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Developing a Training Model for Local Flaps Using Fresh Human Skin Excised During Tummy Tuck Procedures

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Abstract **Original Research Article**

Introduction: The proficient execution of local flaps poses a challenge for surgical residents. This study aimed to assess a training model for local flaps using fresh human skin excised during tummy tuck procedures. ***Methods***: A questionnaire and a surgical skills evaluation, examining theoretical and procedural knowledge of local flaps, were administered before and after the training. All surgical procedures were performed on a simulation model utilizing freshly excised human skin. Skills were evaluated using a modified version of the Objective Structured Assessment of Technical Skills Score. SPSS version 21 was employed for comparing pre- and post-training results. ***Results***: In the pretraining assessment, residents faced difficulties in flap design accuracy and wound coverage adequacy, indicating a need for surgical training beyond the operating theater. Post-training, there was a significant improvement in procedural skills, as reflected in the modified Objective Structured Assessment of Technical Skills score. The mean cumulative pretraining score was 26.81 ± 5.41, while the posttraining score was 43.59 ± 5.72 (P = 0.008). Theoretical knowledge also significantly improved in the posttraining evaluation, except for the indication of a Z-plasty (P = 0.257). The training model received positive feedback and was deemed highly useful and recommendable. ***Discussion***: The presented model demonstrated improved surgical handling and understanding of tissue rotation under realistic conditions. The simulation model, using fresh human skin, is cost-effective and versatile for a broad range of flap procedures, advocating for its further adoption. ***Conclusions***: The training model significantly enhanced surgical handling and comprehension of tissue rotation, replicating realistic conditions. The cost-effective simulation model, based on fresh human skin, offers versatility for various flap procedures, emphasizing the need for its wider implementation.

Keywords: local flaps, posttraining evaluation, Fresh Human Skin, flap procedures.

INTRODUCTION

Local flaps serve as an indispensable technique for wound closure when achieving wound healing through either primary or secondary intention is not feasible [1]. Despite an abundance of literature detailing their geometrical and vascular properties, surgical residents often find local flaps challenging to conceptualize [2, 3]. Precise preoperative planning and meticulous marking of incisions are essential, as even minor inaccuracies can result in significant functional and aesthetic consequences, potentially necessitating additional surgery. The successful execution of local flaps requires a combination of surgical experience and confidence.

Unfortunately, meeting these criteria proves challenging for surgical residents, particularly during the early stages of training and in the face of reduced operative time. The time constraints in the operating theater occasionally lead to unstructured training situations, prioritizing expediency over aesthetic considerations, particularly in the fields of plastic or dermatologic surgery. This can pose a barrier for inexperienced residents in the clinical application of local flaps [5, 6]. There is an evident need for lifelike training simulations for surgical residents outside the operating theater.

An optimal surgical training model must meet crucial requirements, including cost-effectiveness, reproducibility, enhanced availability, and, crucially, an accurate representation of reality [6-8]. Despite advancements in research and emerging technologies, no existing model replicates the anatomical structure and physical properties of human skin with the precision achieved by human skin itself.

In the realm of plastic surgery, numerous procedures, including body contouring after substantial weight loss in post-bariatric patients, involve the removal of excess human skin. This surplus skin, when excised, can serve as an ideal resource for training models. As demonstrated by Rothenberger *et al.*, basic surgical skills such as excising an elliptical skin defect or harvesting skin grafts can be effectively taught using a training model based on fresh human skin obtained from post-bariatric contouring surgery, providing an invaluable introduction for medical students to surgical procedures. Consequently, the objective of the current study was to assess whether this model is also applicable for training plastic surgery residents in the techniques of local flaps.

MATERIALS AND METHODS

The prospective study was carried out at the Department of Plastic and Reconstructive Surgery, Mohamed VI Hospital University, Marrakech, spanning from January 2021 to July 2023. A total of 10 residents willingly participated in the study. The teaching material, comprised of excised human skin, was sourced from patients who had undergone abdominoplasty. All patients underwent preoperative screening for HIV and hepatitis viral markers, with negative results. Prior to the study, informed consent was obtained from both the patients and the participating residents.

Given the study's limited sample size, the ShapiroeWilk test was employed to assess the normality of the data and their residuals. Since the normality assumption was not validated, the Wilcoxon signed-rank test was used to compare the results of the surgical skill evaluation and the questionnaire before and after surgical training. A significance level of $p < 0.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 21.0y.

Preliminary and Posttraining Self-Evaluation:

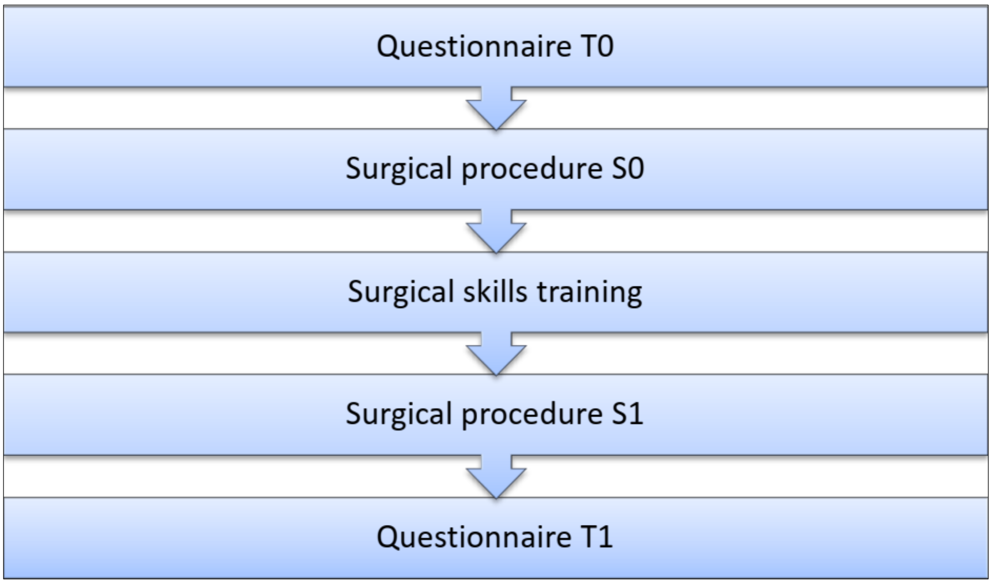


Figure 1: Flow diagram of the study consisting of two question naires (T0 and T1) and two evaluations of procedural skills (S0 and S1), which took place at the same study point and were held at least 1 wk before and after the surgical skills training

The participants were administered a questionnaire both before and after the surgical skills training, denoted as the pretraining questionnaire (T0) and posttraining questionnaire (T1) respectively. These questionnaires, held at the same study point as the surgical procedures, aimed to assess participants' confidence and knowledge regarding the indication and execution of local flaps commonly employed in plastic surgery. Each questionnaire comprised 13 questions with Likert-type responses.

T1, in addition to assessing confidence and knowledge, sought personal feedback on the presented training model. It was distributed after the completion of the surgical procedure (S1). All participants engaged in two surgical procedures - the pretraining surgical procedure (S0) and the posttraining surgical procedure (S1), with a minimum of 1 week between each procedure and the corresponding skills training.

All participants were provided with fresh human skin and tasked with performing various flaps, including transposition flap, rotation flap, advancement flap, Z-plasty, and trident plasty. The surgical equipment required for the execution of these procedures included a scalpel, forceps, skin stapler, and a suitable pen for marking.

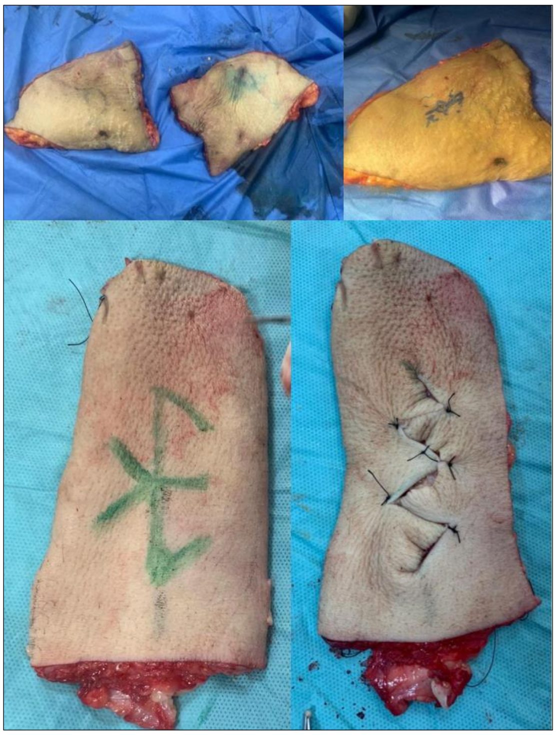


Figure 2: Example of the surgical skills evaluation displaying the preoperative markings

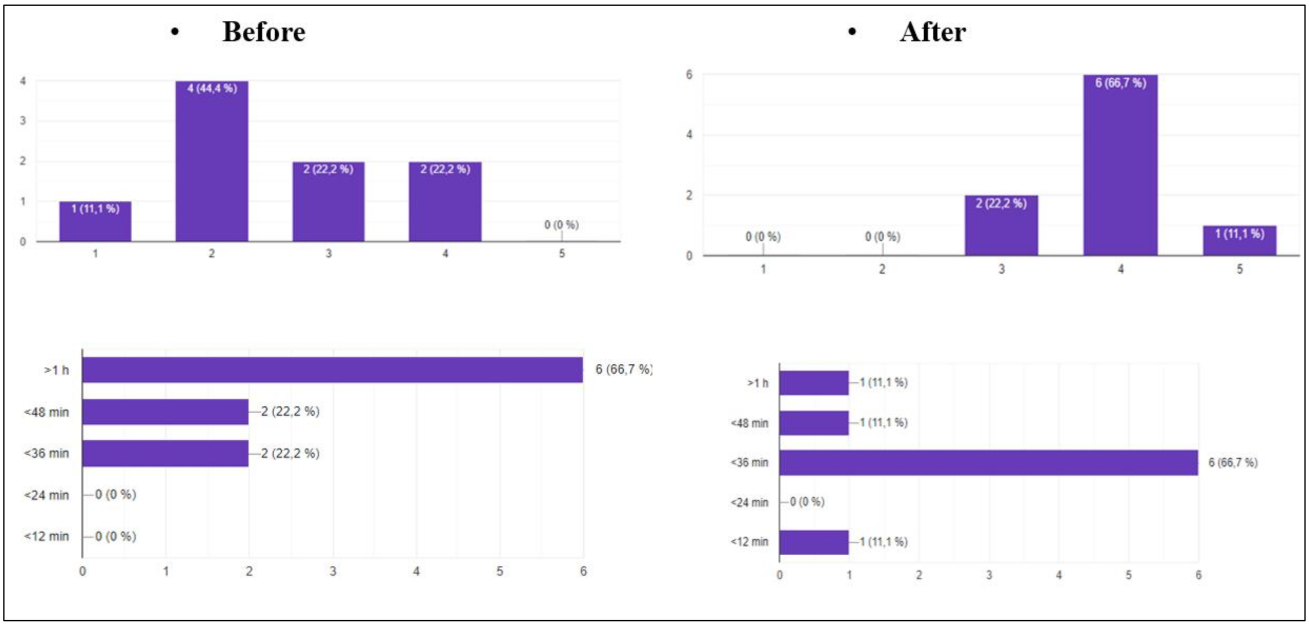
Surgical Skills Training

The surgical skills training was conducted collectively for all residents by a senior resident at an additional study point, occurring after the preliminary questionnaire and the initial surgical evaluation. The objective was to impart both theoretical and technical knowledge to enhance surgical procedural skills through a hands-on session. During this training, each resident had the opportunity to perform surgical procedures on fresh human skin under the close supervision of a senior resident.

Evaluation of Surgical Skills: Global Criteria

Tableau 1: Comparison of the OSATS score before (S0) and after (S1) the surgical training- Global Critera

No	OSAS	S0 (Mean+SD)	S1 (mean+SD)	P value
1	Continuity and safety of procedural handling	3.50 +-0.24	4.22+-0.55	0.010
2	Time procedural	2.45+-0.66	4.10+-0.20	0.005

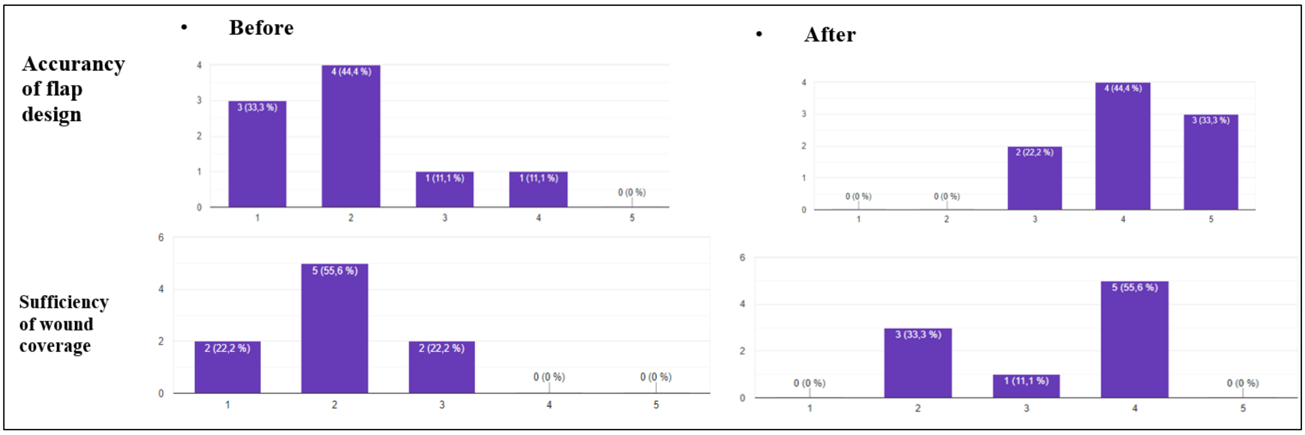


To ensure an objective assessment of procedural skills, a modified version of the Objective Structured Assessment of Technical Skills (OSATS) was employed. For this study, the assessment tool comprised two criteria evaluating general surgical skills and eight criteria assessing specific technical skills, resulting in a total of 10 questions per evaluation. (Table 1,5). Consistent with the earlier-mentioned questionnaires, a Likert-type rating system was employed, allowing for a maximum of five points for each criterion, culminating in a potential maximum score of 50 points. The evaluation of surgical skills involved three blinded senior plastic surgeons, resulting in three ratings per criterion for each resident. An exception was made for assessing the time requirement, which was measured using an electronic time watch during the performance of the specified procedures. All other data were aggregated and presented as mean and standard deviation (SD). Ratings were typically conducted on fresh human skin, ideally on the day of the surgical performance. Alternatively, when necessary, skin was preserved in the refrigerator, and assessments were conducted within the following 3 days.

Evaluation of Surgical Skills: Transposition Flap

Tableau 2: Comparison of the OSATS score before (S0) and after (S1) the surgical training. - Transposition flap

OSAS	S0 (Mean±SD)	S1 (mean±SD)	P value
Accuracy of flap design: transposition flap	2.20+-0.90	4.10+-0.70	0.006
Sufficiency of wound coverage: transposition flap	2.44+-0.70	4.30+-0.55	0.007

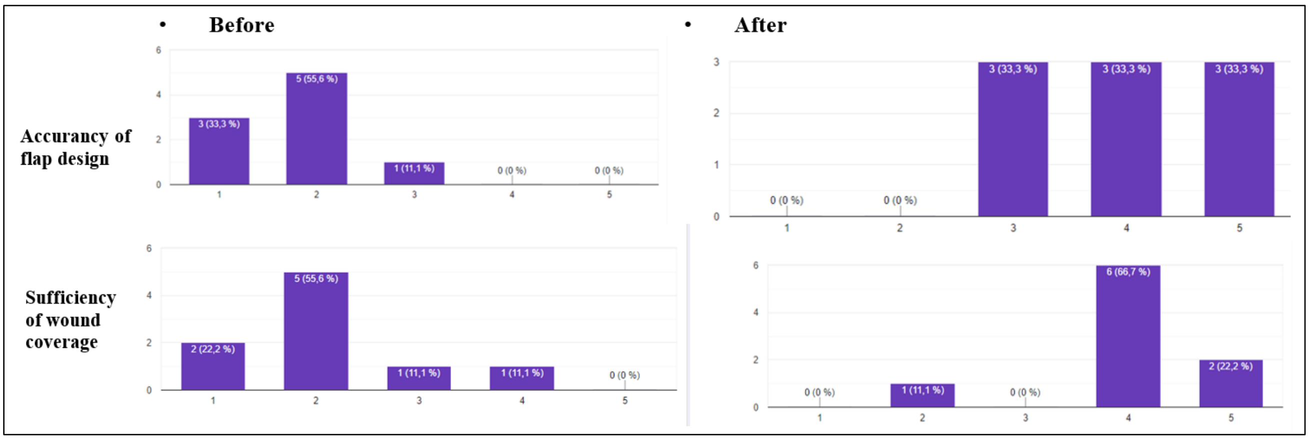


The study group comprised five male and four female residents. The majority of residents were in their first year of training (44.44%), with one resident at the third level. The evaluation of surgical skills unequivocally demonstrated a significant increase in mean scores for all global rating criteria and specific technical skill criteria. (Table 2, 5).

Evaluation of Surgical Skills: Rotation Flap

Tableau 3: Comparison of the OSATS score before (S0) and after (S1) the surgical training - Rotation Flap

OSAS	S0 (Mean±SD)	S1 (mean±SD)	P value
Accuracy of flap design: Rotation Flap	2.50+-1.25	4.55+-0.60	0.007
Sufficiency of wound coverage: Rotation flap	2.18+-0.70	4.60+-0.65	0.007

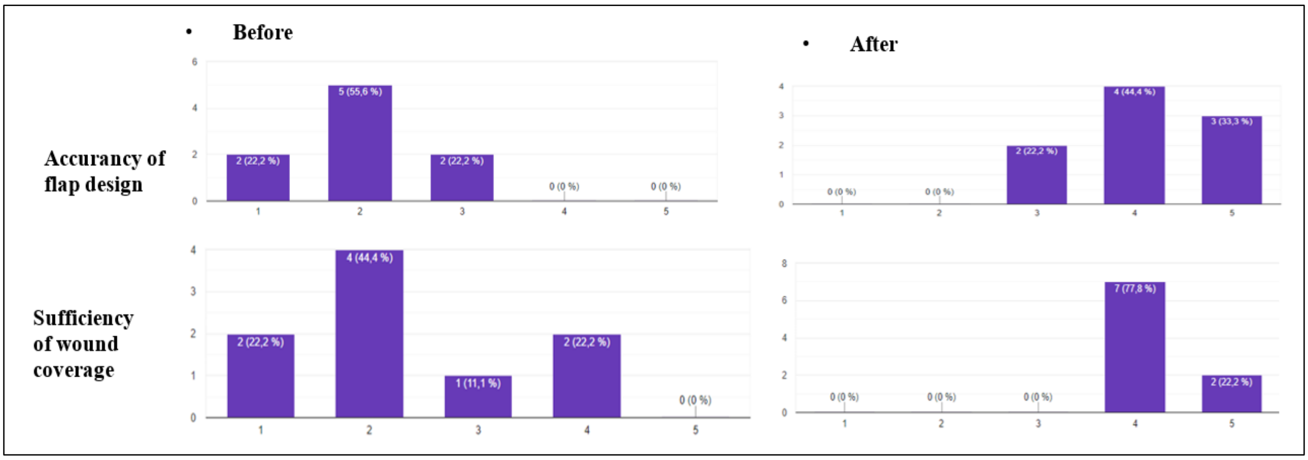


Prior to the training, all residents faced significant challenges in accurately designing the three local flaps, and mean ratings for the adequacy of wound coverage were also notably low for these flaps. Post-training, however, the mean results for all global and specific criteria across all surgical procedures exceeded a score of "4," indicating "good" to "very good" procedural skills. Additionally, the cumulative score of the modified Objective Structured Assessment of Technical Skills (OSATS) significantly increased following the surgical skills training.

Evaluation of Surgical Skills: Advancement Flap

Tableau 4: Comparison of the OSATS score before (S0) and after (S1) the surgical training - Advancement Flap

OSAS	S0 (Mean+SD)	S1 (mean+SD)	P value
Accuracy of flap design: Advancement Flap	1.90 +-1.35	4.40+-0.90	0.008
Sufficiency of wound coverage: Advancement flap	2.68+-0.90	4.50+-0.65	0.007

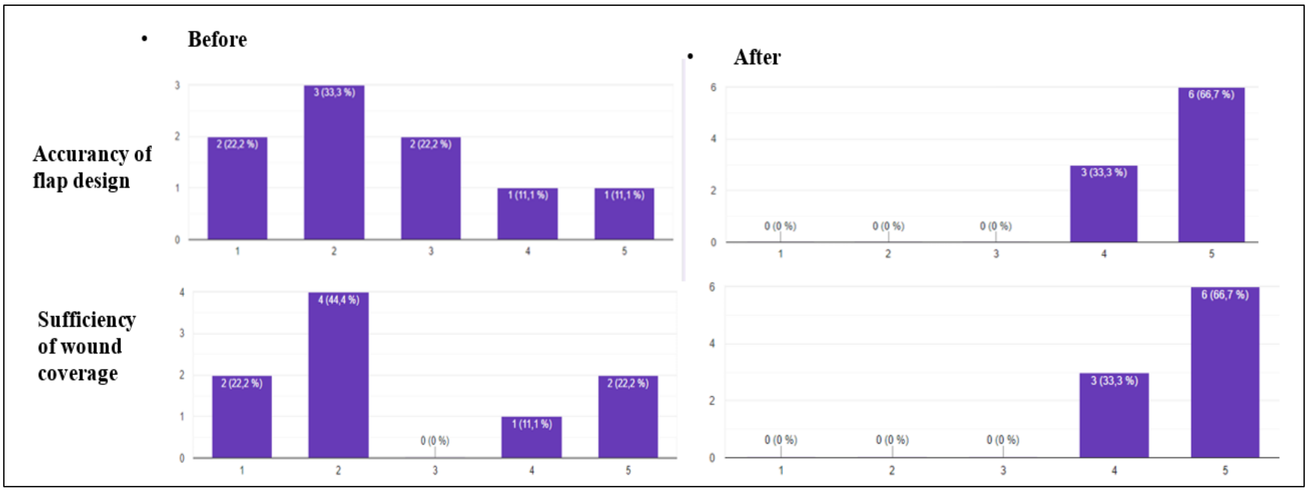


Evaluation of Surgical Skills: Z Plasty

Tableau 5: Comparison of the OSATS score before (S0) and after (S1) the surgical training. - Z plasty

OSAS	S0 (Mean + SD)	S1 (mean+ SD)	P value
Accuracy of flap design: Z plasty	2.00 +-0.35	4.60+-0.80	0.007
Sufficiency of wound coverage: Z plasty	2.58+-0.60	4.40+-0.95	0.007

Following the surgical training, there was a significant increase in participants' self-confidence, as well as an improvement in their theoretical and technical knowledge, with one exception. Notably, participants demonstrated a strong understanding of the indication for Z-plasty, recognizing it as the preferred surgical technique for scar lengthening, especially in cases of contractures resulting from burns. Given that the study took place in a department housing a burn center, where scar revisions and the implementation of Z-plasties are frequent, participants were likely more acquainted with the application of Z-plasty compared to other local flaps.



RESULTS

In the initial questionnaire, participants conveyed uncertainty about their preoperative markings and characterized themselves as lacking confidence and being somewhat slow when undertaking surgical procedures. (Table 6). In general, theoretical knowledge about the indication of local flaps and Z-plasty received higher ratings than participants' self-assessed technical skills when executing these procedures. However, a comparison of the results before and after the surgical training indicated a notable and significant increase in all mean ratings.

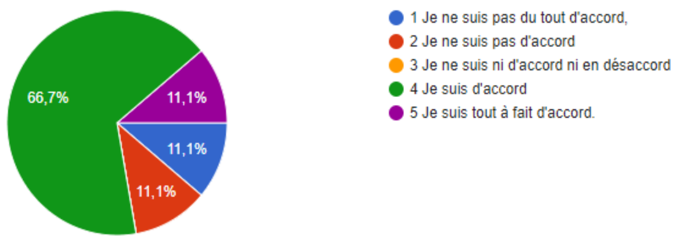
The initial self-evaluation by participants aligned with the outcomes of the first surgical skill assessment, indicating a consistent recognition of a deficit in procedural expertise.

Tableau 6: Evaluation of the questionnaire before (T0) and after (T1) the surgical training

No.	Question	T0 (mean±SD)	T1 (mean±SD)	P value
1	I theoretically know the possibilities of adequate wound closure when using local flaps.	3.78±0.67	4.67±0.50	0.020
2	I feel confident when performing local flaps.	1.78±0.83	3.77± 0.83	0.007
3	My preoperative markings and incisions are precise.	2.44±1.01	4.00±0.71	0.009
4	I know the procedural steps of performing local flaps.	3.33±1.00	4.67±0.50	0.010
5	I think I am quick when performing local flaps.	2.22±1.30	3.56±0.88	0.028
6	I am familiar with the indication of a transposition flap.	3.11±0.78	4.56±0.73	0.010
7	I am familiar with the indication of a rotation flap.	3.56±1.33	4.67±0.50	0.024
8	I am familiar with the indication of an advancement flap.	3.67±1.12	4.78±0.44	0.014
9	I am familiar with the indication of a Z-plasty.	4.33±1.32	4.89±0.33	0.257
10	I know how to execute a transposition flap safely.	2.33±1.00	4.33±0.50	0.007
11	I know how to execute a rotation flap safely.	2.78±1.30	4.44±0.53	0.024
12	I know how to execute an advancement flap safely.	2.89±1.27	4.67±0.50	0.011
13	I know how to execute a Z-plasty safely.	3.22±1.20	4.56±0.53	0.023

The feedback from participants at the conclusion of the study was overwhelmingly positive, as indicated by Table 7. The training model, utilizing fresh human skin, evidently played a significant role in boosting their confidence in performing surgical procedures. Moreover, it was deemed more effective compared to other training methods, including artificial skin, animal models, or anatomical dummies. The latter, in general, fell short of meeting participants' expectations. As a result, the model employed in this study is strongly recommended for adoption by others and should be incorporated into residency programs.

Tableau 7: Evaluation of the participants' feedback

No.	Question	Mean ±SD
1	The course "local flaps on fresh human skin" has increased my expertise. 	4.67 ± 0.50
2	The model and its accompanying surgical training is more effective than "bedside-teaching" during surgery. 	3.89 ± 0.93

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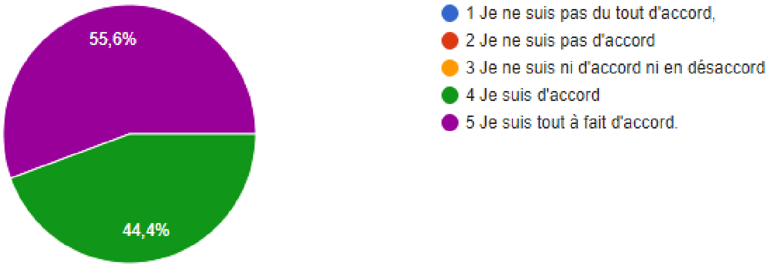
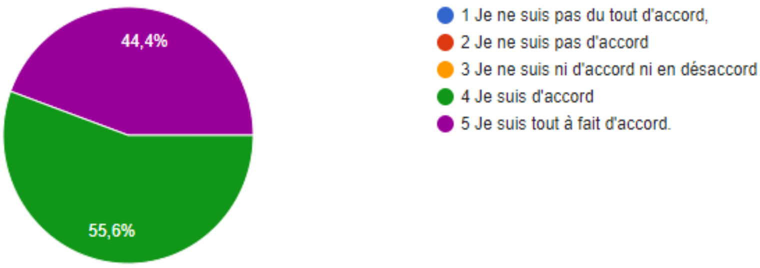
<tr><td>3</td><td>A training model generally increases my confidence when performing surgical procedures in real situations.
</td><td>4.78 ± 0.44</td></tr>
<tr><td>4</td><td>The training of local flaps on fresh human skin should become part of the residency program.
</td><td>4.78 ± 0.44</td></tr>
<tr><td>5</td><td>Training on fresh human skin is superior to other concepts (e.g., artificial skin, animal models, or anatomic dummies).
</td><td>4.67 ± 0.50</td></tr>
<tr><td>6</td><td>I think current training models (e.g., artificial skin, anatomical dolls, or animal models) are sufficient.
</td><td>2.22 ± 1.39</td></tr>
<tr><td>7</td><td>I would recommend the concept of this course to others.
</td><td>4.89 ± 0.33</td></tr>
</table>

8	The level of the course was appropriate.	4.89 ± 0.33

Discussion

The conventional apprenticeship model of surgical training, founded on repetitive practice encapsulated by the adage "learning by doing," needs to be reevaluated in favor of a more didactic or simulation-based approach [6]. While surgical training models can never replace clinical experience, they represent an innovative option for acquiring knowledge and technical skills without posing risks to patients. This study demonstrated that all participants significantly enhanced their procedural skills through the presented simulation model and surgical training. The non-traditional setting of the training allowed participants to express concerns about local flaps that might be concealed in front of patients. This environment facilitated the asking of questions, potentially improving the understanding of local flap execution.

Moreover, the personal feedback provided by the senior resident during the hands-on session was considered a crucial element for enhancing surgical skills. The model employing fresh human skin was strongly endorsed as a recommendable concept, surpassing other training models such as animal skin or inorganic simulations like anatomical dummies or artificial skin. Compared to these alternatives, fresh human skin offered a remarkably close representation of realistic conditions, particularly in terms of anatomical structure and skin elasticity [5-14]. Additionally, fresh human skin allows for a precise differentiation of the skin layers, unlike cadaveric models, for instance, which exhibit varying skin characteristics due to the preservation method [15, 16].

Hence, the presented training concept enhances a fundamental understanding of flap design and the principles of tissue rotation for effective wound closure. The initial surgical evaluation revealed that many residents encountered significant challenges in assessing the flap's size and its rotation angle to achieve adequate wound coverage. Following the hands-on session, however, there was a marked improvement, demonstrated by an increase in the OSATS scores for all flaps and Z-plasty. Not only were there fewer mistakes, but surgical performance in the second evaluation was also quicker than in the pretraining assessment.

The need for a realistic training situation is further underscored by the outcomes of both questionnaires. In the preliminary questionnaires, participants openly admitted feeling unconfident when performing local flaps and expressing uncertainty about their preoperative markings. Additionally, there was a noticeable discrepancy between theoretical knowledge regarding the indication of local flaps and the surgical skills exhibited during these procedures. Considering that residents often tend to be more critical of their own surgical performance, one might argue that the results of questions 10-13 could be considered understated [7]. The initial self-evaluation by participants aligned with the outcomes of the first surgical skill evaluation, indicating a lack of procedural expertise. Following the surgical training, participants' self-confidence and theoretical and technical knowledge significantly increased, with one exception. Question number 9, inquiring about the indication of a Z-plasty, already displayed the highest mean score in the first questionnaire. Consequently, its increase in the post-training evaluation did not reach statistical significance. Unlike other local flaps, a Z-plasty features a highly figurative design, likely contributing to its simpler indication and more comprehensible use [17]. Moreover, a Z-plasty is the preferred surgical technique when scar lengthening is necessary due to contractures, as often seen in burns. Given that the study took place in a department with a burn center, scar revisions and the implementation of Z-plasties are frequent occurrences. This familiarity may explain why participants were more acquainted with the indication of a Z-plasty compared to other local flaps.

Regarding the training model itself, participants highly endorsed the use of biological material that would otherwise be discarded. Considering the substantial number of surgical procedures involving the removal of excess skin, particularly in cases of significant weight loss, the presented model offers ample training opportunities for surgical residents.

The use of fresh human skin as a training model is not restricted solely to plastic surgery residents; it could also serve as an ideal training option for residents in other surgical disciplines, such as otorhinolaryngology or head and neck surgery, where local flaps are commonly performed. Additionally, it is essential to highlight that the presented training model incurred no additional costs, apart from the refrigeration of the excised skin until its use for surgical training. In contrast, alternative training concepts, such as animal models or cadaveric training courses, are often cost-intensive, leading to infrequent practice by residents [6]. Furthermore, high-quality computer-based training models, such as holographic displays that mimic highly realistic conditions, entail substantial installation costs. These costs can act as a barrier, limiting residents' access to such advanced training technologies [18, 19]. Furthermore, digital technologies currently lack realistic tactile and haptic feedback, which is considered essential for the successful performance of local flaps. While the merit of the study lies in proving the concept, there are certain limitations to be acknowledged. Firstly, the presented model did not adhere to anatomical landmarks for a location-based approach to flap-specific training. This aspect might lead to the argument that teaching while performing surgery on real patients ("bedside teaching") is considered more effective than surgical skills training based on fresh human skin.

Secondly, a gender-specific evaluation of results or a correlation between the level of residency and the improvement of surgical skills could not be conducted due to the small sample size of the study. Future studies should consider including residents from other surgical disciplines or adopt a multicenter approach. Expanding the participant pool would allow for a randomized study design, including other training concepts, facilitating a direct comparison of different simulation techniques. A multicenter approach could also benefit from the integration of blended learning, incorporating digital instructional videos, for instance [20, 21]. While the creation of a video would entail some costs, it could significantly enhance the standardization of surgical training. Recording videos might also be considered for the evaluation of residents' surgical performance, ensuring reproducibility and facilitating better comparisons, especially in a multicenter approach. Furthermore, ongoing research should address the validation of OSATS criteria and assess interrater reliability to ensure standardized surgical skills evaluation.

Additionally, exploring the possibility of deep freezing and preserving excised human skin for later use while maintaining the same training qualities as fresh human skin would be intriguing. This potential would simplify integration into everyday clinical practice and broaden its application as a versatile teaching model.

Conclusion

Given the growing financial constraints in the hospital and healthcare sector, coupled with limited operative time, and the heightened expectations of patients, we believe that utilizing fresh human skin excised during abdominoplasty procedures is a highly effective approach for imparting essential plastic surgery skills. The model we present distinctly addresses the recognized requirement for surgical training, aiding practicing surgeons in honing their skills. This, in turn, contributes to enhanced surgical expertise, ultimately elevating patient safety and standards of care.

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