 'hands-on' training for resident doctors. On top of these, most residency programs lack specifically designed curricula [3,16].

Microsurgery has a steep learning curve; hence it is imperative to acquire these skills outside the operative room prior to practicing them on a live patient. This realization has led to the development of simulation models for microsurgery training. These can be classified into bench models (synthetic), cadaveric animal tissue models, cadaveric human tissue models, live animal models and VR simulators [3]. With surgical simulations, skills and techniques can be practiced in a safe and stress-free setting of the laboratory with or without supervision. It allows for a controlled environment in which mistakes can be made and lessons learned without major repercussions. Microsurgery training on synthetic bench models focus on basic microsurgical knot tying and correct suture placement and thus making the trainee more comfortable with an operating microscope and improving hand-eye coordination [17–27]. During residency, young surgeons acquire skills not only during the training session in laboratory, but also while assisting and performing surgical procedures in a clinical setting. A training laboratory provides the residents with an opportunity to apply the knowledge acquired during clinical procedures in a controlled environment without major repercussions. Thus, during residency, longitudinal training is probably the best solution to developing, maintaining and tangibly improving microsurgical (or any other surgical) skill in the long run.

The biggest hurdle in starting a microsurgery training program is the initial set-up of the training laboratory. Traditional microsurgery training models involve the use of live rats, which, if feasible, is probably the ideal training model. A microsurgery training program for resident doctors would require a regular supply of live rats for this purpose, and hence a dedicated animal rearing center. It also requires anesthesia for the animals. Setting up such a training program is not just expensive, but also cumbersome. The limitation in setting up a laboratory with live animal models for training can be overcome by the use of readily available inexpensive cadaveric animal models for training.

The chicken wing model for microsurgery training has been described in the literature [28,29]. Hayashi *et al* have described the vascular anatomy of the chicken wing from a microsurgery training perspective [14]. They described the consistent anatomy as well the mean diameters of the various blood vessels in the chicken wing, which ranged from 0.35 mm to 1.01 mm. Thus, the chicken wing can be used not only for practicing microsurgery but also supermicrosurgery (0.3 mm to 0.8 mm vessels). The biggest drawback of a cadaveric animal tissue model such as chicken wing is the absence of a dynamic blood flow.

Several researchers have attempted to simulate blood flow by infusing various types of colored/clear fluids in the chicken blood vessels [30–33]. However, in our experience, these methods come with several drawbacks. These include the inability to predict thrombosis and leakage from the anastomotic and needle entry sites (due to the absence of platelet plug formation and lower viscosity of the fluids). The leakage results in staining of the tunica intima and surrounding tissue which unlike blood, cannot be 'mopped away', and also leads to unnecessary placement of extra sutures to stop the leakage.

Like any other surgical skill, it is difficult to quantify the microsurgical skill level objectively. Several tools have been used for microsurgical skill assessment in general and for assessing the

**Table 2.** Comparison of Pre-training and Post-training scores of individual items in the GRS (for all participants, mean of both examiners).

| Item | Mean Pre-training score (SD) | Mean Post-training score (SD) | Comparison of pre- and post-training scores (Wilcoxon rank test) |
|---|---|---|---|
| *Dexterity: Steadiness* | 2.75 (SD: 0.50) | 3.33 (SD: 0.39) | $p = 0.006$ |
| *Dexterity: Instrument handling* | 2.83 (SD: 0.58) | 3.58 (SD: 0.47) | $p = 0.018$ |
| *Dexterity: Tissue handling* | 2.83 (SD: 0.62) | 3.33 (SD: 0.39) | $p = 0.035$ |
| *Dexterity (total)* | 8.42 (SD: 1.41) | 10.25 (SD: 0.92) | $p = 0.005$ |
| *Visuo-spatial ability: Dissection* | 2.67 (SD: 0.72) | 3.25 (SD: 0.62) | $p = 0.025$ |
| *Visuo-spatial ability: Suture placement* | 2.75 (SD: 0.54) | 3.63 (SD: 0.43) | $p = 0.003$ |
| *Visuo-spatial ability: Knot technique* | 2.92 (SD: 0.47) | 3.54 (SD: 0.40) | $p = 0.004$ |
| *Visuo-spatial ability (total)* | 8.33 (SD: 1.50) | 10.42 (SD: 1.18) | $p = 0.003$ |
| *Operative flow: Steps* | 2.75 (SD: 0.50) | 3.42 (SD: 0.47) | $p = 0.011$ |
| *Operative flow: Motion* | 2.71 (SD: 0.69) | 3.25 (SD: 0.54) | $p = 0.013$ |
| *Operative flow: Speed* | 2.58 (SD: 0.60) | 3.38 (SD: 0.64) | $p = 0.007$ |
| *Operative flow (total)* | 8.04 (SD: 1.64) | 10.04 (SD: 1.51) | $p = 0.007$ |
| *Judgement: Irrigation* | 2.83 (SD: 0.44) | 3.50 (SD: 0.37) | $p = 0.007$ |
| *Judgement: Anastomosis & patency test* | 2.88 (SD: 0.53) | 3.54 (SD: 0.50) | $p = 0.010$ |
| *Judgement: Checking the flow* | 3.00 (SD: 0.80) | 3.79 (SD: 0.40) | $p = 0.007$ |
| *Judgement (total)* | 8.71 (SD: 1.47) | 10.83 (SD: 1.01) | $p = 0.002$ |

usefulness of training programs specifically, these include: time taken for anastomosis, global rating scales (GRS) and checklists, self-answered questionnaires and hand motion analysis.

GRS include objective scoring of specific steps and techniques in a particular surgical procedure, and have been developed for various surgeries [34–36]. Structured Assessment of Microsurgery Skills (SAMS) is an objective tool that incorporates a GRS designed specifically for microsurgery. The SAMS tool includes three assessments: GRS, errors list, and a summative rating [15]. The SAMS tool has been validated in a clinical setting by the original authors as well as an independent study [37]. SAMS is comprehensive and well suited for periodic evaluation of microsurgery trainees and hence we used it in our study. However, SAMS has been described for use in live models with a dynamic blood flow; hence, we had to modify two evaluation criteria in SAMS which required a blood flow. These changes in SAMS, although minor, mean that the tool may not function with the same validity.

We found that a regular longitudinal training program using a chicken wing model significantly improved the skill level (total GRS score) of trainees (Table 1). Further, each of the 12 items as well as the broad categories in the GRS were found to improve significantly after the 15 training sessions (Table 2), substantiating that the training was effective across all aspects of microsurgical skill development. However, there was no statistically significant improvement in the time taken to perform the procedure. This finding is in contrast to other studies which have shown a significant improvement in the time taken to perform the procedure after microsurgical training on a chicken wing model [38–40]. Similar findings have also been reported by authors who have evaluated chicken leg models [41,42].

Although among the trainees, there were residents of varying levels of experience, the subgroups were too small to allow for any meaningful statistical inference. Still, the improvement in GRS scores were similar across all three years of training, indicating the effectiveness of the chicken wing training model in improving microsurgical skill regardless of the experience.

The most common error in our study was 'Planning: Loss of central view'. Loss of central view can be partly attributed to the video recording device used. The camera converted the circular field of view in the microscope into a widescreen video with 16:9 aspect ratio (Figure 1). This resulted in cropping of parts of the view; the upper and lower segments of the circle.

Although a few studies have validated the chicken leg model using objective assessment scores for microsurgical skills [40, 42–44, however, to the best of our knowledge, no prior study has validated the chicken wing model for microsurgery training using an objective assessment. Other training models that have been validated include the live rat model [45], perfused fresh human cadaver [46], and some novel synthetic training models [24, 45].

One important feature of the current study was the involvement of two independent and blinded examiners who objectively evaluated the videos. This added significant merit to our results by removing the reporting bias. From our literature search, we did not find any other study which incorporated such a study design.

However, there were also a few limitations to our study. Firstly, the study population was small and not homogenous with regards to experience in microsurgery. Although all the trainees in different years of plastic surgery residency showed similar improvements in their GRS scores, the study populations were too small to allow subgroup analysis. The trainees, while participating in clinical procedures, would also have acquired skills outside the microsurgery training laboratory, which was not accounted for. Secondly, we did not use any method of simulating a dynamic blood circulation in chicken wing, this decreases the 'realism' of our training model. Lastly, although we did show the benefit of the chicken wing model in improving the microsurgical skills, we did not compare this model to any other training model for microsurgery. Such a comparison would help ascertain the equality or superiority of the training models.

## Conclusion

Training in microsurgery should be an essential component of the training of all plastic surgeons. The results of our study suggest that the chicken wing is a useful training model for microsurgery. It helps in improving the overall microsurgical skill as well as reducing the number of errors. The advantages of using this model over other training models (synthetic/live-animal/human cadaver) are: cost-effectiveness, ease of availability, and ease of setting-up. The wide assortment of vessels with varying diameters provides ample opportunities for training for microsurgeons of different skill levels. The only disadvantage to using a cadaveric chicken wing model for microvascular anastomosis is the absence of dynamic blood flow. However, the benefits of using this model far outweigh the drawbacks. Thus, in our opinion, a chicken wing is perhaps the ideal training model for microsurgery in a resource-strapped environment. Future studies should be directed towards larger study populations and should compare the various microsurgical training models in well-designed randomized control trials.

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